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## **INTRODUCTION**

## **1 INTRODUCTION**

Two highly integrated units, a Naphtha Reformer Unit (R41) and an Aromatics Complex (R42) constitute part of the facilities of Phase-II Petrochemical Project located in Saudi Arabia. Technologies for both of these units are licensed from the same company.

### **1.1 Facilities Overview**

The Naphtha Reformer and Aromatics complex, which is designed to maximize para-xylene and benzene production, consists of the following units and sections:

#### **R41 NAPHTHA REFORMER UNIT**

- Section-1: Naphtha Splitter And LCN Splitter Section
- Section-2: Naphtha Hydrotreatment Section
- Section-3: Aromizing Section
- Section-4: Catalyst Regeneration Section
- Section-5: PSA Unit
- Section-9: Common Section

#### **R42 AROMATICS COMPLEX**

- Section-1: Xylenes Fractionation Section
- Section-2: Morphylane Section
- Section-3: BT Fractionation and Transplus Section
- Section-4: Eluxyl Section
- Section-5: Xymax Section
- Section-9: Common Section

The Naphtha Reformer unit is designed to process approximately 100,000 BPSD of naphtha, primarily supplied from the existing CDU, but also from the HOFCC and VGO Hydrotreater units, to an aromatics rich stream, or "reformate", through catalytic reformation with continuous catalyst regeneration. **Aromizing is Axens' continuous**

catalyst regeneration (CCR) reforming process expressly designed for aromatics productions. After undergoing fractionation and hydro treatment, the feed to the reforming reactor is approximately 65,000 BPSD. The main reaction is to be carried out in four reactors in series. Part of the H<sub>2</sub> rich gas formed in the reaction is compressed and recycled back to the reactor inlet whilst the balance is processed through the PSA section into hydrogen with LPG, C<sub>5</sub> and fuel gas as by-products. The assumed on-stream factor is 8,500 hours per year.

Coupled with the Naphtha Reformer is the Aromatics Complex based on Axens' Paramax™ suite of process. This unit is designed to process the various aromatics contained in the reformate exiting the Naphtha Reformer into 1,340 KTA of paraxylene and 424 KTA of benzene (benzene production is resulting), with only raffinate, heavy aromatics and fuel gas as by-products. This is achieved through isomerization, transalkylation and disproportionation reactions, and several extraction/distillation processes.

All feedstock's, product streams and outgoing effluents are supplied up to and away from the battery limits. The battery limit interface is the Shared System Section (N200).

Utilities and auxiliary systems constitute the following.

- Electrical power (from the central substation SS230)
- Steam (HP, MP and LP) and Steam Condensate Recovery System.
- Instrument air, utility air, and nitrogen
- Water (cooling water supply and return, fire, demineralized, HP boiler feed, drinking, and utility)
- Fuel gas
- LP and HP flares
- Fuel Oil System
- C<sub>5</sub> rich cut system
- Oily water sewer / Contaminated surface water sewer / sanitary water system
- Closed Drain System
- Sour Water System
- Caustic Drain System
- Aromatic Closed Drain System
- NFM Drain System
- PDEB Drain System

- Chilled Water Circulation System
- Chemicals handling
- Product Benzene Shift/ Buffer Tank & Paraxylene Shift Tank Systems

Safety system includes Fire and Gas detection System, acoustic and visual alarms, manual call points, Emergency Shutdown System (ESD), High Integrity Protective System (HIPS) and emergency depressurising / blowdown / isolation system (EDS), Passive Fire Protection and Active Fire Protection System. Detail description of Safety System is provided in Section 6 “SAFETY SYSTEMS”.

The Process Control System (PCS) for Phase II Petrochemical Project is an integrated Distributed Control System (DCS) with sub-systems that are connected together by a series of Operating Area and plant wide DCS networks and information networks:

- Distributed Control System (DCS)
- Safety Instrumented System (SIS)
- Vibration/Condition Monitoring System (VMS/FFVMS/CMS)
- Plant Asset Management System (PAM)
- Smart ZV Monitoring System (SZVMS)
- Fire & Gas Alarm System (FGAS)
- Alarm Management System (ALMS)
- Compressor/Turbine Control System (CCS/TCS)

Detail description on PCS is provided in Section 3.3.

The incoming power supply at plant battery limit is 34.5 kV. There are three substations (SS231 and SS237 for Unit R42 and SS239 for unit R41). Nominal system voltage levels are AC - 34.5 kV (Incoming), 13.8kV, 4.16kV, 480V, 230V, 120V(UPS), DC-125V DC. Three emergency diesel generator systems, one for each substation are provided to supply emergency power in case of main power failure.

## **1.2 Purpose of R41 Plant**

The main purpose of Naphtha Reformer unit (R41) is to process the Naphtha Feed to produce a Reformate stream rich in Aromatics. The Refromate product is sent to the Aromatic Complex (Unit R42) for further processing to produce mainly Paraxylene and Benzene.

## **1.3 Brief Description of R41 Plant**

The purpose of the Naphtha Splitter (R41-T-112) and LCN Splitter (R41-T-113) section (R41-1) is to fractionate straight-run naphtha coming from Distillation unit and cracked naphtha coming from VGO Hydrotreatment Fractionator in Naphtha Splitter (R41-T-112) and LCN coming from HOFCC in the LCN Splitter (R41-T-113) to produce two different light cuts (Light Naphtha and Light LCN) that is sent to storage and a heavy cut that is routed to the Naphtha Hydrotreating Section (R41-2).

The naphtha feed from Naphtha Splitter and LCN Splitter section R41-1 (Heavy Naphtha from the bottom of the Naphtha Splitter R41-T-112 and Heavy LCN from the LCN splitter R41-T-113) is processed in the Naphtha hydrotreatment section (R41-2) in order to produce Hydrotreated Naphtha containing less than 0.5 wt ppm sulfur and less than 0.5 wt ppm nitrogen which is then sent to the Aromizing Section R41-3.

The Aromizing (**reforming**) process maximizes aromatics production from naphthenes and paraffins for use as a source of specific aromatic compounds. There are three liquid products from Aromizing section (R41-3):

- Reformate to Xylene Fractionation section (R42-1),
- C5 cut to gasoline pool,
- LPG to storage.

There are three gas products from Aromizing section (R41-3):

- Fuel gas from LPG Absorber Drum (R41-D-136100),
- Fuel gas from Deethanizer Reflux Drum (R41-D-13750),
- H<sub>2</sub> Rich gas from HP Absorber Drum (R41-D-13580) going to Naphtha Hydrotreatment section (R41-2) and Catalyst Regeneration section (R41-4),

The catalyst is continuously regenerated in the Catalyst Regeneration section (R41-4) during the normal operation of the Aromizing section (R41-3) to maintain a steady coke level in the Reactors (R41-R- 131/132/133/134), and optimum operating conditions for **Reforming** (Aromizing). These operating conditions are almost constant except for the catalyst end of life. The catalyst circulation through the reactors and through the catalyst regeneration is achieved automatically utilizing AXENS' moving catalyst bed technology .

The PSA section (R41-5) produces high purity hydrogen (99.9 %mol) and maximizes the recovery of hydrogen. There are two products from the PSA section (R41-5)

- Purified Hydrogen from going to Naphtha Hydrotreatment section(R 410-2), Catalyst Regeneration section (R41-4), Transplus section (R42-3), Xymax section (R42-5) and H2 existing header,
- Tail gas from PSA

Purified hydrogen feeds the following users:

- Naphtha hydro treatment section R41-2 for start up
- Catalyst Regeneration Section R41-4
- BT Fractionation and TransPlus Section R42-3
- XyMax Section R42-5
- Preheater as fuel (R41-FR-13110)
- First Interheater as fuel (R41-FR-13210)
- Second Interheater as fuel (R41-FR-13310)
- Third Interheater as fuel (R41-FR-13410)
- Xylene Rerun Column Reboiler as fuel (R42-FR-2130A/B)
- Excess of purified hydrogen is sent to H2 existing header

## **1.4 Operator Judgement in Operation of the plant**

This Operating Manual is meant only as guide and reference for the personnel involved in the operation and maintenance of the R41 NAPHTHA REFORMER UNIT.

This manual describes the process principles, major equipment, operating variables and control features essential to operate the plant successfully. It also includes general descriptions of start-up, shutdown, and emergency procedures.

This manual is intended as a basic guide to operation of the plant for supervisory personnel and doesn't supersede the plant owner's specific operational procedures or statutory requirements. Operating instructions provided by Vendor for specifical equipment such as Heaters, Compressors, Pumps, etc... shall be red in conjunction with this manual

Some of the procedures and operating conditions given herein may require modifications to meet unusual or emergency conditions. It is, therefore, recommended that all Operating Personnel become intimately familiar with all details of unit operation and with the functions of all operating equipment in order to be able to operate the unit safely and efficiently.

It is therefore recommended that all operating personnel become intimately familiar with all construction details and unit operations and with the functions of all operating equipment in order to be in a position to operate the unit safely and efficiently.

Special procedures for catalyst handling or treatment prior to start-up as well as the relevant list of analyses and specific safety recommendations are also included.

## **1.5 Terms and Abbreviations**

API	American Petroleum Institute
AFC	Air Fail - Close
AFL	Air Fail - Last
AFO	Air Fail - Open
AI	Analog Input
ALMS	Alarm Management System

AMU	Air Motor Unit
AO	Analog Output
ATM	Atmosphere
AUTO	Automatically Managed by the Sequence
BL	Battery Limit
BPSD	Barrels Per Stream Day
BT	Benzene Toulene
CALC	Calculator or Function
CCR	Central Control Room
CCS	Compressor Control System
CDU	Crude Distillation Unit
C&E	Cause and Effect
CRT	Cathode Ray Tube
CS	Carbon Steel
CSO	Car Sealed Open
CSC	Car Sealed Closed
DAHS	Data Acquisition and Historization System
DCS	Distributed Control System
DP	Design Pressure
DT	Design Temperature
DV	Deluge Valve
DWG	Drawing
ED	Extractive Distillation
EDS	Emergency Depressurization / Blowdown / Isolation System
EOR	End Of Run
ESD	Emergency ShutDown
FACP	Fire Alarm Control Panel
FCV	Flow Control Valve
FE	Flow Element
FGAS	Fire & Gas Alarm System
FG	Fuel Gas
FI	Flow Instrument/Indicator

FMS	Flow Metering System
FO	Flow Orifice
FP	Full Port
FSV	Flow Solenoid Valve
FT	Flow Transmitter
FV	Full Vacuum
GLV	Gas Lift Velocity
GWR	Guided Wave Radar
HC	HydroCarbon
HFC	Heavy Feed Case
HHLL	High High Liquid Level
HIPS	High Integrity Protective System
HLL	High Liquid Level
HMB	Heat & Mass Balance
HOFCC	High Olefins Fluidized Catalytic Cracking
HP	High Pressure
HS	Hand Switch
HV	Half Vacumm
HVAC	Heating Ventilation and Air Conditioning
H	High alarm function
HDR	Header
HH	High High trip function
HMI	Human Machine Interface
IND	Indication
I/O or IP or OP	Input / Output signals
ISBL	Inside battery Limit
KTA	Kilo Tonne per Annum
kV	Kilo Volt
LAH	Level Alarm High
LAHH	Level Alarm High High
LAL	Level Alarm Low
LALL	Level Alarm Low Low

LCN	Light Cycle Naphtha
LFC	Light Feed Case
LHSV	Liquid Hourly Space Velocity
LHV	Low Heating Value
LOP	Local Operator Panel
LP	Low Pressure
LT	Level Transmitter
LTCS	Low Temperature Carbon Steel
LTD	Level Temperature Density
LV	Level Control Valve
L	Low alarm function
LCP	Local Control Panel
LL	Low Low trip function
LPG	Liquefied Petroleum Gas
LSP	Local Set Point
MABP	Mean Average Boiling Point
MANU	Manually Managed by the Operator
MAV	Maleic Anhydride Value
MCC	Motor Control Centre
MI	Manual Input
MP	Medium pressure
MOC	Material of Construction
MOV	Motor Operated Valve
MRT	Maximum Reaction Temperature
MSD	Material Selection Diagram
MooN	Voting "M" out of "N"
MOS	Maintenance Override Switch
NHT	Naphtha Hydro Treater
NO	Normally Open
NNF	Normally No Flow
NOP	Normal Operating Case
NPSHA	Net Positive Suction Head Available

NPSHR	Net Positive Suction Head Required
OP	Output of a controller calculation block
OSBL	Outside Battery Limit
OW	Oily Water
OWS	Oily Water System/Sewer
PAM	Plant Asset Management System
PCS	Process Control System
PCV	Self actuating pressure control valve
PDC	Pressure Differential Controller
PDV	Pressure Differential Valve
PFC	Pressure Fail Close
PFD	Process Flow Diagram
PLC	Programmable Logic Controller
POS	Process Override Switch
PID	Proportional Integrative Derivative controller
P&ID	Piping & Instrument Diagram
PIONA	Paraffins, Isoparaffins, Olefins, Naphthenes, Aromatics
ppb	parts per billion
ppm	parts per million
PT	Pressure Transmitter
PV	Process Value
PVRV	Pressure Vacuum Relief Valve
PZV	Pressure Safety Valve
RON	Research Octane Number
RONC	Research Octane Number clear
RTU	Remote Thermal Unit
RU	Refrigeration Unit
RVP	Reid Vapor Pressure
RSP	Remote Set Point
SG / Sp. Gr.	Specific Gravity
STP	Sanitary Treatment Plant
SOR	Start Of Run

SO	Steam Out
SR	Straight-Run
SS	Stainless Steel
SWS	Sour Water System
SYS	Contaminated Surface Water Collection
SZVMS	Smart ZV Monitoring System
SIL	Safety Integrated Level
SIF	Safety Instrumented Function
SIS	Safety Instrumented System
SP	Set Point
TBA	To Be Advised
TBC	To Be Confirmed
TCS	Turbine Control System
TDS	Total Dissolved Solids
TDAS	Tank Data Acquisition System
TL	Tangent Line
TT	Temperature Transmitter
TV	Temperature Control Valve
TVP	True Vapour Pressure
t/h	tonnes per hour
UCP	Unit Control Panel
UPS	Uninterrupted Power Supply
VOE	Valve Override Enable
VGO	Vacuum Gas Oil
VMS/FFVMS/CMS	Vibration/Condition Monitoring System
WAIT	Weight Average Inlet Temperature
WABT	Weight Average Bed Temperature
WHSV	Weight Hour Space Velocity
XSV	Solenoid Valve
ZV	Emergency isolating valve (shut down valve)



## General Description

## **2 GENERAL DESCRIPTION**

### **2.1 Process Design Basis**

#### **2.1.1 R41-1 Naphtha Splitter and LCN Splitter Section**

Six different operating cases have been used for the design of this section:

- Case 1 - Light Feed Case
- Case 2 - Heavy Feed Case
- Case 3 - Light Feed Case With O<sub>2</sub>
- Case 4 - Heavy Feed Case With O<sub>2</sub>
- Case 5 - Heavy Feed Case 2% by Volume C4 Content
- Case 6 - Heavy Feed Case 4.6% by Volume C4 Content

Cases with O<sub>2</sub> are used to simulate the operation when naphtha is coming from storage (SR Naphtha Tank – F56-TK-63/64) saturated in oxygen and water.

#### **2.1.1.1 Feedstock**

**2.1.1.1.1 Straight Run Full Range Naphtha from the existing CDU**

**2.1.1.1.1.1 Heavy Feed Case (Base Case)**

#### **Capacity**

80000 BPSD of SR Naphtha

#### **Properties**

Sp. Gravity	-	0.715
Sulfur	wt. ppm	500 max
Nitrogen	wt. ppm	1 max

#### **PIONA Distribution**

Vol %	Nor-paraffins	Iso-paraffins	Naphthenes	Aromatics
C-4	0.87	0.13	0.00	0.00
C-5	8.02	3.98	0.41	0.00

<b>Vol %</b>	<b>Nor-paraffins</b>	<b>Iso-paraffins</b>	<b>Naphthenes</b>	<b>Aromatics</b>
C-6	8.46	6.47	2.21	0.49
C-7	8.10	6.10	3.36	1.63
C-8	7.00	6.74	3.06	3.02
C-9	5.48	6.18	2.11	2.53
C-10	4.27	4.53	0.87	0.97
C-11	0.67	1.97	0.00	0.28
Heavier	0.01	0.05	0.00	0.01
Total	42.88	36.16	12.02	8.93

**Distillation Data (ASTM D-86)**

IBP	°C	43.1
5 vol%	°C	57.7
10 vol%	°C	68.1
30 vol%	°C	92.6
50 vol%	°C	114.3
70 vol%	°C	136.3
90 vol%	°C	151.5
95 vol%	°C	156.2
FBP	°C	162.3

Notes:

- The average of two sets of CDU test run data, i.e., data of 3:30 AM 29-Sep-09 and data of 11:25 AM 29-Sep-09 analyzed in the laboratory, where the total C4 content has been adjusted to 1 vol% (from 5.32 vol%) and the remaining data normalized, considering the practical operation of the upstream CDU stabilizer.
- Approximately 2.5 vol% of C8-C11 olefins were also detected in the straight run naphtha sample but, since no olefins are expected in naphtha from the CDU, these have been incorporated into the values for normal paraffins.
- For the cold SR Naphtha feedstock stream from storage to the splitter, the O<sub>2</sub> content of this material is estimated using a conservative approach (saturation of O<sub>2</sub> at 13 °C (winterization temperature)).
- Refer Attachment-2 of document S-PM-R41-1222-0401 for other impurities in the Naphtha feedstock.

### **2.1.1.1.1.2      Light Feed Case**

#### **Capacity**

75100 BPSD of SR Naphtha

#### **Properties**

Sp. Gravity	-	0.6995
P/N/A	Vol%	82.51 / 11.19 /6.31
Sulfur	wt. ppm	500 max
Nitrogen	wt. ppm	1 max
Pb	wt. ppb	10 max

#### **PIONA Distribution**

Vol %	Nor-paraffins	Iso-paraffins	Naphthenes	Aromatics
C-4	0.87	0.13	0.00	0.00
C-5	12.11	6.04	0.00	0.00
C-6	19.15		2.14	0.74
C-7	16.51		3.34	2.31
C-8	13.63		3.30	2.33
C-9	11.17		1.67	0.52
C-10 +	2.9		0.74	0.41
Total	82.51		11.19	6.31

#### **Distillation Data (ASTM D-86)**

IBP	°C	28.6
10 vol%	°C	57.7
30 vol%	°C	75.6
50 vol%	°C	94.5
70 vol%	°C	114.1
90 vol%	°C	134.7
EBP	°C	155

Notes:

- The above information was provided in original ITB, i.e. prior to the CDU test run. It was collected in Jun 2009 but was only analyzed for PNA over the range of C5 to C10.
- The total C4 content has been adjusted to 1 vol% (from 0 vol%) and the remaining data normalized, considering the practical operation of the upstream CDU stabilizer.
- Refer Attachment-2 of document S-PM-R41-1222-0401 for other impurities in the Naphtha feedstock.

**2.1.1.1.2      Cracked Naphtha from existing VGO Hydrotreater**

**Capacity**

2410 BPSD of Cracked Naphtha (For both Light & Heavy Feed Case)

**Properties**

Sp. Gravity	-	0.7541
RVP	psi	4.1
Sulfur	wt. ppm	35 max
Nitrogen	wt. ppm	10 max
MAV (IFP-9407)	Mg/g	<0.5

**PIONA Distribution**

Vol %	Nor-paraffins	Iso-paraffins	Olefins	Naphthenes	Aromatics
C-3	0.03	0.00	0.01	0.00	0.00
C-4	1.05	0.01	0.02	0.00	0.00
C-5	3.98	1.69	0.04	0.48	0.00
C-6	4.36	3.07	0.05	6.94	0.46
C-7	4.53	3.63	0.03	14.14	3.74
C-8	5.61	5.43	0.59	11.5	7
C-9	2.81	4.66	1.88	7.11	1.17
C-10	0.07	2.44	1.26	0.14	0.02
C-11	0.00	0.05	0.00	0.00	0.00
Total	22.44	20.98	3.88	40.31	12.39

### **Distillation Data (ASTM D-86)**

IBP	°C	32
5 vol%	°C	77
10 vol%	°C	86
30 vol%	°C	103
50 vol%	°C	114
70 vol%	°C	125
90 vol%	°C	137
95 vol%	°C	142
FBP	°C	150

Notes:

- Sample date for the above analysis is 6:30 AM on 29-Sep-09.
- Refer Attachment-2 of document S-PM-R41-1222-0401 for other impurities in the Naphtha feedstock.

#### **2.1.1.3      Light Cracked Naphtha from HOFCC**

##### **Capacity**

18115 BPSD of LCN (For both Light & Heavy Feed Case)

##### **Properties**

Sp. Gravity	-	0.6871
RON	-	95.7
MON	-	85.3
Sulfur	wt. ppm	7 max
Nitrogen	wt. ppm	1 max
MAV (IFP-9407)	mg/g	15.4

### PIONA Distribution

Vol %	Nor-paraffins	Iso-paraffins	Olefins	Naphthenes	Aromatics
C-4	0.06	0.00	0.88	0.00	0.00
C-5	3.98	29.91	20.17	0.63	0.00
C-6	1.17	10.02	3.18	2.78	6.97
C-7	0.44	2.63	1.14	2.86	10.69
C-8	0.01	1.38	0.31	0.53	0.10
C-9	0.00	0.03	0.00	0.00	0.07
C-10	0.00	0.00	0.00	0.00	0.04
C-11	0.00	0.00	0.00	0.00	0.01
Total	5.66	43.97	25.68	6.80	17.88

### Distillation Data (ASTM D-86)

IBP	°C	33
5 vol%	°C	39
10 vol%	°C	41
30 vol%	°C	46
50 vol%	°C	52
70 vol%	°C	67
90 vol%	°C	97
95 vol%	°C	104
FBP	°C	108

### Notes:

- Sample date for the above analysis is 6:30 AM on 28-Sep-09.
- Refer Attachment-2 of document S-PM-R41-1222-0401 for other impurities in the Naphtha feedstock.

Composition and Flow rate of Feed to the Naphtha Splitter and LCN Splitter Section (R41-1) is given below.

Flow Rate Unit: wt %	Naphtha Feed From CDU				Cracked Naphtha from VGO	LCN Feed
	Light Case	Heavy Case	Light Case with O2	Heavy Case With O2	All Cases	All Cases
IPENTANE	5.23	3.49	5.23	3.49	1.46	27.59
CP	0.00	0.00	0.00	0.00	0.00	0.69
mb6	0.56	0.43	0.56	0.43	0.20	1.30
2MP	7.34	5.58	7.33	5.58	2.58	7.92
HEXANE	10.21	7.86	10.21	7.85	3.88	1.54
5N6	1.13	1.14	1.13	1.14	3.43	2.80
6N6	1.22	1.23	1.22	1.23	3.72	0.29
A6	0.94	0.61	0.94	0.61	0.55	8.93
sbP7	5.37	4.72	5.37	4.72	2.72	2.41
mbP7	1.31	1.16	1.31	1.16	0.67	0.64
HEPTANE	9.57	7.81	9.57	7.81	4.19	0.02
5N7	1.79	1.75	1.79	1.75	7.08	2.19
6N7	1.88	1.84	1.88	1.84	7.43	1.10
A7	2.88	1.99	2.88	1.99	4.37	13.50
sbP8	5.54	5.39	5.54	5.39	4.62	1.08
mbP8	1.35	1.31	1.35	1.31	1.12	0.35
OCTANE	6.89	6.96	6.88	6.96	5.35	0.00
N8	3.68	3.33	3.67	3.33	12.00	0.48
A8	2.91	3.69	2.91	3.69	8.21	0.13
sbP9	6.10	6.24	6.10	6.23	6.33	0.03
NONANE	5.41	5.53	5.41	5.53	2.72	0.00
N9	1.85	2.29	1.85	2.29	7.39	0.00
sbP10	3.03	11.85	3.03	11.84	3.76	0.00
A9	0.65	3.07	0.65	3.06	1.36	0.09
A10+	0.46	1.53	0.46	1.53	0.02	0.06
N10	0.79	0.94	0.79	0.94	0.15	0.00
C4 Olefins	0.00	0.00	0.00	0.00	0.00	0.21
C4 Diolefins	0.00	0.00	0.00	0.00	0.00	0.52
C5 Olefins	0.00	0.00	0.00	0.00	0.00	17.29
C5 Diolefins	0.00	0.00	0.00	0.00	0.00	1.05
C6 Olefins	0.00	0.00	0.00	0.00	0.00	3.06
C7 Olefins	0.00	0.00	0.00	0.00	0.00	1.16

C8 Olefins	0.00	0.00	0.00	0.00	0.00	0.30
H2O	0.00	0.00	0.04	0.03	0.00	0.00
<hr/>						
Flowrate (kg/h)	348351	378878	348531	379058	12040	82460
MW	95.96	102.28	95.78	102.09	102.28	78.76
sp. gr.	0.6995	0.7123	0.6996	0.7125	0.7447	0.6968

### **2.1.1.2 Product Specification**

There are five products coming from this Naphtha Splitter and LCN Splitter section:

#### **2.1.1.2.1 C5 Rich Cut from Naphtha Depentanizer (R41-T-111)**

A C5 rich cut is derived in the Naphtha Depentanizer (R41-T-111) prior to the Naphtha Splitter (R41-T-112) in order to adjust the vapor pressure of the Light Naphtha Product. This stream is utilized for fuel in three fired heaters (R42-FR-2130/2330/2520), in R42 Aromatics Complex.

#### **Specifications:**

Properties	Specification	Test Method
C6 Content (mol %)	10 max.	Gas Chromotograph

#### **Expected Properties:**

	Light Feed (with O2)	Heavy Feed (with O2)
Sp. Gr.	0.6246	0.6272
TVP, kg/cm <sup>2</sup> A	0.6	0.6

C5 Rich Cut from Naphtha Depentanizer (R41-T-111) is sent to the C5 Rich Cut Storage Drum (R42-TK-2760) with composition as tabulated below:

Flow Rate Unit: wt %	C5 Rich Cut To storage			
	Light Case	Heavy Case	Light Case with O2	Heavy Case With O2
OXYGEN	0.00	0.00	0.00	0.00
PROPANE	0.01	0.01	0.00	0.00
BUTANE	7.41	8.11	6.72	7.20
IBUTANE	1.08	1.18	0.91	0.97
PENTANE	53.63	51.45	54.31	52.37
IPENTANE	35.87	30.26	36.05	30.45

Flow Rate Unit: wt %	C5 Rich Cut To storage			
	Light Case	Heavy Case	Light Case with O2	Heavy Case With O2
CP	0.00	0.00	0.00	0.00
mb6	0.14	0.52	0.14	0.52
2MP	1.41	5.76	1.41	5.79
HEXANE	0.35	2.18	0.35	2.15
5N6	0.03	0.24	0.03	0.24
6N6	0.01	0.07	0.01	0.07
A6	0.05	0.20	0.05	0.20
sbP7	0.00	0.01	0.00	0.01
mbP7	0.00	0.01	0.00	0.01
HEPTANE	0.00	0.00	0.00	0.00
5N7	0.00	0.01	0.00	0.01
H2O	0.00	0.00	0.00	0.01
<b>Flowrate , kg/h</b>	35000	33500	35000	33500
<b>MW</b>	70.92	71.58	71.06	71.76
<b>sp. gr.</b>	0.6242	0.6266	0.6246	0.6272

#### 2.1.1.2.2 Light Naphtha from Naphtha Splitter (R41-T-112)

Light Naphtha from Naphtha Splitter (R41-T-112) is sent to storage (F56-TK-65/66) and **it is** exported for petrochemical use.

#### Specifications:

Properties	Specification	Test Method
Distillation 50% evaporate (°C) 90% evaporate (°C)	Min. 46 – Max. 82 Max. 127	ASTM D-86
API gravity at 60°F	70 – 88	ASTM D-287
RVP, kPaA	Max 83	ASTM D323 / 5191
TVP, kPaA	Max 90 at 45 °C	-
Sulfur, wt. ppm	700 Max.	ASTM D5453

**Expected Properties:**

Distillation vol% ASTM D86	Light Feed (with O2)	Heavy Feed (with O2)
	Temperature in °C	
IBP	46.5	48.2
5%	46.6	48.5
10%	47.3	49.7
30%	56.5	62.3
50%	60.9	64
70%	63.9	66.6
90%	66.1	67.8
95%	73.1	74.0
EBP	78.4	78.8
Sp. Gr.	0.6571	0.6656

Flow Rate Unit: wt %	Light Naphtha To storage			
	Light Case	Heavy Case	Light Case with O2	Heavy Case With O2
OXYGEN	0.00	0.00	0.00	0.00
PROPANE	0.00	0.00	0.00	0.00
BUTANE	0.03	0.03	0.03	0.03
IBUTANE	0.00	0.00	0.00	0.00
PENTANE	24.97	16.41	24.70	15.91
IPENTANE	7.21	4.65	7.02	4.41
CP	0.00	0.00	0.00	0.00
mb6	2.30	2.08	2.32	2.10
2MP	29.92	27.62	30.13	27.86
HEXANE	30.04	39.03	30.25	39.41
5N6	2.68	5.41	2.70	5.46
6N6	0.49	1.92	0.50	1.93
mbP7	0.03	0.19	0.03	0.19
5N7	0.00	0.01	0.00	0.01
<b>Flowrate, kg/h</b>	81132	70368	80575	69706
<b>MW</b>	80.86	82.44	80.92	82.56
<b>sp. Gr.</b>	0.6569	0.6652	0.6571	0.6656
<b>TVP@ 45°C kPa (abs)</b>	< 90	< 90	< 90	< 90

### **2.1.1.2.3      Light-LCN from LCN Splitter (R41-T-113)**

The LCN **splitted** into light LCN (L-LCN) and heavy LCN (H-LCN) by the LCN Splitter (R41-T-113) **is** used as a gasoline component and feedstock for the downstream Naphtha Hydrotreating Section (R41-2), respectively.

The cut point between L-LCN and H-LCN is determined,

- To produce L-LCN with less than 1 vol% of benzene content for gasoline specification
- To maximize aromatics production by the downstream Naphtha Hydrotreating Section (R41-2)

#### **Specifications:**

Properties	Specification	Test Method
Benzene, vol%	1.0 Max.	IFP-9301

#### **Expected Properties:**

RVP, kPaA	120.7	ASTM D323 / 5191
Sp. Gr.	0.6434	-
RON	94	ASTM D-2699
MON	84	ASTM D-2700
Distillation vol%	Temeprature in °C	ASTM D86
IBP	16.1	
5%	19.8	
10%	23.9	
30%	30.4	
50%	31.0	
70%	35.5	
90%	51.7	
95%	60.0	
EBP	65.6	

Light LCN product from LCN Splitter (R41-T-113) is sent to the storage (S040-TK-0810/0811) with composition as tabulated below:

Flow Rate Unit: wt %	Light LCN To storage
	All Cases
OXYGEN	0.00
PROPANE	0.00
BUTANE	0.01
IBUTANE	0.07

Flow Rate Unit: wt %	Light LCN To storage
	All Cases
PENTANE	5.46
IPENTANE	46.73
CP	1.17
mb6	2.01
2MP	9.71
HEXANE	0.26
5N6	0.17
6N6	0.00
A6	0.94
C4 Olefins	0.35
C4 Diolefins	0.89
C5 Olefins	29.29
C5 Diolefins	1.77
C6 Olefins	1.17
C7 Olefins	0.00
C8 Olefins	0.00
H2O	0.00
<b>Flowrate, kg/h</b>	<b>48688</b>
<b>MW</b>	<b>72.74</b>
<b>sp. gr.</b>	<b>0.6434</b>

#### 2.1.1.2.4 Heavy Naphtha from Naphtha Splitter (R41-T-112)

Heavy Naphtha product from Naphtha Splitter (R41-T-112) sent to Naphtha Hydroteating section (R41-2) with composition as tabulated below:

For specification of the product, refer to feedstock section 2.1.2.1 of Naphtha Hydrotreatment section (R41-2)

Flow Rate Unit: wt %	Heavy Naphtha To Section R41-2			
	Light Case	Heavy Case	Light Case with O2	Heavy Case With O2
PENTANE	0.00	0.00	0.00	0.00
IPENTANE	0.00	0.00	0.00	0.00
CP	0.00	0.00	0.00	0.00
mb6	0.03	0.00	0.03	0.00
2MP	0.45	0.03	0.45	0.03
HEXANE	4.73	0.71	4.72	0.71
5N6	0.88	0.29	0.88	0.29
6N6	1.76	1.31	1.76	1.31
A6	0.59	0.15	0.59	0.15
sbP7	7.79	6.34	7.79	6.34

Flow Rate Unit: wt %	Heavy Naphtha To Section R41-2			
	Light Case	Heavy Case	Light Case with O2	Heavy Case With O2
mbP7	1.90	1.51	1.90	1.51
HEPTANE	13.86	10.48	13.86	10.48
5N7	2.90	2.61	2.90	2.61
6N7	3.04	2.74	3.04	2.74
A7	4.32	2.81	4.32	2.81
sbP8	8.13	7.31	8.13	7.31
mbP8	1.98	1.78	1.98	1.78
OCTANE	10.08	9.41	10.08	9.41
N8	5.83	4.90	5.83	4.90
A8	4.55	5.21	4.55	5.21
sbP9	9.02	8.50	9.02	8.50
NONANE	7.85	7.41	7.85	7.41
N9	3.00	3.33	3.00	3.33
sbP10	4.51	15.79	4.51	15.79
A9	0.99	4.10	0.99	4.10
A10+	0.66	2.02	0.66	2.02
N10	1.13	1.25	1.13	1.25
Flowrate, kg/h	244259	287050	244259	287050
MW	108.52	114.8	108.52	114.8
sp. gr.	0.7301	0.7383	0.7301	0.7383

#### 2.1.1.2.5 Heavy-LCN from LCN Splitter (R41-T-113)

Heavy LCN product from LCN Splitter (R41-T-113) sent to Naphtha Hydrotreating section (R41-2) with composition as tabulated below:

For specification of the product, refer to feedstock section 2.1.2.1 of Naphtha Hydrotreatment section (R41-2)

Flow Rate Unit: wt %	Heavy LCN To Section R41-2
	All Cases
mb6	0.29
2MP	5.34
HEXANE	3.39
5N6	6.59
6N6	0.72
A6	20.45
sbP7	5.88

<b>Flow Rate Unit:</b> <b>wt %</b>	<b>Heavy LCN To Section R41-2</b>
	<b>All Cases</b>
mbP7	1.55
HEPTANE	0.05
5N7	5.36
6N7	2.67
A7	32.95
sbP8	2.64
mbP8	0.85
OCTANE	0.00
N8	1.16
A8	0.31
sbP9	0.08
A9	0.21
A10+	0.15
N10	0.00
C4 Olefins	0.00
C4 Diolefins	0.00
C5 Olefins	0.00
C5 Diolefins	0.00
C6 Olefins	5.78
C7 Olefins	2.83
C8 Olefins	0.73
<b>Flowrate, kg/h</b>	33772
<b>MW</b>	89.42
<b>sp. gr.</b>	0.7915

### **2.1.1.3 Battery Limit Conditions**

#### **2.1.1.3.1 Inlet Streams**

<b>Inlet Streams (all cases)</b>	<b>Normal operating pressure (kg/cm<sup>2</sup> g)</b>	<b>Normal operating temperature (°C)</b>
SR Naphtha + Cracked Naphtha (Direct Feed)	8.1	65
SR Naphtha + Cracked Naphtha (Cold Feed)	8.8	Ambient
LCN (Direct Feed)	6.7	61

#### **2.1.1.3.2 Outlet Streams**

<b>Outlet Streams</b>	<b>Normal operating pressure (kg/cm<sup>2</sup>g)</b>	<b>Normal operating temperature ( °C)</b>			
		<b>All Cases</b>	<b>Light Case</b>	<b>Heavy Case</b>	<b>Light Case with O2</b>
C5 Rich Cut to Storage	5.0	40			
Light Naphtha to Storage	5.0	40			
Light LCN to Storage	5.0	40			
Heavy Naphtha to R41-2	3.8	84	92	84	92
Heavy LCN to R41-2	3.8	71			

## 2.1.2 R41-2 Naphtha Hydrotreatment Section

### 2.1.2.1 Feedstock

The design of the Naphtha Hydrotreating unit has been made considering two operating cases:

- Case 1 : Light Feed Case
- Case 2 : Heavy Feed Case

The naphtha feed for the Naphtha Hydrotreating Unit is a blend of two feeds given below:

- Heavy naphtha from the Naphtha Splitter (R41-T-112) of section R41-1
- Heavy LCN from the LCN Splitter (R41-T-113) of section R41-1

Moreover, there is a third feed injected on the NHT Stripper (R41-T-122) feed line:

- A Non Aromatic Liquid Purge from the Cumene Unit

Hydrogen rich gas from the Aromizing section (R41-3) is used for the Hydrogen make-up for the unit.

#### 2.1.2.1.1 Naphtha feed to Naphtha Hydrotreatment Section (R41-2):

Components	HEAVY FEED CASE 2 (wt%)	LIGHT FEED CASE 1 (wt%)
mb6	0.03	0.06
2MP	0.60	1.08
nP6	1.02	4.56
CP	0.00	0.00
5N6	0.95	1.57
6N6	1.20	1.62
A6	2.29	3.01
nP7	9.39	12.18
sbP7	6.30	7.56
mbP7	1.51	1.85
5N7	2.37	2.62
6N7	2.73	3.00
A7	5.98	7.80
nP8	8.42	8.86
N8	5.03	5.84

<b>Components</b>	<b>HEAVY FEED CASE 2 (wt%)</b>	<b>LIGHT FEED CASE 1 (wt%)</b>
A8	4.70	4.04
nP9	6.63	6.90
iP9	7.61	7.93
N9	2.98	2.64
A9	3.69	0.90
nP10	14.13	3.96
iP10	0.00	0.00
N10	1.12	0.99
A10+	1.82	0.60
C6 Olefins	0.61	0.70
C6 Cyclo Olefins	0.00	0.00
C6 diolefins	0.00	0.00
C7 Olefins	0.30	0.34
C7 Cyclo Olefins	0.00	0.00
C7 diolefins	0.00	0.00
C8 Olefins	0.08	0.09
<b>Total Mass Flowrate (kg/h)</b>	<b>320 830</b>	<b>278 041</b>
<b>Molecular Weight (kg/kmol)</b>	<b>111.48</b>	<b>105.83</b>
<b>Specific Gravity</b>	<b>0.7477</b>	<b>0.7397</b>

**Impurities of the R41-2 feed:**

<b>Impurities</b>		
<b>ppm wt</b>	<b>Heavy Case 2</b>	<b>Light Case 1</b>
Sulfur	594	625
Nitrogen	2	2
As	0.003	0.003
Hg	0.003	0.003
Cu	0.071	0.076
MAV	2.79	2.93

**2.1.2.1.2      Hydrogen Rich Gas from Aromizing section (R41-3)**

H2 from Aromizing section (R41-3)	Composition (wt%)			
	CASE 1		CASE 2	
	SOR operating conditions	EOR operating conditions	SOR operating conditions	EOR operating conditions
H2	51.75	44.62	48.85	41.46
C1	11.36	11.65	11.09	11.08
C2	17.43	23.07	20.95	27.08
C3	11.21	13.04	11.35	13.24
nP4	5.40	5.73	5.29	5.38
iC4	0	0	0	0
nP5	1.18	0.87	1.31	0.98
iP5	0	0	0	0
nP6	0.71	0.41	0.45	0.39
A6	0.43	0.38	0.20	0.18
nP7	0.27	0	0.26	0
A7	0.25	0.22	0.24	0.21
<b>TOTAL</b>	100	100	100	100
<b>Mass flowrate (kg/h)</b>	344	399	381	449
<b>MW (kg/kmol)</b>	3.65	4.16	3.84	4.43

#### **2.1.2.1.3      Non Aromatic Liquid purge from the Cumene Unit**

This stream is fed to the inlet of NHT stripper (R41-T-122) in the Naphtha Hydrotreatment section (R41-2)

<b>Components</b>	<b>Cumene Unit Non-Aromatic purge, composition (wt%)</b>
NH3	0
H2S	0
H2	0
C1	0
C2	0
C3	7.41
C4	0
C5	0
C6P	0
C6N	11.73
A6	77.16
C7P	0
C7N	0
A7	4.32
C8P	0
C8N	0
EB	0
PX	0
MX	0
OX	0
<b>TOTAL</b>	<b>100.00</b>
<b>Mass flowrate (kg/h)</b>	<b>162</b>
<b>Molecular Weight (kg/kmol)</b>	<b>74.98</b>
<b>Specific Gravity</b>	<b>0.8226</b>

**Note:**

Benzene from the Aromatics Complex is the feedstock for the Cumene Unit and any non-aromatics in the benzene product passed through to the Cumene unit are returned to the Aromatics Complex via the above stream.

### **2.1.2.2 Product Specifications**

#### **2.1.2.2.1 Hydrotreated Heavy Naphtha from NHT Stripper (R41-T-122) bottoms**

Hydrotreated Heavy Naphtha **is** fed to the Aromizing section (R41-3). The maximum allowable impurities in hydrotreated heavy naphtha is as follows:

Maximum Contaminants Levels	
Sulfur, wt. ppm	0.5 max
Nitrogen, wt. ppm	0.5 max
Water as oxygenated products, wt. ppm	5 max
Chloride as chlorine, wt. ppm	0.5 max
Fluoride as fluorine, wt. ppm	0.5 max
Arsenic, wt. ppb	5 max
Lead, wt. ppb	5 max
Mercury, wt. ppb	1 max
Olefins, Diolefins	Nil
Cadmium, Calcium, Chromium, Copper, Iron, Magnesium, Manganese, Nickel, Potassium, Silicon, Sodium	No

Composition of Hydrotreated Naphtha or various cases are given below.

<b>Components</b>	<b>CASE 1 SOR</b>	<b>CASE 1 EOR</b>	<b>CASE 2 SOR</b>	<b>CASE 2 EOR</b>
mb6	0.09	0.09	0.06	0.06
2MP	1.31	1.31	0.8	0.8
nP6	4.95	4.95	1.38	1.38
CP	0	0	0	0
5N6	1.57	1.57	0.96	0.96
6N6	1.61	1.61	1.2	1.2
A6	3.04	3.04	2.32	2.32
nP7	12.37	12.37	9.55	9.55
sbP7	7.64	7.64	6.37	6.37
mbP7	1.93	1.93	1.57	1.57
5N7	2.62	2.62	2.37	2.37
6N7	3	3	2.73	2.73
A7	7.8	7.8	5.98	5.98
nP8	8.89	8.89	8.45	8.45
sbP8	7.5	7.5	6.85	6.85
mbP8	1.86	1.86	1.7	1.7
N8	5.84	5.84	5.03	5.03
A8	4.04	4.04	4.7	4.7
nP9	6.9	6.9	6.63	6.63
iP9	7.93	7.93	7.61	7.61
N9	2.64	2.64	2.98	2.98
A9	0.9	0.9	3.69	3.69
nP10	3.96	3.96	14.13	14.13
iP10	0	0	0	0
N10	0.99	0.99	1.12	1.12
A10+	0.6	0.6	1.82	1.82
<b>Total Flowrate, kg/h</b>	<b>277785</b>	<b>277777</b>	<b>320520</b>	<b>320511</b>
<b>MW</b>	<b>105.86</b>	<b>105.86</b>	<b>111.51</b>	<b>111.51</b>
<b>Specific Gravity</b>	<b>0.7396</b>	<b>0.7396</b>	<b>0.7476</b>	<b>0.7476</b>

#### **2.1.2.2.2      Stripper Reflux Drum (R41-D-12250) sour off-gas:**

Sour off gas from the Stripper Reflux drum (R41-D-12250) is sent to the existing Amine Absorber (R220-D-0013).

<b>Components</b>	<b>CASE 1 SOR</b>	<b>CASE 1 EOR</b>	<b>CASE 2 SOR</b>	<b>CASE 2 EOR</b>
NH3	0	0	0	0
H2S	9.13	8.85	9.22	8.9

Components	CASE 1 SOR	CASE 1 EOR	CASE 2 SOR	CASE 2 EOR
H2	70.14	67.83	69.04	66.54
P1	6.81	7.35	6.84	7.3
P2	5.11	6.7	5.88	7.77
P3	3.19	3.59	3.21	3.65
nP4	1.04	1.12	1.04	1.11
iC4	0.49	0.48	0.5	0.48
nP5	0.08	0.07	0.1	0.08
iP5	0	0	0	0
mb6	0.14	0.14	0.2	0.2
2MP	1.55	1.54	2.08	2.08
nP6	1.14	1.14	0.54	0.54
CP	0	0	0	0
5N6	0.17	0.17	0.16	0.16
6N6	0.07	0.07	0.07	0.07
A6	0.81	0.81	0.95	0.95
nP7	0.04	0.04	0.04	0.04
sbP7	0.06	0.06	0.07	0.07
mbP7	0.02	0.02	0.02	0.02
5N7	0.01	0.01	0.01	0.01
6N7	0	0	0.01	0.01
A7	0.02	0.02	0.01	0.01
<b>Total Flowrate, kg/h</b>	<b>762</b>	<b>824</b>	<b>852</b>	<b>929</b>
<b>MW , kg/kgmole</b>	<b>12.91</b>	<b>13.54</b>	<b>13.31</b>	<b>14.00</b>

### 2.1.2.3 Battery Limit Conditions

#### 2.1.2.3.1 Inlet Streams

SI.No	Stream name	Normal operating pressure (kg/cm <sup>2</sup> g)	Normal operating temperature (°C)			
			CASE 1 SOR	CASE 1 EOR	CASE 2 SOR	CASE 2 EOR
1	Heavy Naphtha	3.8	84	84	92	92
2	Heavy LCN	3.8	71	71	71	71
3	Hydrotreated Heavy Naphtha	14.7	40	40	40	40

Sl.No	Stream name	Normal operating pressure (kg/cm <sup>2</sup> g)	Normal operating temperature (°C)			
			CASE 1 SOR	CASE 1 EOR	CASE 2 SOR	CASE 2 EOR
4	Non-Aromatic Liquid Purge	14.7	40	40	40	40
5	H <sub>2</sub> Rich Gas (Make-up)	26.2	36	35	35	34
6	H <sub>2</sub> Pure Gas (Start-up)	21.0	45	45	45	45
7	Washing Water (BFW)	61.5	130	130	130	130

#### 2.1.2.3.2 Outlet streams

Sl.No	Stream name	Normal operating pressure (kg/cm <sup>2</sup> g)	Normal operating temperature (°C)			
			CASE 1 SOR	CASE 1 EOR	CASE 2 SOR	CASE 2 EOR
1	Hydrotreated Heavy Naphtha To Storage	5.0	40	40	40	40
2	Hydrotreated Heavy Naphtha To Aromizing Section	12.8	93	93	100	100
3	Sour Off Gas/H <sub>2</sub> purge gas	9.0	40	40	40	40
4	Sour Water	14.1	40	40	40	40
5	OFF SPEC Naphtha	26.2	36	35	35	34

## 2.1.3 R41-3 Aromizing Reaction Section/ R41-4 Catalyst Regeneration/ R41-5 PSA Section

### 2.1.3.1 Feedstock

The design of the Aromizing Reaction Section has been made considering two different feed cases:

- Case 1 : Light Feed Case
- Case 2 : Heavy Feed Case

For each feed, two operating cases have been considered:

- Normal Operating Case (NOP)
- Maximum Reactor Temperature (MRT)

#### 2.1.3.1.1 Hydrotreated Naphtha feed to Aromizing Reaction Section (R41-3):

The naphtha feed to this unit is the hydrotreated naphtha coming from the bottom of the NHT Stripper (R41-T-122). Following table lists the composition:

Components	HYDROTREATED NAPHTHA (wt %)	
	LIGHT CASE - NOP/MRT	HEAVY CASE - NOP/MRT
2-METHYL PENTANE	1.53	0.98
n-HEXANE	4.88	1.3
METHYLCYCLOPENTANE	1.57	0.96
CYCLOHEXANE	1.61	1.2
BENZENE	3.05	2.33
C7 Paraffins	21.92	17.48
C7 Naphthenes	6.19	5.63
TOLUENE	7.79	5.98
C8 Paraffins	18.25	16.99
C8 Naphthenes	5.26	4.5
ETHYL BENZENE	0.68	0.79
PARA XYLENE	0.73	0.84
META XYLENE	1.65	1.92
ORTHO XYLENE	0.98	1.13
C9 Paraffins and Naphthenes	14.82	14.24
1-TRANS-3,5-TRIMETHYL	2.63	2.98
CUMENE	0.02	0.09
n-PROPYL BENZENE	0.05	0.2
m-ETHYL TOLUENE	0.36	1.48
1,2,4,5-TETRAMETHYL BENZENE	0.46	1.88
INDANE	0.01	0.04

Components	HYDROTREATED NAPHTHA (wt %)	
	LIGHT CASE - NOP/MRT	HEAVY CASE - NOP/MRT
C10 Paraffins and Naphthenes	4.95	15.24
ISOBUTYL BENZENE	0	0.03
4-METHYL-1-ISOPROPYL	0.13	0.32
1,3-DIETHYL BENZENE	0.02	0.06
4-ETHYL-o-XYLENE	0.21	0.58
1,2,3,5-TETRAMETHYL BENZENE	0.16	0.32
C11+ Aromatics	0.09	0.51
PARAFFINS	15.08	14.23
NAPHTHENES	65.37	65.1
AROMATICS	19.55	20.67
<b>Total (kg/h)</b>	<b>277 722</b>	<b>320 521</b>
<b>Specific Gravity @ 15°C</b>	<b>0.7370</b>	<b>0.7452</b>
<b>MW (kg/kmol)</b>	<b>105.77</b>	<b>111.46</b>

#### 2.1.3.1.2 Crude Benzene from Transplus Stabilizer (R42-T-236)

- Crude benzene comes from Transplus stabilizer (R42-T-236) of the Transplus section (R42-3).

Components	CRUDE BENZENE (wt%)	
	LIGHT CASE - NOP/MRT	HEAVY CASE - NOP/MRT
ETHANE	0.11	0.13
PROPANE	0.25	0.31
i-BUTANE	0.00	0.04
n-HEXANE	0.06	0.05
METHYLCYCLOPENTANE	0.04	0.04
CYCLOHEXANE	0.01	0.01
BENZENE	95.55	95.44
C7 Naphtenes	0.01	0.01
TOLUENE	3.97	3.97
<b>Total (kg/h)</b>	<b>24 052</b>	<b>20 620</b>
<b>Specific Gravity @ 15°C</b>	<b>0.8796</b>	<b>0.8786</b>
<b>MW (kg/kmol)</b>	<b>78.31</b>	<b>78.23</b>

**2.1.3.1.3      Recycle C6/C7 from Deheptanizer (R42-T-252) of the Xymax section (R42-5)**

Components	RECYCLE C6/C7 (wt%)	
	LIGHT CASE - NOP/MRT	HEAVY CASE - NOP/MRT
ETHANE	2.16	2.17
PROPANE	0.07	0.14
n-BUTANE	0.06	0.2
n-PENTANE	0.07	0.23
METHYLCYCLOPENTANE	0.26	0.26
CYCLOHEXANE	0.28	0.28
BENZENE	71.54	71.16
C7 Naphthenes	0.03	0.03
TOLUENE	18.06	17.77
C8 Paraffins	0.05	0.12
C8 Naphthenes	0.08	0.12
ETHYL BENZENE	0.22	0.22
PARA XYLENE	2.24	2.29
META XYLENE	4.45	4.55
ORTHO XYLENE	0.43	0.44
C9 Paraffins and Naphthenes	0.00	0.01
<b>Total (kg/h)</b>	13 538	15 760
<b>Specific Gravity @ 15°C</b>	0.8513	0.8494
<b>MW (kg/kmol)</b>	79.08	79.00

**2.1.3.1.4      Hydrogen from Reduction Chamber (R41-D-1412) of the Catalyst Regeneration section (R41-4)**

Hydrogen comes from Reduction Chamber(R41-D-1412) of the Catalyst Regeneration section (R41-4).

Hydrogen to the Reduction Chamber(R41-D-1412) of the Catalyst Regeneration section (R41-4) comes from PSA section (R41-5).

Components	HYDROGEN (mol %)
	ALL CASES
HYDROGEN	99.9
METHANE	0.1
<b>Total (kg/h)</b>	719
<b>Density (kg/m3)</b>	0.2431
<b>MW (kg/kmol)</b>	2.03

**2.1.3.1.5 HP Purge from Separator Drum (R42-D-23550) of Transplus section (R42-3)**

Components	HP PURGE (mol %)			
	LIGHT CASE - NOP	LIGHT CASE - MRT	HEAVY CASE - NOP	HEAVY CASE - MRT
HYDROGEN	78.13	77.17	77.08	76.01
METHANE	2.27	1.20	1.45	0.93
ETHANE	15.41	15.80	17.02	17.09
PROPANE	3.76	5.38	4.05	5.55
i-BUTANE	0.00	0.00	0.06	0.06
BENZENE	0.22	0.24	0.16	0.17
TOLUENE	0.21	0.21	0.18	0.19
<b>Total (kg/h)</b>	1 473	5 710	4 501	10 960
<b>Density (kg/m3)</b>	5.641	6.082	5.927	6.329
<b>MW (kg/kmol)</b>	8.59	9.25	9.01	9.61

**2.1.3.2 Product Specification**

There are three liquid products from Aromizing section:

- Reformate to Xylene Fractionation section (R42-1),
- C5 cut to gasoline pool,
- LPG to storage.

There are five gas products from Aromizing section:

- Fuel gas from LPG Absorber Drum (R41-D-136100)
- Fuel gas from Deethanizer Reflux Drum (R41-D-13750)
- H2 Rich gas from HP Absorber Drum (R41-D-13580) going to Naphtha Hydrotreatment section (R41-2) and Catalyst Regeneration section (R41-4),
- Hydrogen from PSA section (R41-5) going to Catalyst Regeneration section (R41-4), Transplus section (R42-3), Xymax section (R42-5) and H2 existing header,
- Tail gas from PSA (R41-PK-1510) (R41-5).

Expected characteristics are described in the following pages.

#### **2.1.3.2.1      Reformate to Xylene Fractionation section (R42-1)**

Reformate comes from the bottom of the Depentanizer Column (R41-T-136) and goes to the Reformate Splitter (R42-T-2110). The properties of Reformate produced are as follows:

	<b>LIGHT CASE - NOP</b>	<b>LIGHT CASE - MRT</b>	<b>HEAVY CASE -NOP</b>	<b>HEAVY CASE -MRT</b>	<b>TEST METHOD</b>
Sp. Gr.	0.8512	0.8539	0.8539	0.8564	ASTM D-1298
Distillation, Vol%	Temperature in °C				ASTM D86
IBP	88.5	88.5	93.5	93.7	
5%	92.7	92.9	99.2	99.5	
10%	96	96.4	103.6	104.1	
30%	109.6	110.2	118.9	119.6	
50%	117.3	117.7	139.6	139.8	
70%	135.7	136	155	155.2	
90%	161.7	162.1	174.9	174.4	
95%	172.2	172.5	182.6	182.9	
EBP	186.7	186.9	193.1	193	
RON	104	105	104	105	ASTM D-2699
MON	93	94	93	94	ASTM D-2700
RVP, kPaA	11.7	11.4	9.4	9.2	ASTM D-323
PONA, Vol%					
P	12.50	11.24	11.37	10.13	
O	0.98	0.98	1.01	1.01	
N	0.70	0.64	0.57	0.51	IFP-9302
A	85.82	87.14	87.05	88.35	

Composition is as follows:

Components	REFORMATE (wt %)			
	LIGHT CASE - NOP	LIGHT CASE - MRT	HEAVY CASE - NOP	HEAVY CASE - MRT
i-PENTANE	0.02	0.02	0.02	0.02
n-PENTANE	0.03	.03	0.04	0.04
CYCLOPENTANE	0.03	0.03	0.03	0.03
2-METHYL PENTANE	3.56	3.19	2.26	2.00
n-HEXANE	1.30	1.17	0.85	0.75
METHYLCYCLOPENTANE	0.50	0.45	0.36	0.32
CYCLOHEXANE	0.01	0.01	0.01	0.01
BENZENE	19.00	19.25	14.85	15.0
C7 Paraffins	4.58	4.11	4.79	4.25
C7 Naphthenes	0.07	0.07	0.09	0.08
TOLUENE	26.52	26.86	19.98	20.2
C8 Paraffins	0.50	0.45	1.11	0.98
C8 Naphthenes	0.01	0.01	0.03	0.02
ETHYL BENZENE	3.99	4.03	3.88	3.93
PARA XYLENE	4.37	4.42	4.26	4.31
META XYLENE	9.92	10.04	9.68	9.79
ORTHO XYLENE	5.75	5.81	5.60	5.66
C9 Paraffins and Naphthenes	0.02	0.02	0.09	0.08
CUMENE	0.39	0.38	0.44	0.45
n-PROPYL BENZENE	0.86	0.87	0.97	0.98
m-ETHYL TOLUENE	6.22	6.29	7.06	7.13
1,2,4,5-TETRAMETHYL	7.93	8.02	8.99	9.09
INDANE	0.16	0.16	0.18	0.18
ISOBUTYL BENZENE	0.00	0.00	0.27	0.28
4-METHYL-1-ISOPROPYL	0.90	0.91	2.50	2.53
1,3-DIETHYL BENZENE	0.12	0.12	0.49	0.50
4-ETHYL-o-XYLENE	1.47	1.49	4.57	4.62
1,2,3,5-TETRAMETHYL BENZENE	1.13	1.14	2.56	2.59
C11+ Aromatics	0.64	0.65	4.04	4.09
<b>Total (kg/h)</b>	<b>272 051</b>	<b>268 918</b>	<b>307 922</b>	<b>304 477</b>
<b>Specific Gravity @ 15°C</b>	<b>0.8512</b>	<b>0.8539</b>	<b>0.8539</b>	<b>0.8564</b>
<b>MW (kg/kmol)</b>	<b>96.82</b>	<b>96.87</b>	<b>102.02</b>	<b>102.09</b>

### 2.1.3.2.2 C5 cut to gasoline pool

This product comes from Debutanizer Column (R41-T-138) bottom and goes to the gasoline pool.

#### Specification

Properties	Specification	Test Method
Benzene, vol%	1.0 Max.	IFP - 9301

#### Expected Properties

	LIGHT CASE - NOP	LIGHT CASE - MRT	HEAVY CASE - NOP	HEAVY CASE - MRT	TEST METHOD
Distillation, Vol%	Temperature in °C				ASTM D86
IBP	15.9	15.8	15.9	15.8	
5%	22.5	22.5	22.4	22.5	
10%	28.9	29.0	28.9	28.9	
30%	30.3	30.4	30.3	30.4	
50%	30.8	30.9	30.8	30.9	
70%	34.4	34.7	34.2	34.4	
90%	54.2	54.8	41.7	53.6	
95%	75.3	75.7	63.4	74.8	
EBP	90.5	90.9	79.8	90.1	
RON	87.3	87.7	86.1	86.6	ASTM D-2699
MON	79.4	79.3	79.1	79.1	ASTM D-2700
RVP, kPaA	120.1	119.1	121.2	120.7	ASTM D-323/ 5191

Composition is as follows:

Components	C5 CUT (wt %)			
	LIGHT CASE - NOP	LIGHT CASE - MRT	HEAVY CASE - NOP	HEAVY CASE - MRT
i-BUTANE	0.02	0.02	0.02	0.02
n-BUTANE	0.75	0.76	0.75	0.76
1-BUTENE	0.01	0.01	0.01	0.01
CIS-2-BUTENE	0.21	0.20	0.21	0.20
TRANS-2-BUTENE	0.00	0.00	0.00	0.01
3-METHYL-1-BUTENE	0.61	0.62	0.54	0.56
i-PENTANE	45.45	43.92	46.66	45.23
1-PENTENE	8.99	9.84	7.57	8.40
2-METHYL-1-BUTENE	1.21	1.21	1.22	1.22
TRANS-2-PENTENE	0.65	0.64	0.69	0.67
CIS-2-PENTENE	0.35	0.36	0.38	0.36

n-PENTANE	25.79	25.03	28.40	27.69
2-METHYL-2-BUTENE	2.34	2.31	2.42	2.40
CYCLOPENTENE	0.23	0.23	0.25	0.24
CYCLOPENTANE	0.32	0.33	0.29	0.30
2-METHYL PENTANE	1.10	1.23	0.65	0.72
n-HEXANE	0.03	0.03	0.02	0.02
1-HEXENE	9.18	10.20	7.65	8.62
BENZENE	0.17	0.19	0.12	0.14
1-OCTENE	2.59	2.87	2.15	2.43
<b>Total (kg/h)</b>	<b>9 293</b>	<b>8 360</b>	<b>11 155</b>	<b>9 893</b>
<b>Specific Gravity @ 15°C</b>	<b>0.6386</b>	<b>0.6396</b>	<b>0.6372</b>	<b>0.638</b>
<b>MW (kg/kmol)</b>	<b>73.43</b>	<b>73.62</b>	<b>73.13</b>	<b>73.30</b>

#### 2.1.3.2.3 LPG to storage

This product comes from Debutanizer Reflux Drum (R41-D-13850) and goes to storage.

Properties	Specification	Test Method
C5, vol%	2.0 max	IPF- 9909
Vapour Pressure, kPAG @100°F (kg/cm <sup>2</sup> G @ 38°C)	690 max (7.03 max)	ASTM D323 / 5191
H2S, wt. ppm	5 max.	ASTM D6667 for Total Sulfur ASTM D6228 for H2S

Composition is as follows:

Components	LPG (wt %)			
	LIGHT CASE - NOP	LIGHT CASE - MRT	HEAVY CASE - NOP	HEAVY CASE - MRT
ETHANE	0.96	0.92	1.05	0.99
PROPANE	18.73	21.45	20.38	23.59
PROPYLENE	0.21	0.24	0.23	0.26
i-BUTANE	19.60	19.96	19.95	20.15
ISOBUTENE	0.82	0.85	0.85	0.87
n-BUTANE	49.25	47.03	47.75	45.22
1-BUTENE	2.67	2.39	2.47	2.18
CIS-2-BUTENE	5.50	4.89	5.06	4.45
TRANS-2-BUTENE	0.25	0.25	0.25	0.26
1,3-BUTADIENE	0.01	0.00	0.00	0.00
3-METHYL-1-BUTENE	0.11	0.11	0.10	0.10

i-PENTANE	1.40	1.38	1.43	1.42
1-PENTENE	0.18	0.21	0.15	0.17
2-METHYL-1-BUTENE	0.02	0.02	0.02	0.02
n-PENTANE	0.28	0.29	0.30	0.31
2-METHYL-2-BUTENE	0.01	0.01	0.01	0.01
<b>Total (kg/h)</b>	20 238	22 938	22 028	25 304
<b>Specific Gravity @ 15°C</b>	0.5644	0.5619	0.5624	0.5596
<b>MW (kg/kmol)</b>	54.38	53.97	54.08	53.61

**2.1.3.2.4**      Fuel gas from LPG Absorber Drum (R41-D-136100)

Components	FUEL GAS (wt %)			
	LIGHT CASE - NOP	LIGHT CASE - MRT	HEAVY CASE - NOP	HEAVY CASE - MRT
HYDROGEN	8.44	3.08	5.49	1.92
METHANE	17.85	9.65	13.88	6.62
ETHANE	40.70	50.60	48.85	54.66
PROPANE	19.19	23.37	19.60	24.52
i-BUTANE	4.41	4.63	4.11	4.49
n-BUTANE	3.82	3.99	3.52	3.83
i-PENTANE	1.41	1.09	1.40	1.12
n-PENTANE	0.61	0.48	0.65	0.53
2-METHYL PENTANE	0.01	0.01	0.51	0.40
n-HEXANE	0.92	0.68	0.14	0.11
METHYLCYCLOPENTANE	0.24	0.18	0.04	0.04
BENZENE	0.80	0.73	0.51	0.49
C7 Paraffins	0.30	0.24	0.28	0.24
TOLUENE	0.89	0.87	0.63	0.65
C8 Paraffins	0.02	0.01	0.03	0.03
ETHYL BENZENE	0.05	0.05	0.05	0.05
PARA XYLENE	0.05	0.05	0.04	0.05
META XYLENE	0.10	0.11	0.10	0.11
ORTHO XYLENE	0.05	0.05	0.05	0.05
m-ETHYL TOLUENE	0.03	0.04	0.04	0.04
1,2,4,5-TETRAMETHYL	0.02	0.02	0.02	0.03
<b>Total (kg/h)</b>	<b>524</b>	<b>1 461</b>	<b>909</b>	<b>2 654</b>
<b>Density (kg/m3)</b>	<b>2.982</b>	<b>4.739</b>	<b>3.718</b>	<b>5.497</b>
<b>MW (kg/kmol)</b>	<b>13.70</b>	<b>21.98</b>	<b>17.11</b>	<b>25.44</b>

**2.1.3.2.5**      Fuel gas from Deethanizer Reflux Drum (R41-D-13750)

Components	FUEL GAS (wt %)			
	LIGHT CASE - NOP	LIGHT CASE - MRT	HEAVY CASE - NOP	HEAVY CASE - MRT
HYDROGEN	0.02	0.01	0.01	0.01
METHANE	1.45	0.67	0.96	0.43
ETHANE	54.27	54.67	55.62	55.28
PROPANE	34.76	36.05	34.17	36.37
i-BUTANE	4.83	4.33	4.62	4.09
n-BUTANE	3.81	3.41	3.69	3.23
i-PENTANE	0.60	0.40	0.64	0.41
n-PENTANE	0.25	0.17	0.28	0.18
<b>Total (kg/h)</b>	3 118	3 795	4 109	4 694
<b>Density (kg/m<sup>3</sup>)</b>	8.728	8.856	8.781	8.887
<b>MW (kg/kmol)</b>	35.01	35.30	35.12	35.37

**2.1.3.2.6**      H2 Rich Gas from Aromizing Section (R41-3)

H2 Rich Gas from HP Absorber Drum (R41-D-13580) after passing through Hydrogen Rich Gas Chloride Adsorber (R41-R-13590 A/B) is sent to three destinations given below:

- H2 Rich Gas to Naphtha Hydrotreatment Section (R41-2)
- H2 Rich Gas to Catalyst Regeneration Section (R41-4)
- H2 Rich Gas to PSA Section (R41-5)

**Expected Properties:**

Properties	Expected Value	Test Method
Hydrogen Purity, mol%	93.2	Gas Chromatograph

**2.1.3.2.6.1**      H2 Rich Gas to Naphtha Hydrotreatment section (R41-2)

Refer to section 2.1.2.1.2 for composition and flowrate details of H2 Rich gas from Aromizing section (R41-3) to Naphtha Hydrotreatment Section (R41-2).

### 2.1.3.2.6.2 H2 Rich Gas to Catalyst Regeneration section (R41-4)

H2 Rich Gas comes from HP Absorber Drum (R41-D-13580) and goes to Catalyst Regeneration section (R41-4).

Components	H2 RICH GAS TO R41-4 (wt %)			
	LIGHT CASE - NOP	LIGHT CASE - MRT	HEAVY CASE - NOP	HEAVY CASE - MRT
HYDROGEN	51.75	44.44	48.91	41.37
METHANE	11.33	11.66	11.11	11.09
ETHANE	17.42	22.96	21.00	27.01
PROPANE	11.22	13.00	11.33	13.28
i-BUTANE	2.86	2.96	2.74	2.80
n-BUTANE	2.61	2.71	2.49	2.54
i-PENTANE	0.85	0.66	0.89	0.67
n-PENTANE	0.35	0.27	0.39	0.29
2-METHYL PENTANE	0.53	0.40	0.31	0.23
n-HEXANE	0.13	0.10	0.08	0.06
BENZENE	0.37	0.32	0.25	0.22
C7 Paraffins	0.14	0.11	0.14	0.10
TOLUENE	0.32	0.28	0.24	0.21
<b>Total (kg/h)</b>	<b>553</b>	<b>553</b>	<b>553</b>	<b>553</b>
<b>Density (kg/m3)</b>	<b>3.780</b>	<b>4.327</b>	<b>3.985</b>	<b>4.624</b>
<b>MW (kg/kmol)</b>	<b>3.66</b>	<b>4.17</b>	<b>3.84</b>	<b>4.44</b>

### 2.1.3.2.6.3 H2 Rich Gas to PSA section (R41-5)

Remaining Hydrogen is sent to the PSA section (R41-5) to produce purified Hydrogen. Composition of H2 Rich gas to PSA section is same as in section 2.1.3.2.6.2.

	LIGHT CASE - NOP	LIGHT CASE - MRT	HEAVY CASE - NOP	HEAVY CASE - MRT
<b>Total (kg/h)</b>	<b>21525</b>	<b>25461</b>	<b>25204</b>	<b>30697</b>
<b>Density (kg/m3)</b>	<b>3.780</b>	<b>4.327</b>	<b>3.985</b>	<b>4.624</b>
<b>MW (kg/kmol)</b>	<b>3.66</b>	<b>4.17</b>	<b>3.84</b>	<b>4.44</b>

#### **2.1.3.2.7      Hydrogen from PSA Section (R41-5)**

Specification of purified Hydrogen at the PSA unit outlet is as follows:

Properties	Specification	Test Method
Hydrogen Purity, mol%	99.9 min.	Gas Chromotograph
CO + CO <sub>2</sub> , mol ppm	1 max	UOP 603 or Equivalent

#### **2.1.3.2.7.1    Hydrogen from PSA (R41-5) to existing header**

Components	H2 FROM PSA TO EXISTING HEADER (mol %)			
	LIGHT CASE - NOP	LIGHT CASE - MRT	HEAVY CASE - NOP	HEAVY CASE - MRT
HYDROGEN	99.90	99.90	99.90	99.90
METHANE	0.10	0.10	0.10	0.10
<b>Total (kg/h)</b>	7 733	6 576	7 893	6 409
<b>Density (kg/m<sup>3</sup>)</b>	1.771	1.775	1.777	1.782
<b>MW (kg/kmol)</b>	2.03	2.03	2.03	2.03

#### **2.1.3.2.7.2    Hydrogen from PSA (R41-5) to Catalyst Regeneration section (R41-4)**

Hydrogen comes from PSA (R41-5) and goes to Reduction Exchanger (R41-E-1416) of Catalyst Regeneration section (R41-4). Composition of Hydrogen from PSA and its properties are same as in section 0.

	LIGHT CASE - NOP	LIGHT CASE - MRT	HEAVY CASE - NOP	HEAVY CASE - MRT
<b>Total (kg/h)</b>	741	741	741	741

#### **2.1.3.2.7.3      Hydrogen from PSA (R41-5) to Transplus section (R42-3)**

Hydrogen comes from PSA (R41-5) and goes to H<sub>2</sub> Makeup K.O Drum (R42-D-2356) of Transplus section (R42-3). Composition of Hydrogen from PSA and its properties are same as in section 0.

	<b>LIGHT CASE - NOP</b>	<b>LIGHT CASE - MRT</b>	<b>HEAVY CASE - NOP</b>	<b>HEAVY CASE - MRT</b>
<b>Total (kg/h)</b>	1 177	2 492	2 017	3 834

#### **2.1.3.2.7.4      Hydrogen from PSA (R41-5) to Xymax section (R42-5)**

Hydrogen comes from PSA (R41-5) and goes to Xymax Reactor (R42-R-2510) of Xymax section (R42-5). Composition of Hydrogen from PSA and its properties are same as in section 0.

	<b>LIGHT CASE - NOP</b>	<b>LIGHT CASE - MRT</b>	<b>HEAVY CASE - NOP</b>	<b>HEAVY CASE - MRT</b>
<b>Total (kg/h)</b>	341	341	409	409

#### **2.1.3.2.8      Tail Gas from PSA (R41-5)**

<b>Components</b>	<b>PSA TAIL GAS (wt %)</b>			
	<b>LIGHT CASE - NOP</b>	<b>LIGHT CASE - MRT</b>	<b>HEAVY CASE - NOP</b>	<b>HEAVY CASE - MRT</b>
HYDROGEN	10.62	8.13	9.59	7.24
METHANE	20.46	18.87	19.18	17.17
ETHANE	32.51	38.18	37.42	42.95
PROPANE	20.95	21.63	20.19	21.12
i-BUTANE	5.34	4.92	4.88	4.45
n-BUTANE	4.88	4.50	4.44	4.05
i-PENTANE	1.59	1.10	1.58	1.06
n-PENTANE	0.66	0.45	0.69	0.47
2-METHYL PENTANE	0.96	0.67	0.55	0.37
n-HEXANE	0.24	0.17	0.14	0.10
METHYLCYCLOPEN	0.06	0.04	0.04	0.03
BENZENE	0.68	0.54	0.44	0.35
C7 Paraffins	0.26	0.18	0.24	0.17

TOLUENE	0.60	0.47	0.42	0.33
META XYLENE	0.05	0.04	0.05	0.04
<b>Total (kg/h)</b>	<b>11 533</b>	<b>15 311</b>	<b>14 144</b>	<b>19 303</b>
<b>Density (kg/m3)</b>	<b>2.587</b>	<b>3.036</b>	<b>2.761</b>	<b>3.254</b>
<b>MW (kg/kmol)</b>	<b>11.99</b>	<b>13.93</b>	<b>12.71</b>	<b>14.81</b>

### **2.1.3.3 Battery Limit Conditions**

#### **2.1.3.3.1 Inlet Streams**

	Pressure (Kg/cm <sup>2</sup> g)	Light Case NOP/MRT (deg.C)	Heavy case NOP/MRT (deg.C)
Hydrotreated Naphtha ( from R41-2)	12.8	93 / 93	100 / 100
Crude Benzene (from R42-3)	18.1	152 / 152	150 / 150
Recycle C6/C7 (from R42-5)	18.1	59 / 59	59 / 59
H2 from Reduction Chamber (from R41-4) <b>(H2 from PSA - R41-5 to Reduction Chamber - R41-4)</b>	2.3	54 / 54	54 / 54
HP Purge (from R42-3)	16.6	45 / 45	45 / 45

#### **2.1.3.3.2 Outlet Streams**

	Pressure (kg/cm <sup>2</sup> g)	Light Case NOP/MRT (deg. C)	Heavy Case NOP/MRT (deg. C)
Reformate (to R42-1)	4.0	102 / 100	107 / 105
Reformate to storage	5.0	40 / 40	40 / 40
C5+ cut to gasoline pool	5.0	40 / 40	40 / 40
LPG to storage	16.0	46 / 46	46 / 46
Fuel Gas from LPG Absorber drum	4.5	29 / 36	31 / 37
Fuel Gas from Deethanizer reflux drum	4.5	8 / 7	8 / 7
H2 Rich Gas (to R41-2)	26.2	36 / 35	35 / 34
H2 Rich Gas (to R41-4)	26.2	36 / 35	35 / 34
H2 from PSA (to R41-2)	23.7	36 / 35	35 / 34
H2 from PSA (to R42-3)	23.7	36 / 35	35 / 34
H2 from PSA (to R42-5)	23.7	36 / 35	35 / 34
H2 from PSA to existing header	23.7	36 / 35	35 / 34
PSA Tail Gas	4.5	Max 45	Max 45

## **2.1.4 R41-9 Utility System**

For details about Steam system, Fuel Gas system, Drain systems and Flare systems refer to description of utilities in section 2.4.

### **2.1.4.1 Off gas System**

Off gas from Aromizing section, PSA section and Aromatics complex is sent to Fuel gas system and Existing fuel gas header (12"-FG-N200-0006) through pressure control valve R41-PV-7511 and flow control valve R41-FV- 7501 respectively.

- Light Feed Case (EOR):**

Description	Unit	Off gas to Fuel gas system	Off gas to existing Fuel gas header
Heat duty (Normal)	MMkcal/hr	376.0	71.6
Heat duty (Design)	MMkcal/hr	570.9	205.5
Normal Flow	Kg/hr	31198	6272
Design Flow	Kg/hr	48137	17383

- Light Feed Case (SOR):**

Description	Unit	Off gas to Fuel gas system	Off gas to existing Fuel gas header
Heat duty (Normal)	MMkcal/hr	352.8	8.8
Heat duty (Design)	MMkcal/hr	570.9	205.5
Normal Flow	Kg/hr	29083	771
Design Flow	Kg/hr	48137	17383

- Heavy Feed Case (SOR):**

Description	Unit	Off gas to Fuel gas system	Off gas to existing Fuel gas header
Heat duty (Normal)	MMkcal/hr	444.8	16.1
Heat duty (Design)	MMkcal/hr	570.9	205.5
Normal Flow	Kg/hr	36995	1416
Design Flow	Kg/hr	48137	17383

- **Heavy Feed Case (EOR):**

Description	Unit	Off gas to Fuel gas system	Off gas to existing Fuel gas header
Heat duty (Normal)	MMkcal/hr	446.8	124.1
Heat duty (Design)	MMkcal/hr	570.9	205.5
Normal Flow	Kg/hr	37453	10685
Design Flow	Kg/hr	48137	17383

#### **2.1.4.2 Hydrogen Distribution Header**

During normal operation pure hydrogen from PSA is sent to OSBL common header, Catalyst Regeneration section (R41-4), Transplus section (R42-3), Xymax section (R42-5) and excess hydrogen to Aromizing Reaction Section (R41-3) Fired Heaters R41-FR-13110/13210/13310/13410 and to Xylene Fractionation section (R42-1) Xylene Rerun Column Reboiler R42-FR-2130 A/B. Also during normal operation H2 rich gas from Aromizing section (R41-3) is sent to Naphtha Hydrotreatment section (R41-2) and Catalyst Regeneration section (R41-4).

During normal operation pure hydrogen is sent via ZV-3560 to R42 section (Xylene fractionation section, Xymax section, Transplus section). In case of any upset condition hydrogen rich gas from R41 (aromizing section) is sent via ZV-3561 to R42 section (Xymax section, Transplus section)

For initial startup pure hydrogen from OSBL header is sent to Naphtha Hydrotreatment unit, Aromizing Reaction Section, Transplus section and Xymax section.

## **2.2 Process Description**

### **2.2.1 R41-1: Naphtha Splitter and LCN Splitter section**

#### **2.2.1.1 Naphtha Depentanizer and Naphtha Splitter Sections**

Naphtha feed from the storage tanks SR Naphtha Tank (F56-TK-63/64) is fed to Naphtha Preheater R41-E-1112 where the naphtha is preheated from the ambient temperature of the storage to the unit normal inlet temperature (65°C) by means of low pressure steam in Naphtha Preheater (R41-E-1112). The outlet temperature of Naphtha from Naphtha Preheater (R41-E-1112) **tubeside** is controlled by **tubeside** bypass control valve R41-TV-1120. Naphtha coming from Naphtha Preheater (R41-E-1112) arrives at the Naphtha Depentanizer Feed/Naphtha Splitter Bottom Exchangers R41-E-1111A/B shell side where the naphtha is heated against the bottom of the Naphtha Splitter Column (R41-T-112) coming from Heavy Naphtha Pump (R41-P-1120A/B) on tubeside. After going through the exchanger R41-E-1111A/B, the hot naphtha is fed into the tray 13 of the Naphtha Depentanizer Column R41-T-111.

The overhead gas from the Naphtha Depentanizer (R41-T-111) is cooled down in the Naphtha Depentanizer Air Condenser R41-E-1115 and Naphtha Depentanizer Trim Cooler R41-E-1116 and routed to the Naphtha Depentanizer Reflux Drum R41-D-11150. When treating naphtha from the storage, the feed can contain oxygen and water that are separated from the hydrocarbon phase in the Naphtha Depentanizer Reflux Drum (R41-D-1115). The oxygen **is** routed out of the unit through the oxygen rich gas line to fuel gas header from top of Naphtha Depentanizer Reflux Drum R41-D-11150 using pressure control valve R41-PV-1151B. An O<sub>2</sub> Analyzer is provided downstream R41-PV-1151B in the oxygen rich gas line to fuel gas header to measure Oxygen content in the gas. In case of excess oxygen, it will be diluted by Nitrogen using flow control valve R41-FV-1152 and then routed to Flare through pressure control valve (R41-PV-1153).

The free water collected in the Naphtha Depentanizer Reflux Drum (R41-D-11150) boot **is** decanted to OWS through the level control valve R41-LV-1152. The reflux to Naphtha Depentanizer (R41-T-111) comes from the Naphtha Depentanizer Reflux Drum(R41-D-11150) through Naphtha Depentanizer Reflux Pump R41-P-1115A/B.

In the Naphtha Depentanizer (R41-T-111) column, a C5 rich cut is taken on a draw off located in the tray 28 and sent to storage (C5 Rich Cut Storage Drum R42-TK-2760) by means of the C5 Rich Cut Pumps R41-P-1114A/B. The C5 Rich Cut Trim Coolers R41-E-1114A/B cool the C5 rich cut down to a suitable temperature (45 °C) for the

storage. In case C5 Rich Cut from the Naphtha Depentanizer (R41-T-111) is Off-Spec, it is routed to the SR Naphtha Tank (F56-TK-63/64).

The Naphtha Depentanizer (R41-T-111) column is reboiled by the Naphtha Depentanizer Reboiler R41-E-1110 by using medium pressure steam. The reboiler duty is controlled by temperature controller R41-TC-1102 on tray 1, which resets steam side flowrate by means of flow control valve R41-FV-1105. The bottom product from the Naphtha Depentanizer (R41-T-111) flashes on the bottom flow control valve (R41-FV-1101) and is sent to the Naphtha Splitter R41-T-112 column on tray 23.

The overhead gas from the Naphtha Splitter (R41-T-112) is totally cooled down in the Naphtha Splitter Air Condenser R41-E-1125 and routed to the Naphtha Splitter Reflux Drum R41-D-11250. The liquid is pumped by the Naphtha Splitter Reflux Pumps R41-P-1125A/B and divided in two streams: one going as reflux back to the Naphtha Splitter (R41-T-112) through flow control valve R41-FV-1250, and the other one, the Light Naphtha, is cooled down in the Light Naphtha Trim Coolers R41-E-1126A/B to 40 °C and going to storage (F56-TK-65/66) through flow control valve R41-FV-1251.

The Naphtha Splitter (R41-T-112) column is reboiled by the Naphtha Splitter Reboiler R41-E-112A/B by using medium pressure steam. The reboiler duty is controlled by temperature controller R41-TC-1205 on tray 27, which resets steam side flowrate by means of flow control valve R41-FV-1205.

The Heavy Naphtha from Naphtha Splitter (R41-T-112) bottom is sent on flow control to the Naphtha Depentanizer Feed/Naphtha Splitter Bottom Exchangers R41-E-1111A/B (**Tube Side**) and then to the Naphtha Hydrotreatment Section R41-2 by means of the Heavy Naphtha Pumps R41-P-1120A/B. During Start-up or in case of Off-spec product, the Heavy Naphtha is routed to SR Naphtha Tank (F56-TK-63/64) by flow control R41-FV-1200B via SR Naphtha Tank Rundown Aircooler (R41-E-1363) and SR Naphtha Tank Rundown Trim Cooler (R41-E-1364 A/B).

#### **2.2.1.2 LCN Splitter Section**

The LCN coming from the HOFCC unit, goes through the LCN Splitter Feed/Bottom Exchangers R41-E-1131A/B where it is heated against the bottom of the LCN Splitter (R41-T-113) Column to 88 °C. The hot LCN is fed into tray 25 of the LCN Splitter R41-T-113.

The overhead gas from the LCN Splitter (R41-T-113) is totally cooled down in the LCN Splitter Air Condenser R41-E-1135 and routed to the LCN Splitter Reflux Drum R41-D-1135. The liquid is pumped by the LCN Splitter Reflux Pumps R41-P-1135A/B and divided in two streams: one going as reflux back to the LCN Splitter (R41-T-1130) column by flow control valve R41-FV-135, and the other one, the light LCN, is cooled down in the Light LCN Trim Coolers R41-E-1136A/B and going to the storage (S040-TK-0810/0811) using flow control valve R41-FV-1351.

The LCN Splitter (R41-T-113) column is reboiled by the LCN Splitter Reboiler R41-E-113 by using medium pressure steam. The reboiler duty is controlled by temperature controller R41-TC-1302 on tray 1, which resets steam side flowrate by means of flow control valve R41-FV-1305. The Heavy LCN on LCN Splitter (R41-T-113) bottom is sent on flow control using R41-FV-131 to the Naphtha Hydrotreatment Section R41-2 through the LCN Splitter Feed/Bottom Exchangers R41-E-1131A/B by means of the Heavy LCN Pumps R41-P-1130A/B.

### **2.2.2 R41-2 Naphtha Hydrotreatment Section**

Heavy naphtha from Naphtha Splitter (R41-T-112) and Heavy LCN from LCN Splitter (R41-T-113) are fed after blending to the reaction section of the Naphtha Hydrotreatment unit.

#### **2.2.2.1 Reaction section**

There are principally two fundamental reactions occurring:

- Hydrorefining,
- Hydrogenation

Detail discussion regarding the reactions involved in hydrotreating is present in Section 3.1.4.1.

Heavy naphtha from Naphtha Splitter (R41-T-112) and Heavy LCN from LCN Splitter (R41-T-113) are mixed and fed to Feed Surge Drum (R41-D-12010). From there it is pumped by Feed Pump (R41-P-1201A/B and with the recycle gas from Recycle Compressors R41-K-1215A/B. The Naphtha flow is controlled by flow control valves R41-FV-2011 and R41-FV-2013. Recycle gas flow is controlled by flow control valves R41-FV-2150 and R41-FV-2152.

The mixture of Naphtha and Recycle gas is preheated in the two parallel trains of Reactor Feed/Effluent Exchangers R41-E-12110 A to M, and further heated to the required inlet reactor temperature of 335 °C, during EOR, in the Reactor Feed Heater R41-FR-12110 before going to Hydrotreating Reactor R41-R-121.

The Hydrotreating Reactor (R41-R-121) inlet temperature is controlled by temperature controller R41-TC- 2100 by means of controlling the fuel gas flow rate to the burners of Reactor Feed Heater R41-FR-12110. The reactor outlet is cooled down in the two parallel trains of Reactor Feed/Effluent Exchangers R41-E-12110 A to M, then in Reactor Effluent Air Condenser R41-E-1212 to 65 °C and finally in Reactor Effluent Trim Condenser R41-E-1213 A/B to 46 °C and sent to Separator Drum R41-D-12140, where the hydrocarbon flow is separated into vapor and liquid phase. Upstream of the R41-E-1212, BFW is injected whenever required. Purpose of this injection is to dissolve any ammonium salts which precipitate at low temperature downstream of Reactor Effluent Trim Condenser R41-E-1212.

The vapor phase from Separator Drum R41-D-12140 is used as recycle gas and is mixed with hydrogen make-up, which is hydrogen rich gas coming from Aromizing Section (R41-3) by flow control valve R41-FV-2155. The mixture is sent through the Recycle Compressor K.O. Drum R41-D-1215 to Recycle Compressors R41-K-1215 A/B.

During start-up when hydrogen rich gas from Aromizing Section (R41-3) is not available, pure hydrogen from existing header is used as make-up of recycle gas. Whenever required some recycle gas can be purged to flare using flow control valve R41-FV-2156. This gas purge is used to control the reaction section pressure during start-up, and to increase the recycle gas purity during normal operation.

During normal operation, the reaction section pressure is controlled by the pressure controller R41-PC-2145A by adjusting the flow of make-up hydrogen through flow control valve R41-FV-2155. An override mode controller (R41-PC-2145B) is provided in case the pressure control with the H<sub>2</sub> make-up flowrate is not enough. This override mode leads to the opening of the control valve on the flare line (R41-FV-2156) to maintain reactor pressure. Under ideal conditions, the flow rate of gas to flare is zero.

Separator Drum R41-D-12140 water is sent to the Sour Water Drum R41-D-12160 **using level control valve R41-LV-2141 by level controller R41-LC-2141**. The liquid hydrocarbons from Separator Drum R41-D-12140 is routed

under flow control using R41-FV-2140 cascaded with level controller R41-LC-2140 and sent to the NHT Stripper Column R41-T-122.

#### **2.2.2.2 NHT Stripper section**

The Heavy Naphtha from the Separator Drum R41-D-12140 is preheated in Stripper Feed/Bottom Exchangers R41-E-1221 A/B/C, using the NHT Stripper Bottom Product coming from Stripper Bottom Product Pump (R41-P-122A/B/C), and then enters the NHT Stripper column R41-T-122 in tray 23. **Inlet temperature in tray 23 is:**

- 180 °C: Light Feed Case SOR and EOR;
- 187°C: Heavy Feed Case SOR and EOR.

NHT Stripper column R41-T-122 is reboiled by Stripper Reboiler R41-FR-122 and by the convection zone of the Reaction Feed Heater R41-FR-12110 which are fed by the Stripper Bottom Product Pumps R41-P-122 A/B/C under flow control valves R41-FV-2201A-F and R41-FV-2211A-E respectively.

Overhead from the NHT Stripper column R41-T-122 is partially condensed in the Stripper Air Condenser R41-E-1225 and in the Stripper Trim Condenser R41-E-1226A/B. The stream from the Stripper Trim Condenser R41-E-1226A/B is mixed with Sour Gas from Sour Water Drum (R41-D-12160) and sent to the Stripper Reflux Drum R41-D-12250. A corrosion inhibitor solution is injected upstream of Stripper Air Condenser R41-E-1225 to protect the equipment downstream of the condensation point from corrosion.

The purge gas from Stripper Reflux Drum Stripper Air Condenser R41-E-1225 is sent to the sour gas header under pressure control using pressure control valve R41-PV-2250. The liquid is pumped by Stripper Reflux Pump R41-P-1225 A/B under flow control using R41-FV-2250 cascaded with level controller R41-LC-2250 and sent to the top of NHT Stripper column R41-T-122 as reflux.

The bottom product of the NHT Stripper R41-T-122, which is Hydrotreated Heavy Naphtha, is cooled in the Stripper Feed/Bottom Exchangers R41-E-1221A/B/C, and then sent to the Aromizing section (R41-3) under flow control using R41-FV-3110 cascaded with level controller R41-LC-2200. NHT Stripper bottom product can also be sent to storage (S220-TK-0700) under flow control using R41-FV-2203 cascaded with level controller R41-LC-2200 after cooling in Hydrotreated Naphtha Air Cooler R41-E-1222 and Hydrotreated Naphtha Trim Cooler R41-E-1223 A/B. In normal operation, Hydrotreated Naphtha flow sent to storage is nil.

Sour Water from Sour Water Drum (R41-D-12160) is sent to existing Sour Water Stripper under flow control using R41-FV-2160 cascaded with level controller R41-LC-2160. Also sour water from Stripper Reflux Drum R41-D-1225 if any is mixed with sour water from R41-D-12160 downstream of flow control valve R41-FV-2160 before sending to existing Sour Water Stripper via F34-V-08 / R301-D-0001/ R302-D-0001.

### **2.2.3 R41-3 Aromizing Section**

#### **2.2.3.1 Reaction section**

Feed to the Aromizing section (R41-3) comes from bottom of the NHT Stripper R41-T-122 Column (R41-2). Chloride Injection Package (R41-Z-1314) (**37.2 kg/h rated design flow - intermittent service**) and Water Injection Package and (R41-Z-1312) (**3.2 kg/h rated design flow - intermittent service**) are provided upstream the Aromizing section feed flow control valve R41-FV-3110 to control the water-chloride equilibrium when the continuous Regenerator (R41-R-140) is out of service for optimum reforming catalyst performance. A DMDS Injection Package (R41-Z-1313) is also provided to inject sulfiding agent in very small quantity to prevent coke deposit in Preheater/Interheaters (R41-FR-13110/13210/13310/13410) and on Reactor (R41-R-131/132/ 133/134) walls.

After flowing through the feed flow control valve R41-FV-3110, the feed is passed through Feed Filters (R41-F-13110 A/B), to remove any particulate matter which may deposit in the Reformer Feed /Effluent Exchanger (R41-E-13110).

**Feed filter differential pressure for filter switchover is 1 kg/cm<sup>2</sup> detected by PDI-3110 (High Differential Pressure Alarm).**

The feed is then mixed with the recycle hydrogen from the Recycle Compressor (R41-K-13450) in the Reformer Feed / Effluent Exchanger (R41-E-13110). This is a true counter-current exchanger designed for minimum pressure drop and maximum heat recovery against reactor effluent.

**Inlet conditions for Reformer Feed / Effluent Exchanger (R41-E-13110) are the following:**

- Heavy Feed Case MRT (corresponding to Maximum Duty case of Heat Exchanger):
  1. Hydrocarbon Feed: 320521 kg/h;
  2. Recycle gas: 84550 kg/h;
- Light Feed Case NOP (corresponding to minimum recycle gas flowrate):
  1. Hydrocarbon Feed: 277722 kg/h;
  2. Recycle gas: 53231 kg/h.

The combined feed and recycle hydrogen are preheated here against the Fourth Reactor (R41-R-134) effluent and then further heated to the required First Reactor (R41-R-131) inlet temperature in Preheater (R41-FR-13110).

The reactors are radial flow types, the feed flowing through the catalyst bed from the outer circumference towards the center pipe. In the First Reactor (R41-R-131), the reactions are predominantly endothermic and therefore the reactor effluent requires reheating in the First Interheater (R41-FR-13210) to the required inlet temperature of the Second Reactor (R41-R-132). The reactions in this reactor are less endothermic but still require reheating in the Second Interheater (R41-FR-13310) before entering the Third Reactor (R41-R-133). The third reactor effluent is reheated in the Third Interheater (R41-FR-13410) before entering the Fourth Reactor (R41-R-134). The effluent leaves the Fourth Reactor (R41-R-134) at approximately 518 °C (depending on the position in the cycle and feed quality) and 3.3 kg/cm<sup>2</sup>g. The inlet temperatures of the four reactors are identical. These inlet temperatures are gradually increased through the catalyst life time.

In the four reactors the feed is contacted with the aromizing (**Reforming**) catalyst which is divided approximately in the ratio 12/18/25/45%. The catalyst circulates continuously:

- In the Reactors, in the space between the external grid and the central pipe from the top to the bottom,
- From one reactor bottom to the top of the next one,
- From the Fourth Reactor R41-R-134 to the regeneration section for regeneration,
- From the regeneration section, the regenerated catalyst returns to the First Reactor (R41-R-131).

In the Catalyst Regeneration section (R41-4), the catalyst is regenerated by a means of an automatic regeneration loop system. Catalyst circulation is achieved either by gravity flow or by gas lift systems. A detailed description of the regeneration section is provided in the Catalyst Regeneration Section R41-4 (2.2.4).

The four Reactors' (R41-R-131/132/133/134) inlet temperatures are controlled by regulating hydrogen fuel gas flow rate to the burners of Pre/Interheaters R41-FR-13110/13210/13310/13410. Leaving the Fourth Reactor (R41-R-134), the effluent after heat exchange in the Reformer Feed /Effluent Exchanger (R41-E-13110) against reactor feed, is cooled by Reactor Effluent Air Cooler (R41-E-13410) and Reactor Effluent Trim Coolers (R41-E-1342 A/B) before entering the Separator Drum (R41-D-13450). A portion of the separated gas from Separator Drum (R41-D-13450) is compressed in a steam turbine driven Recycle Compressor (R41-K-13450)

and is recycled to the Reactors. The remaining gas which constitutes the hydrogen production gas (H<sub>2</sub> Rich Gas) is routed to a compression and absorption section to improve hydrogen purity and liquid hydrocarbons yield.

The separated liquid in Separator Drum (R41-D-13450) is pumped by Separator Bottom Pumps (R41-P-13450 A/B) under flow control using R41-FV-3452 cascaded with level controller R41-LC-3450 **is** recontacted in the absorption section.

The pressure of the reaction section is controlled by varying the H<sub>2</sub> Rich Gas Compressors (R41-K-135 / R41- K-13550) speed and the purge gas flow rate of the Separator Drum (R41-D-13450) using pressure control valve R41-PV-3450A/B. The purge gas is routed to the flare and under ideal conditions, its flow rate is zero.

#### **2.2.3.2 Compression and Absorption section**

The hydrogen production gas (H<sub>2</sub> Rich gas from R41-D-13450) is mixed with Reduction gas coming from Reduction Chamber (R41-D-1412), after passing through Reduction Exchanger (R41-E-1416) and Hydrogen Lift Gas Exchanger (R41-E-1417), via pressure control valve R41-PV-4162. The mixture is then routed to the H<sub>2</sub> Rich Gas Compressors (R41-K-135 / R41-K-13550) after knock-out in H<sub>2</sub> Rich Gas Compressor K.O Drum (R41-D-135).

H<sub>2</sub> Rich Gas Compressor 1st and 2nd Stage (R41-K-135) provides a two-stage compression of the H<sub>2</sub> production gas (H<sub>2</sub> Rich Gas). First Interstage Air Cooler, (R41-E-1351), First Interstage Trim Cooler, (R41-E- 1352) and First Interstage Drum, (R41-D-1353), are provided between the stages to cool the compressed gas and remove the condensed hydrocarbons.

H<sub>2</sub> Rich Gas Compressor 3rd stage (R41-K-13550) provides a one-stage compression of the H<sub>2</sub> production gas. The Second Interstage Air Cooler,(R41-E-1353), Second Interstage Trim Cooler, (R41-E-1354), and Second Interstage Drum, (R41-D-13550), are provided between the stages to cool the compressed gas and remove the condensed hydrocarbons.

The condensed liquids of the First and Second Interstage Drums (R41-D-1353 / R41-D-13550) are sent back under level control (R41-LV-3530 and R41-LV-3550) to the Reactor Effluent cooling facilities, upstream of the Reactor Effluent Trim Cooler (R41-E-1342 A/B).

HP purge from BT Fractionation and TransPlus Section R42-3 is injected at 2nd stage discharge at downstream of Second Interstage Trim Cooler (R41-E-1354). The reaction section primary pressure control point (R41-PC-3450) is on Separator Drum (R41-D-13450). The pressure control is achieved by varying the H<sub>2</sub> Rich Gas Compressors (R41-K-135 / R41-K-13550) speed and by releasing to flare via pressure control valve R41-PV-3450A/B.

The compressed hydrogen rich gas from H<sub>2</sub> Rich Gas Compressor 3<sup>rd</sup> Stage (R41-K-13550) is recontacted with the separated liquid of the Separator Drum (R41-D-13450) pumped by Separator Bottom Pumps (R41-P-13450A/B). The two-phase flow mixture is then cooled in four stages against cooling water in the HP Absorber Feed Coolers (R41-E-13550 A/B), against H<sub>2</sub> rich gas in H<sub>2</sub> Rich Gas / HP Absorber Feed Exchanger (R41-E-1356), against HP Absorber Drum (R41-D-13580) liquid in HP Absorber Feed / Bottom Exchanger (R41-E-1357) and finally against a refrigerant in HP Absorber Chiller (R41-E-1315) (Refer Section 2.2.3.7 for Refrigeration package process description). The refrigerant medium is supplied through Refrigeration System Package (R41-RU-13580 A/B). The target temperature is 0°C at 27.7 kg/cm<sup>2</sup> g in the HP Absorber Drum (R41-D-13580). These conditions of the final stage separator for the hydrogen production gas are designed for:

- High recovery of the C<sub>3</sub>+ contained in H<sub>2</sub> from H<sub>2</sub> Rich Gas Compressors (R41-K-135 / R41-K-13550),
- High concentration of hydrogen in the hydrogen rich gas product.

The separated hydrogen rich gas is heated in H<sub>2</sub> Rich Gas/HP Absorber Feed Exchanger (R41-E-1356) against the HP Absorber Drum (R41-D-13580) feed. The gas is then treated to remove chlorides in the Hydrogen Rich Gas Chloride Adsorbers (R41-R-13590 A/B), operated in lead-lag, before distribution to Catalyst Regeneration Section R41-4 and Naphtha Hydrotreatment Section R41-2. Excess of H<sub>2</sub> rich gas is sent to PSA Section Package (R41-PK-1510) in PSA section R41-5.

The separated liquid from the HP Absorber Drum (R41-D-13580), after heating against the HP Absorber Drum (R41-D-13580) feed across HP Absorber Feed / Bottom Exchanger (R41-E-1357), is sent under flow control R41-FV-3580 with level reset (R41-LC-3580) to the Depentanizer Section.

### **2.2.3.3 Depentanizer Sections**

The separated liquid from HP Absorber Drum (R41-D-13580), after heat exchange across HP Absorber Feed / Bottom Exchanger (R41-E-1357), is contacted with depentanizer off-gas coming from Depentanizer Reflux Drum (R41-D-13650) and allowed to separate in the LPG Absorber Drum (R41-D-136100). The purpose of this step is to recover the maximum quantity of LPG, i.e. C<sub>3</sub> and C<sub>4</sub>'s from the Depentanizer overheads.

The small quantity of vapor from LPG Absorber Drum (R41-D-136100) is sent to fuel gas system by pressure control valve R41-PV-3650. This stream is predominantly light ends i.e. H<sub>2</sub>, C<sub>1</sub> and C<sub>2</sub>'s and this continuous purge controls the Depentanizer Column (R41-T-136) operating pressure. Separated liquid from LPG Absorber Drum (R41-D-136100) is pumped by LPG Absorber Bottom Pumps (R41-P-13610 A/B) under flow control (R41-FV-3610) with level reset (R41-LC-3610), override by pressure control (R41-PC-3612). In case of low pressure the pressure / flow cascade override the level / flow cascade to prevent vaporization in the Depentanizer Feed Chloride Adsorbers (R41-R-13610 A/B). The mixture passes through Depentanizer Feed/Bottom Exchanger A (R41-E-13610), and through the Depentanizer Feed Chloride Adsorbers (R41-R-13610 A/B) to remove all traces of chlorides. This liquid is mixed with Recycle C<sub>6</sub>/C<sub>7</sub> coming from Deheptanizer Distillate Pump (R42-P- 2526A/B) of XyMax Section R42-5 and Crude Benzene coming from Crude Benzene Pump (R42-P-2364A/B) of BT Fractionation and TransPlus section R42-3 and then sent through Depentanizer Feed/Bottom Exchanger B, (R41-E-1362), to the Depentanizer Column (R41-T-136) in tray 31.

A part of the Depentanizer Column (R41-T-136) bottom is pumped by Depentanizer Reboiler Pumps (R41-P- 136 A/B) and sent to Depentanizer Bottom Steam Generator (R41-E-136) and Convection Reboiler Coil (R41-FR-13110-E). Depentanizer Column (R41-T-136) is reboiled by the Convection Coil (R41-FR-13110-E) of the reaction section heaters. Depentanizer Column (R41-T-136) temperature control (R41-TC-3602) is ensured by varying the quantity of steam generated in the Depentanizer Bottom Steam Generator (R41-E-136).

Depentanizer Column (R41-T-136) overheads are partially condensed in Depentanizer Air Cooler (R41-E- 13650) and in the Depentanizer Trim Coolers (R41-E-1366 A/B) and sent to the Depentanizer Reflux Drum (R41-D-13650). The overhead vapor from Depentanizer Reflux Drum (R41-D-13650) is routed back to LPG Absorber Drum (R41-D-136100) for LPG recovery. A part of the separated liquid in Depentanizer Reflux Drum (R41-D-13650) is pumped by Depentanizer Reflux Pumps (R41-P-13650 A/B) under flow control (R41-FV-3650) with temperature reset (R41-TC-3650) back to Depentanizer Column (R41-T-136) as reflux. The remaining part of the separated liquid, is pumped by Depentanizer Distillate Pumps (R41-P-1366 A/B), and routed to Deethanizer Feed/Debutanizer Bottom Heat Exchanger (R41-E-1381) under flow control (R41-FV-3661) with level reset (R41-LC-3650).

Bottom from the Depentanizer after heat exchange in the Depentanizer Feed/Bottom Exchanger B, (R41-E-1362), are further cooled in Depentanizer Feed/Bottom Exchanger A (R41-E-13610) and sent to Reformate

Splitter Column (R42-T-2110) in Xylenes Fractionation section R42-1 under flow control R42-FV-1110 with level reset (R41-LC-3600).

#### **2.2.3.4 Deethanizer Section**

The liquid pumped by the Depentanizer Distillate Pumps (R41-P-1366 A/B) passes through Deethanizer Feed/Debutanizer Bottom Heat Exchanger (R41-E-1381) and is then sent to Deethanizer Column (R41-T-137) on tray 16 under flow control (R41-FV-3661) with level reset (R41-LC-3650).

The Deethanizer Column (R41-T-137) is reboiled using LP Steam in Deethanizer Reboiler (R41-E-137). Temperature control (R41-TC-3703) is ensured by varying steam condensate flowrate using flow control valve R41-FV-3705 at the outlet of the Deethanizer Reboiler (R41-E-137).

Deethanizer Column (R41-T-137) overhead is partially condensed in Deethanizer Condenser (R41-E-1375), and sent to Deethanizer Reflux Drum (R41-D-13750). The Deethanizer Reflux Drum (R41-D-13750) overhead vapor is routed to fuel gas header using pressure control valve R41-PV-3750. Liquid from Deethanizer Reflux Drum (R41-D-13750) is pumped by Deethanizer Reflux Pumps (R41-P-1375 A/B) and sent back to Deethanizer Column (R41-T-137) as reflux under flow control R41-FV-3750 with level reset (R41-LC-3750). Liquid from the bottom of the Deethanizer Column (R41-T-137) is routed under flow control R41-FV-3700 with level reset (R41-LC-3700) to Debutanizer Column (R41-T-138).

#### **2.2.3.5 Debutanizer Section**

The liquid coming from Deethanizer Column (R41-T-137) bottom is sent to Debutanizer Column (R41-T-138) on tray 22. The debutanizer is reboiled with a LP Steam Thermosyphon, Debutanizer Reboiler (R41-E-138). Temperature control (R41-TC-3803) is ensured by varying steam condensate flowrate using flow control valve R41-FV-3805 at the outlet of the Debutanizer Reboiler (R41-E-138).

Debutanizer Column (R41-T-137) overhead is condensed in Debutanizer Condenser (R41-E-13850), and sent to Debutanizer Reflux Drum (R41-D-13850). Liquid from Debutanizer Reflux Drum (R41-D-13850) is pumped by Debutanizer Reflux Pumps (R41-P-13850 A/B) and sent back to Debutanizer Column (R41-T-138) as reflux by flow control R41-FV-3850. The remaining part of the separated liquid, is routed to LPG storage (F56-D-0930/0931/0932) under flow control R41-FV-3851 with level reset (R41-LC-3850).

Liquid from the bottom of the Debutanizer Column (R41-T-138) is cooled through the Deethanizer Feed/Debutanizer Bottom Heat Exchanger (R41-E-1381), C5 Cut Trim Cooler (R41-E-1382 A/B) and then is routed under flow control (R41-FV-3800) with level reset (R41-LC-3800) to gasoline pool.

#### **2.2.3.6 Waste Heat Boiler Section**

The boiler feed water after heating through the convection section of Reformer Heater Convection Waste Heat Boiler (R41-FR-130 SG) is fed to Steam Drum (R41-D-130). The flashed steam from drum is being used internally in section R41 by R41-E-111, R41-E-112 A/B, R41-E-113. The BFW from Steam Drum (R41- D-130) is circulated by BFW Circulation Pumps R41-P-130 A/B through R41-FR-130 SG.

A continuous blowdown of water from Steam Drum (R41-D-130) to Continuous Blowdown Drum R41-D-1301 and Blowdown Cooler R41-E-1301 is made available to maintain the quality of MP steam generated. Phosphate is injected into the Steam Drum (R41-D-130) from Phosphate Injection Package (R41-Z-1301) to maintain the pH of boiler feed water.

### **2.2.3.7 Refrigeration package**

Refrigeration package R41-RU-13580 consists of a refrigeration unit in which two (2) identical compressor trains are installed.

The Refrigeration package R41-RU-13580 **is designed to** provide the refrigeration load to cool down a two phase stream of hydrogen rich gas, coming from HP Absorber Drum Feed/Bottom Exchanger (R41-E-1357), by means of propane refrigerant.

Overall heat duty is 5.3 Gcal/h (design). The operational capacity range of the refrigeration package is 5% -110 % of normal operating capacity.

#### **2.2.3.7.1 Inlet section**

A two phase stream of hydrogen production gas coming from HP Absorber Drum Feed/Bottom Exchanger (R41-E-1357) is fed to HP absorber chiller R41-RU-13580-E-01, tube side, where it is cooled down from 25 °C to 0 °C by means of propane refrigerant evaporation.

Refrigerant evaporation occurs in the shell side, under level control: a dedicated level control valve R41-LV-3589B is installed at the inlet of HP absorber chiller R41-RU-13580-E-01 (shell side). The control function is performed by R41-LC-3589B. R41-LV-3589B control valve opening is regulated in order to keep HP absorber chiller R41-RU-13580-E-01 liquid level at set point value.

Refrigerant boiling pressure is controlled by R41-PC-3589A that senses the pressure of the refrigerant gas at the outlet of HP absorber chiller R41-RU-13580-E-01. R41-PC-3589A set point is calculated in order to maintain the chilled water outlet temperature at the set temperature, by means of R41-TC-3589B.

R41-PC-3589A is part of slide valves controller that includes also R41-TC-3589B controller that senses the temperature of the process stream at the outlet of HP absorber chiller R41-RU-13580-E-01. The normal operating pressure at the HP absorber chiller R41-RU-13580-E-01 shell side outlet is equal to 3.1 kg/cm<sup>2</sup>g, corresponding to -5 °C (equilibrium value). R41-PC-3589A acts on both screw compressors R41-RU-13580-K-01 A/B slide valves; slide valve is able to increase/reduce the volumetric capacity of the compressor. If refrigerant gas pressure increases (decreases) in the HP absorber chiller R41-RU-13580-E-01, compressors capacity has to be

increased (decreased) in order to suck more (less) refrigerant from HP absorber chiller R41-RU- 13580-E-01 and thus reducing (increasing) the pressure until R41-PC-3589A set-point is reached.

Refrigerant gas is forced to flow towards two demister pad before exiting the HP absorber chiller R41-RU-13580-E-01, in order to avoid liquid droplets (if any) to reach the compressors rotors: in fact, Screw type compressors do not tolerate significant amount of liquid entering in the suction port. Refrigerant gas leaves HP absorber chiller R41-RU-13580-E-01 at -5°C and flows through screw compressors suction port.

#### **2.2.3.7.2      Compressor section**

The installed screw compressors R41-RU-13580-K-01 A/B are Howden screw compressors: they are Oil-injected screw type compressors. Two compressors (2 x 50 % of package design duty) are required for the process duty, hence parallel operation of compressors is required.

#### **Screw Compressors:**

Refrigerant gas exiting from HP absorber chiller R41-RU-13580-E-01 (at -5 °C and 3.1 kg/cm<sup>2</sup> g) is routed to the suction of two screw compressors R41-RU-13580-K-01 A/B through symmetrical piping, in order to guarantee balanced feed flow to the two rotary machines.

Screw compressor uses a rotary type positive displacement mechanism: this kind of compressors use two meshing helical screws (rotors) to compress the gas by means of volume reduction. The male rotor rolls into the female flutes reducing the trapped volume. The male and female rotors are located side by side in the compressor casing. Screw compressors R41-RU-13580-K-01 A/B are driven with MV electric motor R41-RU-13580-KM- 01 A/B, coupled through the male rotor. A small amount of lubricating oil bridges the space between the rotors, providing lubrication, hydraulic seal and transferring mechanical energy between the driving and driven rotor.

Superfeed screw compressor is chosen with the aim of optimizing refrigeration cycle. Superfeed screw compressor is a development of the screw compressor whereby an additional charge of refrigerant gas is handled by the compressor over and above that which is drawn in through the suction in the normal manner. This type of compressor is provided with two suction nozzles and one discharge nozzle. One suction nozzle receives the refrigerant from HP absorber chiller R41-RU-13580-E-01 whereas the other suction nozzle (superfeed port)

receives the refrigerant gas from additional flow which comes from the economizer R41-RU-13580-E-05 (shell side at 5.9 kg/cm<sup>2</sup> g and 13 °C).

Economizer R41-RU-13580-E-05 receives additional charge from the refrigerant accumulator R41-RU-13580-D-01 for extra sub-cooling of refrigerant. By means of this extra subcooling the refrigerant capacity is increased before entering the HP absorber chiller R41-RU-13580-E-01. Inside the screw compressors R41-RU-13580-K-01 A/B the two feed streams are combined and discharged together through the outlet nozzle of the compressors.

If, for any reason, superfeed gas is not available from economizer R41-RU-13580-E-05, the screw compressors R41-RU-13580-K-01 A/B maintain operation. The only impact on refrigeration package is a temporary reduction of package duty until the superfeed flow is reinstated. The screw compressors R41-RU-13580-K-01 A/B discharge flows are combined before entering the oil separator R41-RU-13580-D-02 at 15 kg/cm<sup>2</sup>g and 64 °C.

Screw compressors R41-RU-13580-K-01 A/B are equipped with suction and discharge check valves, to prevent the back flow of high pressure gas on the discharge side (discharge check valve) when the compressor is stopped and to prevent oil back flow from compressors to HP absorber chiller R41-RU-13580-E-01 (suction check valve). Each compressor is equipped with isolation block valves for maintenance purpose only.

#### **2.2.3.7.3      Oil Separator**

Lube oil and refrigerant gas mixture exits the screw compressors R41-RU-13580-K-01 A/B and enters the oil separator R41-RU-13580-D-02. Oil separator R41-RU-13580-D-02 is a vertical vessel that has two main functions:

- it provides a separation of the lube oil from the refrigerant before it passes to the rest of the system;
- it contains the seal oil inventory.

Lube oil is collected into the bottom section of the vessel. In order to prevent that oil temperature decrease below 30°C (minimum required temperature for compressor running) a dedicated oil separator electric heater R41-RU-13580-E-06 is installed and controlled by means of R41-TIC-3589K. To maintain proper compressor bearing lubrication, oil temperature should be maintained above 30°C.

The Level Low Low Limit of the oil separator R41-RU-13580-D-02 is set at 320 mm, so that the oil heater is always be immersed in oil and exposure of heating element is avoided.

Lube oil is separated from refrigerant gas inside the oil separator by means of multiple effects:

- Gravitational separation
- Wiring mesh demister
- Coalescer cartridges
  - After gravitational separation, refrigerant gas and residual lube oil are forced to cross a wire mesh demister where the secondary separation occurs.
  - Oil separated by means of gravitational effect and wire mesh demister is collected on the bottom of the oil separator.
  - Finally, refrigerant gas and lube oil are separated in the coalescer cartridges placed above the demister pack, in order to reach the final required value of oil carry over.

Oil separated by coalescer cartridges is collected above the cartridge support plate located in the top part of the oil separator. Since there is a pressure drop through the coalescing elements and the wire mesh demister, oil recovered with coalescer cannot simply be drained to the bottom of Oil Separator R41-RU-13580-D-02 (where the major quantity of oil is collected) but it **is** returned to the compressor by means of dedicated lines. The quantity of oil recovered in the upper section of the oil separator is minimum (in terms of ppm) and it is dragged continuously by a stream of high pressure refrigerant gas from oil separator to compressors suction line. This quantity of liquid carryover will not affect the functionality of the compressor (compressor could accept a minimum quantity of liquid carryover).

Refrigerant gas leaves oil Separator R41-RU-13580-D-02 14.6 kg/cm<sup>2</sup>g and 64°C (at design conditions) from the top of the vessel, towards refrigerant condenser R41-RU-13580-E-02.

The lubricating oil collected at the bottom of the oil separator R41-RU-13580-D-02 is recirculated back to the screw compressors R41-RU-13580-K-01 A/B by means of a lube oil circuit.

#### **2.2.3.7.4**      Condensing Section

The hot refrigerant gas from oil separator R41-RU-13580-D-02 is sent to refrigerant condenser R41-RU-13580-E-02 where it is condensed and subcooled to 42 °C by means of cooling water. Condensing temperature depends on the stream pressure that is 14.6 kg/cm<sup>2</sup> g at design conditions.

Refrigerant condenser R41-RU-13580-E-02 is a shell & tubes heat exchanger, in which cooling water supply is controlled by R41-PIC-3589K that acts in order to maintain refrigerant accumulator R41-RU-13580-D-01 internal pressure at a set value.

Additional control on refrigerant condenser R41-RU-13580-E-02 is obtained by means of vent to flare (manual operation) on high point of inlet line to refrigerant condenser R41-RU-13580-E-02 for non condensable venting to flare header. The subcooled refrigerant flows from the refrigerant condenser R41-RU-13580-E-02 to the refrigerant accumulator R41-RU-13580-D-01 by gravity.

A balancing line connects refrigerant accumulator R41-RU-13580-D-01 to Refrigerant Condenser R41-RU-13580-E-02. Refrigerant accumulator R41-RU-13580-D-01 is sized for 2 minutes hold-up between LLL (400 mm) and HLL (950 mm). Refrigerant liquid loading occurs to refrigerant accumulator R41-RU-13580-D-01 by means of a loading system. A check valve is fitted in the refrigerant loading line in order to ensure that no refrigerant (liquid or gas) flows back from refrigerant accumulator R41-RU-13580-D-01 in case of overpressure.

Oil separated within the refrigerant accumulator R41-RU-13580-D-01 by gravity is collected in the boot of the receiver (separated boot, piping element) from where it flows to the oil recovery header and, then, to screw compressors R41-RU-13580-K-01 A/B suction lines.

#### **2.2.3.7.5**      Superfeed Section

Liquid refrigerant flows from refrigerant accumulator R41-RU-13580-D-01 towards economizer R41-RU-13580-E-05. Economizer R41-RU-13580-E-05 is a kettle type shell and tube heat exchanger which allows liquid refrigerant main stream further subcooled by vaporization of a smaller stream of liquid refrigerant, both coming from refrigerant accumulator R41-RU-13580-D-01. Vaporization occur in the shell side of economizer R41-RU-13580-E-05, under level control. Control valve R41-LV-3589H is installed at the inlet of economizer R41-RU-13580-E-05 (shell side). The control function is performed by R41-LIC-3589H. R41-LV-3589H control valve opening is regulated in order to keep economizer R41-RU-13580-E-05 liquid level at set point value.

Refrigerant enters economizer R41-RU-13580-E-05 shell side at 5.9 kg/cm<sup>2</sup> g and 13 °C and exits fully vaporized at the same temperature, towards screw compressors R41-RU-13580-K-01 A/B superfeed ports. Superfeed gas return to screw compressors R41-RU-13580-K-01 A/B superfeed ports is regulated by means of pressure control. Control Valves R41-PV-3589LA/B are installed at the outlet of economizer R41-RU-13580-E-05 (shell side) towards screw compressors R41-RU-13580-K-01 A and screw compressors R41-RU-13580-K-01 B respectively. The control function is performed by 410-PIC-3589H. R41-PV-3589H A/B control valves opening is regulated in order to keep economizer R41-RU-13580-E-05 shell side pressure at set point value (5.9 kg/cm<sup>2</sup> g).

Liquid refrigerant enters the economizer R41-RU-13580-E-05 tube side at 14.3 kg/cm<sup>2</sup> g and 42 °C and is subcooled down to 16 °C. Liquid refrigerant exiting from economizer R41-RU-13580-E-05 tube side at 16 °C is fed to the HP absorber chiller through the level control valve R41- LV-3589B where the liquid refrigerant is expanded at 3.1 kg/cm<sup>2</sup> g and -5 °C, closing the refrigerant loop.

#### **2.2.3.7.6      Oil Cooler**

Lube oil is collected in the oil separator R41-RU-13580-D-02 bottom section, at compressor discharge conditions of 64 °C (condition at design operation) and 15 kg/cm<sup>2</sup> g. For each screw compressor R41-RU-13580-K-01 A or B, a dedicated oil circuit is provided. Each oil circuit is made by:

- two screw pumps for compressor A [B] R41-RU-13580-P-01A/B [P-02A/B] (one operating and one in stand-by),
- one bypass PDCV for oil flow rate control R41-PCV-3589A [B]
- one oil cooler R41-RU-13580-E-03 [04]
- one bypass valve TV con Cooling water supply line for cooling temperature control R41-TV-3589Q [R]
- two duplex type oil filters A/B R41-RU-13580-F-01A/B [02A/B]

Oil separator R41-RU-13580-D-02 is common for both oil circuits. To enable seal oil flow to the refrigerant compressor (through dedicated ports and through suction line) a positive constant differential pressure has to be maintained under all operating conditions. The differential pressure to be kept is equal to 2.1 kg/cm<sup>2</sup> between compressor discharge port and lube oil injection ports. Screw pumps for compressor R41-RU-13580-P-01 A/B and R41-RU-13580-P-02 A/B provide a differential pressure of 5.7 kg/cm<sup>2</sup> that are adequate to provide the 2.1 kg/cm<sup>2</sup> required plus the pressure loss along the oil circuit. In order to guarantee that this positive pressure is constant at any operating conditions, screw pumps for compressor R41-RU-13580-P-01 A/B and R41-RU-13580-P-02 A/B have been sized for a maximum oil flow-rate, in order to cover any request that is variable at different loading conditions.

Pump discharge pressure is controlled by R41-PCV-3589 A/B pressure control valve. Excess oil flow will bypass oil circuit, through the R41-PCV-3589A/B pressure control valves, back to oil separator R41-RU-13580-D-02. Pumped oil that is not circulated back to oil separator R41-RU-13580-D-02 bottom section is sent to oil coolers R41-RU-13580-E-03 and R41-RU-13580-E-04, where oil is cooled down to 50 °C. Each operating screw pump sends oil to its dedicated oil cooler by means of an independent circuit.

Oil coolers R41-RU-13580-E-03 and R41-RU-13580-E-04 outlet temperature value is maintained constant by means of a temperature control valves R41-TV-3589 Q/R ,that diverts the oil flow to bypass the oil cooler. The control function is performed by R41-TIC-3589 Q/R in order to keep the oil return temperature at the set point value (50 °C).

Oil coolers R41-RU-13580-E-03 and R41-RU-13580-E-04 are identical and independent plate and frame heat exchanger oil coolers, which use cooling water to cool the lube oil. After cooling, oil passes through the duty oil filters R41-RU-13580-F-01 (A or B) or R41-RU-13580-F-02 (A or B) and the clean and cooled oil then enters the oil manifold, from where screw compressor supply connections and suction line receive pressurised oil. Return lube oil pressure is continuously monitored by means of R41-PDT-3589 B/E and, in case of low pressure differential level, the spare screw pumps for compressor is automatically activated.

The lube oil amount, required in order to keep screw compressor discharge temperature under a proper value, is controlled by a dedicated control valve R41-TV 3589 D/H. The control function is performed by R41-TIC-3589 D/H in order to keep the oil return temperature at the set point value (110 °C).

#### **2.2.3.7.7      Oil Recovery System**

Lube oil separated and collected inside the from HP absorber chiller R41-RU-13580-E-01, economizer R41-RU-13580-E-05 and refrigerant accumulator R41-RU-13580-D-01 is collected into oil recovery header and, then, sent to screw compressors R41-RU-13580-K-01 A/B suction lines. Oil from HP absorber chiller R41-RU-13580-E-01, economizer R41-RU-13580-E-05 requires the installation of a dedicated ejector (R41-RU-13580-EJ-01 and R41-RU-13580-EJ-02 , respectively) in order to reach a proper pressure level towards screw compressors R41-RU-13580-K-01 A/B suction lines. Motive flow for ejectors R41-RU-13580-EJ-01/02 is represented by a small amount of high pressure refrigerant gas from oil separator R41-RU-13580-D-02.Each line to oil recovery header (downstream ejectors, in case) is provided with check valves to prevent reverse flow.

Oil recovery occur discontinuously with manual valve opening by operator.

## **2.2.4 R41-4 Catalyst Regeneration Section**

In order to achieve a good regeneration of the Reforming catalyst, the following operations are carried out continuously in the Catalyst Regeneration Section:

- Coke burning.
- Catalyst oxychlorination.
- Catalyst calcination.
- Catalyst cooling.
- Catalyst reduction.

The first three steps are performed in the Regenerator (R41-R-140), the fourth step in the First Lower Hopper (R41-D-1403) and the last step in the Reduction Chamber (R41-D-1412).

### **2.2.4.1 Regenerator**

#### **2.2.4.1.1 Storage zone**

Spent catalyst, coming from the Lock Hopper (R41-D-1402), is stored in the top of the Regenerator (R41-R- 140) during the equivalent of 1 or 2 hours of catalyst circulation, where it is smoothly preheated by a part of the heat released by the regeneration gas to the first burning bed.

The storage zone is nevertheless slightly over-pressured by the means of a small continuous flow of nitrogen, in order to prevent burning gas, with a high oxygen content, from entering this zone, thus avoiding uncontrolled and undesired coke burning. The spent catalyst flows from this zone to the burning zone by 8 descending pipes.

#### **2.2.4.1.2 Burning zone**

The burning zone inside the Regenerator (R41-R-140) is composed of two radial beds, physically linked by 8 descending pipes. These radial beds are crossed by the combustion gas. The temperature and oxygen content of this gas are increased as the combustion reaction advances from bed to bed. The controlling parameters are the combustion gas temperature and the oxygen content at the inlet of the burning beds. The typical values are the following:

O2,	mol. %	Temperature, °C
First bed	0.8	475
Second bed	0.8	480

A quench line (6"-G-R41-4100) is provided from Regeneration Loop Compressor (R41-K-1465) discharge via temperature control valve R41-TV-4003 to inject a small amount of cooling gas between the two burning beds, in addition of the air for oxygen make-up by flow control valve R41-FV-4720. This injection will decrease the second burning bed inlet temperature and allow proper control of this temperature.

The catalyst is considered as free of coke at the bottom of the second burning bed if oxygen consumption is complete and if no temperature increase occurs.

#### **2.2.4.1.3        Oxychlorination / Calcination zone**

After coke burning, the catalyst flows through another set of 8 pipes towards an axial bed where oxychlorination and calcination reactions take place. In the oxychlorination zone, the gas circulates upward and is composed of:

- The calcination gas, which has crossed the calcination zone (typically 50 % of the flowrate), and
- The oxychlorination gas coming from Oxychlorination Heater (R41-E-1469) introduced in the oxychlorination bed and containing a small amount of chlorination agent and water (typically the other 50 % of the flowrate).

Common characteristics of the mixture of oxychlorination and calcination gas are the following:

- Oxygen content :  
4 to 6 vol. % (standard mode)  
About 21% (recirculation mode)
- Temperature : 510°C

After oxychlorination, the catalyst flows towards the calcination zone. The calcination gas coming from Calcination Heater (R41-E-1473) is introduced in the bottom part of the Regenerator and circulates upward.

Common characteristics of the calcination gas are the following:

- Oxygen content:  
8 to 12 vol. % (standard mode)  
About 21% (recirculation mode)
- Temperature : 520°C
- Water : less than 50 vol. ppm

A minimum pressure drop is maintained between the burning zone and the oxychlorination / calcination zone to prevent the oxychlorination gas, with high oxygen content, from mixing with burning gas.

#### **2.2.4.1.4      Blackburn operation**

If the entire amount of coke is not burnt off at the bottom of the second bed (in case of coke upset on catalyst for instance), the Regenerator (R41-R-140) will be automatically operated in blackburning mode. The catalyst, though not free of coke, flows through the oxychlorination and the calcination zones, where air injection as well as chlorination agent and water injections are already totally stopped. Air injection to the burning zone is maintained by means of the “blackburning line” (6"-PA-R41-1111 coming from Air Dryer R41-DR-1472 by flow control valve R41-FV-4721 and R41-ZV-4720).

Consequently the catalyst returns to the reactors despite a certain coke level. The Aromizing Section (R41-3) can work under these conditions for a short period of time (a few hours), allowing to maintain the catalyst circulation while operating conditions are adjusted to recover an acceptable coke level on catalyst.

#### **2.2.4.2    First Lower Hopper (R41-D-1403): Catalyst Cooling**

The catalyst at the bottom of the Regenerator (R41-R-140) is collected by 8 descending pipes and flows into the First Lower Hopper (R41-D-1403) which is under a slight overpressure of nitrogen by pressure control valve R41-PDV-403, to prevent oxygen from entering into the nitrogen lift gas system. The 8 pipes are not insulated in order to allow a natural cooling of catalyst by convection.

Then the catalyst flows from the First Lower Hopper (R41-D-1403) down to the First Lift Pot (R41-D-1404), where it is lifted by a flow of nitrogen gas, coming from Nitrogen Compressor (R41-K-1405A/B) through flow control valve R41-FV-4040, up to the First Upper Hopper (R41-D-1411), before being introduced in the Reduction Chamber (R41-D-1412).

#### **2.2.4.3    Reduction chamber**

Reduction of the freshly regenerated catalyst is performed in the Reduction Chamber (R41-D-1412). This operation can be slightly exothermal (due to hydrocracking reactions of C<sub>2+</sub> components) and the inlet temperature is adjusted in order to have around 480 °C at the Reduction Chamber (R41-D-1412) outlet.

The reduction gas is a high purity hydrogen-rich gas coming from PSA Unit (R41-5). It is then preheated in the Reduction Exchanger (R41-E-1416). The Reduction Heater (R41-E-1412) which is an electrical heater allows a precise adjustment of the reduction inlet temperature.

After reduction, the reduction effluent is split into two streams. The first stream preheats the reduction gas coming from PSA (R41-5) through R41-FV-4160, going to the Reduction Chamber (R41-D-1412), in the Reduction Exchanger (R41-E-1416). The second stream preheats the H<sub>2</sub> rich gas coming from HP Absorber Drum (R41-D-13580) of Aromizing Section (Unit R41-3) going to the lift system in the Hydrogen Lift Gas Exchanger (R41-E-1417). Both streams are then mixed and sent to the H<sub>2</sub> Rich Gas Compressor K.O. Drum (R41-D-135) in Aromizing Section (Unit R41-3) by pressure control using R41-PV-4162.

The catalyst is then introduced into the First Reactor (R41-R-131) through 12 descending pipes.

#### **2.2.4.4 Regeneration loop**

##### **2.2.4.4.1 Burning gas**

Burning gas is the main stream coming from discharge of Regeneration Loop Compressor R41-K-1465, with an oxygen content of 0.8% mol., and is preheated in the Burning Feed/Effluent Exchanger (R41-E-1466) against Burning effluent from Regenerator (R41-R-140). The Burning Heater (R41-E-1467) which is an electrical heater completes the heating to about 484 °C and allows accurate temperature adjustment of the gas before entering the Regenerator (R41-R-140) burning zone.

The Burning gas enters the Regenerator (R41-R-140) at the uppermost height of the descending pipes (between the storage zone and the burning zone) to preheat the catalyst. Then this burning gas flows through the first radial bed, is collected in the center pipe and is mixed at the outlet of the first burning bed with air using flow control R41-FV-4720 and with a quench gas coming from Regeneration Loop Compressor (R41-K-1465) discharge via temperature control valve R41-TV-4003, to adjust both the oxygen content and the temperature at the inlet of the second radial burning bed. The gas then flows through the second burning bed in similar to the first bed and leaves the Regenerator (R41-R-140).

The Burning effluent coming from the Regenerator (R41-R-140) after the second burning bed zone is sent to the Burning Feed/Effluent Exchanger (R41-E-1466) to recover the main part of the heat produced by the combustion reaction using pressure differential control valve R41-PDV-40090A. This burning effluent contains water, produced by the combustion reaction, and also some traces of chlorine compounds (coming from elution from the catalyst). To avoid corrosion problems at low temperature, this gas is mixed with the oxychlorination effluent coming from Calcination Feed/Effluent Exchanger (R41-E-1468) through pressure difference control valve R41-PDV-40090B, and sent to the gas washing section.

Remark: The burning gas flowrate to the first burning bed is kept constant whatever the coke level of the catalyst. This is achieved by means of the spillback flow control valve R41-FV-466 of the Regeneration Loop

Compressor (R41-K-1465). If the pressure at the Regeneration Loop Compressor (R41-K-1465) becomes high (7.55 kg/cm<sup>2</sup>g), the controller R41-PC-4653 overrides R41-FC-466 and controls the control valve R41-FV- 466 directly. The control valve will open until the pressure recovers to a normal value.

#### **2.2.4.4.2      Quench gas**

Quench gas is the cold gas coming from Regeneration Loop Compressor (R41-K-1465) discharge and is mixed with the gas leaving the 1st burning bed of the Regenerator (R41-R-140). It is used to adjust the inlet temperature of gas to the 2nd burning bed of Regenerator (R41-R-140).

#### **2.2.4.4.3      Oxychlorination / calcination gas**

This stream from Regeneration Loop Compressor (R41-K-1465) discharge is preheated through the Calcination Feed/Effluent Exchanger R41-E-1468 against the oxychlorination effluent from Regenerator R41-R-140.

This gas is then split into two streams:

- The calcination gas: It is mixed by flow control valve R41-FV-4730 with dry air coming from Air Dryer R41-DR-1472 by flow control valve R41-FV-4721 in order to achieve an oxygen content of 8 to 12 vol. % and then is heated through the Calcination Heater (R41-E-1473), which is an electrical heater and allows to control the calcination gas inlet temperature, and is finally sent to the bottom part of the Regenerator (R41-R-140), where it circulates upflow in an axial bed.
- The oxychlorination gas: It has an oxygen content of 0.8 mol. %. Oxychlorination gas comes from Calcination Feed/Effluent Exchanger (R41-E-1468) by flow control valve R41-FV-4680. Water is injected in this gas coming from Oxychlorination Water Package (R41-Z-1468) before entering the Oxychlorination Heater (R41-E-1469), which is an electrical heater and allows accurate temperature control (R41-TC-4006) of oxychlorination gas to Regenerator (R41-R-140). The chlorination agent coming from Chlorination Agent Package (R41-Z-1469) is injected right after the Oxychlorination Heater (R41-E-1469), and contacting is performed by means of the Chlorination Agent Static Mixer (R41-M- 1464), right downstream the injection point. The oxychlorination gas finally enters the Regenerator (R41- R-140) where it circulates upflow through another axial bed.

The oxychlorination gas and the calcination gas are mixed in the oxychlorination bed. The combined effluent is sent to the Calcination Feed/Effluent Exchanger (R41-E-1468) to recover heat and is then mixed with the 2<sup>nd</sup> burning effluent before being routed to the gas washing section in order to eliminate chlorine compounds.

The air injected in the regeneration loop is taken from atmospheric air, compressed in Air Compressors (R41-K-1470), cooled down in Aftercooler (R41-K-1470-E-03 and dried in Air Dryer (R41-DR-1472). It has to contain less than 50 vol. ppm of water.

The pressure of the regeneration loop is controlled by means of the split range between the gas purge (R41-PDV-4731A) and the nitrogen injection (R41-PDV-4731B) at the top of the Washing Drum (R41-D-1460). The pressure of the regeneration loop is reset by the pressure of the First Reactor (R41-R-131), through R41-PDC-41220 which maintains the pressure of the Regenerator bottom around 0.5 kg/cm<sup>2</sup> above the pressure of the First Reactor (R41-R-131) inlet.

#### **2.2.4.4.4      Washing section**

The 2<sup>nd</sup> burning bed effluent, oxychlorination and calcination effluents are washed by contacting with a caustic solution coming from Caustic Recycle Pump (R41-P-1460A/B) and then sent to Washing Drum (R41-D-1460). The caustic solution is injected into the Regeneration gas through the in-line Caustic Spray Injection Nozzle (R41-Z-1461). Contacting is performed in the Caustic Static Mixer (R41-M-1461), right after the injection point. The mixture is further cooled in the Regeneration Loop Trim Cooler (R41-E-1460) and sent to the Washing Drum (R41-D-1460), where gas contacting with washing water, coming from Washing Water Pump (R41-P-1461A/B), across a bed of Raschig rings performs its final washing and cooling.

The caustic solution is recycled from the bottom part of the Washing Drum (R41-D-1460) through Caustic Recycle Pump (R41-P-1460A/B) and its quality is maintained by a constant injection of fresh caustic soda from Caustic Package R41-Z-1460, at suction of Caustic Recycle Pump (R41-P-1460A/B), while purging a small amount of spent solution to Caustic Sump Pit (R41-Z-1480).

The gas leaving the Washing Drum (R41-D-1460) flows through the Regeneration Loop Dryer (R41-DR-1465) to eliminate water, then through the Regeneration Loop Filter (R41-F-1465) where possible particles, in particular alumina particles, are trapped. It is finally sent to the Regeneration Loop Compressor (R41-K-1465) suction.

At the compressor discharge, the gas is split into the three streams described in above sections:

- Burning gas sent to Regenerator (R41-R-140) 1<sup>st</sup> Burning bed via R41-E-1466/1467,

- Quench gas sent to Regenerator (R41-R-140) 2<sup>nd</sup> Burning bed via Temperature control valve (R41-TV-4003),
- Oxychlorination / Calcination gas sent to Regenerator (R41-R-140) bottom via R41-E- 1468/1469 and R41-E-1468/1473 respectively.

#### **2.2.4.4.5 Recirculation Scheme**

An alternative recirculation mode exists. In this mode, the total quantity of air coming from Air Compressors (R41-K-1470 A/B) is preheated through the Calcination Feed/Effluent Exchanger (R41-E-1468) against the oxychlorination effluent, then heated through the Calcination Electrical Heater (R41-E-1473) and finally sent to the bottom part of the Regenerator (R41-R-140), where it circulates upflow in an axial bed.

This Recirculation Package takes a part of the oxychlorination effluent after the Calcination Feed/Effluent Exchanger (R41-E-1468) tube side outlet, and route it back to second burning bed inlet and Oxychlorination Heater (R41-E-1469) inlet.

By recirculating a part of the HCl present in the oxychlorination outlet stream to the second burning bed and to the oxychlorination inlets, the recirculation mode reduces consumptions of chlorination agent, caustic soda and oxychlorination water. This recirculation mode leads to more severe oxychlorination conditions allowing a better metallic dispersion in case of any poisoning of the catalyst.

**(Note: Recirculation Lines will be provided in future. Currently only flange connections with blind flange has been provided in order to connect future recirculation lines)**

#### **2.2.4.5 Catalyst circulation**

##### **2.2.4.5.1 Catalyst circulation control**

The catalyst circulation is carried out continuously by means of a gas lift system which conveys the catalyst from the bottom of the Regenerator (R41-R-140) to the top of the First Reactor (R41-R-131), then from the bottom of each Reactor to the top of the following Reactor, and finally from the bottom of the last reactor to the top of the Regenerator (R41-R-140). The catalyst flows downward through each reactor bed by gravity.

Two lift gases are used:

- Nitrogen gas for :
  - Lift 1, between the Regenerator (R41-R-140) and the First Reactor (R41-R-131). Lift 5, between the Fourth Reactor (R41-R-134) and the Regenerator (R41-R-140).

- Hydrogen rich gas from the Aromizing section (R41-3), i.e. :
   
Lift 2, between the First and the Second Reactors (R41-R-131) & (R41-R-132). Lift
   
3, between the Second and the Third Reactors (R41-R-132) & (R41-R-133). Lift 4,
   
between the Third and the Fourth Reactors (R41-R-133) & (R41-R-134).

The catalyst flow is adjusted as follows: the total flowrate of the lift gas must remain as steady as possible since any change in this flow will affect the velocity of the catalyst in the lift line. This flow rate must be checked carefully because a too high velocity may lead to a high rate of catalyst attrition.

This gas going to the lift pot is divided into two streams:

- The secondary gas, which initiates the lift operation by fluidizing catalyst.
- The primary gas, which governs the catalyst flow.

1st Lift Gas from discharge of Nitrogen Compressor (R41-K-1405A/B) is sent to First Lift Pot (R41-D-1404). The secondary gas which initiates the lift operation by fluidizing catalyst is controlled by flow control valve R41-FV-4040. The flow rate primary gas which controls the catalyst flow is controlled by pressure control valve R41-PDV-4041.

5th Lift Gas from discharge of Nitrogen Compressor (R41-K-1405A/B) is sent to Fifth Lift Pot (R41-D-1444). The secondary gas is controlled by flow control valve R41-FV-4440. The primary gas is controlled by pressure control valve R41-PDV-4441.

Hydrogen Rich gas coming from Aromizing section (R41-3) is used as lift gas for Lift 2,3 and 4. 2nd Lift gas is sent to Second Lift Pot (R41-D-1414). The secondary gas for Lift 2 is controlled by flow control valve R41-FV-4140. The primary gas for Lift 2 is controlled by pressure control valve R41-PDV-4141. 3rd Lift gas is sent to Third Lift Pot (R41-D-1424). The secondary gas for Lift 3 is controlled by flow control valve R41-FV-4240. The primary gas for Lift 3 is controlled by pressure control valve R41-PDV-4241. 4th Lift gas is sent to Fourth Lift Pot (R41-D-1434). The secondary gas for Lift 4 is controlled by flow control valve R41-FV-4340. The primary gas for Lift 4 is controlled by pressure control valve R41-PDV-4341.

Within the proper operating range, the rate of catalyst flow is proportional to the primary flowrate of gas. When the secondary gas is stopped no catalyst can be lifted.

The pressure drop measured between the lift pot and the next upper hopper indicates the catalyst flow: It is nearly equal to 0, when there is no catalyst flow and this pressure drop increases to about 0.1 to 0.3 kg/cm<sup>2</sup> when there is catalyst flow. Therefore this measure is used as an indication of catalyst flow, in particular in the control used for the follow-up of the operation of the lifts. Catalyst circulation rate is calculated by using the number of catalyst unloading from the Lock Hopper (R41-D-1402) versus time.

#### Catalyst levels in upper hoppers

Catalyst surge vessels (upper hoppers) are provided at the top of each reactor in order to compensate for differences in catalyst flow between the lifts. It is also a protection against variations of void fraction of the catalyst in the reactors.

Each upper hopper is equipped with gamma-ray level sensors. One level sensor gives a continuous information for the control, the other one (very low level) gives on/off information for catalyst lift cut-off. The catalyst level is adjusted to 60 % and the measure is used through a cascade to modify the set point of the PDIC used to monitor the catalyst flow (the pressure drop between the lift pot and the upper hopper). Only the lift from the bottom of the Regenerator, the master lift, is controlled by the R41-PDC-4041 used to monitor the first lift. Selection of the required catalyst circulation is performed by adjusting the set point of this delta-pressure controller.

Lift	From	To	PDT	LC	LSLL
1	First Lift Pot R41-D-1404	First Upper Hopper R41-D-1411	4041		
2	Second Lift Pot R41-D-1414	Second Upper Hopper R41-D-1421	4141	4110	4112
3	Third Lift Pot R41-D-1424	Third Upper Hopper R41-D-1431	4241	4220	4221
4	Fourth Lift Pot R41-D-1434	Fourth Upper Hopper R41-D-1441	4341	4320	4321
5	Fifth Lift Pot R41-D-1444	Upper Surge Drum R41-D-1401	4441	4420	4421

#### 2.2.4.5.2 Catalyst batches

Spent catalyst is withdrawn from the bottom of the Fourth Reactor (R41-R-134) and then lifted up to the Upper Surge Drum (R41-D-1401) is sent to the Regenerator (R41-R-140) for regeneration via the Fifth Lift Pot (R41-D-1444). Spent catalyst is stored in this drum at a pressure slightly lower (by around 0.1 to 0.3 kg/cm<sup>2</sup>) than that of the last reactor. In the Regenerator, the pressure is higher (by around 0.5 kg/cm<sup>2</sup>) than that of the

First Reactor inlet. Therefore a pressure adjustment is needed. This is made in the Lock Hopper (R41-D-1402) and induces catalyst batches, i.e., a non-continuous circulation between the Upper Surge Drum (R41-D-1401) and the Regenerator (R41-R-140).

Pressure adjustment and catalyst batches are performed automatically by a specific sequence R41-UC-40020.

#### **2.2.4.5.3      Nitrogen gas lift system: lifts 1 & 5**

Nitrogen gas from lift 5 is separated from the catalyst in the Upper Surge Drum (R41-D-1401) and flows through the Upper Surge Drum Fines Filter (R41-F-1405) where the catalyst dust is recovered. In this filter, the gas circulates upward: it enters at the middle of the drum and flows through several cartridges of filtering elements where catalyst dust is trapped. These cartridges are regularly cleaned, when the pressure drop increases, by a counter current flow of nitrogen (back-flushing system).

Nitrogen gas from lift 1 is separated from the catalyst in the First Upper Hopper (R41-D-1411) equipped with an elutriation system, cooled through the First Upper Hopper Finned Tube Exchanger (R41-E-14150) and cleaned in the First Upper Hopper Fines Filter (R41-F-14150).

A part of this gas is compressed in the Elutriation Blower (R41-B-14150) and flows back to the First Upper Hopper (R41-D-1411) as elutriation gas, to ensure the removal of catalyst fines and chips from the system. The other part of the gas is mixed with the nitrogen gas coming from Upper Surge Drum Fines Filter (R41-F-1405) (lift 5).

The total nitrogen gas flow is cooled through the Nitrogen Loop Trim Cooler (R41-E-1405), passes through Nitrogen Compressors K.O. Drum (R41-D-1405) and recirculated by means of the Nitrogen Compressors (R41-K-1405 A/B) to the lifts 1 and 5. The set point of the pressure controller (R41-PC-4053) at Nitrogen Compressor (R41-K-1405 A/B) suction is reset by the pressure measured (R41-PI-4432) at the outlet of the Fourth reactor (R41-R-134) by means of a delta-pressure controller (R41-PDC-4056). Pressure at Nitrogen compressor discharge is controlled through a spillback pressure control valve R41-PV-4057, returning at Nitrogen Compressor suction, upstream the Nitrogen Loop Trim Cooler (R41-E-1405).

Fresh nitrogen addition from Nitrogen header is made-up upstream of the Nitrogen Compressors K.O. Drum (R41-D-1405) by pressure control valve R41-PDV-4055A. In addition to nitrogen used for elutriation and lifts 1 and 5, a part of the nitrogen is cooled in the Nitrogen Storage Trim Cooler (R41-E-1406) then sent to the Nitrogen Storage Drum (R41-D-1406) and used continuously for the following:

The seal above the Reduction Chamber (R41-D-1412) via flow control valve R41-FV-4110.

The seal under the Fourth Reactor (R41-R-134) via flow control valve R41-FV-4430.

The seal above and under the Regenerator (R41-R-140) via pressure control valve R41-PDV-40010 and R41-PDV-403 respectively.

The Lock Hopper (R41-D-1402) pressurization.

The Upper Surge Drum Fines Filter (R41-F-1405) and First Upper Hopper Fines Filter (R41-F-14150) back-flushing.

The pressure regulation in the regeneration loop by pressure control valve R41-PDV-4731B.

#### **2.2.4.5.4      Hydrogen rich gas lift system: lifts 2, 3 & 4**

The hydrogen rich gas used for lift system is hydrogen-rich gas produced in Aromizing Section (Unit R41-3). It is preheated in the Hydrogen Lift Gas Exchanger (R41-E-1417) before being used in the lift system. Refer Section **2.2.4.5.1** for description of Lift 2, 3, and 4.

The hydrogen rich gas is recovered in the upper hoppers (R41-D-1422/1432/1442) and mixed with the reactors feed. For instance, for lift 2, hydrogen-rich gas is separated from the catalyst in the Second Upper Hopper (R41-D-1422), filtered in the Balance Drum (R41-D-1421) and mixed with the feed of the Second Reactor (R41-R-132). Similarly for Lift 3 and Lift 4, hydrogen rich gas is separated from the catalyst in the Upper Hopper (R41-D-1432/1442) and mixed with Third Reactor (R41-R-133) and Fourth Reactor (R41-R-134) feed respectively.

#### **2.2.4.5.5      Isolation of the regeneration / circulation and the reaction sections**

Using nitrogen gas as lift gas between the regeneration and the reaction sections allows to isolate the regeneration section (rich in oxygen) from the reaction (containing hydrogen and hydrocarbons) section which are connected by the catalyst circulation.

An important point is to prevent hydrocarbons and / or hydrogen and / or oxygen from entering the nitrogen lift gas system.

Therefore, the following protections are provided:

- Nitrogen sealing: a controlled flow of inert gas is used to keep the drums connected with the reaction section at a slightly higher pressure than that of the reaction section i.e., between the First Upper Hopper (R41-D-1411) and the Reduction Chamber (R41-D-1412) and between the Fourth reactor (R41-R-134) and the Fifth Lower Hopper (R41-D-1443) via flow control valve R41-FV-4110 and R41-FV-4430 respectively.

- Shutdown valves: if the nitrogen sealing fails for any reason, the valve (R41-ZV-4111) between the First Upper Hopper (R41-D-1411) and the Reduction Chamber (R41-D-1412) and the valve (R41-ZV-4431) between the Fifth Lower Hopper (R41-D-1443) and the Fifth Lift Pot (R41-D-1444) will close automatically, isolating the two sections. A shutdown valve (R41-ZV-4031) between the First Lower Hopper (R41-D-1403) and the first lift pot (R41-D-1404) is also provided to isolate the Regenerator (R41-R-140) from the nitrogen gas system.
- In the same manner, a pressure drop is maintained between the Lock Hopper (R41-D-1402) and the top of the Regenerator (R41-R-140) by a small flow of nitrogen via R41-RO-4012 to prevent oxygen from entering the nitrogen gas system.
- 3" lines, seal legs, are installed between the First Upper Hopper (R41-D-1411) and the Reduction Chamber (R41-D-1412), between the Fifth Lower Hopper (R41-D-1443) and the Fifth Lift Pot (R41-D-1444) as well as between the First Lower Hopper (R41-D-1403) and the First Lift Pot (R41-D-1404). The pressure balance is made through these pipes full of catalyst, so that a very small flow of gas is sufficient to create significant pressure drop.

#### **2.2.4.5.6      Catalyst addition and draw-off**

Catalyst can be added and withdrawn while the catalyst circulation is in operation. This operation is performed in the Lock Hopper (R41-D-1402): during the drawing-off operation, when the Lock Hopper is full of spent catalyst, it is isolated and depressurized to safe location. The spent catalyst is then withdrawn from the unit by means of the side connection located underneath the Lock Hopper (R41-D-1402). It goes down to the ground through a 3" line and is collected and stored in drums, previously filled up with nitrogen.

The fresh catalyst is introduced in the Lock Hopper through a catalyst loading device, then transferred as usual, down to the Regenerator, where it **is** dried, and finally reduced before entering the reaction section. Thus, this vessel allows proceeding either to a full catalyst replacement while the unit is in operation ("on-the-fly" catalyst replacement) or just to a compensation for losses due to catalyst attrition ("on-the-fly" catalyst make-up).

## **2.2.5 R41-5 PSA section**

H<sub>2</sub> Rich gas from Hydrogen Rich Gas Chloride Adsorbers (R41-R-13590 A/B) in section R41-3 is the feed to PSA Section (R41-5). This Hydrogen Rich gas is first sent to a PSA Feed Coalescer (R41-D-1501) to remove any liquids in the gas stream. The vapour stream from the PSA Feed Coalescer (R41-D-1501) is sent to PSA Unit Package (R41-PK-1510) which uses Polybed technology from UOP.

The UOP POLYBED PSA unit uses Pressure Swing Adsorption (PSA). Impurities are adsorbed at high pressure and then desorbed at low pressure.

Each adsorber goes through the same cycle of adsorption and regeneration without change in temperature, except for the heat of adsorption and desorption.

In the main mode of operation, there are always 2 adsorbers in adsorption, while the others are in depressurisation, regeneration or repressurisation.

- A) During adsorption, feed gas enters the bottom of the adsorber, while purified gas leaves from the top. At the end of adsorption, the adsorber is loaded with impurities, concentrated at the bottom.
- B) The remaining hydrogen concentrated at the top is first removed by co-current depressurisation and used to repressurise (equalise) and purge other adsorbers.
- C) Subsequently, the adsorbers are counter-currently depressurised (from top to bottom) in the blowdown step.
- D) Following the blowdown step the adsorbers are purged with the high purity stream provided in step B (providing purge). In steps C and D the gas leaving the adsorbers at the bottom is sent to an tail gas drum to obtain a steady and homogeneous tail gas flow.
- E) Before going back into the adsorption step, the adsorber has to be repressurised with gas provided in step B (equalisation) Internally this is a batch type process. However, battery limit flows, i.e., feed, product and tail gas are continuous.

For detailed process description refer latest revision of section 3 in the following document:  
V-202-1420-141-U-01-105\_Operating Manual

Hydrogen coming from the PSA Unit Package (R41-PK-1510) are sent to various users and to the existing header as described in section 2.1.3.2.7.

Tail gas from PSA Unit Package (R41-PK-1510) is compressed in Tail Gas Compressors (R41-K-152A/B) and then cooled in Tail Gas Aftercooler (R41-E-152) and then sent to the Off-Gas Header.

## 2.3 Description of Unit Flow

Process description in section 2.2 to be read along with below drawings.

Documents	Reference
Process Flow Diagrams	Refer to section 8.5
Heat & Mass Balances	Refer to section 8.16 – Licensor Data Books
P&IDs	Refer to section 8.6
Plot Plans	Refer to section 8.14

## 2.4 Description of Utilities

Required utilities for the plant is available at the unit battery limit. The battery limit conditions for various utilities are provided below.

### 2.4.1 Steam System

Steam is used in reboilers / heat exchangers for heating and in heaters as snuffing steam. Steam is used in Recycle Compressor (R41-K-13450) Turbine, H<sub>2</sub> Rich Gas Compressor (R41-K-135/13550) Turbine as motive fluid. Also steam is used in start-up ejector R41-EJ-1215. LP Steam is used for equipment steam out. Major consumers of steam are listed below:

HP Steam	MP Steam	LP Steam
Turbine for Recycle Compressor (R41-K-13450)	Naptha Depentanizer Reboiler (R41-E-111)	Deethanizer Reboiler (R41-E-137)
Turbine for H <sub>2</sub> Rich Gas Compressor 1 <sup>st</sup> & 2 <sup>nd</sup> Stage (R41-K-135)	Naptha Splitter Reboiler (R41-E-112 A/B)	Debutanizer Reboiler (R41-E-138)
Turbine for H <sub>2</sub> Rich Gas Compressor 3 <sup>rd</sup> Stage (R41-K-13550)	LCN Splitter Reboiler (R41-E-113)	-

Steam is available at the following conditions at battery limit.

SERVICE	Pressure kgf/cm <sup>2</sup> (g)				Temp °C			
	Normal	Max	Min	Design	Normal	Max	Min	Design
High High Pressure (Note 1)	105	107.5	102.5	120/FV	500	505	495	518
High Pressure	41	43.5	38.5	48/FV	360	365	340	400
Med Pressure	19	19.5	18	25/FV	260	270	250	295
Low Pressure	4.5	5.0	3.5	6/FV	160	180	150	200

Note 1: HHP steam conditions at the battery isolation of the Ethane Cracker.

## 2.4.2 Condensate System

MP Steam condensate from collection header gets flashed at MP Condensate flash drum (R41-D-1630). LP Condensate collected from the MP Condensate flash drum (R41-D-1630) is sent to LP Condensate flash drum (R41-D-1640) via level controller (LV-6300). When the level in LP Condensate flash drum (R41-D-1640) builds up, the condensate is pumped to LP condensate header via hot condensate pumps (R41-P-1640A/B) through level controller (LV-6400). LP Steam which is collected from MP Condensate flash drum (R41-D-1630) is sent to LP Steam header.

### 2.4.2.1 Equipment Design Basis

- **MP Condensate flash drum R41-D-1630**

Normal case: Naphtha Feed Temperature = 34 °C

Description	Unit	Total flow from MP steam Condensate header	LP Steam to header	LP condensate to R41-D-1640
Normal Flow	kg/hr	113900	12520	10138
Temperature	°C	155	155	155
Pressure	kg/cm <sup>2</sup> g	4.5	4.5	4.5

Preheater Design case: Naphtha Feed Temperature = 13 °C

Description	Unit	Total flow from MP steam Condensate header	LP Steam to header	LP condensate to R41-D-1640
Normal Flow	kg/hr	113900	12520	10138
Temperature	°C	155	155	155
Pressure	kg/cm <sup>2</sup> g	4.5	4.5	4.5

- **LP Condensate flash drum R41-D-1640**

Normal case: Naphtha Feed Temperature = 34 °C

Description	Unit	LP condensate from R41-D-1640	LP condensate from LP steam condensate header	Steam to R41-E-1112	Hot condensate to R41-P-1640
Normal Flow	kg/hr	10138	8600	10740	109980
Temperature	°C	155	103	100	100
Pressure	kg/cm <sup>2</sup> g	4.5	0.1	0.1	0.1

Preheater Design case: Naphtha Feed Temperature = 13 °C

Description	Unit	LP condensate from R41-D-1640	LP condensate from LP steam condensate header	Steam to R41-E-1112	Hot condensate to R41-P-1640
Normal Flow	kg/hr	10138	8600	10740	118150
Temperature	°C	155	103	100	100
Pressure	kg/cm <sup>2</sup> g	4.5	0.1	0.1	0.1

#### 2.4.2.2 Operating Parameters of Steam Condensate Recovery System

- **MP Condensate Flash Drum R41-D-1630**

Volume	17m <sup>3</sup>	
Pressure	Operating	4.5 kgf/cm <sup>2</sup>
	Design	6 kgf/cm <sup>2</sup>
Temperature	Operating	155°C
	Design	200°C

- **LP Condensate Flash Drum R41-D-1640**

Volume	15 m <sup>3</sup>	
Pressure	Operating	0.1 kgf/cm <sup>2</sup>
	Design	1.7 kgf/cm <sup>2</sup>
Temperature	Operating	103°C
	Design	135°C

- **Hot Condensate Pump R41-P-1640 A/B**

Type	Horizontal Centrifugal	
Volumetric flow rate	139 m <sup>3</sup> /h	
Differential head	71.5 m	
Temperature	Operating	: 103°C
	Design	: 135°C

The condensate generated is routed to LP condensate header by Hot Condensate Pumps (R41-P-1640A/B) to the battery limit. The steam generated in LP Condensate Flash Drum (R41-D-1640) is used to preheat the Naptha feed from storage in Naptha Preheater (R41-E-1112).

The pumped condensate properties at the unit battery limits are as follows:

Service	PRESSURE kgf/cm2 (g) (Note 1)				TEMP °C	
	Normal	Max	Min	Design	Max	Design
Pumped Condensate	5.0	6.0	4.0	10.0	103	135

Note 1: Pressure at grade

#### 2.4.2.3 Steam Condensate quality :

Quality Parameter	Unit	Quality Standard
Hydrocarbon (oil)	mg/L	Normal: ND (Not Detectable)
Electrical Conductivity@25 degC	mS/m	Normal: less than 1
pH		7.5 to 9.6 @ 25 degC
Hardness	mg/L	0
Silica as SiO <sub>2</sub>	mg/L	Less than 0.05
Total Cu	mg/L	Less than 0.02
Total Fe	mg/L	Less than 0.3

#### 2.4.3 Water Systems

Cooling water, Potable water, Utility water, Boiler feed water and DM water are available at the battery limit with following condition:

Description	Service						Demineralised Water (Note 5)
	Sea Water (Dedicated only to desalination plant.)	Treated Water or Desalted Water (Note 3)	Utility Water (Note 1)	Recirc. Cooling Water (Note 2)	BFW		
HHP	HP						
Design Temp, °C	70	70	70	76	166	166	90
System Design Pressure, kgf/cm <sup>2</sup> (g)	7.5	12	12	7	210	90.6	15.1
Supply Pressure at grade, kgf/cm <sup>2</sup> (g)	3.0	6	7.6 (Note 4)	4	140	61.5	7.7
Return Pressure at grade, kgf/cm <sup>2</sup> (g)	-	-	-	2.0	-	-	-
Supply Temp, °C at unit BL	-	<40	40	36	130	130	60 max.
Return Max Temp for Exchanger Design, °C	-	-	-	46	-	-	-

Note 1: Derived from Waste Water Treatment Plant and used as low grade water for wash down water and Utility Stations only. The consideration for concentration of dissolved components, contamination and/or corrosion is required for the application of Utility Water.

Note 2: Circulating fluid is desal/treated water.

Note 3: Used for cooling water make-up feed, demin plant and within process units.

Note 4: At waste water treatment plant battery limit.

Note 5: Demineralised water **is** used to inject into process systems for commissioning, normal operation, initial start-up and start-up preparation. However treated water can be utilized for water injection into process systems for commissioning, initial start-up and start-up preparation (except for normal operation) only if the treated water header is available and demineralised water header is not.

Description	Fire Water		Potable Water or Drinking Water
	Potable Source	Sea Water Source (Note 1)	
Design Temp, °C	70	70	70
Supply pressure at grade kgf/cm <sup>2</sup> (ga)	11.3	11.3	3
System Design pressure, kgf/cm <sup>2</sup> (ga)	16.7	16.7	7
Supply, °C	Ambient	32	Ambient

Note 1: Sea Water for back up Fire Water.

### **Water Analysis**

- Desalinated Water Specifications: used as Make-up Water for the Cooling Towers

Quality Parameter	Unit	Quality Standard
TDS	mg/L	Less than 10
Chloride as Cl	mg/L	Less than 5
Silica as SiO <sub>2</sub>	mg/L	Less than 0.05
Free Carbon Dioxide as CO <sub>2</sub>	mg/L	Less than 2

- Demineralized Water: used as Process Water

Quality Parameter	Unit	Quality Standard
TDS	mg/L	0.3
pH		6.0-7.0
Silica as SiO <sub>2</sub>	mg/L	0.02
Electrical Conductivity	mS/m	Less than 0.05
Chloride	mg/L	Less than 0.01
Total Fe	mg/L	Less than 0.03
P2O <sub>5</sub>	mg/L	ND (Not Detectable)

<b>Quality Parameter</b>	<b>Unit</b>	<b>Quality Standard</b>
Organics	mg/L	ND (Not Detectable)
Total Cu as Cu	mg/L	Less than 0.03
Sulphates as SO <sub>4</sub>	mg/L	Less than 0.04

- Boiler Feed Water (BFW):

<b>Quality Parameter</b>	<b>Unit</b>	<b>Quality Standard</b>
pH@25 deg.C		8.5-9.5
Hardness	mg/L	0
Oil	mg/L	0
Conductivity	mS/m	Less than 0.05
Oxygen	cc/L	Less than 0.005
Iron, Copper & Nickel	mg/L	Less than 0.02
Total Solids, alkalinity, silica	mg/L	Less than 0.02
Organic Carbon	mg/L	ND (Not Detectable)
Chloride	mg/L	Less than 0.01

Note 1: Desal/Treated water produced by reverse osmosis.

Note 2: The seawater intake is dosed continuously with sodium hypochlorite to achieve 0.5 ppm at the intake. Occasional shock dosing is prohibited to avoid the damage on RO membrane.

#### 2.4.4 Air System

Process unit user battery limit system conditions for Instrument air and Utility air are given in the table below.

<b>Parameters</b>	<b>Service</b>	
	<b>Utility Air</b>	<b>Instrument Air</b>
Operating temp, °C	50	50
Max operating pressure kgf/cm <sup>2</sup> (ga)	9.0	8.5
Normal operating pressure kgf/cm <sup>2</sup> (ga)	8.75	8.25
Minimum operating pressure kgf/cm <sup>2</sup> (ga)	7.25 (Note 1)	5.5
Design temp, °C	80	80
Design pressure kgf/cm <sup>2</sup> (ga)	10.0	10.0

Dew point @ system pressure, °C	Saturated	-20
Present system does furnish oil-free air	Yes	Yes

Note 1: Plant air supply will be shut off when pressure in instrument header drops below 7.25 kgf/cm<sup>2</sup>(g)

#### 2.4.5 Nitrogen System

Process unit user battery limit system conditions for Nitrogen is given in the table below.

Parameters	Nitrogen system
Minimum operating pressure, kgf/cm <sup>2</sup> (ga)	7.5
Normal operating pressure, kgf/cm <sup>2</sup> (ga)	8.9
Maximum operating pressure, kgf/cm <sup>2</sup> (ga)	9.4
Normal operating temperature, °C	Ambient
Design pressure, kgf/cm <sup>2</sup> (ga)	13
Design temperature, °C	70

#### 2.4.6 Fuel Gas System

Fuel gas from battery limit is fed to the Fuel Gas KO Drums (R41-D-1750 & R41-D-1751) which separates condensate if present. The dry fuel gas is routed to pilot burners and main burners of R41-FR-13110, R41-FR-13210, R41-FR-13310, R41-FR-13410, R41-FR-12110, R41-FR-122.

Fuel gas from the refinery gas network **is** available at the following battery limit conditions:

**Normal case:**

Composition (mol%) / Properties	Light SOR Case	Light EOR Case	Heavy SOR Case	Heavy EOR Case
Hydrogen	42.2	41.1	40.2	37.3
Methane	10.0	11.3	9.7	10.3
Ethane	29.2	29.4	32.9	33.0
Propane	13.2	14.9	13.6	15.9
Butane	2.0	0.7	1.1	1.1
I-Butane	1.9	1.4	1.3	1.2
Pentane	0.1	0.1	0.1	0.1
I-Pentane	0.2	0.1	0.2	0.1
Hexane	0.1	0.1	0.1	0.1
Benzene	0.3	0.3	0.3	0.3
Toluene	0.1	0.0	0.0	0.0
Propylene	0.2	0.2	0.1	0.1
1-Butene	0.1	0.1	0.1	0.1
C2-Butene	0.1	0.0	0.0	0.0
H2O	0.3	0.3	0.3	0.3
<b>Total</b>	<b>100.0</b>	<b>100.0</b>	<b>100.0</b>	<b>100.0</b>
MW (kg/kmol)	20.3	20.1	20.4	21.4
LHV (kcal/kg)	11,921	11,932	11,909	11,830
Operating Pressure (kg/cm <sup>2</sup> G)	3.0 to 4.0	3.0 to 4.0	3.0 to 4.0	3.0 to 4.0
Operating Temperature (degC)	26	28	24	27
Design Pressure kg/cm <sup>2</sup> G)	7.5			
Design Temperature (degC)	110			

**Initial Start-up case:**

Composition (mol %) / Properties	Initial Start- up Case
Propane	0.24
Propylene	0.24
i-Butane	18.2
i-Butene	28.6
Butane	7.6
1-Butene	12.2
C2Butene	11.9
T2Butene	18.9
13BD	0.01
1Pentene	2.11
<b>Total</b>	<b>100.0</b>
MW (kg/kmol)	56.9
LHV (kcal/kg)	10,803
Operating Pressure (kg/cm <sup>2</sup> G)	3.0 to 4.0
Operating Temperature (degC)	45
Design Pressure (kg/cm <sup>2</sup> G)	7.5
Design Temperature (degC)	110

Fuel gas line from the battery limit is measured via flow meter R41-FT-7500 and sent through the pressure control valve R41-PV-7513 to Fuel Gas KO Drum (R41-D-1750/1751). Liquid droplets entrained along with the fuel gas is removed in the Fuel Gas KO Drum (R41-D-1750/1751) and sent to flare. Fuel gas from the outlet of the Fuel Gas KO Drum (R41-D-1750/1751) is distributed to all heaters of aromizing reaction section.

The total fuel gas flow from battery limit and fuel gas flow to Fired Heaters R41-FR-13110/13210/13310/13410/12110/122 is tabulated below.

- Heavy Feed Case (SOR):**

Description	Unit	Total fuel gas to KO Drum	Fuel gas to R41-FR-13110/13210/13310/13410	Fuel gas to R41-FR-12110	Fuel gas to R41-FR-122
Heat duty (Normal)	MMkcal/hr	218.5	182.4	15.9	20.2
Heat duty (Design)	MMkcal/hr	259.5	211.2	22.9	25.4

Normal Flow	Kg/hr	18347	15316	1335	1696
Design Flow	Kg/hr	21805	17720	1940	2145

- **Heavy Feed Case (EOR):**

Description	Unit	Total fuel gas to KO Drum	Fuel gas to R41-FR-13110/13210 /13310/13410	Fuel gas to R41-FR-12110	Fuel gas to R41-FR-122
Heat duty (Normal)	MMkcal/hr	218.0	180.6	17.4	20.0
Heat duty (Design)	MMkcal/hr	259.5	211.2	22.9	25.4
Normal Flow	Kg/hr	18428	15266	1471	1691
Design Flow	Kg/hr	21805	17720	1940	2145

- **Light Feed Case (SOR):**

Description	Unit	Total fuel gas to KO Drum	Fuel gas to R41-FR-13110/13210 /13310/13410	Fuel gas to R41-FR-12110	Fuel gas to R41-FR-122
Heat duty (Normal)	MMkcal/hr	197.0	167.2	13.3	16.5
Heat duty (Design)	MMkcal/hr	259.5	211.2	22.9	25.4
Normal Flow	Kg/hr	16525	14026	1116	1384
Design Flow	Kg/hr	21805	17720	1940	2145

- **Light Feed Case (EOR):**

Description	Unit	Total fuel gas to KO Drum	Fuel gas to R41-FR-13110/13210/13310/13410	Fuel gas to R41-FR-12110	Fuel gas to R41-FR-122
Heat duty (Normal)	MMkcal/hr	195.3	164.7	14.4	16.2
Heat duty (Design)	MMkcal/hr	259.5	211.2	22.9	25.4
Normal Flow	Kg/hr	16368	1383	1207	13580
Design Flow	Kg/hr	21805	17720	1940	2145

#### **2.4.7 Electrical Power**

The incoming power supply at plant battery limit is 34.5 kV. There are three substations (SS231 and SS 237 for Unit 420 and SS 239 for unit 410). Nominal system voltage levels are AC - 34.5 kV (Incoming) 13.8kV,4.16kV,480V,230V,120V(UPS),DC-125V DC. An emergency diesel generator system is provided to feed each substation for emergency power supplies in case of power failure.

#### **2.4.8 Flare System**

The ISBL knock-out drums are sized to achieve the greater of the following:

- Elimination of 1000 µm of liquid droplets based on the maximum volumetric flow case
- Hold-up of the liquid relief specified by the licensor for 20 minutes [see note]
- Hold-up of 20% of the maximum vapor relief for 20 minutes

Note that it is not necessary to consider the liquid relief from the four Reactor separators (NHT and Aromizing Reaction Section) for the sizing basis of the ISBL flare knock-out drum, even though it is indicated in the relief load summary provided by the licensor, for the following reasons:

- In the case of a blocked liquid outlet, the level in the drum will increase. When the high high level is reached, the compressor will automatically shutdown, cutting the feed and leading to total unit shutdown.
- Also, considering the large inventory of the entire reactor circuit, including the Reactor and feed-effluent exchangers, continuous liquid relief due to blocked liquid outlet is not realistic. Even if some liquid is released, it will be for very short period of time and therefore should not govern the size of the knock-out drum.

LP Flare from header gets flashed at LP Flare knockout drum(R41-D-181). LP Flare Condensate collected from the LP Flare knockout drum(R41-D-181) is pumped to storage via LP Flare condensate pumps (R41-P- 181A/B) through coolers (E1363 / E1364 A/B).

HP Flare from header gets flashed at HP Flare knockout drum (R41-D-182). HP Flare Condensate collected from the HP Flare knockout drum (R41-D-182) is pumped to storage via HP Flare condensate pumps(R41-P- 182A/B) through coolers (E1363 / E1364 A/B).

#### **2.4.8.1 Sizing Basis for the ISBL Knock-out Drums**

Knock-out Drum	Maximum Vapor Relief Rate (Vol. Flow Basis)	Maximum Liquid Relief	20% of Maximum Vapor Relief Rate (Wt. Flow Basis)
R41-D-181 (LP Flare)	Separator (R41-D-13450) Blocked Vapor Outlet 146,978 kg/h	N/A	Naphtha Splitter (R41-T-112) Reflux Failure 294,671 kg/h x 20% (Governing)
R41-D-182 (HP Flare)	Second Interstage Drum (R41-D-13550) Blocked Vapor Outlet 62,934 kg/h	LPG Absorber (R41-D-136100) Blocked Liquid Outlet 336,606 kg/h (Governing)	NHT Reactor Separator R41-D-12140 Gas Blow-by 620,749 x 20%

#### **2.4.8.2 Operating Parameters of Flare System**

- **LP Flare knock out drum (R41-D-181)**

Pressure	Operating	0.02 kgf/cm <sup>2</sup>
	Design	3.5 kgf/cm <sup>2</sup>
Temperature	Operating	46°C
	Design	225°C

- **LP Flare Condensate Pump (R41-P-181A/B)**

Type	Horizontal Centrifugal	
Volumetric flow rate	16.7m <sup>3</sup> /h	
Differential head	114.5 m	
Temperature	Operating	: 150°C
	Design	: 230°C

- **HP Flare knock out drum (R41-D-182)**

Pressure	Operating	0.02 kgf/cm <sup>2</sup>
	Design	7 kgf/cm <sup>2</sup>
Temperature	Operating	46°C
	Design	265°C

- **HP Flare Condensate Pump (R41-P-182A/B)**

Type	Horizontal Centrifugal	
Volumetric flow rate	79 m <sup>3</sup> /h	

Differential head	116 m
Temperature	Operating : 150°C
	Design : 230°C

#### **2.4.8.3 Slop Oil**

The slop oil from the flare knock-out drums in R41 is routed to the Straight-run (SR) Naphtha Tank (F56-TK- 63/64) through the off-spec naphtha rundown coolers (R41-E-1326 & 1327 A/B) to minimize loss of naphtha and aromatics products.

#### **2.4.8.4 LP flare System**

The low pressure flare system dispose all releases from relief valves with set pressures below 9.5 kg/cm<sup>2</sup>g. The system consists of a LP flare knock-out drum (R41-D-181) and LP flare condensate pumps (R41-P-181 A/B). The LP Flare gas is routed to battery limit and condensate collected in LP flare knock-out drum during relief is pumped out by LP flare condensate pumps (R41-P-181 A/B) to battery limit via SR Naptha Rundown Air Cooler (R41-E-1363) and SR Naptha Rundown Trim Cooler (R41-E-1364 A/B).

#### **2.4.8.5 HP flare System**

The high pressure flare system dispose hydrocarbon releases from relief valves with a nominal set pressure of 9.5 kg/cm<sup>2</sup>g or higher. The system consists of a HP flare knock-out drum (R41-D-182) and HP flare condensate pumps (R41-P-182 A/B). The HP Flare gas is routed to battery limit and condensate collected in HP flare knock-out drum during relief is pumped out by HP flare condensate pumps (R41-P-182 A/B) to battery limit via SR Naptha Rundown Air Cooler (R41-E-1363) and SR Naptha Rundown Trim Cooler (R41-E-1364 A/B).

Service	Pressure (kg/cm <sup>2</sup> g)			Temperature (°C)	
	Normal	Maximum	Design	Normal	Maximum
LP Flare	0.02	0.74 (Note 1)	3.5 / H.V.	46	225
HP Flare	0.02	1.58 (Note 1)	7.0 / H.V.	46	265

Note 1: Value Provided by U01 Contractor.

## **2.4.9 Drain System**

### **2.4.9.1 Closed Drain System**

A closed drain system is provided to avoid release of hydrocarbon to atmosphere during normal operation and maintenance. Hydrocarbon drainage from equipment, instrument and piping is collected in Closed Drain Drum R41-D-1000 to ensure full draining by gravity.

Closed drain system consists of Closed Drain Drum R41-D-1000, Closed Drain Pump R41-P-1000 and Oily Water Drain pump R41-P-1001, control system and associated closed drain network.

- Sources**

Drainage from static equipment, pump, level instruments and control valves assemblies is collected in the closed drain drum during maintenance.

- Destination of Drainage collected in the Closed Drain Drum**

The Closed Drain Drum (R41-D-1000) separates oily water and hydrocarbon. The oily water is pumped out by Oily water Drain Pump (R41-P-1001) and routed to battery limit for WWT/ Liquid incinerator. Degassed hydrocarbon in the Closed Drain Drum (R41-D-1000) is pumped out by Closed Drain Pump (R41-P-1000) and routed to existing Straight Run Naphtha Tanks (TK-63 or 64) in OSBL via SR Naptha Rundown Air Cooler (R41-E-1363) and SR Naptha Rundown Trim Cooler (R41-E-1364 A/B).

### **2.4.9.1.1 Equipment Design Basis**

- Sizing Basis of Closed Drain Drum R41-D-1000 and Pumps R41-P-1000**

The drain drum sized to hold up liquid up to a level 300mm above the bottom TL of the largest vessel. The pump designed to pump out the liquid in the drum within 40 minutes.

Largest Vessel in R41	R41-T-122 (NHT Stripper): 5,800 mm ID Liquid
Hold-up Volume:	33.5 m3
Closed Drain Drum Size	3,200 mm ID x 9,400 TL
Pump Capacity	50 m3/hr.

- Design Conditions of Closed Drain Header and Closed Drain Drum (R41-D-1000)**

Design Pressure:	3.6 kg/cm2g
Design Temperature:	150°C

The collection header is located in a trench. Any draining from hot process systems must not take place until the drainage fluid temperature becomes lower than 150 °C. A temperature indicator TE- 0001 with a high alarm is provided on the closed drain drum.

#### **2.4.9.1.2 Operating Parameters of Closed Drain System**

The operating parameters of Closed Drain Drum (R41-D-1000), Closed Drain Pump (R41-P-1000) and Oily Water Drain Pump (R41-P-1001) are given below.

- **Closed Drain Drum**

Volume	90 m <sup>3</sup>	
Pressure	Operating	0.02 kgf/cm <sup>2</sup>
	Design	3.6 kgf/cm <sup>2</sup> / HV
Temperature	Operating	46 °C
	Design	150 °C

- **Closed Drain Pump**

Type	Vertical Centrifugal
Volumetric flow rate	50 m <sup>3</sup> /h
Differential head	80.4 m
Temperature	Operating : 46 °C
	Design : 150 °C

- **Oily Water Drain Pump**

Type	Vertical Centrifugal
Volumetric flow rate	30 m <sup>3</sup> /h
Differential head	98.7 m
Temperature	Operating : 46 °C
	Design : 150 °C

- **Closed Drain System Discharge Conditions**

	Pressure (kg/cm <sup>2</sup> (g))		Temperature (°C)		
	Service	Normal	Design	Normal	Maximum
OW to Liquid Incinerator	8.5	12.4	46	76	
OW to WWT	4.0	12.4	35	70	

#### **2.4.9.2 OWS System**

The open drain collected from R41 OWS funnels are routed to OWS Lift Station (R41-Z-1010). The collected liquids are pumped out by OWS Lift Station Pumps (R41-P-1010 A/B) and routed to battery limit for WWTP.

OWS lift station (R41-Z-1010) has one duty and one stand-by pump (R41-P-1010 A/B). The lift station pump is operated by on-off control by water level in the lift station sump. Two level transmitters are provided. One is used for pump start / stop control during normal operation and the other is used for pump stop at Low-Low water level in case of failure of main level transmitter.

##### **2.4.9.2.1 Equipment Design Basis**

- Oily Water (OWS) Lift Station Sump (R41-Z-1010)**

Quantity: One (1) for each collection area

Capacity Basis: Minimum 5 minutes of pump rated capacity

- Oily Water (OWS) Lift Station Pumps (R41-P-1010 A/B)**

Type	Vertical Centrifugal
Volumetric flow rate	11 m <sup>3</sup> /h
Differential head	45 m
Temperature	Operating : 35°C Design : 70°C

- OWS System Discharge Conditions**

	Pressure (kg/cm <sup>2</sup> (g))		Temperature (°C)	
Service	Normal	Design	Normal	Maximum
OW to WWT from OWS System	4.0	12.4	35	70

#### **2.4.9.3 Contaminated Surface Sewer (SYS)**

The contaminated surface water collected through open gutters from area UO2 are routed to Intermediate SYS Lift Station (R41-Z-1030) and from area R41 are routed to SYS Lift Station (R41-Z-1020). The collected contaminated water in Intermediate SYS Lift Station is pumped out by Intermediate SYS Lift Station Pumps (R41- P1030 A/B/C) to SYS Lift Station (R41-Z-1020). Finally from the SYS Lift Station the contaminated water is routed

to contaminated surface water tank (C340-TK-3491) located outside the unit battery limit by SYS Lift Station Pumps (R41-P-1020 A/B/C).

SYS lift stations has capacity to receive peak flow rate due to firefighting or storms. Design rainfall intensity in storm case is 20 mm/h. Two SYS lift station pumps which have 50% of required capacity each are provided. The lift station pump is operated by on-off control by water level in the lift station sump. Two level transmitters are provided in the SYS lift station. One is used for pump start / stop control during normal operation and the other is used for pump stop at Low-Low water level in case of failure of main level transmitter.

One SYS pump will start automatically **in case of normal liquid level** and second pump **will start in case high liquid level and also** can be manually started in fire case. SYS collection header is sized based on one SYS pump operation of all the lift stations in overall Phase II plant except product and intermediate tankage area. In case of heavy rain greater than 10 mm/h rainfall, excess water will accumulate inside catchment area or overflow from manholes around buildings. The accumulated water sent to SYS after rainfall. The accumulated water **is** discharged within 2 hours at worst case of 20 mm/h x 2hours rainfall.

#### **2.4.9.3.1      Equipment Design Basis**

- **Contaminated Surface Water (SYS) Lift Station Sump (R41-Z-1020)**

Quantity:                          One (1) for each collection area

Capacity Basis:                   Minimum 5 minutes of total pumping capacity

- **Contaminated Surface Water (SYS) Lift Station Pumps (R41-P-1020 A/B/C)**

Type	Vertical Centrifugal
Volumetric flow rate	505 m <sup>3</sup> /h
Differential head	71 m
Temperature	Operating : 35 °C
	Design : 70 °C

- **Contaminated Surface Water System (SYS) Discharge Conditions**

	Pressure (kg/cm <sup>2</sup> (g))		Temperature (°C)	
	Normal	Design	Normal	Maximum
SYS to B.L.	6.5	11.0	35	70

#### **2.4.9.4 Sanitary Water Collection (SWS)**

Sanitary water from Phase II buildings is collected in SWS lift stations provided in OSBL. Sanitary water from ISBL process buildings is sent to the SWS lift station by gravity or pumping from ISBL lift station depending on the location. Collected sanitary water in SWS lift station is sent to downstream lift station provided in series and finally sent to existing Sanitary Treatment Plant (STP) which is expanded for phase II with additional units. SWS lift station has one duty and one stand-by pump. The lift station pump is operated by on-off control by water level in the lift station sump. Two level transmitters are provided. One is used for pump start / stop control during normal operation and the other is used for pump stop at Low-Low water level in case of failure of main level transmitter. The sump capacity is sized to prevent flooding from the lift station.

##### **2.4.9.4.1 Equipment Design Basis**

- Sanitary Water (SWS) Lift Station Sump (R41-Z-1040)**

Quantity: One (1) for each collection area

Capacity Basis 6 m<sup>3</sup> or 12 m<sup>3</sup>

- Sanitary Water (SWS) Lift Station Pumps (R41-P-1040 A/B)**

Type	Submerged Pump
Volumetric flow rate	6 m <sup>3</sup> /h
Differential head	30 m
Temperature	Operating : 35°C
	Design : 70°C

For capacity of all the lift stations and pumps refer latest revision of Doc No : S-PM-C340-1222-0001

#### **2.4.9.5 Caustic drain system**

Caustic is being used in Catalyst Regeneration section R41-4. All the caustic drains are collected through caustic drain header and routed to Caustic Sump Pit R41-Z-1480. The collected caustic is diluted with utility water. The neutralized caustic is pumped out by Caustic Sump Pit Pump R41-P-1480A and routed to OWS system. The sump is provided with a jet nozzle (connected from caustic sump pit pump discharge) for effective mixing.

Caustic drainage is collected on the open pit to ensure full draining by gravity from the caustic washing drum and caustic pumps in the Naphtha Reformer unit (R41).

- Sources**

Drainage from static equipment, pump, level instruments and control valves assemblies operating under caustic service is collected in the sump pit during maintenance. The major sources of caustic effluents are:

- Washing Drum R41-D-1460
- Caustic Recycle Pump R41-P-1460 A/B
- Caustic Injection Pump R41-P-1460-P1 A/B
- **Destination**

Caustic drainage collected in the sump pit **is** neutralized with the effluent water coming from Washing Drum R41-D-1460 (see explanation below) and sent to the Waste Water Treatment unit.

#### **2.4.9.5.1      Equipment Design Basis**

- **Caustic Sump Pit (R41-Z-1480) and Caustic Sump Pit Pump (R41-P-1480A)**

The Caustic Sump Pit (R41-Z-1480) is sized to hold up liquid at a level of 300 mm from the bottom TL of Washing Drum (R41-D-1461). The capacity of the Caustic Sump Pit Pump (R41-P1480A) is 10.8 m<sup>3</sup>/h such that it is capable of emptying the sump pit within 30 min.

- **Design Condition of Caustic Drain Header and Caustic Sump Pit (R41-Z-1480)**

Design Temperature: 90 °C

Drain Header Size: The drain header is 102mm (4") in diameter.

#### **2.4.9.5.2      Neutralization**

Caustic drainage collected in the Caustic Sump Pit (R41-Z-1480) **is** neutralized to meet the environmental requirement of 6-9 pH before being transferred to the Waste Water Treatment unit. Effluent water from R41-D-1460 that is slightly acidic **is** utilized as required to neutralize the caustic drainage.

There are two sources of the effluent water from the washing water drum, i.e. Spent Caustic Purge and Water Purge with dissolved CO<sub>2</sub>. The pH **is** approximately 6 after mixing these water effluents. The pH of the effluent water is monitored by an online analyzer R41-AE-4601 and kept in the range of 6 and 9 to meet the environmental requirement and the caustic injection rate to the caustic circulation for the Washing Drum will be adjusted as necessary. Excess effluent water from the Washing Drum **is** discharged directly to the oily water sewer, bypassing the caustic sump pit.

#### **2.4.10    Utility Summary**

This section presents the estimated utility consumption for the Naphtha Reforming Unit R41. The overall consumptions of major utilities are provided in the utility summary.

Refer (S-EP-R41-1223-5000) Attachment for detailed Utility Summary.

## **Operating Conditions and Controls**

## **3 OPERATING CONDITIONS AND CONTROLS**

### **3.1 Theory of Process**

#### **3.1.1 Introduction**

The aim of the information given in this chapter is to provide enough theoretical basic background to support the instructions given in the chapters that follow: Startup of the unit, Operation of the unit, Shutdown of the unit. The objective is to help the operators to better understand the reasons of the operating instructions and enable them to make wise decisions, should the circumstances deviate from what is covered in the Operating Instructions.

#### **3.1.2 Thermodynamics and Kinetics**

For any chemical reaction the thermodynamics dictates the possibility of its occurrence and the amount of products and unconverted reactants. Under certain conditions (P, T) some reactions are 100% completed i. e., all the reactants are converted into products. Others are in equilibrium i. e., part of the reactants only are converted. The amount of products and reactants at equilibrium depends upon the operating conditions and is dictated by the thermodynamics. Note that the thermodynamics does not mention the time required to reach the equilibrium or the full completion of a reaction.

Kinetics dictates the rate of a chemical reaction (i.e., the amount of feed that disappears in, say, one second). Kinetics (rate of reaction) is dependant upon operating conditions but can also be widely modified through the use of properly selected catalysts. One reaction (or a family of reactions) is generally enhanced by a specific catalyst.

In other words, thermodynamics dictates the ultimate equilibrium composition assuming the time is infinite. Kinetics enables the prediction of the composition after a finite time. Since time is always limited, when reactions are competing, kinetics is generally predominant.

A catalyst generally consists of a support (earth oxide, alumina, silica, magnesia...) on which (a) finely divided metal(s) is (are) deposited. The metal is always responsible for the catalytic action. Very often, the support has also a catalytic action linked to its chemical nature.

A catalyst is not consumed but can be deactivated either by impurities in the feed or by some of the products of the chemical reactions involved, resulting in coke deposit on the catalyst.

### 3.1.3 Catalyst activity, selectivity, stability

The main characteristics of a catalyst other than its physical and mechanical properties are:

- The **activity** which is the catalyst ability to increase the rate of the reactions involved. It is measured by the temperature at which the catalyst must be operated to produce a product on-specification, for a given feed, all other operating conditions being equal.
  - The **selectivity** expresses the catalyst ability to favor desirable reactions rather than others.
  - The **stability** characterizes the change with time of the catalyst performance (i.e., activity, selectivity) when operating conditions and feed are stable. It is chiefly polymers or coke deposits that affect stability since they decrease the metal contact area. Traces of metals in the feed also adversely affect stability.

### 3.1.4 Chemical Reactions & Catalyst

### **3.1.4.1 Naphtha Hydrotreatment Section (R41-2)**

There are principally two fundamental reactions occurring in the Hydrotreating Reactor (R41-R-121):

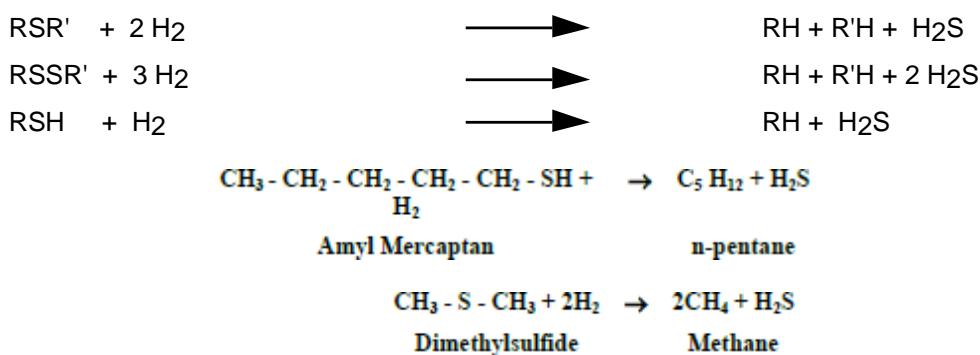
- Hydrorefining,
  - Hydrogenation

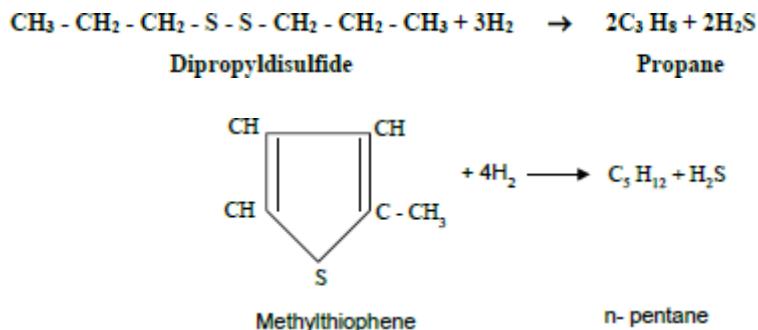
### **3.1.4.1.1 Hydrorefining**

This refers to the replacement of the contaminant molecule with hydrogen. Under hydrorefining there are two primary reactions: Desulphurization and Denitrification

### 3.1.4.1.1.1 Desulphurization

In the naphthas the principal sulfur compounds include mercaptans, aliphatic sulfides, aliphatic disulfides and five- and six-membered ring cyclic sulfides. Thiophenes are found typically in heavier cracked naphthas but are not usually present in straight run naphthas. Under the Hydrotreating Reactor (R41-R-121) conditions, these sulfur compounds react readily to produce the corresponding saturated compound, releasing H<sub>2</sub>S.



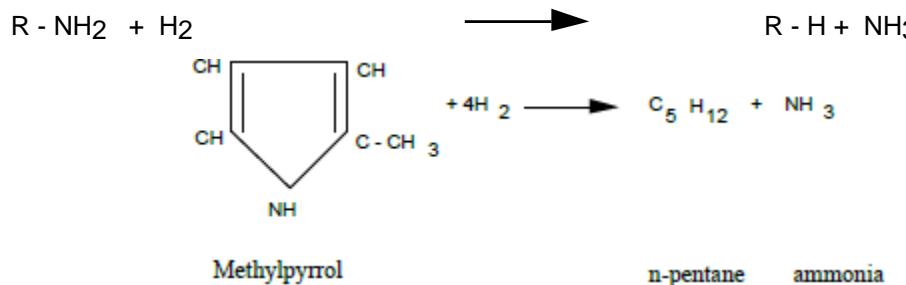


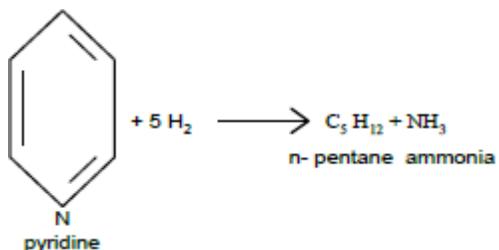
Note that the desulfurization of the ring implies the opening of the ring and its simultaneous hydrogenation. All the desulfurization reactions mentioned are exothermic but, owing to the limited amount of reactant involved, they do not lead to a noticeable temperature increase.

The rate of desulfurization reactions of a single sulfur compound is very fast following firstorder kinetics. However when present in combinations they exhibit apparent reaction orders of up to 1.6.

### **3.1.4.1.1.2 Denitrification**

Nitrogen is removed in catalytic hydrotreating by the breaking of the C-N bond producing a nitrogen free aliphatic and ammonia. The breakage of the C-N bond is much more difficult to achieve than the C-S bond in desulfurization. Consequently denitrification occurs to a much lower extent than desulfurization. Nitrogen is typically not a significant problem in virgin naphtha. If this were the case, a nickel molybdenum catalyst at higher severity hydrotreating conditions would be required. Nitrogen compounds typically found in straight run naphthas are methylpyrrol and pyridine.

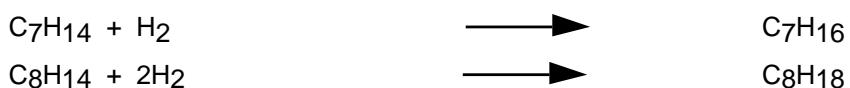




The heat released by the denitrification reactions is also negligible owing to the small amount of nitrogen compound involved.

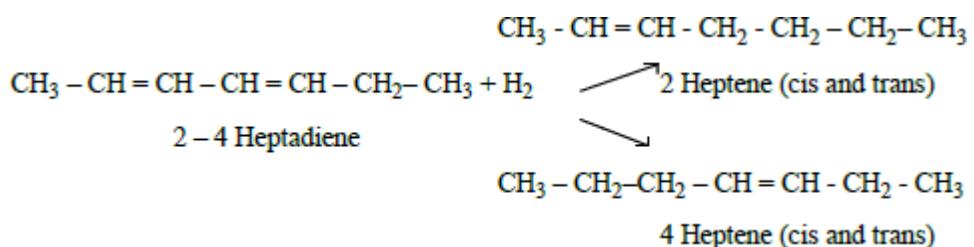
### **3.1.4.1.2 Hydrogenation**

Hydrogenation refers to the saturation of the olefins and diolefins if present in the feed (when processing cracked naphthas). The reaction occurs readily in the top portion of the catalytic bed releasing exothermic heat and consuming hydrogen.



### **3.1.4.1.2.1 Hydrogenation of Diolefins**

Diolefins are hydrogenated into corresponding olefins and some of the olefins are hydrogenated into corresponding paraffins. Diolefins hydrogenation produces several isomers, for example:



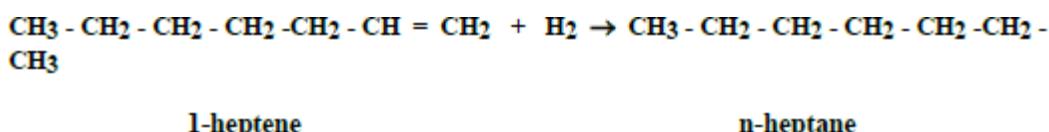
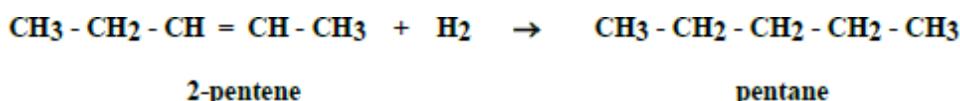
Moreover double bond migration can also occur within the newly generated olefins. Diolefins are very unstable compounds which polymerize easily into gums. Therefore conversion of diolefins into olefins improves the product quality. These reactions are highly exothermic.

### **3.1.4.1.2.2 Hydrogenation of Olefins**

Olefins at temperature involved in reforming process (about 500 °C) result in coke deposit on the reformer catalyst. Hence they must be hydrogenated. Hydrogenation or olefin saturation is the addition of an hydrogen to an unsaturated hydrocarbon to produce a saturated product. Olefinic hydrocarbons are not normally present in

straight-run naphthas but can be found in high concentrations in cracked naphthas. The olefin saturation reaction is highly exothermic and proceeds relatively easily and quickly. Straight chain mono-olefins are easy to hydrogenate while branched cyclic diolefins, such as methylcyclopentadiene, are somewhat more difficult. Aromatic rings are not hydrogenated except under the most severe hydrotreating conditions when minor hydrogenation can occur.

Typical olefins hydrogenation reactions are:



**Olefins hydrogenation reactions** are exothermic. Heat of reaction is around 30 Kcal/mole.

### 3.1.4.1.3 Catalyst Characteristics

There is only one catalyst used in the Naphtha Hydrotreatment section(R41-2): HR-538 ( in Hydrotreating Reactor R41-R-121) for a partial hydrogenation of aromatics and for desulfurization and denitrification.

HR-538 is bimetallic catalyst (nickel and molybdenum) dispersed on high surface alumina support. HR-538 is a NiMo type catalyst presenting very high denitration and aromatic hydrogenation activities, as well as a strong desulfurization activity.

It is manufactured under the oxide state of these metals. In the active form, they are sulfided to form the sulfur-metal complex. Moreover, sulfiding attenuates the superactive catalyst sites which would otherwise promote hydrocracking leading to a shorter cycle life. Sulfiding is carried out by passing hydrogen and a sulfiding agent such as dimethyldisulfide (DMDS) over the catalyst, according to a procedure described later in section 4 (par. 4.2.3.2.5.4 Catalyst Sulfiding (HR-538)).

The main features of these catalysts are:

- High purity alumina support having a strong resistance to attrition.
  - High stability and selectivity towards the desirable hydrotreating reactions.

The association of the above qualities gives the following advantages:

- Efficient hydrotreating,
- Minimal yield loss,
- Long catalyst life.

#### **3.1.4.1.4      Catalyst Mechanism / Activation**

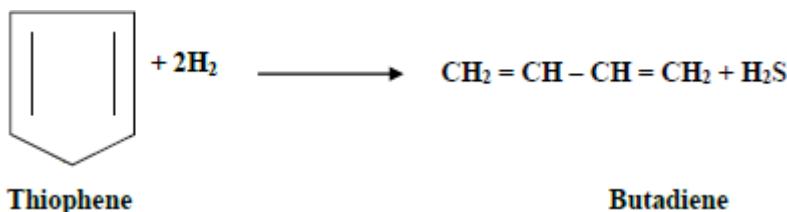
The study of metal-sulfide equilibrium for Ni and Mo shows that, at operating conditions, the stable states are the sulphides which are the catalytic active forms.

- $\text{Ni}_3\text{S}_2$  for Ni
- $\text{MoS}_2$  for Mo

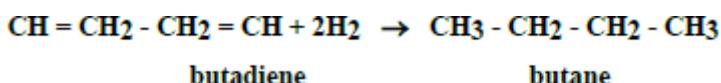
Neglecting to carry out the presulfiding procedure prior to the hot hydrogen circulation of the first start-up phases, would result in a reduction of the metal oxides, leading to sintering and therefore poor sulfiding later. The consequences would be a reduced catalyst activity.

Decreasing the catalyst desulfurization activity must be carried out before feedstock injection. It is essential that each fresh catalyst charge be sulfided before normal operation starts. For the sulfiding procedure, refer to section 4 (par. 4.2.3.2.5.4 Catalyst Sulfiding (HR-538)) on Catalyst Sulfiding of Hydrotreating Reactor (R41-R-121).

Reaction mechanisms in catalytic naphtha hydrotreating are known only for a few reactants and results are not easily generalised. As desulfurization is the predominant reaction taking place, this is the reaction which is discussed in brief in this chapter. Using thiophene as a model reactant, studies have shown that the first reaction of thiophene is the C-S bond cleavage to form 1,3 butadiene, rather than hydrogenation of the C=C bond.



The subsequent reaction is then:



The two reactions of thiophene ring breakage and hydrogenation of butadiene were found to occur on different catalyst sites.

However, in the higher molecular weight thiophenes, found in cycle oils such as benzothiophene, the reverse is true, i.e. as the reactivity of the thiophene ring is decreased by the addition of a benzene ring, the rate of hydrodesulfurization becomes low compared to the rate of hydrogenation of the thiophene ring.

This holds true for denitrification reaction also: for low molecular weight nitrogen compounds, the first reaction breaks the C-N bond to produce the unsaturate before hydrogenation occurs. However for higher molecular weight nitrogen compounds, such as quinoline, saturation of the heterocycle molecule is a necessary step before the C-N bond breakage.

In hydrotreating reactions, the breaking or cleavage of the C-S, C-N or C-O bond or the saturation of a C=C bond are all exothermic. For straight-run naphtha the heat of reaction is mild with a temperature rise across the reactor in the range of 0-5 °C. For cracked naphtha blended with straight run the rise in temperature is somewhat higher, in the range 20-40 °C, because of the heat of reaction associated with the presence of olefins.

The desulfurization reactions are first order reactions in reactant concentration and in hydrogen partial pressure which are virtually irreversible at reactor conditions. However, with over 20-30 kg/cm<sup>2</sup> hydrogen partial pressure, the reaction decreases to an apparent zero order. Hence, there is no incentive to operate at higher hydrogen partial pressure. Studies have also shown that the H<sub>2</sub>S formed inhibits the thiophene reaction and hydrogenation of butadiene by adsorption onto the catalyst surface. But this inhibition is attenuated with higher reaction temperatures. In the range of H<sub>2</sub>S concentration encountered in SR naphtha hydrotreating, H<sub>2</sub>S removal is not required. Inhibition is also the result of coke formation which deposits on the catalyst surface during the course of the operating cycle. This coke blocks the catalyst pores and interstices reducing the overall catalyst surface area available for reaction.

### 3.1.4.1.5 Catalyst Contaminants

Catalyst HR 538

IMPURITIES	METHOD	MAXIMUM CONTENT	CONTAMINANT TYPE	ORIGIN	How to Restore Activity
<b>Gasoline</b>					
Free Water	Visual + Karl Fisher ASTM D6304	15 ppm wt	Mecahnical Damage of Catalyst Carrier	Gasoline	Reactivation
Dissolved Oxygen	Orbisphere (7)	0.1 ppm wt	Temporary Poison	Gasoline Storage	No processing from Storage
Total Sulfur	ASTM D2622 ASTM D5453	4000 ppm wt (1)	Inhibitor	Gasoline	Restore Feed specification
Total Nitrogen	ASTM D-4629	100 ppm wt (1)	Inhibitor	Gasoline	Acid/H <sub>2</sub> O Wash
Organic Chlorides	ASTM D-4929	1 ppm wt	Temporary Poison	Gasoline	Regeneration
Inorganic Chlorides and other mineral salts	ASTM D-4929	50 ppb wt (5)	Permanent Poison	External Pollution	Washing (3)
Existing gums (before heptane wash)	ASTM D-381	5 mg/100 ml	Temporary Poison	Storage	Regeneration
Potential gums (before heptane wash)	ASTM D-873	500 mg/100 ml	Temporary Poison	Gasoline	Regeneration
Diene Value MAV (mg/g)	UOP 326-82 IFP-9407	1 g/100g 4mg/g	Temporary Poison	Feed	Increase severity
Styrenics Indenics	IFP-9420 IFP-9420		Temporary Poison	Steam Cracker Gasoline	
Caustic (NaOH)	Acid/Base Titration	0.1 ppm wt (5)	Permanent Poison	External Pollution	

As	IFP 9312	10 ppb wt	Permanent Poison	Cracker Feed	
P	(6)	10 ppb wt	Permanent Poison	Cracker Feed	
Pb	IFP 9406 (2, 5 ppb)	5 ppb wt	Permanent Poison	Cracker Feed	Regeneration
Si	ICP Detector	50 ppb wt (5)	Permanent Poison	External Polution	
Hg	IFP9606(1 ppb)	(8)			
Amine type antioxidant		25 ppm wt	Inhibitor	Storage	Restore specification
Phenol type antioxidant		50 ppm wt	Inhibitor	Storage	Restore specification
<b>H2 Make-Up/ Recycle</b>		<b>Vol.</b>			
CO + CO2	ASTM D2505	20 ppm	Inhibitor	H2 Source	Restore specification
CO	(4)	10 ppm	Inhibitor		
	ASTM D2504 (9)				
O2	IFP 9809 (GC)	5 ppm	Inhibitor	H2 Source	Restore specification
Amines	IFP 0506	10 ppm	Inhibitor	H2S Scrubber Entrainment	Restore specification
COS	ASTM D5303	10 ppm	Inhibitor	H2 Source	Restore specification
HCl	Draeger Tube	0.5 ppm	Temporary Poison	Reforming	Regeneration

(1) Typical maximum content. This threshold may be increased on a case by case basis depending upon the specific design of the unit.

(2) Uncertain outcome of the treatment.

(3) Provided that contamination is not too severe, this treatment may provide partial activity recovery.

(4) Measured by Infra Red method or for high purity hydrogen (99 % H2 minimum) by Drager tubes (carbon pretube N° CH 24101(to absorb HC) followed by tube N° CH19701 for CO analysis)

(5) Specification below available techniques quantification limit, back calculated on the basis of spent catalyst analysis

(6) No available technique.

(7) Contact Axens or Orbisphere company

(8) Hg is not trapped on Naphtha Hydrotreating Catalyst. Consequently maximum Hg content in Hydrotreater feed is fixed by downstream unit constraints (1.5 wt ppb max for feed to Isomerization and Reformer units).

(9) Method valid for high purity hydrogen (99 % H<sub>2</sub> minimum). Instead Dual Draeger Tube Test shall be used (Carbon Pretube N° CH 24101 (to absorb HC) followed by tube N° CH19701 for CO analysis)

Catalyst contaminants are classified in two categories: temporary poisons and permanent poisons.

#### **3.1.4.1.5.1      Temporary poisons**

When referring to the Naphtha Hydrotreatment section (R41-2), the operator has little concern over temporary poisons as the purpose of the section is to remove these poisons which would prove detrimental to the downstream units. The hydrotreating catalyst is considered rugged and highly stable and therefore can tolerate large swings in contaminant levels without too much of a problem. Hydrotreating catalysts are designed to handle certain levels of contaminants. If these levels increase dramatically, then the operator must react accordingly to protect not the Hydrotreating catalyst but the Reformer and Isomerization catalysts against potential breakthrough of contaminants into the Hydrotreated Naphtha. Naphtha hydrotreating units are typically monitored on a daily basis for sulfur content in both feed and hydrotreated product but on a periodic basis for nitrogen.

However the reformer operation in Aromizing section (R41-3) usually gives the first signal of a sulfur or nitrogen breakthrough. The reformer catalyst responds within minutes of poisoning with sulfur, indicated by a shift in Reactor (R41-R-131/132/133/134) ΔT and product yield loss. Correcting the hydrotreating section (R41-2) for sulfur breakthrough is normally straight forward unless recombination reactions are occurring. Refer the troubleshooting section 4.3.2 for further discussion on handling sulfur breakthrough.

Nitrogen breakthrough will also most likely be detected first in the reformer operation in Aromizing section (R41- 3). The nitrogen forms ammonia and combines with the chloride to form NH<sub>4</sub>Cl which deposits in the compressor and upsets the reformer catalyst chloride balance. Again as with sulfur, nitrogen breakthrough is easily corrected by increasing reactor temperature. Refer the troubleshooting section 4.3.2 for more discussion.

Chloride as organic chloride in the raw-naphtha charge gets a lot of attention from refiners. If chloride based solvents are used in crude oil recovery at the well-heads, the organic chlorides tend to end up in the naphtha fraction **is** hydrotreated, causing ammonium chloride deposits and extensive HCl corrosion. The best control method is elimination of the chloride at source. Other methods which depend very much on the quantity of chloride are the use of filming amine inhibitors and ammonia injection.

Coke deposit is essentially the only temporary poison common to hydrotreating catalysts. Coke deposits affect the catalyst activity by reducing the contact area between the catalyst and the reactants. Polynuclear aromatics are the assumed precursors of coke formation. They result from slight amounts in the feed. Small amounts of diolefins are also potential coke precursors. Coking is a gradual process. Sudden coking of the catalyst can be the result of loss of hydrogen or a large quantity of heavier hydrocarbons in the feed. Regeneration by coke combustion restores most of the catalyst activity. Typically hydrotreating catalysts can accumulate 5-10 % wt of coke before a shutdown is necessary. As activity begins to decline through coke formation the operator can maintain the activity level by increasing the reactor temperature. The maximum temperature increase is limited by the design temperature of the equipment.

To minimise the coke deposits, do not exceed the maximum allowed feed end-point, operate at the lowest possible reactor temperature, ensure the minimum hydrogen partial pressure is always met and do not feed any feedstock which may contain small amounts of unsaturated material.

#### **3.1.4.1.5.2      Permanent poisons**

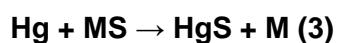
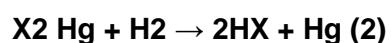
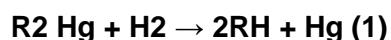
Permanent poison means that, once poisoned, the catalyst activity cannot be restored. The catalyst must be replaced by a fresh one. Nearly all metals are permanent poisons to the hydrotreating catalyst. When guarding against metal contamination in the Reformer and Isomerization feeds, the hydrotreating catalyst acts like a catch-all filter as discussed below.

- Elimination of metals. The contaminant metals are adsorbed onto the catalyst surface up to an equilibrium level which varies from metal to metal. This equilibrium level then gradually moves down through the bed. Typically straight run naphtha contains minimal amount of metals and therefore, at the end of cycle, metals would be found only in the top layer of the catalyst bed (in 10-20 cm). It is generally good practice to remove the top 30 cm of catalyst after each regeneration under Licensor supervision. This should be analysed for metals content before discarding. When higher contents of metals are present, then specific adsorbent beds are utilized to adsorb the predominant contaminants.

#### **3.1.4.1.5.3      Elimination of Mercury**

If the source of one of the naphthas feed section is a condensate contaminated with mercury, there is a significant level of mercury present in the naphtha fraction. Mercury found in condensates is present in various chemical forms, elemental, ionic and organometallic. In the Hydrotreating Reactor (R41-R-121), in the presence of hydrogen, the ionic and organometallic mercury compounds are hydrogenated to produce elemental mercury

(reaction 1 & 2 below). This mercury then reacts with the active metal sulfide of the demercurization adsorbent (when provided), at reduced temperature, yielding mercury sulfide (reaction 3 below).



#### **3.1.4.1.5.4      Elimination of Arsenic and other metals**

Arsenic and other metals, when present, are typically in organometallic form. After hydrogenation in the reactor, the hydrogenated form reacts with the hydrotreater catalyst forming a bimetallic compound. As a result arsenic and other metals are physically adsorbed on the catalyst creating a gradient along the catalyst bed.

During the operating cycle the equilibrium level of the contaminants will progressively move down the bed. It is good operating practice to analyse and replace the top portion of the catalyst bed as necessary to prevent contaminant breakthrough into the Hydrotreated product.

All metals are permanent poisons; activity cannot be recovered by regeneration. Analyses of metal deposits on the catalyst can be performed to assess the degree of contamination. Axens or other specialized laboratories can carry out the analyses. To prevent breakthrough to the reformer, the hydrotreated product must be analysed at regular intervals.

#### **3.1.4.1.5.5      Polymer fouling / Catalyst crusting**

This phenomenon is more attributed to the treating of cracked naphthas, e.g. coker naphtha. Silica, which is an ingredient of antifoaming agents in fractionators can foul the top of a catalyst bed. Also any oxygenates, dissolved oxygen, in the presence of unsaturates can produce gums which deposit in heat exchange equipment as well as on the top of the catalyst bed. These deposits along with scale and fines result in poor flow distribution, high reactor pressure drop and poor hydrotreating.

When this happens, the unit must be shutdown and the crusted/gum material skimmed off the top of the catalyst bed. There are preventive measures to alleviate the fouling, e.g. injection of anti-oxidants, gas blanketing the feed tanks and direct rundown of feeds from the upstream units. During the design it is also ensured that, when processing cracked naphtha, the naphtha is fully vaporized before the fired heater, i.e. the feed passes through its dry point in the feed effluent exchangers. This reduces the fouling tendency of the high tube wall temperature in the fired heater with liquid feed.

### **3.1.4.2 Aromizing Reaction Section (R41-3)**

The chemical reactions involved in reforming processes are of two types:

- Desirable reactions, i.e. reactions which lead to an increased octane number as well as a high purity hydrogen production. These are the reactions to promote.
- Adverse reactions, i.e. reactions which lead to a decreased octane number, a decrease in hydrogen purity or a loss in products yield. These are the reactions to minimize.

The heat of the reactions mentioned hereafter as well as their relative rate are necessary to understand the process. They are listed for the ease of reference in Table below. A catalyst is being used to promote the desirable reactions at the expense of the adverse ones through its action on reaction kinetics.

Remark :

When reaction is promoted by :

- the metallic function of the catalyst (m) is written on the summarized reaction.
- the acidic function of the catalyst (a) is written on the summarized reaction.

**REFORMING REACTIONS**  
**HEAT OF REACTION - RELATIVE RATE OF REACTION**

Reactions	Heat of Reaction (1) kcal/mole	Relative Rate Approx. (2)
Naphthenes Dehydrogenation	-50	30
Paraffin Dehydrocyclization	-60	1 (base)
Isomerization: Paraffin Naphthenes	+2 +4	3
Cracking	+10	0.5

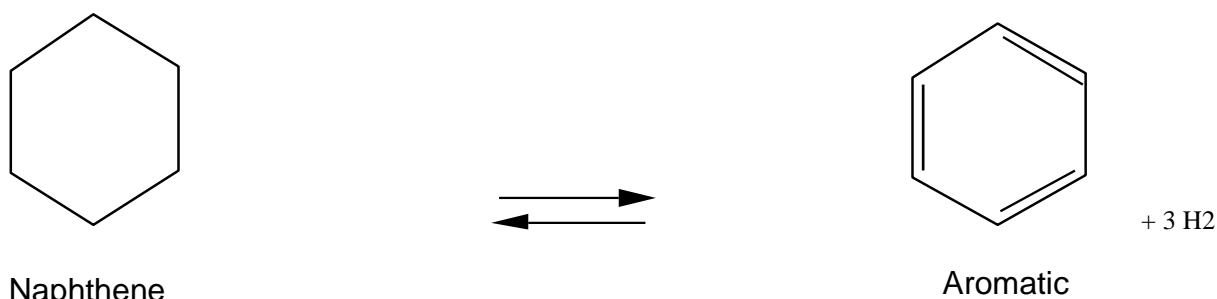
(1) Heat of reaction < 0 = endothermic reaction.

(2) For pressure below 12 kg/cm<sup>2</sup> g (217.6 psi).

### **3.1.4.2.1 Desirable Reactions with Hydrogen Production**

#### **3.1.4.2.1.1 Dehydrogenation of Naphthenes**

Naphthenic compounds i.e. cyclohexane, methylcyclohexane, dimethylcyclohexane up to C10 naphthenes are dehydrogenated respectively into benzene, toluene, xylenes, C9 and C10 aromatics with the production of 3 moles of hydrogen per mole of naphthene.



Thermodynamically the reaction is highly endothermic and is favored by high temperature and low pressure. In addition, the higher the number of carbon atoms, the higher the aromatics production at equilibrium.

From a kinetic view point, the speed of reaction increases with temperature (Refer Figure 2) and is not affected by the hydrogen partial pressure (Refer Figure 1). The rate of reaction is high compared to other reactions as given in table above. It also increases with the number of carbon atoms. At the selected operating conditions the reaction is very fast and almost total. It is promoted by the metallic function (m) of the catalyst. Since it yields a high octane product, promoting this reaction is most desirable. Refer to octane number below:

	RON	MON
Cyclohexane	83	77.2
Methylcyclohexane	74.8	71.1
1,3 dimethylcyclohexane	71.7	71
Benzene	114.8	>100
Toluene	120	103.5
m-Xylene	117.5	115

The table below summarise the effect of the main parameters governing the dehydrogenation reactions.

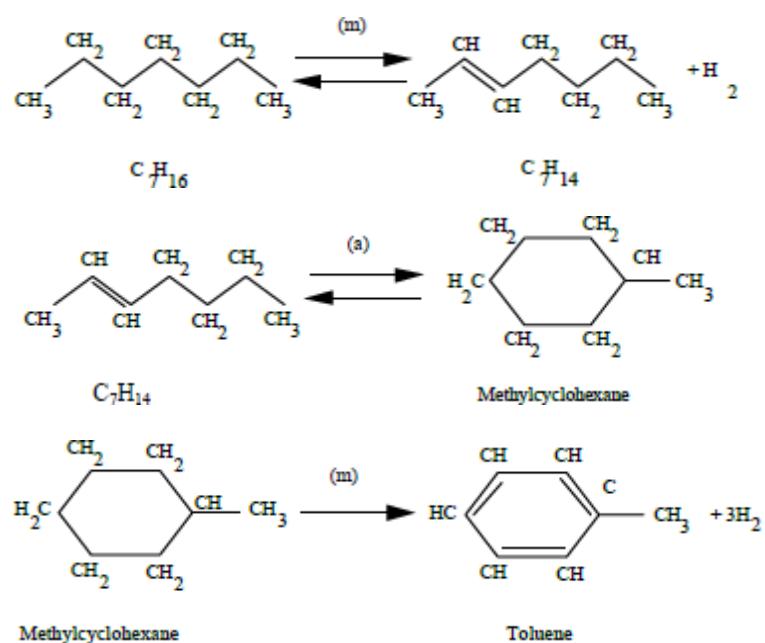
Thermodynamics dictates the equilibrium which could be theoretically reached (i.e. if the time was infinite). Kinetics dictates the rate of reaction, i.e. the possibilities to reach a state close to equilibrium in a finite time.

Increase Of	Effect on Dehydrogenation due	
	to Thermodynamics	to Kinetics
Pressure	Decreases	Non affected
Temperature	Increases	Increases
H <sub>2</sub> / HC ratio	Slightly decreases	Slightly decreases

### 3.1.4.2.1.2 Paraffins Dehydrocyclization

This is a several step process which applies either to the normal paraffins (linear) or ISO-paraffins (branched). It involves a dehydrogenation with a release of one hydrogen mole followed by a molecular rearrangement to form a naphthene and the subsequent dehydrogenation of the naphthene.

The molecular rearrangement to build a naphthene is the most difficult reaction to promote but the subsequent aromatization of the naphthene yields a noticeable octane increase.



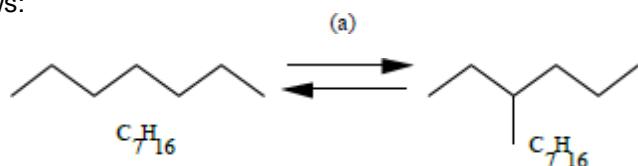
The paraffin dehydrocyclization step becomes easier as the molecular weight of the paraffin increases, however the tendency of paraffins to hydrocrack increases concurrently (Refer Figure 3). Kinetically, the rate of dehydrocyclization increases with low pressure and high temperature (Figure 1 and Figure 2), but altogether, at the selected operating conditions, this rate is much lower than that of naphthalene dehydrogenation (30/1). The reaction is promoted by both catalytic functions, metallic and acidic.

Increase Of	Effect on Dehydrocyclization due	
	to Thermodynamics	to Kinetics
Pressure	Decreases	Decreases
Temperature	Increases	Increases
H <sub>2</sub> / HC ratio	Slightly decreases	Slightly decreases

### 3.1.4.2.2 Desirable Reactions for Octane Number improvement without Hydrogen Production

#### 3.1.4.2.2.1 Isomerization of Linear paraffins

Reaction is as follows:



These reactions are fast, slightly exothermic and do not affect the number of carbons. The thermodynamic equilibrium of isoparaffins to paraffins depends mainly of the temperature (see table below). The pressure has no effect.

#### Iso-N paraffin equilibria

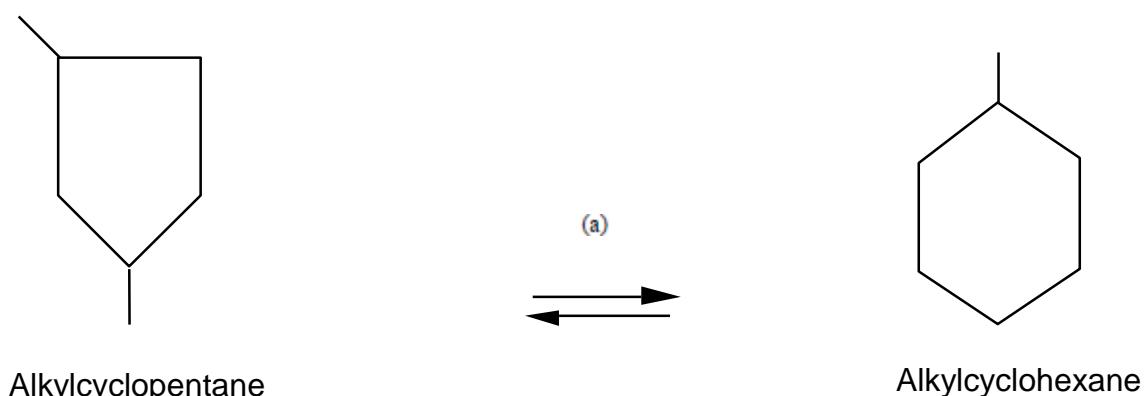
Carbon atom	C4	C5	C6	C7	C8
% Isoparaffin at 500deg. C	44	58	72	80	88

The paraffins isomerization results in a slight increase of the octane number. From a kinetic view point (Figure 1 and Figure 2) high temperature favors isomerization but hydrogen partial pressure is indifferent. These reactions are promoted by the acidic function of the catalyst support.

### 3.1.4.2.2.2 Isomerization of Naphthenes

The isomerization of an alkylcyclopentane into an alkylcyclohexane involves a ring rearrangement and is desirable because of the subsequent dehydrogenation of the alkylcyclohexane into an aromatic. Owing to the difficulty of the ring rearrangement, the risk of ring opening resulting in a paraffin is high.

The reaction is slightly endothermic. The reaction can be summarized as follows:



Theoretically, at the selected operating temperature (about 500°C) the thermodynamics limits the alkylcyclohexane formation. But the subsequent dehydrogenation of the alkylcyclohexane into an aromatic shifts the reaction towards the desired direction. This type of reaction is also easier for higher carbon number. The octane number increase is significant when considering the end product (aromatics) as shown below:

	RON	MON
Ethylcyclopentane	67.2	61.2
Methylcyclohexane	74.8	71.1
Toluene	120	103.5

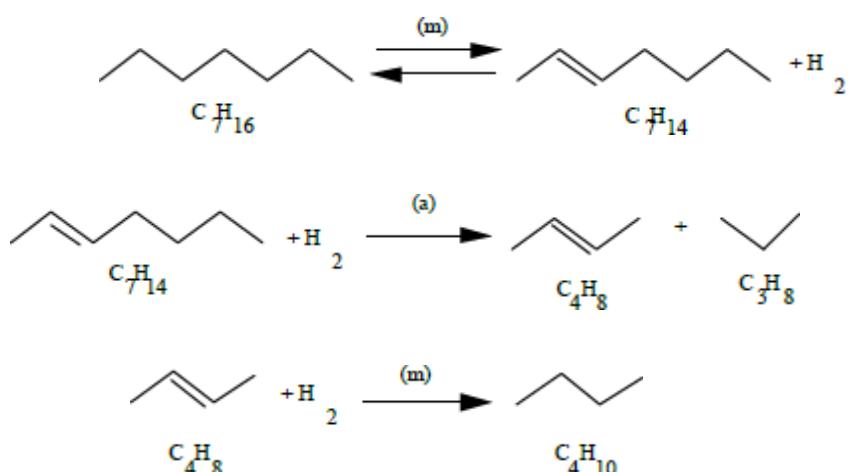
### 3.1.4.2.3 Adverse Reactions

#### 3.1.4.2.3.1 Cracking

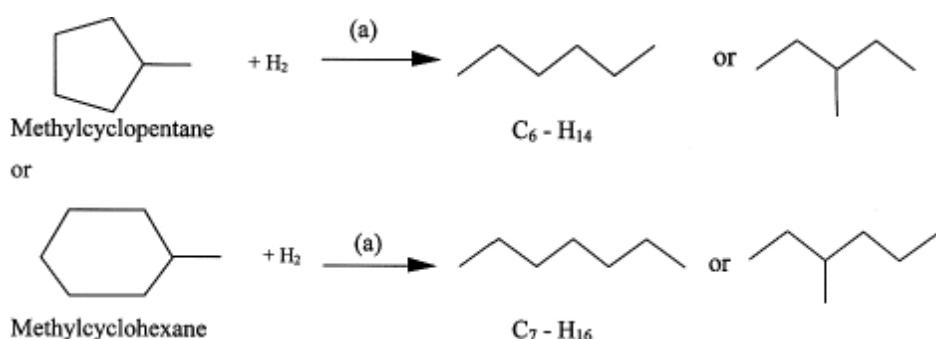
Cracking reactions include hydrocracking and hydrogenolysis reactions.

Hydrocracking affects either paraffins (normal or iso) or naphthenes. It involves both the acid and metallic function of the catalyst. It is, to some extent, a parallel reaction to paraffin dehydrocyclization. It can be schematized by a first step of dehydrogenation which involves the metallic function of the catalyst, followed by a breakage of the resulting olefin and the hydrogenation of the subsequent short chain olefin. The second reaction is promoted by the

acidic function of the catalyst. The first reaction involves the same reactants as the dehydrocyclisation and is likewise catalysed by the metallic function.



Hydrocracking also affects the naphthenes, the overall reaction can be summarized as follows:



At the selected operating conditions, hydrocracking reaction could be almost complete. Fortunately it is somewhat limited by its kinetics. Compared to its desirable concurrent reaction (dehydrocyclization), hydrocracking becomes significant as the temperature increases. It is also favored by high pressure.

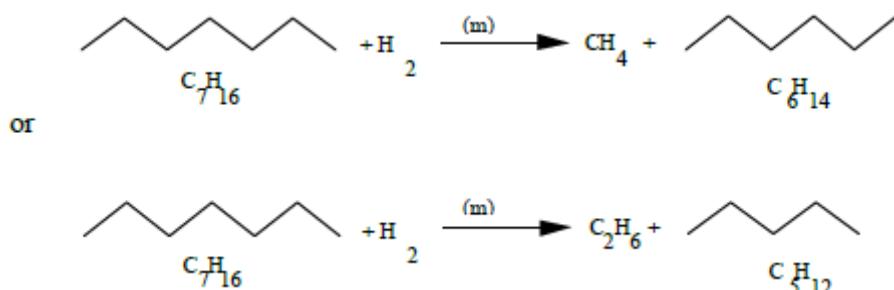
The main effects of hydrocracking are:

- a decrease of paraffins in the reformate which results in an increase of the aromatics percentage (i.e. an increase in octane number) and a loss of reformate yield.
- a decrease in hydrogen production.
- an increase of LPG production.

### 3.1.4.2.3.2 Hydrogenolysis

This undesirable reaction has some similarity with hydrocracking since it involves hydrogen consumption and molecule breakage. But it is promoted by the metallic function of the catalyst and leads to lighter hydrocarbon C1 + C2, which are even less valuable than LPG (C3 + C4).

It can be schematized as follows:



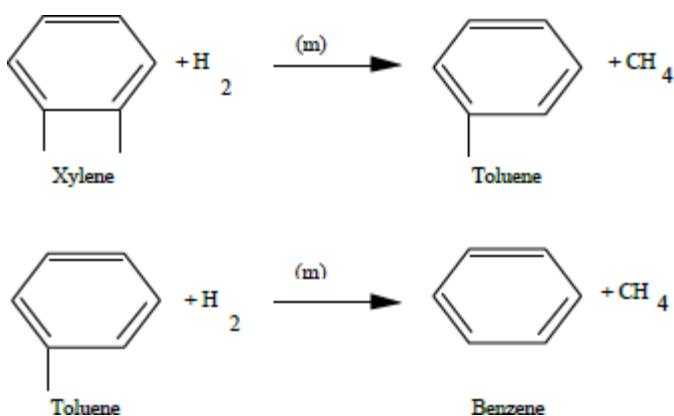
Like hydrocracking it is exothermic and favored by high pressure and high temperature.

Both hydrogenolysis and hydrocracking may induce runaway reactions owing to their exothermicity.

### 3.1.4.2.3.3 Hydrodealkylation

Hydrodealkylation is the breakage of the branched radical ( $-\text{CH}_3$  or  $-\text{C}_2\text{H}_5$ ) of an aromatic ring. Xylene (two radical groups) can be dealkylated into toluene (one radical group) which in turn can be dealkylated to benzene.

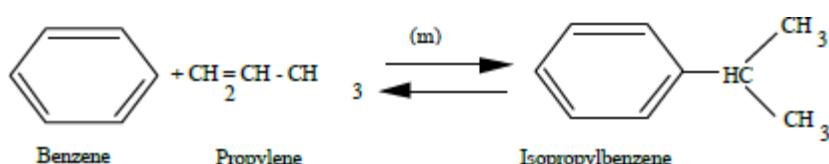
The standard representation is:



Hydrodealkylation consumes hydrogen and produces methane. It is favored by high temperature and high pressure and promoted by the metallic function of the catalyst. At the operating conditions and with the selected catalyst this reaction is not significant.

### **3.1.4.2.3.4      Alkylation**

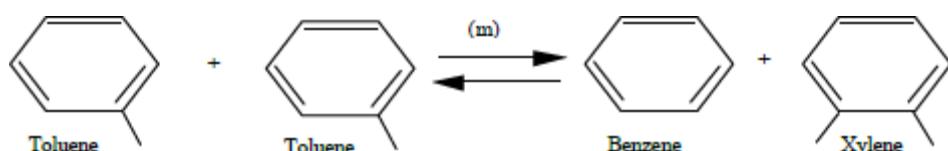
Alkylation is a condensation reaction which adds an olefin molecule on an aromatic ring. It results in an aromatic with an increased molecular weight. The reaction writes as follows:



This reaction, promoted by the catalyst metallic function, is not hydrogen consuming. But it leads to heavier molecules which may increase the end point of the product. In addition the high molecular weight hydrocarbons also have a high tendency to form coke. This reaction must be avoided.

### **3.1.4.2.3.5      Transkylation (Alkyl disproportionation)**

Two toluene rings (one branched CH<sub>3</sub> radical) can dismutate to produce one benzene ring (no branched radical) and one xylene ring (two branched radicals), as shown:



This reaction, promoted by the catalyst metallic function, occurs only in very severe conditions of temperature and pressure. This reaction is negligible with the selected catalyst at the selected operating conditions.

### **3.1.4.2.3.6      Coking**

Coke formation on the catalyst results from a very complex group of chemical reactions, the detailed mechanism of which is not fully known yet. Coke formation is linked to heavy unsaturated products such as polynuclear aromatics (or polycyclics which can be dehydrogenated) resulting either from the feed or from the polymerization of aromatics involved in some of the reforming reactions (dehydrocyclisation, dismutation). Traces of heavy olefins or diolefins may also result from the Aromizing (**reforming**) reactions (dehydrocyclization, alkylation, for instance) and promote coke formation.

A high end boiling point of the feed likely means greater amount of polyaromatics and then a higher coking tendency. Since polymerization is promoted by high temperature, poor distribution in a reactor favors local high temperatures and coke build up. Coke deposit on the catalyst support reduces the active contact area and greatly reduces catalyst activity.

Low pressure unfortunately favors coke formation (see Figure 1). This is why a low pressure reforming like Aromizing (which has a lot of advantages) requires a continuous regenerated catalyst. In Aromizing the continuous catalyst regeneration loop maintains a controlled low coke content on the catalyst while operating at low pressure.

#### **3.1.4.2.4**      Kinetic analysis of the chemical reactions

The effect of the main operating conditions on the rate of the reactions involved in the reforming process using the selected catalyst (Refer to 4.6.2.2) is summarized below.

##### **3.1.4.2.4.1**      Effect of Hydrogen Partial Pressure

Figure 1 shows, with a logarithmic scale, the relative rate of the various reactions as a function of hydrogen partial pressure. The dehydrogenation rate is used as reference and taken at 100 ( $\log 100 = 2$ ). Other reaction rates are measured against this reference.

At 10 kg/cm<sup>2</sup> hydrogen partial pressure, the dehydrogenation of naphthalene is about 10 times, faster than isomerization, 30 times faster than dehydrocyclization and 50-60 times faster than cracking (hydrocracking and hydrogenolysis). At relatively high pressure the rate of coking is low compared to the other reactions but it increases noticeably at lower pressure, which is the case in CCR reformers.

To sum up, Figure 1 shows that there is an incentive to operate at low pressure: cracking rate will be reduced and dehydrocyclization rate increased as well as the coking rate. On another hand thermodynamics also favors low pressure for dehydrogenation and dehydrocyclization. The only drawback of low pressure is the high coking rate but this is compensated by a continuous catalyst regeneration.

##### **3.1.4.2.4.2**      Effect of Temperature

Temperature influences the rate of the various reactions as shown in Figure 2. Energy of activation is linked to the slope of the curves. Dehydrogenation has a moderate energy of activation (~ 20 Kcal.mole<sup>-1</sup>) as does isomerization (~ 25 Kcal. mole<sup>-1</sup>) and consequently temperature only slightly increases the rate of these reactions. Deshydrocyclisation has a higher energy of activation (35 Kcal mole<sup>-1</sup>) consequently temperature increases the rate of this reaction. Cracking and coking have higher energy of activation (45 and 35 Kcal. mole<sup>-1</sup> respectively). The rate of these undesirable reactions is more significantly increased by temperature.

To sum up, a higher temperature clearly favors the undesirable reactions more than the desirable one. However a moderate temperature rise is required during the catalyst life to maintain catalyst activity and therefore product octane.

#### **3.1.4.2.4.3      Effect of carbon number**

The kinetic study of the chemical reactions becomes even more complicated owing to the presence of molecules with different numbers of carbon atoms. As is the case for thermodynamic equilibria, it appears that the rates of the reactions are affected by the length of the chain of the reactant. Figure 3 presents the rates of dehydrocyclization and cracking of C6 to C10 paraffins related to that of n-heptane, as a function of the number of carbon atoms of reactant. Figure 3 shows that the cracking reaction rate, (the curve represents in fact the sum of hydrocracking and hydrogenolysis), increases regularly with the number of carbon atoms, whereas dehydrocyclization rate exhibits a sudden increase between hexane and heptane as well as between heptane and octane, while the variation between the higher homologues remains relatively slight.

To sum up, the dehydrocyclization of C6 paraffins to benzene is more difficult than that of C7 paraffin to toluene, which itself is more difficult than that of C8 paraffin to xylenes. Accordingly the most suitable fraction to feed a reforming process is the C7-C10 fraction.

From the above analysis it can be concluded:

- a) Dehydrogenation reactions are very fast, about one order of magnitude faster than the other reactions.
- b) Low pressure favors all desirable reactions and reduces cracking. To compensate the detrimental effect of low pressure on coking, low pressure reformer requires continuous catalyst regeneration.
- c) An increase in temperature favors the kinetics of dehydrogenation, isomerization, dehydrocyclization, but accelerates the degradation reactions (cracking, coking) even more. Consequently an increase in temperature leads to an increased octane associated with a decrease in reformate yield.
- d) The reaction rates of such important reactions as paraffins dehydrocyclization increase noticeably with the number of carbon atoms. Cyclization is faster for C8 paraffin than for C7, and for C7 than for C6. Consequently the C7 - C10 fraction is the most suitable feed.

#### **3.1.4.2.5      Aromizing section Catalyst Characteristics**

The catalysts are a multimetallic catalyst consisting of platinum plus metal promoters on an alumina support.

The main features:

- High purity alumina support having a strong resistance to attrition.
- High stability and selectivity due to the platinum associated with other metals (promoters).
- High regenerability ideally suited for the continuous regeneration operations.
- High chloride retention.

The association of the above mentioned qualities with the continuous regeneration gives the following advantages:

- High reformate yield.
- High hydrogen yield.
- High stream factor.
- Low life duration.
- Low catalyst inventory.
- Low operating cost.

The detailed Aromizing **section** Catalyst's chemical and physical properties are listed in chapter 4.6.2 Catalyst properties and special procedures.

#### **3.1.4.2.6      Aromizing (Reforming) Catalyst mechanism**

##### **3.1.4.2.6.1    Activity: Metallic and Acidic functions**

The catalyst affects reaction rates through its two different functions: metallic and acidic, which promote different type of reactions. Dehydrogenation and hydrogenation reactions are enhanced by the catalyst metal. Structural rearrangements of the molecules (from linear to cyclic for instance) which involve a reorganization of the carbon bonds are primarily catalyzed by the acidic function of the support.

Because of its high activity in hydrogenation and dehydrocyclization, platinum has been selected for the base catalytic metal. Promoters have been added to improve catalyst selectivity and stability. The support is high purity alumina (acidic function) which is chiefly active for the cyclization of the paraffins to aromatics.

In short, the main reactions involved in reforming processes are catalyzed essentially either by the support or the metal functions, as indicated below:

Dehydrogenation	Metallic function
Dehydrocyclization	Metallic + acidic functions
Isomerization	Acidic function
Hydrogenolysis	Metallic function
Hydrocracking	Metallic + acidic functions

##### **3.1.4.2.6.2    Metallic function**

For a maximum catalyst activity, the metal must be highly dispersed on the alumina support and under the minimum possible particle size (actual figure is in the range of 1.10-6 mm). This high dispersion and micrometric

particle size, which result from the special manufacturing process, must be maintained during the catalyst life by the use of proper operating conditions.

A decrease of the performance of the metallic function can be caused by :

- a poisoning of the metallic phase (see 3.1.4.2.7 for details), or
- an alteration of the metallic phase on the support.

Indeed, a sintering of the metallic phase may occur during the first regeneration step (coke burning), due to local high temperatures and high level of partial pressure of water. The oxychlorination step, which is led right after coke burning, allows a good re-dispersion of this metallic phase.

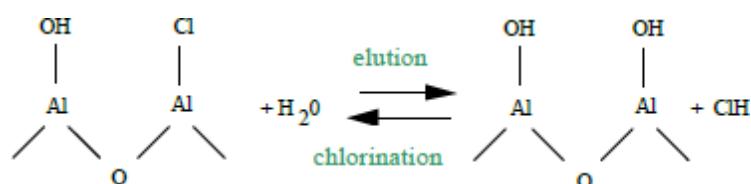
A wet reduction leads also to sintering of the metallic phase.

#### 3.1.4.2.6.3      Acidic function

A certain level of acidity of the catalyst support is required to promote some of the desired reactions (isomerization, dehydrocyclization) which consequently lead to a maximization of the desired performance (reformate production, hydrogen or octane number yields). The optimum level of acidity changes somewhat with these desired performance.

The acidity of the catalyst is dependant on the amount of chlorine which is fixed on the catalyst at the manufacturing stage. In operation, the chlorine content of the catalyst varies with the recycle gas moisture and the elution of chlorine by water, which happens mainly during the coke burning step, due to the formation of combustion water. That's why this level must be adjusted during oxychlorination and maintained in the optimum range of 0.9% to 1.1% wt.

A simplified representation of the catalyst support chemical structure and the processes of chlorination and chlore elution by water is as follows:



The simplified theory, generally accepted today, is that the optimum acidity level (which varies with the requested performance) is a function of ratio of the -OH bonds to the -Cl bonds, which are adsorbed at the catalyst surface. This ratio, in turn, is a function of the water and HCl content in the recycle gas, because of the equilibrium which exists between water and HCl in the recycle and -OH and -Cl bonds on the catalyst.

- **Excess of moisture**

Good acidity of the catalyst is controlled by the balance between H<sub>2</sub>O and HCl. An excess of water in the recycle will shift the balance towards excess of -OH and thus reduce the activity.

- **Lack of moisture**

Conversely, if the amount of water in the recycle is too low (an infrequent case) the catalyst is reputed too dry, and the -OH to -Cl balance is shifted towards -Cl. In other words, the catalyst is over-chlorinated, which means its acidic function is exacerbated (trend to hydrocracking). Of course, over-chlorination of the catalyst may result merely from the accidental presence of chlorine, or uncontrolled addition, in the feed.

There are a couple of other occurrences worth mentioning:

- If a catalyst is excessively dry (i.e. it has been operated with a deficiency of water for sometime) it will exhibit a very high acidic function indicated by an increased hydrocracking activity.
- If a catalyst (especially in case of excessively dry catalyst) undergoes a water upset(amount of water in the recycle over 50 ppm vol.) a situation may occur where the water displaces the chlorine from the first reactors towards the last reactor with a subsequent temporary increase of the acidic function and hydrocracking activity in the last reactor.

To conclude, for an optimum operation of the Aromizing **Section (R41-3)**:

- The water content in the recycle must be maintained between 15 to 25 ppm volume and the associated HCl content should be approximately 1 ppm volume. Note that the determination of the HCl content is not very reliable. (Refer to 3.2.4.4 "Adjustment of Operating Conditions").
- The chlorine content of the regenerated catalyst must be maintained between 0.9 to 1.1% wt. Operators can adjust the chlorine injection rate in the oxychlorination zone of the regenerator, based on catalyst analysis.

#### **3.1.4.2.6.4      Alteration of catalyst activity**

The causes and consequences of catalyst activity loss (due to an unbalance of either the acidic or metallic function) are listed in below Table. Remedial actions are covered in 3.1.4.2.7 (Catalyst contaminants).

	<b>Decrease of acidic function</b>	<b>Increase of acidic function</b>	<b>Decrease of metallic function</b>
Causes	<ul style="list-style-type: none"> <li>• Elution of chlorine due to high water content in the recycle.</li> <li>• Nitrogen compounds (loss of Cl through NH<sub>4</sub>Cl) refer to Catalyst contaminants.</li> </ul>	<ul style="list-style-type: none"> <li>• Over chlorinated catalyst due to:           <ul style="list-style-type: none"> <li>– regeneration chlorination</li> <li>– chlorine in the feed</li> <li>– or too low water in recycle</li> </ul> </li> <li>• High water content in the recycle (upset) on a very dry catalyst (the acidic function increase is temporary).</li> </ul>	<ul style="list-style-type: none"> <li>• Temporary reversible poisoning by sulfur.</li> <li>• Permanent poisoning by metals (Refer to Catalyst contaminants).</li> <li>• Poor regeneration conditions and/or reduction.</li> </ul>
Consequences	<ul style="list-style-type: none"> <li>• Decreased octane.</li> <li>• Decreased LPG production.</li> <li>• Increased Cl production related to C1-C4 cut.</li> <li>• Increased recycle gas purity.</li> <li>• Increased liquid product yield.</li> </ul>	<ul style="list-style-type: none"> <li>• Slight increase in octane.</li> <li>• Decrease in liquid product and H<sub>2</sub> yields.</li> <li>• Increased LPG production.</li> <li>• Decreased C1 production related to C1-C4 cut.</li> <li>• Decreased recycle gas purity.</li> </ul>	<ul style="list-style-type: none"> <li>• Large decrease in octane.</li> <li>• Decreased delta T in first reactor.</li> <li>• Decreased C1 + C2 production.</li> <li>• Increased liquid production.</li> <li>• Large decrease of H<sub>2</sub> production.</li> <li>• Decreased recycle gas purity.</li> </ul>

#### **3.1.4.2.7      Catalyst Contaminants**

Catalyst contaminants are classified in two categories. Temporary poisons (also called sometimes inhibitors) and permanent poisons.

Temporary poisons are those which can be removed from the catalyst without a shutdown and for which the catalyst proper activity and selectivity is restored once the contaminant disappears. The effect of temporary poisons, if the operators maintains the operating conditions prevailing before the poisoning, is a temporary decrease of performance. The most common temporary poisons (inhibitors) of reforming catalysts are sulfur, organic nitrogen, water and oxygenated organics, halogens.

Coke, in a regenerative unit, although it could fall within this category is treated separately.

Permanents poisons are those which induce a loss of activity which cannot be recovered, even with a regeneration and which is so severe that the catalyst must be replaced. For conventional fixed bed catalysts as well as for continuously regenerated catalysts, the main permanent poisons are arsenic, lead, copper, iron, nickel, chromium, mercury, sodium, potassium.

In order to ensure the optimum use of the catalyst, the design includes:

- The removal of poisons from the feed prior to its introduction to the reforming unit;
- The necessary procedures to remove, as far as possible, the temporary poisons from the contaminated catalyst.

Impurities from the feed are removed by hydrotreating units. However their efficiency is never complete, and generally limited depending upon the type of impurities to be removed. In addition, a poor adjustment of the operating conditions of the hydrotreating unit results in a decreased efficiency.

A smooth and successful operation of this reforming unit requires the proper adjustment and control of the operating conditions of the hydrotreating unit.

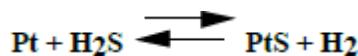
#### **3.1.4.2.7.1      Temporary poisons**

- Sulfur

Sulfur is the most common impurity found in the feed of any reforming unit. The maximum allowable concentration is 0.5 ppm wt expressed as S. Whenever possible, operation at lower sulphur content will provide additional catalyst stability and selectivity.

##### *- Mechanism:*

Poisoning is caused by H<sub>2</sub>S, either contained in the unit feed, or resulting from the decomposition, on the catalyst, of sulfur compounds contained in the feed. H<sub>2</sub>S reacts with platinum according to the equilibrium reaction:



and consequently it reduces the activity of the catalyst while decreasing the metallic contact area. The same type of reaction occurs with H<sub>2</sub>S towards the other catalyst promoters, and further reduces the catalyst activity.

##### *- Effect of sulfur contamination:*

Sulfur contamination inhibits the metal function of the catalyst. This is indicated by:

- A decrease in hydrogen yields.
- A decrease in recycle purity.
- An increase in hydrocracking (LPG yield increase).

- A reduced temperature drop in the reactors especially first one and sometimes an increase of temperature drop across the second reactor.
- An increase coking rate.

*- Prevention and causes of contamination:*

Sulfur removal is achieved by hydrotreating the naphtha feed, which results in H<sub>2</sub>S production. Poor operation of the hydrotreater is generally the cause of sulfur poisoning of the reforming catalyst:

- Either low activity of the hydrotreater catalyst.
- Sudden change of feed characteristics (EBP, total sulfur).
- Or too low hydrotreater hydrogen partial pressure or reactor temperature which leads to an insufficient sulfur removal. Unsatisfactory operation of the hydrotreater stripper can also result in dissolved H<sub>2</sub>S being fed to the reforming unit. In such case water content of the reforming feed also increases.

*- Detection:*

Analytical methods are available to detect sulfur in the unit feed (4.7.3). A very easy way, however, is to check sulfur content in the recycle gas using Draeger tubes. The H<sub>2</sub>S content in the recycle which corresponds to the 0.5 ppm wt in the feed, is approximately 1 ppm (volume). H<sub>2</sub>S detection can also be performed on the depentanizer column off-gas (about 5 ppm volume in depentanizer column off-gas corresponding to 1 ppm volume in the recycle gas).

*- Remedies:*

When the sulfur content in the recycle gas increases, the reactor inlet temperature must be reduced. Typically for an H<sub>2</sub>S level of 5 vol. ppm in the recycle the reactor inlet temperature must be lowered to 480 °C ; the reformer feed must be reduced accordingly to maintain product quality (octane number). These conditions must be maintained until the cause of the upset has been found and corrected.

The high severity operating conditions can only be resumed when the H<sub>2</sub>S content in the recycle gas is lower than 1 ppm vol. In no instance the lost activity due to sulfur poisoning is compensated with temperature.

- Nitrogen

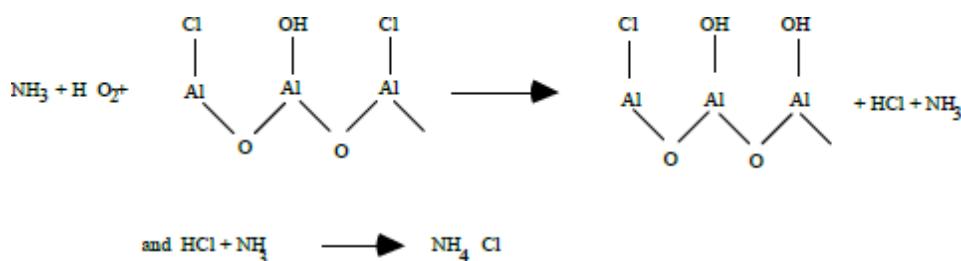
Nitrogen is less frequently present in the reforming feed than sulfur. Scarcely present in straight run naphtha, nitrogen is a usual impurity of cracked naphtha and may also result from injection of amine based corrosion inhibitors. The maximum allowable concentration in the feed is 0.5 wt ppm expressed as organic nitrogen.

*- Mechanism:*

In fact, organic compounds containing nitrogen are responsible for inhibition but nitrogen gas itself (N<sub>2</sub>) has no detrimental effect. Contamination is due to NH<sub>3</sub> formed by decomposition of compounds containing organic

nitrogen, on the catalyst. Then NH<sub>3</sub> which is alkaline, reacts with chlorine decreasing the acidic function of the catalyst and producing ammonium chloride NH<sub>4</sub>Cl. This compound is volatile in the conditions of the reactors and is eliminated inducing a loss of chlorine.

The reaction can be schematized as follows:



#### - Effect of nitrogen contamination:

Nitrogen contamination reduces the acidic function and is indicated by:

- A decrease in octane.
- A slightly increased in hydrogen production.
- A reduced reactor temperature drop.

On top of this, ammonium chloride present in the recycle gas can deposit in coolers, separators compressors etc. creating mechanical problems, as it becomes solid under 80 °C. It is worth remembering that 0.5 ppm wt of organic nitrogen in the feed leads to approximately 2 T/year of NH<sub>4</sub>Cl for a 1 10<sup>6</sup> T/year unit.

#### - Prevention and causes of contamination:

Organic nitrogen removal is also achieved by naphtha hydrotreating of the feed. But it ~~sis~~ be emphasized that nitrogen removal is more difficult than sulfur. Efficient nitrogen removal often requires the use of a specific catalyst, also active for desulfurization, but generally operating at higher hydrogen partial pressure. Naphtha, with high nitrogen content must not be fed to a hydrotreater not designed for it.

Cracked naphthas are generally characterized by high organic nitrogen content, consequently cracked naphthas ~~should~~ never be introduced to a pretreater designed to process straight-run feeds without getting technical advice from the licensor and/or the catalyst manufacturer.

In the pretreating unit, decomposition of nitrogen compounds gives NH<sub>3</sub>. However the amount is generally limited and easy to remove by stripping. The corrosion inhibitor (amine based), usually injected in the pretreatment stripper overhead line **is selected such that** decomposed at the condition of the stripper to avoid contamination of the stripper bottom product (Reforming feed). In fact, the presence of nitrogen compounds in the feed is typically due to a low activity of the pretreatment catalyst towards denitrification.

- *Detection:*

There is no available method for ammonia detection in the recycle gas. Thus laboratory analyses need to be performed on the feed to detect nitrogen compounds.

- *Remedies:*

When nitrogen contamination is detected operators must:

- Not try to make up for the drop in octane number of the reformate by an increase of the reactor inlet temperature. This will only increase the loss of chlorine.
- Take the necessary actions to lower the nitrogen content down to the acceptable figure of 0.5 ppm wt.
  - Water and oxygenated organic compounds:

Oxygenated organic compounds (methanol, MTBE, TAME, phenol etc) are converted into water at reactor conditions. Water is not exactly a poison since some water is necessary to activate the acidic function of the catalyst. However, in usual practice, elimination of water from reforming feed is a major concern of operators, because an excess of water leads to a decrease in catalyst activity.

Water is often present in naphtha feeds, moreover water is frequently injected in reforming feed hydrotreaters to remove formed salts in the cold part of the reaction section. The maximum allowable content is 4 ppm (wt) in the feed which corresponds to approximately 20 ppm volume in the recycle gas for typical conditions ( $P = 2.5$  to  $10$  kg/cm<sup>2</sup> g ;  $T = 40$ deg. C at the separator).

- *Mechanism:*

Water affects the acidic function of the catalyst, as previously explained ("Catalyst mechanism").

- *Prevention and causes of contamination:*

Water removal is usually achieved in the stripper of the feed hydrotreater. Generally contamination by water results from a poor operations of this equipment.

- *Detection:*

Since water contamination is a major concern for the operator, on line analyzer is provided for the recycle gas.

Operating experience shows that the optimum water content in the recycle gas must be within a range of 15 to 25 ppm (vol.). **Then** the associated chlorine level **is** between 1 to 2 ppm vol. Above 50 ppm vol. of water, the reactor

inlet temperature must be lowered to reduce the chlorine elution from the catalyst. The following figures are generally accepted:

- > 50 ppm water      Temperature < 480 °C
- > 100 ppm water      Temperature < 460 °C

Below 10 ppm of water in the recycle gas, the catalyst acidic function is enhanced. Water injection may be used: 1 ppm wt in the feed results in an increment of 2 to 5 ppm vol. in the recycle gas. Anyway this normally never happens for CCR Reformer as the freshly reduced catalyst contents a certain amount of water.

- *Remedies:*

In case of water upset,

- Decrease reactor inlet temperature as indicated above.
- Restore operating conditions upstream of the unit to reduce water contamination.
- Check amount of oxygenated compounds in the feed.

• Halogens (chlorine, fluorine):

The maximum allowable amount in the unit feed is 0.5 ppm wt for each of them.

- *Mechanism:*

The presence of chlorine in the feed modifies the acidic function of the catalyst and promote the hydrocracking reaction. Once chlorine is eliminated, the proper chlorine balance of the catalyst can be restored. The effect of fluorine is similar but it is more difficult to remove from the catalyst.

- *Effect of chlorine, fluorine contamination:*

Hydrocracking reactions are enhanced:

- Lower reformate liquid product yield.
- Higher LPG and C1 yields.
- Slightly higher octane.
- Decrease of hydrogen production.

- *Prevention and causes of contamination:*

Chlorine and fluorine are sometimes present in crude as organic halides owing to the technicals of the production field. They are normally eliminated in the pretreatment stage, but if present in notable quantity (several wt ppm) can lead to a huge corrosion in the cold part of the Hydrotreater reaction section.

### **3.1.4.2.7.2      Permanent poisons**

Permanent poisons have been defined as contaminants which irreversibly damage the catalyst. Table below lists the main permanent poisons as well as their acceptable level in the feed and their most likely source.

Poisons	Max. Level (wt)	Source
Arsenic	5 ppb max	Cracked Naphtha
Lead	5 ppb max	Recycled Slops
Copper, Iron, Nickel, Chromium	<Detection Limit	Corrosion
Mercury	1 ppb mzx	Naphtha-Condensates
Sodium, Calcium, Manganese, Magnesium	<Detection Limit	Crude
Silicon	<Detection Limit	Additives (Foaming)

#### *- Mechanism:*

Most metals poison the metal function (platinum and promoter) of the catalyst. Metal poisons tend to affect the first reactor, then to break through and affect the 2nd reactor. The first reactor is typically the reactor where the poisoning is first detected. As in continuos reformer unit catalyst is circulating from 1st reactor to the successive ones poisoning can affect the whole catalyst hold-up if the cause of pollution is not found.

#### *- Effect of metal contamination:*

Metal contamination is characterized by:

- A dramatic decrease of the  $\Delta T$  in the first reactor associated with an increased  $\Delta T$  in the second reactor.
- A decrease in octane number.
- An increase in liquid product yield.
- Decrease of hydrogen production.

In addition, mechanical problems may result from the collection of corrosion products (scale, rust) in the first layer of the first catalyst bed, or the accumulation of scale, rust in the dead ends, of the first reactor.

#### *- Prevention and causes of contamination:*

The contaminants and the source of contamination are listed in Table above. Prevention consists of adequate hydrotreating and appropriate material selection to limit corrosion. Metal poisons are generally partially retained on the upstream hydrotreating catalysts. However the retention capacity is limited and breakthrough may occur. Such a breakthrough would result in a very harmful situation for the unit since these poisons would not be eliminated by the catalyst regeneration.

It is very important to check periodically the metal content of the hydrotreater feed and product. It enables to monitor the performance of the hydrotreater with regard to demetallization and also to be warned of a possible metal breakthrough of the hydrotreatment catalyst, providing the maximum metal retention of the hydrotreatment catalyst is known. When the metal loading of the hydrotreater catalyst is nearing this figure, the hydrotreatment catalyst needs be replaced.

#### **3.1.4.2.7.3      Coke**

The coke which deposits on the catalyst is a temporary poison since its detrimental effect is reversible through regeneration. Owing to its paramount importance in catalytic reformers, coke formation is treated separately.

##### *- Mechanism:*

Indane derivatives, polynuclear aromatics, naphthenes are the assumed precursors of coke formation. They result either from slight amounts of polynuclear aromatics in the feed (depending upon the nature of the crude and the end point of the feed) or from the aromatics producing reactions of the reforming process itself. Some diolefin intermediates of reforming reactions are also potential coke precursors. Coke deposit affects the catalyst activity by reducing the contact area between catalyst and the reactants.

The normal coke content of the catalyst lies between 4 to 6% by weight. "Normal" means throughput, feedstock quality and severity within the range defined in the design basis, and catalyst circulation within the design operating range.

Catalyst with noticeably higher coke content can be handled provided a few precautions are taken (Refer 3.2.4.4 "Adjustment of operating conditions").

Somewhere below 3% wt of coke, the operation of the regeneration may become unsteady and it is recommended to momentarily shut it down.

##### *- Prevention and causes of contamination:*

Since coke formation is inherently associated with the reforming reactions, there is no real way to avoid it. Coke will be reduced by a decrease of reactor temperature (i.e. if severity is reduced) and an increase in hydrogen circulation. Low total pressure, to the contrary, favors coke formation. Hence the need for a continuous regeneration for reforming units which operate at high severities (high temperature) and low pressure.

Another parameter to watch, to minimize coke is the feed end point, in order to limit heavy polycyclic aromatic hydrocarbons amount. In European countries the maximum allowable feed end point must not exceed 180 °C (ASTM D86), as the marketed gasoline end boiling point is limited at 205 °C.

Note that in case of mixed feeds (use of imported naphtha, SR + cracked naphtha, etc...) the final boiling point of the mixture does not give sufficient information. Each feed **should** be analysed separately as to know the final boiling point of each stream.

#### **3.1.4.2.7.4      CR Series Catalyst Cumulative Poison Limit**

When reaching the limit for one poison catalyst performances start to deteriorate.

S wt ppm	=	~ 300
Pb wt ppm	=	~ 200
As wt ppm	=	~ 200
Zn wt ppm	=	~ 400
Co wt ppm	=	~ 400
Cr wt ppm	=	~ 400
Mo wt ppm	=	~ 400
Cd wt ppm	=	~ 400
Cu wt ppm	=	~ 400
Fe wt ppm	=	~ 5000
Si wt ppm	=	~ 400
Na wt ppm	=	~ 500
Ca wt ppm	=	~ 100
K wt ppm	=	~ 500
Mg wt ppm	=	~ 100

### **3.1.4.2.8      Catalyst distribution in reactors**

Thermodynamics and kinetics have shown that there is an optimum operating temperature range, approximately 450 °C-520 °C in order to simultaneously favor the rate of the desirable reactions and limit the undesirable ones to an acceptable level. For each specific case, the most appropriate operating temperature is selected taking account of the feed quality (PNA, distillation range) and product requirement (octane number).

Owing to the great endothermicity of the most important and desirable reactions (naphthenes dehydrogenation and paraffins dehydrocyclization) this optimum temperature cannot be sustained through out the whole catalyst volume. In addition, dehydrogenation is also, by far, the fastest reaction, which means that the temperature drops very sharply over the first part of the catalyst. In order to restore the catalyst activity, when temperature has dropped to a certain level which depends upon the reactions involved, the reactor feed is reheated. To achieve this, the catalyst is distributed in four reactors and intermediate heaters are provided.

Figure 5 illustrate this question, shows for a given feed (Paraffins: 45% LV, Naphthenes 45% LV, Aromatics 10% LV) the profile of the amount of P.N.A along the catalyst volume. In this case there is no need to have more than 10% of the catalyst in the First Reactor (R41-R-131) because the naphthenes dehydrogenation results in a temperature too low to sustain the reaction any longer.

The reactor effluent is reheated to allow for the naphthenes hydrogenation to continue and the paraffin dehydrocyclization to start. Over the next 15% of catalyst, distributed in the Second Reactor (R41-R-132), temperature drops again to a level where reheating is required to enable the paraffin hydrocyclization to proceed.

The catalyst distribution in this case is:

- R1 = **10%**
- R2 = **15%**
- R3 = **25%**
- R4 = **50%**

Each specific case has, obviously, a specific catalyst distribution.

In a somewhat simplified but practical way, for operational guidance, the main reactions take place in the various reactors in the following order:

- First Reactor (R41-R-131):

- Dehydrogenation
- Isomerization
- Second Reactor (R41-R-132):
  - Dehydrogenation
  - Isomerization
  - Cracking
  - Dehydrocyclization
- Third and Fourth Reactor (R41-R-133/134):
  - Cracking
  - Dehydrocyclization

## 3.2 Operating Parameters

### 3.2.1 R41-1: Naphtha Splitter and LCN Splitter section

The process variables (pressure, temperature, reflux ratio) according to the thermodynamics have an impact on the separation performance of the Naphtha Splitter and LCN Splitter section (R41-1), affecting in this way, the quality of top and bottom products. In the present chapter the process variables are discussed from a practical standpoint as operating parameters, and how the operators can actually use them to adjust the performance of the Naphtha Splitter and LCN Splitter section (R41-1).

#### 3.2.1.1 Pressure

The pressure of the columns (Naphtha Depentanizer R41-T-111, Naphtha Splitter R41-T-112, LCN Splitter R41-T-113) play an important role in the separation performance of the unit. If the columns operate at a higher pressure than normal, the reboiler duties and reflux ratio will increase accordingly to compensate for the reduced relative volatility of the chemical species to be separated. Operators **to** check carefully the pressure indicator at top of columns and reflux drums in order to make sure that the columns are operating correctly.

#### 3.2.1.2 Temperature

The temperature profile of the columns (Naphtha Depentanizer R41-T-111, Naphtha Splitter R41-T-1120, LCN Splitter R41-T-113) is a key variable, whose change affects the quality of top and bottom products. A sensitive tray has been chosen on the columns, and its temperature resets the respective reboiler duty by acting on the steam condensate flow rate from the reboiler, in order to make sure that the required temperature profile is met.

### **3.2.1.3 Reflux ratio**

Reflux ratio on Naphtha Depentanizer (R41-T-111) is automatically adjusted by the liquid level on Naphtha Depentanizer Reflux Drum (R41-D-11150) whereas in both splitters (R41-T-112 and R41-T-113) the reflux ratio is manually adjusted. An increase in the reflux ratio will improve the separation performance of the columns, at the cost of higher energy consumption (reboiler duties) and increased L/V traffics.

### **3.2.1.4 Operating Conditions**

<u>Naphtha Depentanizer (R41-T-111)</u>	<b>Light Case</b>	<b>Heavy Case</b>	<b>Light Case with O2</b>	<b>Heavy Case With O2</b>
Number of trays			30	
Feed temperature °C	114	123	114	123
Top temperature ° C	79	78	80	80
Bottom temperature ° C	155	169	155	169
Feed pressure kg/cm <sup>2</sup> g			4.7	
Top pressure kg/cm <sup>2</sup> g			4.5	
Bottom pressure kg/cm <sup>2</sup> g			4.9	
Reflux drum temperature ° C			60	
Reflux drum pressure kg/cm <sup>2</sup> g			4.1	
Reflux/feed ratio (wt/wt)	0.59	0.58	0.59	0.58

### Naphtha Splitter (R41-T-112)

	<b>Light Case</b>	<b>Heavy Case</b>	<b>Light Case with O2</b>	<b>Heavy Case With O2</b>
Number of trays			51	
Feed temperature °C	131	146	132	146
Top temperature ° C	90	94	90	95
Bottom temperature ° C	154	166	154	166
Feed pressure kg/cm <sup>2</sup> g			2.1	
Top pressure kg/cm <sup>2</sup> g			1.7	
Bottom pressure kg/cm <sup>2</sup> g			2.3	
Reflux drum temperature deg. C			60	
Reflux drum pressure kg/cm <sup>2</sup> g			1.1	
Reflux/feed ratio (wt/wt)	0.66	0.63	0.66	0.63

## LCN Splitter

	Light Case	Heavy Case	Light Case with O <sub>2</sub>	Heavy Case With O <sub>2</sub>
Number of trays	47			
Feed temperature °C	88	88	88	88
Top temperature ° C	81	81	81	81
Bottom temperature ° C	140	140	140	140
Feed pressure kg/cm <sup>2</sup> g	3.0			
Top pressure kg/cm <sup>2</sup> g	2.7			
Bottom pressure kg/cm <sup>2</sup> g	3.3			
Reflux drum temperature °C	60			
Reflux drum pressure kg/cm <sup>2</sup> g	2.1			
Reflux/feed ratio (wt/wt)	0.76	0.76	0.76	0.76

### 3.2.2 R41-2 Naphtha Hydrotreatment Section

There are four primary process variables which have a direct effect on the reactors performance:

- reactor temperature,
- space velocity,
- hydrogen partial pressure,
- feed composition.

The above are independant variable: each of them can be fixed by the operator -within the operating range of the equipment- independently from all the others.

#### 3.2.2.1 Reactor temperature

The inlet temperature to the Hydrotreating Reactor (R41-R-121) bed is the most direct variable the operator has available to control product quality. High temperature will enhance the hydrotreatment reactions but will also increase cracking and coke deposits on the catalyst. Therefore, an optimum temperature is determined to balance the efficiency of hydrotreatment with catalyst life. This optimum temperature varies with feedstock variations, catalyst activity levels and space velocities.

The operator will only adjust the reactor temperature:

- to treat a different quality feed,
- to treat a different feed quantity,
- to counteract against coke deposits and catalyst ageing.

Items 1 and 2 are temperature step changes made prior to the feed change. Item 3 a gradual temperature change over the length of the cycle. This unit is designed for a maximum inlet temperature differential of 30 °C between start of run (SOR) and end of run (EOR).

### **3.2.2.2 Space Velocity**

Space velocity is defined as the ratio of the hourly flowrate of liquid feed to the volume of catalyst, i.e.:

$$\text{Weight Hourly Space Velocity: } (WHSV) = \frac{\text{Weight of feed per hour} (kg/h)}{\text{Volume of catalyst} (m^3)}$$

$$\text{Liquid Hourly Space Velocity: } (LHSV) = \frac{\text{Volume of feed per hour} (m^3/h)}{\text{Volume of catalyst} (m^3)}$$

The inverse of the space velocity is proportional to the residence time of the feed in the reactor.

Space velocity is a measure of the severity of the operations at constant reactor temperature, the higher the space velocity, the lower the severity and vice-versa. The quantity of catalyst being a constant, the space velocity can only be changed by varying the liquid feed rate. Decreasing the feed rate decreases the space velocity. At constant temperature this increases activity and therefore improves the hydrotreating efficiency.

For small changes in the feed rate, no action is required by the operator, for large reductions however it is recommended that the operator operates at a lower temperature to preserve the cycle length.

### **3.2.2.3 Hydrogen partial pressure**

This is defined as the ratio of the moles of hydrogen to the total moles of hydrogen plus hydrocarbons in the gas phase of the reactor multiplied by the reactor absolute pressure. The design partial pressure for hydrotreating at the reactor effluent is as indicated in 3.2.2.5 "Operating conditions" and depends very much on the feed quality and presence of unsaturates.

An increase in this variable enhances the hydrotreatment reactions and decreases the coke deposits on the catalyst and vice-versa. Any meaningful change to the hydrogen partial pressure is accomplished by varying the feed rate, the recycle gas flowrate or the amount of make-up gas.

This is not a variable that the operator purposely changes to improve the efficiency of the hydrotreating process. He must, however, always ensure that the unit does not, at any time, operate below the design partial pressure.

#### **3.2.2.4 Feed composition**

Feed composition is an indirect variable, a variable the operator reacts to, rather than adjusts for performance control. As the feedstock compositions change, from processing different crudes or different quantities of cracked feedstocks, then the hydrotreater operator should make the necessary adjustments to compensate for higher impurities content or higher final boiling point feed. A higher impurities content or higher final boiling point must be matched with a higher severity i. e. a lower flow rate or a higher temperature. This is at the expense of a shorter catalyst cycle.

#### **3.2.2.5 Operating Conditions**

##### Hydrotreating Reactor (R41-R-121)

	CASE 1 SOR	CASE 1 EOR	CASE 2 SOR	CASE 2 EOR
Reactor outlet pressure, kg/cm <sup>2</sup> g			26.1	
Inlet Temperature °C	300	335	300	335
Outlet Temperature °C	306	341	305	340
Partial Pressure of H <sub>2</sub> , kg/cm <sup>2</sup> g	14.12	13.58	14.07	13.52
Space velocity LHSV (1) , h <sup>-1</sup>			6 (HR-538)	
Estimated cycle length (year)			8	

(1) Expressed as m<sup>3</sup> of fresh feed per m<sup>3</sup> of catalyst perhour.

##### NHT Stripper (R41-T-122)

	CASE 1 SOR	CASE 1 EOR	CASE 2 SOR	CASE 2 EOR
Number of trays			45	
Feed temperature °C	180	180	187	187
Top temperature ° C	161	161	161	161
Bottom temperature ° C	218	218	231	231
Feed pressure kg/cm <sup>2</sup> g			10.8	

Top pressure kg/cm <sup>2</sup> g	10.7
Bottom pressure kg/cm <sup>2</sup> g	11.0
Reflux drum temperature °C	40.0
Reflux drum pressure kg/cm <sup>2</sup> g	9.7
Reflux/feed ratio (wt/wt)	0.25

### **3.2.2.6 Adjustment of Operating Conditions**

#### **3.2.2.6.1 Temperature**

As stated, the inlet temperature to the reactor is the most direct variable the operator has available to control product quality. The Hydrotreating Reactor (R41-R-121) inlet temperature adjustment is performed in a conventional manner via a temperature controller (R41-TC-2100) which resets the Reactor Feed Heater (R41-FR-12110) firing by acting on the fuel gas to burners flow control valve (R41-FV-2114). The design value of temperatures at start of run and end of run is given above, in section 3.2.2.5 “Operating conditions”. However, because fresh catalyst is very active, it is sometimes possible to operate at a lower temperature at start-up.

A temperature increase favors all the following reactions: desulfurization, hydrogenation of olefins and coking. The latter also reduces the cycle length of the catalyst. Typically, during operation, when the unit is lined up at design capacity and the NHT Stripper (R41-T-122) bottom product is on-spec. There are only a few instances when the operator needs to adjust the reactor inlet temperature.

##### a) As coke accumulates on the catalyst surface

During the cycle, coke will build-up on the catalyst surface within the pores, reducing the reaction surface and consequently the activity. An adjustment will be required on the Hydrotreating Reactor (R41-R-121) inlet temperature to compensate for this activity loss. The difference between start of run and end of run inlet temperatures could be as much as 35°C. This change is very gradual over typically a 2-3 years period.

##### b) If the feed quality changes

If the feed quality changes, i.e. there is a higher level of contaminants in the feed or a higher sulfur content, then the operator must increase the Hydrotreating Reactor (R41-R-121) inlet temperature by 3 to 5 °C increments until the efficiency of the hydrotreating reactions is restored.

c) For major changes in feed rate

As catalyst activity is higher with lower space velocity, then the Hydrotreating Reactor (R41-R-121) inlet temperature at 60 % capacity should be different from than for 100 % capacity. Typically a temperature decrease of 5-8 °C should be enough. The operator can lower the reactor inlet temperature if there is a lower space velocity and therefore the catalyst cycle length won't be shortened.

**3.2.2.6.2      Hydrogen partial pressure**

The hydrogen partial pressure is achieved:

- By a flow control (R41-FC-2156) reset by pressure control (R41-PC-2145B), of the purge gas from the Separator Drum (R41-D-12140) using the flow control valve R41-FV-2156, which enables operator to vary the hydrogen excess. All other conditions being equal, an increase of the flow controller set point means an increased hydrogen partial pressure. During normal operation this flow control valve (R41-FV-2156) is closed.
- By feeding more or less make-up gas, to match the hydrogen consumption, through the action of the Separator Drum (R41-D-12140) pressure controller (R41-PC-2145A) which resets the flow controller R41-FC-2155 and changes the makeup gas flow rate using flow control valve R41-FV-2155.
- By the recycle flow which is generally maintained at the normal operating value (100% flow) for catalyst preservation. But it can be reduced in proportion to the naphtha feed rate, if the latter is noticeably reduced.

The design hydrogen partial pressure is fixed by the reaction section pressure, the hydrogen recycle rate, the H<sub>2</sub> quality and unit feed rate. An increase of these variables enhances the hydrotreating reactions. Increasing the hydrogen partial pressure decreases coke deposits therefore increasing the catalyst cycle life. The pressure of the unit being fixed, if there is a decrease of the feed rate, the operator can reduce the hydrogen recycle rate to save energy but must always ensure that the hydrogen partial pressure is above its minimal design value.

If the recycle gas quality decreases due to a lack of make-up, this will have an impact on the hydrogen partial pressure. The operator must maintain the hydrogen recycle quality within the design range by adjusting the purge rate and hydrogen make-up injection rate.

**3.2.2.6.3      Space velocity**

Space velocity can be varied by changing the naphtha feed flow (R41-FC-2011 / R41-FC-2013). Space velocity is reduced, when the naphtha feed flow is reduced.

As the quantity of catalyst is fixed, the space velocity will change by varying the feed rate. Decreasing the feed rate decreases the space velocity. At constant temperature this increases the activity as there are now more catalyst active sites per cubic meter of feed. This will improve the hydrotreating efficiency. For small changes in the feed rate, no action is required by the operator. For important reductions however, the operator may lower the Hydrotreating Reactor (R41-R-121) inlet temperature to keep the catalyst cycle life unchanged. It is recommended that if a temperature adjustment is to be considered, it must be carried out by increments no greater than 2 °C until the new temperature level is reached.

If temperature is to be adjusted, an important rule to remember is:

- For feed increases: Increase the temperature first then feed rate.
- For feed decreases: Decrease feed rate first then temperature.

#### **3.2.2.6.4      Feed quality**

The Hydrotreating Reactor (R41-R-121) is designed for a particular feedstock with a maximum design level of sulfur and nitrogen and with other contaminant levels defined in the design basis. If the quality of the feed changes, particularly if there are higher levels of nitrogen and sulphur, then the operator must raise the reactor inlet temperature to maintain the unit performances.

Prior to a crude change, the operator must be aware of potential higher contaminant levels by reviewing the crude assays. For any crude change, the naphtha feed of the unit must be thoroughly analyzed to define all contaminants including metals. If possible this analysis must be done as soon as possible, prior to feeding the Hydrotreating Reactor (R41-R-121). This is to avoid higher rates of saturation of the Hydrotreating Reactor (R41-R-121) catalysts due to metals.

A higher boiling point feed will not significantly affect the Hydrotreating Reactor (R41-R-121) performance ( $\pm$  20 °C). Additional coke deposit may occur as a consequence, shortening the catalyst cycle life. In this case the only severity should be adjusted if the unit is not operating within the safety margin of the product quality.

A more detrimental contaminant in the feed is the presence of unsaturates i.e. olefins, diolefins. Should there be a potential for increase in unsaturates in the feed, Licensor must be contacted prior to developing new operating conditions or necessary design changes. This could result from changes of the olefins (contaminants) content of one of the feed or from an increased quantity of unsaturated naphtha in the feed mix.

### **3.2.3 R41-3 Aromizing Section**

The process variables are:

- Pressure.
- Temperature.
- Space velocity.
- Hydrogen partial pressure or H<sub>2</sub>/HC recycle ratio.
- Quality of the feed.
- Coke content of the spent catalyst at Fourth Reactor (R41-R-134) outlet.

The above are independent variables: each of them can be fixed by the operator - within the operating range of the equipment - independently from the others. For one set of independent variables, for same feed characteristics, there is only one performance of the unit i.e. one set of values for:

- Product yields.
- Product quality (octane).
- Catalyst stability (coke make).

In this section the effect on the unit performance of each independent variable is discussed separately.

#### **3.2.3.1 Pressure**

Hydrogen partial pressure is the basic variable because of its inherent effect on reaction rates. But for the ease of understanding total reactor pressure can be used. Reactor pressure is most accurately defined as the average catalyst pressure. Due to catalyst distribution in the four Reactors (R41-R-131/132/133/134), it is usually close to the Fourth Reactor (R41-R-134) inlet pressure.

All the hydrogen producing reactions i.e. dehydrogenation, dehydrocyclisation are enhanced by low pressure. The lower the pressure the higher the yields of both reformate and hydrogen for a given octane number. This is the reason for minimizing unit pressure drop and operating at the lowest practical pressure. Low pressure however increases the coke make.

Operators action on pressure is limited:

- Operating pressure rise is limited by equipment design pressure.
- Operating pressure lowering is limited by Recycle Compressor (R41-K-13450) design power and intake volume.

### **3.2.3.2 Temperature**

In the Aromizing section the coke amount on the catalyst is maintained at a constant low level through the continuous regeneration. Consequently a temperature adjustment is required only:

- To change the reformate octane.
- To process a different feed quantity.
- To process a different feed quality.
- To balance a temporary loss of activity due to a temporary poisoning.
- To balance catalyst ageing which occurs slowly over several years.

An increase of the reactor inlet temperature results in an increased conversion of the non aromatic compounds of the feed mainly the paraffins. But since the hydrocracking reaction is more favored than the cyclization of paraffins, the end result is:

- An increased octane but a decrease in reformate yield.
- An increase of the coke deposit which is compensated by a catalyst circulation increase to maintain at same level the coke content of the catalyst.

### **3.2.3.3 Space velocity**

The space velocity is the amount of liquid feed, expressed in weight (or in volume) which is processed in one hour, divided by the amount of catalyst contained in reactors, expressed in weight (or in volume). Weight (volume) of feed and catalyst must be expressed with the same unit.

$$\text{Weight Hourly Space Velocity: } WWWW\text{h} = \frac{W\text{h} \text{ (kg/h)}}{W\text{h} \text{ (kg/h)}} = \frac{W\text{h} \text{ (m³/h)}}{W\text{h} \text{ (m³/h)}} = \frac{W\text{h} \text{ (m³/h)}}{W\text{h} \text{ (m³/h)}} = \frac{W\text{h} \text{ (m³/h)}}{W\text{h} \text{ (m³/h)}}$$
$$\text{Liquid Hourly Space Velocity: } LLWW\text{h} = \frac{L\text{h} \text{ (m³/h)}}{L\text{h} \text{ (m³/h)}} = \frac{L\text{h} \text{ (m³/h)}}{L\text{h} \text{ (m³/h)}} = \frac{L\text{h} \text{ (m³/h)}}{L\text{h} \text{ (m³/h)}}$$

The inverse of the liquid hourly space velocity i.e. (LHSV)-1 is linked with the residence time of the feed in the reactor. The space velocity then affects directly the kinetics of the reforming reactions. A decrease in the space velocity means an increased residence time, hence a higher severity which results in increased octane, lower reformate yield, higher coke deposit.

When changing feed rate, an important recommendation derives from the above:

- **Always decrease reactor inlet temperature first and decrease feed flow rate afterwards.**
- **Always increase feed flow rate first and increase temperature afterwards.**

### **3.2.3.4 Hydrogen to Hydrocarbon ratio and Hydrogen Partial Pressure**

The H<sub>2</sub>/HC ratio is the ratio of pure hydrogen in the recycle gas (mole/hour) to the feed flow rate (mole/hour).

$$\frac{H_2}{HC} = \frac{\text{Pure hydrogen (mole/hour) in recycle}}{\text{Naphtha flow rate (mole/hour)}}$$

Hydrogen partial pressure is linked to the H<sub>2</sub>/HC ratio. Since there is, in practice, little flexibility in the total pressure, hydrogen partial pressure is mainly adjusted through recycle flow. Recycle hydrogen is necessary in the reformer operation for purposes of catalyst stability. It has the effect of sweeping the reaction products and condensable materials from the catalyst and supplying the catalyst with readily available hydrogen. An increase in H<sub>2</sub>/HC ratio will move the naphtha through the four Reactors (R41-R-131/132/133/134) at a faster rate and supply a greater heat sink for the endothermic heat of reaction. The end result is an increased stability.

A lower H<sub>2</sub>/HC ratio decreases the hydrogen partial pressure and increases coke formation. Within the typical operating range, the H<sub>2</sub>/HC ratio has little influence on product quality or yields. It is not a variable that the operator typically adjusts, it is set by design based on an economic balance between equipment sizing i.e. recycle compressors, fired heaters and the regeneration unit. Moreover, for a given unit, the amount of recycle is limited by the Recycle Compressor (R41-K-13450) characteristics (power, suction flow).

### **3.2.3.5 Feed Quality**

#### Distillation range

Light fractions have a poor naphthenic and aromatic content and consequently a high C<sub>6</sub> paraffinic content. Cyclization of C<sub>6</sub> paraffins to aromatics is more difficult than cyclization of C<sub>7</sub> or C<sub>8</sub> paraffins, as discussed in "Kinetics analysis" 3.1.4.2.4. Hence, for a required octane number, the lighter the feed the higher the required severity or, conversely, at constant severity, low initial boiling point results in lower aromatic and hydrogen yields.

In recent years, the restriction of benzene content in gasoline has resulted in selecting feed with IBP above 82 °C to eliminate cyclohexane. Heavy fractions have a high naphthenic and aromatic hydrocarbons content, thus they need a lower severity to obtain good yields. But these fractions contain also polycyclic compounds which produce a high coke deposit on the catalyst. High final boiling point of the feed is favorable up to a certain level, detrimental above. An end boiling point above 180 °C is generally not recommended.

#### Chemical composition

The detailed chemical composition of the feed is determined by gas chromatography analysis. This analysis is necessary to predict the aromatics and hydrogen production as well as the severity of the operation.

Even if not sufficient for a complete prediction, an index of characterization of the feedstocks related to the actual and potential aromatics content of the feed, is very useful. The higher this index, the lower the severity of operation to meet the same product specifications. The lower this index (i.e. the higher the paraffins content), the higher the severity of operation to meet the same product specifications as the dehydrocyclization of paraffins becomes important. Note that cracked naphthas have a ratio naphthenes C6 nucleus / naphthenes C5 nucleus much lower than SR naphthas.

### 3.2.3.6 Effect Of Process Variables

Increased	RONC	Reformate yield	H <sub>2</sub> yield	Coke deposit
Pressure	↓	↓	↓	↓
Temperature	↑	↓	↑	↑
Space velocity	↓	↑	↓	↓
H <sub>2</sub> /HC ratio	→	→	→	↓
Naphtha Quality	A + 0.85 N End boiling point Initial boiling point	↑ ↑ ↑	↑ ↑ ↑	↑ → ↑

Note: OFF-SPEC REFORMATE must not be rerun to the reformer as:

- a) It does not generate hydrogen and consequently the recycle gas hydrogen purity decreases (partial pressure of ↓ H<sub>2</sub>, ↓ H<sub>2</sub>/HC ratio).
- b) Aromatics desorption from catalyst takes more time than paraffins and naphtenes desorption, thus less room left for the useful reactions.

Both effects lead to an increased catalyst coking.

### **3.2.3.7 Operating conditions**

#### **Reactors (R41-R-131/132/133/134)**

		Light Case		Heavy Case	
		NOP	MRT	NOP	MRT
Reactor inlet/outlet temperatures, °C					
First Reactor	R41-R-131	524 / 413	550 / 445	520 / 419	550 / 455
Second Reactor	R41-R-132	524 / 441	550 / 471	520 / 448	550 / 482
Third Reactor	R41-R-133	524 / 462	550 / 491	520 / 469	550 / 502
Fourth Reactor	R41-R-134	524 / 482	550 / 510	520 / 487	550 / 518
Space velocity WHSV h <sup>-1</sup> *		1.8		1.8	
Recycle ratio **		1.8		2.5	
Last reactor inlet operating pressure (kg/cm <sup>2</sup> g)		3.5			

\* Ratio of kg/hr of fresh feed to kg of catalyst inside the four reactors.

\*\* Moles/h of pure H<sub>2</sub> in the recycle gas to moles/h of fresh feed.

#### **Depentanizer Column (R41-T-136)**

		Light Case – NOP/MRT	Heavy Case – NOP/MRT
Number of Trays		51	
Feed temperature	°C	172 / 163	171 / 162
Top temperature	°C	90 / 82	88 / 80
Bottom temperature	°C	243 / 244	254 / 255
Top pressure	kg/cm <sup>2</sup> g	14.6	
Bottom pressure	kg/cm <sup>2</sup> g	15.1	
Reflux Drum temperature	°C	46	
Reflux Drum pressure	kg/cm <sup>2</sup> g	14.0	
Reflux / feed ratio	wt/wt	0.361 / 0.349	

Deethanizer Column (R41-T-137)

		Light Case – NOP/MRT	Heavy Case – NOP/MRT
Number of Trays		19	
Feed temperature	°C	69 / 65	67 / 64
Top temperature	°C	63 / 62	63 / 61
Bottom temperature	°C	127 / 122	128 / 122
Top pressure	kg/cm <sup>2</sup> g	30.4	30.4
Bottom pressure	kg/cm <sup>2</sup> g	30.6	30.6
Reflux Drum temperature	°C	46	46
Reflux Drum pressure	kg/cm <sup>2</sup> g	30.0	30.0
Reflux / feed ratio	wt/wt	0.253 / 0.298	0.252 / 0.299

Debutanizer Column (R41-T-138)

		Light Case – NOP/MRT	Heavy Case – NOP/MRT
Number of Trays		37	
Feed temperature	°C	76 / 72	77 / 72
Top temperature	°C	68 / 67	68 / 66
Bottom temperature	°C	124 / 124	123 / 124
Top pressure	kg/cm <sup>2</sup> g	9.2	9.2
Bottom pressure	kg/cm <sup>2</sup> g	9.5	9.5
Reflux Drum temperature	°C	46	46
Reflux Drum pressure	kg/cm <sup>2</sup> g	30.0	30.0
Reflux / feed ratio	wt/wt	0.860 / 0.790	0.881 / 0.801

### **3.2.3.8 Adjustment of Operating Conditions**

#### **3.2.3.8.1 Reaction section and HP absorber section pressure**

Theoretically, the lower the pressure, the higher the reformate yield and hydrogen purity - for a given space velocity - and feed characteristics (Refer to 3.2.3.1 "Process variable, Pressure"). The pressure at the Fourth Reactor (R41-R-134) inlet is generally considered as the most representative for the purpose of this discussion.

However, there is little flexibility since the unit and the Recycle Compressor (R41-K-13450) are designed for a given pressure. Lowering the operating pressure below the intended pressure results in higher pressure drop and is limited by the recycle compressor design power. The low pressure which favors high yields, favors also coke build up. During transient conditions (startup, shutdown, upsets) it is recommended to increase the pressure. Provision for this purpose is included in the design pressure of the equipment.

The philosophy behind the pressure control is to maintain the reactor outlet pressure within a narrow range. To do so the pressure is controlled at the Separator Drum (R41-D-13450), at the Second Interstage Drum (R41-D-13550) and by delivering at the battery limit all the produced hydrogen. In normal operation no hydrogen gas is purged at the Separator Drum (R41-D-13450).

R41-PC-3450 located on top of the Separator Drum (R41-D-13450) and R41-PC-3550 located on top of the Second Interstage Drum (R41-D-13550) normally sees no flow. Its set point is purposely slightly above the operating pressure. It works only as a safeguard, in last resort against any upset in reaction section pressure.

Please refer to control narrative section 3.4.3 for detailed description of the control loops.

#### **3.2.3.8.2 Reactor temperature control**

Temperature, together with space velocity (see hereafter) is the most important and most used operating parameter. By simply raising or lowering the four Reactor (R41-R-131/132/133/134) inlet temperatures, operators can raise or lower the octane number of the product.

Since all reactor inlet temperatures are not necessarily identical, it is commonly accepted to consider the weight average inlet temperature (WAIT) as representative of the reactor temperatures.

The WAIT is defined as follows:

$$\text{WAIT} = \frac{(\text{wt of catalyst R}_1 \times T_{i1}) + (\text{wt Catalyst R}_2) \times T_{i2} \dots + (\text{wt Catalyst R}_4) \times T_{i4}}{\text{Total wt of catalyst}}$$

Ti1, Ti2, ... Ti4 are inlet temperatures to reactors R41-R-131 (R1), R41-R-132 (R2), R41-R-133 (R3), R41-R-134 (R4)

(wt of catalyst R1) are the weight of catalyst in reactors R1, R2

An increase of temperature (i.e. WAIT) has the following effects, assuming the space velocity (i.e. the feed rate) and feed characteristics stay unchanged:

- Increases octane.
- Decreases the yield (of C5+ fraction).
- Decreases the H<sub>2</sub> purity.
- Increases the coke deposit.

At constant WAIT, the ageing of the catalyst (caused by the numerous regenerations, the possible metal deposit, the unavoidable upsets) results in a slight but steady loss of activity (i.e. of octane). A slight increase of temperature (WAIT) through the life of the catalyst makes up for this activity loss.

Larger and temporary changes in temperature are required:

- To change octane - at constant feed quality and quantity.
- To change feed quantity and still maintain octane (see space velocity hereunder).
- To change feed quality and still maintain octane (see feed quality).

The set of curves given in the attachment (Figure 18 to Figure 22) allows an estimate of the increment in the WAIT which would result from increment in the selected parameter:

- Space velocity (WHSV)
- Pressure
- RON Clear
- Feed quality (A + 0.85N and MABP).

Example: one wants to increase RON from 96 to 100. Refer to Figure 20.

RON 96       $\Delta$  WAIT = -4.5

RON 100       $\Delta$  WAIT = 5.5

Result       $\Delta$  WAIT = 5.5 - (-4.5) = 10 °C

WAIT must be raised by 10 °C (18 °F).

WABT, weight average bed temperature is defined as follows:

$$WABT = \frac{\left( \text{catalyst wt } R_1 \times \frac{T_{i1} + T_{i1}'}{2} \right) + \left( \text{catalyst wt } R_2 \times \frac{T_{i2} + T_{i2}'}{2} \right) + \left( \text{catalyst wt } R_3 \times \frac{T_{i3} + T_{i3}'}{2} \right)}{\text{Total weight of catalyst}}$$

$T_{i1}, T_{i2}, T_{i3}, \dots$  are inlet temperatures to reactors  $R_1, R_2, R_3, \dots$

$T_{i1}', T_{i2}', T_{i3}', \dots$  are outlet temperatures for reactors  $R_1, R_2, R_3, \dots$

Catalyst wt  $R_1, R_2, R_3, \dots$  are the weight of catalyst for reactors  $R_1, R_2, R_3, \dots$

### 3.2.3.8.3 Space velocity

Knowing the liquid flow rate (or the space velocity), plus the recycle flow and the reactors operating conditions enables to calculate the actual flow in the reactor, hence the contact time. The lower the space velocity (i.e. the higher the contact time), the higher the severity, assuming all other conditions unchanged.

Lowering the space velocity has, then, the same effects as increasing the temperature i.e., it:

- Increases the octane.
- Decreases the product yields.
- Decreases H<sub>2</sub> purity.
- Increases coke deposit.

If temperature increase is limited (by heater design duty or anything else) lowering space velocity (i.e. decreasing flow rate) can give an additional boost to octane number.

Operators must bear in mind that each time liquid feed rate is changed, a temperature correction must be applied if octane number is to be maintained. When feed is increased, temperature must be raised and conversely, when feed is reduced temperature must be lowered.

When changing feed rate, an important rule is:

- For feed increase: Increase feed first, then adjust temperature increase to meet octane number.
- For feed reduction: Lower temperature first, then adjust feed reduction to meet octane number.

Example of temperature adjustment with space velocity (refer Figure 18).

Parameters	Units	Original conditions	Increased feed
Feed Vol	m3/h	127.19	158.99
Specific gravity	kg/m3	756.9	no change
Feed wt	t/h	96.270	120.340
Catalyst	(t)	53.480	no change
WHSV		1.8	2.25
WAIT reading	(°C)	- 2	+ 2.5
WAIT change	(°C)	Base	+ 4.5

Conclusion: For an increase of WHSV from 1.8 to 2.25 the WAIT must be increased by 4.5 °C.

### 3.2.3.8.4 H2 to Hydrocarbon ratio

The H2/HC ratio is calculated as follows:

$$\frac{H_2}{HC} = \frac{R/M \times Y}{F/m}$$

Where,

R is the recycle flow in kg/h

M is the recycle gas molecular weight

F is the feed rate in Kg/h

m is the feed molecular weight

Y vol. fraction of H2 in the recycle gas

The recycle gas MW is obtained by chromatographic analysis, as well as the H2 vol. fraction (Y). The feed MW is obtained by chromatographic analysis or by correlation from its distillation range and specific gravity.

Operators can change the H2/HC ratio by lowering or increasing the Recycle Compressor (R41-K-13450) flow. The H2/HC ratio has no obvious impact on the product quality (octane) or yield. But a high H2/HC ratio reduces the coke build up.

**It is strictly recommended to operate with a H2/HC ratio equal to (or higher than) the design figure.**

This ratio is adjusted by variation of the Recycle Compressor (R41-K-13450) rotating speed.

### **3.2.3.8.5      Feed quality**

#### **a) Chemical analysis**

The chemical analysis of the feed will give for each carbon number (C6, C7, ... to C10) the breakdown into Paraffins, Naphthenes, Aromatics (or PNA).

As the fastest reaction is the dehydrogenation of naphthenes into aromatics, the value of a specific feed can be characterized by its initial concentration in naphthenes and aromatics. An index ( $A + 0.85N$ ) where N and A are the liquid volume percent of naphthenes and aromatics in the feed, is used by Licensor to characterize the process feed. A feed with a high ( $A + 0.85N$ ) will be easier to process than one with a lower ( $A + 0.85N$ ) i.e.:

- The same octane will be obtained at a lower severity (temperature) and the product yield will be higher.
- Or for the same severity (temperature), the octane will be higher.

Typically, with a feed having a higher reforming index, the naphtenic hydrocarbon content is generally higher, the endothermic reaction heat is increased and the feed flow rate will be limited by the heater design duty. In the opposite case, with a paraffinic feed the hydrogen purity of the recycle gas decreases and operation will be limited by the Recycle Compressor (R41-K-13450) capacity.

Figure 21 gives an estimate of the relationship between PNA and severity. As with the other figures it is used by determining increments related to an existing base case (see example below).

#### **b) Distillation range**

The initial boiling point is controlled at the NHT Stripper (R41-T-122). The feed distillation range is generally as follows:

		°C
IBP	Initial Boiling Point	70-100
EP	End Boiling Point	150-180

This IBP enables to include in the feed components such as methylcyclopentane (BP 72 °C) and cyclohexane (BP 80.7 °C) which are benzene precursors. In some cases, however, the benzene content in the gasoline is strictly limited. In these cases, the IBP must be raised to 82 °C or above.

A feed with a low IBP generally contains more C6 and lighter paraffins and requires a higher severity to obtain the same octane number than a feed with a higher IBP. One must also consider the distillation end boiling point (EP).

High EP means heavier fractions which are richer in aromatics and naphthenes and thus are easier to process. However the high boiling point fractions are potential sources of polynuclear aromatics which are coke precursors. EP higher than 180 °C are generally not recommended.

Figure 22 gives an estimate of the change in severity associated with a change in the distillation range. The distillation range is expressed by the mean average boiling point (MABP).

Example based on Figure 21 and Figure 22.

	<b>Base case</b>	<b>Alternate</b>
(A + 0.85 N) LV%	42	35
MABP (deg. C)	130	122
Δ WAIT Fig. 21	-4.8	+ 0.7
Δ WAIT Fig. 22	- 1.2	+ 0.8
Δ WAIT from Fig. 21 (A + 0.85 N)		5.5
Δ WAIT from Fig. 22 (MABP)		+ 2

Conclusion: WAIT must be increased by 7.5 °C.

### **3.2.3.8.6      H2S content in the recycle gas**

In normal operation, at high severity, the H2S content in the recycle gas **is** lower than 1 ppm vol. as the sulfur content of the feed to the Aromizing section (R41-3) is lower than 0.5 ppm after the Naphtha Hydrotreatment Section (R41-2). Hence a higher content of H2S in the recycle gas in Aromizing section indicates a malfunction of the Hydrotreating Reactor (R41-R-121), either a too low temperature in the Hydrotreating Reactor (R41-R- 121), a sudden increase of total sulfur in the hydrotreater feedstock, or simply a poor operation of the NHT Stripper (R41-T-122). The cause must be found and corrected so as to reduce the total sulfur of the feed coming to the Aromizing section (R41-3) down to the design value.

If the H2S content of the recycle gas tends to increase, do not compensate with a temperature increase. The reason for the sulfur content in the feed must be found and corrected. Anyway if this value reaches 5 ppm vol. the feed flowrate and severity must be decreased to 480 °C until the problem is solved and the H2S content of the recycle gas restored to its normal value.

### **3.2.4 R41-4 Catalyst Regeneration Section**

#### **3.2.4.1 Catalyst Circulation & Regeneration**

Catalyst circulation and catalyst regeneration are two parameters closely linked. The operators will have to master them in order to ensure a complete combustion of the coke deposit without exceeding equipment design conditions.

The following must be kept in mind in order to understand how to control the catalyst regeneration:

- The regeneration is achieved by two steps of coke combustion, followed by an oxychlorination and calcination step where the optimum amount of chlorine is restored (Refer to Figure 17 “Principle of regeneration control loop”).

The aim of the regeneration section is two fold:

- a) To make sure that the coke deposit of the catalyst is fully burnt before entering the oxychlorination zone - otherwise temperature runaway could occur and damage the catalyst.
- b) To make sure than the temperatures of the catalyst during oxychlorination and calcination operations are suitable to perform chlorine adjustment and catalyst drying out.

The first combustion step operates with a limited inlet O<sub>2</sub> content (0.6 to 0.8% vol.) controlled through analyzer controller (R41-AC-4661) on first burning bed inlet resetting analyzer controller (R41-AC-4730) on oxychlorination and calcination gas, which then resets the flow controller R41-FC-4721 on inlet air flow. This limits the temperature increase. The 2<sup>nd</sup> combustion step operates with an excess of O<sub>2</sub> (0.2 % vol. at outlet) to ensure a complete combustion: the analyzer controller R41-AC-4003 controls the oxygen content by resetting the flow controller R41-FC-4720 on inlet air flow.

The regeneration is designed to burn a given amount of coke per hour. Trying to exceed this limit results in excessive regeneration temperature and possible catalyst damage. During the various steps of the regeneration, the catalyst must not be overheated (max. temperature in calcination shall not exceed 520 °C).

The operators must then monitor the catalyst regeneration and set the catalyst circulation with the following guidelines.

- A circulation rate (say between 60 - 90% of design rate) **is** selected - based on the trend in coke deposit (higher circulation when increased coke deposit).
- Burning and oxychlorination/calcination gas flows are set to design values.

- Temperatures at burning beds inlets are adjusted through the electrical heaters (as explained in 2.2.4.4 “Regeneration loop”).
- Air injections are adjusted to get oxygen content of 0.6 - 0.8% vol. at first burning bed inlet and 0.2% vol. at second burning bed outlet.

Then operators must watch the first burning bed outlet temperature. If this temperature is too high, the following options are possible:

- Decrease the TI at inlet temperature (not below 470 °C).
- Decrease catalyst circulation rate.

Note that if high regeneration temperature is due to an increased coke deposit content, decreasing the catalyst circulation is only a short term solution, because coke keeps building up, if the conditions which caused the increased coke are still prevailing. In this case, sooner or later the severity must be lowered.

The catalyst circulation rate is first set by the operators for lift 1 (between the Regenerator R41-R-140 and the First Reactor R41-R-131). Operators selects the set point of R41-PDC-4041 of that lift. The catalyst flow in the following lift i.e. lift 2 (from 1<sup>st</sup> Reactor R41-R-131 to 2nd Reactor R41-R-132) is then adjusted through the relevant PDV (R41-PDV-4141) in order to maintain the catalyst level in the First Upper Hopper (R41-D-1411).

Refer Section 2.2.4.5 for description of catalyst circulation.

Catalyst flow is then adjusted in the same manner in other lift pipes.

- Lift 3 from 2nd Reactor (R41-R-132) to 3rd Reactor(R41-R-133)
- Lift 4 from 3rd Reactor (R41-R-133) to 4th Reactor(R41-R-134)
- Lift 5 from 4th Reactor (R41-R-134) to Regenerator (R41-R-140)

**IMPORTANT:** Catalyst inlet pipes must always be full of catalyst otherwise the sealing system between nitrogen section and reaction section would not work.

The recommended figure for PDC set point of lift 1 is between 0.12 to 0.20 kg/cm<sup>2</sup>.

The PDC set points for the other lift pots are adjusted in order for the catalyst level in the upper hoppers to stay constant. Operator must keep in mind that too high figures for these set points may affect adversely the flow of catalyst into the lift pot, and end up in a complete stop of the catalyst circulation.

### **3.2.4.2 Pressure control and bias (Figure 23)**

Another important parameter to control is the pressure. The Regenerator (R41-R-140) bottom pressure must be maintained above the First Reactor (R41-R-131) pressure to allow catalyst lift from the Regenerator to the First Upper Hopper (R41-D-1411). In order not to upset the catalyst flow each time the reactor pressure varies (changes in feed quality or quantity) this differential pressure must be constant.

This is achieved as follows:

- A regeneration loop pressure controller (R41-PC-4730) is installed at the calcination gas inlet to the Regenerator (R41-R-140), in order to maintain a positive pressure difference between the regenerator bottom and the regenerator lift pot. The set point of this pressure controller is equal to the First Reactor (R41-R-131) inlet pressure plus an adjustable BIAS (about 0.7 kg/cm<sup>2</sup>).

$$\text{PC calcination inlet set point (R41-PC-4730)} = \text{PI (R41-PI-4723)} \text{ on First Reactor (R41-R-131)} + \text{Bias}$$

Once the appropriate value for the bias is selected it does not need to be changed.

### **3.2.4.3 N2 lift gas suction pressure and bias (Figure 24)**

The pressure at the N2 Compressor K.O. Drum (R41-D-1405) is set by the pressure at the Fourth Reactor (R41-R-134) outlet minus an adjustable bias (around 1.05- kg/cm<sup>2</sup> which is adjusted on site) using pressure controller R41-PDC-4056.

The aim of this bias is to enable the 2 PDC's (R41-PDC-412 and R41-PDC-44330) downstream the catalyst fines filters (F-1405 and F-14150) , to maintain their opening of the associated control valves PDV within the middle of the range. The bias value can be adapted to keep the PDV in an acceptable opening percent.

### **3.2.4.4 Adjustment of Operating Conditions**

#### **3.2.4.4.1 Water and chlorine in the recycle gas**

The impact of water and chlorine on catalyst activity has been discussed in 3.1.4.2.7 "Catalyst Contaminants".

Although too large amount of water in the recycle (over 30 ppm vol.) is detrimental to the catalyst; it is also recognized that some water (15 to 25 ppm vol.) is required to activate the acid function of the catalyst.

In an Aromizing section (R41-3), the amount of water produced in the reduction phase normally results in 15-25 ppm vol. in the recycle gas. An on-line moisture analyzer enables to check this figure. Chlorine is injected in the

oxychlorination phase and its flow is adjusted to meet the recommended range of 0.9% wt to 1.1% wt of chlorine on catalyst.

In Aromizing (**Reforming**), under normal conditions, there is no need for water or chlorine injection into the feed. Chlorine injection into the feed may be required in a few instances such as after a water upset in the feed, or if the regeneration unit is shutdown. In this case, chlorine injection is a function of water content in the recycle. The following figures are recommended.

Water content in recycle (ppm vol.)	Chlorine injection (ppm wt in feed)
25 to 35	1
35 to 50	2
50 to 100	2 (lower temperature to 480deg. C)
above 100	5 (lower temperature to 460deg. C)

The two last cases result obviously from operation upsets. Severity must be lowered to protect catalyst against quick deactivation. Such water upsets must be corrected: the operation of the NHT Stripper (R41-T-122) or the source of water contamination in the storage must be investigated.

Water injection in the feed when regeneration is stopped is even more unlikely.

If water content in recycle is lower than 15 ppm vol. water injection must be started to restore 15-25 ppm.

One ppm wt of water in feed yields approximately 4 ppm vol. in the recycle.

Note that some water analyzers drift, with time, towards lower readings. It is wise to check the analyzer prior to start water injection.

#### **3.2.4.4.2      Lift gas flow**

The lift gas flow needs to be adjusted each time the specific gravity of the H<sub>2</sub> lift gas varies due to a change in the operating conditions. This adjustment must be made to maintain a constant speed of catalyst in the lift pipe and to prevent an excessive attrition of the catalyst.

The lift gas flow rate is modified as follows, in order to keep the actual lift gas velocity constant:

$$(Flow)_C = (Flow)_T \times \sqrt{\frac{MW_{d}}{MW_{op}} \times \frac{P_{op} T_d}{P_d T_{op}}}$$

Where:

(Flow)<sub>c</sub> : corrected flow (vol.) for Pop, Top, MW<sub>op</sub>

(Flow)<sub>r</sub> : flow (vol.) reading for P<sub>d</sub>, T<sub>d</sub>, MW<sub>d</sub>

Pop, Top, MW<sub>op</sub> : operating P, T and MW

P<sub>d</sub>, T<sub>d</sub>, MW<sub>d</sub> : design P, T and MW for which the flow meter is calibrated

Temperature : must be expressed in R or K

For each change of feed quality and / or severity which can lead to a change of the H<sub>2</sub> rich gas composition, a lift gas flowrate check **is** made, using the formula above to calculate the actual flow, at conditions, and the calculation example hereunder to calculate the recommended flow.

When the unit operates at steady conditions a check is made once a week.

#### Calculation of the recommended lift gas flow

##### **Calculation basis**

a) Lift pipe : Ø 3" - SCH 160

$$\text{Ø } i = 66.44 \text{ mm} - S = 3.5 \cdot 10^{-3} \text{ m}^2$$

b) Conditions

Lift gas = N<sub>2</sub> or Hydrogen rich gas

Molecular weight (MW) N<sub>2</sub> = 28.0  
Hydrogen rich gas = to be calculated with gas chromatograph analysis

Pressure (P) expressed in bar a = Read at the gages located downstream the gas FV's

Temperature (T) expressed in °C = Average temperature between lift pot and upper hopper

Density at conditions (ρ) expressed in Kg/m<sup>3</sup> = ρ = MW x P x 273 / (22.4 x 1 x (273 + T))

Free fall (FF) expressed in m/s = 
$$FF = \frac{7.67}{\sqrt{\rho}}$$

Catalyst optimal velocity = 2.5 m/s

Gas lift velocity = GLV = FF + 2.5 (m/s)

### Calculation examples

a) N2 Gas

$$\begin{aligned} T(\text{°C}) &= P(\text{bar a}) = 6.8 \\ &= (100 + 250)/2 = 175\text{°C} \\ \rho &= 28 \times 6.8 \times 273 / (22.4 \times 1 (273 + 175)) = 5.18 \text{ Kg/m}^3 \\ FF &= 3.37 \text{ m/s} \end{aligned}$$

Gas lift velocity

$$= 3.37 + 2.5 = 5.87 \text{ m/s}$$

Flow (volume)

$$= 3.5 \times 10^{-3} \times 3600 \times 5.87 = 74.2 \text{ m}^3/\text{h} (\text{P and T})$$

Flow (weight)

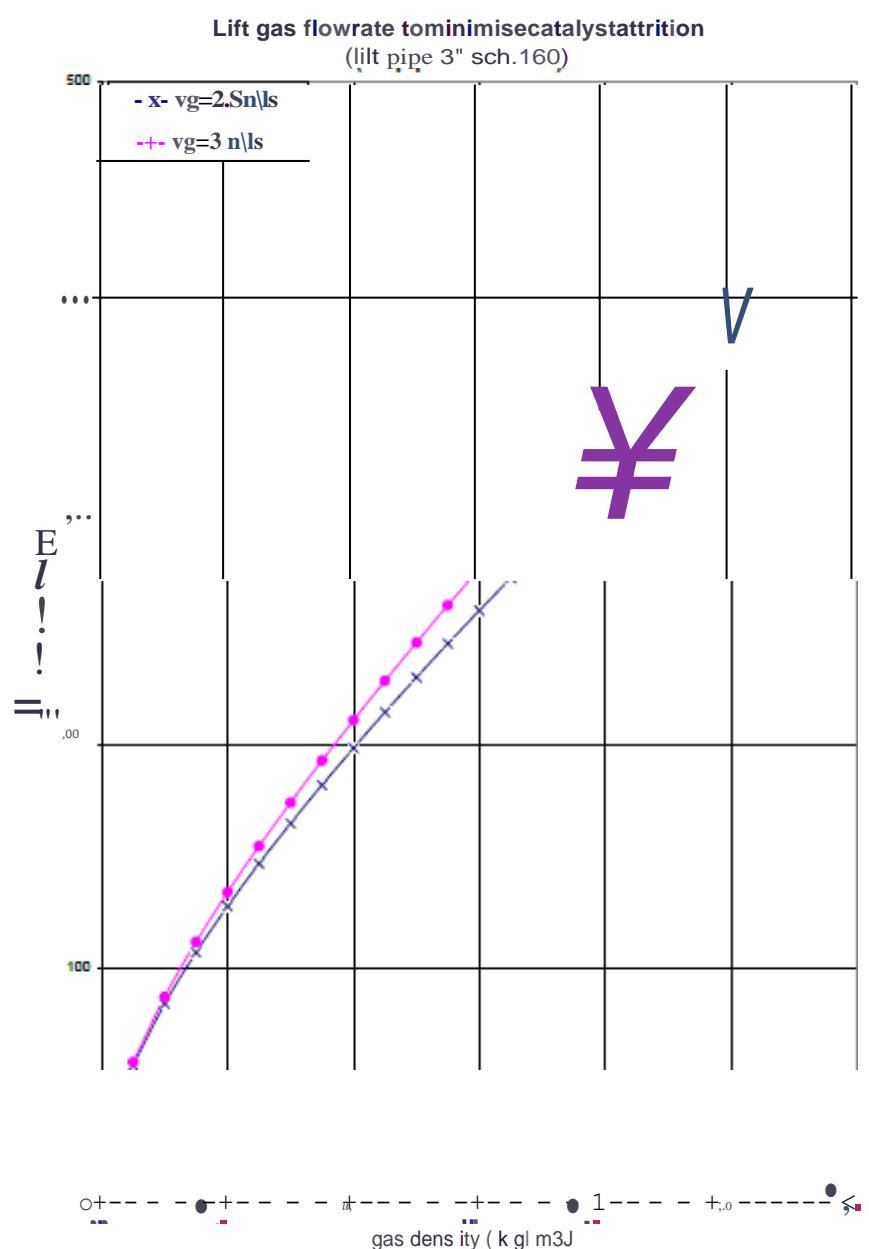
$$= 74.2 \times 5.18 = 384 \text{ Kg/h}$$

b) H2 Gas lift

$$\begin{aligned} T(\text{°C}) &= P(\text{bar a}) = 6.1 \\ &= (200 + 250)/2 = 225 \\ MW &= 3.9 \\ \rho &= (3.9 \times 6.1 \times 273) / (22.4 \times 1 (273 + 225)) = 0.58 \text{ Kg/m}^3 \\ FF &= 10.07 \text{ m/s} \\ \text{Gas lift velocity} &= 10.07 + 2.5 = 12.57 \text{ m/s} \\ \text{Flow (volume)} &= 3.5 \times 10^{-3} \times 3600 \times 12.57 = 158.8 \text{ m}^3/\text{h} (\text{P and T}) \\ \text{Flow (weight)} &= 158.8 \times 0.58 = 92.1 \text{ Kg/h} \end{aligned}$$

For a given catalyst flow a decrease of the lift pipe  $\Delta P$  is the consequence of an increase of the actual lift gas flow, if all other conditions are unchanged.

The graph below gives the recommended lift gas flow to maintain a catalyst velocity between 2.5 and 3 m/s, at various gas density. This graph is valid for 3" schedule 160 pipes.



### **3.2.4.4.3      Regeneration loop**

The operating conditions of the regeneration loop are linked to the amount of coke deposited on the catalyst and to the quantity of circulated catalyst. In order to know the trends of carbon and chlorine contents, Licensor recommends to analyze on a daily basis the carbon and chlorine on the spent and on the regenerated catalyst and to plot on a chart the results versus time.

When the operating conditions are steady the coke level of the spent catalyst **is** preferably maintained between 4 to 6% wt, depending upon the unit capacity, the required severity and the feed quality. This is obtained through adjustment of the catalyst circulation rate. However, when operating at high severity, high flow rate and relatively poor feedstock (paraffinic feeds), the percent of coke deposit may momentarily exceed the above value. In this case, operators must remember that the burning capacity of the unit is limited and that the catalyst circulation must match the burning capacity.

Then catalyst circulation must not exceed the design capacity of the circulation. Moreover regeneration temperature must be carefully watched. It is obvious that, if the severity is such that the actual amount of coke build-up is, on average, higher than the design coke burning capacity, the severity must be lowered - or the feed rate reduced.

An increase of coke deposited on the spent catalyst or an increase of catalyst circulation can lead to a prohibitive temperature increase ( $\Delta T^\circ$ ) in the burning zone. In such a case, as the  $\Delta T^\circ$  is related to the O<sub>2</sub> in the burning zone, an increase of regeneration gas flow and the decrease of the inlet O<sub>2</sub> analyzer (R41-AC-4730/4003) set point will decrease the  $\Delta T^\circ$  and leave the burning quality unchanged.

Also care **to** be taken in keeping an O<sub>2</sub> > 0.2 vol. % at the 2nd burning zone outlet, to be sure that full coke combustion takes place in the second burning zone. Otherwise residual combustion will occur in the oxychlorination zone inducing undesired  $\Delta T^\circ$  and a possible shutdown by TAHH trips.

The O<sub>2</sub> analyzers on the various streams must be set as follows:

- First burning bed inlet O<sub>2</sub>% vol. 0.6 to 0.8%
- Second burning bed inlet O<sub>2</sub>% vol. 0.6 to 0.8%
- Second burning bed outlet O<sub>2</sub>% vol. 0.2 to 0.3%
- Gas to calcination and oxychlorination O<sub>2</sub>% vol. 8.0 to 12.0%

The quantity of air sent to the calcination zone should be higher (or equal) than the quantity sent to the second burning zone. If necessary, the analyzer controller R41-AC-4730 on the first burning bed inlet **is** set higher to increase the air flow to the calcination (therefore to the 1st burning bed).

#### Temperature

Temperatures must be adjusted as follows :

- The 1st bed inlet temperature is monitored at 480 °C through the burning heater.
- The 2nd bed inlet temperature is adjusted at 480 °C with the quench gas recovered at the Regeneration Loop Compressor (R41-K-1465).

However, the first burning zone outlet must be controlled between 535 °C to 545 °C by action on inlet temperature and on inlet O2 analyzer (R41-AC-4730). Use following rule of thumb: 0.1% O2 leads to 10° C temperature rise.

The temperature at the second burning zone outlet must not exceed 510 °C and simultaneously the O2 content must be kept above 0.2%. If the temperature exceeds 520 °C one must:

- either decrease slightly O2 analyzers (R41-AC-4003) set point, it will result in a lower ΔT across first and second bed.
- or decrease catalyst circulation to get the same temperature decrease.

#### Oxychlorination zone inlet temperature

This temperature is monitored by the R41-TI-4691 at the outlet of the Oxychlorination Heater (R41-E-1469) and adjusted around 510 °C through R41-TC-4006 using the heater control.

#### Calcination zone inlet temperature

This temperature is monitored by the R41-TI-4731 at the outlet of the Calcination Heater (R41-E-1473) and adjusted between 500 °C and 520 °C through R41-TC-4007 using heater control. If the requested temperature cannot be reached, check the R41-PDV-40090 on oxychlorination outlet line, tubes side outlet of Calcination Feed Effluent Exchanger (R41-E-1468)..

Note: If the differential pressure between the 2nd burning bed and the calcination zone is set too low, some gas may flow back through the catalyst pipes to the burning zone and the Oxychlorination, Calcination Feed/ Effluent Exchanger efficiency will be reduced.

### Catalyst level in the regenerator

The level of the upper section of the regenerator, before the transfer from the Lock Hopper (R41-D-1402) to the Regenerator (R41-R-140), must be monitored carefully. When it drops below 30% a catalyst make-up is necessary.

### Pressure

The pressure at the Regenerator (R41-R-140) bottom (i.e. calcination gas inlet) is controlled through two PDV's (R41-PDV-4731 A/B) located on top of the Washing Drum (R41-D-1460). This pressure set point is equal to the First Reactor (R41-R-131) top pressure plus a selected increment (or bias). The recommended value for the bias is 0.7 kg/cm<sup>2</sup>.

### Chlorination agent injection to Regenerator Oxychlorination zone

This amount **is** set by stroke adjustment of the injection pump and checked by the calibrated gage of the tank in the Chlorination Agent Package (R41-Z-1469).

### Water injection to Regenerator Oxychlorination zone

This amount **is** set by stroke adjustment of the injection pump and checked by the calibrated gage of the tank in the Oxychlorination Water Package (R41-Z-1468).

### Sodium hydroxide injection and caustic solution circulation

Keep the caustic recycle pump flow close to the design figure - whatever the unit throughput. Add fresh sodium hydroxide to maintain 7.5 < pH < 8.5 in the solution.

The total salt content in the circulating solution must not exceed 3% wt (expressed in total sodium). This figure is adjusted through the quantity of water injected and drained.

### Water washing

Keep the water injection flow close to design figure - whatever the unit throughput.

### **3.3 PCS System Overview**

The PCS consists of the following Systems and sub-systems. YKSA is the PCS vendor to design, supply, integrate and test the following PCS systems as a complete system.

#### **PCS List**

<b>System</b>	<b>Manufacturer</b>	<b>Model / Description</b>
Distributed Control System (DCS)	Yokogawa	CENTUM VP
Safety Instrumented System (SIS)	Yokogawa	ProSafe-RS
Fire and Gas System (FGAS)	Yokogawa	ProSafe-RS
High Integrity Protection System (HIPS)	Yokogawa	ProSafe-RS
Plant Asset Management System (PAM) Smart Safety Valve Monitoring System (SZVMS) for PST	Yokogawa	PRM
Alarm Management System (ALMS)	Yokogawa	AAM
Network and Security System (NSS)	Supply/ Implementation by Yokogawa	Microsoft Windows Server Update Services (WSUS) Network Management system (NMS) Backup Recovery System (BRS) Antivirus Servers (AVS) Active Directory (ADS)
Vibration Monitoring System (VMS)	Bently Nevada	3500 Series
Fin Fan Vibration System (FFVMS)	Bently Nevada	Trendmaster Pro
Condition Monitoring System (CMS)	Bently Nevada	System-1
Compressor Control System (CCS)	Woodward	MicroNet Plus
Third-Party System (Interface with DCS)	----	---- (supplied by EPC/others)
DAHS Interface (through DCS ExaOPC servers)	Yokogawa	
PR1 and PR2 Interface (through DCS ExaOPC servers and SIOS, Redundant)	Yokogawa	

### **3.3.1 Distributed Control System (DCS)**

The DCS provides process control and monitoring for the entire Plant. The DCS design and configuration is modular and integrated. It performs basic regulatory control, logic functions, sequence and batch control, process monitoring, alarm management, trending and reporting. The DCS is the operator interface to all PCS systems. (the DCS system hardware and software design are detailed in the following sections)

### **3.3.2 Safety Instrumented System (SIS)**

The phase-II Complex is equipped with SIS based on IEC/TÜV certified Safety PLC's to meet the SIL classification requirements. The SIS is a fail-safe, stand alone system that does not rely on any other systems to fulfill its function. It provides shutdown and protection for all plant safety related operation, which extends to process, equipment, personnel and environment.

### **3.3.3 Fire and Gas System (FGAS)**

The FGAS is a protective system implemented based on dedicated, stand-alone fault-tolerant system. Each FGAS is based on a dedicated and standalone Safety Controller in full dual-redundant configuration. It receives input signals from Fire, Combustible Gas, Toxic Gas, Smoke detectors, etc. and actives output devices like Horns, Beacons, Deluge Valves, etc.

### **3.3.4 High Integrity Pressure Protection System (HIPS)**

The HIPS is a protective system implemented based on dedicated, stand-alone fault-tolerant and independently certified system. The HIPS is used to provide overpressure protection and flare load mitigation for process equipment. The HIPS functionally replace or augment mechanical overpressure relief devices or systems to reduce flare or relief system loads.

### **3.3.5 Plant Asset Management (PAM)**

The management and maintenance activities for the FF-H1 Fieldbus devices and HART devices are achieved through the PAM. The PAM manages the FF and HART AI/AO signal directly hardwired to DCS, SIS FGAS, HIPS I/O module and hardwired to HART multiplexer to CCS.

SZVMS system is a part of PAM system. The SZVMS is for online partial stroking test (PST) of ESD/HIPS valves controlled by SIS/HIPS system respectively. The SIS/HIPS system controls the shutdown action of the ESD/HIPS valve and provides a HART interface to SZMVS system.

Yokogawa's Plant Resource Manager (PRM) system is used as PAM and the details of PRM system hardware and software design, refer to the following documents::

V-EP-PRII-CORE-0131: Plant Asset Management (PAM) Specification.

### **3.3.6 Alarm Management System (ALMS)**

The ALMS uses plant alarm and event data collected from a number of sub-systems comprising the Process Control System (PCS). The ALMS provides the alarm and event analysis, reporting and management facilities for the benefit of operators and users both on and off-site who require concurrent access to process alarm related information.

Note: VMS Alarms **are** routed through the DCS Modbus communication.

For details of ALMS system hardware and software design, refer to the following documents:

V-EP-PRIICORE- 0129: Alarm Management System (ALMS) Specification.

### **3.3.7 Network Security System (NSS)**

AV (Anti-Virus Server), WSUS (Windows Security Update System), NMS (Network Monitoring System) and BRS (Backup Recovery System) **are** provided as NSS (Network and Security System). This system **is** installed as common to PCS which are shared with whole plants.

For details of NSS system hardware and software design, refer to the following documents:

V-EP-PRII-CORE-0130: Network Interface & System Security Guidelines

### **3.3.8 Vibration Monitoring System (VMS/FFVMS/CMS)**

The Vibration Monitoring System (VMS) interfaces to monitor and protect rotating equipment. The VMS consists of VMS (for Level 1 and 2 rotating machinery monitoring), FFVMS (for the fin fan monitoring only (Level 2)), and CMS (for Level 1 rotating machinery high-level performance monitoring).

For certain critical machines, data acquired from VMS or FFVMS are stored and analyzed in CMS for machine condition, performance diagnosis and management.

The details of VMS/FFVMS/CMS system hardware and software design, refer to the following documents:.

V-EP-PRII-CORE-0502: System Design Document (VMS/FFVMS)

### **3.3.9 Compressor Control System (CCS)**

The Compressor Control System (CCS) **is** interface to continuously monitor and control/protect compressors. The CCS **interfaces** with the DCS, via a redundant data link, to transmit alarm/status and other operational data between CCS and DCS.

The CCS function consists of data acquisition, diagnostic and analysis software, to provide current and historical information regarding the state of compressors and associated equipment.

For details of CCS system hardware and software design, refer to the following documents:

V-EP-PRII-CORE-0602: System Design Document (CCS)

### **3.3.10 Third-Party System**

Systems not included in YKSA scope and that required to be integrated with DCS supplied by YKSA are called third-party Systems. The followings are the list of third-party systems .

- Data Acquisition and Historization System (DAHS)
- Closed Circuit Television (CCTV)
- Fire Alarm Panel (FAP)
- Tank Data Acquisition System (TDAS)
- Flow Metering System
- Gas Chromatographs, Analyzers
- HVAC system status
- Status of electrical equipment from the substation
- Power Monitoring
- Motor Protection
- Laboratory Information Management System (LIMS)

## **3.4 Control Narrative**

Refer latest revision of document V-EP-RP02-PKGE-0116 for the DCS Graphic Printout. Following control narratives to be read in conjunction with the DCS Graphic Printout.

### **3.4.1 R41-1: Naphtha Splitter and LCN Splitter section control narrative**

**For detailed control narrative of R41-1 Refer latest revision of S-EP-R41-1223-2000**

#### **3.4.1.1 Naphtha Depentanizer Reflux Drum (R41-D-11150) Pressure Control:**

When the pressure in the vessel meets the set point, the regulator PC-1151 output (OP) valves PV-1151A & PV-1151B will be at 50% and both valves will be closing at 100 %.

When the pressure is below the set point, the regulator OP valve PV-1151A will be in the range of 0 to 50% and the control valve PV-1151A starts to open while the control valve PV-1151B will remain closed.

When the pressure is above the set point, the regulator OP valve PV-1151B will be in the range 50 to 100% and the control valve PV-1151B starts to open while the control valve PV-1151A will remain closed.

#### **3.4.1.2 Naphtha Depentanizer (R41-T-111) Level Control:**

The level controller R41-LC-1100 is cascaded on the R41-FC-1101. The master controller is R41-LC-1100 and the slave controller is R41-FC-1101. R41-FC-1101 varies the flow by modulating R41- FV-1101.

The increase of Naphtha Depentanizer R41-T-111 level results in opening of R41-FV-1101 and reciprocally in case of decrease of the level.

#### **3.4.1.3 Naphtha Splitter (R41-T-112) Pressure Control:**

The column operating pressure is set by pressure controller PC-1250.

#### **3.4.1.4 Naphtha Splitter (R41-T-112) Level Control:**

##### **Start-up/Upset Mode:**

Selector R41-FHS-1200 is in “Start-up mode”

In this mode, the level controller LC-1200 is cascaded on the FC-1200B. The master controller is R41-LC-1200 and the slave controller is FC-1200B. The R41-FC-1200B varies the flow of Heavy Naphtha to SR Naphtha Tank Rundown Air cooler R41-E-1363 during upset conditions and start-up by modulating R41- FV-1200B. This is a NNF loop.

**Normal Mode:**

Selector R41-FHS-1200 is in “Normal mode”

In this mode, the level controller LC-1200 is cascaded on the FC-1200A. The master controller is R41-LC-1200 and the slave controller is FC-1200A. The R41-FC-1200A varies the flow of Heavy Naphtha from Naphtha Depentanizer Feed / Naphtha Splitter bottom Exchanger R41-E-1111A/B to Naphtha Hydrotreatment Section (R41-2) by modulating R41- FV-1200A.

The increase in the Naphtha Splitter R41-T-112 level results in opening of R41-FV-1200A/B in both normal and start-up mode. The valves R41-FV-1200A/B are AFC.

**3.4.1.5 LCN Splitter (R41-T-113) Pressure Control:**

The column operating pressure is set by pressure controller PC-135

**3.4.1.6 LCN Splitter (R41-T-113) Level Control**

The level controller R41-LC-130 is cascaded on the R41-FC-131. The master controller is R41-LC-130 and the slave controller is R41-FC-131. R41-FC-131 varies the flow by modulating R41- FV-131.

The increase of LCN Splitter R41-T-113 level results in opening of R41-FV-131 and reciprocally in case of decrease of the level.

**3.4.1.7 Naphtha Depentanizer Reflux Drum (R41-D-11150) Level Control****Increased C4 content mode:**

Selector R41-FHS-1155 is in “Increased C4 content mode”

In this mode, the level controller R41-LC-1150 is cascaded on R41-FC-1154. The master controller is R41-LC-1150 and the slave controller is R41-FC-1154. The R41-FC-1154 varies the flow of Naphtha to C5 Rich cut Storage Drum R41-TK-2760 by modulating R41-FV-1154.

**Standard Mode:**

Selector R41-FHS-1155 is in “Standard mode”

In this mode, the level controller R41-LC-1150 is cascaded on R41-FC-1150. The master controller is R41-LC-1150 and the slave controller is R41-FC-1150. The R41-FC-1150 varies the flow of Naphtha to Naphtha Depentanizer Column R41-T-111 by modulating R41-FV-1150.

The increase of level in Naphtha Depentanizer Reflux Drum R41-D-11150 results in opening the R41-FV-1150 in standard mode and R41-FV-1154 in increased C4 content mode. The valves R41-FV-1150 and R41-FV-1154 are AFO.

#### **3.4.1.8 Naphtha Splitter Reflux Drum (R41-D-11250) Level Control**

The level controller R41-LC-1250 is cascaded on the R41-FC-1251. The master controller is R41-LC-1250 and the slave controller is R41-FC-1251. R41-FC-1251 varies the flow by modulating R41-FV-1251.

The increase of naphtha splitter reflux drum level results in opening of R41-FV-1251 and reciprocally in case of decrease of the level.

#### **3.4.1.9 LCN Splitter Reflux Drum (R41-D-1135) Level Control**

The level controller R41-LC-135 is cascaded on the R41-FC-1351. The master controller is R41-LC-135 and the slave controller is R41-FC-1351. R41-FC-1351 varies the flow by modulating R41-FV-1351.

The increase of LCN splitter reflux drum level results in opening of R41-FV-1351 and reciprocally in case of decrease of the level.

#### **3.4.1.10 C5 Rich Cut Control**

The temperature controller R41-TC-1103 is cascaded on the R41-FC-1140. The master controller is R41-TC-1103 and the slave controller is R41-FC-1140. R41-FC-1140 varies the flow of C5 rich cut by modulating R41-FV-1140.

The increase of temperature at R41-TT-1103 (corresponding to an increase of heavy compounds at tray 27 of the column) results in closing R41-FV-1140 and reciprocally in case of decrease of the temperature.

#### **3.4.1.11 Naphtha Depentanizer Reboiler (R41-E-111) Duty Control**

Objective of this loop is to control the temperature of the Naphtha Depentanizer R41-T-111 sensitive tray by cascade control on Naphtha Depentanizer Reboiler R41-E-111 duty.

The master controller is R41-TC-1102, the slave controller is the R41-FC-1105 set in cascade mode.

The PV value to R41-FC-1105 is the MP Steam flowrate to the Naphtha Depentanizer Reboiler R41-E-111 on the inlet line from R41-FT-1105.

The OP from R41-FC-1105 actuates R41-FV-1105 on the outlet line of the MP condensate from the reboiler.

The increasing of Naphtha Depentanizer R41-T-111 sensitive tray temperature results in the closing of R41-FV-1105.

#### **3.4.1.12 Naphtha Splitter Reboiler (R41-E-112A/B) Duty Control**

Objective of this loop is to control the temperature of the Naphtha Splitter R41-T-112 sensitive tray by cascade control on Naphtha Splitter Reboiler R41-E-112A/B duty.

The master controller is R41-TC-1205, the slave controller is the R41-FC-1205 set in cascade mode.

The PV value to R41-FC-1205 is the MP Steam flowrate to the Naphtha Splitter Reboiler R41-E-112A/B on the common inlet line from R41-FT-1205.

The OP from R41-FC-1205 actuates R41-FV-1205 on the common outlet line of the MP condensate from the reboiler.

The increasing of Naphtha Splitter R41-T-112 sensitive tray temperature results in the closing of R41-FV-1205.

#### **3.4.1.13 LCN Splitter Reboiler (R41-E-113) Duty Control**

Objective of this loop is to control the temperature of the LCN Splitter R41-T-113 sensitive tray by cascade control on LCN Splitter Reboiler R41-E-113 duty.

The master controller is R41-TC-1302, the slave controller is the R41-FC-1305 set in cascade mode.

The PV value to R41-FC-1305 is the MP Steam flowrate to the LCN Splitter Reboiler R41-E-113 on the inlet line from R41-FT-1305.

The OP from R41-FC-1305 actuates R41-FV-1305 on the outlet line of the MP condensate from the reboiler.

The increasing of LCN Splitter R41-T-113 sensitive tray temperature results in the closing of R41-FV-1305.

### **3.4.2 R41-2 Naphtha Hydrotreatment Section Control Narrative**

**For detailed control narrative of R41-2 Refer latest revision of S-EP-R41-1223-2005**

#### **3.4.2.1 Feed Surge Drum R41-D-12010 Pressure Control**

When the pressure in the vessel meets the set point, the PC-2010 output (OP) to the valves PV-2010A & PV-2010B will be at 50% and both valves are closed (0% valves opening).

When the pressure is below the set point, the controller OP will be in the range of 0-50% and the control valve PV-2010A starts to open while the control valve PV-2010B will remain closed.

When the pressure is above the set point, the controller OP will be in the range 50-100% and the control valve PV-2010B starts to open while the control valve PV-2010A will remain closed.

#### **3.4.2.2 Reaction Loop Pressure Control**

The aim of this control loop is to control the reaction section pressure by adjusting the injection rate of H<sub>2</sub> make-up gas in the reaction section by means of the following valves :

R41-FV-2155: H<sub>2</sub> make up.

R41-FV-2156: Purge to HP Flare.

R41-PC-2145 A/B is the pressure controller of reaction section.

If R41-PT-2145 signal decreases compared to R41-PC-2145 A/B SP, signal from R41-PC-2145 A/B decreases. If R41-PT-2145 signal increases compared to R41-PC-2145 A/B SP, signal from R41-PC-2145 A/B increases. There are three different operating modes:

- Start-up mode**

This control is used during start-up.

- Selector R41-PHS-2157 is in "Start-up mode":

- Control valve R41-FV-2155 is closed.

- R41-PC-2145 B is cascade on R41-FC-2156 that controls Off-Gas control valve R41-FV-2156 to HP flare header.

If the pressure in the reaction section increases, valve R41-FV-2156 to HP flare header will open more.

- **Normal mode**

- Selector R41-PHS-2157 is in "Normal operation mode":
- Control valve R41-FV-2156 is closed.
- R41-PC-2145A is cascade on R41-FC-2155 that controls H2 make-up control valve R41-FV-2155 to the reaction section.

If the pressure in the reaction section increases, valve R41-FV-2155 on the H2 make-up line closes.

- **Override mode (override on normal operation mode)**

- Selector R41-PHS-2157 is in "Normal operation".

In case of separator drum's high pressure alarm R41-PAH-2145 is reached, the override mode is activated.

- R41-FC-2155 passes in manual mode and the output of controller close H2 Make up control valve R41-FV-2155.
- R41-FC-2156 passes in automatic control and receives set point signal from R41-PC-2145 B which open R41-FV-2156 and send off-gas to the HP flare header.

#### **3.4.2.3 Low Signal Selector R41-FY-21540**

The low signal selector R41-FY-21540 is foreseen at Recycle Gas Compressors R41-K-1215A/B discharge. The role of this low signal selector is to balance the total flow rate through the 2 trains of Feed/Effluent Exchangers R41-E-12110 A to F and R41-E-12110 G to M.

Selector receives and compares continuously and simultaneously signals from 2 flowrate controllers. The lowest signal is detected and selector resets set point of this flowrate controller to open more the control valve and balance the flowrates through the 2 trains of Feed/Effluent exchangers.

Controllers	Selector	Valve
R41-FC-2150	R41-FY-21540	R41-FV-2150
R41-FC-2152	R41-FY-21540	R41-FV-2152

#### **3.4.2.4 Feed Surge Drum R41-D-12010 Level Control**

The objective of this loop is to control the level of Feed Surge Drum R41-D-12010 by cascade control on R41-FC-2011 and R41-FC-2013 in parallel range : half of the flowrate pass through valve R41-FV-2011 and half of the flowrate pass through valve R41-FV-2013.

The process value corresponds to the level of Feed Surge Drum R41-D-12010. The Master controller is R41-LC-2010 and the slave controllers are R41-FC-2011 and R41-FC-2013. The cascade set point is sent to the controllers R41-FC-2011 and R41-FC-2013 to control the flow Feed Naphtha by modulating R41-FV-2011, R41-FV-2013 in parallel.

The increase of Feed Surge Drum R41-D-12010 level (R41-LT-2010 / R41-LC-2010) results in opening of the valves R41-FV-2011 and R41-FV-2013 and reciprocally in case of decrease of level.

#### **3.4.2.5 Separator Drum R41-D-12140 Level Control**

The objective of this loop is to control the hydrocarbon level of Separator Drum R41-D-12140 by cascade control. The master controller is R41-LC-2140, the slave controller is the R41-FC-2140 set in cascade mode. The Set Point from R41-LC-2140 is sent to R41-FC-2140 to control the hydrocarbon flow by modulating R41-FV-2140.

The increase of Separator Drum R41-D-12140 hydrocarbons level results in opening of the valve R41-FV-2140.

#### **3.4.2.6 Reactor Feed Heater R41-FR-12110 Duty Control**

The objective of this control loop is Reactor Feed Heater R41-FR-12110 duty control.

The OP of R41-TC-2100 at outlet of Reactor Feed Heater (R41-FR-12110) process side is sets in cascade the controller R41-FC-2113 which varies the flow rate of fuel gas by modulating R41-FV-2114. In such way, the furnace duty is modified to reach R41-TC-2100 set point.

Fuel gas flowrate is compensated by calculation block R41-FY-2113 where the measured FG flowrate indicated by R41-FT-2113, is compensated by the FG actual pressure (from R41-PT-7500), the FG actual temperature (from R41-TT-7500) and the FG actual molecular weight (manual input value by R41-FHX-2113).

By using the DCS compensation exclusion switch R41-FHS-2113, the operator can choose between operating with the flowrate R41-FI-2113B calculated by R41-FY-2113 ("compensated FG flow"), or operating with R41-FI- 2113A ("uncompensated FG flow"). The selected signal is the input for R41-FC-2113 and R41-QY-2110. R41- QY-2110 calculation block calculates the Duty of the furnace by means of the Fuel Gas Lower Heating Value (LHV) manually input in R41-QHC-2110. The result is displayed in R41-QI-2100.

- **Fuel gas control system**

The master controller is R41-TC-2100.

The slave controller is R41-FC-2113 set in cascade mode while R41-PC-2113 is in auto mode.

The SP for R41-PC-2113 is input manually and represents the minimum allowed FG pressure. When the pressure (from R41-PT-2113) falls down to a value below the R41-PC-2113 SP, the signal from R41-PC-2113 becomes higher than the signal from R41-FC-2113. Hence, the high signal selector R41-FY-2114 selects the pressure controller R41-PC-2113 to operate the valve R41-FV-2114.

To summarize :

The PV value for R41-FC-2113 comes from R41-FHS-2113 (chosen FG flowrate).

The OP from R41-FC-2113 is compared with the OP from R41-PC-2113. The biggest value is selected from the high signal selector R41-FY-2114 and actuates R41-FV-2114 on the FG inlet line.

The increase of the Hydrotreating Reactor (R41-R-121) inlet temperature results in closing of R41-FV-2114. The valve R41-FV-2114 is AFC.

#### **3.4.2.7 Reactor Feed Heater R41-FR-12110 Fuel Gas Valve Closure Control**

Objective of the listed logics is to check the complete and contemporary closure of all the on/off valves located on the fuel gas line to burners/pilots.

Logic R41-UC-2115 checks the complete closure of the on/off valve R41-ZV-2115 on the fuel gas line to burners.

If the check is ok, a "Purge allowed" lamps R41-ZL-2115 CR is lighted and closure status of ZV-2115 is sent to SIS logic (see C&E Matrix).

Logic R41-UC-2116 checks the complete closure of the on/off valve R41-ZV-2116 on the fuel gas line to pilots. If the check is ok, a “Purge allowed” signal is lamp R41-ZL-2116 CR is lighted and closure status of ZV-2116 is sent to SIS logic (see C&E Matrix).

#### **3.4.2.8 Stripper Reboiler R41-FR-122 Duty Control**

The objective of this control loop is Stripper Reboiler R41-FR-122 duty control: during normal operation this is done by controlling the temperature of the sensitive tray of NHT Stripper R41-T-122 whereas during start-up this is done controlling the temperature of the return stream of the Stripper Reboiler R41-FR-122. The mode is selected by the operator with the normal/start-up mode selector R41-THS-2203.

The output of NHT Stripper sensitive tray temperature controller (R41-TC-2203) during normal operation or the output of Stripper reboiler outlet temperature controller (R41-TC-2201) during start-up sets in cascade the controller R41-FC-2204 which varies the flow rate of fuel gas by modulating R41-FV-2207. In such way, the furnace duty is modified to reach desired set point.

The fuel gas flowrate is compensated by the calculation block R41-FY-2204 where the measured FG flowrate indicated by R41-FT-2204, is compensated by the FG actual pressure (from R41-PT-7500), the FG actual temperature (from R41-TT-7500) and the FG actual molecular weight (manual input value by R41-FHX-2204).

By using the DCS compensation exclusion switch R41-FHS-2204, the operator can choose between operating with the flowrate calculated by R41-FY-2204 (“compensated FG flow”), or operating with the flowrate from R41-FI-2204A (“uncompensated FG flow”). The selected signal is the input for R41-FC-2204 and R41-QY-2200. R41-QY-2200 calculation block calculates the Duty by means of the Fuel Gas Lower Heating Value (LHV) manually input in R41-QHC-2200. The result is displayed in R41-QI-2200.

- Normal mode:**

The selector R41-THS-2203A is positioned in “normal mode”.

The master controller is R41-TC-2203 set in cascade mode on the fuel gas controller R41-FC-2204

- Start-up mode:**

The selector R41-THS-2203A is positioned in “start-up mode”.

The master controller is R41-TC-2201 set in cascade mode on the fuel gas controller R41-FC-2204

- **Fuel gas control system:**

The master controller is R41-TC-2201 (start-up mode) or R41-TC-2203 (normal mode).

The slave controller is R41-FC-2204 set in cascade mode while R41-PC-2204 is in auto mode.

The SP for R41-PC-2204 is input manually and represents the minimum allowed FG pressure. When the pressure (from R41-PT-2204) falls down to a value below the R41-PC-2204 SP, the signal from R41-PC-2204 becomes higher than the signal from R41-FC-2204. Hence, the high signal selector R41-FY-2207 selects the pressure controller R41-PC-2204 to operate the valve R41-FV-2207.

To summarize :

The PV value for R41-FC-2204 comes from R41-FHS-2204 (chosen FG flowrate).

The OP from R41-FC-2204 is compared with the OP from R41-PC-2204. The biggest value is selected from the high signal selector R41-FY-2207 and actuates R41-FV-2204 on the FG inlet line.

The increase of the sensitive tray temperature (or reboiler return temperature for start-up mode) results in closing of R41-FV-2204. The valve R41-FV-2204 is AFC.

#### **3.4.2.9 Stripper Reboiler R41-FR-122 Fuel Gas Valve Closure Control**

Objective of the listed logics is to check the complete and contemporary closure of all the on/off valves located on the fuel gas line to burners/pilots.

Logic R41-UC-2205 checks the complete closure of the on/off valve R41-ZV-2205 on the fuel gas line to burners.

If the check is ok, a “Purge allowed” lamps R41-ZL-2205 CR is lighted and ZV-2205 closure status signal is sent to SIS logic (see C&E matrix).

Logic R41-UC-2206 checks the complete closure of the on/off valve R41-ZV-2206 on the fuel gas line to pilots. If the check is ok, a “Purge allowed” lamps R41-ZL-2206 CR is lighted and ZV-2206 closure status signal is sent to SIS logic (see C&E matrix).

### **3.4.2.10 NHT Stripper R41-T-122 Level Control**

The objective of this loop is to control the level of NHT Stripper Column R41-T-122 by cascade control.

There are two modes: Normal mode and Start-up mode. In normal mode, the level control of R41-T-122 is cascaded on controller R41-FC-3110; in start-up mode, the level control of R41-T-122 is cascaded on controller R41-FC-2203.

- **Start-up/Upset Mode:**

Selector R41-FHS-2205 is in “Start-up mode”

The master controller is R41-LC-2200 and sets in cascade the flow controller R41-FC-2203 which varies the flow to Hydro treated Naphtha Air cooler R41-E-1222 during upset conditions and start-up by modulating R41- FV- 2203.

- **Normal Mode:**

Selector R41-FHS-2205 is in “Normal mode”

The master controller is R41-LC-2200 and sets in cascade the flow controller R41-FC-3110 which varies the flow to Reformer Feed/Effluent Exchanger R41-E-13110 by modulating R41- FV-3110.

- **Requirements:**

The increase of NHT Stripper R41-T-122 level (R41-LT-2200 / R41-LC-2200) results in opening of the valves R41-FV-3100 and R41-FV-2203 in both normal and start-up/upset mode. The valves R41-FV-2203 and R41- FV-3100 are AFC.

- **Special alarm condition, alarm inhibition:**

In case the NHT Stripper R41-T-122 liquid level in the column is below the low low liquid level (R41-LALL-2201 is activated), which **will** limit the set point of the flow controllers indicated hereafter to a maximum threshold value equal to 60% of the normal flow set point of the controller at plant design capacity.

- R41-FC-2201A/B/C/D/E/F
- R41-FC-2111A/B/C/D/E

In this configuration, if any of the above controllers was operating with a set point above the threshold value before activation of R41-LALL-2201, the set point of the controller **to** be reduced to the threshold value when the low low level alarm is activated. If any of the above controller was operating with a set point lower than the threshold value, no reset of the flow controller set point will be performed at the activation of the low low level alarm.

### **3.4.2.11 Stripper Reflux Drum R41-D-12250 Level Control**

The objective of this loop is to control the level of Stripper Reflux Drum R41-D-12250 by cascade control.

The master controller is R41-LC-2250, the slave controller is the R41-FC-2250 set in cascade mode. The Set Point from R41-LC-2250 is sent to R41-FC-2250 to control the hydrocarbon flow by modulating R41-FV-2250.

The increase of Stripper Reflux Drum R41-D-12250 level (R41-LT-2250 / R41-LC-2250) results in opening of the valve R41-FV-2250. The valve R41-FV-2250 is AFO.

### **3.4.2.12 Sour Water Drum R41-D-12160 Level Control**

The objective of this loop is to control the emptying rate of Sour Water Drum R41-D-12160. Sour Water Drum R41-D-12160 is intermittently filled so that the operator select the set point of FC-2160 to empty the vessel at the appropriate rate. The valve R41-FV-2160 is hence normally controlled by R41-FC-2160.

The values from R41-LC-2160 and R41-FC-2160 are compared and the lowest is taken by low selector R41- FY-2160 to control the Sour Water flow by modulating R41-FV-2160. Hence, if the level in the drum decrease too much, the level controller R41-LC-2160 will override the flow control and reduce the opening of R41-FV-2160.

The increase of Sour Water Drum R41-D-12160 level at R41-LC-2160 results in opening the valve R41-FV-2160. The increase of flowrate at R41-FC-2160 results in closing the valve R41-FV-2160.

The valve R41-FV-2160 is AFC.

### **3.4.2.13 Stripper Bottom Product Pumps R41-P-122A/B/C Autostart**

Objective of this loop is to activate the autostart of the stand-by Stripper Bottom Product Pump (R41-P- 122A/B/C). During normal operation two pumps are running and one is in stand-by. The low pressure signal from one of the two running pumps discharge (R41-PT-2201A/B/C) activates the autostart logic (R41-UC-2201). The auto-start logic starts the pump in stand-by.

### **3.4.3 R41-3 Aromizing Reaction Section Control Narrative**

**For detailed control narrative of R41-3 Refer latest revision of S-EP-R41-1223-2006**

#### **3.4.3.1 H<sub>2</sub>/HC Ratio Controller**

The purpose of this H<sub>2</sub>/HC ratio controller is to calculate the parameters allowing to control steam turbine R41-K-13450 speed. Indeed, the head of the compressor being the consequence of pressure control R41-PC-3450 at Separator Drum R41-D-13450, the flow of the compressor (and hence the speed of the turbine) **is** adjusted to meet the correct H<sub>2</sub>/HC ratio Set Point.

This ratio is based on molar flowrate (mol/mol). The entering formula in DCS system depends on instrument units with the appropriate corrections (P;T). Here below is an example of what can be implemented:

Molecular weight (MW) and standard liquid density (d) of the fresh feed **to** be obtained from regular analysis of the fresh feed. Assumed molar volume is V<sub>0</sub>.

Controller operation: calculation of H<sub>2</sub>/HC molar ratio

$$\frac{H_2}{HC} = \frac{FI - 3451(Nm^3/h) \times AI - 3450(H_2 \% \text{ vol})}{100 \times FC - 3110 (Nm^3/h)} \times \frac{MW_{FEED} (\text{kg / kmol})}{d_{FEED}^{15} (\text{kg / Sm}^3) \times V_0 (\text{Nm}^3 / \text{kmol})}$$

MW<sub>FEED</sub>: Feed molecular weight, input manual by operator through FHX-3451A;

d<sub>FEED</sub>: Feed density, input manual by operator through FHX-3451B;

V<sub>0</sub>: Feed molar volume, input manual by operator through FHX-3451C.

H<sub>2</sub> recycle molar flowrate is corrected considering the corresponding temperature (TI-3451) and pressure (PI-3453). When the calculation result (displayed on DCS by FI-3451A) is below the ratio set point, the recycle gas flowrate is increased. This is achieved through a manual action by operator on the compressor (R41-K-13450) turbine speed controller set point so as to increase the turbine speed.

#### **3.4.3.2 Separator Drum R41-D-13450 Level Control**

The objective of this loop is to control the level of Separator Drum R41-D-13450 by cascade control.

The master controller is R41-LC-3450 and sends the Set Point in cascade mode to R41-FC-3452 to control the Separator Bottom Pumps R41-P-13450 A/B discharge flowrate by modulating R41-FV-3452.

The increase of Separator Drum R41-D-13450 level results in opening of the valve R41-FV-3452. The valve R41-FV-3452 is AFC.

#### **3.4.3.3 Separator Drum R41-D-13450 Pressure Control**

The control of the whole reaction section is done at the Separator Drum R41-D-13450 thanks to R41-PC-3450. R41-PC-3450 is acting in split-range on the venting valves R41-PV-3450 A/B and on R41-SC-3500 H2 Rich Gas Compressor (1st & 2nd stage) R41-K-135 speed controller of the turbine.

In normal operating conditions R41-PV-3450 A/B are closed.

If the pressure in the reaction loop increases than the speed of the turbine will increase.

If pressure in the Separator Drum R41-D-13450 is still above the set point then the small venting valve R41-PV-3450 B will open. This valve is sized to pass 10 % of the H2 rich gas flowrate to the H2 Rich Gas Compressor. In case of very high pressure increase (for example because of H2 Rich Gas Compressor (1st & 2nd stage) R41-K-135 trip) this valve will not be sufficient to vent to the flare. So second valve R41-PV-3450 A will open since it is sized to pass the whole flowrate going to R41-K-135.

If the pressure in the reaction loop decreases than the speed of the turbine will decrease.

#### **3.4.3.4 Second Interstage Drum R41-D-13550 Pressure Control**

The control of the pressure at the inlet of H2 Rich Gas Compressor (3rd stage) R41-K-13550 is done at the Second Interstage Drum R41-D-13550 thanks to R41-PC-3550.

R41-PC-3550 is acting in split-range on the venting valve R41-PV-3550 and on R41-SC-3550 H2 Rich Gas Compressor (3rd stage) R41-K-13550 speed controller of the turbine.

In normal operating conditions R41-PV-3550 is closed.

If the pressure in the reaction loop increases, the speed of the turbine will increase. If pressure in the Separator Drum R41-D-13550 is still above the set point then the venting valve R41-PV-3550 will open. This valve is sized to pass all the flowrate going to R41-K-13550.

If the pressure in the reaction loop decrease, the speed of the turbine will decrease.

#### **3.4.3.5 HP Absorber Drum R41-D-13580 Level Control**

The objective of this loop is to control the level of HP Absorber Drum R41-D-13580 by cascade control.

The master controller is R41-LC-3580 and sends the Set Point in cascade mode to R41-FC-3580 to control the HP Absorber Drum outlet flow by modulating R41-FV-3580.

The increase of HP Absorber Drum R41-D-13580 level results in opening of the valve R41-FV-3580. The valve R41-FV-3580 is AFC.

#### **3.4.3.6 LPG Absorber Drum R41-D-136100 Level Control**

The objective of this loop is to control the level of LPG Absorber Drum R41-D-136100 by cascade control.

The master controller is R41-LC-3610 and sends the Set Point in cascade mode to R41-FC-3610 to control the LPG Absorber Bottom Pumps R41-P-13610A/B discharge flowrate by modulating R41-FV-3610.

The increase of LPG Absorber Drum R41-D-136100 level results in opening of the valve R41-FV-3610. The valve R41-FV-3610 is AFC.

#### **3.4.3.7 Depentanizer Column R41-T-136 Level Control**

The objective of this loop is to control the level of Depentanizer column R41-T-136 by cascade control.

There are two modes: Normal mode and Start-up mode.

In normal mode R41-LC-3600 output is sent to R42-FHS-3612 (Refer to Control Narrative for Aromatics Complex R42-1 doc. N° S-EP-R42-1223-2000 section 3.8). In Start-up mode R41-LC-3600 is cascaded on R41-FC-3611.

- **Start-up/Upset Mode:**

Selector R41-FHS-3612 is in “Start-up mode”

The master controller is R41-LC-3600 and sends the Set Point in cascade mode to the controller R41-FC-3611 which varies the flow to SR Naphtha Tank Rundown Air Cooler R41-E-1363 during start-up by modulating R41-FV-3611. This is a NNF loop.

- **Normal Mode:**

Selector R41-FHS-3612 is in “Normal mode”. Refer to Control Narrative for Aromatics Complex R42-1 doc. N° S-EP-R42-1223-2000 section 3.8)

The increase of Depentanizer Column R41-T-136 bottom level results in opening R42-FV-1110 and R41-FV- 3611 in both normal and start-up mode respectively . The valves R41-FV-3611 and R42-FV-1110 are AFC.

#### **3.4.3.8 Depentanizer Column R41-T-136 Reboiling Duty Control**

Objective of this control loop is to maintain Temperature in Depentanizer Column R41-T-136.

The reboiling duty of Depentanizer Column R41-T-136 is provided by the Convection Reboiler Coil R41-FR- 13110-E. However, this coil being part of the convection zone of the furnace, the duty recovered in this coil cannot be adjusted: the duty available for Convection Reboiler Coil R41-FR-13110-E depends on the duty released by radiant section of R41-FR-13110/13210/13310/13410. In order to control the reboiling duty, the flow entering in the reboiling coil is cooled through Depentanizer Bottom Steam Generator R41-E-136 in such a way that the outlet temperature of R41-FR-13110-E (start-up mode) or the temperature at R41-TC-3602 (normal mode) is kept constant. This is achieved by a split-range control.

There are two different operating modes: Normal mode and Start-up mode.

- **Start-up/Upset Mode:**

Selector R41-THS-3608 is in “Start-up mode”

R41-TV-3601A/B are controlled by R41-TC-3601A

- **Normal Mode:**

Selector R41-THS-3608 is in “Normal mode” R41-

TV-3601A/B are controlled by R41-TC-3602

When the temperature downstream R41-FR-13110-E meets the set point, the controller output (OP) to the valves R41-TV-3601A & R41-TV-3601B will be at 50 % ( the exact curve to be adapted to control valve real characteristic ).

When the temperature is below the set point, the controller OP is in the range of 0% to 50 %. With decreasing controller OP the control valve R41-TV-3601B closes while control valve R41-TV-3601A opens.

When the temperature is above the set point, the controller OP is in the range of 50 % to 100%. With increasing controller output the control valve R41-TV-3601A closes while the control valve R41-TV-3601B opens.

The valve R41-TV-3601A is AFC and R41-TV-3601B is AFO.

#### **3.4.3.9 Depentanizer Bottom Steam Generator R41-E-136 Level Control**

The objective of this loop is to control the Boiler Feed Water level in Depentanizer bottom steam Generator R41- E-136 by a cascade control.

The boiler feed water level in Depentanizer Bottom Steam Generator R41-E-136 is controlled by the master level controller R41-LC-3602 acting upon slave flow controller R41-FC-3605 in the boiler feed water supply line. A feed forward calculation block R41-FY-3607 adjusts the output signal of the level controller based on the MP steam generated by the steam generator (measured by FT-3606A/B), thus compensating the supply flow set point for rapid changes in the MP steam flow. When the level is lesser than set point value, R41-FV-3605 opens and allows more BFW flow to maintain the level and R41-FV-3605 closes when the level is higher than the set point value.

The decreasing level in Depentanizer Bottom Steam Generator R41-E-136 results in opening of R41-FV-3605. The valve R41-FV-3605 is AFC.

R41-LAHH-3603 Forces controller R41-FC-3605 in MANUAL and 0% output in order to close R41-FV-3605.

#### **3.4.3.10 Depentanizer Reflux Drum R41-D-13650 Level Control**

The objective of this loop is to control the level of Depentanizer Reflux Drum R41-D-13650 by cascade control. The master controller is R41-LC-3650 and sends the Set Point in cascade mode to R41-FC-3661 to control the Depentanizer Distillate Pumps R41-P-1366A/B discharge flowrate by modulating R41-FV-3661.

The increase of Depentanizer Reflux Drum R41-D-13650 level results in opening of the valve R41-FV-3661. The valve R41-FV-3661 is AFC.

#### **3.4.3.11 Depentanizer Column R41-T-136 Overhead Temperature Control**

The objective of this loop is to control the overhead temperature of Depentanizer Column R41-T-136 by cascade control.

The master controller is R41-TC-3650 and sends the Set Point in cascade mode to R41-FC-3650 to control the Depentanizer Reflux Pumps R41-P-13650A/B discharge flowrate by modulating R41-FV-3650.

The increase of Depentanizer Column R41-T-136 overhead temperature results in opening of the valve R41-FV-3650. The valve R41-FV-3650 is AFO.

#### **3.4.3.12 Depentanizer Reboiler Pumps R41-P-136 Autostart**

Objective of this loop is to activate the autostart of the stand-by Depentanizer Reboiler Pump R41-P-136A/B in case of low pressure at pump discharge. During normal operation one out of two pumps is running and the other one is in stand-by. The low pressure signal from the running pumps discharge R41-PT-3601 activates the autostart logic R41-UC-3601.

#### **3.4.3.13 Convection Reboiler Coil R41-FR-13110E Pass Balance Control**

The objective of the pass-balance controller is to adjusts the flow rate through each pass of R41-FR-13110E (process value given by FT-3600 AA to BB), while maintaining the total flow rate and achieving equal pass outlet temperatures (process value given by TI-3114 AA to BB). These equal pass outlet temperatures are equal to the weighted average pass outlet temperature. This temperature remains unchanged by the act of pass balancing.

The total flowrate set point **is** an input from the operator and is the final controlled parameter. The pass balance controller **will** calculate for each of the 28 individual pass flow controller FC-3600 AA to BB the parameters required to achieve equal pass outlet temperature at TI-3114 AA to BB. The convection reboiler R41-FR-13110E weighted outlet temperature is calculated using the following equation:

$$TWA = \text{SUM}(F3600_{ii} * TI3114_{ii}) / \text{SUM}(F3600_{ii})$$

where

TWA = convection coil weighted average outlet temperature

SUM(F3600ii\*TI3114ii) = Sum of the products of each pass flow controller setpoint times its outlet temperature

SUM(F3600<sub>ii</sub>) = Sum of all pass flow controller setpoints

An increase of temperature through one pass above the weighted outlet temperature **is** corrected by an increase of the flow through this pass.

An increase of the flow above the pass flow controller set point **will** reduce the opening of the pass flow valve FV-3600ii. The valves FV-3600 AA to BB are AFC.

#### **3.4.3.14 Reforming Furnace Damper Control**

The objective of this loop is to maintain the pressure in the two common convection sections (R41-FR-311/13210 and R41-FR-13310/13410 respectively) varying the furnace damper position.

The process values (pressure in the First Convection Section from R41-PT-3116/PI-3116 and pressure in the Second Convection Section from R41-PT-3316/PI-3316) are sent into calculation block R41-PY-3110A that perform an average of the two values. The output is then sent to the R41-PC-3110 which acts on the damper modulating the pressure.

In case of increasing pressure the damper will open. The actuator position is AFO.

#### **3.4.3.15 Reformer Preheater R41-FR-13110 Duty Control**

Objective of this loop is to control the inlet temperature of Reaction Section First Reactor R41-R-131. This is done by actuating the valves of Fuel Gas (main control) and Hydrogen (separated and independent) controlling the firing in the Reformer Preheater R41-FR-13110.

The temperature controller R41-TC-3100 (master controller) is cascaded through R41-HY-3114 on R41-FC- 3113 (slave controller). The temperature at reactor inlet is hence controlled by variation of fuel gas flowrate.

Hydrogen flow controller R41-FC-3111 is independent and its set point is manually input by operator.

Each fuel flowrate is compensated by calculation blocks:

- R41-FY-3111: is the H<sub>2</sub> compensation calculation block where the measured H<sub>2</sub> flowrate coming from R41-FT-3111 / FI-3111A is compensated with the H<sub>2</sub> actual pressure (from R41-PT-5104 / PI-5104) and the H<sub>2</sub> actual temperature (from R41-TI-5103).

- R41-FY-3113: is the FG compensation calculation block where the measured FG flowrate coming from R41-FT-3113 / FI-3113A is compensated with the FG actual pressure (from R41-PT-7516 / PI-7516), the FG actual temperature (from R41-TT-7513 / TI-7513) and the FG actual molecular weight (manually input value by R41-FHX-3113)

The operator can choose between operating with the compensated flowrates or the original uncompensated flowrates, by using the DCS compensation exclusion switches:

- R41-FHS-3111: the operator can choose between the signal from R41-FI-3111A ("uncompensated H<sub>2</sub> flow") and from R41-FY-3111 ("compensated H<sub>2</sub> flow"). The selected signal is the input for R41-FC- 3111 and R41-FY-3115.
- R41-FHS-3113: the operator can choose between the signal from R41-FI-3113A ("uncompensated FG flow") and from R41-FY-3113 ("compensated FG flow"). The selected signal is the input for R41-FC- 3113 and R41-FY-3115.

The total fuel calculation is based on FG equivalent flowrates:

- FG actual Lower Heating Value (LHV) is measured periodically through the proper sample connection and manually input in R41-QHC-3112. The output is sent in parallel to the ratio calculation blocks R41-FY-3114 (H<sub>2</sub>) and total duty calculation block R41-QY-3110.
- H<sub>2</sub> actual LHV is measured periodically through the proper sample connection and manually input in R41-QHC-3111.
- R41-FY-3114 calculates the ratio between the H<sub>2</sub> LHV (from R41-QHC-3111) and the FG LHV (from R41-QHC-3112). The R41-FY-3114 output is sent to the calculation block R41-FY-3115.
- R41-FY-3115 sums: (R41-FHS-3111 output x R41-FY-3114 output) + R41-FHS-3113 output.

The sum is the fuel flowrate in FG equivalent and it is displayed on DCS by R41-FI-3115 ("total fuel"). The output from R41-FI-3115 together with the output from R41-QHC-3112 is sent to R41-QY-3110 where the total flowrate (FG equivalent) is "expressed" in terms of total duty. The result is displayed in R41-QI-3110.

In case of First Reactor R41-R-131 increased temperature R41-FV-3113 (on fuel gas burners inlet line) **will** close.

### **3.4.3.16 Reformer Preheater R41-FR-13110 Fuel Gas And H2 Valve Closure Control**

Objective of the listed logics is to check the complete and contemporary closure of all the on/off valves located on the relevant fuel line to burners/pilots.

Logic R41-UC-3115 checks the complete closure of the on/off valve R41-ZV-3115 on the fuel gas line to burners. If the check is ok, a “Purge allowed” lamps R41-ZL-3115 CR is lighted and closure status of ZV-3115 is sent to SIS logic R41-ZC-3111 (see C&E matrix).

Logic R41-UC-3116 checks the complete closure of the on/off valve R41-ZV-3116 on the fuel gas line to pilots. If the check is ok, a “Purge allowed” lamps R41-ZL-3116 CR is lighted and closure status of ZV-3116 is sent to SIS logic R41-ZC-3111 (see C&E matrix).

Logic R41-UC-3117 checks the complete closure of the on/off valve R41-ZV-3117 on the hydrogen line to burners. If the check is ok, a “Purge allowed” lamps R41-ZL-3117 CR is lighted and closure status of ZV-3117 is sent to SIS logic R41-ZC-3111 (see C&E matrix).

### **3.4.3.17 Reformer 1st Inter heater R41-FR-13210 Duty Control**

Objective of this loop is to control the inlet temperature of Reaction Section Second Reactor R41-R-132. This is done by actuating the valves of Fuel Gas (main control) and Hydrogen (separated and independent) controlling the firing in the Reformer Preheater R41-FR-13210.

The temperature controller R41-TC-3200 (master controller) is cascaded through R41-HY-3214 on R41-FC- 3213 (slave controller). The temperature at reactor inlet is hence controlled by variation of fuel gas flowrate. Hydrogen flow controller R41-FC-3211 is independent and its set point is manually input by operator.

Each fuel flowrate is compensated by calculation blocks:

- R41-FY-3211: is the H<sub>2</sub> compensation calculation block where the measured H<sub>2</sub> flowrate coming from R41-FT-3211 / FI-3211A is compensated with the H<sub>2</sub> actual pressure (from R41-PT-5104 / PI-5104) and the H<sub>2</sub> actual temperature (from R41-TI-5103).

- R41-FY-3213: is the FG compensation calculation block where the measured FG flowrate coming from R41-FT-3213 / FI-3213A is compensated with the FG actual pressure (from R41-PT-7516 / PI-7516), the FG actual temperature (from R41-TT-7513 / TI-7513) and the FG actual molecular weight (manually input value by R41-FHX-3213)

The operator can choose between operating with the compensated flowrates or the original uncompensated flowrates, by using the DCS compensation exclusion switches:

- R41-FHS-3211: the operator can choose between the signal from R41-FI-3211A ("uncompensated H<sub>2</sub> flow") and from R41-FY-3211 ("compensated H<sub>2</sub> flow"). The selected signal is the input for R41-FC- 3211 and R41-FY-3215.
- R41-FHS-3213: the operator can choose between the signal from R41-FI-3213A ("uncompensated FG flow") and from R41-FY-3213 ("compensated FG flow"). The selected signal is the input for R41-FC- 3213 and R41-FY-3215.

The total fuel calculation is based on FG equivalent flowrates:

- FG actual Lower Heating Value (LHV) is measured periodically through the proper sample connection and manually input in R41-QHC-3212. The output is sent in parallel to the ratio calculation blocks R41-FY-3214 (H<sub>2</sub>) and total duty calculation block R41-QY-3210.
- H<sub>2</sub> actual LHV is measured periodically through the proper sample connection and manually input in R41-QHC-3211.
- R41-FY-3214 calculates the ratio between the H<sub>2</sub> LHV (from R41-QHC-3211) and the FG LHV (from R41-QHC-3212). The R41-FY-3214 output is sent to the calculation block R41-FY-3215.
- R41-FY-3215 sums: (R41-FHS-3211 output x R41-FY-3214 output) + R41-FHS-3213 output.

The sum is the fuel flowrate in FG equivalent and it is displayed on DCS by R41-FI-3215 ("total fuel"). The output from R41-FI-3215 together with the output from R41-QHC-3212 is sent to R41-QY-3210 where the total flowrate (FG equivalent) is "expressed" in terms of total duty. The result is displayed in R41-QI-3210.

In case of Second Reactor R41-R-132 increased temperature R41-FV-3213 (on fuel gas burners inlet line) **will** close.

### **3.4.3.18 Reformer 1st Interheater R41-FR-13210 Fuel Gas And H2 Valve Closure Control**

Objective of the listed logics is to check the complete and contemporary closure of all the on/off valves located on the relevant fuel line to burners/pilots.

Logic R41-UC-3215 checks the complete closure of the on/off valve R41-ZV-3215 on the fuel gas line to burners. If the check is ok, a “Purge allowed” lamps R41-ZL-3215 CR is lighted and closure status of ZV-3215 is sent to SIS logic R41-ZC-3211 (see C&E matrix).

Logic R41-UC-3216 checks the complete closure of the on/off valve R41-ZV-3216 on the fuel gas line to pilots. If the check is ok, a “Purge allowed” lamps R41-ZL-3216 CR is lighted and closure status of ZV-3216 is sent to SIS logic R41-ZC-3211 (see C&E matrix).

Logic R41-UC-3217 checks the complete closure of the on/off valve R41-ZV-3217 on the hydrogen line to burners. If the check is ok, a “Purge allowed” lamps R41-ZL-3217 CR is lighted and closure status of ZV-3217 is sent to SIS logic R41-ZC-3211 (see C&E matrix).

### **3.4.3.19 Reformer 2nd Interheater R41-FR-13310 Duty Control Scheme**

Objective of this loop is to control the inlet temperature of Reaction Section Third Reactor R41-R-133.

This is done by actuating the valves of Fuel Gas (main control) and Hydrogen (separated and independent) controlling the firing in the Reformer Preheater R41-FR-13310.

The temperature controller R41-TC-3300 (master controller) is cascaded through R41-HY-3314 on R41-FC- 3313 (slave controller). The temperature at reactor inlet is hence controlled by variation of fuel gas flowrate. Hydrogen flow controller R41-FC-3311 is independent and its set point is manually input by operator.

Each fuel flowrate is compensated by calculation blocks:

- R41-FY-3311: is the H<sub>2</sub> compensation calculation block where the measured H<sub>2</sub> flowrate coming from R41-FT-3311 / FI-3311A is compensated with the H<sub>2</sub> actual pressure (from R41-PT-5104 / PI-5104) and the H<sub>2</sub> actual temperature (from R41-TI-5103).

- R41-FY-3313: is the FG compensation calculation block where the measured FG flowrate coming from R41-FT-3313 / FI-3313A is compensated with the FG actual pressure (from R41-PT-7516 / PI-7516), the FG actual temperature (from R41-TT-7513 / TI-7513) and the FG actual molecular weight (manually input value by R41-FHX-3313)

The operator can choose between operating with the compensated flowrates or the original uncompensated flowrates, by using the DCS compensation exclusion switches:

- R41-FHS-3311: the operator can choose between the signal from R41-FI-3311A ("uncompensated H<sub>2</sub> flow") and from R41-FY-3311 ("compensated H<sub>2</sub> flow"). The selected signal is the input for R41-FC- 3311 and R41-FY-3315.
- R41-FHS-3313: the operator can choose between the signal from R41-FI-3313A ("uncompensated FG flow") and from R41-FY-3313 ("compensated FG flow"). The selected signal is the input for R41-FC- 3313 and R41-FY-3315.

The total fuel calculation is based on FG equivalent flowrates:

- FG actual Lower Heating Value (LHV) is measured periodically through the proper sample connection and manually input in R41-QHC-3312. The output is sent in parallel to the ratio calculation blocks R41-FY-3314 (H<sub>2</sub>) and total duty calculation block R41-QY-3310.
- H<sub>2</sub> actual LHV is measured periodically through the proper sample connection and manually input in R41-QHC-3311.
- R41-FY-3314 calculates the ratio between the H<sub>2</sub> LHV (from R41-QHC-3311) and the FG LHV (from R41-QHC-3312). The R41-FY-3314 output is sent to the calculation block R41-FY-3315.
- R41-FY-3315 sums: (R41-FHS-3311 output x R41-FY-3314 output) + R41-FHS-3313 output.

The sum is the fuel flowrate in FG equivalent and it is displayed on DCS by R41-FI-3315 ("total fuel"). The output from R41-FI-3315 together with the output from R41-QHC-3312 is sent to R41-QY-3310 where the total flowrate (FG equivalent) is "expressed" in terms of total duty. The result is displayed in R41-QI-3310.

In case of Third Reactor R41-R-133 increased temperature R41-FV-3313 (on fuel gas burners inlet line) **will** close.

### **3.4.3.20 Reformer 2nd Interheater R41-FR-13310 Fuel Gas And H2 Valve Closure Control**

Objective of the logic is to check the complete and contemporary closure of all the on/off valves located on the relevant fuel line to burners/pilots.

Logic R41-UC-3315 checks the complete closure of the on/off valve R41-ZV-3315 on the fuel gas line to burners. If the check is ok, a “Purge allowed” lamps R41-ZL-3315 CR is lighted and closure status of ZV-3315 is sent to SIS logic R41-ZC-3311 (see C&E matrix).

Logic R41-UC-3316 checks the complete closure of the on/off valve R41-ZV-3316 on the fuel gas line to pilots. If the check is ok, a “Purge allowed” lamps R41-ZL-3316 CR is lighted and closure status of ZV-3316 is sent to SIS logic R41-ZC-3311 (see C&E matrix).

Logic R41-UC-3317 checks the complete closure of the on/off valve R41-ZV-3317 on the hydrogen line to burners. If the check is ok, a “Purge allowed” lamps R41-ZL-3317 CR is lighted and closure status of ZV-3317 is sent to SIS logic R41-ZC-3311 (see C&E matrix).

### **3.4.3.21 Reformer 3rd Interheater R41-FR-13410 Duty Control Scheme**

Objective of this loop is to control the inlet temperature of Reaction Section Fourth Reactor R41-R-134. This is done by actuating the valves of Fuel Gas (main control) and Hydrogen (separated and independent) controlling the firing in the Reformer Preheater R41-FR-13410.

The temperature controller R41-TC-3400 (master controller) is cascaded through R41-HY-3414 on R41-FC-3413 (slave controller). The temperature at reactor inlet is hence controlled by variation of fuel gas flowrate. Hydrogen flow controller R41-FC-3411 is independent and its set point is manually input by operator.

Each fuel flowrate is compensated by calculation blocks:

- R41-FY-3411: is the H<sub>2</sub> compensation calculation block where the measured H<sub>2</sub> flowrate coming from R41-FT-3411 / FI-3411A is compensated with the H<sub>2</sub> actual pressure (from R41-PT-5104 / PI-5104) and the H<sub>2</sub> actual temperature (from R41-TI-5103).

- R41-FY-3413: is the FG compensation calculation block where the measured FG flowrate coming from R41-FT-3413 / FI-3413A is compensated with the FG actual pressure (from R41-PT-7516 / PI-7516), the FG actual temperature (from R41-TT-7513 / TI-7513) and the FG actual molecular weight (manually input value by R41-FHX-3413)

The operator can choose between operating with the compensated flowrates or the original uncompensated flowrates, by using the DCS compensation exclusion switches:

- R41-FHS-3411: the operator can choose between the signal from R41-FI-3411A ("uncompensated H<sub>2</sub> flow") and from R41-FY-3411 ("compensated H<sub>2</sub> flow"). The selected signal is the input for R41-FC- 3411 and R41-FY-3415.
- R41-FHS-3413: the operator can choose between the signal from R41-FI-3413A ("uncompensated FG flow") and from R41-FY-3413 ("compensated FG flow"). The selected signal is the input for R41-FC- 3413 and R41-FY-3415.

The total fuel calculation is based on FG equivalent flowrates:

- FG actual Lower Heating Value (LHV) is measured periodically through the proper sample connection and manually input in R41-QHC-3412. The output is sent in parallel to the ratio calculation blocks R41-FY-3414 (H<sub>2</sub>) and total duty calculation block R41-QY-3410.
- H<sub>2</sub> actual LHV is measured periodically through the proper sample connection and manually input in R41-QHC-3411.
- R41-FY-3414 calculates the ratio between the H<sub>2</sub> LHV (from R41-QHC-3411) and the FG LHV (from R41-QHC-3412). The R41-FY-3414 output is sent to the calculation block R41-FY-3415.
- R41-FY-3415 sums: (R41-FHS-3411 output x R41-FY-3414 output) + R41-FHS-3413 output.

The sum is the fuel flowrate in FG equivalent and it is displayed on DCS by R41-FI-3415 ("total fuel"). The output from R41-FI-3415 together with the output from R41-QHC-3412 is sent to R41-QY-3410 where the total flowrate (FG equivalent) is "expressed" in terms of total duty. The result is displayed in R41-QI-3410.

In case of Fourth Reactor R41-R-134 increased temperature, R41-FV-3413 (on fuel gas burners inlet line) **will Close**.

### **3.4.3.22 Reformer 3rd Interheater R41-FR-13410 Fuel Gas And H<sub>2</sub> Valve Closure Control**

Objective of the listed logics is to check the complete and contemporary closure of all the on/off valves located on the relevant fuel line to burners/pilots.

Logic R41-UC-3415 checks the complete closure of the on/off valve R41-ZV-3415 on the fuel gas line to burners. If the check is ok, a “Purge allowed” lamps R41-ZL-3415 CR is lighted and closure status of ZV-3415 is sent to SIS logic R41-ZC-3411 (see C&E matrix).

Logic R41-UC-3416 checks the complete closure of the on/off valve R41-ZV-3416 on the fuel gas line to pilots. If the check is ok, a “Purge allowed” lamps R41-ZL-3416 CR is lighted and closure status of ZV-3416 is sent to SIS logic R41-ZC-3411 (see C&E matrix).

Logic R41-UC-3417 checks the complete closure of the on/off valve R41-ZV-3417 on the hydrogen line to burners. If the check is ok, a “Purge allowed” lamps R41-ZL-3417 CR is lighted and closure status of ZV-3417 is sent to SIS logic R41-ZC-3411 (see C&E matrix).

### **3.4.3.23 Deethanizer Column R41-T-137 Level Control**

The objective of this loop is to control the level of Deethanizer Column R41-T-137 by cascade control.

The master controller is R41-LC-3700 and sends the Set Point in cascade mode to R41-FC-3700 to control the Deethanizer Column R41-T-137 bottom outlet flowrate by modulating R41-FV-3700.

The increase of Deethanizer Column R41-T-137 level results in opening of the valve R41-FV-3700. The valve R41-FV-3700 is AFC.

### **3.4.3.24 Deethanizer Reboiler R41-E-137 Duty Control**

Objective of this loop is to control the temperature of the Deethanizer Column R41-T-137 sensitive tray by cascade control on Deethanizer Reboiler R41-E-137 duty.

The master controller is R41-TC-3703, the slave controller is the R41-FC-3705 set in cascade mode.

The PV value to R41-FC-3705 is the LP Steam flowrate to the Deethanizer Reboiler R41-E-137 on the inlet line from R41-FT-3705.

The OP from R41-FC-3705 actuates R41-FV-3705 on the outlet line of the LP condensate from the reboiler.

The increasing of Deethanizer R41-T-137 sensitive tray temperature results in the closing of R41-FV-3705. The valve R41-FV-3705 is AFC.

#### **3.4.3.25 Deethanizer Reflux Drum R41-D-13750 Level Control**

The objective of this loop is to control the level of Deethanizer Reflux Drum R41-D-13750 by cascade control. The master controller is R41-LC-3750 and sends the Set Point in cascade mode to R41-FC-3750 to control the Deethanizer Reflux Pumps R41-P-1375A/B discharge flowrate by modulating R41-FV-3750.

The increase of Deethanizer Reflux Drum R41-D-13750 level results in opening of the valve R41-FV-3750. The valve R41-FV-3750 is AFO

#### **3.4.3.26 Debutanizer Column R41-T-138 Level Control**

The objective of this loop is to control the level of Deutanizer Column R41-T-138 by cascade control. The master controller is R41-LC-3800 and sends the Set Point in cascade mode to R41-FC-3800 to control the Deutanizer Column R41-T-138 bottom outlet flowrate by modulating R41-FV-3800.

The increase of Deutanizer Column R41-T-138 level results in opening of the valve R41-FV-3800. The valve R41-FV-3800 is AFC.

#### **3.4.3.27 Deethanizer Reboiler R41-E-137 Duty Control**

Objective of this loop is to control the temperature of the Deutanizer Column R41-T-138 sensitive tray by cascade control on Deutanizer Reboiler R41-E-138 duty.

The master controller is R41-TC-3803, the slave controller is the R41-FC-3805 set in cascade mode.

The PV value to R41-FC-3805 is the LP Steam flowrate to the Deutanizer Reboiler R41-E-138 on the inlet line from R41-FT-3805.

The OP from R41-FC-3805 actuates R41-FV-3805 on the outlet line of the LP condensate from the reboiler.

The increasing of Deutanizer R41-T-138 sensitive tray temperature results in the closing of R41-FV-3805. The valve R41-FV-3805 is AFC.

#### **3.4.3.28 Debutanizer Reflux Drum R41-D-13850 Level Control**

The objective of this loop is to control the level of Debutanizer Reflux Drum R41-D-13850 by cascade control. The master controller is R41-LC-3850 and sends the Set Point in cascade mode to R41-FC-3851 to control the Debutanizer Reflux Pumps R41-P-13850A/B discharge flowrate to storage by modulating R41-FV-3851.

The increase of Debutanizer Reflux Drum R41-D-13850 level results in opening of the valve R41-FV-3851. The valve R41-FV-3851 is AFC.

#### **3.4.3.29 Steam Drum R41-D-130 Level Control**

The objective of this loop is to control the level of Steam Drum R41-D-130 by adjusting the Boiler Feed Water flow rate at inlet of Reformer Heater Convection Waste Heat Boiler R41-FR-130-SG by a cascade control. The boiler feed water level to Reformer Heater Convection Waste Heat Boiler R41-FR-130-SG is controlled by master level controller R41-LC-3000 acting upon slave flow controllers R41-FC-3004A and R41-FC-3004B in parallel range on the boiler feed water supply line. A feed forward calculation block R41-FY-3006 adjusts the output signal of the level controller based on the MP steam generated by the steam drum (measured by FT-3002), thus compensating the supply flow set point for rapid changes in the MP steam flow.

When the level is lesser than set point value, R41-FV-3004A/B open and allow more BFW flow to maintain the level and R41-FV-3004A/B. The valves R41-FV-3004A/B are AFO.

#### **3.4.3.30 BFW Circulation Pump R41-P-130B Autostart**

Objective of this loop is to activate the autostart of the motor driven stand-by Depentanizer Reboiler Pump R41-P-130B in case of low flow at pump discharge. During normal operation one out of two pumps is running (R41-P-130A steam turbine driven) and the other one (R41-P-130B motor driven) is in stand-by. The low flow signal from the running pumps discharge R41-FT-3000 activates the autostart logic R41-UC-3000.

In case the motor drive pump is the running pump, the Autostart of the turbine driven pump is achieved by opening the HP steam turbine inlet On-Off Valve (R41-UV-3000).

### 3.4.4 R41-4 Catalyst Regeneration Section Control Narrative

For detailed control narrative of R41-4 Refer latest revision of S-EP-R41-1223-2007

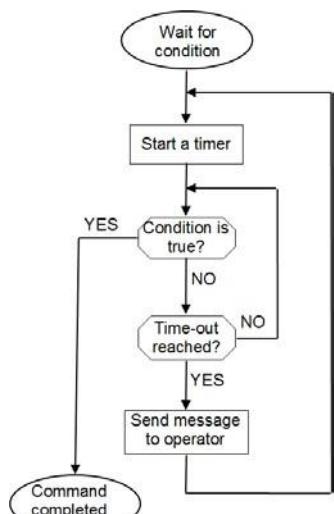
#### 3.4.4.1 Catalyst Transfer Sequence UC-40020

##### 3.4.4.1.1 Functions Used By The Transfer Sequence UC-40020

- **Function: Wait For Condition**

As long as a given condition is not true, the sequence is waiting. A message can be displayed after a time-out to inform the operator that the sequence is waiting.

Example: "Wait for PI-4020 ≤ PI-4015 + 0.15 kg/cm<sup>2</sup>, 2 min".



- Wait for condition -

- **Function: ON/OFF Valve Monitoring**

This function is used when an on/off valve involved in the catalyst transfer is operated by the sequence or by an operator. The function executes sequentially the 3 tests described hereafter.

### Test 1: Test of valve mode

The mode defines which entity (the sequence program or the operator) has the control on the on/off valve. The valves can be in AUTO mode (automatically managed by the sequence) or in MANU mode (manually managed by the operator). A valve mode can be changed at any time.

During sequence execution, if a valve to be operated is not in AUTO mode, the sequence is frozen. A message is displayed (for example, "SET VALVE xxx IN AUTO MODE") and the operator must change the valve mode. After operator acknowledgement, the sequence tests again the valve mode and continues its execution.

### Test 2: Test of permissive conditions (for Open commands only)

The opening actions on the on/off valves are protected by permissive conditions which are implemented in the DCS. These permissive conditions are described in the paragraph 3.4.4.1.4. The permissive conditions must filter all commands: manual commands (from operator) and automatic commands (from the sequence program).

- When an open command by operator is forbidden by the permissive conditions, a message is displayed (for example, "VALVE xxx NOT OPEN DUE TO PERMISSIVE"). The operator can correct the problem and re-command the valve.
- When an open command by the sequence is forbidden by the permissive conditions, the sequence is frozen and a message is displayed. After correction of the problem, the operator can acknowledge to restart the sequence execution. The sequence tries again to open the valve (the sequence re-tests the valve mode and the permissive conditions).

Note: Bypasses of the permissive conditions (one for each on/off valve) should be foreseen to allow operation during start-up or maintenance period. These bypasses should be under restricted access. When a valve is operated by the sequence or by operator and if the corresponding bypass is set, a warning message is displayed ("for example, "PERMISSIVE ON VALVE xxx BYPASSED").

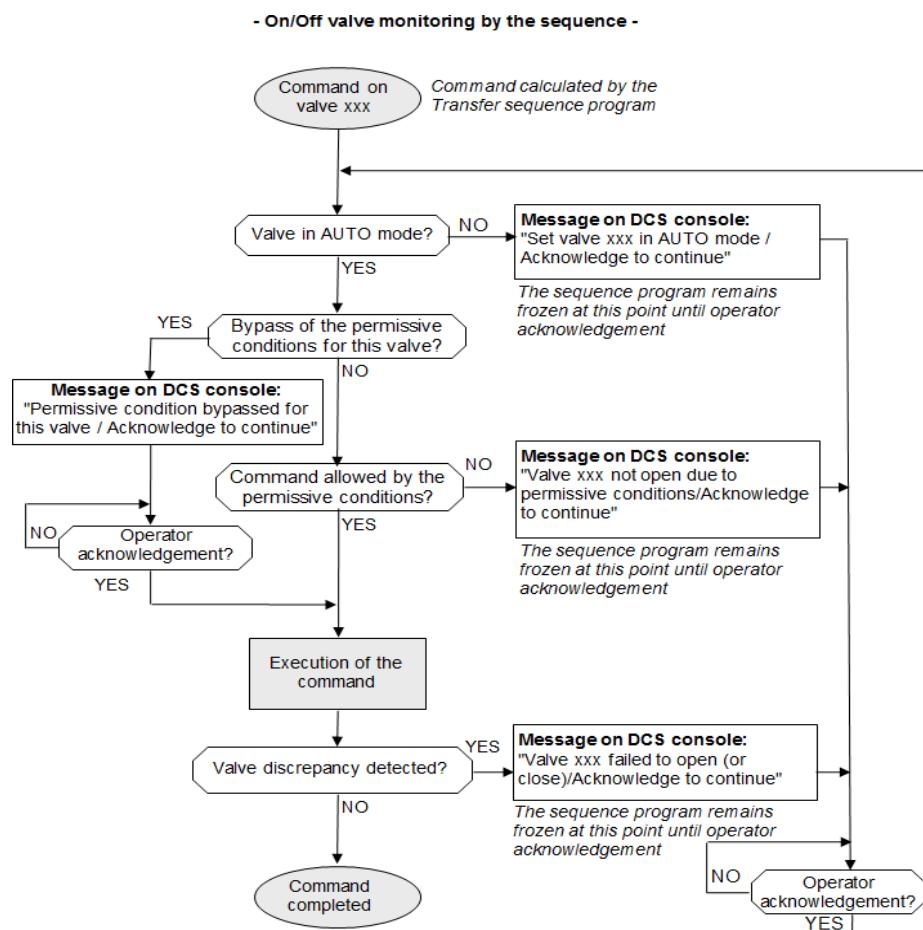
### Test 3: Test of valve discrepancy

The valve limit switches are tested in order to check the command execution. Duration (noted feedback time) is allowed to match the requested position. After the feedback time, if the valve is not in the requested position, the valve is considered failed.

A message (for example: "VALVE xxx FAILED TO CLOSE) is displayed to inform the operator. The discrepancy can be due to a valve failure or to a limit switch failure.

In case of a command by the sequence, if a discrepancy is detected, the sequence is frozen and a message is displayed. After a maintenance operation (on the valve or on its limit switches), the operator can acknowledge to restart the sequence execution.

The sequence tries again to command the valve going through the three tests described here above.



### **3.4.4.1.2      Description Of The Transfer Sequence UC-40020**

- **Introduction**

Periodically when the catalyst in the Upper Surge Drum R41-D-1401 reaches a determined level, it is transferred by gravity to the Lock Hopper R41-D-1402 and then to the Regenerator R41-R-140. The capacity of the Lock Hopper is approximately one hour of catalyst circulation.

However, the pressure in the Upper Surge Drum is much lower than the pressure in the Regenerator. Consequently, in order to allow this transfer, the pressure between the drums must be first equalized.

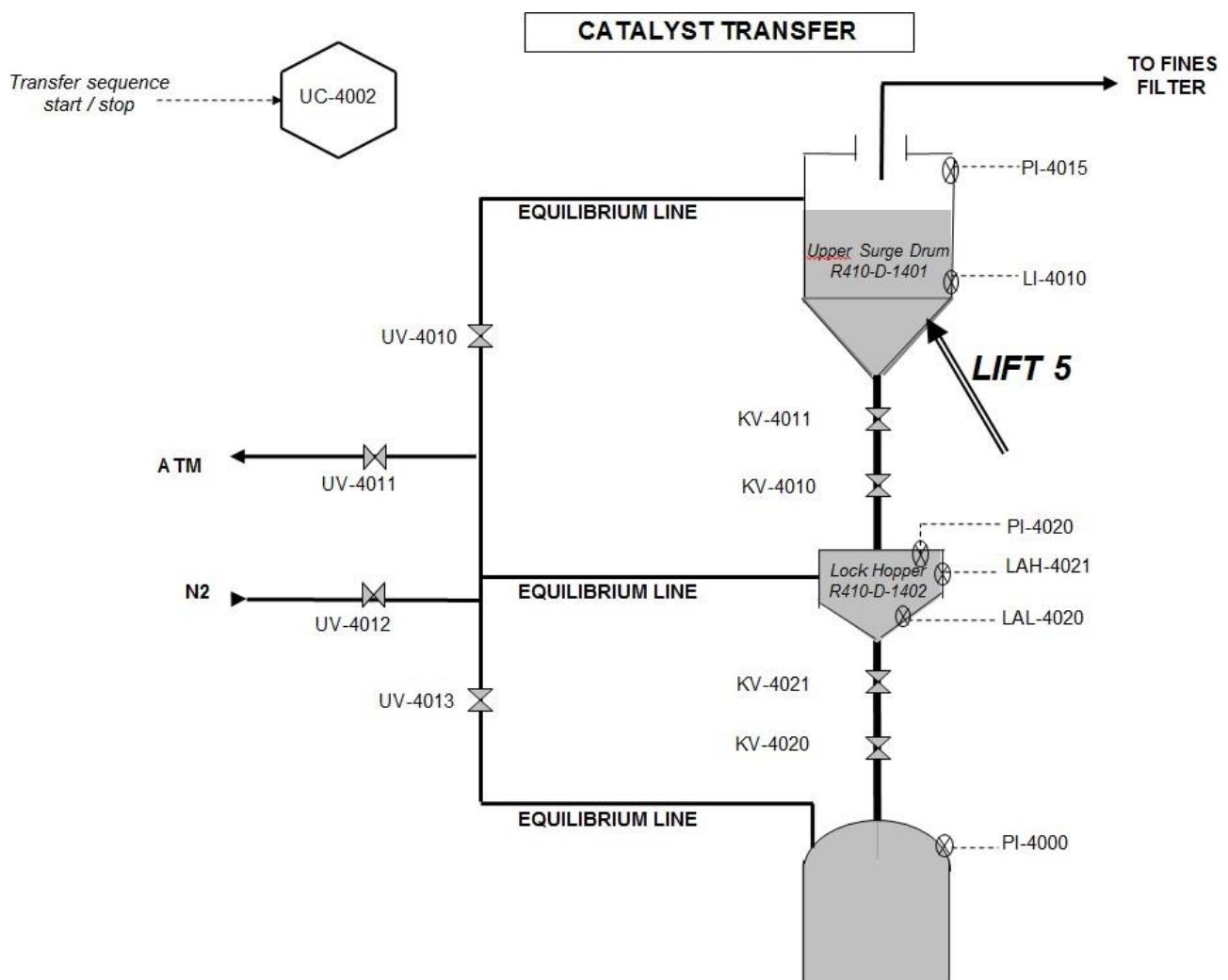
The operations are done automatically. A sequence (noted Transfer sequence UC-40020) is implemented in the DCS. This sequence uses process information (pressure measures, level switches, limit switches...). According to the state of these parameters, the sequence will open or close on/off valves.

This sequence is divided into 2 phases: LOAD and UNLOAD. The LOAD phase is dedicated to the loading of the Lock Hopper from the Upper Surge Drum. The UNLOAD phase is dedicated to the unloading of the Lock Hopper into the regenerator. The duration of each phase is about 20 minutes.

At any time the operator can stop the transfer from the DCS console. The sequence can start with a LOAD or UNLOAD phase.

Permissive conditions are implemented to forbid direct communication between the Regenerator and the Upper Surge Drum R41-D-1401 through the Lock Hopper.

In case of abnormal conditions detected by the sequence (incorrect valve mode, permissive conditions, valve limit switch failure, instrument failure or process trouble), the sequence remains frozen at its current order. After resolution of the problem (maintenance operation, correction of operating parameters...) the operator can acknowledge to let the sequence continue or request the sequence stop.



- **Sequence interlocking**

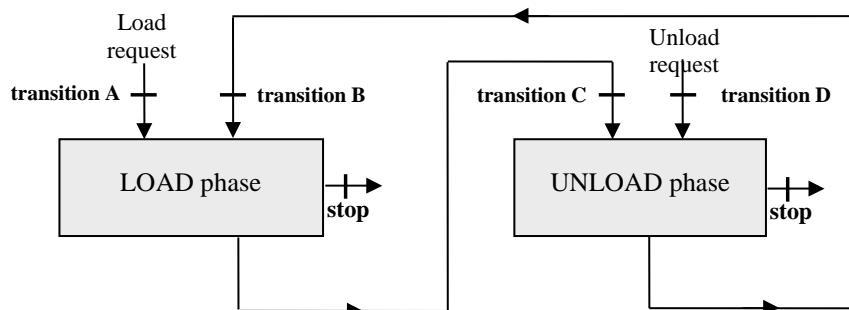
As explained previously, the sequence is divided in 2 phases (LOAD and UNLOAD) which are alternatively executed. In normal operation, this cycle is running permanently.

The LOAD phase can be started through the transition A or the transition B and the UNLOAD phase execution can be started through the transition C or the transition D.

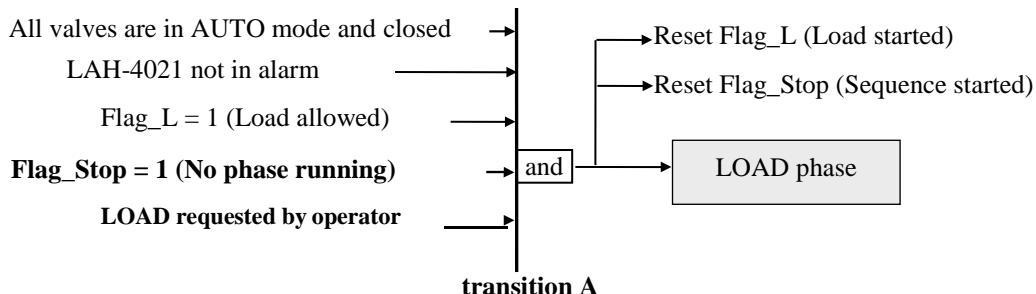
A system of flags is foreseen in order to avoid simultaneous execution of both phases.

- FLAG\_L: This flag is used to forbid starting the LOAD phase if the Unload phase is currently running. FLAG\_L is set to 1 (= Load allowed) at the initialization of the automation program, at the end of the UNLOAD phase or when the sequence is stopped.
- FLAG\_U: This flag is used to forbid starting the UNLOAD phase if the LOAD phase is currently running. FLAG\_U is set to 1 (= Unload allowed) at the initialization of the automation program, at the end of the LOAD phase or when the sequence is stopped.
- FLAG\_STOP: This flag is used to forbid starting the LOAD or the UNLOAD phase if one of these phases is already started.

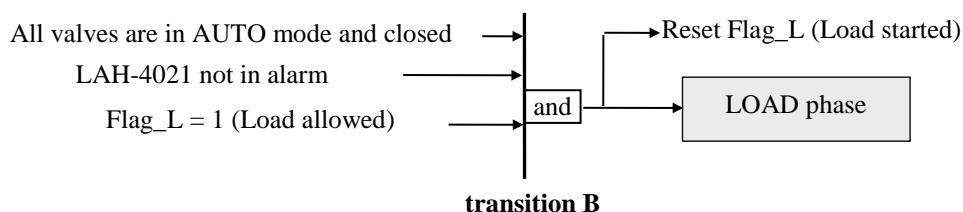
FLAG\_STOP is set to 1 (= No phase running) at the initialization of the automation program or when the sequence is stopped.



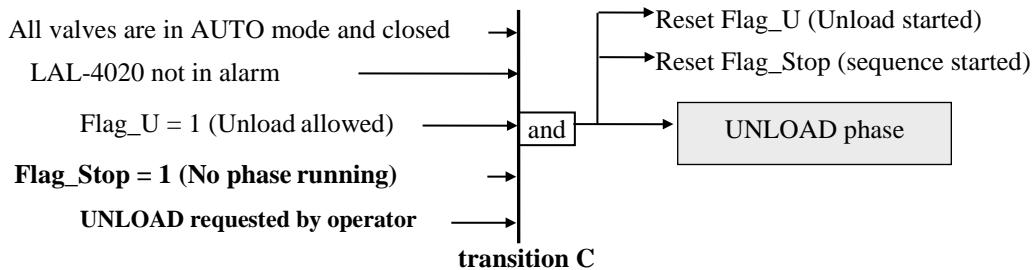
#### Description of transition A (Load phase requested by operator)



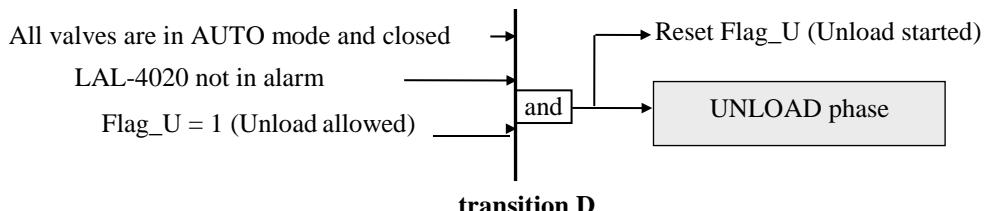
#### Description of transition B (Load phase after Unload phase execution)



#### Description of transition C (Unload phase requested by operator)



#### Description of transition D (Unload phase after Load phase execution)



- **Initialization of the Transfer sequence**

If valves are in calibration mode or in test mode or if some limit switches are bypassed, the program is frozen and a warning message is displayed. After operator acknowledgement, the program continues its execution.

During this initialization, the flags FLAG\_L, FLAG\_U and FLAG\_STOP are set to 1 to allow starting a phase.

- **Conditions checked before execution of LOAD and UNLOAD phases**

Before starting the execution of a phase, the automation program checks that conditions (valves, level switches...) are correct. If one of these conditions is not correct, the automation program is frozen and a message is displayed.

Once the problem has been solved, the operator acknowledges and the automation program re-tests all the conditions.

If all conditions are correct, the automation program starts the phase execution.

## **LOAD**

### **Test if conditions are good to start LOAD phase**

- Valves KV-4020, KV-4021, KV-4010, KV-4011, UV-4013, UV-4010, UV-4011, UV-4012 must be in AUTO and closed (test on the command and on the state of the valves)
- Lock hopper must not be full (LAH-4021 not in alarm)
- Phase LOAD must be allowed (FLAG\_L = 1)

### **Load phase**

1. Reset FLAG\_L to 0

2. Check delta pressure between lock hopper (PI-4020) and upper surge drum (PI-4015):

- if PI-4020 > PI-4015 + 0.15 kg/cm<sup>2</sup>

Open purge valve UV-4011 (lock hopper depressurization to atmosphere)

- if PI-4020 is included in [PI-4015 – 0.15 ; PI-4015 + 0.15]

Go directly to step 5 (pressure in lock hopper is correct)

- if PI-4020 < PI-4015 – 0.15 kg/cm<sup>2</sup>

Display a message and wait for stop by operator <sup>(1)</sup>

3. Wait for  $(PI-4015 - 0.15 \text{ kg/cm}^2) \leq PI-4020 \leq (PI-4015 + 0.15 \text{ kg/cm}^2)$
4. Close valve to atmosphere UV-4011
5. Open equilibrium valve UV-4010
6. Wait for LI-4010 > 70 % (enough catalyst in the upper surge drum)
- 7. Open gas tight valve KV-4010 <sup>(2)</sup>**
8. Open catalyst tight valve KV-4011 <sup>(2)</sup> (catalyst will fill up the lock hopper)
- 9. Wait for LAH-4021 in alarm (high level in the lock hopper) <sup>(3)</sup>**
- 10. Close catalyst tight valve KV-4011 <sup>(2)</sup>**
11. Wait 10 seconds
- 12. Close gas tight valve KV-4010 <sup>(2)</sup>**
13. Close equilibrium valve UV-4010.
14. Set FLAG\_U to 1

Go to UNLOAD

- (1) This is an abnormal situation. The operator must stop the sequence and pressurize manually the lock hopper through UV-4012 until pressure equilibrium.
- (2) These valves are special valves. Refer to Valve data sheets for details.
- (3) To compensate for small catalyst level fluctuations in the lock hopper, the sequence should acknowledge high level only after the signal LAH-4021 is on alarm for a few seconds (5 seconds for example).

## **UNLOAD**

**Test if conditions are good to start the UNLOAD phase**

- Valves KV-4020, KV-4021, KV-4010, KV-4011, UV-4013, UV-4010, UV-4011, UV-4012 must be in AUTO and closed (tests on both valve command and valve state)
- Lock hopper must not be empty (LAL-4020 not in alarm)
- Phase UNLOAD must be allowed (FLAG\_U = 1)

## **Unload phase**

1. Reset FLAG\_U to 0
2. Check the delta pressure between lock hopper (PI-4020) and regenerator (PI-4000):
  - if PI-4020 < PI-4000 – 0.15 kg/cm<sup>2</sup>
- Open nitrogen valve UV-4012 (pressurization of the lock hopper)
  - if PI-4020 ≥ PI-4000 – 0.15 kg/cm<sup>2</sup>
- Go directly to step 5 (pressure in lock hopper is correct)
3. Wait for PI-4020 ≥ PI-4000 – 0.15 kg/cm<sup>2</sup>
4. Close pressurization valve UV-4012
5. Open equilibrium valve UV-4013
6. Wait for LI-4000 < 30 % (enough space in the regenerator storage zone)
7. Open gas tight valve KV-4020 (4)
8. Open catalyst tight valve KV-4021 (4) (the catalyst will fill up the regenerator)
9. Wait for LAL-4020 in alarm low (the batch has been transferred in the regenerator)
10. Close catalyst tight valve KV-4021 (4)
11. Wait 10 seconds
12. Close gas tight valve KV-4020 (4)
13. Close equilibrium valve UV-4013
14. Calculations processing (described in paragraph F)
15. Set FLAG\_L to 1

Go to LOAD

- (4) These valves are special valves. Refer to Special Valve data sheets for details.

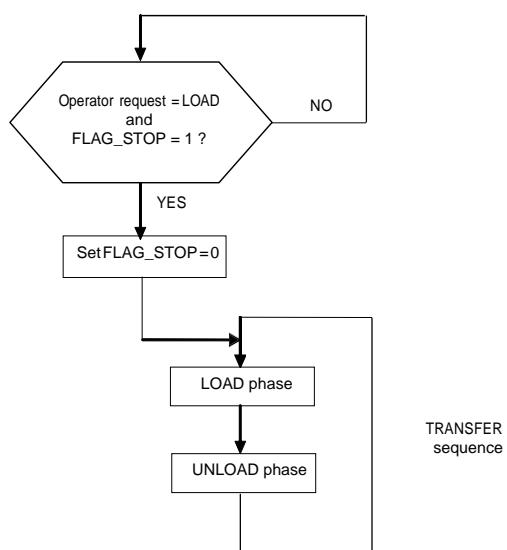
- **Stop and start management**

Two commands on DCS console are present for the operator to start the sequence:

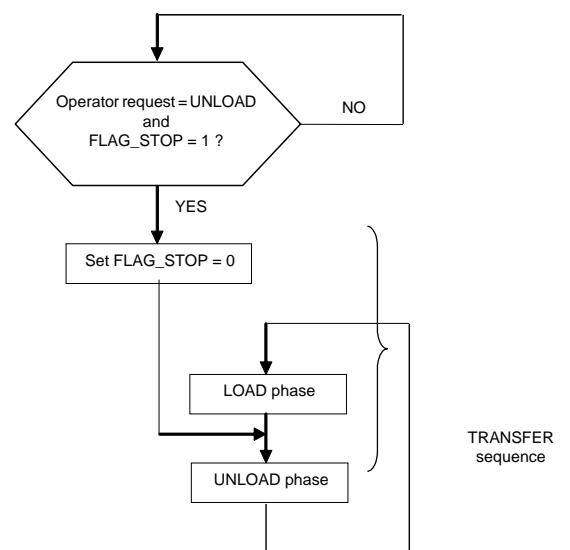
- The Load command is used to start with a LOAD phase.
- The Unload command is used to start with an UNLOAD phase.

As soon as a Load or Unload command is started, a flag is set (FLAG\_STOP) and the only other command which is now allowed is the Stop command. The Load and Unload commands are no more taken into account as long as the sequence is running.

### Load command



### Unload command



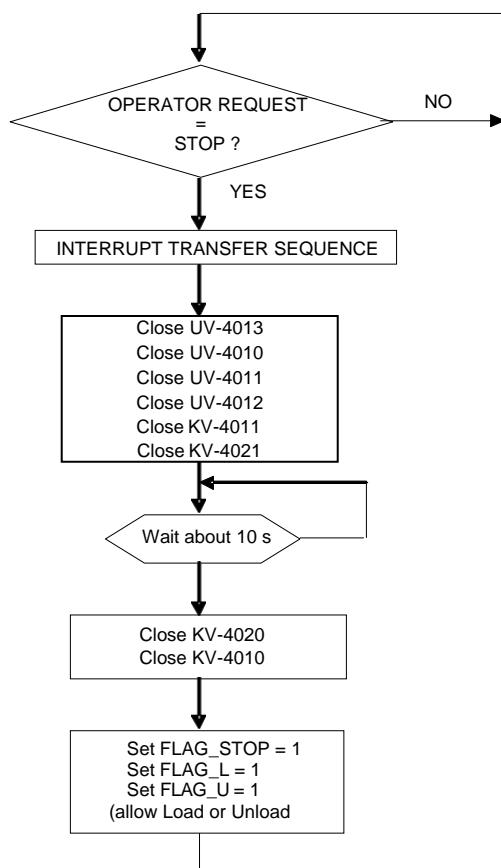
### STOP command

The Stop command on DCS console is used to stop the transfer sequence. The sequence can be stopped by the operator at any time.

When a Stop command is detected, the transfer sequence is interrupted. The on/off valves are closed. If some valves happen to be in manual mode at this time, they are forced in Auto and then closed. A delay (about 10 seconds after closure of catalyst tight valves) is foreseen before closing the gas tight valves KV-4010 and KV-4020

to be sure that the pipe is free of catalyst. Even though gas tight valves are foreseen to operate in emergency situation with a pipe full of catalyst, this way of proceeding will ensure a longer life time of those valves.

When the Stop command is executed, the flags are reset and the Load and Unload commands are again available.



Note: At sequence program start-up, the flags FLAG\_STOP, FLAG\_L, FLAG\_U are initialized to 1

### **3.4.4.1.3      Calculations**

The following data are calculated at the end of each UNLOAD phase in order to improve the tuning of the catalyst circulation and regeneration. These data are displayed on the DCS console in the view dedicated to the catalyst transfer.

- Number of transfers (N)**

This value is incremented at the end of each transfer. It should be possible to reset this value at any time. Counting the catalyst batches is useful at unit start-up to follow-up the catalyst.

- Process durations (Timers 1, 2, 3, 4)**

Two timers (timers 1 and 2) in minutes to measure the duration of the LOAD phase and the UNLOAD phase. After determination of the average phase duration, these timers **are** coupled to an alarm signaling a too high duration (exceeding normal duration by 5 minutes for instance).

Similarly two timers (timers 3 and 4) to follow-up the lock hopper pressurization or depressurization operations.

- Catalyst rate (HQCATA)**

Another timer (timer 5) **is** implemented to measure the duration between two successive catalyst transfers. This timer is started at the end of each UNLOAD phase and reset at the end of the next UNLOAD phase.

This timer allows estimating the catalyst velocity in the unit according to the following formula:

$$\text{HQCATA} = \text{Batch} / \text{Timer5} * 3600 \quad (\text{kg/h})$$

With:

Batch = Mass of a catalyst batch (input by process specialist) (kg) = quantity of catalyst in lock hopper

Timer5 = Duration between two successive transfers (seconds)

- Average catalyst rate during the X last transfers (AQCATA)**

The average catalyst rate during the X latest transfers is calculated at the end of each transfer as follows:

$$\text{AQCATA} = (\text{AQCATA})_{\text{old}} * (1-1/X) + \text{HQCATA} * (1/X) \quad (\text{kg/h})$$

With:

$(AQCATA)_{old}$  = Previous average catalyst rate (kg/h)

$HQCATA$  = Current catalyst rate (kg/h)

X = Number of transfers used for the average calculation (default value: 5)

- **Coke burning rate and coke deposit (CARBON & COKE)**

Input	PID	Tag	Unit
Air injection to calcination	1408	FC-4721	Nm <sup>3</sup> /h
Air injection to second bed	1404	FC-4720	Nm <sup>3</sup> /h
%O <sub>2</sub> in first burning bed	1405	AC-4661	% vol
Catalyst circulation	-	AQCATA	kg/h

N<sub>2</sub> content in % of analysis point S5-4650: Y = 80.95 % (defined by Licensor)

#### Coke burning rate (CARBON)

- If flow-rates are in Nm<sup>3</sup>/h:

$$CARBON = \frac{(FC\ 4720 + FC\ 4721)}{22.414} \cdot \left( 0.21 - \frac{AC\ 4661}{Y} \cdot (1 - 0.21) \right) \cdot \frac{4}{5} \cdot 13 \quad (\text{Nm}^3/\text{h})$$

- If flow-rates are in kg/h:

$$CARBON = \frac{(FC\ 4720 + FC\ 4721)}{MW\ AIR} \cdot \left( 0.21 - \frac{AC\ 4661}{Y} \cdot (1 - 0.21) \right) \cdot \frac{4}{5} \cdot 13 \quad (\text{kg}/\text{h})$$

These formula are deduced from following calculations:

#### Oxygen injected in the regeneration loop (N<sub>1O<sub>2</sub></sub>)

AIR1 = Air make-up injected in second bed = FC4720

AIR2 = Air injected in calcination = FC4721

$N1O_2 = (AIR1 + AIR2) / 22.414 * 0.21$

### Oxygen purged at washing drum (N<sub>2</sub>O<sub>2</sub>)

Nitrogen injected in the regeneration loop:

$$N_{1N_2} = (AIR1 + AIR2) / 22.414 * (1-0.21)$$

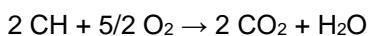
Gas purged at washing drum outlet = N<sub>1N<sub>2</sub></sub> / Y \* 100

$$N_{2O_2} = (%O_2 \text{ at first burning bed}) / 100 * (N_{1N_2} / Y * 100) = AC4661 / 100 * (N_{1N_2} / Y * 100) = AC4661 * N_{1N_2} / Y$$

### Oxygen consumed during coke burning (OXYGEN)

$$OXYGEN = N_{1O_2} - N_{2O_2}$$

### Coke generated (CARBON)



M<sub>CH</sub> = 13 kg/kmol (Molecular weight of coke)

$$CARBON = OXYGEN * M_{CH} * 4/5 = OXYGEN * 13 * 4/5$$

### Coke deposit on catalyst (COKE)

$$COKE = 100 \cdot \frac{CARBON}{HQCAT} \quad (\text{wt \%})$$

#### • Graphic interface

On the DCS console, a view is dedicated to the catalyst transfer operation. This view includes:

- A graphic with the different drums and associated instruments
- 3 TOUCH TARGETS FOR THE OPERATOR COMMANDS (STOP, LOAD AND UNLOAD)
- The state of the sequence (current phase, current step, information messages)
- Some data (number of transfer, catalyst rate, averaged catalyst rate ...)
- 1 touch target for the reset of the data

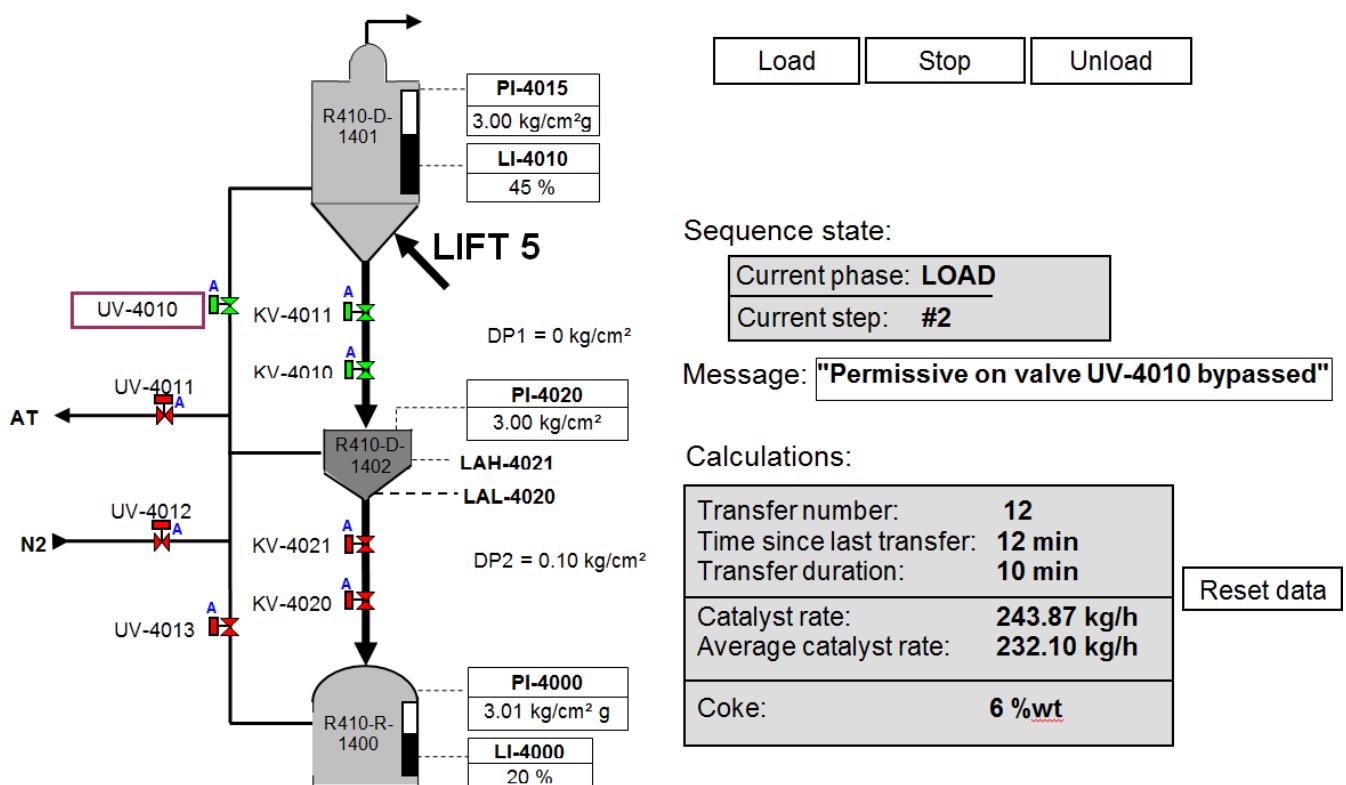
The current mode of the valve is also displayed through a color animation or a symbol (for example, "M" for manual mode and "A" for auto mode).

A color animation is present to provide information about the valve commands and states. For example this animation could be:

- Background in red color = valve closed
- Background in green color = valve open
- Background flashing red = valve closing
- Background flashing green = valve opening
- Background in black color = valve in bad state
- Border in red = close command
- Border in green = open command

The border or the top of the valve can be animated according to the command state while the valve body is animated according to the valve state.

See an example of recommended synoptic on following page.



#### **3.4.4.1.4**      Permissive Conditions

To protect the operation with the transfer valves (KV-4020, KV-4021, KV-4010, KV-4011, UV-4013, UV-4010, UV-4011, UV-4012), permissive conditions are implemented in the DCS. These permissive conditions filter the valve commands in AUTO mode (sequence request) and in MANU mode (operator request).

Depending on the valves configuration, the permissive conditions forbid to open a valve. They do not force any valve to close.

If a valve opening is forbidden by a permissive condition, a message is displayed (for example, "KV-4020 NOT OPENED DUE TO PERMISSIVE CONDITIONS").

For each valve, a bypass of the test of the permissive conditions are provided (under restricted access) to allow valve operation during start-up or maintenance period. The status of these bypasses (set or not) should be indicated on the DCS synoptic views.

When the permissive condition bypass of a valve is set, a message is displayed (for example: "PERMISSIVE CONDITIONS ON VALVE KV-4020 BYPASSED"). When this valve is requested to open, the valve is actuated whatever the results of the permissive conditions test.

The permissive conditions are:

- When either the command or the state of any of these valves KV-4020, KV-4021, UV-4013, UV-4011 or UV-4012 is OPEN, it is forbidden to open the valves KV-4010 or KV-4011 or UV-4010.
- When either the command or the state of any of these valves KV-4010, KV-4011, UV-4010, UV-4011 or UV-4012 is OPEN, it is forbidden to open the valves KV-4020 or KV-4021 or UV-4013.
- When either the command or the state of any of these valves KV-4020, KV-4021, KV-4010, KV-4011, UV-4013, UV-4010 or UV-4012 is OPEN, it is forbidden to open the valve UV-4011.
- When either the command or the state of any of these valves KV-4020, KV-4021, KV-4010, KV-4011, UV-4013, UV-4010 or UV-4011 is OPEN, it is forbidden to open the valve UV-4012.

**WARNING:** These permissive conditions ensure a safe operation of the unit. They prevent different sections from contaminating each other. Therefore they must not be bypassed during normal operation.

### **3.4.4.2 Lift Control**

The purpose of the lift control is:

- to minimize catalyst attrition
- to maintain a continuous catalyst circulation

The total lift gas is divided into two flows:

- The "primary lift" which ensures the lift operation
- The "secondary lift" which governs the catalyst flow-rate by fluidizing catalyst in the lift pot

#### **3.4.4.2.1 Total lift gas flow rate control (for all the lifts)**

The following description is applicable to all loops R41-FC-4x40 ( $x = 0$  to 4)

The loop R41-FC-4x40 is a simple control loop. In case of increase of the flow, the valve R41-FV-4x40 will close to go back to the flow set point and vice-versa. However, a DCS calculation is necessary for each lift to give indication to the operator of the recommended flow set point value.

The total lift gas flow-rate determines the catalyst velocity in the lift pipe. This velocity must be high enough to perform a good catalyst circulation but not too high to avoid excessive catalyst attrition. A typical value for this velocity is 3 m/s.

Operating parameters have an effect on the total lift gas flow-rate and thus on the catalyst velocity. These parameters are the molecular weight of the lift gas, the temperature and the pressure in the lift pot. For example, if the temperature in the lift pot increases, the velocity will increase.

Consequently, the total lift gas flow-rate (controlled by the loop R41-FC-4x40) must be adjusted by the operator according to these operating parameters.

Calculation blocks R41-FY-4x40 are proposed for each lift to determine automatically the flow-rate setpoint in function of the operating parameters (calculations are detailed next page).

This calculated value is displayed for information near the corresponding flow-rate controller on the DCS synoptic. If the operator decides to use the value, he has to input it in the controller setpoint.

The operating parameter to be taken into account in the calculation are the following :

- Operating parameters

Catalyst velocity (=target) (m/s):	Spd	(Input by operator)
Pressure in lift pot (kg/cm <sup>2</sup> g):	P	(Read by DCS)
Temperature in lift pot (°C):	T	(Read by DCS)
Pressure near orifice plate (kg/cm <sup>2</sup> g):	P <sub>orif</sub>	(Read by DCS)
Temperature near orifice plate (°C):	T <sub>orif</sub>	(Read by DCS)
Gas molecular weight (kg/kmol):	MW	(Input by operator)

- Theoretical mass lift gas flow-rate to ensure the catalyst velocity Spd: **(LIFT\_TH)M**

Density of the lift gas under lift pot conditions:

$$\rho_{\text{gas}} = \frac{\text{MW}}{22.414} \cdot \frac{(\text{P} + 1.033)}{1.033} \cdot \frac{273.15}{\text{T} + 273.15} \quad (\text{kg/m}^3)$$

Velocity of the lift gas in the pipe to ensure the catalyst velocity (Spd):

$$\text{Speed} = \text{Spd} + (\text{Free Fall}) = \text{Spd} + \frac{7.67}{\sqrt{\rho_{\text{gas}}}} \quad (\text{m/s})$$

Mass flow-rate of the lift gas to ensure the catalyst velocity (Spd):

$$(\text{LIFT\_TH})_M = \rho_{\text{gas}} \cdot \text{Speed} \cdot \left| \left( \frac{\pi \cdot D^2}{4} \right) \right| \cdot 3600 \quad (\text{kg/h})$$

Note: D is the lift pipe internal diameter = 0.097 m (Pipe: 4", Schedule 80)

- Orifice correction: K<sub>M</sub> or K<sub>V</sub> (no unit)

The operating conditions near the orifice plate can be slightly different from its design conditions.

Correction for **gas in mass:**

$$K_M = \sqrt{\frac{(\text{P}_{\text{orif}} + 1.033)}{(\text{P}_{\text{design}} + 1.033)} \cdot \frac{(\text{T}_{\text{design}} + 273.15)}{(\text{T}_{\text{orif}} + 273.15)} \cdot \frac{\text{MW}}{\text{MW}_{\text{design}}}}$$

Compensation for **gas in volume**

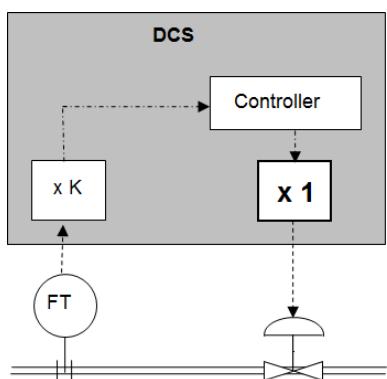
$$K_V = \sqrt{\frac{(\text{P}_{\text{orif}} + 1.033)}{(\text{P}_{\text{design}} + 1.033)} \cdot \frac{(\text{T}_{\text{design}} + 273.15)}{(\text{T}_{\text{orif}} + 273.15)} \cdot \frac{\text{MW}_{\text{design}}}{\text{MW}}}$$

T<sub>design</sub> = Orifice design temperature (°C)

$$P_{\text{design}} = \text{Orifice design pressure (kg/cm}^2 \text{ g)}$$

$$MW_{\text{design}} = \text{Design gas molecular weight (kg/kmol)}$$

If orifice measure is compensated by DCS, no corrective parameter is applied to theoretical setpoint



- Lift gas flow-rate setpoint:  $(LIFT\_SP)_M$  or  $(LIFT\_SP)_V$

$$(LIFT\_SP)_M = K_M \cdot (LIFT\_TH)_M \quad (\text{kg/h})$$

$$(LIFT\_TH)_V = (LIFT\_TH)_M \cdot 22.414 / MW \quad (\text{Nm}^3/\text{h})$$

$$(LIFT\_SP)_V = K_V \cdot (LIFT\_TH)_V \quad (\text{Nm}^3/\text{h})$$

The value **(LIFT\_SP)** should be displayed for information on the synoptic close to the corresponding lift gas flow-rate controller. This value indicates the setpoint which should be used by the flow-rate controller to ensure a catalyst velocity equal to **Spd** in the pipe.

The operating parameters and relevant data inputs for the calculation for each lift are given in the following tables:

Operating parameters for the lift 1 calculation block R41-FY- 4042 (dedicated to R41-FC-4040 – PID 1413)

Catalyst velocity in lift pipe (Spd1)	input by operator FHX-4042B	P&ID n°1413	By default: 3 m/s
Pressure in first lift pot:	PI-4040	P&ID n°1413	5.35 kg/cm <sup>2</sup> g
Temperature in first lift pot:	TI-4040	P&ID n°1413	200 °C
Pressure near orifice plate	PC-4057	P&ID n°1424	8.02 kg/cm <sup>2</sup> g
Temperature near orifice plate	Max (TI-4054A, TI-4054B)	P&ID n°1424	152 °C
T <sub>design</sub> = Orifice design temperature	FE-4040	P&ID n°1413	188 °C
P <sub>design</sub> = Orifice design pressure	FE-4040	P&ID n°1413	9.2 kg/cm <sup>2</sup> g
Gas molecular weight (MWN2)	Input by operator FHX-4042A	P&ID n°1413	By default: 28.01 kg/kmol

Operating parameters for the lift 2 calculation block R41-FY– 4142 (dedicated to R41-FC-4140 – PID 14150)

Catalyst velocity in lift pipe (Spd2)	input by operator FHX-4142B	P&ID n°14150	By default: 3 m/s
Pressure in second lift pot:	PI-4140	P&ID n°14150	4.6 kg/cm <sup>2</sup> g
Temperature in second lift pot:	TI-4140	P&ID n°14150	200 °C
Pressure near orifice plate	Input by process specialist FHX-4142C	P&ID n°1422	6.45 kg/cm <sup>2</sup> g
Temperature near orifice plate	TI-4171	P&ID n°1422	220 °C
T <sub>design</sub> = Orifice design temperature	FE-4140	P&ID n°14150	298 °C
P <sub>design</sub> = Orifice design pressure	FE-4140	P&ID n°14150	8.0 kg/cm <sup>2</sup> g
Gas molecular weight (MWH2)	Input by operator FHX-4142A	P&ID n°14150	By default: 4.43 kg/kmol

Operating parameters for the lift 3 calculation block R41-FY– 4242 (dedicated to R41-FC-4240 – PID 1417)

Catalyst velocity in lift pipe (Spd3)	Input by operator FHX-4242B	P&ID n°1417	By default: 3 m/s
Pressure in third lift pot:	PI-4240	P&ID n°1417	4.15 kg/cm <sup>2</sup> g
Temperature in third lift pot:	TI-4240	P&ID n°1417	200 °C
Pressure near orifice plate	Input by process specialist FHX-4242C	P&ID n°1422	6.44 kg/cm <sup>2</sup> g
Temperature near orifice plate	TI-4171	P&ID n°1422	220 °C
T <sub>design</sub> = Orifice design temperature	FE-4240	P&ID n°1417	298 °C
P <sub>design</sub> = Orifice design pressure	FE-4240	P&ID n°1417	8.0 kg/cm <sup>2</sup> g
Gas molecular weight (MWH2)	Input by operator FHX-4242A	P&ID n°1417	By default: 4.43 kg/kmol

Operating parameters for the lift 4 calculation block R41-FY-4342 (dedicated to R41-FC-4340 – PID 1419)

Catalyst velocity in lift pipe (Spd4)	Input by operator FHX-4342B	P&ID n°1419	By default: 3 m/s
Pressure in fourth lift pot:	PI-4340	P&ID n°1419	3.7 kg/cm <sup>2</sup> g
Temperature in fourth lift pot:	TI-4340	P&ID n°1419	200 °C
Pressure near orifice plate	Input by process specialist FHX-4342C	P&ID n°1422	6.44 kg/cm <sup>2</sup> g
Temperature near orifice plate	TI-4171	P&ID n°1422	220 °C
T <sub>design</sub> = Orifice design temperature	FE-4340	P&ID n°1419	298 °C
P <sub>design</sub> = Orifice design pressure	FE-4340	P&ID n°1419	8.0 kg/cm <sup>2</sup> g
Gas molecular weight (MWH2)	Input by operator FHX-4342A	P&ID n°1419	By default: 4.43 kg/kmol

Operating parameters for the lift 5 calculation block R41-FY-4442 (dedicated to R41-FC-4440 – PID 1421)

Catalyst velocity in lift pipe (Spd5)	Input by operator FHX-4442B	P&ID n°1421	By default: 3 m/s
Pressure in fifth lift pot:	PI-4440	P&ID n°1421	3.2 kg/cm <sup>2</sup> g
Temperature in fifth lift pot:	TI-4440	P&ID n°1421	200 °C
Pressure near orifice plate	PC-4057	P&ID n°1424	8.02 kg/cm <sup>2</sup> g
Temperature near orifice plate	Max (TI-4054A, TI-4054B)	P&ID n°1424	152 °C
T <sub>design</sub> = Orifice design temperature	FE-4440	P&ID n°1421	188 °C
P <sub>design</sub> = Orifice design pressure	FE-4440	P&ID n°1421	9.2 kg/cm <sup>2</sup> g
Gas molecular weight (MWN2)	Input by operator FHX-4442A	P&ID n°1421	By default: 28.01 kg/kmol

### 3.4.4.2.2 Catalyst level control (for all lifts except lift 1)

Upper hoppers are provided at the top of the reactors in order to compensate for the difference of catalyst flow-rate in the lifts.

To have a continuous catalyst circulation, the level in each upper hopper is controlled by a LC cascaded to the PDC of the following secondary lift. LC is the master controller and PDC is the slave controller

When the level in the upper hopper is higher than the setpoint, the LC will increase the PDC setpoint. The valve PDV will open and the catalyst flow-rate will increase in the following lift line. Consequently, the level in the upper hopper will decrease.

When the level in the upper hopper is lower than the setpoint, the LC will decrease the PDC setpoint. The valve PDV will close and the catalyst flow-rate will decrease in the following lift line. Consequently, the level in the upper hopper will increase.

This description is applicable to the fourth level controllers summarized in the following table:

Service	Process value master controller (AI)	Master controller tag (PID)	Process value slave controller (AI)	Slave controller tag (secondary lift DP control) (PID)	Actuator tag	Ref PID
First upper hopper level control	R41-LT-4110	R41-LC-4110	R41-PDT-4141	R41-PDC-4141	R41-PDV-4141	1414 14150
Second upper hopper level control	R41-LT-4220	R41-LC-4220	R41-PDT-4241	R41-PDC-4241	R41-PDV-4241	1416 1417
Third upper hopper level control	R41-LT-4320	R41-LC-4320	R41-PDT-4341	R41-PDC-4341	R41-PDV-4341	1418 1419
Fourth upper hopper level control	R41-LT-4420	R41-LC-4420	R41-PDT-4441	R41-PDC-4441	R41-PDV-4441	1420 1421

### 3.4.4.2.3 Graphic Interface Example

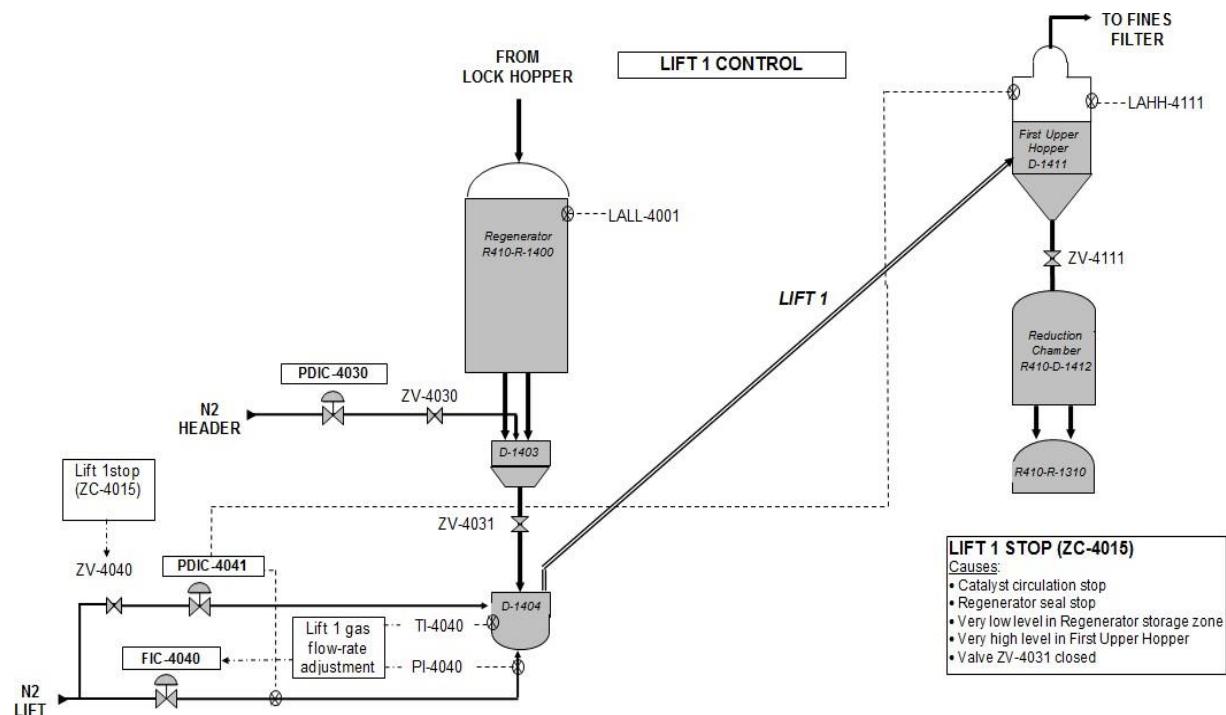
On the DCS consoles, a view displaying all the lifts is useful for a convenient follow-up of the catalyst circulation. This view should also display the controllers PDIC-4733 (PID-1409) and PDIC-4055 (PID-1425) whose actions are directly linked to the circulation.

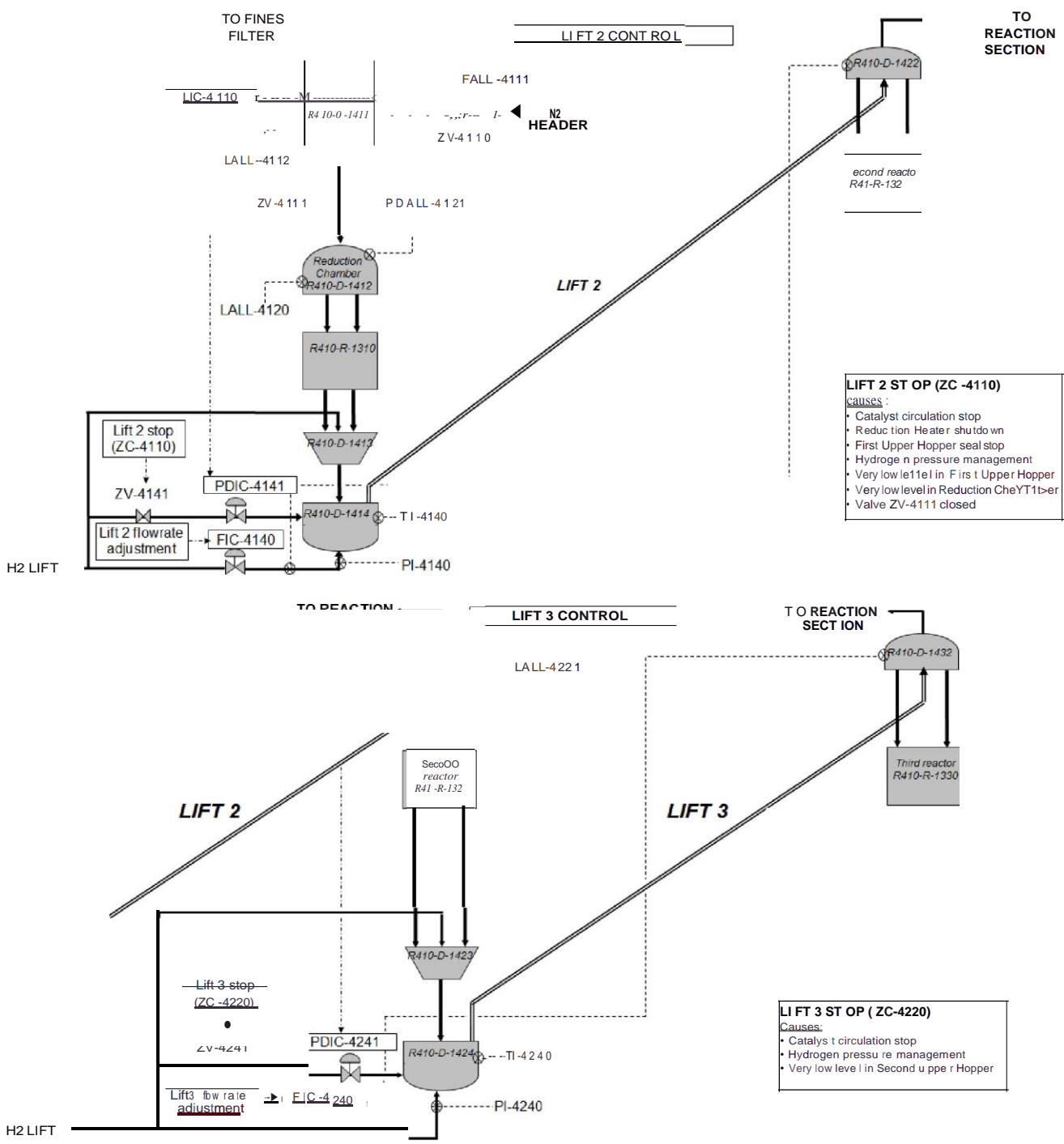
A view for each lift is implemented. Some examples are given in the following pages.

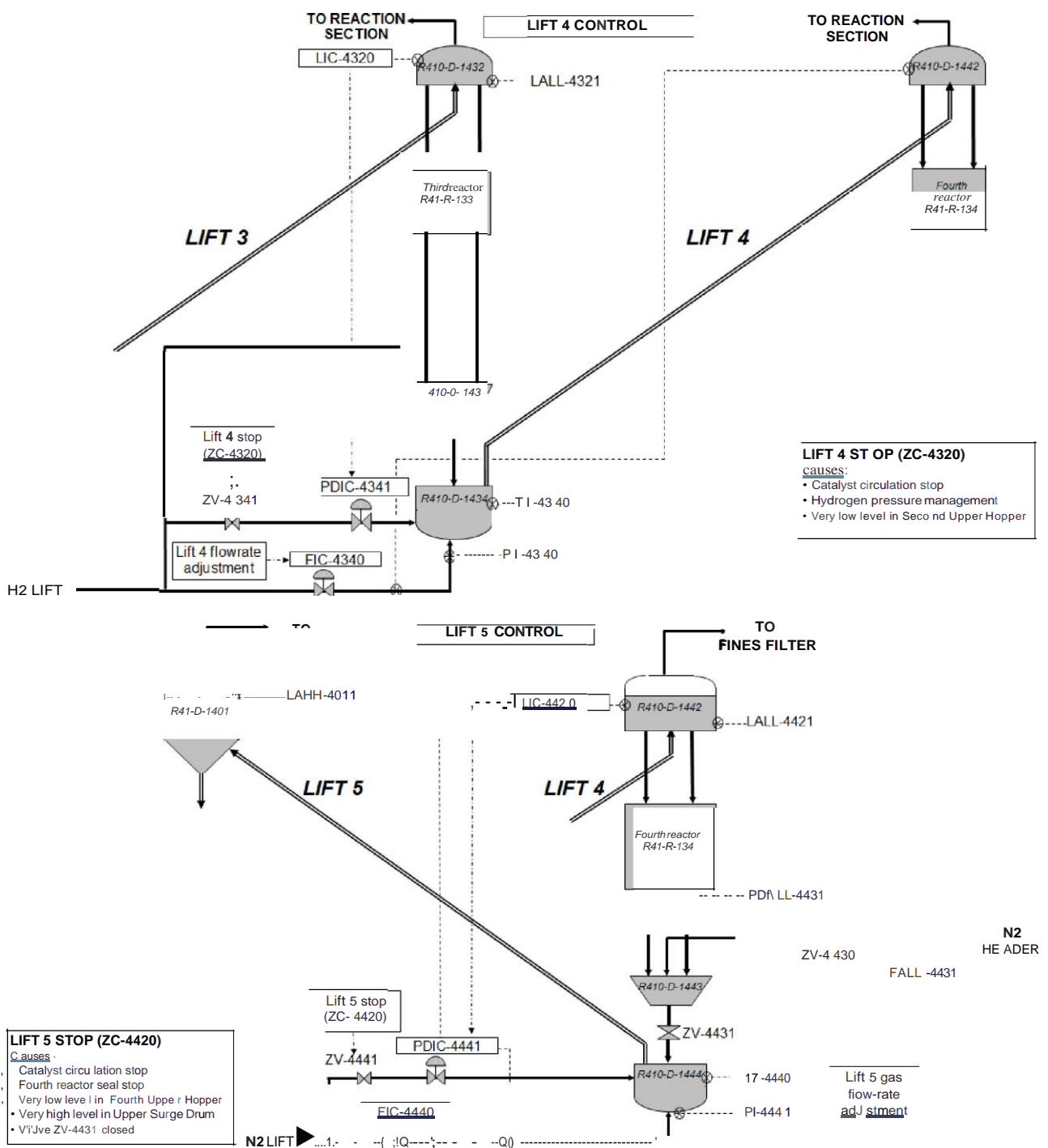
Regarding the catalyst levels in the drums, the drums always full of catalyst can be displayed as full. For the other drums, if a level sensor exists, the content of the drum can be displayed with a barograph linked to the level measure.

The view displays as well the ZV valves which close in case of lift shutdown (refer to cause and effect matrix). When an abnormal operating condition for a lift (very low level in an upper hopper for example) is detected or on operator request, the lift is automatically stopped by a safety. The lift safety closes the valve ZV on the secondary lift line by action on its solenoid. There is one safety per lift and one overall safety called "catalyst circulation stop" which stops all the lifts at the same time. When all the stop conditions have disappeared and when the safety has been reset (action via ESD), the corresponding valve ZV can be opened again.

Operator action is needed to restore the LC/PDC cascade and re-establish the circulation.







### **3.4.4.3    Regeneration Control**

#### **3.4.4.3.1      Oxygen Content Control**

##### Regeneration Loop Oxygen Content Control AC-4661

This objective of this loop is to maintain oxygen content at correct value in the regenerator, the final adjustment parameter being the air flowrate sent to regeneration via FV-4721. This control can be applied under two different modes:

- Standard mode
- Blackburn mode

The Blackburn mode is a safety mode which is used during start-up or in case of abnormal event (coke upset on catalyst). This mode is activated by ESD in case of operation upset or at DCS by the operator via the standard/blackburn mode selector R41-HS-4731, in start-up case for instance.

In blackburn mode, no air is injected in the calcination and oxychlorination zone and air from FC-4721 is injected directly in the first burning bed. This is achieved by inverting the position of the valves ZV-4720 & ZV-4721 compared with the standard operating mode.

- **Standard Mode**

The selector R41-HS-4731 is in standard mode.

In standard mode, the analyzer AC-4661 (setpoint  $\approx$  0.8% vol. O<sub>2</sub>) at first burning bed inlet is cascaded to analyzer AC-4730 (setpoint  $\approx$  9.10 % vol. O<sub>2</sub>) at calcination inlet which is itself cascaded to FC-4721. The AC-4661 is the master controller of AC-4730 which is the master controller of FC-4721.

In case of increase of the process value (increased oxygen content at AC-4661), the set point of AC-4730 **will** decrease and consequently the set point of FC-4721 **will** decrease.

In case of decrease of the process value (decreased oxygen content at AC-4661), the set point of AC-4730 **will** increase and consequently the set point of FC-4721 **will** increase.

- **Blackburning Mode**

The selector R41-HS-4731 is in blackburning mode.

Analyzer AC-4661 (setpoint  $\approx$  0.8% vol. O<sub>2</sub>) at first burning bed inlet is cascaded to FC-4721 while the controller AC-4730 is disabled.

The master controller is R41-AC-4661 and the slave controller is FC-4721.

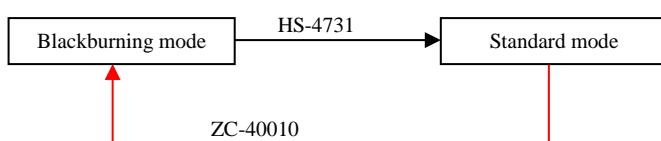
In case of increase of the process value (increased oxygen content at AC-4661), the set point of FC-4721 **will** decrease. In case of decrease of the process value (decreased oxygen content at AC-4661), the set point of FC-4721 **will** increase.

The activation of the blackburning control mode by the selector R41-HS-4731 activates the logic ZC-40010 at ESD. This logic will open the valve ZV-4720 and close the valve ZV-4721 (via ESD) and activates the chlorination shutdown (refer to cause & effect matrix) allowing to operate the unit during some hours without sending air to the calcination and the oxychlorination zones while the operator tunes the unit to restore a normal coke level on the catalyst.

- **Mode management**

During unit start-up, the regeneration loop is first established in Blackburning mode. When normal conditions are reached, operation people switch manually with HS-4731 to Standard mode so that standard mode control loop is activated (cascade AC-4661 => AC-4730 => FC-4721 is activated). This action **will** also reset the ZC-4721 & ZC-4720 in their standard mode position (ZC-4720 closed and ZC-4721 open).

In case of coke upset, the mode returns automatically to Blackburning by action of the safety ZC-40010 (refer cause and effect diagram for further details).



### Oxygen Content Control At Second Burning Bed Inlet AC-4003

Air make-up controlled by FC-4720 is foreseen at second burning bed. To control the oxygen content at the second burning bed inlet, the analyzer AC-4003 (setpoint  $\approx 0.8\%$  vol.) is cascaded on the FC-4720.

The master controller is R41-AC-4003 and the slave controller is FC-4720.

In case of increase of the process value (increased oxygen content at AC-4003), the set point of FC-4720 **will** decrease. In case of decrease of the process value (decreased oxygen content at AC-4003), the set point of FC-4720 **will** increase.

### Oxygen Content Calculation In Oxychlorination Zone UC-4681

The function block UC-4680 is foreseen to determine the oxygen content in the oxychlorination zone ( $\%O_2$ )<sub>oxy</sub> in function of the air flow-rate injected in the calcination zone.

The content calculated is displayed for information on the corresponding view to help the process specialists tuning the unit.

The calculations are as follows:

$$(\%O_2)_{oxy} = \frac{(FC-4680) \cdot (AC-4661) + (FC-4730) \cdot (AC-4730)}{(FC-4680) + (FC-4730)} \quad (\% \text{ vol})$$

With,

(AC-4661) : Oxygen content at first burning bed inlet in % vol.

(AC-4730) : Oxygen content in calcination inlet in % vol.

(FC-4680) : Oxychlorination inlet flow-rate in Nm<sup>3</sup>/h

(FC-4730) : Calcination inlet flow-rate in Nm<sup>3</sup>/h

Note: If the flow-rates are measured in kg/h in the DCS, the calculations should include the density.

Density (oxychlorination inlet) at flowing conditions (5.35 kg/cm<sup>2</sup> g, 510 °C) = 2.928 kg/m<sup>3</sup>

Density (calcination inlet) at flowing conditions (5.45 kg/cm<sup>2</sup> g, 520 °C) = 2.876 kg/m<sup>3</sup>

### **3.4.4.3.2      Pressure Control**

#### **Nitrogen Loop Pressure Control R41-PDC-4056**

This control allows nitrogen loop pressure to follow variations of pressure of the Reaction section and thus enables the catalyst circulation in the fifth lift. The pressure in the nitrogen compressor KO drum R41-D-1405 must be lower (about 1.15 kg/cm<sup>2</sup>g, to be confirmed during start-up) than the pressure at the last reactor outlet. For this purpose, the delta pressure between the nitrogen compressor KO drum and the pressure at the last reactor outlet is controlled by PDC-4056 (Normal mode) acting in split range on valves PDV 4055 A & B.

During start-up or other transient operations, the nitrogen loop pressure control is performed by a simple pressure control (PC-4053) acting in split range on valves PDV 4055 A & B.

The operator can switch with PDHS-4055 selector from the control in normal mode (PDC-4056) to the control in start-up mode (PC-4053) and reciprocally.

- **Normal mode :**

Selector PDHS-4055 is on normal mode.

PDC-4056.measure = PI-4432 (reactor outlet) – PC-4053 OP (KO drum).

PDC-4056 is acting in split range through PDY 4055A on the nitrogen injection valve from network and through PDY 4055B on the gas purge.

- **Start-up mode mode :**

Selector PDHS-4055 is on start-up mode.

PC-4053 is acting in split range through PDY 4055A on the nitrogen injection valve from network and through PDY-4055B on the gas purge.

- **Mode management**

The switch between the two control modes must be done without jump. The output of the controller currently used must be permanently copied (tracking) by the other controller.

#### **Split-range PDY-4055 A/B requirements**

##### **In Normal mode:**

If the differential pressure value increases too much, the nitrogen injection valve PDV-4055A will open.

If the differential pressure value decreases too much, the gas purge valve PDV-4055B will open.

In steady state condition, the nitrogen valve is slightly open (compensation of nitrogen loss in the unit) and the gas purge valve is closed.

**In start-up mode :**

If the pressure in the nitrogen KO drum increases too much, the gas purge valve PDV-4055B will open.

If the pressure in the nitrogen KO drum decreases too much, the nitrogen injection valve PDV-4055A will open.

**Regeneration Loop Pressure Control R41-PDC-4733**

This control allows regeneration loop pressure to follow variations of pressure of the Reaction section and thus enables the catalyst circulation in the first lift. The pressure in the regeneration loop must be higher (about 0.60 kg/cm<sup>2</sup>g, to be confirmed during start-up) than the pressure in the reaction section. For this purpose, the delta pressure between the calcination heater outlet (PT-4730) and the first reactor inlet (PI-4123) is controlled by PDC-4733 (Normal mode) acting in split range on valves PDV 4731 A & B.

During start-up or other transient operations, the regenerator loop pressure control is performed by a simple pressure control (PC-4730) acting in split range on valves PDV 4731 A & B.

The operator can switch with PDHS-4732 selector from the control in normal mode (PDC-4733) to the control in start-up mode (PC-4730) and reciprocally.

**• Normal mode :**

Selector PDHS-4732 is on normal mode.

PDC-4733.measure = PC-4730 OP (calcination inlet) – PI-4123 (reactor inlet).

PDC-4733 is acting in split range through PDY 4731B on the nitrogen injection valve at top of the washing drum and through PDY 4731A on the gas purge.

**• Start-up mode mode :**

Selector PDHS-4732 is on start-up mode.

PC-4730 is acting in split range through PDY 4731B on the nitrogen injection valve at top of the washing drum and through PDY 4731A on the gas purge.

**• Mode management**

The switch between the two control mode must be done without jump. The output of the controller currently used must be permanently copied (tracking) by the other controller.

- **Split-range PDY-4731 A/B requirements**

If the differential pressure value (normal mode) or if the pressure in the regeneration loop (start-up mode) increases, the gas purge valve PDV-4731A will open. If the differential pressure value (normal mode) or if the pressure in the regeneration loop (start-up mode) decreases, the nitrogen injection valve PDV-4731B will open. In steady state conditions, the nitrogen injection valve is closed and the gas purge valve is slightly open.

#### **3.4.4.3.3      Delta Pressure Between Burning And Oxychlorination Zones R41-PDC-40090**

To prevent oxychlorination gas with high content in oxygen from flowing upward in the burning zone, the pressure must be slightly higher (typically 0.10 kg/cm<sup>2</sup>, to be confirmed during start-up) in the burning zone than in the oxychlorination zone.

The delta pressure between the burning zone and the oxychlorination zone is controlled by PDC-40090 which is acting in split range on the valve PDV-40090A at burning zone outlet and on the valve PDV-40090B at oxychlorination zone outlet.

In steady state conditions, both valves are open.

If the delta pressure increases too much, the controller will close the oxychlorination outlet valve PDV-40090B. If the delta pressure decreases too much, the controller will close the burning outlet valve PDV-40090A.

#### **3.4.4.3.4      Regeneration Loop Compressor Spill-Back Control FC-466**

During normal operation, the valve FV-466 on the compressor spill-back is used to adjust the flow-rate in the regeneration loop. If flowrate value at FT-466 increases, the valve FV-466 opens. If the flowrate value at FT- 466 decreases, the valve FV-466 closes.

If the pressure at the regeneration loop compressor outlet becomes too high (set point: 6.55 kg/cm<sup>2</sup> g normal pressure plus 1 kg/cm<sup>2</sup>, to be confirmed during start-up), the controller PC-4653 overrides FC 466 and controls directly the valve. The control valve will open until the pressure recovers a normal value.

#### **3.4.4.4 Seal Control**

##### **3.4.4.4.1 Regenerator Catalyst Storage Zone Seal Control R41-PDC-40010**

The purpose of this control is to prevent the gas rich in oxygen injected in the first burning bed of the regenerator R41-R-140 from flowing upward into the storage zone and then into the lock hopper R41-D-1402 (risk of oxygen contamination<sup>12</sup> of the nitrogen network).

The delta pressure (pressure in regenerator storage zone minus pressure at first burning bed inlet) is controlled by PDC-40010 which is acting on the nitrogen flow-rate injected at the top of the regenerator. The pressure in the regenerator storage area must be slightly higher than the pressure in the first burning bed inlet (typically 0.10 kg/cm<sup>2</sup>, to be confirmed during start-up).

If the delta pressure is increasing, the controller will close the valve PDV-40010. Reciprocally if the delta pressure is decreasing, the valve will open.

##### **3.4.4.4.2 Regenerator Bottom Seal Control R41-PDC-403**

The purpose of this control is to prevent the gas rich in oxygen in the regenerator R41-R-140 from flowing down into the first lift pot R41-D-1404 (risk of oxygen contamination of the nitrogen network).

The delta pressure between the regenerator and the first lower hopper R41-D-1403 is controlled by PDC-403 which is acting on the nitrogen injected into the lower hopper. The pressure in the lower hopper must be slightly higher than the pressure in the regenerator (typically 0.05 kg/cm<sup>2</sup>, to be confirmed during start-up).

If the delta pressure is increasing, the controller will close the valve PDV-403 to decrease the pressure in the lower hopper. Reciprocally if the delta pressure is decreasing, the valve will open.

##### **3.4.4.4.3 First Upper Hopper Seal Control R41-PDC-412**

The purpose of this control is to over-pressurize the first upper hopper R41-D-1411 in order to prevent the hydrogen rich gas injected in the reduction chamber R41-D-1412 from flowing upward into the first upper hopper (risk of hydrogen contamination of the nitrogen network).

The delta pressure between the first upper hopper and the reduction chamber is controlled by PDC-412 which is acting on the valve PDV-412 located at the outlet of the first upper hopper fines filter R41-F-

14150. The pressure in the upper hopper is slightly higher than the pressure in the reduction chamber (typically 0.15 kg/cm<sup>2</sup>, to be confirmed during start-up).

If the delta pressure is increasing, the controller will open the valve PDV-412 to decrease the pressure in the upper hopper. Reciprocally if the delta pressure is decreasing, the valve will close.

#### **3.4.4.4.4      Delta pressure between fifth lower hopper and fifth lift pot R41-PDC-44330**

There is a control of the delta pressure between the fifth lower hopper R41-D-1443 and the fifth lift pot R41-D-1444 to avoid process disturbances on the fifth lift.

The delta pressure (pressure in the lower hopper minus pressure in the lift pot) is controlled by PDC-44330 which is acting on the valve PDV-44330 located at the upper surge drum fines filter R41-F-1405. The pressure in the lower hopper is slightly higher than the pressure in the lift pot (typically 0.15 kg/cm<sup>2</sup>, to be confirmed during start-up).

If the delta pressure is increasing, the controller will close the valve PDV-44330 to increase the pressure in the lift pot. Reciprocally if the delta pressure is decreasing, the valve will open.

#### **3.4.4.4.5      Delta pressure between reduction chamber and first reactor R41-PDC-41220**

There is a control of the delta pressure between the reduction chamber R41-D-1412 and the first reactor R41-R-131 in order to prevent feed gas from flowing upward into the reduction chamber instead of flowing down into the reactor. The pressure in the reduction chamber is slightly higher (typically 0.10 kg/cm<sup>2</sup>, to be confirmed during start-up) than the pressure in the first reactor.

PDC-41220 maintains the delta pressure (reduction chamber pressure minus first reactor pressure) by acting on the valve PDV-41220 at the reduction chamber outlet.

If the delta pressure is increasing, the controller will open the valve PDV-41220 to decrease the pressure in the reduction chamber. Reciprocally if the delta pressure decreases, the valve will close.

#### **3.4.4.6      Caustic Recycle Pumps R41-P-1460A/B Autostart UC-460**

Objective of this loop is to activate the autostart of the stand-by Caustic Recycle Pump R41-P-1460A/B in case of low pressure at pump discharge. During normal operation one out of two pumps is running and the other one is in stand-by. The low pressure signal from the running pumps discharge R41-PT-4601 activates the autostart logic R41-UC-460.

#### **3.4.4.7      Minimum Flow Rate And Variable Speed Of Motor (Elutriation Blower R41-B-14150)**

The control of the section is done on the discharge side of Elutriation Blower (R41-B-14150). The controller FC-4150 acts in split range on spill back valve FV-4150 and on B-14150 speed controller.

In normal operation valve FV-4150 is normally open (720 kg/h) and FC-4150 acts on speed of Blower. When the discharge flow of the Elutriation Blower (R41-B-14150) above the typical operating point, the controller FC-4150 acts on FY-4151 to control the speed of rotation of blower.

When the discharge flow of the Elutriation Blower (R41-B-14150) increases, the controller FC-4150 provides the signal to FY-4151 in order to reduce the speed. When blower reaches the minimum flowrate, signal is sent to FY-4150 to increase the flow rate of blower by opening the valve FV-4150 in the By-pass line from discharge side to suction side of the blower.

### **3.4.5 R41-5 PSA Section Control Narrative**

**For detailed control narrative of R41-5 Refer latest revision of S-EP-R41-1223-2008**

#### **3.4.5.1 PSA Feed Gas Flow Pressure Control Scheme**

The objective of this loop is to control the flow going to PSA Package R41-PK-1510 in order not to exceed PSA Package capacity depending on PSA operating mode.

The controller Set Point value (maximum PSA feed flow) is sent by PSA Package R41-PK-1510 PLC.

In case the PV (from R41-FT-5101) exceeds the controller Set Point, the valve R41-FV-5101 opens and discharges the excess gas to HP flare.

High selector R41-FY-5101 acts modulating R41-FV-5101 to flare selecting the higher opening signal from R41-PC-5103 and R41-FC-5101, in order to protect the PSA Package R41-PK-1510 in case of overpressure.

R41-PC-5103 is also used for pressure control during PSA shutdown and start-up.

The increase of both flow or pressure at the vapour outlet of PSA Feed Coalescer R41-D-1501 results in opening of the valve R41-FV-5101. The valve R41-FV-5101 is AFC and is closed during normal operation.

#### **3.4.5.2 Tail Gas Compressor R41-K-152A/B Pressure Control Scheme**

The objective of this loop is to control the upstream pressure of Tail Gas Compressor R41-K-152A/B.

- a) Split range through compressor capacity control and spill over valve R41-PV-5102A.

In normal operating conditions R41-PV-5102A is closed and the whole flowrate is going to Tail Gas Compressor R41-K-152 A/B which is operated under suction pressure control. The Process Value (suction pressure at Tail Gas Compressor R41-K-152A/B) from R41-PT-5102 is sent to controller R41-PC-5102. The controller generates two output in split range:

- the first one to R41-PY-5102B sent to compressor capacity control through low selector R41-PY-5201;
  - the second one to R41-PY-5102A acting on spill over valve R41-PV-5102A which opens only if signal sent to R41-PY-5102B is not enough to meet the Set Point.
- b) Compressor discharge pressure override.

Output from R41-PY-5102B is sent to low selector signal R41-PY-5201 that receives also the Process Value (discharge pressure) from R41-PC-5200 installed at Tail Gas Compressor R41-K-152 A/B discharge. The low

selector compares the two values (from R41-PY-5102B and from R41-PC-5200) and selects the lower one acting, in parallel range, on the two compressors capacity control:

- R41-PY-5200AA/R41-PY-5200AB: split range for Tail Gas Compressor R41-K-152A capacity control;
- R41-PY-5200BA/R41-PY-5200BB: split range for Tail Gas Compressor R41-K-152B capacity control.

A high pressure at compressor suction (at R41-PT-5102) tends to increase compressors capacity.

A high pressure at compressor discharge (at R41-PT-5200) tends to decrease compressors capacity.

The low signal selector R41-PY-5201 selects the lowest signal and adjusts compressors capacity accordingly.

c) Compressor R41-K-152A/B capacity control.

Compressor R41-K-152A/B are oil flooded screw compressor type and each one is regulated by:

- a slide valve (compressor vendor scope) which allows a regulation of the compressor flowrate from 30% to 100% of the compressor design capacity without recirculation of the gas;
- a recycle (spillback) valve (contractor scope) which allows to operate between 0% (full recycle) and 30% of the compressor design capacity.

The recycle loop is always in auto mode when the compressor is in operation but the valve opens only when the compressor **is operating at reduced capacity** and the slide valve is already at or below its minimum position.

On the following graphs is summarized the capacity control for each compressor. Control of slide valve is indicative only and is part of compressor vendor scope of work (please refer to vendor control description).

Train A: the output of the low selector R41-PY-5201 generates a split range between:

- R41-PY-5200AA acting on R41-PV-5200A (R41-K-152A spill back valve);
- R41-PY-5200AB acting on R41-K-152A slide valve

Train B: the output of the low selector R41-PY-5201 generates a split range between:

- R41-PY-5200BA acting on R41-PV-5200B (R41-K-152B spill back valve);
- R41-PY-5200BB acting on R41-K-152B slide valve

### **3.4.6 R41-9 Utility systemcontrol narrative:**

#### **3.4.6.1 Closed Drain HC And Oily Water Level Control**

Objective of this loops is to control the level of Hydrocarbon (HC) and Oily water (OW) sections of closed drain drum R41-D-1000, by an automatic start & stop of relevant pumps (R41-P-1000 and R41-P-1001).

When R41-LT-0001 detects the high HC level in drum, it will automatically start pump R41-P-1000.

When R41-LT-0001 detects the low HC level in drum, it will automatically stop pump R41-P-1000.

When R41-LT-0002 detects the high OW level in drum, it will automatically start pump R41-P-1001.

When R41-LT-0002 detects the low OW level in drum, it will automatically stop pump R41-P-1001.

#### **3.4.6.2 Hot Condensate Pumps Autostart**

Objective of this loop is to activate the auto start of the stand-by Hot Condensate Pump (R41-P-1640 A/B). During normal operation one pump is running and one is in stand-by. The low pressure signal from the running pump discharge (R41-PT-6400) activates the auto start logic (R41-UC-6400).

#### **3.4.6.3 OWS Lift Station Level Control and OWS Lift Station Pumps Autostart**

Objective of this loop is starting/stopping the OWS Lift Station Pumps (R41-P-1010 A/B) to to keep the water level in a range between low level (LLL) and high level (HLL).

#### **Action:**

- The main pump is determined by Selector R41-HS-0101.
- The logic UC-0100 starts main OWS Lift Station Pump at high liquid level (HLL) detected by LT-0100 in the OWS Lift Station sump R41-Z-1010.
- The logic UC-0100 stops main OWS Lift Station Pump at low liquid level (LLL) detected by LT-0100 in the OWS Lift Station sump R41-Z-1010.
- In case main OWS Lift Station Pump failure, the logic UC-0100 starts spare OWS Lift Station Pump at high high liquid level (HHLL) detected by LT-0101 in the OWS Lift Station sump R41-Z-1010.
- The logic UC-0100 stops main and spare OWS Lift Station Pumps at low low liquid level (LLLL) detected by LT-0101 in the OWS Lift Station sump R41-Z-1010.

**During normal operation no pump are running.**

### **Special alarm condition, alarm inhibition**

Level sets for OWS Lift Station Pumps are set to provide the following:

- LAH-0100: Main pump starts
- LAHH-0101: Spare pump starts in case main pump is not started
- LAL-0100: Main pump stop
- LALL-0101 Both pumps stop

#### **3.4.6.4 SYS Lift Station Level control and SYS Lift Station Pumps Autostart**

Objective of this loop is starting/stopping the SYS Lift Station Pumps R41-P-1020 A/B/C (3x50%) to keep the water level in a range between low level (LLL) and high level (HLL).

##### **Action:**

- The spare pump is determined by the 3 position Selector R41-HS-0201 (A means R41-P-1020A, B means R41-P-1020B and C means R41-P-1020C) and automatically the other 2 pumps are selected as main pumps.
- The logic UC-0200 starts first main SYS Lift Station Pumps at normal liquid level (NLL) and the second main SYS Lift Station Pump at high liquid level (HLL), detected by LT-0200 in the SYS Lift Station sump R41-Z-1020.
- In case of one main pump failure, the logic UC-0200 starts the spare SYS Lift Station Pump if low flowrate (FL) is detected by FT-0200, located in the discharge line of SYS Lift Station Pumps, and HLL is detected by LT-0200.
- The logic UC-0200 stops running SYS Lift Station Pumps at low liquid level (LLL) detected by LT-0200 in the SYS Lift station sump R41-Z-1020.
- The logic UC-0200 stops all SYS Lift Station Pumps at low low liquid level (LLLL) detected by LT-0201 in the SYS Lift Station sump R41-Z-1020.

##### **During normal operation no pump are running.**

Once the start command is received by the main SYS Lift Station Pumps, a 15 second timer (configurable) will be initiated. This is to allow the SYS flow to raise and stabilize. After the 15 second timer has expired the SYS discharge pumps flow rate FAL-0200 alarm and action are enabled.

### **Special alarm condition, alarm inhibition**

Level sets for SYS Lift Station Pumps are set to provide the following:

- NLL-0200: First Main Pump Starts
- LAH-0200: Second Main Pump start
- FL-0200 & HLL0200: Spare pump start
- LAL-0200: Running pump stop
- LALL-0201 All pumps stop

#### **3.4.6.5 HP Steam Flow Compensation**

Objective of this loop is to monitor HP Steam flow rate and totalized flow in a time through flow compensation. The process variable (flow rate) corresponds to temperature and pressure measured by R41-TT-6100 and R41-PT-6100 is calculated in R41-FY-6100 and the calculated flow rate is indicated in R41-FI-6100. The totalized flow in a time is monitored through R41-FO-6100.

In normal operation HP steam flow rate is indicated in R41-FI-6100 through flow compensation.

#### **3.4.6.6 MP Steam Flow Compensation**

Objective of this loop is to monitor MP Steam flow rate and totalized flow in a time through flow compensation. The process variable (flow rate) corresponds to temperature and pressure measured by R41-TT-6200 and R41-PT-6200 is calculated in R41-FY-6200 and the calculated flow rate is indicated in R41-FI-6200. The totalized flow in a time is monitored through R41-FO-6200.

In normal operation MP steam flow rate is indicated in R41-FI-6200 through flow compensation.

#### **3.4.6.7 LP Steam Flow Compensation**

Objective of this loop is to monitor LP Steam flow rate and totalized flow in a time through flow compensation. The process variable (flow rate) corresponds to temperature and pressure measured by R41-TT-6300 and R41-PT-6300 is calculated in R41-FY-6300 and the calculated flow rate is indicated in R41-FI-6300. The totalized flow in a time is monitored through R41-FO-6300.

In normal operation LP steam flow rate is indicated in R41-FI-6300 through flow compensation.

### **3.4.6.8 Intermediate SYS Lift Station Level control and Intermediate SYS Lift Station Pumps Autostart**

Objective of this loop is starting/stopping the Intermediate SYS Lift Station Pumps R41-P-1030 A/B/C (3x50%) to keep the water level in a range between low level (LLL) and high level (HLL).

#### **Action:**

- The spare pump is determined by the 3 position Selector R41-HS-0301 (A means R41-P-1030A, B means R41-P-1030B and C means R41-P-1030C) and automatically the other 2 pumps are selected as main pumps.
- The logic UC-0300 starts first main Intermediate SYS Lift Station Pumps at normal liquid level (NLL) and the second main Intermediate SYS Lift Station Pump at high liquid level (HLL), detected by LT-0300 in the SYS Lift Station sump R41-Z-1030.
- In case of one main pump failure, the logic UC-0300 starts the spare Intermediate SYS Lift Station Pump if low flowrate (FL) is detected by FT-0300, located in the discharge line of Intermediate SYS Lift Station Pumps, and HLL is detected by LT-0300.
- The logic UC-0300 stops running Intermediate SYS Lift Station Pumps at low liquid level (LLL) detected by LT-0300 in the SYS Lift station sump R41-Z-1030.
- The logic UC-0300 stops all Intermediate SYS Lift Station Pumps at low low liquid level (LLLL) detected by LT-0301 in the SYS Lift Station sump R41-Z-1030.

**During normal operation no pump are running.**

Once the start command is received by the main Intermediate SYS Lift Station Pumps, a 15 second timer (configurable) will be initiated. This is to allow the SYS flow to raise and stabilize. After the 15 second timer has expired the Intermediate SYS discharge pumps flow rate FAL-0300 alarm and action are enabled.

#### **Special alarm condition, alarm inhibition**

Level sets for SYS Lift Station Pumps are set to provide the following:

- NLL-0300: First Main Pump Starts
- LAH-0300: Second Main Pump start
- FL-0300 & HLL0300: Spare pump start
- LAL-0300: Running pump stop
- LALL-0301 All pumps stop

### **3.4.6.9 SWS Lift Station Level Control and OWS Lift Station Pumps Autostart**

Objective of this loop is starting/stopping the SWS Lift Station Pumps (R41-P-1040 A/B) to keep the water level in a range between low level (LLL) and high level (HLL).

#### **Action:**

- The main pump is determined by Selector R41-HS-0401.
- The logic UC-0400 starts main SWS Lift Station Pump at high liquid level (HLL) detected by LT-0400 in the SWS Lift Station sump R41-Z-1040.
- The logic UC-0400 stops main SWS Lift Station Pump at low liquid level (LLL) detected by LT-0400 in the SWS Lift Station sump R41-Z-1040.
- In case main SWS Lift Station Pump failure, the logic UC-0400 starts spare SWS Lift Station Pump at high liquid level (HHLL) detected by LT-0401 in the SWS Lift Station sump R41-Z-1040.
- The logic UC-0400 stops main and spare SWS Lift Station Pumps at low low liquid level (LLLL) detected by LT-0401 in the SWS Lift Station sump R41-Z-1040.

**During normal operation no pump are running.**

#### **Special alarm condition, alarm inhibition**

Level sets for SWS Lift Station Pumps are set to provide the following:

- LAH-0400: Main pump starts
- LAHH-0401: Spare pump starts in case main pump is not started
- LAL-0400: Main pump stop
- LALL-0401 Both pumps stop

### **3.4.6.10 Fuel Gas/Off Gas Header Pressure Control Scheme With Split Range**

The control of the fuel gas system is done at R41 Unit Battery Limit by means of R41-PC-7511 which acts in split-range on R41-PY-7511A (modulating R41-PV-7511A) and on R41-PY-7511C (acting on R41-PV-7511B through high selector R41-PY-7511B).

Valve R41-PV-7511A sends fuel gas to existing fuel gas header (Phase I).

Valve R41-PV-7511B sends fuel gas to Fuel Gas Mixing Drum (C295-D-2950). (Phase II)

In normal operation (Phases I and II in operation) overflow of fuel gas is sent to Phase I through R41-PV-7511A and R41-PV-7511B is closed except if there is a high signal override coming from C295-PC-2954 (pressure control of Phase II Fuel Gas System outside battery limit) requesting more Fuel Gas to Phase II network hence opening R41-PV-7511B.

In case Phase I facilities are shutdown, R41-PV-7511A outlet is closed and pressure at R41-PT-7511 is controlled by opening R41-PV-7511B.

a) Split range

The Process Value (pressure of Fuel Gas on Existing FG Header) from R41-PT-7511 is sent to controller R41-PC-7511. The controller generates two output in split range:

- to R41-PY-7511A acting on R41-PV-7511A;
- to R41-PY-7511C acting on R41-PV-7511B through high selector R41-PY-7511B.

b) High signal selector R41-PY-7511B

Output from R41-PY-7511C is sent to high selector signal R41-PY-7511B that receives also the output from pressure controller C295-PC-2954 installed at Fuel Gas Mixing Drum C295-D-2950 (outside RP2 Battery Limit). The high selector compares the two values (from R41-PY-7511C and from C295-PC-2954) and selects the higher one, acting on R41-PV-7511B.

### **3.5 Emergency Shutdown Philosophy**

The purpose of ESD systems are to safely shut down the operating plant when the distributed control system (DCS) has failed to maintain conditions within the normal working range.

This **is** achieved by:

- Preventing process conditions from reaching design values and causing relief valves to lift
- Containing or disposing of significant liquid and vapour inventories so as to minimize any potential for loss of containment and the creation of a hazardous situation.

The primary functions of the system includes:

- The isolation of hydrocarbon streams entering and/or leaving equipment
- The removal of heat inputs via process heaters or reboilers
- The shutdown of equipment including pumps and compressors
- The removal of inventories by the depressurisation of high pressure systems.

#### **System Hierarchy**

The four levels of emergency shutdown are as follows:

- Layer 1 – total plant shutdown (i.e. total complex shutdown)
- Layer 2 – unit isolation and depressuring
- Layer 3 – equipment isolation system
- Layer 4 – equipment protection systems.

Emergency isolation valves function as required at more than one level.

Specific functional requirements are shown on the P & IDs and in the Cause and Effect Charts.

#### **Logic Narrative**

Refer latest revision of Cause and Effect Diagram no. **S-EP-R41-1223-8003**

### **3.7 Emergency Diesel Generator (239-G-101)**

Power supply guaranteed by emergency power generator, for which a time of out of service is allowed to permit its start-up. The essential electrical users ensure the integrity of the equipment and of the plant and/or keep in service the system necessary.

Following are the list of common areas which receive supply from Diesel generator 239-G-101:

- Battery Charger B for SS239
- PIB31 - Emergency Small Power and lighting Panel PIB31
- SS239 - HVAC MCC feeder B to ATS
- PIB31 - HVAC MCC feeder B to ATS
- PIB31 - Instr. UPS A Main Power
- PIB31 - Instr. UPS B Main Power
- SS239 - Emergency Small Power and lighting Panel SS239
- SS239 - HVAC ACCU
- SS239 - HVAC ACCU
- PIB31 - HVAC ACCU
- PIB31 - HVAC ACCU PIB31
- PIB31 - Tele UPS A Main Power
- PIB31 - Tele UPS B Main Power

Following are the list of plant areas which receive supply from Diesel generator 239-G-101:

- Analyzer Shelter 1 from Emergency Bus
- Analyzer Shelter 2 from Emergency Bus
- Reactor Effluent Air Cooler A (R41-E-13410)
- Reactor Effluent Air Cooler B (R41-E-13410)
- Reactor Effluent Air Cooler C (R41-E-13410)
- Reactor Effluent Air Cooler D (R41-E-13410)
- Reactor Effluent Air Cooler E (R41-E-13410)

- Reactor Effluent Air Cooler F (R41-E-13410)
- Reactor Effluent Air Cooler G (R41-E-13410)
- Reactor Effluent Air Cooler H (R41-E-13410)
- Reactor Effluent Air Cooler J (R41-E-13410)
- Reactor Effluent Air Cooler K (R41-E-13410)
- Reactor Effluent Air Cooler L (R41-E-13410)
- Reactor Effluent Air Cooler M (R41-E-13410)
- Emergency Lighting Power Distribution Panel 1
- Emergency Lighting Power Distribution Panel 2
- Emergency Lighting Power Distribution Panel 3
- Emergency Lighting Power Distribution Panel 4
- Main Oil (LO & CO) Pump for Recycle Compressor (R41-K-13450)
- Auxiliary Oil (LO & CO) Pump for Recycle Compressor (R41-K-13450)
- Main Oil (LO & CO) Pump for 1st & 2nd Stg H2 Rich Gas Compressor (R41-K-135)
- Auxiliary Oil (LO & CO) Pump for 1st & 2nd Stg H2 Rich Gas Compressor (R41-K-135)
- Turning Gear System for Recycle Compressor (R41-K-13450)
- Main Condensate Transfer Pump (R41-K-13450-P-02A)
- Auxiliary Condensate Transfer Pump (R41-K-13450-P-02B)
- Turning Gear System for 1st & 2nd Stg H2 Rich Gas Compressor (R41-K-135)
- Main Condensate Transfer Pump (R41-K-135-P-02A)
- Auxiliary Condensate Transfer Pump (R41-K-135-P-02B)
- LP Flare Condensate Pump A (R41-P-181A)
- LP Flare Condensate Pump B (R41-P-181B)
- HP Flare Condensate Pump A (R41-P-182A)
- HP Flare Condensate Pump B (R41-P-182B)
- Elevator
- Aviation Warning Lighting Panel for R41 Furnaces
- Aviation Warning Lighting Panel for CR-140

### **3.8 High Integrity Protection System (HIPS)**

High Integrity Protection System (HIPS), used in lieu of a separate mechanical overpressure protection device, or to mitigate a particular flare load.

Instrumented protection systems are an alternative to conventional relief device protection and utilise a High Integrity Protection System (HIPS) to eliminate the source of overpressure, thereby making relief capacity unnecessary. They are typically used where the provision of relief capacity is inappropriate.

This is typically (but not always) due to one of the following factors:

- The fluid which would be discharged via a relieving device is toxic or extremely hazardous
- Realistic evaluation of the overpressure scenario and quantification of the relief load is difficult or impossible (e.g. explosive reaction)

A HIPS is a highly sophisticated shut-down system which requires visible ownership by the Operator. Since it is an alternative to a relieving device, the required reliability of a HIPS **is** greater than that of the ESD system.

The following are key features of the design:

- Independence from other instrumented systems
- Multiple detectors with voting to provide a reliable input
- A dedicated logic system
- Dedicated fast-acting final elements
- Duplication of components to allow on-line testing
- Increased frequency of testing and inspection to ensure reliability and testing

Typically HIPS valve configuration is 2 valves in series and 2 in parallel (total 4 valves). Before closing any HIPS valve in operation for maintenance or testing, operator ensure the HIPS valves on the parallel line are open. For detailed maintenance and testing procedures for HIPS valve, refer to the vendor instructions.

In case of General Power Failure, HIPS will be activated to mitigate these relief loads.

### **3.8.1 Application Of HIPS**

To manage the overall flare loads, within the overall limitations, application of HIPS is considered for the following 10 systems with major relief loads (greater than 120 tons/hr):

SI No	Item No	Service
1	R41-T-111	Naphtha Depentanizer
2	R41-T-112	Naphtha Splitter
3	R41-T-113	LCN Splitter
4	R42-T-2130	Xylenes Rerun Column
5	R42-T-2110	Reformate Splitter
6	R42-T-2320	Benzene Column
7	R42-T-2330	Toluene Column
8	R42-T-2340	C9/C10 Aromatics Column
9	R42-T-2440	Raffinate Column
10	R42-T-2420	Extract Column

The detailed consideration of HIPS for each system in Unit R41 is described below. The individual relief cases covered by HIPS are indicated in the Flare load summary (Refer to document no. R400-ZA-D-05005).

#### **Naphtha Depentanizer R41-T-111 / Naphtha Splitter R41-T-112**

- The HIPS ZV-1105 A/B/C/D are provided on the common MP steam supply line to the reboilers for Naphtha Depentanizer and Naphtha Splitter.
- The HIPS will be activated, to cut the steam supply to the reboilers, by the pressure high high switch (PAHH-1152 / PAHH-1251) at either of the column overheads. When one of the PSHHs at these columns is activated, both columns will be shutdown. Once the steam is cut by the HIPS ZVs, heat input will be stopped.
- With the HIPS, no relief is expected from these columns (except in the cases that are not covered by HIPS, i.e. Fire case)

#### **LCN Splitter R41-T-113**

- The HIPS ZV-1305 A/B/C/D are provided on the MP steam supply line to the LCN Splitter reboiler. [see Note below]
- The HIPS will be activated, to cut the steam supply to the reboiler, by the PAHH-1351 at the column overhead.
- With the HIPS, no relief is expected from this column (except in the cases that are not covered by HIPS, i.e. Fire case).

#### Note

The Naphtha Depentanizer and Naphtha Splitter are configured in series such that an upset of one of the columns will lead to an upset of the other. Therefore, a common set of ZVs, instead of individual ZVs for each reboiler has been provided for the system. However, a dedicated HIPS is provided for the LCN Splitter. Since the LCN Splitter is only processing a minor feedstock, the unit can continue to run without the LCN Splitter column and it is not considered desirable to disturb operation of the other systems due to an upset on the LCN Splitter.

For other service details refer to R42 Operating Manual.

#### **3.8.2 Pzv Sizing For The System With HIPS**

In general, the HIPS is designed to achieve a SIL-3 level of availability, which is equivalent to a traditional mechanical relief device (PZV). Therefore, when HIPS is applied, a relief valve is provided to cover only the relief load that cannot be covered by HIPS (i.e. external fire) since no consideration of HIPS failure is required.

For the R41 and R42 units, however, in consideration of the number of HIPS applications and their individual relief loads relative to the overall flare load, the flare system is designed based on the relief loads of any single failure of HIPS activation, except the relief cases with extremely high loads, that cannot be covered by the capacity of the overall flare system. This exception only applies to the following systems:

- R42-T-2440 Raffinate Column
- R42-T-2130 Xylenes Rerun Column

## Operating Instructions

## **4 OPERATING INSTRUCTIONS**

### **4.1 Preparation for Initial Start-up**

The following gives a general outline for the procedures of the various checks to be done on the unit prior to initial start-up. This also covers the preparation of the unit for start-up from an open unit condition following a major shutdown. If any major repair, alteration or replacement has been carried out during the shutdown period, appropriate portions of these procedures should be implemented. Although the procedures apply to complete systems, they can also be applied to small portions of circuits that have been opened up during shutdown periods for maintenance and repair work. It is essential that the preparation of the unit for start-up is carried out systematically and thoroughly so that delays at start-up can be minimized. The procedures described below are carried out, under the supervision of the operations supervisor responsible for the unit. Many of the checks may be made simultaneously, depending on the degree of completion of each system of the unit.

This section covers general procedures for preparation for initial start-up after construction/major, minor modifications and includes:

- Hydrotesting
- Leak testing
- Cleaning and flushing
- Unit inspection
- Rotating Equipment Run-in

Unit inspection covers major equipments. General procedures for initial running of compressors and pumps are also included.

#### **4.1.1 Process Systems**

##### **4.1.1.1 Hydrotesting**

The purpose of hydrostatic testing - "hydrotesting" - is to check the mechanical integrity of lines and equipment following maintenance and/or repair work and before the unit is subjected to the various process design conditions. It is usual only to hydrotest the piping and equipment which has either been repaired or opened to the atmosphere. The extent of the hydrotest loop should be as small as possible, but all repairs on pressure-containing equipment must be pressure tested, as well as items of equipment that have been opened up during the shutdown period. Each test loop must be positively isolated from adjacent circuits by line blinds inserted between pipe flanges as required.

Normally the piping, exchangers, vessels, pumps, etc. associated with various towers are hydrotested together with the main vessels, and the loop test pressure is determined by the lowest design pressure in the loop. Hydrotest pressure is normally 150% of the design pressure of the loop.

Check the individual shop hydrotest procedures for large items (such as reactors) and special purpose machines. For equipment which is supplied in certain alloy materials, such as austenitic stainless steel, special precautions must be taken to guard against corrosion, pitting and cracking if the hydrotest water contains more than 50ppm of chlorides.

Hydrotesting is normally carried out using desalinated water which is of low chloride content and has no deleterious effects on piping or equipment. The preparations which need to be carried out prior to hydrotesting are as follows:

- Remove all in-line instruments whose design pressure is less than the hydrotest pressure, e.g. ball float switches.
- Blank off all bolted relief and safety valves by inserting a blind flange between the piping flange connection and the valve inlet flange.
- Check all flanged connections for loose bolts, missing gaskets and blinds. In addition, check the provision of temporary and permanent strainers against the P&I diagram and insert as necessary.
- Remove all screwed relief and safety valves and replace by screwed caps or plugs.
- Remove or isolate all direct mounted instruments or controls from the process lines and equipment, e.g. pressure gauges, vacuum gauges, temperature indicators, flow controllers, etc. Blind or plug the piping connections if isolation valves are not installed.
- Close tightly all isolation valves in instrument lead lines from process piping or equipment and vent the instruments if possible. Install blinds in the lead lines on the process side of the isolation valves.
- Remove all flow restrictions such as orifice plates, mixing nozzles and flow meters and replace them with temporary pipe spools.
- Remove steam traps and plug or blind the trap connections. Remove all control valves and replace them with temporary spools, unless the valves can be isolated by inserting blinds at the block valves and opening a bypass line. In this case vent the control valve either by opening the valve body bleed point or untightening the connecting flanges.
- Lock open all other valves in the test loop, then remove the handwheel or lever and wire it to the valve. Temporarily attach a red tag to these valves to prevent unauthorised operation.
- Remove check valve flappers or alternatively lock them in the open position.
- Remove the internals from ball and piston check valves, putting the parts in a labelled sack and wire the sack to the valve. Alternatively, remove the check valves and replace them with temporary spools.

- Open vents and insert blinds at flanged connections on piping and equipment which connects to the test loop but is outside the test loop. This prevents overpressure of adjacent systems due to leakage from the test loop.
- Remove all bellows/expansion joints and replace with temporary spools to prevent deformation of the bellows due to the weight of water.
- On vapour lines within the test loop, ensure that all spring supports are fitted with rigid spring stops to prevent spring extension and that adequate temporary pipe supports are provided to prevent the lines sagging due to the weight of water.
- Isolate or disconnect all pump seal flush piping and small bore cooling water piping to prevent ingress of dirt and scale from the test loop.
- Connect at least two indicating pressure gauges to the test loop piping for operator monitoring during the hydrotest operation. One of these gauges should be a combination pressure-vacuum gauge. Install one of these gauges in such a position so that the operator controlling the applied pressure can easily read the dial. Additional pressure gauges can be installed if required.
- In the unlikely event that a tower system has to be hydrotested, install a pressure gauge at the bottom of the tower and a combined pressure-vacuum indicator at the top of the tower. The top gauge will indicate any vacuum caused by water leakage. If vacuum is indicated, open a top tower vent to atmosphere, locate and tighten the leaking connections then refill the tower completely again and check for leaks before closing the vent.

Connect up the hydrotest water supply and proceed to fill the loop, closing individual vents when they cease to exhaust air and pass water only. Close the highest vent last, once air has ceased to be expelled and the vent is passing water only. The system should now be full of liquid.

With all the vents closed, raise the pressure in the loop to the test pressure, holding the pressure at two intermediate stages whilst the loop is visually checked for leaks. At each stage, tighten up leaking flanges and ensure the test loop is not leaking before increasing the loop pressure further. Once the test pressure is reached, the loop should be held at constant pressure for one hour on major vessels and equipment or for half an hour for pipework only. Disconnect the hydrotest water supply before the test period begins. After a successful hydrotest period, relieve the loop pressure by opening the top vents, allowing the filled system to breathe whilst proceeding to cleaning and flushing operations.

Refer to Hydrotest P&ID numbers mentioned below for the hydrotest loops and details.

S. No	Section /System	P&ID number
1	R41-1	D-EP-R41-1225-4101 to D-EP-R41-1225-4113
2	R41-2	D-EP-R41-1225-4114 to D-EP-R41-1225-4132
3	R41-3	D-EP-R41-1225-4133 to D-EP-R41-1225-4180
4	R41-4	D-EP-R41-1225-4181 to D-EP-R41-1225-4212
5	R41-5	D-EP-R41-1225-4213 to D-EP-R41-1225-4216
6	R41-9	D-EP-R41-1225-4217 to D-EP-R41-1225-4234
7	Fire Water	D-EP-R41-1225-4235 to D-EP-R41-1225-4240
8	Utilities	D-EP-R41-1225-4241 to D-EP-R41-1225-4279
9	Vendor Package	D-EP-R41-1225-4280 to D-EP-R41-1225-4357

#### **4.1.1.2 Leak Testing**

Before introducing the hydrotest water, close all vents and drains and connect the loop to an air supply. Pressure the test loop to 1.8 kg/cm<sup>2</sup>g or at a pressure less than the lowest relief valve setting. Locate and eliminate major leakages through open lines or loose flanges, thus preventing the wastage of hydrotest water and the formation of pools of water in the unit.

The pressure decrease must be checked on several pressure gauges and possibly checked on a pressure recorder. Leaks must be carefully located and tightened. Their location must be recorded. The leak test is satisfactory when the pressure decrease is lower than 0.05 kg/cm<sup>2</sup>/hour over a period of 4 consecutive hours (at approximately constant temperature). Once the loop is checked out, carefully reduce the loop pressure to atmosphere and open all the vents in the system at the piping highpoints and items of equipment. The air (nitrogen) used for leak tests should be purged out of the unit using low points drains to remove free water, if any.

Note: "Always", during initial leak test make sure, that all pumps/compressors are isolated with vents/drains open to atmosphere to prevent accidental pressurization and as such possible seal damage by effect of "reverse pressure". Pumps and compressors are only to be leak tested when seal systems are cleaned and properly commissioned by Vendor/Suppliers representatives and/or Rotating Equipment specialists.

During the "Construction Phase" ; all seals and all rotating equipment must be carefully isolated, must never be pressurized and should always be kept in a protective clean environment with conservation oil in the seals, if lubricated by oil, or nitrogen in the seals operated by gas (compressors).

For the purpose of leak tests the unit **is** divided into sections of approximately the same design pressure. Air (nitrogen) **is** injected at different locations depending on check valves locations.

Refer section 0 for leak test drawings of various sections. Equipment in each leak test section is described below. Equipment along with their connections are included for leak test.

All sections have to be isolated from the other sections by blinds, or valves. In addition, all utilities lines, especially the ones connected to the flare and fuel gas networks (including safety valves) **is** fitted with blind flanges.

#### **4.1.1.2.1**      Leak Test for R41-1

##### **4.1.1.2.1.1**      Naphtha Depentanizer Section

- Naphtha Preheater (R41-E-1112) Shell Side
- Naphtha Depentanizer Feed / Naphtha Splitter Bottom Heat Exchangers (R41-E-1111A/B) Shell Side
- Naphtha Depentanizer Column (R41-T-111)
- Naphtha Depentanizer Reboiler (R41-E-111) Shell Side
- Naphtha Depentanizer Air Condenser (R41-E-1115)
- Naphtha Depentanizer Trim Cooler (R41-E-1116)
- Naphtha Depentanizer Reflux Drum (R41-D-11150)

##### **4.1.1.2.1.2**      C5 Rich Cut Section

- C5 Rich Cut Trim Coolers (R41-E-1114A/B)

##### **4.1.1.2.1.3**      Naphtha Splitter Section

- Naphtha Splitter Column (R41-T-112)
- Naphtha Splitter Reboiler (R41-E-112A/B) Shell Side
- Naphtha Splitter Air Condenser (R41-E-1125)
- Naphtha Splitter Reflux Drum (R41-D-11250)
- Light Naphtha Trim Coolers (R41-E-1126A/B)

##### **4.1.1.2.1.4**      LCN Splitter Section

- LCN Splitter Feed/ Bottom Exchangers (R41-E-1131A/B) Shell Side
- LCN Splitter Column (R41-T-113)
- LCN Splitter Reboiler Shell Side (R41-E-113A/B)

- LCN Splitter Air Condenser (R41-E-1135)
- LCN Splitter Reflux Drum (R41-D-1135)
- Light LCN Trim Coolers (R41-E-1136A/B)

**4.1.1.2.1.5        Heavy Naphtha Section**

- Naphtha Depentanizer Feed / Naphtha Splitter Bottom Heat Exchangers (R41-E-1111A/B) Tube Side

**4.1.1.2.1.6        Heavy LCN Section**

- LCN Splitter Feed/ Bottom Exchangers (R41-E-1131A/B) Tube Side

**4.1.1.2.2        Leak Test for R41-2**

For the purpose of leak testing, R41-2 is divided into below sections.

**4.1.1.2.2.1        Feed section**

- Feed Surge Drum (R41-D-12010)

**4.1.1.2.2.2        Hydrotreating reaction section**

- Reactor Feed/Effluent Exchangers (R41-E-12110A to M)
- Reactor Feed Heater (R41-FR-12110)
- Hydrotreating Reactor (R41-R-121)
- Reactor Effluent Air condenser (R41-E-1212)
- Reactor Effluent Trim Condenser (R41-E-1213A/B)
- Separator Drum (R41-D-12140)
- Recycle Compressors K.O. Drum (R41-D-1215)

**4.1.1.2.2.3        Stripper section**

- Sour Water Drum (R41-D-12160)
- Stripper Feed/Bottom Exchangers (R41-E-1221A/B/C)
- NHT Stripper (R41-T-122)
- Stripper Reboiler (R41-FR-122)
- Reactor Feed Heater Convection zone (R41-FR-12110)
- Hydrotreated Naphtha Air Cooler (R41-E-1222)
- Hydrotreated Naphtha Trim Cooler (R41-E-1223A/B)

- Stripper Air Condenser (R41-E-1225)
- Stripper Trim Condenser (R41-E-1226A/B)
- Stripper Reflux drum (R41-D-12250)

#### **4.1.1.2.2.4      Fuel Gas Section**

- NHT Reactor Feed Heater FR-12110 Fuel Gas Section
- Naphtha Stripper Reboiler Heater FR-122Fuel Gas Section

#### **4.1.1.2.3      Leak Test for R41-3 & R41-4**

##### **4.1.1.2.3.1      Reaction section**

- Reactors (R41-R-131/132/133/134),
- Upper Hoppers (R41-D-1422/1432/1442) except the First Upper Hopper (R41-D-1412),
- Balance Drums (R41-D-1421/1431/1441) ,
- Lower Hoppers (R41-D-1413/1423/1433/1443), except the first (R41-D-1403),
- Reduction chamber (R41-D-1412),
- Fired Heaters (R41-FR-13110/13210/13310/13410),
- Feed/Effluent Exchanger R41-E-13110,
- Reactor Effluent Air Cooler (R41-E-13410),
- Reactor Effluent Trim Cooler (R41-E-1342A/B),
- Separator Drum (R41-D-13450),
- lift pots, except the first and last ones,
- Hydrogen Lift Gas Exchanger (R41-E-1417) and Reduction Exchanger (R41-E-1416),
- H2 Rich Gas Compressors KO drum (R41-D-135).

##### **4.1.1.2.3.2      HP absorber section**

- H.P. Absorber feed coolers (R41-E-13550A/B),
- H2 Rich gas/ H.P. Absorber feed exchanger (R41-E-1356),
- H2 Absorber Feed/Bottom exchanger (R41-E-1357),
- H.P. Absorber Chiller (tube side) (R41-RU-13580),
- H.P. Absorber Drum (R41-D-13580),
- Hydrogen Rich Gas Chloride Adsorbers (R41-R-13590A/B),

Note: The intercoolers and the interstage drums of the H<sub>2</sub> rich gas compressors ([R41-K-135/13550](#)) are to be tested separately.

#### [4.1.1.2.3.3](#)      Depentanizer section

- LPG Absorber drum (R41-D-136100),
- Depentanizer Feed / Bottom Exchangers A/B (R41-E-13610/1362),
- Depentanizer (R41-T-136),
- Depentanizer Bottom Steam Generator (R41-E-136),
- Convection Reboiler Coil (R41-FR-13110-E),
- Depentanizer Trim coolers and Air cooler (R41-E-13650/1366A/B/C/D),
- Depentanizer Reflux Drum (R41-D-13650),
- Depentanizer Feed Chloride Adsorbers (R41-R-13610A/B),

#### [4.1.1.2.3.4](#)      Nitrogen section

- Nitrogen lift gas lines,
- First Upper Hopper (R41-D-1412),
- First and Fifth Lift Pots ([R41-D-1404/1444](#)),
- First and last catalyst lift pipes,
- Nitrogen loop trim cooler ([R41-E-1405](#)), Nitrogen Storage Trim cooler ([R41-E-1406](#)) and Nitrogen Storage Drum ([R41-D-1406](#)),
- Upper Surge Drum ([R41-D-1401](#)),
- Catalyst fines filters ([R41-F-1405/14150](#)),
- Nitrogen Compressors KO. Drum ([R41-D-1405](#)).

#### [4.1.1.2.3.5](#)      Regeneration loop

- Lock Hopper [R41-D-1402](#),
- Burning, Oxychlorination and Calcination heaters([R41-E-1467/1469/1473](#)),
- Regenerator ([R41-R-140](#)) and First Lower Hopper ([R41-D-1403](#)),
- Burning feed/effluent exchanger ([R41-E-1466](#)),
- Calcination feed/effluent exchanger ([R41-E-1468](#)),
- Regeneration loop trim cooler ([R41-E-1460](#)),
- Washing drum ([R41-D-1460](#)),
- Regeneration loop dryer([R41-DR-1465](#)) and Regeneration Loop filter ([R41-F-1465](#)),

- Air Compressor Aftercooler (R41-K-1470-E-03), Air Dryer drum (**R41-D-1472**) and Dryer (**R41-DR-1472**).

#### **4.1.1.2.3.6      Deethanizer section**

- Deethanizer Feed / Debutanizer Bottom heat exchanger (tube side) (**R41-E-1381**),
- Deethanizer Column (**R41-T-137**),
- Deethanizer Condenser (**R41-E-1375**),
- Deethanizer Reflux drum (**R41-D-13750**),
- Deethanizer Reboiler (**R41-E-137**),

#### **4.1.1.2.3.7      Debutanizer section**

The following vessels with their connections are included:

- Debutanizer column (**R41-T-138**),
- Debutanizer condenser (**R41-E-13850**),
- Debutanizer reflux drum (**R41-D-13850**),
- Debutanizer reboiler (**R41-E-138**),
- Deethanizer feed / Debutanizer bottom heat exchanger (shell side) (**R41-E-1381**),
- C5 cut trim cooler (**R41-E-1382 A/B**)

#### **4.1.1.2.3.8      Fuel Gas Section**

- Reactor Feed Heater FR-13110/13210/13310/13410 Fuel Gas Section

### **4.1.1.3    Cleaning and Flushing**

Following a successful hydrostatic test, the system must be cleaned by water flushing.

The following are general recommendations which should be implemented for cleaning sequences:

- Wherever possible, flushing should be performed through all piping, in order to ensure complete cleaning of the plant.
- Columns and larger vessels should be cleaned by hand before flushing.
- Before flushing water is routed to individual pumps from newly installed piping, the dirt traps in the suction lines must first be checked to ensure that strainers are installed. Entrained welding beads, welding slag and stones can cause serious damage to pump impellers if this check is neglected.

- Wherever possible, piping must always be flushed away from the vessels or process equipment into open space, and not vice versa. However, in case flushing into a vessel or exchanger is necessary, manual cleaning is required.
- Flushing sequences should preferably start at high points and end at lower points in the plant.
- Vessels and self-contained plant systems must be able to breathe freely against the atmosphere during filling with flushing water (danger of overpressure) and during draining (danger of vacuum).
- All piping which was not possible to flush by means of discharge of vessels or recirculation operation must be flushed separately.
- Maximum possible flow rate must be maintained during flushing in order to achieve the best results. The flushing flow must be set accordingly.
- In order to prevent damage, control valve internals must be removed; small control valves must be removed from the system.
- Measuring orifices shall be installed just only after completion of the flushing sequence.
- Sensitive instruments, such as pressure gauges, differential pressure transmitters and analysers installed in lines must be isolated from the system during flushing and pressurisation.
- All discharge and degassing valves and fittings must be flushed through, in order that possible blockages can be found out.
- If possible, flushing should be carried out against free pipe outlets. By-pass lines must always be flushed first before flushing process equipment. The flushing water flow must not be restricted.
- If possible, suction and discharge lines of pumps should be disconnected from the pump casing for flushing.
- Once the suction lines of pumps are flushed and cleaned the test run of pumps with water can be performed. Even for flushing the discharge sides and min. flow lines, the pumps can be used. For test runs and operation of pumps refer to manufacturers' manuals.
- For flushing/cleaning procedure, refer to the following document:

<b>Document Title</b>	<b>Document Number</b>
PRE-COMMISSIONING MANUAL	S-EP-R400-172-0002
GENERAL PROCEDURE FOR PIPING AND EQUIPMENT CLEANING	S-EP-R400-172-0003
GENERAL PROCEDURE FOR PIPING MECHANICAL CLEANING	S-EP-R400-172-0004

GENERAL PROCEDURE FOR CHEMICAL CLEANING	S-EP-R400-172-0005
GENERAL PROCEDURE FOR HIGH PRESSURE WATER FLUSHING (AQUAMILLED OR HYDROJETTING)	S-EP-R400-172-0006

#### 4.1.2 Utility systems

Following major shut down or during initial start-up after construction , the various utilities such as steam, cooling water, air, etc., must be put into service.

The techniques described in previous sections are generally described below for each utility system.

General note: In each unit, all the utility systems must be in service at normal conditions before beginning operations on process equipment.

It is considered that all utility systems connected to the unit are commissioned to the unit battery limits before preparations for start-up of the process unit commence. The start-up of each utility system within the unit battery limits should follow the same step-wise procedures that apply to a process systems. Pressure tests should be carried out on all steam, steam condensate, air, fuel gas, fuel oil, water, nitrogen and flare lines as on process lines. All utility lines in the unit should be either blown with air or flushed with water to ensure their cleanliness. During blowing operations, use target cards at the blowdown points until unmarked cards are obtained. After flushing, all control loops in the utility systems should be tested for correct operation. The following general comments are applicable to individual systems.

##### 4.1.2.1 Air Systems

Air piping (both plant and instrument systems) should be hydrostatically tested up to individual block valves on lead lines to instruments. Hydrostatic test water should not be allowed to enter instruments and measuring elements must not be subjected to pressures outside their operating range.

###### 4.1.2.1.1 Instrument Air

Instrument air network **is** blown through completely from battery limit with a high airflow rate in order to clean and dry all the lines. The main header is blown first with a high air rate. First the lines from the header to the instrument air regulators should be disconnected and any other regulator removed from the lines. Each individual airline should be blown and dried. The instrument air system **to** be tested pneumatically with dry air. All impulse piping

downstream of block valves should be tested at 7 kg/cm<sup>2</sup> g with compressed air and a soap solution applied to all joints to check for leakage. Care should be taken to ensure that this high pressure is not applied to instruments or control valve diaphragms. After testing, air piping (transmission and signal piping and impulse piping) must be blown clean before admitting air to the instruments. Lead lines should be disconnected at the header block valves and blown through until free from all traces of dirt and moisture. All joints and connections **to** be checked for tightness with a soapy water solution. Header and branch lines **are** blown through with a high flow rate of air. During all these tests, the instruments that **are** supplied with air **to** be carefully isolated from the system. At the end of blowing and drying, all regulators and instruments should be connected again and the instrument air system is placed in service at the normal operating pressure. The water dew point of the air should be low enough to avoid condensation (and freezing) of water at the local atmospheric conditions.

#### **4.1.2.1.2      Plant Air**

Plant air system **is** blown through completely from battery limit with a high air flow rate in order to clean all the lines. The main header is blown first while the lines from the header to the users are disconnected at the inlet to the users. Next, the header is blown with a high airflow. After the main header, each individual line should be blown. After cleaning and drying, the plant air system should be placed in service at the normal operating pressure. The systems should be maintained at a slight positive pressure with dry instrument air if the system is not to be used immediately. This will prevent the ingress of moisture and dust.

#### **4.1.2.2    Water Systems**

Water lines (plant water, process water, cooling water, and tempered water systems) should be hydrostatically tested in the same way as process lines. The cooling water network should be cleaned with a high velocity flush of water after all equipment (coolers, condensers, case jackets at pumps, etc.) has been disconnected at the inlet and at the outlet. When the system has been washed out successfully, connect equipment and pressurize the lines and equipment to the normal operating pressure. The cooling water network is then ready for use.

If the system, once commissioned, is not to be used for some time, the system should be dried out by air blowing and then inerted with nitrogen (or dry instrument air if nitrogen is not available) at a slight positive pressure (0.3 kg/cm<sup>2</sup> g). If inerting is not to be carried out, the water-filled system should be circulated on a regular basis. Passivation and chemical addition and procedures should be followed, and packaged items should be started up once the piping distribution is ready for service. After testing the cooling system, water piping to machinery and plant water leads to utility hose stations should be flushed until free from all traces of dirt.

Notes:

Normally equipment delivered from the factory is clean and it is not always necessary to clean them. It is recommended to check if this equipment has to be cleaned.

During filling of equipment, do not forget:

- To open all vents at high points in order to evacuate the air contained in the equipment and piping.
- To open the valves at battery limit slowly and steadily.

#### **4.1.2.2.1 Demineralized Water/Boiler Feed Water Lines**

All lines should be flushed with raw water first and then with demineralized water. After flushing the network can be commissioned in the normal way.

#### **4.1.2.2.2 Potable Water Lines**

Potable water lines to safety eyewashes, showers, and drinking fountains should be flushed, and then left running to remove and dilute any harmful substance. Analysis of the water should be made to be sure the water is suitable for human consumption. After cleaning, the potable water network should be placed in service.

#### **4.1.2.3 Fire Water and Sprinkler Systems**

After removing all nozzles, each fire hydrant and monitor should be flushed. All monitor nozzles should be placed when flushing is completed. Before flushing sprinkler systems, all sprinkler heads should be removed and the entire system flushed. When lines are clean, heads should be re-installed. Each head must be inspected before installation to ensure that it is clean. After cleaning, the fire water system is placed in service and maintained ready for service.

#### **4.1.2.4 Fuel Gas Systems**

Again with these systems, the general approach to hydrostatic testing, cleaning and flushing, etc, should be adopted. Once testing is complete, the systems should be blown with dry instrument air to clear all lines of dirt and moisture. The systems must be dry and dust-free before nitrogen is admitted for purging. The nitrogen purge should be continued until analysis of the exhaust gas indicates that the oxygen content is 0.2% or less. Once this stage is reached, the systems should be left under a slight positive pressure ( $0.3 \text{ kg/cm}^2\text{g}$ ) to prevent ingress of air.

#### **4.1.2.5 Nitrogen Lines**

The nitrogen lines should be disconnected from the equipment and any regulator and pressure reducer should be removed. The header should be blown first with plant air connected by hoses to the nitrogen lines. It should be swept with a high flow rate through the vents to remove impurities. Then the lines should be flushed with inert gas, nitrogen, at a low flow rate to remove air and dry the network. Check for oxygen content before stopping inert gas

sweeping; check for dew point. The oxygen content in the nitrogen lines must be below 0.2%. Typically the required O<sub>2</sub> content (0.2% volume) is achieved with 3 cycles(pressurization/depressurization).

Note: Nitrogen is an asphyxiating gas and any activity regarding nitrogen should be considered for this safety aspect.

#### **4.1.2.6 Steam System**

Once equipment and vessel connections have been blinded off, testing of these systems is carried out in the same manner as for process lines. Once testing is complete, the lines should be cleared by blowing with steam. This can be conveniently carried out whilst steam is introduced to the system. Before putting steam into the system, all steam traps, control valves, turbines, instruments, vacuum ejector and strainers should be removed or blinded off from the system. If there is to be a significant time between testing and the introduction of steam, the system should be dried by air blowing and then inerted with nitrogen. Alternatively, dry instrument air could be used if inert gas is not available. The system should be maintained at a slight positive pressure. When steam is available, it should be gradually introduced into the system so that headers warm up gradually. This aspect is important as a carefully controlled warm-up prevents water hammer and lets the system expand gradually on its pipe supports and guides. During warm-up, the system should be inspected to see that all guides, anchors and spring supports are performing correctly.

Scale and dirt should be removed from the steam lines by blowing them down for as long as necessary, exhausting the steam at the ends of headers. The headers should then be blown using a low-pressure, high-velocity sweep. A second steam blow can be performed for better removal of scaling.

When the headers are warm, the drain and vent valves should be opened and blown vigorously for a few moments before closing again. Each down-comer to heater, exchangers or service lines should be blown in the same manner, but never more than one at the time. A temporary movable silencer to be used to avoid exceeding noise level limitations during the steam blowing operation.

The leads should be cleaned by blowing through. In order to gauge the effectiveness of the steam blowing activity, clean target plates should be placed at blowdown points. When virtually unmarked target plates are obtained, the lines can be considered clean.

Condensate lines and steam traps should be regularly checked for plugging, and the traps removed and cleaned as necessary. Steam tracing lines should be tested and cleaned in a similar manner.

After cleaning, vent the system, re-install all control valves, test control loops and check all strainers.

When blowdown of the steam system is completed, traps and other equipment that were removed prior to the blowdown may be reconnected. After the steam has passed the steam test, it can then be placed into service.

#### **4.1.2.7 Condensate Lines**

Condensate lines may be cleaned in the same manner as steam lines. However, close observation of the pressure on the condensate line is necessary since the working pressure and the temperature of the condensate lines are generally lower than that of the steam headers.

LP/MP Condensate Lines:

All lines should be flushed with raw water first and then with LP/MP Condensate. After flushing, commission the network normally.

#### **4.1.2.8 Flare System**

The flare system is blown by depressurization of vessels, either using air after the tightness test of the vessel or using nitrogen during the inerting exercise on the vessels, or better, on both. After the blowing operation, the flare system is inerted.

#### **4.1.2.9 Sewers**

These systems are the first to be prepared and put into service, ready to receive the various releases. They are generally prepared as follows, in parallel with the washing of the fire water network:

- Check peep holes and all drains.
- Fill with water until full.
- Check if the oily water treatment system can accept feed.

#### **4.1.2.10 Closed drain system**

This system should be commissioned in a similar way as the flushing oil and refinery fuel oil systems. Check if the common closed drain system is available for service.

#### **4.1.2.11 Electricity**

The electric facilities should be checked and commissioned by the electrical specialists/vendors and other parties that are involved in these facilities.

#### **4.1.3 Inspection of the unit**

After completion of installation of process equipment and machinery, piping, electrical equipment and instrumentation systems, the plant must be checked for completeness and correct assembly using the P&I diagrams and the specifications in the technical data sheets. The accessibility of the operating and monitoring equipment must be checked. These are, in addition to valves and fittings in process piping, for example, vents, drainage points and lines, trace heating systems, level glasses, pressure gauges and sampling points. The installation of check valves, shut-off and control valves and fittings must be checked to ensure correct direction of flow. Completion of assembly work also includes checking for tightness and cleaning of all gas and process-fluid-bearing lines and equipment.

Operating utilities, such as electrical energy, plant air, instrument air, steam, cooling water, nitrogen and process water, must be available. It must be ensured that thermal expansion can take place without obstruction (fixed point supports, sliding point supports, spring suspensions and supports). This applies in particular to heat exchanger supports, pipe connections to columns and piping in the process and steam paths. Trial runs and function tests must be performed for all paths and all media to ensure that all equipment and other plant components can properly fulfil their function during operation and in case of malfunctions. Such trial runs must be performed sufficiently and for a sufficient long time to ensure that the systems are adequately prepared and cleaned for operation.

##### **4.1.3.1 Operability Checks**

This consists of an assessment of the possibility to carry out all the operations required for commissioning, start-up and shutdown. It focuses mainly on access to instruments and valves (including vents, drains), to manholes, to spectacle blinds, and to parts of equipment that need to be dismantled. The presence of the required start-up and pressurization lines is checked as well as the impact of safety devices on start-up operations. Fire hoses should be available at the intended points.

##### **4.1.3.2 Mechanical Checks**

Equipment inspection may be carried out in several phases.

- At the manufacturer's workshops
- On site prior to the catalyst loading to reactors or prior to the mechanical completion (other vessels)
- During and at the end of the catalyst loading for inspection of internals, etc.
- The workshop inspection is optional depending upon the complexity of the internals and the critical nature of the items to be inspected.

The site inspections prior to and during catalyst loading are mandatory, even if the workshop inspection has been witnessed by licensor's representative and proved satisfactory.

#### **4.1.3.3 Columns / Drums and Vessels**

Before the first start-up of the plant the internals of the columns need to be cleaned. The internals are normally covered by a small film of oil or grease by the vendor to prevent corrosion. These agents would be dissolved by the hydrocarbons and /or the solvent and accumulated in the solvent circuit. Such impurities would cause problems (foaming) during start-up period and can only be remedied by an early start of the solvent regeneration ahead of schedule.

To allow access to the vessels for inspection, Columns, Drums and Vessels to be isolated by blinds from any potentially dangerous source (flare, fuel gas, hydrogen, N<sub>2</sub>, chemicals, HC etc.,). Manways and vents open, atmosphere breathable. Internals assembled.

A field inspection should check that the repair/maintenance work has been carried out in accordance with instructions. New welding generally should be checked. New internal welding should be checked for absence of slag and cleaned as necessary. All internal bolting should be checked for tightness and any missing bolts installed. All mesh or fibre blankets, chimneys, grids, etc., should be checked for good fit. All elements should be cleaned in accordance with the manufacturers instructions. Supports for internal pipework and stab-in side reboilers should be checked for mechanical integrity and space to accommodate expansion. All pipework connecting to the vessel should be reviewed from the support aspect. All supports should be checked for proper function i.e. anchor, guide, spring support etc. and permissible extent of movement checked as correct.

During internal vessel inspections, the alignment of seal pipes etc. should be checked with the location of seal pans, and weir heights checked against clearances between seal pipe ends and seal pan or tray base plates. The vessel relief valves, both for pressure and vacuum, should be bench tested. All vents and blowdown lines should be checked out. If repair welding has been carried out on pressure containment parts, the vessel should be hydrostatically tested and when all internals and external pipework are finally connected, a leak test should be carried out.

The condition of fireproofing and external insulation should be checked. Each vessel should be internally cleaned prior to line blowing and all sediment, weld spatter, mill scale and loose debris should be removed by wire brushing and vacuuming if possible. After blowing operations have ceased, the vessel should be inspected again and cleaned if necessary.

All instrumentation installed on vessels should be disconnected and cleaned during the internal vessel cleaning work. Particular attention should be paid to level and differential pressure instrument piping and valves, etc. If dirt and scale are not removed from these items before start-up, it is likely that erroneous readings or control signals will

be experienced which could lead to safety and maintenance problems later on. Lines connecting to the bottom of vessels e.g. pump suction lines, should be disconnected and cleaned before refitting.

A typical, but not complete list of items to be checked is given hereafter. The list needs to be adapted according to the specific requirements of the unit.

- Vessel temperature and pressure rating
- Vessel metallurgy
- Vessel elevation
- Vessel lining, internals

Trays: number, type, spacing, levelness, liquid seal, weir height, valve number and type, metallurgy, weep holes, supports

- Distributors: location, levelness, size and number of holes and chimneys, correct installation with gaskets
- Quench devices: location, size and number of holes for quench pipe, size of quenchbox
- Ability to reinstall manways covers and associate elements after catalyst loading
- Nozzles
- Vortex breakers
- Demisters: size, materials, support
- Pressure instruments: location, range
- Thermowells: location and length
- Level instruments: location, level, range
- Fireproofing, insulation
- Presence of names plates
- Cleanliness

CAUTION: Before entering a vessel, the Refinery's safety precautions must be observed. These usually include the following:

- Sampling the vessel for the presence of toxic vapors and verifying the oxygen concentration (21% mandatory).
- Provision of adequate lighting and access platform.
- Wearing of breathing apparatus if deemed necessary.
- Wearing a safety harness, and having an attendant outside the vessel.
- An unattended vessel should never be entered

#### **4.1.3.4 Reactors**

##### **4.1.3.4.1 Internals assembly and inspection (R41-R-121)**

It is advised to assemble the internals and have them inspected as early as possible, in order to perform any adjustment without delaying the start-up planning. This description applies to Hydrotreating reactor (R41-R-121): Before inspecting the internals, the Reactor should be Isolated by blinds, from any potentially dangerous source(flare, fuel gas, hydrogen, N<sub>2</sub>, chemicals, HC...). Manways open and atmosphere breathable to allow 1st inspection for reactor wall state and a 2nd inspection after assembly of the internals (without internal manways).

- Install the outlet collector at the reactor bottom. As applicable check the size of the wiremesh, seal welding and the fastening of the various parts. In case of a Johnson screen, check its fastening and the slot opening.
- Close the catalyst draw-off pipe. The wool plug **is** inserted later prior to the catalyst loading. Set in place the thermowells and check the thermocouples location.
- Check the feed diffuser. Perform a blank assembly on the reactor top flange. Once this blank assembly has been carefully performed, the internals are dismantled to prepare for the catalyst loading. Each piece must be clearly identified.

##### **4.1.3.4.2 Internals assembly and inspection (R41-R-131/132/133/134 and R41-R-140)**

The status prior to inspection is supposed to be as follows: reactor is erected with all its internals installed. Piping is connected. Four catalyst pipes from the upper hoppers **are** dismantled to ease the removal of the inlet elbow. The inlet distributor is removed then and checked for size and positioning. Air must be circulated through the reactor to allow for entry.

- **Upper section**

The sealing rings around the catalyst feed pipes must be checked for free movement. Clearance between the various pieces must be checked. The thermocouples, if any, must also move freely in the cover plate and their dedicated seal ring must slide along the thermowell pipe. Remove four cover plates and one or two conical sectors in order to access the space allowed for catalyst.

- **Outer catalyst support grid or scallops**

The clearance between the vertical wires of the screen is checked, for conformity, using a random method. The screen will also be inspected for abnormal wave amplitudes. They are the main causes of future deformation.

The concentricity of the grid is checked at the top part. The mobile centering pieces are adjusted in order to have 10 mm between the edge of the pieces and the shell. For the bottom part of the screen the bolts must be untightened in order to check the clearance between the support ring and the lower flange of the screen. Concentricity of the bottom part is checked at this occasion.

Tighten the bolts on the spacers not on the support ring. This is to provide for thermal expansion of the outer grid (heating and cooling of the catalyst beds).

- **Center pipe**

The clearance between the vertical wires is checked for conformity, using a random process.

Abnormal wave shapes could affect catalyst circulation.

Check the following:

- holes in the perforated pipe must not be blinded by the reinforcement bars of the screen.
- the three pins for the center pipe orientation are in place and fastened with the keys.
- the seal rings in the lower centering ring are correctly fitted in their grooves.

- **Catalyst pipes**

Clean the catalyst pipes (reactor top and bottom) to remove debris, scales etc.

Calibrate each pipe individually, using for instance a calibrated ball.

For the upper hopper catalyst pipe, remove the top section of the hopper, check the catalyst pipe size and finish, check that the drum is clean, and that the ring is the right one.

- **Regenerator**

If the removable parts of the regenerator are not installed yet, they will be cleaned, checked on ground and preassembled before being fitted in.

If they are already installed, they will be inspected from inside.

- Upper manhole MH1:
  - Open and check cleanliness.
- Other manholes MH2, MH3, MH4, MH5:
  - Check overall cleanliness.
  - Check fixation and centering of the central collector.
  - Check fastening of the internal catalyst support grid on the central collector.
  - Check concentricity of external and internal catalyst support grid.
  - Check that the partitions trays between the different sections are properly fixed.
  - Check free movement of slide rings fitted on internal catalyst pipes.
  - Check oxychlorination inlet and outlet screens.

Special attention is drawn to the following drums:

- All drums in catalyst circulation (hoppers, lift pots...).
- The regeneration washing drum.

Special care must be taken regarding the washing drum. It is coated with a non-metallic corrosion resistant coating. The following points have to be noticed:

- In any case the operating temperature in this drum must not exceed 80 °C in order to respect physical coating integrity. Consequently steam out is totally forbidden.
- Internals assembly **to** be performed under supervision.
- Dedicated cares **to** be taken to avoid any damage on FRP-coating during internals installation.
- As far as possible isolate the drum during the piping washing phase.

- **Lift pipes and catalyst pipes**

The smooth finish of these pipes is of paramount importance to avoid excessive catalyst attrition which is the source of various troubles.

#### **4.1.3.5 Fired Heaters**

An inspection should be carried out to verify the following:

**Radiant Section:** Inspect the refractory, checking its integrity and paying particular attention to the following items if refractory repair work has been carried out. (Heater dryout procedures will not be necessary during normal start-up operations unless major repair work has been carried out on the refractory. For details of the heater dry out procedure see heater vendor manual).

Ensure that all expansion joints are clean and fully packed with the correct material, e.g. ceramic fibre. Check that refractory does not encroach on any tubes, shell penetrations or nozzles. Remove any remaining refractory debris and check that the tubes are free to expand as per the drawings. Check the installation of the tube coil supports and guides. Check the condition of the burner wall refractory.

Check that the burner tips are clean. If new or refurbished burners have been installed, check that the relative positions of the pilot burner tips to the main burners are in accordance with the burner manufacturer's drawings.

**Convection Section:** Check that no refractory debris remains on any of the tubes and check the condition of tube supports and guides. Inspect the damper movement, check that the damper can travel over the full range and that the damper indicator is in the correct position relative to the shaft. The damper should be weighted to fail open. All other relevant aspects mentioned for the radiant section should be checked.

**Fuel system:** Inspect the combination burner connections, valving, fuel and steam pipework and instrumentation for correct installation. Establish that all control loops have been function tested. Verify that all alarm and trip circuits are correctly installed and tested. Check that all control valves in fuel lines fail closed. Check the cleanliness of all line and instrument filters and that the instrumentation tubing has been cleaned.

#### **4.1.3.6 Piping**

A field inspection should check that repair/maintenance work(if done) has been carried out in accordance with instructions. Where piping systems have been dismantled and subsequently re-installed, block valves should be checked for correct direction of flow and all flanged joints should be checked for correct gasket materials and adequate bolt lengths. At spec breaks, non-return valves should be inspected for correct direction of flow. Valve stops and control valve positioners, where installed, should be checked for correct setting. All locked open or locked closed valves should be checked for correct locking position. The valve keys, allowing the operation of these valves, should be retained in a secure place (normally in the unit control room) to guard against inadvertent operation. All internal pipe linings should be inspected for discontinuities, cracks, holes, etc. All valves, irrespective of size or type, should be inspected, paying particular attention to direction of flow, packing glands, seat inserts, bonnet gaskets and seals. Gear operators should be checked for ease of operation as should all handwheel operated valves. All blinds should be swung, checking ease of operation. All relief valves should be bench tested before start-up. Once the physical check has been completed and all corrections carried out, all modifications carried out during the shutdown should be noted on the "as-built" drawings.

#### **4.1.3.7 Exchangers**

Shell and tube exchanger supports should be checked out including the supports on connected pipework. Check that the insulation is in good condition and that any repair work has been satisfactorily completed. Confirm that all local instruments are correctly piped and wired up and that they function correctly. If the exchangers have been opened during the shutdown, check the condition of all internal linings and sacrificial anodes (if installed). Replace all anodes that have been significantly consumed.

On air-cooled exchangers, check that extended surface finned tubes are free of debris, accumulated dust, dirt and grease and the fins are not damaged. Inspect the tube bank supports. Check that the pitch control gear is clean and in good working order. Check that the fan shaft bearings, drive pulleys and belts are in good condition and correctly tensioned. Ensure that all the belt guards are securely fastened.

#### **4.1.3.8 Pumps**

Check that adequate spares are available for use during start-up.

From the certified pump curves, note the maximum amperage and throughput for operation with water as the pumped fluid. Relate this to the discharge control valve opening position so that if the pumps are used in the system for flushing or circulation, the motor will not be overloaded. Check whether any additional packing or alternative seals should be used for pumping water and whether, due to the materials of construction used, the pump has to be

blinded off during hydrotest, cleaning or flushing operations because it is unsuitable for operation with water. Check that seal flushing arrangements, lubrication and cooling water systems are in operation.

Note any specific procedures or precautions which the manufacturer's literature states must be observed during start-up or normal operation. If any pumps are provided with internal filters and/or cooled by the pumped fluid, ensure that they are noted for isolation during start-up until such time as the system is clean.

At completion of maintenance/repair work, a field inspection should be carried out to check that the pump has been re-installed correctly. In addition, check that all local instruments, e.g. pressure gauges, flow indicators, ammeters, thermometers and differential pressure indicators that have been re-installed are visible from the associated local pushbutton control station and discharge isolation valve location. Check that control valves, isolation valves and check valves are correctly re-installed for direction of flow.

Check out the seal flushing pipework and equipment and verify that ancillary equipment in the flushing loop such as cyclones, strainers, coolers, etc., have been cleaned and re-installed correctly. Verify that cooling water supplies are available where specified, to pedestals, bearings, coolers and mechanical seal chambers.

Check that the pump baseplate is firmly bolted to the bedplate or grouted into the foundation, and that the pump and its motor have been properly re-coupled. Ensure that all flanged piping connections to the pump on the ancillary utility circuits are tightly bolted. Check that all levels in lube and seal oil reservoirs are at maximum and that all grease points have been serviced. If necessary, top up the lubrication inventory after referring to the unit lubrication schedule. Check that all oil piping circuits are leak tight. Ensure that the pump casing drain and vent plugs are tightly installed but not seized up in the threaded bosses with rust or dirt. Check that all the pump instrumentation has been function tested.

Before any liquid is allowed to pass through pumps from lines which **is** dirty, conical or basket type screen must be installed in the suction piping to protect the pump from mechanical damage during the hydrostatic testing, cleaning and flushing operations of lines. If this exercise is not carried out, mill scale, weld slag, spatter and debris will be drawn down the suction piping and into the pumps. Not only do the screens protect the pumps, but they trap the debris so that it can be manually removed. It is therefore important to check that handholes are provided at the screen locations. In any event, the screen must be positioned downstream of the suction blockvalve so that when debris is removed, the system does not need to be drained. The screens must be installed before test water is introduced to the system. The screens should be fabricated from 20 mesh steel wire gauze and should be inserted even if temporary strainers have already been installed. To facilitate removal of debris by hand, the cones or baskets should point upstream, thereby ensuring that the trapped debris **is** in the suction pipe but not inside the screen. Flat plate screens must not be used as they can severely restrict the liquid flow to the pumps when they become dirty and are less robust

than cone or basket screens. When the screens are installed, they must be a close fit inside the pipe so that dirt is not able to bypass them and enter the pump.

#### **4.1.3.9 Compressors**

Verify that the compressor suction strainers have been cleaned and correctly re-installed.

Check that the cooling water to the cylinder jackets, gearbox, lube oil cooler, inter- or after-coolers is available.

If the lube and seal oil piping systems have been opened for maintenance or repair, the system must be cleaned before the machine is started up. Check the vendor's documentation **for** the procedures to be used. Once cleaning has been completed, the oil piping should be maintained under inert gas purge.

Inspect the compressor suction piping between the machine and suction drum for cleanliness and, if new pipework has been fitted, verify that any acidising requirements have been met. See that all acidised piping is under an inert gas atmosphere. (If degreasing or descaling has to be carried out, the manufacturer's recommended procedure must be followed).

Verify that all control instrumentation and interlock circuits have been function tested and that the correct alarm and trip signals are initiated and connected to the unit shutdown system.

#### **4.1.3.10 Electric motors**

The following notes assume that the complete electrical system in the unit has been put into operation and the proper functioning of the various systems, including all control interlock, alarm and sequence circuits has been verified. If maintenance/repair work has been carried out, subsequent alignment of the motor and coupled driven equipment should be carried out in one operation. Before a motor is put back into service a Megger test to measure the insulation resistance should be carried out. A check must be made to verify that the bearings are properly lubricated and reservoirs are filled to the correct oil level with the nominated lubricant according to the manufacturer's lubrication schedule. If the lubricant is contaminated with dirt or water, it must be replaced before the motor is energized. Drain plugs should be removed and housings checked for internal moisture or dirt before the plugs are replaced.

Before a motor is re-connected to its driver the motor should be disconnected at the coupling and run unloaded. During this unloaded run period, the motor should be checked for excessive noise, vibration and overheating of the bearing housing and motor frame. A check should also be made that space heaters and winding heaters, if provided, are properly interlocked with the motor controller. Where the driven equipment is spared, the automatic starting control system of the spare motor must be simulation checked for correct operation. Time delay relays used in the automatic restart of motors drivers must be set and tested in accordance with the intended control function. Heater elements of

thermal overload relays used for motor protection should be individually checked. Once the above checks have been carried out satisfactorily, the motor should be reconnected to the driven coupling.

When the driver is initially run-in, the motor should be "bump started" (refer to paragraph 4.1.5.1).

#### **4.1.3.11 Instrumentation, Alarm and Shutdown System**

Prior to unit start-up, all instruments must have been checked with regard to:

- Proper tagging,
- Proper location in the process,
- Correctness of assembly,
- Operating range consistent with the operating conditions,
- Calibration,
- Flow orifice size, coefficients, orientation versus flow,
- Level instruments **to** be calibrated using the design liquid density,
- Instrument wiring integrity, polarity, grounding.
- All thermocouple, electric and electronic instrument wiring should be checked for continuity and insulation resistance between conductors and conductors to earth.
- All solenoid valves should be re-checked for change-over action, and where applicable, electrical and manual reset override and time delay features.
- All instrument loops that have been subjected to maintenance or repair work should be tested and loop check sheets should be signed off. The same philosophy should apply to alarm and trip circuits

##### **4.1.3.11.1 Alarm checking**

Make sure that the released mechanism on the unit actuates the corresponding light or audible alarm in the control room.

##### **4.1.3.11.2 Valves**

The control valves are removed during cleaning operations. They will be checked for cleanliness of the seats and free movement of the plug or ball. Check the valves motion and their response to the controller signal. When all the single instruments have been individually checked, when all their addresses have been verified in the DCS, then the loop checking can take place for each loop or group of control loops. Each automatic action, either linked to the process or to equipment, **should** also be individually tested. Control valves should be subjected to a valve test for correct operation and specified failure position on loss of air supply.

Once the above procedures have been completed the instrumentation on the unit should be visually inspected to check that all tubing and wiring is still correctly connected up.

#### **4.1.3.12 Electrical system**

Before start-up of the unit, function checking of the unit electrical system and equipment items should be carried out to prove the integrity of the system. The test records produced should be retained and filed.

The tests should cover the proper functioning of all disconnect switches, circuit breakers, motor control equipment, relays, motors, motor-operated valves, emergency generator/power facilities, uninterruptable power systems, automatic transfer equipment, batteries and battery chargers, lighting systems, and should include a complete check of all the control, interlock, alarm and sequence circuits.

Prior to high voltage testing, personnel warning signs should be posted.

Other checks must be performed to cover resistance measurements of earthing systems and connections, phase orientation and marking of buses and cable systems, tagging of cables and conductors, lighting systems including polarity checks, ground continuity checks of receptacle circuits and flash tests on insulating oils.

Seal fittings should be checked to ensure each one is still properly compound sealed. Area lighting layouts should be checked at night to locate any areas of deficiency.

Any relays, control or equipment components that have proved to be sluggish or unpredictable in operation or have affected the operational control of the unit should be repaired or replaced.

In addition, a physical inspection of the unit should be carried out. The inspection should include:

- Cabling in general, ensuring that trenches are dry, and above-ground cable trays, ducts and protective pipe sleeves are installed as required.
- Unit earthing (grounding) system.
- Flameproof or pressurised terminal boxes, etc., ensuring that purge gas supplies are available where necessary.
- Air pressurization equipment for substations in hazardous areas. Communications systems.
- Power outlet receptacles.

#### **4.1.3.13 Steaming out**

##### **4.1.3.13.1 Heat Exchangers**

The steam supply lines of heat exchangers should be steamed out through. Heating sides of reboilers and heating coils should be blown through with LP-steam during steaming out in order to remove scale. To avoid thermal stress in the tubes of the heat exchangers the cold side must be filled with boiler feed or demineralised water.

### Steaming out of steam heated heat exchangers (steam side)

Proceed for heat exchanger / coils as follows:

- Blow supply line towards inlet of heat exchanger into open space.
- Blow through heat exchanger with outlet line disconnected.
- Blow outlet lines to condensate trap into open space.
- Fill condensate trap several times and drain to ground.
- Blow / flush through the condensate discharge line to inlet condensate main header.
- Flowmeters and flow control valves must not be blown through with steam.
- To avoid thermal stress in the tubes of the heat exchangers, the cold side must be filled with condensate or demineralised water during steam blowing period.
- The discharge points at all the lowest level points and vents must be fully open.
- Steam should be fed in slowly, to allow for thermal expansion and condensate outflow.
- Close vents and throttle back discharge points until only a mixture of steam and condensate escapes.
- Check freedom of expansion before feeding steam (do not lock any spring suspenders or supports).
- Blow lines through several times vigorously after heating up. All discharge systems and condensate discharge connections must be vigorously blown through.

It is recommendable for good and full removal of metal scale and rust to shut-off the steam supply, permit the piping to cool down with the discharge and venting systems open, then to reheat the system and blow it through again. Repeat this procedure until the condensate is clean. Condensate traps should not be installed until the condensate drain system is free of scale. After cleaning of the plant, empty all systems and drain the remaining water at the lowest

drain points. Blow and dry all remaining systems by means of air or nitrogen (if possible heated up) as much as possible similarly to the inertization procedure of other plant systems.

#### **4.1.3.13.2      Vessels and Columns**

During heat-up thermal expansion of the vessels takes place. Therefore steam injection must be started slowly to avoid thermal stress.

For steaming out of columns proceed as follows:

- Open vent on top of vessel.
- Open a sufficient drain for condensate at the vessel bottom.
- Remove blinds in the temporary steam supply lines to the vessel bottom.
- Open steam supply slowly.
- Heat-up the vessel until steam is leaving through the top vent. Allow condensate to flow out freely.

- Blow steam through the column until the discharged condensate is clear. To remove the oil and grease completely let steam supply open for another 12 hours.
- Close steam supply and install blind again. Vessel vent must remain open until cooling down of the system is completed.

#### **4.1.3.14 Safety**

All safety equipment which **is** required for hydrocarbon introduction to the unit is to be on-site and fully operable. Check that:

- All portable fire fighting equipment is in place
- The firewater and hydrant system is in service
- Miscellaneous safety equipment is available
- The area is reasonably free from obstructions
- Necessary warning signs are posted
- All relief valve keys are removed
- Adequate lighting is available for night operations
- Communications with the Control Room are in service.

##### **4.1.3.14.1 Safety devices check**

The process includes a number of specific safety devices referred to Interlocks Safety (ZC) which are implemented in the Emergency Shutdown System (ESD). These devices are designed either to protect the unit against misoperation or to fulfill safety actions.

The Interlocks Safety (**ZC**) is composed of independent systems which in the occurrence of pre-defined potentially harmful events, initialize various actions such as:

- Valve(s) are set to their failure position (AFC, AFO or AFL)
- Shutdown of equipment (pumps, compressors, furnace, electrical heater, etc.) to alleviate the risk.
- A simulated default signal from the primary sensor **is** fed into the system and the resulting signal output to valves or equipment **to** be checked.
- Whenever possible, the end result of the signal output such as actual valve failure or machine shutdown **to be observed**.
- Ultimately, a real test which requires running machines must be performed during the forthcoming operation procedures.

Throughout this exercise, the actual physical position of the valves or status of machines **to be checked** against the indications shown in the control room.

The check of the motorized valves is part of the same task. It includes:

- A site test of the opening/closing of the valve upon the input signal.
- A check of the reported information in the control room and a check of the control room command.

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- A check of the reported information in the control room and a check of the control room command.

#### **4.1.3.14.2      Interlocks Safety**

The Interlocks Safety (**ZC**) are independent systems which in the occurrence of pre-defined potentially harmful events, initialize various actions such as:

- Valve(s) are set to their failure position ( AFC, AFO or AFL )
- Shutdown of equipment ( pumps, compressors, furnace, electrical heater, etc..) to alleviate the risk.

#### **4.1.3.14.3      Interlocks Sequential**

- The Interlocks Sequential (UC) are a series of actions in sequence which are programmed into the control/command system (DCS) and are designed to ensure a trouble free, automatic and safe operation of the catalyst circulation and regeneration.

### **4.1.4    Loading of Reactors**

#### **4.1.4.1    Catalyst Loading in Reactors**

For catalyst loading in Hydrotreating Reactor R41-R-121, refer to section 4.2.3.1.2 for detailed procedure.

For catalyst loading in the reactors in Aromizing section (R41-R-131/132/133/134 and R41-R-140) refer to section 4.2.4.1.4 for detailed procedure.

For adsorbent handling in Hydrogen Rich Gas Chloride Adsorbers R41-R-13590A/B and Depentanizer Feed Chloride Adsorbers R41-R-13610A/B refer to section 4.6.2.3

#### **4.1.5 Run in of Pumps**

Pumps are run-in after the flushing operation to increase the effectiveness of cleaning and to check the operation of new and repaired pumps before process fluid is introduced into the unit.

A new pump installation should be thoroughly checked and started up in a methodical manner as indicated in the following guide:

##### **4.1.5.1 Checks before starting of Pump**

- Check the strainer is in position and is tightly fitted into the suction line to prevent the water bypassing it.
- Ensure that electric power and steam (as necessary) is available at the driver control station. Check that all pressure gauges, etc. are open to the process lines and are visible from the control station.
- In most cases, the pump will be operating with water which is heavier than its design fluid. It is therefore necessary to throttle the pump discharge valve to avoid a motor overload trip. Never open the discharge valve when the pump is operating on water to more than a few turns from the closed position. Note the maximum operating motor amps from the data sheet and closely monitor the ammeter during operation.
- Flush the mechanical seal chamber and the associated seal flush piping and equipment with clean water before operation.
- If vapour phase mechanical seals are used, open the steam line to the seal chamber before operation. Check with the vendor's documentation to see whether additional packing is required for initial run-in on water.
- Check that all auxiliary oil systems on both pump and driver are topped up to the correct level with the recommended grade of lubricant noted on the vendor's lubrication schedule.
- With the coupling between the pump and driver disconnected, bump start the motor (by pressing the start button and immediately afterwards pressing the stop button) to check for proper rotation and that nothing prevents shaft movement. Manually rotate the pump to check that its movement is clear. Check that pump and motor directions of rotation are correct.
- Reconnect the coupling between pump and driver and recheck the alignment.
- Open the pump casing vent and the suction and discharge vents. Close the pump discharge valve. Open fully the suction block valve and fill the pump full of water by checking the discharge from the open vents. When water is passing through the vents at full bore flow, close the vents (lowest first, highest last).
- Check that the circuit in which the pump is to be run is a closed loop, in as much as the pumped fluid is returned to source.
- Open the utility lines to the equipment and establish circulation, e.g. cooling water, etc.

#### **4.1.5.2 Starting of Pump**

- Crack the pump discharge valve open. Start the pump and immediately check the discharge pressure gauge. If no increase in discharge pressure is indicated, stop the pump and investigate the cause. If the pressure indication is satisfactory, slowly open the discharge valve, but limit the valve opening so that the motor amps never exceed 90% of the normal rated value.
- If the pump is fitted with a recycle or minimum flow bypass line, keep the line open as this will provide minimum flow to the pump and protect it from cavitation and overheating even if the external suction source dries up.
- Inspect the pump for any unusual vibration or noise and stop the equipment immediately if this becomes evident. Investigate the cause and remedy the condition.
- Check the bearing housings of both pump and driver for signs of overheating. Check all the oil reservoir levels. Check the mechanical seal flushing system for vibration. Check the pump casing for hot spots which will be attributable to internal rubbing. If these are apparent, stop the pump immediately and investigate.
- Run the pump for one hour, then shut it down by closing the discharge valve, stopping the driver, closing the suction valve and finally the recycle or bypass line. Open the casing vent to equalize the pressure and to allow the isolated pump to breathe. Drain the pump using the suction drain connection, then clean the suction pipe, screen and strainer either by manual cleaning through the strainer spool handhole or by removing the strainer spool completely. Strainer removal and cleaning should be carried out repeatedly until two consecutive inspections reveal that the strainer is clean.
- Re-install the strainers and operate the pump again for at least 4 hours, preferably for 24 hours if possible.

#### **4.1.5.3 Specific instructions for equipment in Pump discharge circuit**

When operating in a closed loop situation for prolonged periods up to 24 hours it is sometimes necessary to switch from the operating pump to the standby as the water slowly increases in temperature and the normal operating temperature of the pump can be exceeded over a long period. Do not exceed the normal operating temperature but do check the pump alignment, bearing housing temperatures, oil levels, etc. at normal operating temperatures if possible. Sometimes operation at the normal operating temperature cannot be reached and therefore final alignment checks must be left for initial unit operation on process fluid.

When shell and tube exchangers are included in a flushing loop, the inlet flange connections should be disconnected before flushing water is introduced to the exchanger. Steel sheets should be placed over the exchanger connections to keep debris out whilst the lines are flushed thoroughly. Once the lines are flushed, the flanges can be reconnected and the exchanger flushed out.

When flushing through a fired heater or reboiler, each pass should be flushed individually at first. Once the tubes are clean, the tube passes can be flushed as a whole.

After the loop has been flushed and cleaned, it can be drained of water, (either to sewer or to an adjacent loop which still has to be flushed), taking care not to pull a vacuum by draining water at a faster rate than the vents can let air in. All the low point drains should be checked in the open position and all water flow out of the lines and equipment must have stopped before the unit can be air blown and dried out.

In addition, all vessels and exchangers etc. should be opened up and inspected for damage and any accumulated dirt and debris should be removed at the same time. All blinds not necessary for start up of the unit should be removed. All temporary mesh screens inserted to protect pumps and equipment during the flushing operations should be removed. All permanent fine mesh strainers should be cleaned and re-installed.

Once the above work has been completed, the system should be connected up to a dry air supply and pressurized to between 0.8 kg/cm<sup>2</sup>g and 1.0 kg/cm<sup>2</sup>g. Systematically each vent and drain in turn should then be opened to drive any retained moisture out of the system. Once this is completed, the air supply should be maintained, exhausting the air through the partially open drain points in order to dry it out.

In addition, all vessels, towers and exchangers must be internally inspected for cleanliness. Internal vessel equipment and supports must be checked for correct installation and fixing.

Control valves should be reinserted in place of the temporary spools and all block valve seats inspected for cleanliness.

All instrument lead blinds should be removed, the lines should be reconnected and the block valve opened. Instrument bleeds should be closed.

All orifice plates previously removed should be carefully reinstalled, taking note to install them correctly with the sharp edge of the orifice on the upstream side. Check that the orifice plate weep hole is at the bottom for lines in vapour service to prevent build up of condensate in front of the plate. Conversely, for lines in liquid service, the weep hole is to be at the top to prevent the formation of vapour pockets.

Once the system has been put back into its original condition prior to hydrotest, connect it up to an inert gas supply. Introduce inert gas into the system, blowing out the air through vents until tests establish that the atmosphere in the system is at a maximum oxygen content of 1.0%. When this condition is reached, pressure the

system to a slight positive pressure (0.1 kg/cm<sup>2</sup> to 0.2 kg/cm<sup>2</sup>), having closed all vents. Check for leaks at newly made up flanges by the application of soap solution and once the system is leaktight maintain the inert gas purge pressure until the unit is ready for start-up activities. The inert gas atmosphere will ensure that, in the interim period, little if no internal corrosion takes place even if there happens to be residual moisture in the system due to inadequate dry out activities.

#### **4.1.6 Run-In of Compressors**

The following procedure is only applicable as a whole if a compressor undergoes major maintenance or repair work, or a new machine is installed.

For normal start-ups following shutdowns where no remedial work has been carried out on compressors, and the compressor loop has been maintained intact under a gas purge, this procedure can be replaced by the manufacturer's standard start-up instructions.

The compressors should be run-in as early as possible after the completion of maintenance or repair work in order to correct any problems that become evident.

Before run-in, all compressor suction piping must be thoroughly cleaned of grease, mill scale, weld spatter and debris. This may involve an acid cleaning procedure specified by the compressor manufacturer, based on the compressor loop materials of construction. Check that all necessary cleaning work has been carried out and the system has been certified as clean by the Maintenance Department. If a manufacturer's representative is present, obtain his agreement that the cleanliness of the loop is acceptable before the run-in begins. Check that the system has been maintained under an inert gas atmosphere since cleaning was completed.

All lines and vessels in the compressor loop must be pressure tested, flushed, cleaned and dried out.

- Suction strainers must be installed either in the suction drum overhead outlets or in the suction lines.
- All safety valves must be installed and operating correctly.
- All lube and seal oil circuits must be scrupulously clean in accordance with the manufacturer's procedures.
- All oil systems and cooling systems must be operational.
- All auxiliary equipment should be checked and commissioned, e.g. auxiliary oil pumps, etc.
- All associated interlocks, instrument control loops and control valves must be checked for correct operation.
- Simulation checks have been carried out on the portion of the unit alarm and shutdown system which interrelates to compressor operation.

## **4.2 Detailed start-up procedure**

### **4.2.1 Start-up Procedure for Utilities**

#### **4.2.1.1 Utility air**

	Action	Remarks
1.	Ensure that all maintenance jobs on utility air system are completed and system is complete in all respect.	
2.	Inform utilities section.	
3.	Deblind SB-2000, and open isolation valve at the battery limit in line 4"-UA-R41-7907-1CS1U01-NI.	
4.	Line up the utility air network.	
5.	Pressurize the header to normal operating level and check for leaks	
6.	Ensure that plant air is available at all hose stations.	

#### **4.2.1.2 Instrument air**

	Action	Remarks
1.	Ensure that all maintenance jobs on instrument air system are completed and system is complete in all respect.	
2.	If modifications are carried out in the instrument air header, blow the header with Nitrogen / plant air to remove dirt / debris / water. Clean the instrument air filter (F-1720A/B).	
3.	Inform utilities section.	
4.	Deblind SB-4000, and open isolation valve at battery limit in line 6"-IA-R41-7906-1CS1U01-NI.	
5.	Line up the instrument air network.	
6.	Check for leaks and attend.	
7.	Ensure that the header is pressurized to normal level.	

#### **4.2.1.3 Nitrogen**

	Action	Remarks
1.	Ensure that all maintenance jobs on nitrogen header are completed and the system is ready in all respect.	
2.	Inform Utility section.	

3.	Line up nitrogen network.	
4.	Deblind SB-3000, and open isolation valve at battery limit in line 6"-N-R41-7905-1CC1P01-NI.	
5.	Pressurize the header and check for leaks.	
6.	After the leak test, purge the nitrogen header to displace air from the network.	
7.	Gradually pressurize the header to normal operating level.	

#### 4.2.1.4 Fuel gas

	Action	Remarks
1.	The fuel gas header is inerted with nitrogen.	
2.	Inform Utility section.	
3.	Deblind B-5000, and open isolation valve at battery limit in line 12"-FG-R41-7908-1CC1P01-ST.	
4.	Pressurize fuel gas network by opening PV-7513 manually and then PC-7513 is set on auto mode to maintain the header to normal operating pressure (P=3.2 kg/cm <sup>2</sup> (g)).	
5.	The fuel gas is routed to Fuel Gas KO Drum (R41-D-1751 & R41-D-1750). Purge the nitrogen from the fuel gas network from Fuel Gas KO Drum (R41-D-1751 & R41-D-1750)bottom drains.	
6.	Ensure that the KO drums are lined up and ready for operation	

#### 4.2.1.5 Drinking water

	Action	Remarks
1.	Ensure that all maintenance job on the drinking water circuit are over and the circuit is ready in all respect.	
2.	Inform Utility section.	
3.	Line up drinking water network by deblinding SB-9000, and opening isolation valve at battery limit in line 3"-DW-R41-6900-12PUOU16-NI.	

#### 4.2.1.6 Demineralised Water

	Action	Remarks
1.	Ensure that all the maintenance job on the DM water circuit are over and the circuit is ready in all respect.	
2.	Inform utility section.	
3.	Deblind SB-7000 and open isolation valve in line 3"-DMW-R41-6902-1SC9U16-NI at	

	battery limit and route DM water to header.	
4.	Flush Each network user point	

#### 4.2.1.7 Caustic

Action	Remarks
1. Ensure that all the maintenance job on the caustic circuit are over and the circuit is ready in all respect.	
2. Inform utility section.	
3. Deblind SB-6001 and open ZV-460 in line 3"-CA-R41-0001-1CC1C37-NI at battery limit and route caustic to Caustic Package (R41-Z-1460).	
4. Refer to Vendor document for detailed start-up procedure for Caustic Package ( <b>R41-Z-1460</b> ) in document number V-202-1420-137-I-04-361.	

#### 4.2.1.8 Utility Water

Action	Remarks
1. Inform utility section.	
2. Deblind SB-8000 and open isolation valve in line 3"-UW-R41-6901-1CS2U16-NI at battery limit.	
3. Route utility water to header.	

#### 4.2.1.9 Boiler Feed Water

Action	Remarks
1. Ensure that all maintenance job on the boiler feed water circuit are over and the circuit is ready in all respect.	
2. Inform utility section.	
3. Deblind SB-6002, and open isolation valves at the battery limit in line 6"-BFW-R41-6907-6CS1P05-IH. Introduce boiler feed water into the header.	
4. Open vent valves on header to displace air. Route boiler feed water to individual users (R41-FR-130-SG, R41-E-136). Boiler feed water is supplied to the reactor effluent from R41-E-12110 A/M	

#### 4.2.1.10 HP / MP / LP steam

The Naphtha reformer unit is using HP (~ 42.5 kg/cm<sup>2</sup>G), MP ( 20.0 kg/cm<sup>2</sup>G) and LP (5.0 kg/cm<sup>2</sup>G) steam (Normal pressure) in various equipment.

	<b>Action</b>	<b>Remarks</b>
1.	Ensure that the maintenance jobs are over and the entire steam network is complete in all respect.	
2.	Keep all the tracings out of service. Isolate steam line to all the equipment such as turbines, ejectors, furnaces, pumps, steam generators etc.	
3.	Inform utility section.	
4.	Deblind SB-1001B, and SB-2001B in warm up line of HP steam header and MP steam header respectively. Deblind B-1000A and B-2000A in main line of HP steam header and MP steam header respectively. Slowly open the warm up valves first. Keep low point drain open. Avoid sudden heating / pressurization to ensure against thermal shock.	
5.	After ensuring that the line is warmed up and completely drained of condensate, throttle the drain bleeders and pressurize the line. Check for any leaks and attend.	
6.	When the pressure is equal at both, upstream and downstream sides of the battery limit block valve, slowly open the battery limit block valves wide and commission the line.	
7.	Open isolation valves at the battery limit in line 20"-HS-R41-6903-6CS1P05-IH and introduce HP steam into the header.	
8.	Open isolation valves at the battery limit in line 16"-MS-R41-6905-6CS1P05-IH and introduce MP steam into the header.	
9.	Commission steam traps to condensate headers and close drain points.	
10.	LP steam is generated within R41 and exported to battery limit. Deblind B-3001 before steam generation and when steam is available from R41, and open isolation valve in line 10"-LS-R41-6906-1CS1P05-IH.	

#### 4.2.1.11 Hot Condensate

Low Pressure clean hot condensate header collects the condensate from LP steam header steam traps and flashed condensate from Medium Pressure condensate header.

	<b>Action</b>	<b>Remarks</b>
1.	Ensure that the maintenance job on LP clean hot condensate system / MP steam hot condensate system is over and the circuit is complete in all respect including MP condensate flash drum (R41-D-1630) and LP Condensate flash drums (R41-D-1640) and hot condensate pumps (R41-P-1640 A/B)	
2.	Steam condensate from surface condensers of compressors (R41-K-13450 and R41-K-	

	135) is routed to cold condensate header which joins the main hot condensate header. Ensure that the maintenance job on cold condensate system is over and the circuit is complete in all respects. Line up the cold condensate header in the unit. Keep level control valves of surface condensers closed.	
3.	Inform utilities section.	
4.	Line up the hot condensate system in the unit by deblinding B-403 in line 10"-LC-R41-6911-1CS1P05-PP at battery limit. Keep the steam trap isolation valves on LP steam header closed.	
5.	Line up the contaminated condensate system in the unit by deblinding SB-4040 in line 6"-LC-R41-6649-1CS1P05-PP at battery limit.	
6.	Open high point vents to displace air from the circuit.	
7.	Once condensate level starts building in the MP condensate flash drum D-1630, slowly opening level control valve LV-6300 and MP condensate is sent to LP condensate Flash drum D-1640.	
8.	Once level in LP Condensate Flash Drum D-1640 is increased , start hot condensate pumps P-1640 A in minimum circulation mode by flow control valve FV-6400. Set level controller LC-6400/LV-6400 in auto mode after the level keeps rising in LP condensate flash drum D-1640. Route LP condensate to the contaminated condensate header 6"-LC-R41-6913 or to the normal LP condensate header 6"-LC-R41-6911 based on condensate quality sensed by analyser AE-6400.	

#### 4.2.1.12 Cooling Water

	Action	Remarks
1.	Ensure that all the maintenance job on the cooling water circuit are over and the circuit is ready in all respect.	
2.	Inform utility section.	
3.	Deblind B-5010, and open isolation valves at the battery limit in line 56"-CWS-R41-6914-12FEOU16-NI and introduce cooling water into the header.	
4.	Open high point vents to displace air from the circuit.	
5.	Check for any leaks and attend.	
6.	Following successful checks as mentioned above start lining up the cooling water lines for specific sections.	

7.	Deblind B-5010, and open isolation valves at the battery limit in line 56"-CWR-R41-6920-12FEOU16-NI and route cooling water return to battery limit.	
8.	Ensure cooling water flow through all heat exchangers in cooling water service.	

#### 4.2.1.13 Closed Drain

All low point drains and equipment drains in the system are collected in this drum through line 8"-CD-R41-8002-1CC1D01-NI. The oily water gets separated from oil and gathered in oily water compartment of Closed Drain Drum (R41-D-1000).

	Action	Remarks
1.	Deblind SB-1001C and open isolation valve in line 3"-OW-R41-0018-1CC1P01-NI and line up oily water to incinerator. Isolation valve in Oily water discharge pump P-1001 discharge line is in open position.	
2.	Ensure isolation valves on Closed Drain Pump P-1000 discharge are in open position.	
3.	During initial start-up of the unit, it is necessary to maintain a water level in the closed drain drum to prevent hydrocarbons from entering into the water section. So for initial start-up utility water connection is used to fill the closed drain drum with water level above the LLL and below HLL.	
4.	Once water level is achieved, hydrocarbons can be routed to the closed drain drum through the closed drain header.	
5.	When HLL is reached in closed drain drum oil compartment, the Closed Drain Pump (R41-P-1000) will autostart and route hydrocarbons to battery limit through SR Naptha Tank Rundown Cooler and SR Naptha Tank Rundown Trim Cooler. When HLL is reached in closed drain drum water compartment, Oily Water Drain Pump (R41-P-1001) will autostart and route oily water to battery limit through line 3"-OW-R41-0018-1CC1P01-NI.	

#### **4.2.1.14 Flare**

##### **4.2.1.14.1 LP Flare KO drum (R41-D-181)**

All the Low Pressure relief loads from R41 is routed to LP flare system. Any condensate present in reliefs are collected in LP flare knockout drum.

	<b>Action</b>	<b>Remarks</b>
1.	Ensure LP Flare condensate pump suction and discharge isolation valves are open. Also the battery limit isolation valve ZV-3640 of Off spec reformatte line is in open position and B-6400 is deblinded.	
2.	Line up steam through the heating coils of LP flare knockout drum.	
3.	Ensure ZV-8100 is open.	
4.	When liquid level reaches HLL in LP flare knockout drum, LP Flare Condensate Pumps (R41-P-181 A/B) will autostart and route LP flare condensate to battery limit through SR Naptha Tank Rundown Cooler and SR Naptha Tank Rundown Trim Cooler.	
5.	Drain the liquid collected in boot of LP flare knockout drum to closed drain header.	

##### **4.2.1.14.2 HP Flare KO drum (R41-D-182)**

All the High Pressure relief loads from R41 is routed to HP flare system. Any condensate present in reliefs are collected in HP flare knockout drum.

	<b>Action</b>	<b>Remarks</b>
1.	Ensure HP Flare condensate pump suction and discharge isolation valves are open. Also the battery limit isolation valve ZV-3640 of Off spec reformatte line is in open position and B-6400 is deblinded.	
2.	Line up steam through the heating coils of HP flare knockout drum.	
3.	Ensure ZV-8200 is open.	
4.	When liquid level reaches HLL in HP flare knockout drum, HP Flare Condensate Pumps (R41-P-182 A/B) will autostart and route HP flare condensate to battery limit through SR Naptha Tank Rundown Cooler and SR Naptha Tank Rundown Trim Cooler.	
5.	Drain the liquid collected in boot of HP flare knockout drum to closed drain header.	

#### **4.2.1.15 Oily Water Sewer (OWS)**

	<b>Action</b>	<b>Remarks</b>
1.	All oily water sewer in R41 is routed to OWS lift station (R41-Z-1010)	
2.	Deblind SB-1010 to route oily water to waste water treatment unit.	
3.	OWS Lift Station Pumps (R41-P-1010A/B) will autostart when liquid level in OWS lift station reaches HLL and route oily water to battery limit.	

#### **4.2.1.16 SYS Lift station**

	<b>Action</b>	<b>Remarks</b>
1.	All contaminated surface sewer in the system is routed to SYS lift station (R41-Z-1020)	
2.	Deblind B-2018 to route contaminated surface water to Contaminated Surface Water tank C340-TK-3491	
3.	When level in SYS lift station reaches NLL, SYS Lift Station Pump R41-P-1020A will autostart. In case of HLL, second pump R41-P-1020B will autostart & route contaminated surface water to battery limit.	

#### **4.2.1.17 Intermediate SYS lift station**

	<b>Action</b>	<b>Remarks</b>
1.	All contaminated surface water from UO2 are routed to intermediate SYS lift station (R41-Z-1030).	
2.	When level in Intermediate SYS lift station reaches NLL, Intermediate SYS Lift Station Pump R41-P-1030A will autostart and in case of HLL, second pump R41-P-1030B will autostart and route contaminated surface water to R41 SYS UG network.	

#### **4.2.1.18 SWS lift station**

	<b>Action</b>	<b>Remarks</b>
1.	Sanitary waste water from R41 is routed to SWS lift station (R41-Z-1040).	
2.	SWS Lift Station Pumps (R41-P-1040A/B) will autostart when liquid level in SWS lift station reaches HLL and route Sanitary waste water to battery limit.	

#### **4.2.2 Start-up procedure for R41-1**

##### **4.2.2.1 Chronology of start-up operations**

The chronology of the various start-up tasks is shown below. The durations shown are those required to perform the tasks. The time gap between two consecutive operations has not been taken into consideration.

- Complete inerting of the Naphtha Depentanizer (R41-T-111), the Naphtha Splitter (R41-T-112) and the LCN Splitter (R41-T-113).
- naphtha circulation to the columns.
- columns start-up on total reflux.
- Lining up of the unit at 50% capacity.
- Lining up of the unit at design capacity.

**Start-up Schedule**

TIME (DAYS)	0	1	2	3	4	5	6	7	8	9	10	11	12	13
<b>TASKS</b>														
- COMPLETE INERTING			██████████											
- FINAL LEAK TEST AND COLUMNS AT TOTAL REFLUX				██████████										
- LINE UP						██████████								

##### **4.2.2.2 Inerting**

	Action	Remarks
1.	<p>The Naphtha Depentanizer (R41-T-111), Naphtha Splitter (R41-T-112) and LCN splitter(R41-T-113) sections are inerted with nitrogen.</p> <p>Nitrogen normal operating pressure 8.1 kg/cm<sup>2</sup>(g) (in accordance with Doc. N. S-PM-G000-1222-0001).</p>	

	The purpose of this step is to reduce the O <sub>2</sub> content. O <sub>2</sub> content in all the sections shall be below 0.2% vol. prior to the introduction of hydrocarbons (Care however must be taken here as the design pressure of this section is much lower than the Nitrogen supply pressure)	
2.	Ensure PZV-1150A/B/C/D/E, PZV-1250A/B/C/D/E/F, PZV-1251A/B, PZV-135A/B/C, PZV-1351A/B in R41-1 are lined up with the flare system (Ensure nitrogen purge in the Flare header)	
3.	The battery limit shutdown valve ZV-1120 and spectacle blind SB-1207A in SR Naphtha Feed line (10"-P-R41-0004) is in closed position . The flow control valve FV-1120 at battery limit is closed on manual mode, upstream and downstream isolation valves are open	
4	HOFCC Unit LCN feed valve ZV-131 and spectacle blind SB-3100 in line no:6"-P-R41-0008 is closed position. The isolation valves and spectacle blind SB-1207B in SR Naphtha bypass line 4"-P-R41-0007 to LCN Spiltter is in closed position.(Note: Feed from HOFCC is lined up to LCN Spiltter once the Column is stabilized using SR Naphtha Feed)	
5	The battery limit valve ZV-136 and spectacle blind SB-3600A in Light LCN to storage line no:6"-P-R41-1027 is in closed position	
6	Ensure Cooling water is running through the exchangers <ul style="list-style-type: none"> <li>• Naphtha Depentanizer Trim Cooler E-1116</li> <li>• C5 Rich Cut Trim Coolers E-1114 A/B</li> <li>• Light Naphtha Trim Coolers E-1126 A/B</li> <li>• Light LCN Trim Coolers E-1136 A/B</li> <li>• SR Naptha Tank Rundown Trim cooler -1364 A/B</li> </ul>	
7	Ensure MP Steam is charged up to inlet isolation valve in below mentioned reboilers <ul style="list-style-type: none"> <li>• Naphtha Depentanizer Reboiler E-111</li> <li>• Naphtha Splitter Reboiler E-112 A/B</li> <li>• LCN Splitter Reboiler E-113</li> </ul>	Ensure that all steam condensate are drained from header by opening low point drains before MP Steam is charged by

		opening manual isolation valve at the inlet of each reboiler column.
8	During Initial startup LP steam is not available for SR Naphtha preheating in E-1112 Once the Naphtha Depentanizer Reboiler E-111 is started, MP steam line to E-111 is commissioned and return condensate flashed in MP condensate flash drum (R41-D-1630). Once condensate level starts building in the MP condensate flash drum D-1630, slowly opening level control valve LV-6300 and MP condensate is sent to LP condensate Flash drum D-1640. Also LP steam is flashed in LP condensate flash drum D-1640 by slowly opening HV-6350. Now LP steam is available for unit R41. Once LP steam is available line up the Naphtha Preheater (R41-E-1112). Line up TV-1120 (E-1112 tube side temperature controller) in auto mode. Now E-1112 preheats SR Naphtha from the ambient temperature of the storage to the unit normal temperature (65°C) inlet by means of LP steam.	
9	Once level in LP Condensate Flash Drum D-1640 is increased , start hot condensate pumps P-1640 A in minimum circulation mode by flow control valve FV-6400. Set level controller LC-6400/LV-6400 in auto mode after the level keeps rising in LP condensate flash drum D-1640. Route LP condensate to the contaminated condensate header 6"-LC-R41-6913 and later to the normal LP condensate header 6"-LC-R41-6911 based on condensate quality.	
8	Ensure T-111 bottom ZV-1100 is in closed position.	
9	Ensure T-112 bottom ZV-1200 is in closed position.	
10	Ensure T-113 bottom ZV-130 is in closed position	
11	Ensure D-11150 bottom ZV-1150 is in closed position.	
12	Ensure T-1125 bottom ZV-1250 is in closed position.	
13	Ensure T-1135 bottom ZV-135 is in closed position	

#### 4.2.2.3 tha circulation

The purpose of this procedure is to fill up the unit with naphtha, to circulate this fluid around the bottom of each columns (Naphtha Depentanizer T-111, Naphtha Splitter T-112 and LCN Splitter T-113, as well as associated equipment) and to remove water accumulation.

Naphtha circulation is configured in such a way that all the outgoing product streams are recombined in the SR Naphtha Tank (F56-TK-63/64) and fed again to the unit, while the columns are operating.

#### **4.2.2.3.1      Naphtha circulation flow sequence**

The start-up Naphtha circulation flow rate is fixed at 50% design throughput.

SR Naphtha from battery limit → FV-1120→E-1112 shell side →E-1111A/B shell side→T-111 column bottom →FV-1101 →T-112 column bottom →P-1120 A/B→E-1111A/B tube side→FV-1200B (Startup mode)→E-1363→E-1364 A/B shell side →SR naphtha / Off spec reformat to SR Naphtha storage tank F56-TK-63/64. (Line no: 10"-P-R41-3186)

SR Naphtha from battery limit (for LCN Splitter- through start up bypass line no:4"-P-R41-0007) → E-1131 A/B shell side →T-113 column bottom→P-1130 A/B →E-1131 A/B tube side →(E-1131 outlet start up bypass line no: 3"-P-R41-1024) → E-1136 A/B shell side→ Jump over line for startup 4"-P-R41-1027) → Off spec product to SR Naphtha storage tank F56-TK-63/64 (ZV-136 Light LCN to storage tank at Battery limit is closed)

(Initially the Feed for LCN Spiltter T-113 is through the SR Naphtha bypass line to LCN feed through E-1131 A/B shell side. HOFCC unit LCN feed valve ZV-131 in line no:6"-P-R41-0008 is in closed position before opening SR Naphtha feed valve ZV-1120.)

**Please refer to the below paragraphs for the more detailed start-up procedure relevant to section R41-1.**

#### **4.2.2.4    Start-up of Naphtha Depentanizer Section**

##### **4.2.2.4.1    Preparation for start-up**

	<b>Action</b>	<b>Remarks</b>
1.	Ensure the blind list is verified along with the checklist.	
2.	Pressurize the Naphtha Depentanizer (R41-T-111) section to 4.5 kg/cm <sup>2</sup> g with Nitrogen. Drain water from low points under nitrogen pressure	

3.	Naphtha Depentanizer section (R41-T-111) is pressurized using Nitrogen by opening pressure control valve PV-1151A bypass line via RO-1150 on top of drum D-11150	
4.	The temperature control valve TV-1120 across Naphtha Preheater E-1112 tube side is closed on manual mode, upstream and downstream isolation valves are open	
5.	The flow control valve FV-1101 at bottom of Naphtha Depentanizer T-111 is closed on manual mode, upstream and downstream isolation valves are open	
6.	Ensure that the pressure control valve PV 1151A on the nitrogen connection at the inlet of Naphtha Depentanizer Reflux drum D-11150 is in manual mode, upstream and downstream isolation valves are open	
7.	The flow control valve FV-1150/1154 in Naphtha Depentanizer Reflux line is closed on manual mode, upstream and downstream isolation valves are open	
8.	The pressure control valve PV-1151B/1153 in Naphtha Depentanizer Reflux Drum top is closed on manual mode, upstream and downstream isolation valves are open	
9.	The Nitrogen flow control valve FV-1152 in Naphtha Depentanizer Reflux Drum top is closed on manual mode, upstream and downstream isolation valves are open	
10.	The flow control valve FV-1105 in Naphtha Depentanizer Reboiler tube side is closed on manual mode, upstream and downstream isolation valves are open	

#### 4.2.2.4.2 Start-up procedure

The following steps should be performed to startup Naphtha Depentanizer section:

	Action	Remarks
1.	Remove blind (B-1207A) and open isolation valve ZV-1120 located at battery limit in line 10"-P-R41-0004 and introduce SR Naphtha into Unit R41-1. The flow control valve FV-1120 at battery limit are kept on maual mode during start-up till stabilization of R41-1.	
2.	Start bringing in naphtha from SR Naphtha Tank (F56-TK-63/64) to inlet of the Naphtha Depentanizer R41-T-111 through Naphtha pre heater (R41-E-1112) tube side and Naphtha depentanizer feed / Naphtha splitter bottom exchanger shell side (R41-E-1111A/B).	

3.	During Initial startup LP steam is not available for SR Naphtha preheating in E-1112 and also naphtha splitter bottoms <b>is</b> not available to provide heat to Naphtha depentanizer feed / Naphtha splitter bottom exchanger. Therefore SR Naphtha sent to Naphtha Depentanizer T-111 at ambient condition	Once LP steam is available TV-1120 will be in auto mode
4.	When the bottom level starts to rise in T-111 and reaches 80% level, open ZV-1100 and start feeding the Naphtha Splitter T-112 by slowly opening FV-1101 in manual mode. In parallel bring some naphtha from the battery limit by reversing the blind and opening the manual valves on line 4"-P-R41-0007 to the LCN Splitter T-113. When the bottom levels of columns T-111, T-112 & T-113 indicate 80%, stop the naphtha feed by closing the battery limit valve in line 10"-P-R41-0004.	
5.	During startup naphtha splitter bottoms <b>is</b> not available to provide heat to Naphtha depentanizer feed / Naphtha splitter bottom exchanger. At this point the temperature required for the column operation <b>is</b> provided by Naphtha Depentanizer Reboiler E-111. (Once unit is stabilized, naphtha is heated against the bottom of the Naphtha Splitter T-1120 in the Naphtha Depentanizer Feed/Naphtha Splitter Bottom Exchangers E-1111A/B. After going through the E-1111A/B, the hot naphtha is fed into the tray 13 of the Naphtha Depentanizer column T-111.	
6.	Naphtha depentanizer reboiler E-111 tube side is charged with MP steam by opening MP steam inlet isolation valve on line 10"-MS-R41-6102 <b>and opening the relevant 11/2" drain valve on gravel pit.</b>  <b>Once only condensate flows thorugh the drain valve, open slowly flow control valve FV-1105 in manual mode (in MP condensate line to the MP condensate header) and make sure that steam will not send to MP condensate header downstream FV-1105.</b> The Naphtha Depentanizer temperature is controlled by TC-1102 temperature controller on tray 1, which resets steam side FV-1105 flowrate.	Once T-111 is stabilized on total reflux TC-1102 to be cascaded with FV-1105 to reset steam flow
7.	When overhead temperature start to increase above 79°C, start the fans of Naptha Depentanizer Air Condenser E-1115. 50% of the fans are provided with auto variable pitch control for temeperature control by TC-1151. This stream is further cooled in Naphtha depentanizer trim cooler R41-E-1116 to cool the vapors to 60°C.	

8.	The cooled Naphtha depentanizer overhead vapors are then fed to Naphtha Depentanizer reflux drum D-11150. When the level of the reflux drum indicate 50% in LC-1150, open ZV-1150 and start Naphtha Depentanizer Reflux Pumps P-1115 A/B. By slowly opening flow control valve FC-1150 in manual mode, route reflux to column operating on total reflux. Once flow rate is stabilized at 50% of normal operating flow FC-1150 in auto mode cascaded with level controller LC-1150. (The outlet valve ZV-1150 from the Naphtha depentanizer reflux drum to the Naphtha depentanizer pumps must be fully open before the pumps can start)	The control valve FV-1154 on line 4"-P-R41-1160-1CC1P01-NI is kept closed to route all the reflux to T-1110
9.	By opening PV-1151 A/B/PV-1153 in manual mode Naphtha Depentanizer reflux drum D-1115 pressure is maintained. Once column is stabilized in total reflux mode , O2 rich gas is routed to flare by opening pressure control valve PV-1151B / PV-1153. The pressure controllers PC-1151 and PC-1153 are kept in auto mode which maintains the operating pressure of Naptha Depentanizer Reflux Drum	
10.	Continue bringing naphtha to the column as required to maintain the level at the bottom. Any excess level in the reflux drum (apart from reflux flow through FV-1150) can be routed to the Off spec C5 rich cut to SR Naphtha Tank by aligning the valves on line 4"-P-R41-1051-1CCB01-NI (open) and 6"-P-R41-1049-1CC1P01-NI (closed).	
11.	When treating SR Naphtha directly from the upstream units, the Naphtha Depentanizer overhead <b>is</b> totally condensed in a single phase, and the reflux <b>is</b> pumped back to the column by means of the Naphtha Depentanizer Reflux Pumps R41-P-1115A/B.	

12.	<p>Straight-run naphtha coming from outside Battery Limit can contain oxygen and water, that are separated from the hydrocarbon phase in the Naphtha Depentanizer Reflux Drum, R41-D-11150.</p> <ol style="list-style-type: none"> <li>1. The oxygen is routed Fuel Gas Header (in normal operation) or to Flare (in start-up);</li> <li>2. The free water is decanted through reflux drum, R41-D-11150 boot; level control valve LV-1152 routes water to OWS.</li> </ol>	<p>Due to the dissolved oxygen present in straight-run naphtha coming from Storage tank, the off-gas generated from Naphtha Depentanizer (R41-T- 1110) contains a certain level of oxygen</p>
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13.	<p>During normal operation Naphtha Depentanizer Reflux drum off gas <b>is</b> routed to the fuel gas header in R41 unit as the primary destination to Reformer Heater R41-FR-13110/13210/13310/13410.</p> <p>During start-up, when the reformer heater (R41-FR-13110/13210/13310/13410) is not started or in case of heater shutdown, the off-gas has to be vented to the flare after dilution with Nitrogen by means the action of AC-1150. Pressure controller PC-1153 is provided for the vent to flare to release off gas automatically. Set point of this pressure controller PC- 1153 is higher than the normal operating pressure so that the pressure control valve is normally closed.</p>	<p>Oxygen analyser AIC-1150 (located on off gas line) measures the O<sub>2</sub> %vol. Whether concentration of O<sub>2</sub> is higher than 3%vol, Nitrogen will be injected in line in order to dilute the Off-Gas before to send it to flare.</p>
14.	<p>In the Naphtha Depentanizer column, a C5 rich cut is taken on a draw off located in tray 28. Start C5 Rich Cut Pump in minimum circulation mode through C5 Rich Cut Trim Coolers R41-E-1114A/B back to pump suction. Once T-112 is stabilized on total reflux mode and send C5 rich cut to SR Naphtha tank by means of the C5 Rich Cut Pumps R41-P-1114A/B via C5 Rich Cut Trim Coolers R41-E-1114A/B by slowly opening flow control valve R41-FC-1140 in manual mode . Once flow is 50% of normal operating flow FC-1140 cascaded with temperature controller R41-TC-1103 .The increase of temperature at R41-TT-1103 (corresponding to an increase of heavy compounds at tray 27 of the column) results in closing R41-FV-1140 and reciprocally in case of decrease of the temperature</p>	<p>Ensure isolation valve in C5 rich cut to storage is in closed position Isolation valve in off spec line 4"-P-R41-1051 is in open</p>

#### **4.2.2.5 Start-up of Naphtha Splitter Section**

##### **4.2.2.5.1 Preparation for start-up**

	<b>Action</b>	<b>Remarks</b>
1	Ensure the blind list is verified along with the checklist.	
2	The pressure control valve PV-1252 on Naphtha Splitter Reflux Drum is closed on manual mode, upstream and downstream isolation valves are open.	
3	Pressurize the Naphtha Splitter (R41-T-112) section to 1.7 kg/cm <sup>2</sup> g with Nitrogen. Drain water from low points under nitrogen pressure.	
4	Naphtha Splitter section (R41-T-112) is pressurized using Nitrogen line 2"-N-R41-7103 on top of drum R41-D-11250	
5	Ensure R41-D-11250 bottom ZV-1250 is in closed position	
6	The flow control valve FV-1250 in Naphtha Splitter Reflux line is closed on manual mode, upstream and downstream isolation valves are open.	
7	The flow control valve FV-1205 in Naphtha Splitter Reboiler tube side is closed on manual mode, upstream and downstream isolation valves are open	
8	The flow control valve FV-1200B in E-1111 A/B tube side outlet is closed on manual mode, upstream and downstream isolation valves are open	
9	The flow control valve FV-1200A in E-1111 A/B tube side outlet is closed on manual mode, upstream and downstream isolation valves are open	
10	The flow control valve FV-1251 in Light Naphtha rundown line is closed on manual mode, upstream and downstream isolation valves are open.	

##### **4.2.2.5.2 Start-up procedure**

The following steps should be performed to start-up Naphtha Splitter section:

	<b>Action</b>	<b>Remarks</b>
1.	Ensure Naphtha Splitter section (R41-T-112) is pressurized using Nitrogen line 2"-N-R41-7103 on top of drum D-11250	

2.	Withdraw bottoms from Naphtha Depentanizer by opening ZV-1100 and slowly opening flow control valve FV-1101 to route it to Naphtha Splitter (R41-T-112). Once the flow stabilized to 50% of normal operating flow then T-111 bottom level controller LC-1100 and flow control valve FV-1101 are aligned in auto mode to maintain the level in Naphtha Depentanizer bottom.	
3.	<p>Once level builds to 80% in Naphtha Splitter bottom (LC-1200). Start Naphtha Splitter Reboiler E-112A/B by introducing steam <b>into the tube side by opening the isolation valves in steam inlet line 10"-MS-R41-6119 and opening the relevant 1 1/2" drain valve on gravel pit.</b></p> <p><b>Once only condensate flows through the drain valve, open slowly flow control valve FV-1205 in manual mode (in MP condensate line to the MP condensate header) and make sure that steam will not send to MP condensate header downstream FV-1205.</b></p> <p>The Naphtha Splitter temperature is controlled by TC-1205 temperature controller on tray 27, which resets steam side FV-1205 flowrate.</p> <p>Note: By adjusting isolation valve in shell side inlet line 30"-P-R41-1056 the vapourization rate</p>	Once T-112 is stabilized on total reflux, TC-1205 to be cascaded with FV-1205 to reset steam flow
4.	When overhead temperature starts to increase (monitored by TI-1250), start fans of Naphtha Splitter Air Condenser E-1125. 50% of the fans are provided with auto variable pitch control. The overhead vapor from the Naphtha Splitter is cooled down in the Naphtha Splitter Air Condenser E-1125 and routed to the Naphtha Splitter Reflux Drum R41-D-11250	
5.	By opening PV-1250 in manual mode Naphtha Splitter reflux drum D-11250 pressure is maintained. Once column is stabilized in total reflux mode The pressure control valve PV-1250 located on D-11250 top is aligned to flare in auto mode to maintain operating pressure of T-112 as 1.7 kg/cm <sup>2</sup> g	

6.	When the level of the reflux drum D-11250 indicate 50% in LC-1250, open ZV-1250 /MOV- 1250 A/B and start Naphtha Splitter Reflux Pumps (R41-P-1125 A/B). By slowly opening the flow control valve FC-1250 in manual mode, route the reflux to column operating on total reflux. (The outlet valve ZV-1250/MOV-1250A/B from the Naphtha depentanizer reflux drum to the Naphtha depentanizer pumps must be fully open before the pumps can start). Refer vendor operating manual V-202-1420-134-F-02-856 for detailed pump startup.	
7.	The operating pressure of naphtha splitter reflux drum (1.1 kg/cm <sup>2</sup> (g) is maintained by PC-1252.	
8.	Once T-112 is stabilized on total reflux mode, Naptha Splitter bottoms (16"-P-R41- 1028-1CC1P01-IH) is routed SR Naphtha Tank. Start Heavy Naptha Pumps R41-P- 1120A/B by fully opening the valve ZV-1200 and MOV-1200A. (Naphtha Splitter bottom routed to SR Naphtha Tank through Naptha Depentanizer Feed / Naptha Splitter Bottom Exchangers / SR Naphtha Tank Rundown Aircooler E-1363 / SR Naphtha Tank Rundown Trim cooler E-1364 A/B during start-up). Refer vendor operating manual V-202-1420-134-F-02-857 for detailed start-up procedure of the Heavy Naptha Pumps.	
9.	By slowly opening flow control valve FV-1200B in manual (start mode operation) route Heavy Naphtha to Naphtha Depentanizer Feed/Naphtha Splitter Bottom Exchangers R41-E-1111A/B (tube side).	Once T-112 is stabilized, LC-1200 to be cascaded with FV-1200B
10.	Then, switch on the fans of SR Naphtha Tank Rundown Aircooler (R41-E-1363) to cool Heavy Naphtha stream and it is further cooled in SR Naphtha Tank Rundown Trim cooler (R41-E-1364 A/B) then routed to SR Naphtha Tank through line 10"-P-R41-3186-1CC1B01-NI by opening ZV-3640 at battery limit.	

11.	By slowly adjusting the operating condition of Naphtha Depentanizer T-111 / Naphtha Splitter T-112, once column is stabilized and the products reached the acceptable cut point. Then heavy naphtha is routed to Naphtha Hydrotreatment Section R41-2 by slowly opening flow control valve FV 1200A and closing FV-1200B in manual mode manual mode. Also C5 rich cut is taken on a draw off located in the tray 28 and sent to C5 reach cut Storage Drum TK-2760 A/B by means of the C5 Rich Cut Pumps R41-P- 1114A/B via C5 Rich Cut Trim Coolers R41-E-1114A/B by opening the isolation valve in line 6"-P-R41-1049 and closing the isolation valve in line 4"-P-R41-1051 (off spec C5 Rich cut to SR naphtha Tank)	Sampling point S7-1200 is used to monitor Heavy Naphtha composition)
12.	Parallelly the light naphtha composition is checked using sample point S5-1250 and once the acceptable cut point is reached start sending Light Naphtha product to storage by slowly opening flow control valve FV-1251 in manual mode. Once 50% of operating flow is reached FV-1251 cascaded with T-112 bottom level control LC-1250 in light naphtha rundown line 6"-P-R41-1026.	
13.	The oily water from the naphtha splitter reflux drum (R41-D-11250) is routed to OWS manually by monitoring the level indicator LI-1351. once the interface between hydrocarbon and water is seen in LI-1351, the operator must close the gate valve on the line to OWS and open the gate valve on the line to CDA. Now open the main boot discharge valve in line 1.5"-P-R41-1104-1CC1P01-NI , so that the hydrocarbon is sent to CDA.	

#### 4.2.2.6 Start-up of LCN Splitter Section

##### 4.2.2.6.1 Preparation for start-up

	Action	Remarks
1	Ensure the blind list is verified along with the checklist.	
2	The pressure control valve PV-1352 on LCN Splitter Reflux Drum is closed on manual mode, upstream and downstream isolation valves are open.	
3	Pressurize the LCN Splitter section (R41-T-113) to 2.7 kg/cm2g with Nitrogen. Drain water from low points under nitrogen pressure	
4	LCN Splitter section (R41-T-113) is pressurized using Nitrogen line 2"-N-R41-7102 on	

	top of drum D-1135	
5	Ensure D-1135 bottom ZV-135 is in closed position	
6	The flow control valve FV-135 in LCN Splitter Reflux line is closed on manual mode, upstream and downstream isolation valves are open.	
7	The flow control valve FV-1305 in LCN Splitter Reboiler tube side is closed on manual mode, upstream and downstream isolation valves are open	
8	The flow control valve FV-1351 in E-1136 A/B shell side inlet (Light LCN to storage) is closed on manual mode, upstream and downstream isolation valves are open	
9	The flow control valve FV-131 in E-1131 A/B tube side outlet (Hydrotreated Naphtha to R41 section 2) is closed on manual mode, upstream and downstream isolation valves are open	

#### 4.2.2.6.2 Start-up procedure

The following steps should be performed to start-up LCN Splitter section

	Action	Remarks
1.	Ensure LCN Splitter section (R41-T-113) is pressurized using Nitrogen line 2"-N-R41-7102 on top of drum D-1135.	
2.	Deblind (SB-1207B) and open the isolation valves in line 4"-P-R41-0007 to route SR Naphtha to LCN Splitter. Prior to opening the valves in line 4"-P-R41-0007-1CC1P01-NI Ensure battery limit valve ZV-131 in line 6"-P-R41-0032 is closed	
3.	Route SR Naphtha from battery limit to LCN Splitter (R41-T-113) through shell side of LCN Splitter Feed/Bottom Exchangers (R41-E-1131A/B). The feed is fed into the tray 25 of the LCN Splitter column. During startup LCN splitter bottoms <b>is</b> not available for heating up the feed in LCN Splitter Feed/Bottom Exchangers. During this time the LCN splitter reboiler (R41-E-113) provides the required heat for column operation	FI-13110 to monitor SR Naphtha flow
4.	Ensure 80% level in LCN Splitter bottom with LC-130, and stop the naphtha feed by closing the isolation valves line 4"-P-R41-0007	
5.	Start LCN Splitter Reboiler (R41-E-113) by introducing steam into the tube side by opening the isolation valves in steam inlet line (8"-MS-R41-6123) <b>and opening the relevant 11/2" drain valve on gravel pit.</b>	Once T-113 is stabilized on total reflux,

	<p>Once only condensate flows through the drain valve, open slowly flow control valve FV-1305 in manual mode (in MP condensate line to the MP condensate header) and make sure that steam will not send to MP condensate header downstream FV-1305.</p> <p>The Naphtha Splitter temperature is controlled by TC-1302 temperature controller on tray 1, which resets steam side FV-1305 flowrate.</p>	TC-1302 to be cascaded with FV-1305 to reset steam
6.	When overhead temperature starts to increase, start fans of LCN Splitter Air Condenser (R41-E-1135). 50% of the fans are provided with auto variable pitch control. The overhead gas from the LCN Splitter is totally cooled down in the LCN Splitter Air Condenser R41-E-1135 and routed to the LCN Splitter Reflux Drum R41-D-1135.	
7.	By opening PV-135/1352 in manual mode LCN Splitter reflux drum D-1135 pressure is maintained. Once column is stabilized in total reflux mode The pressure control valve PV-1352 located on D-1135 top is aligned to flare in auto mode and also pressure controller PC-135 and PDV-1351 to maintain operating pressure of T-113 as 2.7 kg/cm <sup>2</sup> g. The operating pressure of LCN splitter reflux drum (2.1 kg/cm <sup>2</sup> g) is maintained by PC-1352	
8.	When the level of the reflux drum D-1135 indicate 50% in LC-135, open ZV-135 and start LCN Splitter Reflux Pumps (R41-P-1325 A/B). By slowly opening the flow control valve FC-135 in manual mode, route the reflux to column operating on total reflux. (The outlet valve ZV-135 / isolation valves at bottom of LCN Splitter reflux drum must be fully open before the pumps can start) Refer vendor operating manual V-202-1420-134-F-02-829 for detailed pump startup procedure.	
9.	Once the column stabilized on total reflux mode, slowly adjust operating condition of LCN Splitter T-113 to reach the acceptable cut point. Open T-113 bottom ZV-130 and start Heavy LCN pump P-1130 A/B to route off-spec LCN to Light LCN storage through LCN Splitter Feed/Bottom Exchanger (R41-E-1131A/B) via startup bypass line 3"-P-R41- 1024 and Light LCN Trim coolers E-1136 A/B. Refer vendor operating manual V-202-1420-134-F-02-830 for detailed start-up procedure of the pump.	
10.	Bring additional SR Naphtha from battery limit by opening isolation valves in line 4"-P-R41-0007 and maintain level in the LCN Splitter bottom.	
11.	is Once column stabilized, close isolation valves and reverse blind (SB-1207B) in line 4"-P-R41-0007. Deblind and open isolation valves in line 6"-P-R41-0032 and introduce LCN feed from HO FCC unit . Once the column is stabilized and the product reaches the	Sampling point S7-131 is used to

	acceptable cut point	monitor the heavy LCN composition
12.	By slowly opening flow control valve FV-131 in manual mode, Heavy LCN is sent to Naphtha Hydrotreating section by opening isolation valve in line 4"-P-R41-1023 and isolation valve in startup bypass line 3"-P-R41-1024 to be closed. Once 50% of the normal operating flow has reached cascade FC-131 with level control LC-130 in T-1130 bottom in auto mode to maintain the level of T-113.	
13.	Parallelly the light LCN composition is checked using sample point S5-135 and once acceptable cut point is reached start sending the product to storage. By slowly opening flow control valve FV-1351 in manual mode to route Light LCN to storage through Light LCN trim Coolers E-1136A/B . Once 50% of the normal operating flow has reached cascade FC-1351 with level control LC-135 in LCN Splitter reflux drum in auto mode to maintain the level of D-1135.	
14.	The boot oily water from the LCN splitter reflux drum (R41-D-1135) is sent to OWS. This is a manual operation, by monitoring the level indicator LI 1351. Once the interface between hydrocarbon and water is seen the operator must close the main valve in the boot discharge (The level gauge is readable from this valve). Next step is to close the gate valve on the line to OWS and open the gate valve on the line to CDA. Now open the main boot discharge valve so that the hydrocarbon is sent to CDA.	

### **4.2.3 Start-up procedure for R41-2**

#### **4.2.3.1 Preparation for First Start-up**

##### **4.2.3.1.1 Dry-Out of the unit**

The reaction section must be thoroughly dried prior to catalyst and adsorbent loading to avoid damaging the hydro treating catalyst with free water during unit heat-up.

The refractory drying of the Reactor Feed Heater FR-12110 can be conducted simultaneously with the unit heat-up. In this case, the procedure for refractory drying will control the rate of temperature rise and the duration of the drying step. (Refer vendor operating manual V-202-1420-144-K-01-1267 for Refractory drying for the Reactor Feed Heater). The AXENS start-up representative will consult with the heater manufacturer's representative to agree on an acceptable procedure.

Refer to "Reactor Feed Heater R41-FR-12110 Dry Out Procedure – Naphtha HDT Section" (Doc.N. S-EP-R400-173-0020) and "Hydrotreating Reactor R41-R-121 Dry Out Procedure – Naphtha HDT Section" (Doc.N. S-EP-R400-173-0018).

Drying is carried out under nitrogen. Refer to attachment in section 8.1 for Drying Out.

##### **4.2.3.1.1.1 Preparation for Dry-Out**

	<b>Action</b>	<b>Remarks</b>
1.	Ensure all thermocouples and the furnace fuel controllers have been checked (including firebox and skin thermocouple)	
2.	The blinds should still be in place, isolating the reaction section from the other sections and from the flare, sewers, etc	
3.	Isolate the Recycle Compressors K-1215A/B suction ZMV-2151A and spectacle blind B-2156A is in closed position	
4.	Ensure the entire reaction section is open, i.e., all pathways between pieces of equipment are clear. Remove the blinds on the "start-up" lines or intermittent use lines	
5.	Commission the Reactor Effluent Air Condenser E-1212	
6.	Ensure cooling water is running through the Reactor Effluent Trim Condenser E-1213A/B	
8.	The flow control valve FV-2011 and FV-2013 in Heavy Naphtha Feed line (Discharge from Feed Pumps P-1201A/B), upstream and downstream isolation valves and its manual	

	bypass is closed. Also blind B-2014 is in closed position.	
9.	Ensure FV-2120 in HP BFW make-up is closed on manual and upstream and downstream isolation valves is isolated. Also double block and bleed valves and spectacle blind SB-2021 in BFW line 3"-H-R41-21540 is in closed position	
10.	Ensure ZV-2141 (bottom of Separator Drum D-12140 boot) is closed. Level control valve LV-2141 is closed on manual, upstream and downstream isolation valves and its bypass valve is isolated from Sour Water Drum D-12160	
11.	Ensure ZV-2140 (bottom of Separator Drum D-12140) and flow control valve in separator liquid line FV-2140, upstream and downstream isolation valves are closed and isolated from the Stripper Feed/Bottom Exchanger E-1221 A/B/C	
12.	Ensure ZV-2150 and FV-2155 (on hydrogen rich gas / Pure H <sub>2</sub> from Aromizing <b>Section</b> / Distribution Header) is closed and upstream and downstream isolation valves is isolated.	
13.	Ensure FV-2156 to route recycle gas to flare is closed on manual mode, upstream and downstream isolation valves are open	
14.	Ensure manual valve which is provided at the bottom of Recycle compressor KO drum D-1215 is isolated.	
15.	Ensure that the emergency depressurizing valve ZV-2145 provided on Separator Drum D-12140 top is closed.	
16.	Introduce nitrogen upstream of Recycle Compressor K-1215A/B	

#### **4.2.3.1.1.2 Dry out procedure**

The drying out operation **is** held in a single phase. Refer to drying out drawings given in section 8.1.

Start the Recycle Compressor K-1215A/B and circulate the nitrogen at maximum rate through the reaction section as indicated in the drying out drawings in section 8.1. (Refer latest revision of vendor operating manual V-202-1420-130-M-01-457 for the Recycle Compressor R41-K-1215 A/B)

The following equipment's with their connections are included:

- Hydrotreating Reactor (R41-R-121)
- Reactor Feed Heater (R41-FR-12110)
- Reactor Feed Effluent Exchangers (R41-E-12110 A to M)

- Reactor Effluent Air Condenser (R41-E-1212)
- Reactor Effluent Trim Condenser (R41-E-1213 A/B)
- Separator Drum (R41-D-12140)
- Recycle Compressor KO drum (R41-D-1215) OVHD section.

Steps to be followed for drying out procedure:

	Action	Remarks
1.	Reaction section loop is pressurized with Nitrogen to normal operating pressure of Nitrogen supply header 8.1 kg/cm2g	
2.	When the suction pressure of Recycle compressor R41-K-1215A/B indicated by PT-21540A is 8.1 kg/cm2g and circulate nitrogen at maximum rate through the reaction section as indicated in the PFD (D-EP-R41-1223-4201). Refer latest revision of vendor operating manual V-202-1420-130-M-01-457 for detail start-up procedure of R41-K-1215A/B.	Max N <sub>2</sub> flow 48400 kg/h
3.	By slowly opening the flow control valve FV-2156 in manual mode Separator Drum pressure is maintained during drying out operation	
4.	Light up one by one all pilots of the Reactor Feed Heater FR-12110. Refer latest revision of vendor operating manual V-202-1420-144-K-01-1267 for detail start-up procedure of R41-FR-12110.	
5.	Start free water draining at all the low points and the Separator Drum water boot D-12140. While the system is heating up, check for leaks. If required, perform hot bolting to tighten.	
6.	Raise the Hydrotreating Reactor ( <b>R41-R-121</b> ) inlet temperature up to 300° C maximum at 15°C/hr. Hold this temperature for 36 hours. The Reactor inlet temperature is controlled by temperature controller TC-2100 by varying fuel gas flow (FV-2114) to FR- 12110. During this operation flames inside Reactor Feed Heater FR-12110 should be observed to detect any wrong pattern and specially flame impingement.	
7.	Continue free water draining at all the low points and the Separator Drum water boot D-12140. The system is considered as dry when the amount of water drained at all the low points is less than 1.0 liter/h for two consecutive hours.	
8.	Decrease Hydrotreating Reactor ( <b>R41-R-121</b> ) inlet temperature down to 150° C at 50°C/hr by varying the fuel gas flow to FR-12110	

9.	Shutdown the Reactor Feed Heater FR-12110 and continue the circulation of nitrogen in reaction section loop until Hydrotreating Reactor ( <b>R41-R-121</b> ) temperature reaches Recycle Compressor K-1215 A/B discharge temperature (107°C).	
10.	Shutdown and isolate Recycle Compressor K-1215 A/B. Ensure that the emergency depressurizing valve ZV-2145 provided on Separator Drum (R41-D-12140) is Opened.	
11.	Depressurize the reaction section loop and start the preparation of Hydrotreating Reactor ( <b>R41-R-121</b> ) catalyst loading.	

#### **4.2.3.1.2      Reactors catalyst loading**

Correct catalyst loading is absolutely necessary for achieving the expected performance from the unit. This section presents guidelines for correct loading of the Hydrotreating Reactor (**R41-R-121**).

##### **4.2.3.1.2.1      Preliminary checkings for catalyst loading under nitrogen**

- Check that the Hydrotreating Reactor (**R41-R-121**) are properly isolated. This verification should be recorded on the commissioning/start-up blind list.
- Make sure that the catalyst and gradings material ACT 069/078/108/139 and inert balls drums are gathered in a sheltered place, close to the Reactor.
- Check the quality of the inert balls and of the grading material ACT 069/078/108/139. If they are broken, they must be sorted and fines removed.
- Check that all the internal parts to be installed during loading are available. Check their conformity to the drawings and numbering done during preliminary assembling. If some gaskets remain in place during catalyst loading protect them with adequate hard protections (plywood or aluminium).
- All the Reactor internals are made of parts, which can be dismantled in order to allow passage through the manhole. Their assembly must be checked beforehand.
- Ensure that all the necessary safety and personnel protection equipment is available (gloves, dust masks, respirators, safety harness, etc.) as well as means of communication (walkytalkies).
- Before loading, the catalyst drums must be stored in a safe place and protected from rain.

##### **4.2.3.1.2.2      Specific Recommendations**

- To avoid catalyst attrition, do not roll drums of catalysts.

- Whenever possible in case of sock loading a person **should** be inside the Reactor to level the catalyst bed and move the loading sleeve. Another person must be in attendance outside with equipment and instructions in case of emergency.
- Catalyst must be loaded carefully to minimize free fall. Maximum permissible free fall height is 1 meter. Do not walk directly on catalyst. Use wooden walking boards.
- In case of heavy rains stop loading. If prolonged rainy weather is forecast, provision for a weatherproof cover must be made. If loading operations are not to continue for an extended period, then the inlet flanges must be covered in a weather tight fashion whilst unattended.
- Working in a dusty catalyst atmosphere is not physically harmful, provided that dust masks are worn. Make sure that no foreign material is left in the reactor (pieces of sleeve, walking boards, tools, etc.).

#### **4.2.3.1.2.3        Special loading devices**

The equipment includes:

- A stationary hopper to be built on site (see drawings in attachment given in section 8.18.1). The stationary hopper is fitted with a slide valve. The hopper legs should be long enough to allow access into the Reactor.
- Canvas sleeves (adequate length, 150 mm diameter).
- A mobile hopper containing about 3 drums of catalyst (see drawings in attachment given in section 8.18.1).
- A lifting device to lift the mobile hopper from the ground level. This lifting device could be either a crane or a system of winches.
- At ground level a temporary platform should be erected at the level of the truck used to transfer the catalyst drums or big bags from storage to the reactor site. The drums will be transferred from the truck to the platform, opened, and poured in the mobile hopper. Empty drums should be stored on site or immediately returned to storage facilities (see drawings in attachment given in section 8.18.1).
- On top of the Reactor a temporary platform should be installed, to allow the operation of the mobile hopper slide valve during loading (see drawings in attachment given in section 8.18.1).

To protect catalyst from rain, temporary shelters should be installed on top of Reactor and ground level platform.

- A vacuum cleaner should be available to eliminate dust and catalyst fines inside the reactor.
- Tooling, lighting facilities, dust masks, respirators, safety harnesses, should be also prepared. It is particularly recommended that personnel involved in handling and loading of the catalyst be properly clothed, e.g. long-sleeved shirts, gloves and safety glasses

- Furthermore self-contained breathing apparatus (SCBA) **to** be used by any person who must handle the catalyst or enter a closed area containing the catalyst, e.g. inside the Reactor
- Bottles should be available to take samples of the catalyst during loading.

#### **4.2.3.1.2.4 Detail procedure on loading of the catalyst**

It is important that good housekeeping be maintained throughout the loading. Various heights (catalyst bed and alumina layers etc...) **to be as per relevant equipment datasheet**. Inside the reactor measurement **to be taken from the welding line**. Manufacturer's vessels measurements are generally shown from tangent lines. Make the necessary adjustment. Materialize the various levels with chalk marks on the reactor wall.

##### **Loading of R41-R-121 with HR-538:**

Loading of catalyst and fitting of internal parts are as per the following procedure.

Refer to drawings about loading under air.

Check that the quality of the catalyst and the amount available are as specified. It also assumes that the internals have been, first inspected in position, and then dismantled to speed up the loading process.

- Insert the plugs in the catalyst draw-off pipes.
- During the following operation note and record the volumes of alumina balls, grading material and catalyst loaded and other data such as manpower, loading time and problems encountered.
- Load the required volume of alumina balls and build up the bottom layer of  $\frac{3}{4}$ " alumina balls, carefully level the surface, then build up the volume of  $\frac{1}{4}$ " alumina ball layer and planks so as not to mix the layers.
- Take care not to dislodge or bend the thermocouples sleeves.
- Start loading the catalyst bed HR-538 with the sleeve. The person inside the reactor **should** move the sleeve around to build a level of catalyst as uniformly as possible. Stop loading every meter and level the material to ensure uniform packed density. The sleeve, when retracted, can be shortened by a meter at this point.
- Load the required volume of ACT-139, ACT-108, ACT-078 and ACT-069. Between each layers, carefully level the surface and check the height of loaded ACT by measuring from a fixed point.
- The loading is now completed. Check that no tools have been left behind in the vessel.
- Install the feed diffuser and the top flange.
- Remove any blind flanges around the reactor (except on main process inlet and outlet lines, which remain in place until purging operations are completed).

#### **4.2.3.1.2.5 Leak test for Reactor**

- After the catalyst loading completion, the tightness of the reactor has to be ascertained.
- The reactors being isolated are pressurized with oxygen or nitrogen to the maximum pressure compatible with the equipment.

- The tightness is considered as satisfactory when the pressure loss is less than 0.05 kg/cm<sup>2</sup>/hour over four consecutive hours.
- After the leak test, the unit is purged with nitrogen until the oxygen content is 0.2% volume maximum.

If for any reason the leak test of the unit as described earlier has not been performed yet, proceed to an overall leak test of the unit, reactors included. After the leak test, the reactors are isolated by blinds if startup is not going to take place immediately and kept under a nitrogen atmosphere.

For reactor loading, a loading report (Sample Catalyst Report Sheet on the following page) must be carefully filled:

- Number of drums loaded in each bed.
- Catalyst batch and drums reference numbers.

The loading density is checked at the end of the loading.

Operator's attention is drawn to the necessity of checking that the internals are correctly installed:

- Bottom collector: centering, fastening, wire mesh.
- Catalyst draw-off nozzles: lids, ceramic fiber plug.
- By-pass pipe: cleanliness, slot size and orientation.
- Feed diffuser: ceramic fiber rope installation between top flange cover and diffuser support ring.

## Sample Catalyst Report Sheet

RZ.ACTO R LO.U. U.G REPORT				PL. -y n'PE:							
C'Lm-\Y..t JOB NUMBER:				LOCATION:							
ti'MT NDUBII:											
RZ.ACTO R:				DATE:							
CAT ALYST TYP! :				SHU T OP							
...											
		No.	W,		No.	N.	W,		N.	No.	W,
I				14				"			
"				13				28			
"				"				"			
•				"				30			
5				IS				31			
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7				, •				"			
8				21				"			
"				t2				35			
10				, ..				"			
11				"				37			
11				13				38			
13				, ..				"			
TOTAL\\'EIGHT LO.U. ! D:				LOADD'iGSUPII \\'ISO&NA.II!:							
r-11Mt R O P DRti\ 15:				SCGNATti"ll :							
LOADIN G D!N SIY:											

#### **4.2.3.2 Detailed Start-up Procedure**

##### **4.2.3.2.1 Status of the unit prior to start-up**

The following describes the first start-up of a newly built unit. Any subsequent start-up of the same unit may or may not include all of the following steps, depending upon the status of the unit after the shutdown. For instance, catalyst sulfiding would not be required if the catalyst was not replaced. The status of the unit prior to its first start-up is as follows: The leak test and vacuum test have been successfully completed. (Refer latest revision of Pre-commissioning manual S-EP-R400-172-0002 for Leak Test procedures)

- The reaction section is under a nitrogen pressure.
- The reaction section has been dried out.
- The stripper section has been drained thoroughly of free water.
- All utilities are in service. Blinds in the headers have been removed, and valves opened to all users.
- The catalyst is correctly loaded in the reactor.
- The reactor is under nitrogen pressure.
- All instrumentations have been checked.
- All safety devices and emergency sequences have been tested.
- Safety valves for all equipment items **should** have been de-isolated, and these actions recorded on a checklist.
- The reaction section is isolated from upstream and downstream equipment.
- Pumps and compressors (and their drivers) have been aligned and run-in (where applicable).
- Heat exchangers/air fin coolers have been checked and are ready for operation.
- Ensure H<sub>2</sub> is available from the existing header.
- Chemical product injection systems have been prepared and chemical pumps calibrated.
- The chemical injection lines have been filled-up to the injections points.
- Start-up naphtha is available. Ideally the start-up naphtha would satisfy the following specifications:

Distillation range ASTM : 50-180° C

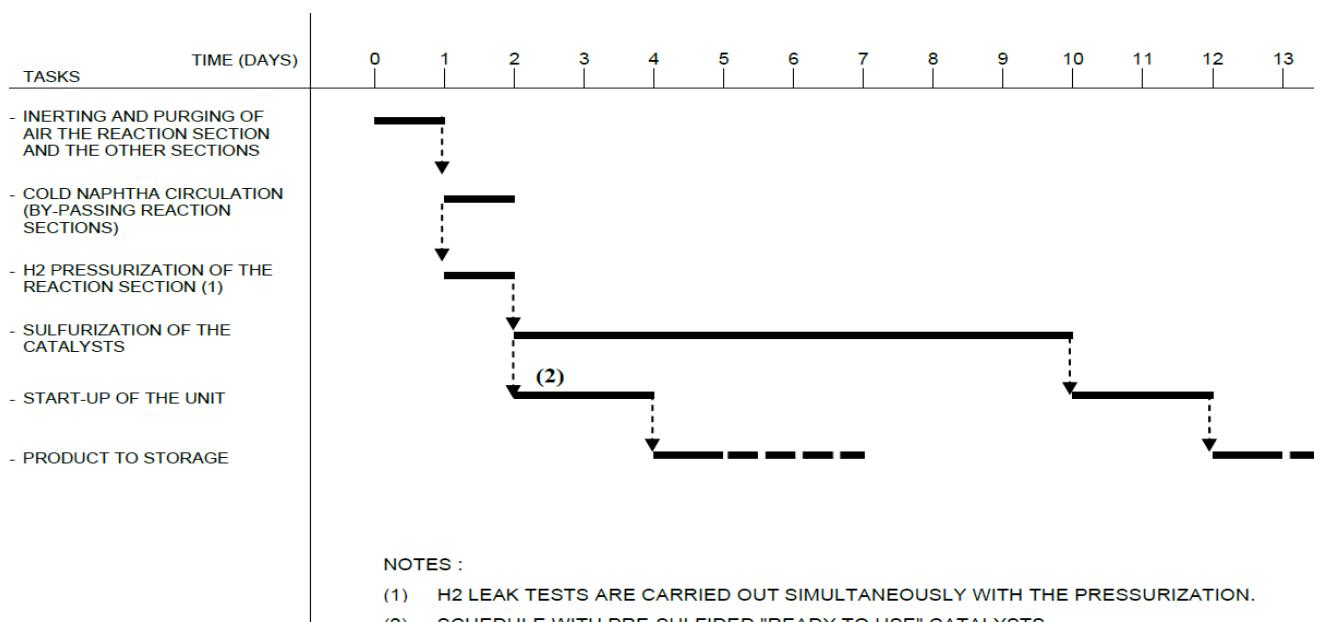
- Sulfur : 0.05 to 2 wt%
- Bromine Number < 2g/100g
- C7 insoluble : NIL
- Color (ASTM D1500) < 2
- Nitrogen < 20 wtppm
- No free water

**It is strongly recommended not to use hydrotreated naphtha (Sulfur free) for sulfiding**, moreover the use of unsaturated feedstock is prohibited for the sulfiding step.

#### **4.2.3.2.2      Chronology of the start-up operations**

The sequence of the first start-up is as follows :

- Complete inerting and purging of oxygen of:
  - the feed section,
  - the reaction section,
  - the stripper section,
- Start-up Naphtha circulation by-passing the reaction section and stripper start-up.
- Start-up Naphtha circulation and reaction section start-up:
  - Hydrogen sweep and final leak test ( $H_2$  leak tests are carried out simultaneously with the pressurization)
  - Reaction section feeding with start-up naphtha for catalyst pre-wetting
  - Catalysts HR-538 sulfiding
  - Hydrogen injection
- Lining up of the unit at 60% capacity
- Lining up of the unit at design capacity



#### 4.2.3.2.3 Inerting

Complete inerting/purging of oxygen

##### Feed section

The following equipment's with their connections are included:

Feed surge drum D-12010 and connected lines. The purpose of this step is to reduce the O<sub>2</sub> content in all the sections below 0.2% vol. prior to the introduction of hydrogen or hydrocarbons.

The feed section consists of the Feed Surge Drum and the feed lines from battery limits. This section may still contain some free water held up in pocket. It is inerted with nitrogen, ensure that appropriate vent valves are opened at all times during steaming.

	Action	Remarks
1.	Open all vent valves within the section between the isolation blinds at battery limits and the blind at the reaction section. The connections to flare and nitrogen should still be blanked.	
2.	Pressurize the section with nitrogen and purge through all low points, dead legs, vents,	

	etc.	
3.	Repeat until the O <sub>2</sub> content is below 0.2% volume. Leave a residual N <sub>2</sub> pressure of 0.1 kg/cm <sup>2</sup> g.	

#### Reaction section

The reaction section inerting procedure is exactly the same as the drying out procedure without any heating of the nitrogen.

#### Stripper section

This section include the following equipments:

- Stripper Reflux Drum (R41-D-12250)
- NHT Stripper (R41-T-122)
- Stripper Reboiler (R41-FR-122)
- Stripper Air Condenser (R41-E-1225)
- Stripper Trim Condensers shell side (R41-E-1226 A/B)
- Stripper Feed / Bottom Exchangers shell side and tube side (R41-E-1221 A/B/C)
- Hydrotreated Naphtha Air Cooler (R41-E-1222)
- Hydrotreated Naphtha Trim Coolers shell side (R41-E-1223 A/B)

The stripper section can be inerted with nitrogen or steam.

If inerting with nitrogen is chosen, follow the same procedure as per feed section (pressuring and depressurising until the O<sub>2</sub> content reaches 0.2 %vol) with the nitrogen supply line 1.5"-N-R41-7203-1CC1P01-NI located at Stripper Reflux Drum D-12250 .

If inerting with steam is chosen, follow the procedure below:

	Action	Remarks
1.	Inerting is performed with LP steam: vent from all the high points and drain condensate from all the low points.  Commission the Stripper Reboilers FR-122, Reactor Feed Heater FR-12110 with minimum firing load to prevent the steam from condensing. (Refer latest revision of vendor operating manual V-202-1420-144-K-01-1065 for detail start-up procedure of R41-FR-122& V-202-1420-144-K-01-1267 of R41-FR-12110)	
2.	Steam the NHT Stripper T-122 from the bottom (using the steam-out nozzle), steam the	

	feed lines and the reboilers FR-122, FR-12110 (using low point drains). Steam the reflux drum D-12250 separately with utility connection nozzle. If necessary steam separately the feed/bottoms exchangers E-1221A/B/C. Continue steaming for one hour minimum after steam appears at all the vents.	
3.	Shut-off the steam and pressurize with nitrogen the stripper up to 1 kg/cm <sup>2</sup> g and drain water at all low points. Pressuring with nitrogen immediately prevents any possibility of a vacuum occurring as the steam condenses. As the nitrogen is admitted, the system will cool down and condensate can be drained off. Leave this section at this pressure until ready to be charged with naphtha	

#### **4.2.3.2.4      Start-up naphtha circulation in feed section and stripper section start-up**

##### **4.2.3.2.4.1      Coordination with the Reformer unit start-up**

Since a sufficient source of hydrogen of adequate purity is available without start-up of the Aromizing section (R41-3), NHT unit can be started with this hydrogen and on-spec. Pretreated heavy naphtha can be produced to start later the Aromizing section. If hydrogen is not available from a source different from Reformer, then sufficient desulfurized heavy naphtha must be available to start-up the reformer to produce the hydrogen needed to start-up the NHT unit. This naphtha must be on-spec. and free of water. It is mandatory for security to route this naphtha through the NHT stripper, to remove any moisture. In this scenario, an oil circulation loop can be set up, using hydro treated naphtha from storage, passing through the stripper to feed the Aromizing Reaction Section. When hydrogen becomes available the NHT unit could be started-up with the naphtha recovered in the stripper bottom sent back to storage. Once on-spec., the stripper bottom product can be routed to the Reformer while closing the valve on the hydro treated naphtha feed line of the stripper.

Cold and hot circulation in Naphtha Splitter section, pre-sulfiding in NHT section and cold circulation in Aromizing section to be conducted simultaneously in order to minimize start-up schedule. To achieve this operation for initial start-up, hydrotreated naphtha needs to be imported from outside of the refinery. This will contribute to minimizing the start-up schedule. The procedure described below assumes that an independent source of hydrogen is available, so pre-treater section (R41-1 and R41-2) will be started before Aromizing section (R41-3).

##### **4.2.3.2.4.2      Preparation of Start-up**

The feed control valves are closed and blocked in and the feed control valve FV-2140 of the stripper are closed and blocked in.

	Action	Remarks
1.	The feed section is under nitrogen but still isolated from the reaction section through the block valves	
2.	The reaction section is isolated under a nitrogen pressure after inserting	
3.	The NHT stripper is under nitrogen pressure	
4.	Ensure the blind list is verified along with the checklist	
5.	The feed control valves FV-2011 / 2013 are closed and blocked in and blind B-2014 is in closed position. The feed control valve FV-2140 of the NHT Stripper are closed and blocked in	
6.	Ensure PZV-2010A/B, PZV-2130AA/BA, PZV-2140A/B, PZV-2150A/B, PZV-2250A/B/C/D, PZV-2160 in NHDT section R41-2 are lined up with the flare system	
7.	Ensure cooling water circulation is achieved for the Stripper Trim Condensers E-1226A/B, Hydrotreated Naptha Trim Coolers E-1223A/B	
8.	Close the isolation valve in Hydrotreated Naptha line 10"-P-R41-2151 to Aromizing section unit in order to isolate section R41-3 from the NHT Stripper bottom.	
9.	Isolate reaction section from feed section and stripper section by closing ZV-2011and ZV-2140. Feed control valves FV-2011, FV-2013 with associated block valve and by-pass globe valves and manual isolation valve in Feed pump R41-P-1201 A/B discharge line 10"-P-R41-2013 is in closed position. FV-2140 in Separator Drum D-12140 liquid outlet line to Stripper section via R41-E-1221A/B/C with associated block valve in closed position. LV-2141 with associated block valve and by-pass globe valves in Separator Drum D-12140 boot liquid outlet to R41-D-12160 is in closed position. Close globe valve at bottom of R41-D-1215 and block valves on line 8"-P-R41-0011 heavy hydro treated naphta from storage / Purge from cumene unit	
10.	Ensure battery limit valve ZV-2230 is in closed position and open battery limit valve ZV-3640 to route SR Naphtha storage tank (F56-TK-63/64) till column stabilization	

#### **4.2.3.2.4.3      Cold Circulation**

For the SR naphtha circulation and stripper section start-up, refer to drawing in section 8.2.2 (Circulation of Feed section and Stripper section)

The following steps should be performed to start-up feed section and stripper section in cold circulation loop:

	<b>Action</b>	<b>Remarks</b>
1.	Heavy Naphtha from Naphtha Splitter T-112 bottom is lined up to Feed Surge Drum D-1201.	
2.	Start feeding Feed Surge Drum D-12010 with heavy naphtha. When the level in the Feed Surge Drum D-12010 reaches 60%, commission level transmitter LT-2010 in manual mode and compare information with R41-LG-2100A/B.	
3.	Start the Feed Pump P-1201A/B (Refer latest revision of vendor operating manual V-202-1420-134-F-03-386 for detailed pump start up) and route naphtha to NHT Stripper T-122 via the start-up line by-passing the reaction section (Line no:8"-P-R41-2023). Set the flow rate (60% of normal flow) with the globe valve readable from FI-2015 (the line 8"-P-R41-2023 to be drained after start up)	
4.	Ensure the naphtha is routed to Stripper Feed/Bottom Exchanger E-1221A/B/C then to NHT Stripper T-122.	
5.	When the level in the NHT Stripper T-122 bottom reaches 60%, commission the level controller LC-2200 and put flow control FC-2203 in startup mode using flow hand switch FHS-2205. Commission Hydrotreated Naphtha Air Coolers E-1222 and Hydrotreated Naphtha Trim Coolers E-1223A/B and route NHT Stripper bottom back to SR Naphtha storage tank (F56-TK-63/64) through start up bypass line 8"-P-R41-2108	
6.	Adjust the flow rate on the bypass line FI-2015 to reach a circulation rate of 60% of max operating throughput by opening the manual globe valve on the line 8"-P-R41-202). Increase the NHT Stripper T-122 pressure if necessary using nitrogen so as to move the naphtha back to the Straight Run Naphtha storage tank (TK-63/64). Commission pressure controllers PC-2250. Nitrogen is pressurized in NHT Stripper through Stripper Reflux Drum D-12250 connected to the stripper and excess pressure is relief by PV-2250 connected to sour gas header.	

#### **4.2.3.2.4.4      Hot Circulation**

Hot circulation is lining up the reboilers, condensers, reflux drums and overhead system.

The following steps should be performed to start-up feed section and stripper section in hot circulation loop:

	<b>Action</b>	<b>Remarks</b>
1.	When the level in the NHT stripper T-122 reaches 80%, Commission the Stripper Reboiler FR-122, set THS-2203A in start-up mode to use TC-2203 for reboiler FR-122 temperature control. Refer latest revision of vendor operating manual V-202-1420-144-K-01-1065 for detail start-up procedure of R41-FR-122.	
2.	Slowly bring the NHT stripper up to the operating temperature (161°C) and pressure (10.7 Kg/cm2g). When overhead temperature starts to increase to 161°C (monitored by TI-2250), start the fans of Stripper Air Condenser (R41-E-1225) and the NHT Stripper overhead vapors are condensed and sent to Stripper Trim Condenser (R41-E-1226A/B).	
3.	The NHT Stripper operating pressure (10.7 kg/cm2g) is maintained by PC 2250	
4.	As the level increases to 50% in the Stripper Reflux Drum D-12250, start the Stripper Reflux Pumps R41-P-1225A/B and commission level/flow controllers R41-LC- 2250/R41-FC-2250 in manal mode. By slowly opening the flow control valve FV-2250 the reflux is sent to T-122. Once the flow reaches 60% of normal operating flow set FC- 2250 in auto mode. Ensure Stripper Reflux Drum D-12250 liquid outlet valve ZV-2250 is fully open before stripper reflux pump P-1225A/B starts. Refer latest revision of vendor operating manual V-202-1420-134-F-02-831 for detailed pump start up.	
5.	The operating pressure of stripper reflux drum (9.7 kg/cm2g)is maintained by PV-2250	
6.	Once the interface between hydrocarbon and water is seen, the sour water from the Stripper Reflux Drum D-12250 boot is sent to sour water header, by opening globe valve manually by monitoring the level indicator LI 2251 (The level gauge is readable from this valve)	
7.	At this step, SR naphtha is circulating from SR Naphtha Tank (F56-TK-63) via section R41-1 to NHT Stripper T-122 by-passing the reaction section. NHT Stripper is in total reflux, with bottom product routed back to SR naphtha tank (F56-TK-63).	

The cold & hot circulation flow sequence is as follows:

Heavy Naphtha from Naphtha splitter R41-T-112 bottom →R41-P-1120 A/B (Heavy Naphtha Pumps)→R41-E-1111A/B tube side→FV-1200A (Normal operation mode) →Heavy Naphtha to Naphtha hydro treating section→ Feed surge drum D-12010→ZV-2010 → Feed Pumps R41-P-1201 A/B→Stripper Feed Bottoms Exchanger R41-E-1221A/B/C tube side (Through start up filling line 8"-P-R41-2023)→ Stripper feed to R41-T-122→ZV-2200 →MOV-2200→Stripper bottom pump R41-P-122 A/B/C→ Stripper Feed Bottoms Exchanger R41-E-1221A/B/C shell side →FV 2203 → Hydrotreated Naphtha Air cooler R41-E-1222→ Hydrotreated Naphtha Trim Cooler R41-E-1223A/B shell side→ Naphtha storage tank via line 8"-P-R41-2108 (Through start up bypass line to 10"- P-R41-3186). Keep ZV 2230 closed and ZV 3640 open.

#### **4.2.3.2.5      Start-up naphtha circulation and reaction section start-up**

#### **4.2.3.2.5.1      Hydrogen sweep and final leak test of the reaction section**

Prior to introduce liquid hydrocarbon in the unit, it is recommended to perform a leak test of the reaction section at normal operating pressure. Make up hydrogen is used for that purpose. (Pure make up hydrogen from existing distribution header is used. Line no: 2"-H-R41-2088.

Action	Remarks
1. Prior to H <sub>2</sub> introduction, the reaction section is still under nitrogen pressure.	
2. Deblind B-1003 and Open ZV-5100 & isolation valves in line 10"-H-R41-5000. Introduce gradually the pure hydrogen gas from battery limit. Open ZV-2150 in line 2"-H-R41-2156 and the isolation valves in line 2"-H-R41-0027, close PV-2010A and raise the pressure of the reaction section up to a few kg/cm <sup>2</sup> . It is not necessary to completely nitrogen free the system, as gaseous nitrogen is not detrimental to the hydrotreater catalyst. Commission pressure controller PC-2145B (start-up mode) which controls FV-2156 routed to flare header to balance the pressure.	
3. Close the isolation valves in line 2"-H-R41-0027 and perform a leak test at this pressure (duration four hours). Check all the flanges with an explosimeter. The pressure loss shall not exceed 0.05 kg/cm <sup>2</sup> /h.	
4. Once all leaks have been tightened, resume hydrogen injection and pressurize up to the normal operating pressure(26.2 kg/cm <sup>2</sup> g).	

5.	<p>It is very important to notice that at all times the Hydrotreating Reactor (R41-R-121) temperatures (inside and skin) and pressure <b>is</b> in accordance with the temperature/pressure charts provided by the reactor supplier. The minimum pressurization temperature (MPT) of the reactor under hydrogen <b>to</b> be carefully respected. As a matter of fact low alloy steel reactors are subjected to temper embrittlement, this is why a minimum temperature must be achieved before pressurisation. MPT is a function of the metallurgy of the vessel, but also of its age. Suitable reactor catalyst bed temperatures are between 80° C minimum to 150 °C maximum.</p>	
6.	<p>In case MPT is higher than 150° C, the reaction section <b>to</b> be pressurized at the maximum allowable pressure at 150° C (typical is ¼ of the normal operating pressure). Pressurize progressively the Recycle Compressor K-1215A/B. Start the compressor and circulate hydrogen through the reaction section at maximum available flowrate. Refer latest revision of vendor operating manual V-202-1420-130-M-01-457 for detailed compressor startup. Notice that after completion of the leak test, meaning that pressure decrease is lower than 0.05 kg/cm<sup>2</sup>/hour, over a period of 4 consecutive hours, one can check the Emergency Depressurisation (EDPS), if not done during the previous step (HP leak test with nitrogen).</p>	
7.	<p>This is done through the depressurization valve ZV-2145 in the Separator Drum D-12140. There is no need to depressurize all the way, as the reason for testing of the emergency depressurization system is that the actual depressurisation rate under operating conditions can be calculated. The test <b>is to</b> assure that the valves and/or orifices have been properly sized and that there are no unusual restrictions in the lines.</p>	
8.	<p>Before performing the EDPS test, a sample of recycle gas should be taken to analyse gas molecular weight. This figure along with time duration of depressurization and the pressure drop <b>is</b> used to check the efficiency of the depressurization.</p>	
9.	<p>In case EDPS trial has been performed, repressurize the unit with H<sub>2</sub>, at a pressure close to normal operating pressure provided that the reactor wall temperature is above the minimum pressurizing temperature (check against Temperature/Pressure charts of the supplier) one <b>to</b> ensure that this pressure is consistent with the first temperature step of the catalyst sulfiding procedure.</p>	

**4.2.3.2.5.2      Status of the unit before reaction section Oil-In.**

	Action	Remarks
1.	Reaction section is under H <sub>2</sub> recycle gas at maximum flow rate (12832 kg/h)	
2.	Reaction section pressure and reactor temperatures : the suitable initial conditions are as follows : - Reactor catalyst temperatures <b>is</b> 80° C minimum and 150° C maximum over the whole bed. - The reaction section pressure <b>is</b> close to the normal operating pressure.	
3.	Make up H <sub>2</sub> from existing header is available.	
4.	HP purge gas valve FV-2156 is closed: During all the sulfiding operation, this valve <b>is</b> closed to minimize H <sub>2</sub> S losses and pressure will be controlled by the H <sub>2</sub> make up valve FV-2155. The purge may be opened only if the H <sub>2</sub> purity of the recycle gas falls below 50 %.	
5.	Water washing section is isolated , nevertheless it is recommended to establish interface level in Separator Drum boot D-12140 before sulfiding.	
6.	Reaction section is by-passed via start-up line 8"-P-R41-2023 and NHT stripper T-122 is in service as described in section 4.3.3.4.4	
7.	DMDS injection facilities Z-1201 at Feed Pump P-1201A/B suction are ready to be operated. Pump must be first calibrated with the adequate flowmeter.	

**4.2.3.2.5.3      Reaction section start-up naphtha in : pre-wetting of the catalyst**

For the start-up naphtha circulation and catalyst sulfiding,( refer to drawing in section 8.2.2 Sulfiding/Startup Naphtha Circulation)

The purpose of this step is to ensure that the whole catalytic bed and the pores of the catalyst have been in contact with hydrocarbons prior to proceed to the sulfiding. The catalyst prewetting has a beneficial impact on the sulfiding achievement, on the catalyst activity and on the reactor hydrodynamic.

Prior to catalyst pre-wetting and sulfiding, a close loop **to** be established from:

Feed surge drum D-12010→ZV2010→R41-P-1201 A/B(Feed pump)→R41-E-1221A/B/C tube side(through stripper filling line 8"-P-R41-2023)→ Stripper feed to R41-T-122→ZV-2200→Stripper bottom product pumps R41-P-122 A/B/C→ R41-E-1221A/B/C shell side → Feed surge drum D-12010 (Through start up bypass line 8"- P-R41-2111).

While this loop is established, feed from R41-1 is stopped. Refer to operating instructions of R41-1 to keep this section in safe conditions without rundown to R41-2.

	<b>Action</b>	<b>Remarks</b>
1.	Reduce the recycle gas flow down to 50% of the nominal flow.	
2.	Lower the operating pressure in the reaction section by 2 to 3 bar to anticipate the pressure rise in consecutive to the filling with the SR naphtha (Decrease PC-2145B set point)	
3.	Start to feed the Hydrotreating Reactor ( <b>R41-R-121</b> ) with SR naphtha at 10 to 20% of the nominal feed rate by opening ZV-2011, FV-2011, FV-2013 and increase gradually within 2 hours to 60% of the normal operating feed rate.	
4.	At this stage, particular attention should be paid because liquid naphtha contact with catalyst under hydrogen atmosphere may result in an increase of the temperature of catalyst.	
5.	Depending on the recycle gas flowrate, the delta T could reach 20° C. Moreover, pressure drop across the Hydrotreating Reactor ( <b>R41-R-121</b> ) should be carefully monitored by PDI-2101. If it increases too fast, stabilize the feed rate by throttling FV-2011/FV-2013 and maximize the whole reactor temperature up to 150° C by means of increase in fuel gas flow (through FV-2114 to FR-12110 by monitoring TC-2100) to lower the naphtha viscosity. Once the reactor pressure drop is stabilized, feed rate could be increased again.	
6.	Adjust the SR naphtha flowrate (FV-2203) from stripper bottom to fill the Separator Drum D-12140 while maintaining level steady in the Feed Surge Drum D-12010 . If necessary import SR naphtha from section R41-1 to Feed Surge Drum D-12010.	
7.	As the level increases in the Separator Drum D-12140, commission the level controller LC-2140 and the flow controller FC-2140, to feed SR naphtha to the NHT Stripper from the	

	Separator Drum D-12140.	
8.	Increase gradually the feed rate up to 100% of normal operating feed rate and reduce accordingly part of the flow by-passing the reaction section (line 8"-P-R41-2023). At the end of this stage, reaction section is fed at 100% of normal operating flowrate and NHT stripper T-122 is fed at 100% from Separator Drum (R41-D-12140). Reaction section by pass line 8"-P-R41-2023 is closed.	
9.	Now the SR naphtha circulation loop is sourced from Feed Surge Drum D-12010 and involves the reaction section and the stripper section. At stripper bottom, naphtha is routed back to Feed Surge Drum D-12010 through start up line 8"-P-R41-2111. This circulation <b>is</b> kept for 4 hours.	

Prior to start the catalyst sulfiding step, the following conditions should be adjusted:

	Action	Remarks
1.	Reduce SR naphtha loop circulation to 60% of normal flow rate.	
2.	Maintain catalyst bed temperature at 150° C	
3.	Increase recycle gas flowrate to maximum available.	
4.	Set reaction section pressure at normal operating pressure. At this stage, sulfiding step could be started.	

#### **4.2.3.2.5.4      Catalyst sulfiding (HR-538)**

Prior to establishing design operating conditions with naphtha feed, catalyst must be sulfided as they are more active in their sulfide form. To enhance the catalyst activity, it is necessary to convert the catalyst metal from the oxide form to the sulfide form to take advantage of the reversible formation of sulfides during the hydrotreating reactions.

	Action	Remarks
1.	The sulfiding agent, DMDS (Dimethyl disulfide) is injected with the sulfiding agent Injection Pump Z-1201-P1A from the Sulfiding Agent Tank Z-1201-T1 in its pure form into the suction of the Feed Pumps P-1201A/B	
2.	The reactions involved and the amount of DMDS required are explained later: Refer to	

	chapter 4.6.1.4	
3.	It is important that sulfiding of the catalyst metal is complete. If not, the catalyst metals convert to their reduced form (bare metal) which could lead to metal sintering, resulting in agglomeration and consequently poor activity due to a decrease in metallic area.	
4.	In addition the reduced metals will act as hydrocracking catalysts with the naphtha and could cause local overheating and heavy coke deposits.	

The catalysts sulfiding can now proceed as follows (for the sulfiding of the catalysts, refer to attachment given in section 8.2.2)

#### Stand-by to step 1 :

	Action	Remarks
1.	Start heating the Hydrotreating Reactor ( <b>R41-R-121</b> ) up to the first temperature step, i.e 220° C at the inlet of the reactor; by means of increase in fuel gas flow FV-2114 to FR-12110 by monitoring TC-2100. The recommended heating rate is 20 to 30° C/h.	
2.	When the reactor inlet temperature reaches 180° C, start DMDS injection. Increase DMDS flow rate up to 320 l/h in about 1 hour.	
3.	Sulfiding reactions are exothermic and a temperature wave along the reactor will be noticed during this step.	
4.	Check DMDS injection flow rate regularly. Record it as well as the cumulated weight of DMDS consumed.	
5.	Stabilize the reactor inlet temperature at 220° C. Increase DMDS flow rate up to 650 l/h. Maintain reactor inlet temperature at 220° C until H2S breakthrough occurs, in the recycle gas (H2S > 0.2 % vol.) and in any case for at least 4 hours. Depending on the exotherms, adjust the bed inlet temperatures to maintain the bed outlet temperatures at 230° C maximum.	
6.	The sulfiding progress is confirmed by the amount of water produced by the catalyst sulfiding reactions and recovered in the Separator Drum D-12140 boot as well as in the Stripper Reflux Drum boot D-12250, and by CH4 build up in the recycle gas (the % H2 decreases). A total amount of approximately 7 tons of water will be produced per 100 tons of catalyst. This water contains H2S and should be routed to sour water treatment. Record the amount of water produced.	

7.	<p>Once the DMDS injection is started, the H<sub>2</sub>S and H<sub>2</sub> concentrations in the recycle gas are monitored as follows:</p> <p><b>H<sub>2</sub>S content:</b> Once per hour by reactive tubes (Draeger tubes or similar) and/or laboratory analyses. As H<sub>2</sub>S reacts with metal oxides, the H<sub>2</sub>S content of the recycle gas remains low during the first part of the sulfiding. At the end of the first step, H<sub>2</sub>S concentration increases quickly (H<sub>2</sub>S breakthrough). For safety issue related to H<sub>2</sub>S, operators performing Draeger tests must wear air breathing equipment.</p> <p><b>H<sub>2</sub> content:</b> Once every two hours by laboratory analyses. H<sub>2</sub> is consumed by sulfiding reactions and by DMDS decomposition and CH<sub>4</sub> is produced from this decomposition. If H<sub>2</sub> content in the recycle gas decreases below 50 vol. %, open the reaction section purge (FV-2156) as necessary.</p>	
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**Remarks:** The exotherm should not be allowed to exceed 30° C. If it is observed to be rising too rapidly, the DMDS injection rate should be reduced, or, if necessary, stopped and the bed inlet temperatures kept constant. In addition, increase the recycle hydrogen and hydrocarbon flows to remove the heat. If control of the exotherm cannot be regained in this manner, the bed inlet temperatures should be reduced rapidly below 200° C. If the exotherm can still not be controlled, shut down the heater.

**Note:** It is recommended to adjust the reactor temperature alarm set points to warn the operator of any exotherm in excess of 30 °C.

- If DMDS injection fails to start when the reactor inlet temperature has reached 180° C, stop temperature increase and cool the reactor down to 150° C. Resume the procedure when DMDS is available again.
- H<sub>2</sub> purity of the recycle gas must be maintained above 50 % vol.
- In case of no H<sub>2</sub>S breakthrough after 4 hours, check that the DMDS injection is correct and that H<sub>2</sub>S analyses are done properly.

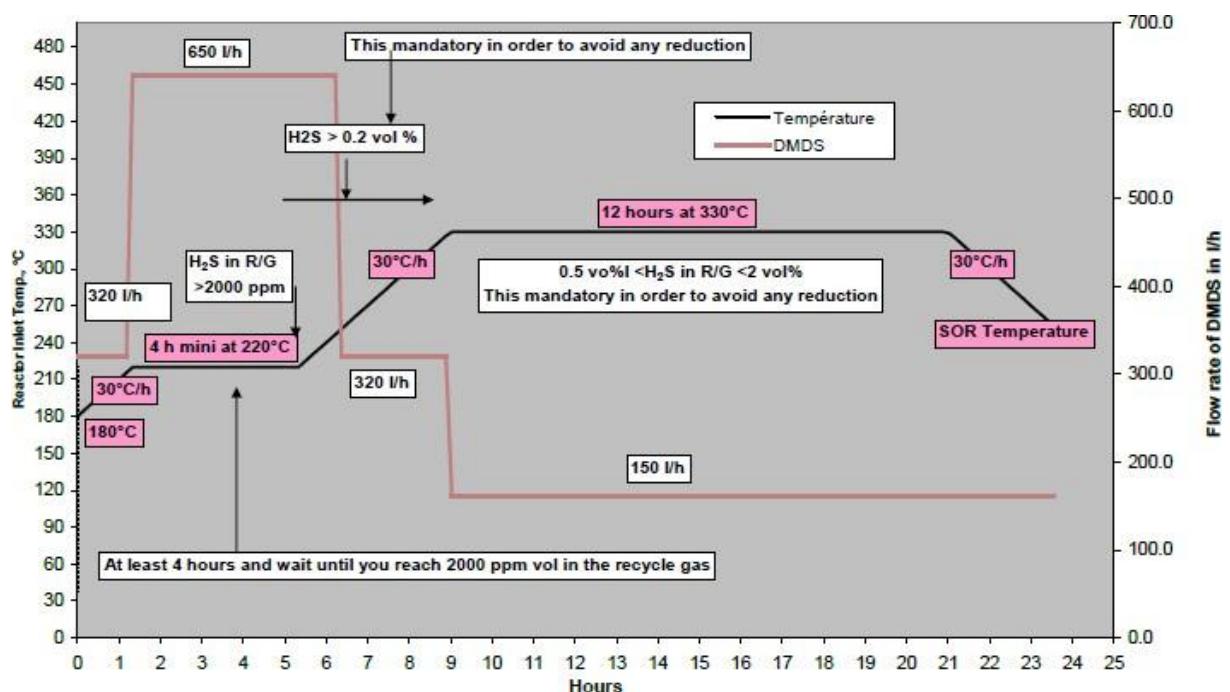
#### Step 1 to step 2:

	Action	Remarks
1.	At the end of the first temperature step, after the H <sub>2</sub> S breakthrough, increase reactor inlet temperature at 20 to 30°C/h up to the final high temperature step.	
2.	The final temperature step is performed at 30° C higher than the reactor SOR	

	temperature and in any case at 330° C minimum and 350° C maximum.	
3.	During the temperature rise, the DMDS flowrate is reduced stepwise (down to 320 l/h). The injection rate is adjusted to monitor the H <sub>2</sub> S content in the recycle gas between 0.2 % vol (min) and 2 % vol (max). When the reactor temperatures reach 260-280° C, the naphtha will start to be desulfurized and this will contribute to H <sub>2</sub> S build up in the recycle gas. Hydrogenation reactions of aromatics will also start, which will enhance exotherms and H <sub>2</sub> consumption as a consequence hydrogen make up demand will increase.	
4.	If exotherms go too high (above 30° C) or if the H <sub>2</sub> make up demand cannot be supplied, reactor temperature increase <b>to</b> be stopped temporarily. Note also that at around 320° C a second wave of water production may be observed.	
5.	When reactor inlet temperature reaches 330°C, DMDS injection flow is reduced down to 150 l/h.	
6.	Maintain the reactor inlet temperature constant during 12 hours. During this final step, the suitable H <sub>2</sub> S content in the recycle gas is still 0.2 to 2 % vol. In the case H <sub>2</sub> S measures are on the low side of the range (< 0.5 % vol.), DMDS injection has to be maintained (150l/h) during the entire step. If H <sub>2</sub> S measures are on the high side of the range (> 1.5 % vol.), DMDS injection can be stopped, but the injection facilities shall remain available till the completion of the step. If H <sub>2</sub> S increases above 2 %vol., DMDS injection <b>to</b> be cut (injection facilities remain available).	
7.	Decrease reactor inlet temperature to SOR temperature : 300° C	

**Remarks:**

In case of unexpected DMDS shortage during the final step, fresh straight-run naphtha can be injected in order to keep the H<sub>2</sub>S content in the recycle gas above 0.2 % vol. In such a case, the bed inlet temperature must be decreased due to the exothermicity in order to keep the reactor outlet temperatures within the limit of 335 °C maximum. At the end of this step, the catalyst is considered sulfided and reaction section is ready for fresh feed introduction. Below figure explains DMDS injection flow rate vs reactor temperature



#### 4.2.3.2.5.5 Lining up of the reaction and stripper sections at 60% capacity

When the temperature in the reactors is near or above the SOR temperature and catalyst sulfiding well advanced, straight run naphtha can start being desulfurized and hydrogenated. After sulfiding step, the stripper bottom product is still recycled to the Feed Surge Drum D-12010; line up of the unit is:

Action	Remarks
1. Start feeding the unit with straight run naphtha from SR Naphtha Tank (F56-TK-63/64) through unit R41-1 at 10% of its normal operating flowrate and decrease by the same amount the recycle Straight Run Naphtha from stripper bottom so that the overall flowrate entering the unit remains at 60% of the normal operating capacity.	
2. While monitoring carefully the temperature gradient in Hydrotreating Reactor (R41-R-121), balance the straight run naphtha from storage and the naphtha recycled from stripper bottom by steps of 10% until recycle flowrate is resumed. Decrease the inlet temperature of the reactors if the temperature rise is too fast.	
3. While decreasing recycle flowrate from stripper bottom to Feed Surge Drum, increase	

	meanwhile flowrate from stripper bottom to SR Naphtha tank (F56-TK-63/64) to maintain a constant level in the stripper bottom.	
4.	Stabilize operating conditions (reactor temperature and stripper temperature) after each increase of flowrate of naphtha from R41-1 in the NHDT unit.	
5.	Set normal operating conditions for reaction section (pressure at the Separator Drum) and for NHT Stripper column.	
6.	Check product quality (sulfur in the stripper bottom product).	

#### 4.2.3.2.5.6 Lining up of the unit at design capacity

The catalyst is sulfided, the unit is operating at 60 % of design capacity with straight run naphtha from tank (F56-TK-63/64) through R41-1. The reactor bed is at the required temperature. Hydrogen make-up is on pressure control. The NHT Stripper is operating at design operating conditions and on pressure control. The stripper bottom is sent back to the SR Naphtha storage tank (F56-TK-63/64).

	Action	Remarks
1.	Check the sulfur level in the bottom of the stripper, adjust the reactor inlet temperature and stripper operating conditions accordingly to reach less than 0.5 ppm wt of sulfur.	Sulfur content is checked from sampling point S7-2203
2.	Slowly increase the naphtha feed rate to design feed rate by adjusting feed control valve FV-2011/2013 in increments of 10 %/hour.	
3.	Allow the unit to stabilize after each change and adjust operating conditions as necessary.	
4.	Monitor the stripper bottoms carefully and always operate on the conservative side of less than 0.5 ppm wt of sulfur when making unit changes.	
5.	Record the operating conditions, sulphur levels in the stripper bottoms, recycle gas chromatographs etc, at each capacity increment.	
6.	Carry out a thorough check of all instrumentation and set alarm ranges accordingly	
7.	Allow the unit to stabilize, for a few hours and once all parameters are well controlled and	

	the unit is stable, switch the destination of the stripper bottom product from the Straight Run naphtha storage tank (F56-TK-63) to either hydrotreated naphtha tank out to the <b>Reformer</b> unit if available.	
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#### **4.2.4 Start-up procedure for R-410-3 and R-410-4**

##### **4.2.4.1 Preparation for First Start-up**

###### **4.2.4.1.1 Chronology of operations**

- Unit inspection (note that instrument checks will extend almost until the oil in).
- Initial leak test
- Once the Recycle Compressor K-13450 and the Preheater / First/Second/Third Interheaters FR-13110/13210/ 13310/13410 are available the dry out of the reaction section can start. The Nitrogen Compressor K-1405 A/B **to be started simultaneously or subsequently.**
- The dry out of the regeneration section is carried out as soon as the Regeneration Compressor K-1465 and the relevant electrical heaters E-1467/1469/1473 are available.
- After a cooling down period and a last inspection of the internals the catalyst loading takes place.
- A second leak test and partial inerting of the reaction section and the regeneration section is performed.
- Catalyst is circulated and dried.
- Final inerting.
- The reaction section is pressurized with hydrogen and catalyst reduction takes place.
- Oil-in: feed is introduced at reduced throughput:
  - first at low severity.
  - then at high severity.
  - throughput is increased to its nominal figure.
- Regeneration startup.

###### **4.2.4.1.2 Unit Inspection and Initial Leak test**

The first inspection activity takes place towards the end of the construction work.

For equipment inspection refer chapter 4.1.3. It takes place prior to the mechanical completion of the unit.

For Initial leak test refer to section 4.1.1.2.3

###### **4.2.4.1.3 Dry-Out of the unit**

###### **4.2.4.1.3.1 Introduction**

Reaction, catalyst circulation and regeneration sections must be dried out prior to catalyst loading, firstly to avoid damaging the catalyst with water, secondly to shorten the duration of the low severity operation after first oil in.

Unit dry out is conducted simultaneously with the heater refractory drying. Heaters manufacturer representative will be consulted to agree on a procedure (chiefly rate of temperature rise and duration of steps) mutually acceptable.

The dry out operation is carried out using hot nitrogen circulating in two loops, physically separated.

The first loop uses the Recycle Compressor K-13450 and the Nitrogen Compressor K-1405 A/B and includes the reaction section, absorber section and nitrogen section. The Preheater /First/Second/Third Interheaters FR-13110/13210/13310/13410 are used for warming up.

The second loop is the regeneration section and uses the Regeneration Loop Compressor K-1465 to circulate nitrogen which is heated in the electrical heaters (Burning, Oxychlorination and Calcination Heaters).

The regeneration drying loop is isolated from the previous one by the special gas tight valves between the Lock Hopper D-1402 and the Upper Surge Drum D-1401 and the valve on the seal leg between the First Lower Hopper D-1403 and First Lift Pot D-1404.

#### **4.2.4.1.3.2      Inerting of the Depentanizer section**

During drying out of the unit, reaction section heaters (FR-13110/13210/13310/13410) **is** used to increase temperature to 500° C. Therefore heaters convection section (Convection reboiler Coil FR-13110E) has to be filled and circulation of hydrocarbons to be implemented to remove heat and avoid damaging heaters tubes.

The Depentanizer section can be inerted either with nitrogen or with steam. The choice must take into consideration the effect of water on downstream units (if any)

The initial status of the depentanizer section is: isolated from the reaction section and blind flanges on safety valves to flare, on PCV to fuel gas and flare, and on products to battery limits.

If inerting is performed with nitrogen process of depressurization / pressurization applies.

Once the O<sub>2</sub> content is lower than 0.2%, remove the blinds on:

- Safety valves to flare.
- PCV to fuel gas and flare from LPG absorber drum.
- Products to battery limits.

**If inerting is performed with LP steam:** Vent air from the high points and drain condensate from the low points. Steam the column from the feed lines and through the reboilers. The reboiler heaters should have some pilots in

service to keep steam from condensing. Steam each drum separately. Continue steaming for one hour minimum after steam appeared at all vents.

Remove the blinds as above.

**Shut-off the steam and immediately pressure the section with fuel gas or hydrogen to prevent vacuum as steam condenses.** A dedicated line is provided for this purpose, connected to the upper section of the depentanizer. As the fuel gas is admitted, the system will cool down, and condensate can be drained off. The column is now ready for charging with naphtha.

#### **4.2.4.1.3.3 Preparation of Depentanizer Section**

If the depentanizer section was inerted with steam it has been subsequently pressurized with fuel gas. If the depentanizer section was inerted with nitrogen, purge nitrogen to vent or to flare, then pressurize with fuel gas.

	<b>Action</b>	<b>Remarks</b>
1.	Ensure that the reaction section is isolated from the separator section. Close Aromizing section Feed valve ZV-3110/FV-3110. Ensure Separator Drum bottom ZV-3450 and isolation valve is in closed position Ensure HP Absorber Drum bottom ZV-3581 is in closed position	
2.	Ensure ZV 2210 and FV 2210 on the battery limit are fully open. Deblind B-2100B and open isolation valves in line 8"-P-R41-0012	
3.	Ensure that the gate valve on line number 10"-P-R41-2151 in the NHT unit is closed. This ensures that the NHT Stripper section section is isolated during cold circulation of Aromizing section.	
4.	Deblind B-3110N / B-3454 and open isolation valves in startup line 8"-P-R41-3007/3064	
5.	Control valve FV-3452 is closed on manual, upstream and downstream isolation valves are open. Ensure the isolation valve in line 8"P-R41-3042 is closed and open isolation valves and deblind B-3550 in start-up line 8"P-R41-3106.	
6.	Control valve FV-3610 is closed on manual, upstream and downstream isolation valves are open. Ensure LPG Absorber Drum bottom ZV-3610 is in closed position	
7.	Ensure Depentanizer bottom ZV-3600 is in closed position	
8.	Pressure control valve PV 3612 in Depentanizer Feed Chloride Adsorber R-13610 A/B	

	bottom is closed on manual, upstream and downstream isolation valves are open	
9.	Ensure ZV-3613 in Reformate line is in closed position	
10.	Ensure cooling water flow to the Depentanizer Trim Coolers E-1366 A/B/C/D	
11.	Control valve FV-3650 in depentanizer reflux is closed on manual, upstream and downstream isolation valves are open	
12.	Control valve FV-3661 in depentanizer distillate line is closed on manual, upstream and downstream isolation valves are closed	
13.	Ensure Depentanizer Reflux Drum ZV-3650 is in closed position	

#### 4.2.4.1.3.4 Depentanizer startup on total reflux

Action	Remarks
1. Start bringing Naphtha from battery limit (Storage Tank S220-TK-0700) to Aromizing section. Fill-up the bottom of the Depentanizer with desulfurized naphtha from storage through startup line 8"-P-R41-3007 (bypassing the reactor section). The desulfurized naphtha is sent to Separator Bottoms Pumps P-13450 A/B suction	
2. Start Separator Bottoms Pumps P-13450 A/B (Refer latest revision of section 5 in vendor manual V-202-1420-134-F-03-404 for Separator bottoms pump startup)	MOV3451A/B fully open
3. By Slowly opening FV-3452 the naphtha is routed to LPG Absorber Drum D-136100 through startup line 8"-P-R41-3107	
4. Once level in LPG Absorber Drum is above 50 % (LC-3610), open ZV-3610 and start the LPG Absorber Bottom Pumps P-13610 A/B	MOV3610A/B fully open
5. From LPG Absorber Bottom Pumps naphtha is sent to Depentanizer Feed Chloride Adsorber R-13610A/B through Depentanizer Feed / Bottom Exchanger A E-13610	
6. By slowly opening PV-3612 at Depentanizer Feed Chloride Adsorber outlet, the naphtha is sent to Depentanizer T-136 through Depentanizer Feed/Bottom Exchanger B(E-1362)	
7. When the level LC-3600 of the Depentanizer bottom indicates 80%, stop the naphtha feed and open ZV-3600 (at Depentanizer bottom)	
8. Start Depentanizer Reboiler pump P-136 A/B and establish a close loop around the depentanizer reboiler (Convection Reboiler Coil FR-13110E) and Depentanizer Steam Generator E-136/by-pass by slowly opening TV-3601A/B and FV-3600AA-BB upstream of Convection Reboiler Coil (Refer latest revision of vendor manual V-202-1420-134-F-03-440 for detailed startup of Depentanizer Reboiler Pump).	MOV3600A/B fully open

9.	Ensure THS 2608 at the outlet of Convection Reboiler Coil is in startup mode (Refer vendor operating manual V-202-1420-144-K-01-0342 for detail startup)	
10.	Start the Depentanizer Air Cooler E-13650	
11.	When drying out of the reaction section starts, the convection section will slowly warm up the Depentanizer column. Pressure should stay around 6 to 7 kg/cm <sup>2</sup> g.	
12.	When the level of the Depentanizer Reflux Drum indicates 50%, open ZV-3650 and start Depentanizer Reflux Pump. Send reflux to the column by slowly opening FV-3650 in manual mode. Once the column conditions are stabilized FC-3650 cascaded with LC-3650. Operate Depentanizer (R41-T-136) on total reflux. Refer latest revision of vendor operating manual V-202-1420-134-F-02-832 for detailed startup of Depentanizer Reflux pumps (R41-P-13650A/B).	
13.	Commission BFW to Depentanizer Bottom Steam Generator E-136 by slowly opening FV-3605 in manual mode. Once operating condition stabilized, FC-3606 cascaded with LC-3602. Set the flow at design conditions.	
14.	Commission MP Steam header to reboilers E-111 /1120 A/B / E-113 from the Depentanizer Bottom Steam Generator (R41-E-136)	

The HDT naphtha circulation flow sequence is as follows:

Heavy Naphtha from Storage Tank S220-TK-0700 → ZV-2210 → FV 2210 → Startup cold circulation line no:8"-P-R41-0012 → Startup cold circulation to Aromizing section(Line no:10"-P-R41-2151) → Startup line (Bypass around reaction section (Line no:8"-P-R41-3007) → MOV 3451 → Hydro treated Naphtha to R41-P-13450A/B (Separator bottom pumps) →FV 3452→ Pump outlet bypass line to R41-D-136100(Line no: 8"-P-R41-3106) →ZV 3610 → MOV 3610 → R41-P-13610A/B (LPG Absorber bottom pumps) → FV 3610 → R41-E-13610shell side (Depentanizer feed/ bottom exchanger ) →R41-R-13610 A/B (Depentanizer feed chloride adsorber A) → PV 3612 → R41-E-1362 shell side (Depentanizer feed/ bottom exchanger B ) →To Depentanizer column R41-T-136

#### 4.2.4.1.3.5 Preparation and lining up

	Action	Remarks
1.	All TIs and TRs (in the firing box, in the process fluid, tube skin) have been checked. The burners, dampers, control and safety systems have been checked. (Refer Fired Heater Vendor manual document number V-202-1420-144-K-01-0342 for all safety measures and control normally involved in the firing of heaters (FR-13110/13210/13310/13410)	

2.	Make a list of required instruments and check that they are connected and in service. Check that orifices plates are installed where required and correctly calibrated (coefficient adjusted for nitrogen) check that all safety valves are installed and connected to atmosphere or flare collector isolated by blind in B/L.	
3.	Make sure that all blinds between reaction section and HP absorber section are removed.	
4.	The following compressors must be commissioned prior to start (blinds <b>are</b> removed and left in open position): <ul style="list-style-type: none"> <li>• Recycle Compressor (R41-K-13450) Refer latest revision of section 5 in vendor manual V-202-1420-126-H-01</li> <li>• Nitrogen Compressors (R41-K-1405A/B) Refer latest revision of vendor manual V-202-1420-130-S-03-614 for compressor startup</li> <li>• Regeneration Loop Compressors (R41-K-1465) Refer latest revision of section 6.2 in vendor manual V-202-1420-126-H-01</li> </ul>	
5.	Ensure cooling water flow to: <ul style="list-style-type: none"> <li>• Reactor Effluent Trim Cooler.( R41-E-1342A/B)</li> <li>• HP Absorber Feed Cooler. (R41-E-13550A/B)</li> <li>• Nitrogen Storage Trim Cooler. (R41-E-1406)</li> <li>• Nitrogen Loop Trim Cooler. (R41-E-1405)</li> <li>• Air trim cooler. (Air trim cooler and associated lines are shown as part of vendor package in the P&amp;ID and not numbered)</li> <li>• Regeneration loop trim cooler. (R41-E-1460)</li> </ul>	
6.	Commission and start Reactor Effluent Air Cooler (R41-E-13410)	

**Note:** To initiate the dry out of the reaction section, the Recycle Compressor only is required.

#### **4.2.4.1.3.6        Reaction, HP Absorber and Nitrogen sections dry out**

Refer to section 8.1 for Dry-out drawings.

	Action	Remarks
1.	Ensure reaction section is blocked in at the Feed Filters F-13110A/B. Close ZV-3110 and FV-3110	
2.	Ensure Separator Drum D-13450 and Separator Bottom Pumps P-13450 A/B are isolated. Close ZV-3450.	

3.	<p><b>Reaction section pressurization:</b></p> <ul style="list-style-type: none"> <li>• Nitrogen is introduced at Recycle Compressor K-13450 discharge (line 6"-N-R41-7308) and the reaction section is pressurized to 2 kg/cm<sup>2</sup> g.</li> <li>• The pressure controller PC-3450 on H<sub>2</sub> Rich Gas Compressor KO drum inlet is commissioned and set to 2 kg/cm<sup>2</sup> g. Off gas is routed to atmosphere during catalyst drying out</li> <li>• Special precautions must be followed concerning the Reformer Feed/Effluent Exchanger E-13110 (see note 2)</li> </ul>	
4.	<p><b>Nitrogen section pressurization:</b></p> <ul style="list-style-type: none"> <li>• The equipment of the nitrogen section are lined up</li> <li>• The section is pressurized to 2 kg/cm<sup>2</sup> g.</li> <li>• Then reactor and absorber sections on one hand, nitrogen section on the other hand, are connected while the following isolating valves are opened: ZV-4111 on First Upper Hopper (R41-D-1411) to Reduction Chamber(R41-D- 1412). ZV-4431 on Fifth Lower Hopper (R41-D-1443) to Fifth Lift Pot (R41-D-1444). On startup line between Separator Drum D-13450 and Nitrogen Loop Trim Cooler E-1405 (6"-N-R41-7309)</li> </ul>	
5.	<p><b>Nitrogen circulation and dry out initiation:</b></p> <ul style="list-style-type: none"> <li>• Open suction (ZMV-3451) and discharge valve (MOV-3450) of Recycle Compressor K-13450 and start the machine according to manufacturer's instructions.</li> <li>• This initiates nitrogen circulation through the reaction section. Once the section is online, start draining free water from all low points.</li> <li>• Light small fires in the Preheater FR-13110 and First /Second/Third Interheaters FR-13210/13310/13410 according to manufacturer's instructions and increase reactor inlet temperature at a rate of 40° C per hour up to 200° C (Refer vendor manuals)</li> </ul>	
6.	<p>The following steps must now take place to circulate nitrogen in nitrogen section:</p> <ul style="list-style-type: none"> <li>• Line up start up Nitrogen to R41-E-1416 and R41-E-1417 through start up lines (3"- N-R41-7502 and 3"-N-R41-4085)</li> <li>• Line up the N<sub>2</sub> circuit to the First Lift Pot (R41-D-1404) and the Fifth lift pot (R41-D-1444), Upper Surge Drum (R41-D-1401) and First Upper Hopper (R41-D-1411),</li> </ul>	

	<p>Fines Filters.</p> <ul style="list-style-type: none"> <li>• Set PDHS-4055 (on N2 compressor suction) on start up mode at 3 kg/cm<sup>2</sup> g and PDV-4055B routed to ATM</li> <li>• Line up the N2 circuit to reduction chamber (R41-D-1412) and to First Lift Pot (R41-D-1404), Second Lift Pot (R41-D-1414) and Third Lift Pot (R41-D-1424)</li> <li>• Start Nitrogen Compressor (R41-K-1405A/B) and load the valves to circulate the gas at 100% capacity.</li> <li>• Establish flow of gas to the Regenerator (R41-R-140).and Fifth Lift Pot (R41-D- 1444) up to the normal flow.</li> <li>• When the above steps are completed, the nitrogen circulation for drying purpose is fully established, as shown on drawings in section 8.1</li> <li>• The Reduction electrical heater (R41-E-1412) is then switched on and Reduction Chamber (R41-D-1412) inlet temperature is progressively increased at a rate of 20°C per hour up to 200°C.</li> </ul>	
7.	<p><b>Follow-up and end of drying</b></p> <ul style="list-style-type: none"> <li>• Purge water from Separator drain and all low points (air cooler and trim cooler outlets, separators, compressors KO. drums etc.). Keep record of all the water drained to follow the drying rate, showing total amount of water drained at regular intervals.</li> <li>• The system is considered dry, at this temperature (200° C), when the water draw-off is less than 10 liters per hour. Then the temperatures are increased to 400° C at a rate of 20° C per hour. When the amount of water drained is lower than 5.0 liter per hour the temperature is increased to 500° C and maintained until the total water draw-off is less than 1.0 liter per hour.</li> <li>• Note that the Reduction Heater outlet temperature is increased to 450° C only.</li> <li>• The 500°C temperature must be reached in the reaction section in order to check if any problem, due to the thermal expansion of the reactor internals, occurs.</li> <li>• When the system is dry, lower the temperature to 200 °C (50 °C/h). Then stop firing or stop Reduction heaters and circulate nitrogen until the reactors are cooled down to 40° C. The doors of the heater boxes could be opened in order to speed-up the cooling process. Stop then the recycle and close the block valves at suction and discharge.</li> <li>• Depressurize and repressurize the unit with air, to remove nitrogen. Check that the</li> </ul>	

	atmosphere is suitable for entry into the vessels. <b>Note:</b> The PSA unit package is isolated.	
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**Notes:**

1. During the temperature rise, watch the skin temperatures of the heater tubes and flue-gas temperature to avoid any overheating of the tubes. Check also the temperature of each equipment in order not to exceed the design figures.

2. Reformer Feed/Effluent Exchanger R41-E-13110

The following precautions must be carefully observed:

- Owing to the narrow space (2.5 mm) between plates, the upstream piping must be thoroughly flushed prior to flow through the exchanger.
- During shell or bundle flushing (to remove air or process fluids) the differential temperature between the feed stream and the effluent stream must not exceed 50° C.
- The plate are stainless steel. Presence of chloride and liquid water for an extended period must be avoided.
- Ensure that the feed side pressure always exceeds the effluent side pressure. Consequently:  
the exchanger must be pressurized only from the feed inlet (recycle compressor discharge).  
the exchanger must be depressurized only from the effluent outlet (Separator Drum).
- Introduce the naphtha feed at a linear rate in order to reach 60% of the design within ten minutes. Ensure that both inlet flows are balanced.

**4.2.4.1.3.7      Regeneration section dry out**

Refer to section 8.1 for Dry-out drawings.

- The section is fully isolated from the reaction- absorber - nitrogen section by the special tight valves on top of the Lock Hopper (R41-D-1402) and by the valve on the seal leg (on the lower hopper bottom pipe).
- When the equipment of the regeneration loop is lined-up, the Regeneration Loop Compressor (R41-K-1465) is pressurized up to 6 kg/cm<sup>2</sup> g with nitrogen, open the valves at suction and discharge of the regeneration compressor.
- Start the compressor K-1465 and load the valves to circulate the gas, establishing flows equivalent to design values, to the burning and to the oxychlorination /calcination zones. When circulation is established, drain free water from low points.

- Switch-on the burning heater (R41-E-1467), oxychlorination heater (R41-E-1469) and calcination heaters (R41-E-1473) and bring temperatures up, at a rate of 20° C per hour, until the Regenerator inlet temperature reaches 200° C.

#### **4.2.4.1.3.8      Follow-up and end of drying**

Refer to section 8.1 for Dry-out drawings.

- A procedure similar to the reaction section drying **to** be followed (rate of temperature increase:20° C per hour), except that the temperature is limited to 400° C for the regeneration section.
- After reaching 400° C with a total water draw off less than 1.0 liter per hour, the temperature is lowered to 200° C, then heaters are switched off and nitrogen circulation continued until the regenerator cools down to 40° C. Then nitrogen is replaced by air and the atmosphere checked suitable before allowing entry to the vessels.
- Reactors, regenerator and vessels are now ready for inspection (thermal expansion of internal devices) and for catalyst loading.

**Note:** Typically, the drying of all the sections take place at the same time. However the drying of the regeneration section may also be carried out separately.

#### **4.2.4.1.4      Catalyst Loading – Section R41-3 & R41-4**

##### **4.2.4.1.4.1      Preliminary checking before catalyst loading**

When the reaction section drying out is complete and nitrogen has been replaced by air, the Aromizing (Reforming) reactors and the regenerator can be opened for inspection of the internals, cover plates and grids, to make sure that thermal expansion has not caused any damage. If needed, the reactors and regenerator **is** brushed and vacuum cleaned before catalyst loading starts.

During this period, in the reactors catalyst sealing rings are installed. The procedure is given here after. The catalyst loading period must be as short as possible to minimize the risk of moisture entering the reaction system. If necessary, the job **to** be done in shifts.

Catalyst loading will preferably be interrupted in case of rain or snow, or efficient protection must be in place. The catalyst must be handled with care to avoid breakage of the catalyst spheres. During the loading, the loading sleeves **is** adjusted to allow a free fall no higher than 2 meters above the catalyst level.

##### **4.2.4.1.4.2      Equipment and personnel required for loading**

The list below is based on the following basis: catalyst loading **is** carried out with 2 cranes at the same time. One crane **is** dedicated to load the first reactor and regenerator. This crane must be able to handle a mobile hopper full of catalyst, above the structure. For the others reactors, a second crane **is** used.

- 2 telescopic cranes capable of lifting approximatively 3 tons, 5 meters above the reactor upper manhole (See section 8.18.2.1).
- 1 forklift to handle the catalyst drum pallets.
- 2 stationary hoppers equipped with Ø 8 to 10" nozzles to be installed on the reactor upper manhole (See section 8.18.2.2 and 8.18.2.4).
- 4 mobile hoppers, each with a capacity of about 5 to 6 catalyst drums (See section 8.18.2.3 and 8.18.2.4).
- 1 structure (scaffolding and timbers) to unload the drums into the mobile hoppers (See section 8.18.2.5).
- 1 safety harness, portable oxygen analyzer, dust masks, goggles, plastic sheets to protect drums and reactor in case of rain.
- 2 empty half drums (for lift pots) and plastic sheets to install underneath.
- 2 Ø 600 mm funnels (for upper hoppers)

To serve the above mentioned equipment the following personnel is necessary:

- 1 foreman,
- 2 crane operators,
- 1 fork lift operator,
- 1 team of 6 riggers at ground level for catalyst handling and loading into the mobile hoppers,
- 1 gamma ray level specialist, assisted by one instrument technician during the loading of the vessels located above reactors and regenerator.
- 1 team of 6 fitters for vessels opening and closing (inlet elbows, manholes,...).

Note: This personnel **should** be permanently present during the loading operation. The total number of personnel **to** be obtained by multiplying by the number of shifts.

#### **4.2.4.1.4.3      Manholes, piping and internals to be removed**

For internal inspection and catalyst loading, some equipment must be removed: (See section 8.18.2.7)

- For each reactor:
  - 4 inlet catalyst pipes
  - 1 inlet elbow
  - 8 cover plates
  - 3 conical sectors

- For each lift pot:
  - 1 primary injection nozzle
- For each balance drum
  - 3 x 3" flanges
- For the 1st upper hopper and upper surge drum:
  - 1 elutriator (2 flanges each)
  - 1 manhole
- For the lock hopper:
  - 1 manhole
- For the reduction chamber:
  - 1 manhole
- For the regenerator:
  - 4 manholes
  - 1 man way
- For each upper hopper, except the first :
  - 1 catalyst loading nozzle
  - 1 shell removal (MH flange untied)
  - 1 liaison pipe flanges untied.

#### **4.2.4.1.4.4      Catalyst Sealing Ring Installation Procedure**

Catalyst sealing rings on Aromizing reactors (**Reformer**) centerpipe are provided to significantly improve centerpipe bottom tightness.

Installation procedure is described here below. The reference are from drawing 5 given with reactor drawings in Process Datasheet.

- Preparation prior to assembly:

The supplied ceramic fiber gasket (referenced “9” on drawing 5) must be first fixed in place (with glue) onto the inside face of the catalyst sealing ring (surface referenced “A” of cover ring part referenced “1” – see drawing 5) for an easy assembly.

This must be done for all three segments composing catalyst sealing ring.

This will avoid damaging the V-profiles of centerpipe grid (those wires have been heat treated in order to reduce their hardness: the direct contact with the catalyst sealing ring, which is made of the same material –i.e. SS 321– may be detrimental) during the subsequent operations.

- Trial-fit of the catalyst sealing ring into the vessel:

The surface referenced "B" of cover ring part referenced "1" (see drawing 5) must be in contact with upper face of centerpipe support ring. Bolt the assembly plates (part referenced "3" – see drawing 5) together with only one bolt and nut (take care not to tighten too much the bolts and nuts in order to avoid seizing).

Note: The caps for the centerpipe locking pins (element referenced "2" – see drawing 5) must be aligned with the pins if applicable. The assembly plates must be positioned precisely in-between two catalyst outlet nozzles in order not to disturb catalyst gravity flow. Given the various tolerances on the implied elements, either one of two possibilities may now prevail:

- a) The catalyst sealing ring is obviously loose around the center pipe. In this case, add a second layer of ceramic fiber gasket (referenced "9" – see drawing 5) on surface "A" (a spare must have been provided, as per drawing 5).
- b) There is a clearance between assembly plates (part referenced "3" – see drawing 5). Given this clearance, stuff in consequence a proper quantity of provided ceramic fiber gasket material (referenced "8" on drawing 5) onto their surface referenced "C" (see drawing 5). Keep in mind that those are compressible gasket (i.e. their usual thickness is approximately 2mm but becomes 0.2 to 0.5mm when compressed).

Note: In case the average clearance turns out to be larger than 1-2mm, shim plates have been provided and must then be inserted between assembly plates to compensate.

- Final assembly of the catalyst sealing ring:

All the required ceramic fiber gaskets (and shim plates if needed) being in place, align the catalyst sealing ring in its correct position (refer to point 1 here above) and finish bolting of all the assembly plates.

#### Final Notes for catalyst sealing ring installation:

- 1) The catalyst sealing ring must not be loose around the center pipe grid.
- 2) There must be no gaps that are wider than 0.9mm anywhere (between assembly plates, etc.)
- 3) The catalyst sealing ring must not be in contact with any part of the reactor bottom head (except with the top side of the centerpipe support ring).
- 4) Take care not to bend or damage anywhere the V-profile wires of the center pipe grid during the above activities.
- 5) Reactor bottom must be cleaned prior to and after catalyst sealing ring assembly. All precautions must be taken not to lose any tool, or parts, into the catalyst outlet nozzles.

#### **4.2.4.1.4.5      Catalyst drums location**

(See section 8.18.2.8)

Most of catalyst is loaded by mean of the stationary hopper. For the X-ray levels calibration the loading **is** carried out with drums. These drums **are** located above the following equipment. The number of drums hereunder **is** determined on site.

First Reactor	:	drums *
Second Reactor	:	drums *
Third Reactor	:	drums *
Fourth Reactor	:	drums *
First Upper Hopper	:	drums
Second Upper Hopper	:	drums
Third Upper Hopper	:	drums
Fourth Upper Hopper	:	drums
Regenerator manhole 5	:	drums *
Lock Hopper	:	drums
Upper Surge Drum Elutriator	:	drums

\*: Check of the outlet catalyst pipes

#### **4.2.4.1.4.6      Estimated catalyst inventory**

(See section 8.18.2.9)

The figures shown hereunder are determined at the process design stage. The actual amount loaded may differ slightly and must be carefully recorded.

Approximated number of drums for the initial loading (approx. 105 kg for each drum).

<b>Reactor Parts</b>	<b>m3</b>	<b>DRUMS</b>
First Reactor Upper hopper	2.9	18.5
Reduction chamber	10.3	65.9
Reduction chamber legs	0.2	1.1
Other legs	0.1	0.8
First Reactor	32.7	208.6
First Reactor lower hopper and lift pot	0.1	0.8
<b>TOTAL FIRST REACTOR SECTION</b>	<b>46.4</b>	<b>295.9</b>

<b>Reactor Parts</b>	<b>m3</b>	<b>DRUMS</b>
Second Reactor Upper hopper	2.3	15.
Second Upper hopper legs	0.2	1.1
Other legs	0.1	0.8
Second Reactor	49.0	312.5
Second Reactor lower hopper and lift pot	0.1	0.8
<b>TOTAL SECOND REACTOR SECTION</b>	<b>51.8</b>	<b>330.2</b>

<b>Reactor Parts</b>	<b>m3</b>	<b>DRUMS</b>
Third Reactor Upper hopper	2.3	15.0
Third Upper hopper legs	0.2	1.1
Other legs	0.1	0.8
Third Reactor	<b>67.9</b>	<b>433.2</b>
Third Reactor lower hopper and lift pot	0.1	0.8
<b>TOTAL THIRD REACTOR SECTION</b>	<b>70.7</b>	<b>450.9</b>

<b>Reactor Parts</b>	<b>m3</b>	<b>DRUMS</b>
Fourth Reactor Upper hopper	<b>2.3</b>	<b>15.</b>
Fourth Upper hopper legs	0.2	1.1
Other legs	0.1	0.8
Fourth Reactor	<b>121.9</b>	<b>777.6</b>
Fourth Reactor lower hopper and lift pot	0.1	0.8
<b>TOTAL FOURTH REACTOR SECTION</b>	<b>124.6</b>	<b>795.3</b>

<b>Reactor Parts</b>	<b>m3</b>	<b>DRUMS</b>
Legs	0.1	0.4
Lock hopper	4.0	25.7
Regenerator	<b>24.0</b>	<b>153.0</b>
First Lower Hopper and First Lift Pot	0.1	0.8
<b>TOTAL REGENERATOR SECTION</b>	<b>28.</b>	<b>180.0</b>

<b>TOTAL CATALYST TO BE LOADED</b>	<b>Volume</b>	<b>No. of Drums</b>
Reactors :	293.5 m3	1872
Regenerator :	28.2 m3	18
<b>TOTAL</b>	<b>321.7 m3</b>	<b>2052</b>

Note: Four additional drums to be stored nearby the catalyst loading device for future loading and to be protected against rain.

#### **4.2.4.1.4.7      Reactors loading**

The recommended number of drums **is** determined on site.

- **Loading preparation**

1. For each reactor, dismantle the four inlet catalyst pipes to permit the removal of the inlet elbow. Protect the flanges against shocks.
2. Remove the reactor inlet elbows.
3. Pull out the reactors inlet distributors to permit entering into the reactors and protect the manhole flanges against shocks.
4. Check that the atmosphere is suitable to enter the reactors (the previous operation was drying with nitrogen).

5. As during reaction section dry out, high temperatures have been reached (about 500 degrees C), the reactors internals must be inspected to detect any problems caused by thermal expansion.
6. Some of the cover plates and sector pieces have to be dismantled to allow internal inspection, cleaning and catalyst loading.
7. Before catalyst loading starts, make sure that the 4 catalyst nozzles at the top of the reactors are free of any foreign material and covered with plastic bags. A good housekeeping around the reactor top manholes must be maintained.
8. Remove the primary gas injection from the bottom of each lift pot.
9. Check each lift pot again for primary injection nozzle location.
10. Open the special tight manual valves on the catalyst lines under the lower hoppers .
11. Remove the first upper hopper manhole and elutriator tube to permit lift piping checking. Catalyst loading nozzles are opened on the Second, Third and Fourth Upper Hoppers.
12. Close special tight manual valves on the lift pipes.
13. Catalyst outlet pipes and lower hoppers must be checked to make sure that no foreign material remains inside. Air flush from inside the reactors each of the 12 catalyst pipes.
14. When the flow from the lift pot bottom is dust free, close the special tight manual valve on the catalyst line under the lower hoppers of each reactor.

- **Reactors and Lower Hoppers loading**

#### CATALYST FLOW TEST

1. The beginning of catalyst loading operation is the same for each reactor (see appendix 1 "Reactor and lower hopper loading").
2. Load two drums of catalyst into the reactor, in order to fill up the outlet catalyst pipes, lower hopper and seal leg. Make sure that every 12 spider legs are equally filled with catalyst.
3. Knock on the pipe wall to check whether catalyst pipes are full.
4. Open the special tight manual valves under each lower hopper and unload the catalyst in a clean drum installed under the lift pot. We recommend to measure the time required to dump the two drums. This operation should take around 2 minutes for a seal leg in 3" Sch.80 (1 minute for 4" Sch.80 seal leg). A longer time required for dumping catalyst may be an indication that some foreign object is blocking catalyst flow. Incriminate piping(s) can be detected either by dropping an 1" ceramic ball in each spider leg or by radiography.
5. When catalyst flow stops, check again by knocking that the catalyst pipes are empty.

Note : Depending on cleanliness of catalyst lines after air flushing, the two drums used for flow test may need to be discarded for screening in order to remove foreign particles prior to loading.

6. Close special tight manual valves under the lower hoppers and reinstall the primary hydrogen gas nozzle on the lift pots.
7. When the test is completed, catalyst loading can start.

#### CATALYST LOADING

1. When the catalyst level reaches the upper part of the reactor centerpipe, the catalyst loading is stopped.
2. Reinstall the sectors pieces and the removed cover plates, except 4 of them located at 90° kept dismantled to control the end of catalyst loading.
3. Fill up the conical parts of the catalyst bed.
4. Fit in the last 4 cover plates.
5. Install the reactor inlet distributors.
6. Install the reactor inlet elbows.
7. Install the four upper inlet catalyst pipes. For the end of catalyst loading, the procedure for the first reactor is different from the other reactors (go to first reactor end of loading).

- **Second, Third and Fourth Reactors End of Loading**

#### CATALYST LOADING AND CALIBRATION

1. Through the catalyst feed nozzle, fill up the catalyst inlet pipes of the reactor. Stop catalyst loading when they are full (checking by knocking).
2. Fill up Second, Third and Fourth upper hoppers, calibrate the levels LC-4220/4320/4420 with the manufacturer.

Note also at which level % the LSLL are activated.

Note : For an easier and quicker end of loading, it may be needed to dismantle upper hopper's top flanges. In this case, remind to plug the end of lift pipe in order to avoid filling up the line (this plug **to** be removed prior to closing the vessel).

3. Open the special tight manual valves under the lower hoppers. The lift pots **are** filled. Check in parallel the deviation of Second, Third and Fourth upper hopper levels at the DCS.
4. Close the Second, Third and Fourth upper hoppers catalyst loading nozzles.

- **First Reactor End of Loading**

1. Check the First Upper Hopper catalyst sampling device.
2. Open the manual and auto special tight valves between the First Reactor Upper Hopper and the Reduction Chamber.

#### CATALYST LOADING AND CALIBRATION

(See section 8.18.2.11)

1. Fill up the inlet catalyst pipes by loading catalyst through the 1st upper hopper top hand hole.
2. Stop catalyst loading when they are full (checking by knocking).
3. Close the special tight manual valve under the 1st upper hopper.
4. Fill up the First upper hopper, with only xxx drums, about 40%.
5. Open the special tight manual valve under the First upper hopper, the reduction chamber **is** filled up partially.
6. Fill the First upper hopper, with 1 additional drum.
7. Close the special tight manual valve under the First upper hopper.
8. Fill up the First upper hopper, calibrate its level LC-4110, in coordination with the level manufacturer:
  - xx drums and xx liters are loaded, this is 0% of the LI
  - xx drums are loaded, to fill completely the cone: xx% of the LI
  - xx drums are loaded: xx% of the LI per drum.

A total of xx drums **are** loaded.

9. Note that low level alarm LALL-4112 of the First upper hopper should be switched off before reaching 20% at the LI-4110.
10. Open the special tight manual valve under the First upper hopper and finish filling the reduction chamber. Check the deviation of the First upper hopper level LI-4110 on the DCS.
11. Check that the primary hydrogen nozzle of the first lift pot is reinstalled and open the special tight manual valves under the First reactor lower hopper. The lift pot **is** filled up. Check again the deviation of the First upper hopper level LI-4110 indication on the DCS.
12. Install the First upper hopper elutriator pipe and connect the piping. This finishes the initial loading of the reactors.

#### **4.2.4.1.4.8      Regenerator loading**

##### **Operation schedule**

1. Open manholes MH2, MH3, MH4 and MH5 of the regenerator and the MH of the upper surge drum.
2. Check if the atmosphere in the regenerator is breathable, for entry, then open the manway at storage zone catalyst support tray.
3. After inspection, close the manway at storage zone catalyst support tray, set the internal plug, then close the top manhole MH2 and reinstall the catalyst line from the lock hopper bottom to the regenerator. After setting the internal plug, close the MH of the upper surge drum.
4. A good housekeeping around the regenerator top manhole MH1 must be maintained.
5. Remove the primary gas injection nozzle from the bottom of the lift pot.
6. The lift pot under the regenerator must be checked (primary injection nozzle location).
7. Remove the upper surge drum elutriator to permit lift pipe checking.
8. After lift pipe checking close the special tight manual valve on the lift pipe.
9. The catalyst pipes of the first lower hopper must be checked to make sure that no foreign material remains inside.
10. Air flush from the regenerator each of the 8 catalyst pipes one by one.
11. Then, when the flow from the lift pot bottom is dust free, close the special tight manual valve under the first lower hopper.
12. The catalyst flow test can now be carried out.

##### **CATALYST FLOW TEST**

1. One drum of catalyst **is** loaded into the calcination zone of the regenerator through the lower manhole MH5, in order to fill the first lower hopper and the catalyst outlet pipes.
2. Check that the hopper pipes are full of catalyst (knock on the pipe wall).
3. Open the special tight manual valve under the first lower hopper and unload the catalyst into a clean drum installed under the lift pot. We recommend to measure time required to dump the two drums. This operation should take around 2 minutes for a seal leg in 3" Sch. 80 (1 minute for 4" Sch. 80 seal leg). A longer time required for dumping catalyst may be an indication that some foreign object is blocking catalyst flow. Incriminate piping(s) can be detected either by dropping an 1" ceramic ball in each spider leg or by radiography.
4. When catalyst flow stops, check that the first lower hopper pipes are empty.

5. Close the special tight manual valve under the first lower hopper and reinstall the primary gas nozzle on the lift pot.
6. When the test is complete close the lower manhole MH5 after having set the internal plug.

Note : Depending on cleanliness of catalyst lines after air flushing, the two drums used for flow test may need to be discarded for screening in order to remove foreign particles prior to loading.

7. Catalyst loading can now start.
8. At the beginning of the operation catalyst **is** loaded from the upper surge drum using the elutriator nozzle.
9. Open the automatic special catalyst tight valve UV between the upper surge drum and the lock hopper.
10. Open the automatic special gas tight valve UV between the lock hopper and the regenerator.
11. Open the automatic special gas tight valve UV between the upper surge drum and the lock hopper.
12. Close the automatic special catalyst tight valve UV between the lock hopper and the regenerator.
13. Check the lock hopper catalyst sampling device.

#### CATALYST LOADING AND CALIBRATION

(See section 8.18.2.12 and 8.18.2.13)

1. Lock hopper level alarm test (1 to 8). Load 1 drum in this vessel. The low level alarm must stay ON
2. Add catalyst in ten liter quantities until the low level alarm (LAL) is switched OFF. The quantity to be added is xxx liters.
3. Open the automatic special catalyst tight valve KV-4020/4021 between the lock hopper and the regenerator. The lock hopper low level alarm LAL-4020 will be switched ON.
4. Close the automatic special catalyst tight valve KV-4020/4021 between the lock hopper and the regenerator.
5. Add xxx drums in the upper surge drum. The lock hopper low level alarm LAL-4020 will be switched OFF and the high level alarm LAH-4021 must stay OFF.
6. Add catalyst in ten liter quantities until the lock hopper high level alarm LAH-4021 is switched ON. The quantity to be added is xxx liters.
7. Open the automatic special catalyst tight valve KV-4020/4021 between the lock hopper and the regenerator. The high level alarm LAH-4021 will be switched OFF, and the low level alarm LAL-4020 will be switched ON, as the catalyst loads the regenerator.
8. Close then automatic special catalyst tight valve KV-4010/4011 between the upper surge drum and lock hopper. Close the automatic special catalyst tight valve KV-4020/4021 between the lock hopper and the regenerator.
9. Upper surge drum level indicator LI-4010 tests (10 to 16).

10. Load one drum into the upper surge drum The level must show 0%.
11. Add catalyst in ten liter quantities until the level indicator show 10%. The quantity to be added is xxx liters.
12. Open the automatic special catalyst tight valve between the upper surge drum and the lock hopper. The level indicator must show 0% again.
13. Close the automatic special catalyst tight valve KV-4010/4011 between the upper surge drum and the lock hopper.
14. Add xxx drums into the upper surge drum . The LI-4010 should indicate 100% but high level alarm LAHH-4011 must stay OFF.
15. Add one catalyst drum first and then in ten liter quantities until the high high level LAHH-4011 is switched ON.  
The quantity to be added is xxx liters
16. Open the automatic special catalyst tight valve between the upper surge drum and the lock hopper. LAHH-4011 will be switched OFF. The low level alarm LAL-4010 will be switched ON.
17. Open the automatic special catalyst tight valve KV-4020/4021 between the lock hopper and the regenerator.
18. Check that the system is catalyst tight at the manholes MH2 and MH3.
19. Open the 4 catalyst valves at lock hopper top and bottom KV-4010/4011/4020/4021.
20. Fill the regenerator from the top of the upper surge drum with catalyst until the low low level alarm LALL-4010 is switched OFF (xxx drums).
21. The level indicator LI-4000 of the Regenerator can now be calibrated. This must be done, in coordination with the level manufacturer.
22. Catalyst **is** loaded drum by drum from the top of the upper surge drum, all 4 catalyst valves at lock hopper top and bottom being still opened KV-4010/4011/4020/4021.
23. The low low level alarm LALL-40010 is switched OFF while the level indicator LI-4000 shows 0%
24. Load xxx drum. The level indicator LI-4000 must show 10%.
25. Load drum after drum to perform level calibration including DCS low level and high level alarms of this vessel.
26. Total number of drums added: xxx.
27. Check that the primary gas nozzle of the lift pot is reinstalled and open the special tight manual valve between the first lower hopper and the regenerator lift pot.
28. The lift pot **is** filled. Check in parallel the deviation of the upper surge drum level indicator LI-4010 on theDCS.
29. Close the 2 catalyst valve KV-4020/4021 between lock hopper and regenerator, then load the lock hopper with xxx drums, from the top of the upper surge drum. Finally close the 2 catalyst valves KV-4010/4011 between upper surge drum and lock hopper.
30. Reinstall then the elutriator and the related piping on top of the upper surge drum.

31. Close manholes MH3, MH4 of the regenerator. This finishes the initial loading of the regeneration section.

Note : For better accuracy of solid level measurement, it may be required to proceed several times to calibration of gamma ray levels on a same vessel. This may require to partially dump catalyst from the regenerator through lift pot primary nozzle.

#### **4.2.4.1.5      Second Leak test and partial inerting**

After the catalyst loading, the reaction section and the regeneration section must be leak tested again.

Leak test is combined with partial inerting: the objective is to reach an oxygen content between 2 and 5% for the purpose of catalyst circulation. This is achieved by successive pressurizations and depressurizations with nitrogen. Since catalyst circulation requires the running of the H<sub>2</sub> Rich Gas Compressor, the absorber section is also subject to partial inerting.

Leak test (using nitrogen):

- Reaction section, regeneration section and absorber section are isolated from the rest of the unit. All pumps and compressors (suction / discharge valves) are isolated.
- All connections to the flare are blinded.
- All safety valves are connected to atmosphere, if not possible, the collector to the flare is blinded at battery limit.
- Blind the hydrogen lines from the HP absorber (R41-D-13580) to fuel gas system, to downstream users and all lines going out to battery limits.
- A temporary blind is installed on liquid feed line to the LPG absorber (R41-D-136100) All sections are pressurized with nitrogen up to 3.5 kg/cm<sup>2</sup> gage.

The test is considered satisfactory when the average pressure decrease is lower than 0.05 kg/cm<sup>2</sup> per hour during 4 hours.

#### **4.2.4.2 Detailed Start-up procedure**

##### **4.2.4.2.1 Introduction**

The following describes the very first startup of a newly built unit. Any subsequent startup of the same unit **is** very likely not include all the following steps but part of them only, depending upon the status of the unit after the shutdown. For instance the catalyst reduction procedure needs not be performed again, except in the case of catalyst renewal. Note that this procedure is not fully applicable either in case of use of fresh pre-reduced catalyst or in case of re-startup with coked catalyst (see paragraph 4.2.4.2.4).

##### **4.2.4.2.2 Status of the Unit prior to Start-up**

The status of the unit prior to its initial startup is as follows:

- Each section as defined in section 4.1.1.2.3 has been leak tested (initial leak tests).
- All the sections (except the depentanizer, deethanizer and debutanizer sections) have been dried.
- Catalyst has been loaded in the reactors and the regenerator and the relevant sections leak tested again and partially inerted (residual content of O<sub>2</sub> between 2 and 5% volume).
- The depentanizer, deethanizer and debutanizer sections have not been inerted
- The unit is isolated with blinds at the battery limits:
  - on the feed and products lines.
  - on the flare and fuel gas headers.
- Pressure relief valves in the reaction and HP absorber sections are blanked off, except those to atmosphere.
- The PV-3450B on the Separator Drum (R41-D-13450) discharges to atmosphere.
- Pressure relief valves in the regeneration and nitrogen sections are directed to atmosphere (normal status).

##### **4.2.4.2.3 Chronology of Operation**

The sequence of first startup is as follows:

- Circulation of catalyst and drying of catalyst under an atmosphere with a residual O<sub>2</sub> content of ~ 3 vol. %.
- Complete inerting of the sections involved in the circulation (i.e. all sections except depentanizer, deethanizer and debutanizer) O<sub>2</sub> content is reduced to less than 0.2% volume.
- Complete inerting of the depentanizer, deethanizer and debutanizer sections
- Depentanizer section startup on total reflux.
- Pressurization with hydrogen of the reaction section and the HP absorber section.
- Heating up and reduction of catalyst.
- Oil in.

- Operation of the unit at low capacity and low severity.
- Operation of the unit at low capacity and high severity.
- Operation of the unit at nominal capacity and high severity.
- Start of the catalyst circulation.
- Start of catalyst regeneration.
- Deethanizer (R41-T-137) and debutanizer (R41-T-138) start-up on total reflux.

#### **4.2.4.2.4      Catalyst circulation, heating and drying procedures**

The above operations must take place prior to oil in, in order to:

- Test the catalyst circulation and let the beds expand (the catalyst gets closer to its density in operation)
- Dry the catalyst.

The catalyst is dried by a mixture of air and nitrogen. Air is used to prevent sintering of the metals on the catalyst.

The oxygen content in the sections concerned must be kept between 3 and 5% volume.

**Note:** When fresh pre-reduced catalyst or coked catalyst are used heating and drying of the catalyst cannot be performed as obviously in both cases, the test of catalyst circulation must be performed under pure nitrogen ( $O_2 < 0.2$  vol. %). After recycle gas compressor startup reaction section heaters pilots are lighted-on and the temperature of the circulating gas **should** not be higher than 100° C.

#### **4.2.4.2.4.1      Outline of circulation procedure and principle of catalyst transportation**

The sections concerned are the reaction section and the HP absorber section, the nitrogen section and the regeneration section. These sections have normally been left under a pressure of air and nitrogen, at the end of the second leak test and partial inerting (4.2.4.1.5). Nitrogen circulation is then started in the reaction and absorber section through the Recycle Compressor (R41-K-13450) and the Hydrogen Rich Gas Compressors (R41-K-135/55), in the nitrogen section by means of the Nitrogen Compressors (R41-K-1405 A/B). In the regeneration section which is isolated from the latter ones, nitrogen is circulated through the Regeneration Loop Compressor (R41-K-1465).

N<sub>2</sub> seal gas is established first. Although this is not strictly mandatory at this moment (there is no H<sub>2</sub> nor HC yet in the unit), it is advised to do so, to train operators to use the right sequence and to test the interlocks associated with N<sub>2</sub> seal. Catalyst circulation is started from Fifth Lift Pot (R41-D-1444) to the Upper Surge Drum (R41-D-1401), then from Fourth lift pot (R41-D-1434) to Fourth Upper Hopper (R41-D-1442), from Second Lift Pot

(R41-D-1414) to Second Upper Hopper (R41-D-1422) and ultimately from First Lift Pot (R41-D-1404) to First Upper Hopper (R41-D-1411). Figures 8.19.9 and 8.19.10 (Refer in Attachments) show how the catalyst flows in the reactors and the regenerator. In order to understand how catalyst flow is started and controlled, the principles of catalyst transport and catalyst flow control are shown in Figure 11 (Refer Attachments).

The total lift gas (primary plus secondary gas) must be kept constant to ensure a constant catalyst particles velocity. The secondary lift gas controls the amount of catalyst which **is** circulated in the lift pipe with the help of the primary lift gas.

Within the design operating range, the catalyst flow is proportional to the secondary flow of gas. Moreover the differential pressure in the lift pipe is proportional to the catalyst flow, hence lift catalyst flow is measured and controlled by the differential pressure. The differential pressure controller of the catalyst lift pipe is reset by the level of its feeding upper hopper. This applies to the lift pipes B to E. It does not apply to lift pipe A because the lock hopper level works on an ON/OFF basis. The PDC set point of lift pipe A is fixed by the operator and actually governs the catalyst flow in the whole unit. A paramount criteria in catalyst circulation is safety. During normal operation, when hydrocarbons are present in the reaction section, they must be prevented from entering the regeneration section, and air from entering the reaction section. Hence, the lifts from the Fifth Lift Pot to the Upper Surge Drum and from the First Lift Pot to the First Upper Hopper use nitrogen. Moreover an independent source of nitrogen referred to as " N2 seal gas" is used (Refer Figure 12 in attachments):

- To maintain a controlled nitrogen over pressure between the First Upper Hopper and the Reduction Chamber
- To maintain an overpressure in the Fifth Lower Hopper against the lift pot pressure on one side and the reactor pressure on the other side (refer Figure 13 in attachments).
- To maintain an overpressure in the First Lower Hopper against the lift pot pressure and the regenerator pressure (refer to Figure 13 in attachments).

**Note:** Seal gas using hydrogen is also injected in the lower hoppers of First, Second, Third Reactors to prevent hydrocarbons from entering into the lift pipes.

In normal operation (hydrocarbons in the reaction section) nitrogen seals and hydrogen seals must always be established prior to starting catalyst circulation.

The details of the catalyst circulation and drying procedure are covered in the following paragraphs.

#### **4.2.4.2.4.2 Preparation for Catalyst Circulation**

Prior to start, check the status of the unit:

	<b>Action</b>	<b>Remarks</b>
1.	Reaction section and HP absorber section are interconnected and isolated from the rest of the unit	
2.	<p>Nitrogen section isolated (see attachment 8.1 for catalyst drying) as follows:</p> <p><b>Special catalyst tight manual valves:</b></p> <ul style="list-style-type: none"> <li>• on seal legs at bottom of First, Second, Third Reactors : closed</li> <li>• on seal legs at bottom of Fourth Reactor and Regenerator : open</li> <li>• on lift lines : open</li> <li>• from First Upper Hopper to Reduction Chamber : open</li> </ul> <p><b>Lock hopper is isolated by remote operated ON/OFF valves</b></p> <ul style="list-style-type: none"> <li>• from Upper Surge Drum R41-KV-4010 and 4011 : closed</li> <li>• from Regenerator R41-KV-4020 and 4021 : closed</li> <li>• from N2 seal gas R41-UV-4012 : closed</li> </ul> <p><b>N2 seal gas to Upper Surge Drum R41-UV-4010: closed First upper hopper isolated (by ROV, ON/OFF):</b></p> <ul style="list-style-type: none"> <li>• from Reduction Chamber R41-ZV-4111 : closed</li> <li>• from N2 seal gas R41-ZV-4110 : closed</li> </ul> <p><b>First Lower Hopper isolated (by ROV, ON/OFF):</b></p> <ul style="list-style-type: none"> <li>• from First Lift Pot R41-ZV-4031 : closed</li> <li>• from N2 seal gas R41-ZV-403 : closed</li> </ul> <p><b>Last lower hopper isolated (by ROV, ON/OFF):</b></p> <ul style="list-style-type: none"> <li>• from Lift Pot R41-ZV-4431 : closed</li> <li>• from N2 seal gas R41-ZV-4441 : closed</li> </ul>	
3.	<p>Regeneration section: is already isolated from nitrogen section:</p> <p>On top of regenerator R41-KV-4020 and 4021 closed.</p> <p>On bottom line of First Lower Hopper R41-ZV-4031 closed:</p> <ul style="list-style-type: none"> <li>• Commission the oxygen analyzer AE-4730 to the calcination zone at the shell outlet of the calcination feed / effluent exchanger.</li> <li>• Commission the oxygen analyzer AI-4051 at the suction of the Nitrogen Compressor</li> </ul>	

	<p>and set the scale on 0-10% vol. (at Nitrogen compressor K.O. Drum inlet)</p> <ul style="list-style-type: none"> <li>• Temporarily connect the oxygen analyzer AE-4661 located on shell side inlet of Burning Feed / Effluent Exchanger to any point of the reaction section, (scale 0-10%), in order to follow the O<sub>2</sub> concentration in the reaction section.</li> </ul> <p>Note that the information from the O<sub>2</sub> analyzers to the interlock systems must be inhibited.</p>	
4.	<p>General:</p> <ul style="list-style-type: none"> <li>• All connections to the flare must be blinded. Check that the PSVs to atmosphere are in service on the Separator Drum and Recycle Compressor discharge as well as all safety valves to atmosphere in the catalyst circulation and regeneration sections.</li> <li>• Blinds must be installed on the hydrogen gas line from the Separator Drum to flare and H<sub>2</sub> Rich Gas Compressor KO drum to fuel gas system.</li> <li>• Spectacle blinds must be closed on the hydrogen gas line to all down stream users.</li> <li>• Spectacle blind must be closed on the Separator Drum to ejector suction.</li> <li>• Suction and discharge block valves must be closed on Separator Bottom Pumps</li> <li>• Air coolers are started in all sections involved.</li> <li>• Cooling water is commissioned on all coolers.</li> <li>• Catalyst level indicators and alarms have been commissioned (4.2.4.1.4“Catalyst loading”).</li> </ul>	

#### 4.2.4.2.4.3 Nitrogen circulation

##### **Step 1 – Start of Recycle Compressor (R41-K-13450)**

- The circulation involves the reaction section as shown in the DRY OUT process flow schemes given in section 8.1
- Start the Recycle Compressor (**R41-K-13450**) as per manufacturer's instructions and adjust flow to the maximum acceptable with nitrogen.
- The pressure in the Separator Drum is set at 3.5 kg/cm<sup>2</sup> g and monitored by the pressure controller.
- The pressure controller PV-3450B is directed to atmosphere.

##### **Step 2 – Start of Nitrogen Compressor (R41-K-1405A/B)**

- The circulation involves the nitrogen section (Refer to DRY OUT process flow scheme in section 8.1).
- Start the Nitrogen Compressor, at 100% capacity.
- Pressure set point for PC-4035: 3.5 kg/cm<sup>2</sup> g at the suction.

- Pressure set point for PC-4057: 6.0 kg/cm<sup>2</sup> g at the discharge (check the temperature at compressor discharge).

#### **Step 3 – Start of Regeneration Loop Compressor (R41-K-1465)**

- The circulation involves the regeneration section (Refer to DRY OUT process flow scheme [in section 8.1](#))
- Start-up the Regeneration Loop Compressor and increase capacity to 100% (compressor by-pass FV-466 is progressively closed). Set burning, oxychlorination and calcination flows at 80% of design value.
- Pressure set point for regeneration loop pressure PC-4653: First Reactor inlet pressure + 0.700 kg/cm<sup>2</sup>.
- Commission the Regeneration Loop Dryer DR-1465.
- Put in service pressure differential controller R41-PDV-40010 between Regenerator top and first burning zone.
- Put in service R41-PDV-40090A/B (Differential Pressure between second burning zone and oxychlorination/calcination zone in regenerator) but keep corresponding control valves PDV-40090A and PDV-40090B in manual.

#### **Step 4 - Establish N2 seal gas to the First Upper Hopper (R41-D-1411)**

Refer to PID D-EP-R41-1225-1414 "FIRST REACTOR (TOP)"

- Override interlocks R41-ZC-4060 and R41-ZC-4111 to allow to proceed with the next steps.
- Open ON /OFF valve R41-ZV-4110 (N2 seal gas to upper hopper).
- Open R41-FV-4110 (before R41-ZV-4110) manually: adjust flow to the design value. Switch into auto.
- Set corresponding FSLL at design value.
- Put R41-PDC-412 and R41-PDALL-4121 in service (Differential Pressure First upper hopper / reduction chamber).
- Open ON/OFF valve R41-ZV-4111 manually
- Wait a few minutes to allow pressure and flow to stabilize.
- Reset interlock R41-ZC-4111. (R41-ZV-4111 and R41-ZV-4110 must remain open).
- Since the first upper hopper (R41-D-1411) is now sealed from the reduction chamber (R41-D-1412), reduction gas circulation can be established to the reduction heater (R41-E-1412), reduction chamber and coolers (refer to Figure 14 in attachments).
- Line up the equipment involved and put in service pressure differential controller R41-PDV-41220 at tube side outlet of Reduction Exchanger R41-E-1416, flow control valve R41-FV-4160 at shell side inlet of Reduction

Exchanger and Pressure controller R41-PV-4170 at shell side inlet of Hydrogen Lift Gas Exchanger R41-E- 1417.  
Correct flow coefficient of orifice for use of nitrogen.

#### **Step 5 - Establish N2 seal gas to the Fourth Reactor.**

Refer to PID : D-EP-R41-1225-1421 "FOURTH REACTOR (BOTTOM)".

- Override interlock R41-ZC-4430.
- Open in manual, ON/OFF valve R41-ZV-4431 (between Fifth Lower Hopper and Lift Pot).
- Open in manual, ON/OFF valve R41-ZV-4430 (N2 seal gas to Fifth Lower Hopper).
- Open R41-FV-4430 (before R41-ZV-4430) manually: adjust flow to the design value. Switch into auto.
- Put R41-PDC-44330 in service (Diff. Pressure between N2 seal gas and primary lift gas).
- Put R41-PDI-4430, R41-PDALL-4431 in service (Diff. pressure between Fourth Reactor and N2 seal gas).
- Reset interlocks R41-ZC-4430, R41-ZC-4060. ON/OFF valves R41-ZV-4431 and R41-ZV-4430 must remain open.

#### **Step 6 - Establish N2 seal gas to Regenerator seal leg.**

Refer to PID: D-EP-R41-1225-1413 "REGENERATOR (BOTTOM)".

- Override interlock R41-ZC-4060.
- Open ON/OFF valve R41-ZV-403 manually.
- Put R41-PDC-403 in service (Diff. Pressure between N2 seal gas and Regenerator bottom).
- Put PDI-4031 , R41-PDALL-4031 in service (Diff. Pressure between N2 seal gas and primary lift gas).
- Reset interlock R41-ZC-4060, R41-ZV-403 must remain open.

#### **Step 7 - Establish H2 seal gas to First, Second and Third Reactors bottoms.**

Note: at this stage nitrogen is used instead of hydrogen.

Adjust seal gas with globe valve to the First, Second and Third Reactors bottom, in order to meet design value for the three corresponding PDI-4130/4230/4330.

##### **4.2.4.2.4.4      Catalyst circulation**

Catalyst circulation can now be started and stabilized at ~ 25% of design flow.

It is reminded the following remote operated valves on catalyst flow are now open:

- R41-ZV-4111 top of Reduction Chamber
- R41-ZV-4431 on Fourth Reactor seal leg

-R41-ZV-4031 on Regenerator seal leg

### Step 8 – Catalyst Circulation

Operators must now open the other valves on catalyst (manual local catalyst tight valves): on seal legs between lower hoppers and lift pots of First, Second and Third Reactors.

For each of the five lift pots, first adjust total gas flow manually through the five corresponding FCs (FC-4040/4140/4240/4340/4440) to the recommended figure as indicated in "Lift gas flow" (Refer 3.2.4.4.2). For the FCs through Second, Third and Fourth Lift Pots, correct coefficient for nitrogen. Then switch to auto mode.

	Action	Remarks
1.	Open slowly R41-PDV-4441 (Fifth Lift Pot) in order to lift catalyst to the Upper Surge Drum until the level in the Fourth Upper Hopper decreases to 40%.	
2.	Then open slowly R41-PDV-4341 (Fourth Lift Pot) in order to lift catalyst to the Fourth Upper Hopper until the level in the Third Upper Hopper decreases to 40%.	
3.	Then open slowly R41-PDV-4241 (Third Lift Pot) in order to lift catalyst to Third Upper Hopper until the level in the Second Upper Hopper decreases to 40%.	
4.	Then open slowly R41-PDV-4141 (Second Lift Pot) in order to lift catalyst to the Second Upper Hopper until the level in the First Upper Hopper has been decreased by about 30%.	
5.	Then open slowly R41-PDV-4041 (First Lift Pot) in order to lift catalyst to the First Upper Hopper.	
6.	Make Adjustments to keep the levels constant.	
7.	The PDI-4041/4141/4241/4341/4441 of the lift pipes <b>is</b> set at a value between 0.1 and 0.2 kg/cm <sup>2</sup> as to obtain equal catalyst flows.	
8.	Stabilize the circulation, in manual mode, until the levels in the upper hoppers are steady. Set the catalyst circulation at about 25% of the design flow. Then set the control in auto cascade from level controllers (LC-4110/4220/4320/4420) to differential pressure controllers (PDC-4141/4241/4341/4441).	
9.	At the beginning of the catalyst circulation, it is recommended to carry out the first transfers from the Upper Surge Drum to the Lock Hopper and from the Lock Hopper to the Regenerator in manual mode.	

10.	The level of catalyst increases in the Upper Surge Drum while it decreases in the Regenerator. When these levels reach the transfer conditions, open the pressure equalizing valve UV-4010 between the Lock Hopper and the Upper Surge Drum: the pressures will equalize. Open then the two ON/OFF valves KV-4011/4010 below the Upper Surge Drum, allowing the catalyst transfer into the Lock Hopper. Then close the pressure equalizing valve and the two ON/OFF valves.	
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After the transfer from the Upper Surge Drum to the Lock Hopper the situation is as follows:

- The four automatic ON/OFF valves between Upper Surge Drum and Lock Hopper (KV-4010/4011) and between Lock Hopper and Regenerator (KV-4020/4021) are closed.
- The two pressure equalizing valves (UV-4010/4013) are closed.
- The Upper Surge Drum is empty but the catalyst coming from the bottom of the Fourth Reactor is filling up the lower part of the vessel.
- The high level alarm (LAH-4021) of the Lock Hopper indicates full
- The level in the upper part of the Regenerator is still going down as catalyst is withdrawn. Regenerator level is in the middle of the range.
- Open the pressure equalizing valve (UV-4013) between the Lock hopper and the Regenerator.
- When the pressures between the two vessels are equalized, open the ON/OFF valves (KV-4020/4021) under the Lock Hopper. The catalyst is transferred to the Regenerator.
- When LAL-4020 of the Lock Hopper is activated, close the ON/OFF valves (KV-4020/4021) to Regenerator and pressure equalizing valves (UV-4013). Open again the pressure equalizing valve (UV-4010) between Lock Hopper and Upper Surge drum. The sequence is in stand-by conditions.

After a few transfer sequences to solve the teething problems, if any, the catalyst transfer is switched to full auto mode.

#### **4.2.4.2.4.5      Catalyst heating up and drying**

##### **Step 9 – Oxygen content in Reaction and Regeneration Section**

Make sure the O<sub>2</sub> content in reaction section and regeneration section is between 3 to 5% by volume. If required, inject air in reaction section at the Recycle Compressor K-13450 suction (tapping point available at upstream of FE- 3450) and in regeneration section at suction of Regeneration Loop Compressor K-1465. Oxygen content must

always remain between 3% and 5% volume until the end of the heating. To test the make up Air Compressor (R41-K-1470), if possible, operate this machine to introduce air in the regeneration section.

#### **Step 10 – Mild Heating up of Reactors and Regenerator**

When oxygen content is confirmed and catalyst circulation steady conditions, light small fires in the Pre/Interheaters FR-13110/13210/13310/13410 (Reforming heaters). Start electrical heaters (E-1467/1469/1473/E-1412) on the regeneration loop and on H<sub>2</sub> gas to the reduction chamber. Increase the temperatures in the Reactors and Regenerator beds at a rate of 20° C per hour. Start to perform hot bolting around 250°C.

#### **Step 11 – Draining of water at low points**

When temperatures in the Reactors and Regenerator are above 300° C, start to drain water at all low points of the sections and keep a record of the amount drained.

#### **Step 12 – Further Heating up to high temperatures**

Increase the temperatures up to 480° C in the reaction section and to 420° C in the regeneration section and reduction section. Keep these values for at least 8 hours or more if the amount of drained water stays above 0.05% of the catalyst weight per hour.

#### **Step 13 – Decrease of Temperature**

When the total amount of water drained at the low points is lower than 0.05% of the catalyst weight per hour, decrease the bed temperatures to 300° C at a rate of 40° C per hour.

#### **Step 14 – Shutdown of equipment**

Stop the fired and electrical heaters but keep pilot burners on for fired heaters.

Stop catalyst circulation while closing the five FVs (FV-4040/4140/4240/4340/4440) on lift pots streams and the five PDV's (PDV-4041/4141/4241/4341/4441) measuring the lift pots ΔP. Close block valves related to the control valves. The closure of the catalyst tight manual valves under the lower hoppers, under the first upper hopper and the closure of KV (bottom of Regenerator) is optional. Stop the compressors when the heaters are shut down.

#### **4.2.4.2.4.6      Instruments Set Points**

The recommended set points for nitrogen circulation and catalyst circulation are listed below: the figure shown must be confirmed by AXENS start up representative.

## Pressure

Tag No.	Service	kg/cm <sup>2</sup> (g)
R41-PT-3451	Recycle Compressor suction	2.1
R41-PT-3500	H2 Rich Gas Compressor suction	2.1
R41-PC-4053	Nitrogen Compressor suction	2.15
R41-PC-4057	Nitrogen Lift Gas Compressor discharge	8.05
R41-PDC-412	Differential Pressure N2 seal gas/Reduction Chamber	0.10
R41-PDALL-4121	Differential Pressure N2 seal gas/Reduction Chamber	0.10
R41-PDC-41220	Differential pressure Reduction Chamber / First Reactor	0.10
R41-PDC-44330	Differential Pressure N2 seal gas/Fourth Reactor lift pot.	0.15
R41-PDI-403	Differential Pressure N2 seal gas/Regenerator bottom	0.05
R41-PDC-4041	Primary lift gas / First Reactor	0.35
R41-PDC-4141	Primary lift gas / Second Reactor	0.20
R41-PDC-4241	Primary lift gas / Third Reactor	0.20
R41-PDC-4441	Primary lift gas / Fourth Reactor lift pot	0.35
R41-PDI-4430	Differential Pressure N2 seal gas/ Fourth Reactor outlet	0.05
R41-PDALL-4431	Differential Pressure N2 seal gas/Fourth Reactor outlet	0.05
R41-PDI-4031	Differential Pressure N2 seal gas/First Lift Pot	0.15
R41-PDALL-4031	Differential Pressure N2 seal gas/First Lift Pot	0.15
R41-PDI-4130	Differential Pressure H2 seal gas/First Reactor outlet	0.05
R41-PDI-4230	Differential Pressure H2 seal gas/Second Reactor outlet	0.05
R41-PDI-4330	Differential Pressure H2 seal gas/Third Reactor outlet	0.05

## Flow

Tag No.	Service	kg/h *
R41-FC-4110	N2 seal gas to First Upper Hopper	17

R41-FALL-4111	N2 seal gas to First Upper Hopper	8
R41-FC-4430	N2 seal gas to Fifth Lower Hopper	85
R41-FALL-4430	N2 seal gas to Fifth Lower Hopper	34
R41-FC-4160	Hydrogen from PSA to reduction	741
R41-FC-4040	Total lift gas to First Lift Pot	636
R41-FIC-4140	Total lift gas to Second Lift Pot	170
R41-FC -4240	Total lift gas to Third Lift Pot	162
R41-FC-4340	Total lift gas to Fourth Lift Pot	153
R41-FC-4440	Total lift gas to Fifth Lift Pot	506

#### 4.2.4.2.5 Final inerting

The purpose is to reduce the O<sub>2</sub> content in all the sections below 0.2% volume prior to hydrocarbons introduction. All the sections (with the exception of the deethanizer and debutanizer sections) have been partially inerted (2 to 5% volume of residual O<sub>2</sub>). The deethanizer and debutanizer sections have not been inerted at all. The depentanizer section is already filled with hydrocarbons under nitrogen atmosphere.

#### 4.2.4.2.5.1 All sections except deethanizer and debutanizer sections

	Action	Remarks
1.	The catalyst beds have been left at approximately 300° C at the end of the catalyst circulation	
2.	Electrical and Fired Heaters are off. But Fired Heaters pilot burners are on.	
3.	All compressors are stopped. They must be isolated and purged with N <sub>2</sub> and left under an atmosphere of pure N <sub>2</sub> .	
4.	Remove blinds on all process lines between the sections (if any remain) - with the exception of the depentanizer, deethanizer and debutanizer sections - remove also blinds to/from the battery limits (with the exception of the liquid feed).	
5.	Remove blinds on the safety valves to flare.	
6.	Install blinds on the safety valves which were previously routed to atmosphere. (Reaction, HP absorber and depentanizer sections only). Install also a blind on the PCV previously	

	directed to atmosphere (suction of Recycle Compressor).	
7.	Close double block valves on start-up lines (6"-G-R41-3079/3"-H-R41-4085): Between Recycle Compressor suction and Nitrogen Compressor suction Between hydrogen rich gas product and Nitrogen Compressor discharge	
8.	Depressurize the reaction section to 0.1 kg/cm <sup>2</sup> g then introduce N <sub>2</sub> to Recycle compressor discharge and raise the pressure to 4 kg/cm <sup>2</sup> g. Depressurize again to 0.1 kg/cm <sup>2</sup> g, through all the low points dead legs, etc. Vent and drain the special heat exchanger (Reactor Feed/Effluent) last. Renew the operation until the O <sub>2</sub> content is below 0.2% volume. Leave a residual N <sub>2</sub> pressure of 0.05 to 0.1 kg/cm <sup>2</sup> g	
9.	Repeat same steps for the HP absorber section. Residual pressure 0.05 to 0.1 kg/cm <sup>2</sup> g	
10.	Do the same for the regeneration section. Residual pressure 3.5 kg/cm <sup>2</sup> g. Typically the required O <sub>2</sub> content (0.2% volume) is achieved with 3 cycles (pressurization/depressurization).	

#### **4.2.4.2.5.2      Deethanizer and debutanizer sections**

The deethanizer and debutanizer sections can be inerted either with nitrogen or with steam. The choice must take into consideration the effect of water on downstream units (if any).

For details refer to section 4.2.4.2.8

#### **4.2.4.2.6      Putting the unit into service**

For the first startup (or any subsequent startup), the following products are required

- Pure hydrogen gas (electrolytic).
- Desulfurized naphtha (free of water).

#### **4.2.4.2.6.1      Depentanizer startup on total reflux**

Refer section 4.2.4.1.3.4 for procedure to start up Depentanizer section on total reflux.

#### **4.2.4.2.6.2      Pressurization of the unit**

After catalyst drying, the unit has been purged with nitrogen to be oxygen free (less than 0,2% vol.) and is now under a slight positive pressure.

Inlet temperatures of the reforming reactor beds are now about 250°C.

#### Preparation

	Action	Remarks
1.	Nitrogen lift gas circuit is pressurized with nitrogen up to 3.5 kg/cm <sup>2</sup> at Nitrogen	

	Compressor KO Drum	
2.	Regeneration circuit is pressurized with N2 up to 4.5 kg/cm <sup>2</sup> at the suction of the Regeneration Loop Compressors	
3.	N2 seal gas lines are commissioned	
4.	Pressurize the reaction section with pure hydrogen (electrolytic H2)	
5.	The resulting nitrogen in these sections is about 25 vol. % which is favorable for a steadier catalyst circulation. Set pressure controller PC-3450 of the Separator Drum at 0.3 kg/cm <sup>2</sup> above the start-up pressure	
6.	Increase the pressure of the Separator Drum up to startup pressure via the Recycle Compressor discharge	
7.	Check again all the flanges for leaks using an explosimeter	
8.	All interlocks related to catalyst circulation are made operational	

#### Operation

Refer to PID No: D-EP-R41-1225-1404 "REGENERATION LOOP COMPRESSOR"

D-EP-R41-1225-1424 and 1425 "NITROGEN SYSTEM"

	Action	Remarks
1.	Start one Nitrogen Compressor K-1405 A/B at 100% capacity, the PC-4057 at Nitrogen Compressor discharge set at design pressure	
2.	Start Regeneration Loop Compressor K-1465 and increase capacity to 100% (BIAS not in service). The FC-466 of the Burning gas is set at 80% of design capacity	
3.	The FCs R41-FV-4730 and R41-FV-4680 of calcinations and oxychlorination gases are set in auto mode at 80% of design capacity. Commission all oxygen analyzers. Remember that certain ranges have been changed during catalyst drying and information to DCS inhibited	
4.	Commission the Regeneration Loop Dryer DR-1465	
5.	Commission the hydrogen purity online analyzer AI-3450	
6.	All H2 users and lines to fuel gas are isolated, only the FV-4160 on reduction gas, the PDV-41220 at the tube side outlet of Reduction Exchanger E-1416 and the HV-4170 at the tube side outlet of the Hydrogen Lift Gas Exchanger E-1417 are closed but block valves are open	

4.2.4.2.6.3

Catalyst heating-up and reduction

(See example of schedule, on Figure 15 in attachments).

**During this reduction step:**

Action	Remarks
1. Additional leak tests can be made when the reaction section temperature is increased. The pressure must be maintained by make-up of hydrogen or nitrogen. Nitrogen content in the circulating gas must not exceed 30% vol. Some water released from the catalyst. <b>is</b> collected in the Separator Drum. Light the burners of the preheater and interheaters and increase the temperatures at the inlet of Reactors up to 400° C at the rate of 40° C/h.	
2. Switch-on the Burning Heater (R41-E-1467), Calcination Heater (R41-E-1473) and Oxychlorination heater (R41-E-1469), then increase the temperature at the heater outlet TI-4671/4691/4731, up to 300°C at the rate of 40°C/h. Set the flow H2 FC-4160 to Reduction Chamber at 80% of design capacity and PDC-41220 between Reduction Chamber outlet and First Reactor at 0.1 kg/cm <sup>2</sup> . Switch on the Reduction Heater (electrical) and increase its TI-4124 outlet temperature to 400deg.C at the rate of 40° C/h.	
3. When the temperature of 400°C is reached in the Reactors, start catalyst circulation first from the Fifth Lift Pot to the Upper Surge Drum etc. (as described in "Catalyst circulation"). Note however that either nitrogen or hydrogen <b>is</b> used depending on the lift pot (nitrogen for the Fifth Lift Pot and First Lift Pot)	
4. Set the catalyst circulation flow at the maximum compatible with the ΔP in the reaction section. Increase the temperature to 480° C at the Reactors inlets and at the Reduction Chamber inlet at a rate of 40° C/h. Maintain this temperature for a minimum of 12 hours until the total water drained at the low points is lower than 0.05% of the catalyst weight per hour	
5. Owing to the difficulty of sustaining a steady catalyst circulation when the reaction section is under hydrogen (low DP in reactors), this step <b>to</b> be maintained long enough to ensure that the catalyst contained in the upper and lower hoppers has been reduced	
6. Whenever possible it is recommended to stop the catalyst circulation after a transfer from the Upper Surge Drum to the Lock Hopper. The reason for leaving an empty surge drum is explained in regeneration startup (Section Regeneration startup).	
7. Decrease then temperatures at Reactors and Reduction Chamber inlets down to 400° C at the rate of 40° C/hour. Stop catalyst circulation: isolate the manual catalyst tight valves	

	<p>under the lower hoppers.</p> <p>Close the remote operated ON/OFF valves on the catalyst pipes:</p> <ul style="list-style-type: none"> <li>• Between First Upper Hopper and Reduction Chamber</li> <li>• Between First Lower Hopper and lift pot.</li> <li>• Between Fifth Lower Hopper and lift pot.</li> </ul>	
8.	<p>Keep in service the Nitrogen and the Regeneration Loop Compressor at 100% capacity for 80% at burning oxychlorination and calcination beds with the 3 electrical heaters in service (300°C outlet temperature). Note that water washing injection and caustic solution circulation are not yet in service. Both will be started after OIL-IN, before catalyst circulation start-up, when increasing temperature from 300° C up to 480° C</p>	

**Note:** During the reduction period the pressure indicated in the procedure must be maintained in the reaction section, by H2 make-up and in the regeneration section or N2 lift section, by N2 make-up.

**Remark:** When starting the reformer with pre-reduced or coked catalyst where catalyst reduction is not necessary, RIT's are increased at the rate of 40° C/h up to 440° C and stabilized at this temperature at which OIL-IN is performed.

#### 4.2.4.2.6.4      Oil in

##### Preparation

The Aromizing section (R41-3) is started with desulfurized naphtha coming from the NHT Stripper of the Naphtha Hydrotreatment section.

**The status of the Aromizing section** is as follows:

	Action	Remarks
1.	The Depentanizer T-136 is operating on total reflux, its pressure being maintained by H2 injection if required.	
2.	Reaction section is under H2 at start-up pressure.	
3.	Check that blinds have been removed: at Separator Bottom Pumps (suction and discharge) and at LPG Absorber Pump P-13610A/B	
4.	The Recycle Compressor K-13450 is operating at full capacity.	
5.	Catalyst circulation is stopped.	
6.	The regeneration loop is in stand-by: electrical heaters are in service (300°C outlet temperature), the Regeneration Loop Compressor in service (75% capacity), air injection	

	is carefully closed.	
7.	The Nitrogen Compressor K-1405A/B is in operation.	
8.	<p>The following ON/OFF valves on catalyst are also closed:</p> <ul style="list-style-type: none"> <li>– Between First Upper Hopper and Reduction Chamber.</li> <li>– Between First Lower Hopper and Lift Pot.</li> <li>– Between Fifth Lower Hopper and Lift Pot.</li> </ul> <p>Manual valves on all seal legs are closed.</p>	
9.	Reactors inlet temperatures are steady at 400° C in auto mode.	
10.	Inlet temperature of the Reduction Heater is maintained at 400°C and the flow is about 80% of design capacity.	
11.	Separator Bottom Pump P-13450A/B is commissioned and ready to start	
12.	Air coolers fans are in service.	
13.	Ensure cooling water is in service on all users	
14.	Differential pressure between the Reduction Chamber and the First Reactor is set at 0.1 kg/cm <sup>2</sup> .	
15.	All instruments of the HP absorber section are commissioned. A last check of all other instruments in the reaction section and nitrogen section is made. Commission the moisture analyzer on the recycle gas.	
16.	Prepare a batch of chlorine solution (2% vol. of chloriding agent in hydrotreated naphtha).	
17.	Commission Chloriding Agent Injection Pump R41-Z-1314-P1 A/B for injection in the feed.	
18.	Remove blinds from the Feed Filters (R41-F-13110A/B)	
19.	Drain water from the Feed Filter and from the feed line to the inlet FV-3110.	

**Note:** During the oil in, when the water content of the recycle is within the range of the analyzer and until the reaction section operating conditions are stabilized, the water content in the recycle gas must be recorded every hour.

### Feed introduction

	Action	Remarks
1.	Feed is introduced in 10 minutes at 60% capacity, through FV-3110 and <b>is</b> enough to ensure a minimum flow on the fresh catalyst.	
2.	Stop the H <sub>2</sub> rich gas make-up, if any.	
3.	<p>Start H<sub>2</sub> Rich Gas Compressor and bring the pressure up to design conditions in HP Absorber Drum D-13580. Before starting Compressor K-135 stage 1 and 2, pressure control valve to HP flare on D-13550 is opened and a reduced set point of 2 kg/cm<sup>2</sup>(g) is kept for the control valve. The Compressor K-135 stage 1 and 2 are started after the system has stabilized. Once the compressor picks up speed, flow starts to recycle through the anti-surge valves. Anti-surge valves FV-3502/3503 are kept full open. Once the compressor reaches 70% of the normal operating speed, then anti-surge valves go into auto mode. Also the setpoint of pressure control valve to HP flare is increased to its normal setpoint of 16 kg/cm<sup>2</sup>(g). The K-13550 circuit is pressurized to 16 kg/cm<sup>2</sup>(g). Once K-135 has stabilized and system is pressurized, K-13550 is started. Initially flow is recycled through the anti-surge valve FV-3551. Once compressor reaches 70% speed, anti-surge control goes into auto mode and flow is sent forward. (For details refer to Dynamic Simulation Study Report - S-EP-R41-1224-0105).</p> <p>Operator must check that MOV-3500/3550/3551 must be opened prior to start up the steam turbine TK-13550 (local and DCS indication of open/close valve position)</p>	
4.	The export gas PV, in auto mode, at the beginning of the operation <b>and</b> send part of the H <sub>2</sub> rich gas to the pretreater section, part elsewhere, depending upon local facilities.	
5.	Commission the H <sub>2</sub> Rich Gas Chloride Adsorbers (R41-R-13590A/B).	
6.	When liquid appears in the Separator Drum, and the level is above 50%, start the Separator Bottom Pump P-13450 A/B and send the product to the HP absorber section by slowly opening control valve FV-3452 in manual mode.	
7.	When liquid appears in the HP absorber Drum D-13580 and the level is above 50%, start to feed the LPG Absorber Drum (R41-D-136100) by slowly opening control valve FV-3580 in manual mode	
8.	When liquid appears in the LPG Absorber Drum, start the LPG Absorber Bottom Pump P-13610 A/B and feed, as smoothly as possible, the Depentanizer Column T-136 by slowly	

	opening control valve FV-3610 in manual mode	
9.	Commission the Depentanizer T-136 bottom level controller LC-3600 (FHS-3612 in startup mode) and route the reformat to Straight Run Naphta Tank through SR Naphta Tank Rundown Air Cooler E-1363 and SR Naphtha Tank Rundown Trim Cooler E-1364 A/B. Depentanizer (R41-T-136) operates at total reflux.	
10.	Start chloriding agent injection to feed, starting rate 25 wt ppm of pure component related to feed. Start DMDS injection to feed as to have a sulfur content in feed equal to 0.2 / 0.3 wt ppm.	

#### 4.2.4.2.6.5 Low severity operation at reduced capacity

The low severity operation allows to lower the water and hydrogen sulfide content in the recycle gas, without damage to the catalyst. It also enables a check of the operation of the catalyst circulation and to carry out the reduction of this fraction of the catalyst which was at the very beginning in the regenerator, and has not been contacted by H<sub>2</sub> gas.

The low severity operation is characterized by:

- A higher than design H<sub>2</sub>/HC ratio (feed at 60% and Recycle Compressor at full capacity).
- A pressure higher than normal.
- Temperatures **is** increased step by step as the water content in the recycle drops

The low severity operation yields a gasoline with a relatively low RONC. This product can be routed to the gasoline pool when found suitable by the **Operator**. During the different steps the water content of the recycle **is** determined by lab analysis until it falls within the range of the on line moisture analyzer.

**IMPORTANT:**

From the moment when feed is introduced do not stop the Recycle Compressor since this would favor a quick build up of coke on the catalyst. In an emergency shutdown of the Recycle Compressor, shut-off heaters and feed immediately (refer to "Emergency shutdown").

**Step at 480° C** (Refer to Figure 16 in attachments)

	Action	Remarks
1.	After the unit conditions are stabilized at RIT's = 400° C, in 4 hours, increase the	

	temperature at the Reactors inlet to 480° C. Stabilize the unit and keep this temperature as long as the water content in the recycle is higher than 200 ppm vol.	
2.	Start-up the Refrigeration Package (R41-RU-13580 A/B).	
3.	Increase the H <sub>2</sub> rich gas to the Reduction Chamber Heater E-1412 up to 100 % of design flow, and bring the reduction chamber inlet temperature to 430° C. Set HV-4170 at tube side outlet of Hydrogen Lift Gas Exchanger E-1417 opening and PDV-41220 at tube side outlet of Reduction Exchanger set point at design value. When flows are stabilized commission hydrogen purification unit (PSA-R41-5) then increase reduction chamber inlet temperature to design value. (For detail startup of R41-5 refer section 7 in V-202-1420-141-U-01-105_4C_0010_Operating Manual).	
4.	Reduce chloride injection to 5 wt ppm related to feed	
5.	Decrease the pressure at the Separator Drum D-13450 down to design pressure over a two hours period.	
6.	Check that the two bias are operational, and that pressure in both regeneration section and nitrogen lift loop decreases in parallel.	
7.	Start the catalyst circulation in order to perform the reduction of the catalyst included in the regeneration system as soon as reductor is operating steadily at design condition	
8.	Catalyst circulation is also started during the step at 480° C in the case of startup with pre-reduced catalyst or coked catalyst.	
9.	After reduction of the total inventory of catalyst contained in the regeneration system, the catalyst circulation rate is increased to fill the Lock Hopper in about 3 hours.	
10.	At the end of the catalyst reduction phase, the Upper Surge Drum has been left empty. Hence the catalyst <b>which is recovered</b> in the Upper Surge Drum is representative of the catalyst from the bottom of the Fourth Reactor.	
11.	Take sample of catalyst every day in order to analyse carbon and chlorine contents. The regeneration will be started when the coke level of the circulating catalyst reaches 3%. In the particular case of coked catalyst startup, the regeneration <b>to be started</b> as soon as the catalyst circulation is stabilized.	

#### 4.2.4.2.6.6 High severity operation

- **High severity at 60% capacity – Step 1**

Until now the unit is operated at 60% capacity, with maximum recycle gas flow. Reactors inlet temperature are stabilized at 480° C.

When the moisture content of the recycle gas falls under 200 vol ppm, increase RIT's up to 495°C at the rate of 3%. The expected RON for these conditions should be sufficient to route the reformat to on-spec storage.

Reduce chlorine injection to 2 wt ppm related to feed.

**• High severity at 60% capacity – Step 2**

When the moisture content of the recycle gas falls under 30 vol ppm, increase RIT's up to the required value to obtain the desired RON, at the rate of 2° C/h.

Stabilize the unit under these conditions. Stop the chloride injection.

**• High severity at nominal capacity**

Increase the feed by increments of 5% per hours. After each increment of feed, raise the RIT's at the rate of 2° C per hour in order to maintain the reformat RON.

Allow the unit to stabilize before increasing the reformat RON. A flow increase must always be achieved prior to temperature increase.

**4.2.4.2.7      Regeneration startup**

Refer to PID "Nitrogen system 1 & 2" - D-EP-R41-1225-1424/1425

"Hydrogen system 1 & 2" - D-EP-R41-1225-1422/1423

"Regenerator (top & bottom)" – D-EP-R41-1225-1412/1413

Regeneration is started when the coke content of catalyst is higher than 3% wt. For the first startup, the catalyst circulation only is already on stream. During routine operation, situations may occur when the regeneration (and the catalyst circulation subsequently) have been stopped. The sequence below describes the catalyst circulation and regeneration startup.

**4.2.4.2.7.1      Overall sequence**

The overall sequence is as follows:

- The regeneration loop is first started under an atmosphere of nitrogen. The Regeneration Loop Compressor is started and flows to the first burning zone and oxychlorination/calcination zones are controlled in auto mode. Gas washing is started simultaneously (caustic circulation pump, water injection, etc.). Air injection is kept closed although the Air Compressor is started.
- Inlet temperatures to the burning and oxychlorination/calcination zones are set through the electrical heaters.

- The catalyst circulation is started according to the relevant procedure as stated in section 4.2.4.2.4.4.
- Air is introduced into the burning zone and controlled through the relevant O<sub>2</sub> analyzer. Temperatures are adjusted in the different burning zones.

The detailed procedure is given below.

#### **4.2.4.2.7.2      Catalyst circulation startup**

##### **Status**

	Action	Remarks
1.	N <sub>2</sub> lift loop has been kept in service. Set the bias between the pressure of the Fourth Reactor outlet and the Nitrogen Compressor KO Drum at 0.02 kg/cm <sup>2</sup>	
2.	The regeneration section is in the following conditions: the compressor is running at 75% capacity, the temperature at the electrical heaters outlets is set at 300° C, the bias between the 1st reactor inlet and the regeneration loop pressures is set at about 0.7 kg/cm <sup>2</sup> .The regeneration dryer is in operation.	
3.	All sequences and interlocks are in service	
4.	N <sub>2</sub> seal gas on First Lower Hopper (seal gas N°1) and on Fourth Reactor lower hopper (seal gas N°5) are in operation (manual).	

##### **Preliminary operations**

	Action	Remarks
1.	Set the two FV's (FV-4040, FV-4440) of N <sub>2</sub> lift in auto mode. The two corresponding lift PDV's (PDV-4041, PDV-4441) are kept close in manual.	
2.	Check that R41-PDC-412 between First Upper Hopper and Reduction Chamber is set at 0.150 kg/cm <sup>2</sup>	
3.	Set First and Last Lower Hoppers seal gas in automatic mode (PDV-403 and PDC-4056 in auto mode).	
4.	Set the three FV's (FV-4140, FV-4240, FV-4340) of H <sub>2</sub> lift in auto mode. The three corresponding lift PDV's (PDV-4141, PDV-4241, PDV-4341) are kept close in manual.	
5.	Increase the Burning Heater outlet temperature up to 450° C at a rate of 50° C/h. The scope being to reach ~ 410/415° C in the first catalyst bed at the inlet TI. Increase the calcination and oxychlorination heaters outlet temperatures to 530° C.	

6.	Start the washing water injection to the Washing Drum D-1461 top section at design value.	
7.	Prepare a solution of water and caustic soda (3% wt concentration) in the bottom of the washing drum, then commission the LV-4601 to waste water treatment and set the fresh caustic solution and water make-up at their design values.	
8.	Start the caustic solution circulation at its design value. Check that the DP at the caustic injector is ~1.5 kg/cm <sup>2</sup> . Put in service the pH analyzer to control the circulating caustic solution	
9.	Adjust the Regeneration Loop Trim Cooler E-1460 outlet temperature as near as possible to design conditions	
10.	Both air injection FV's (FV-4121, FV-412) (oxychlorination/calcination and burning air) are closed, including the block valves, set the discharge pressure of the Air Compressor at design value.	
11.	Put in service the Air Dryer DR-1472	
12.	Line up piping to be ready for air injection to the burning zone only.	

### Catalyst circulation startup and stabilization

When the temperature at the 1st burning zone inlet reaches 410/415° C, the catalyst circulation can be started-up.

	Action	Remarks
1.	Make sure H2 reduction (flow rate and temperature) is in operation	
2.	Open the manual special tight valve between the First Upper Hopper and the Reduction Chamber. Check that ON/OFF remote operated valve is open (R41-ZV-4111)	
3.	Check the PDI-4031 between the First Lower Hopper and First Lift Pot. Open the ON/OFF remote operated valve under the regenerator (R41-ZV-4031).	
4.	Open the manual special tight valve under the Fourth Reactor. Check that ON/OFF remote operated valve is well open (R41-ZV-4431).	
5.	Open the manual special tight valves under the First / Second / Third Reactors lower hoppers	
6.	Start then the catalyst circulation, lift by lift, according to the actual catalyst level in the	

	Upper Surge Drum and upper hoppers, by manually opening slowly the PDV's on N2 and H2 lift gas (Refer to 4.2.4.2.4.4 "Catalyst circulation").	
7.	Stabilize the circulation in manual until the levels in the upper hoppers are steady. Set the catalyst circulation at about 50% of the design capacity. Then set the control in autocascade from LC to PDC.	
8.	The level of catalyst increases in the Upper Surge Drum while it decreases in the regenerator.	
9.	When these levels reach the transfer conditions, the automatic sequence of catalyst transfer from the Upper Surge Drum to the Lock Hopper and to the Regenerator <b>is</b> energized.	
10.	If for any reason the automatic sequence fails, this transfer <b>to</b> be performed manually and the defect of the sequence <b>to</b> be found and cleared.	

#### 4.2.4.2.7.3 Regeneration system startup procedure

Refer to Principle of regeneration loop control : refer Figure 17 in attachments.

The catalyst circulation is ~ 50% of design capacity, the burning bed is at about 410/415° C at the inlet TI, the washing drum is in service, the Air Compressor is in operation with its PV to atmosphere.

	Action	Remarks
1.	When the coke content of the circulated catalyst reaches 3.0% wt the coke burning can be started.  CAUTION: As the catalyst contained in the calcination / oxychlorination zone has a coke content similar to the catalyst of the burning zone, the air coming from FV-4721 (before R41-ZV-4720) <b>is</b> routed through the blackburning/startup line entirely to the burning zone and isolated to the calcination zone (the reason is to avoid too high temperature in the calcination zone).	
2.	R41-ZV-4720 air to 1st bed is open while R41-ZV-4721 air to oxychlorination / calcination is closed.	
3.	The air is slowly introduced through FV-4721 (before R41-ZV-4720) in order to reach 0.4vol.% of O2 in the flow to the burning zone (check analyzer AC-4661 at the shell side inlet of the burning feed effluent exchanger (R41-E-1466)).	

4.	At 410/415° C in the burning zone the combustion will start immediately and all the oxygen will be consumed.	
5.	<p>Check the first burning bed <math>\Delta T</math> read by difference of TI indication at inlet and outlet of the bed, which must not exceed 40° C.</p> <p>Then begin to inject air through FV-466 in the second burning bed in order to reach ~ 0.2% vol. O<sub>2</sub> (check relevant analyzer AI-4004 on the air line to the second burning bed ) at the outlet.</p>	
6.	Stabilize the conditions and then set in auto cascade these AC and FC through HS-4000 selector (O <sub>2</sub> content to the first burning zone / total air flow to the 1st burning zone) and the AC to FC (O <sub>2</sub> content at the second burning zone inlet / air flow to the second burning zone).	
7.	Air can be switched from the 1st burning zone to the oxychlorination/calcination zone only when the catalyst contained in the oxychlorination/calcination zone has been replaced by regenerated catalyst	
8.	The safe way is to change the air injection only when the catalyst sampled in the First Upper Hopper has a coke level lower than 0.2% wt	
9.	For such a purpose the catalyst circulation can be increased up to 75%. Air switch is made by opening R41-ZV-4721 to oxychlorination /calcination and closing R41-ZV-4720 to 1st burning bed.	
10.	After stabilization of FC-4721, air injection will be cascaded to analyzer AC-4730 on oxychlorination/ calcination gas which will receive its set point from analyzer AC-4661 on first burning bed inlet.	
11.	This period of replacement of the coked catalyst with regenerated catalyst will take place after 8 to 10 hours of burning. In case of temperature increase after the switch of the air injection to the oxychlorination/calcination zone, return immediately to the previous situation and wait another couple of hours before switching again air to the oxychlorination/calcination zone.	
12.	Check carefully the operation of the Regeneration Loop Trim Cooler E-1460	
13.	Check the operation of the Washing Drum, caustic solution circulation, caustic soda and water make-up, water injection. The gas effluent temperature <b>to</b> be maintained as low as possible.	

14.	The circulating caustic solution to be analyzed, twice a day, for total sodium concentration (to be kept higher than 3%) and the pH analyzer AI-460 at caustic recycle pump (R41- P-1460A/B) suction, it shall remain higher than 7.5 (8.5 max.)	
15.	Check the operation of the Regeneration Loop Dryer DR-1465 and Air Dryer DR-1472 (Once per shift during startup period)	

Check that O<sub>2</sub> content to the calcination zone stays between 8 to 12 vol.%. When the temperature in oxychlorination zone reaches 470deg. C, the chlorination agent injection can be started. The amount to be injected is calculated as follows:

$$\begin{aligned}
 & \text{target value %wt Cl on catalyst} \\
 & \text{wt% Cl- on spent catalyst} \\
 & \text{estimated losses during burning} \\
 & \text{Kg/h} \\
 & \boxed{(1.1 - \text{Actual}) + 0.2} \quad \times \text{Catalyst circulation} \\
 & \text{Cl}_2 \text{ injection} = \frac{100 \times 0.85 \times 0.810 \times 1.465}{\text{1/h}} \\
 & \text{Cl}_2 \text{ Sp. gr.} \\
 & \text{Cl}_2 \text{ wt fraction of chlorine} \\
 & \text{Chlorine fixation rate}
 \end{aligned}$$

This formula applies to ethylene trichloride. For other chlorination agent use the characteristics in table hereunder. This flow **is** set by pump stroke adjustment and cross checked by the level decrease in the calibration gage.

#### CHARACTERISTICS OF CHLORINATION AGENT

NAME	Formula	MW	Density	% wt Cl
Methane trichloride	CHCl <sub>3</sub>	119.5	1.483	89
Ethylene dichloride	C <sub>2</sub> H <sub>2</sub> Cl <sub>2</sub>	97	1.218	73

Ethylene trichloride	C2HCl3	131.5	1.464	81
Ethylene tetrachloride	C2Cl4	166	1.623	86
Ethane trichloride	C2H3Cl3	133.5	1.325	80
Propylene trichloride	C3H3Cl3	144.5	1.382	73
Propylene tetrachloride	C3H2Cl4	180	1.537	79

#### 4.2.4.2.7.4 Final adjustments

The regeneration and catalyst circulation loops are now set in auto mode on all controllers. By raising the PDC of the governing lift (from Regenerator to First Reactor), increase slowly the catalyst circulation. Check that the lift flows are set at the recommended value, as indicated in "Lift gas flow" (Refer 3.2.4.4.2).

Adjust TC-40010 (Burning Heater outlet) between 470-480° C

Adjust TC-4003 (2nd burning bed inlet) between 470-480° C

Adjust TC-4007 (Calcination Heater outlet) between 510-520° C

Adjust TC-4006 (Oxychlorination Heater outlet) between 500-510° C .

Then the catalyst circulation **is** increased until the following values are obtained:

- 1st burning zone:

470 ° C < inlet T° < 480° C

535 ° C < outlet T° < 545° C

- 2nd burning zone:

470 ° C < intlet T° < 480° C

500 ° C < outlet T° < 510° C

- Oxychlorination zone

500 ° C < outlet T° < 510° C

- Calcination zone:

510° C < outlet T° < 520° C

The oxygen analyzer controllers **are** in the following range:

- O2 content at first burning zone inlet: 0.5 to 0.8 % vol.
- O2 content at second burning zone outlet: approximately 0.25 % vol.
- O2 content at calcination zone inlet: 8.0 to 12.0 % vol.

Take catalyst samples from the First Upper Hopper to control coke and chlorine content on the regenerated catalyst. The chlorination agent injection is adjusted in proportion to the catalyst circulation and to the chlorine level of the spent catalyst contained in the Upper Surge Drum (refer to injection rate formula).

Check regularly the satisfactory operation of the dryers as well as all washing drum parameters. The field operators **should** regularly perform the following operations:

- Drain the analyzer upstream KO pots. Check and if necessary correct the sampling flow rates
- Drain the dryers upstream KO pot.
- Drain the loop compressor suction bottles.
- Check NaOH injection rate (pump strokes and tank level).
- Check chlorination agent injection rate (pump strokes and tank level).

They must report to the shift foreman for any deviation.

During the increase of temperature, the thermal expansion of the reactor internals will tend to increase the quantity of catalyst contained in the Reactors and consequently will tend to decrease the quantity of catalyst in the circulation loop. The level of the First Upper Hopper will have to be set at a lower value to compensate for this "loss". Conversely when temperatures are reduced the upper hoppers will operate at a higher catalyst level.

#### **4.2.4.2.8      Deethanizer and Debutanizer start-up on total reflux**

##### **4.2.4.2.8.1      Preparation for Start-up**

	Action	Remarks
1.	Ensure cooling water flow to Deethanizer Condenser E-1375 / Debutanizer Condenser E-13850	
2.	Pressure controller PV 3750 / 3851 aligned to flare	
3.	Deethanizer Bottom ZV-3700 is in closed position	
4.	Ensure Debutanizer Reflux Drum bottom ZV-3850 is in closed position.	
5.	Ensure Debutanizer bottom ZV-3820 and FV-3800 are in closed position.	
6.	Ensure the cooling water flow to C5 cut trim cooler E-1382A/B	

#### **4.2.4.2.8.2      Startup Procedure**

	Action	Remarks
1.	Ensure dethanizer and debutanizer section are inerted completely and are ready for feed in.	
2.	Once the depentanizer section is stabilized and cut points are achieved, start Depentanizer Distillate Pumps P-1366 A/B and send distillate from Depentanizer Reflux Drum D-13650 to Deethanizer T-137. (Refer latest revision number of vendor manual V-202-1420-134-F-03-458 for details startup of the pump)	
3.	Commission FC-3660/3661 and open FV-3661 to route distillate to De-Ethanizer T-137 via Deethanizer Feed/Bottom Exchanger E-1381. Since Debutanizer is not yet commissioned no heat will be available for the Deethanizer Feed/Debutanizer Bottoms Exchanger E-1381	
4.	Once the Deethanizer level reaches 80% cut the feed.	
5.	<p>Start Deethanizer Reboiler E-137 by introducing steam into the tube side by opening the isolation valves in steam inlet line 6"-LS-R41-6364 <b>and opening the relevant 11/2" drain valve on gravel pit.</b></p> <p>Once only condensate flows through the drain valve, open slowly flow control valve FV-3705 in manual mode (in LP condensate line to the LP condensate header) and make sure that steam will not send to LP condensate header downstream FV-3705. The Deethanizer temperature is controlled by TC-3703 temperature controller on tray 9, which resets steam side FV-3705 flowrate.</p>	
6.	When overhead temperature starts to increase the vapor from Deethanizer gets condensed in Deethanizer Condenser E-1375 and level in Deethanizer Reflux Drum D-1375 starts to build	
7.	Once column is stabilized and pressure in D-13750 starts to increase, slowly open PV-3750 to route off gas to OSBL	
8.	Continue feeding Deethanizer T-137 as required.	
9.	<p>Once the level in the Deethanizer Reflux Drum is 50%, start Deethanizer Reflux Pump P-1375A/B and by slowly opening flow control valve FV-3750 at the discharge of Deethanizer Reflux Pumps P-1375 A/B, start sending reflux to column.</p> <p>Refer latest revision of vendor operating manual V-202-1420-134-F-02-833 for detailed</p>	

	start-up procedure.	
10.	Operate the Deethanizer T-137 in total reflux Once column is stabilized in total reflux mode, cascade FC-3750 with level control LC-3750 in reflux drum in auto mode to maintain the level of D-13750.	
11.	Open ZV-3700, Start feeding Debutanizer T-138 by slowly opening flow control valve FV-3700 in manual.	
12.	<p>Start Debutanizer Reboiler E-138 by introducing steam into the tube side by opening the isolation valves in steam inlet line 8"-LS-R41-6369 and opening the relevant 11/2" drain valve on gravel pit.</p> <p>Once only condensate flows through the drain valve, open slowly flow control valve FV-3805 in manual mode (in LP condensate line to the LP condensate header) and make sure that steam will not send to LP condensate header downstream FV-3805. The Deethanizer temperature is controlled by TC-3803 temperature controller on tray 9, which resets steam side FV-3805 flowrate.</p>	
13.	Continue feeding Debutanizer. When the overhead temperature starts increasing commission Debutanizer Condenser E-13850	
14.	Ensure that the pressure differential controller PDC-3851 is commissioned	
15.	Once column is stabilized and pressure in D-13850 starts to increase slowly open PV-3850 to route off gas to OSBL	
16.	The overhead vapor from debutanizer gets condensed at Debutanizer Condenser and level starts increasing in Debutanizer Reflux Drum D-13850.	
17.	<p>When the level in the Debutanizer Reflux Drum reaches 50% start Debutanizer Reflux Pump P-13850 A/B. By slowly opening flow control valve FV-3850 at the discharge of Debutanizer Reflux Pumps P-13850 A/B, start sending reflux to column.</p> <p>Refer latest revision of vendor operating manual V-202-1420-134-F-02-834 for detailed start-up procedure of the pump.</p>	
18.	Operate the Debutanizer T-138 in total reflux. Once column is stabilized in total reflux mode, cascade FC-3851 with level control LC-3850 in reflux drum in auto mode to maintain the level of D-13850.	
19.	At this point both Deethanizer T-137 and Debutanizer T-138 are operating in total reflux.	

20.	<p>When the level in the Debutanizer reaches 80%, open ZV-3820 and start sending the bottoms from the Debutanizer column to Straight Run Naphtha tank (TK-63/64) or HDT Naphtha Tank S220-TK-0700 by slowly opening FV-3800 via Deethanizer Feed/Debutanizer Bottom Exchanger E-1381 and C5 Cut Trim Cooler E-1382A/B until the column gets stabilized.</p>	
21.	<p>Once the column is stabilized and product reaches the desired cut point (based on Sampling point S5 3800 &amp; S5 3850) start sending the debutanizer bottoms to gasoline pool and debutanizer overhead to storage (T-138).</p>	

#### **4.2.5 Start-up procedure for R-410-5**

For detail startup of R41-5 refer latest revision of section 7 in the below document:

**V-202-1420-141-U-01-105\_4C\_0010\_Operating Manual**

## 4.3 Troubleshooting Procedures

This section offers some guidelines for troubleshooting various problems that may be encountered over the course of normal operation of unit R41. It is important to be aware of the fact that these guidelines do not substitute the advice of experienced personnel, who should guide the management of upset and emergency situations.

The following instructions are general. For more specific problems the Licensor and/or the Equipment Vendors should be consulted.

### 4.3.1 Troubleshooting procedure for R41-1

Process Symptoms	Possible Cause	Remedies
<b>C5 rich cut</b>		
C5 rich cut going off spec from Naphtha Depentanizer (R41-T-1110) overhead	Incorrect setting of column parameters	<ul style="list-style-type: none"><li>Check column pressure using R41-PT-1151 and adjust accordingly.</li><li>Check reflux rate (R41-FC-1150) and increase if required</li><li>Check reboiler duty using R41-FC-1105 and increase if necessary</li><li>Check the set point of temperature controller TC-1103</li></ul>
<b>Light LCN Product</b>		
Light LCN going off spec on heavies from LCN splitter overhead (R41-T-113)	Incorrect setting of column parameters	<ul style="list-style-type: none"><li>Check reboiler duty using R41-FC-1305 and increase if necessary</li><li>Check column operating pressure (R41-PC-135) and increase accordingly</li><li>Check reflux rate (R41-FC-135) and increase if required</li></ul>
<b>Light Naphtha Product</b>		
Light naphtha product going off spec on heavies from Naphtha Splitter (R41-T-112)	Incorrect setting of column parameters	<ul style="list-style-type: none"><li>Check reboiler duty using R41-FC-1205 and increase if necessary.</li><li>Check column operating pressure (R41-PC-1250) and increase accordingly</li><li>Check reflux rate (R41-FC-1250) and increase if required</li></ul>

### **4.3.2 Troubleshooting procedure for R41-2**

#### **4.3.2.1 General**

The main cause of concern for the operator of the Naphtha Hydrotreatment Section (R41-2) is sulfur and nitrogen breakthrough into the hydrotreated naphtha contaminating the reformer feed going to Aromizing section (R41-3). If an upset occurs, the operator must be knowledgeable and experienced enough to make the proper corrective actions immediately and to know if he should shut-off feed to the reformer unit before any catalytic activity loss occurs. The ultimate safe rule is to cut capacity, switch the NHT Stripper (R41-T-122) bottoms to storage (S030-TK-63/64). Operators must make sure that the storage tank (S030-TK-63/64) and rundown lines are free of water and that the water content of the stored naphtha meets the specification (4 ppm wt). If there are doubts it is advisable to reduce the reformer severity or even shutdown the downstream units. The seriousness of the upset and the level of contaminant breakthrough will dictate the necessary course of action to take.

In this chapter some of the potential problems which the operator may have to face are highlighted.

#### **4.3.2.2 Increase in sulfur content in Hydrotreated Naphtha**

Increase in sulfur content in the NHT Stripper (R41-T-122) bottom (From 0.1 ppm to 1.0 ppm):

- Alert the reformer unit (Section R41-3) operator as he may wish to reduce unit severity.
- Check the NHT Stripper (R41-T-122) operation and the Hydrotreating Reactor (R41-R-121) conditions If nothing is obvious:
  - Increase the NHT Stripper R41-T-122 bottoms temperature using TC-2203 and reflux rate through control valve FV-2250.
  - Recheck the NHT Stripper R41-T-122 bottoms sulfur content through sample point S7-2203, if no change.
  - Increase the reactors inlet temperature by 5 °C using TC-2100.
  - Recheck the NHT Stripper bottoms, if no change, increase the reactor inlet temperature by another 5 °C.
  - At this point if the sulfur level is still high reduce the feed rate using FC-2011/2013 to 50% capacity.  
Recheck.
  - If the sulfur level remains high, switch the NHT Stripper bottoms to the sour naphtha storage (S030-TK-63/64).

As none of the previous actions have corrected or reduced the problem, then a more serious problem exists. A thorough investigation is required to include the recent operation history and mechanical integrity of the equipment (e.g. heat exchangers).

#### **4.3.2.3 High nitrogen content in the stripper bottoms**

This is more likely to be a function of nitrogen in the feed and Hydrotreating Reactor (R41-R-121) temperature.

- Check nitrogen content in the feed using sample point S7-1200.
- Increase the reactor inlet temperature by 5 °C steps using TC-2100 until the problem is solved.

#### **4.3.2.4 High reactor pressure drop in the reactors**

This unit is designed for a given maximum reactor pressure drop. During normal operation the pressure drop **is** approximately 2.06 bar. The high pressure drop design is to allow the processing of contaminated naphtha on a periodic basis. The reactor pressure drop indicator (PDI-2101) is transmitted to the DCS and the trend data will allow the operator to foresee any unit shutdown for ACT (Catalyst Bed Protection Material) and catalyst skimming.

$\Delta P$  is strongly dependent on the feed quality (coke precursors in the feed). That is why a special attention to the feed quality must be taken.

#### **4.3.2.5 Feed/Effluent or Feed/Bottoms Exchanger leaks**

In several cases, the feed is at higher pressure than the product (Reactor Feed/Effluent (R41-E-12110 A-M) and Stripper Feed/ Bottom (R41-E-1221 A/B/C)), therefore the high pressure side fluid (with higher sulphur content) may leak into the low pressure side, free of sulphur, contaminating the hydrotreated naphtha. If sulfur shows up in the NHT Stripper (R41-T-122) bottom and contaminates the hydrotreated product despite all corrective actions have been taken without any improvement, it is then highly possible that a leak occurs in the Reactor Feed/Effluent Exchangers (R41-E-12110 A-M) or Stripper Feed/ Bottom (R41-E-1221 A/B/C) exchangers. This leak can be easily detected by sampling upstream and downstream the exchangers.

### **4.3.3 Troubleshooting procedure for R41-3 & R41-4**

#### **4.3.3.1 General**

The main causes of concern, related to process, are:

- Unexpected decrease of octane number.
- Loss of reformate yield.
- Unexpected  $\Delta T$  reduction in the first catalytic bed.
- High hydrocracking rate and risk of a temperature runaway.
- High pressure drop in the reactor(s) or the regenerator.

On top of these, mechanical troubles or failures which, hopefully do not result in immediate shutdown, must also be considered. The most frequent are covered in this chapter:

- Failure of regeneration.
- Failure of nitrogen lift system.
- Failure of chlorine injection.
- Failure of catalyst circulation.
- Washing section default.
- Difficulties in controlling the regeneration temperatures.

Note that critical equipment or system failures (Recycle compressor, H<sub>2</sub> Rich Gas Compressor, Instrument Air, Cooling Water ...) which lead to an automatic emergency shutdown are covered in "Emergency shutdown".

#### **4.3.3.2 Unexpected decrease of the octane number**

Cases where the octane number decrease is easily related to such as below are not considered in this section:

- A change in feedstock quality (more paraffins).
- A lowering of the reactor inlet temperature.
- An increased feed flow rate.

An unexpected decrease of the octane number may be caused by one or several of the following:

- Leak in the Reformer Feed/Effluent Exchanger (R41-E-13110).
- Presence of nitrogen in the feed.
- Presence of sulfur in the feed.
- Presence of metals in the feed.

- Low chlorine content of the catalyst.
- Partial by-pass of the catalyst.

#### **4.3.3.2.1      Leak in the Reformer Feed/Effluent Exchanger (R41-E-13110)**

Since the feed is at higher pressure than the effluent, it may leak through the exchanger. Relatively small leaks can lower the product octane number significantly.

Exchanger leaks can be detected by injecting tracers in the feed. An easy tracer is methylcyclohexane which is present in the feed and not in the product. Another method is by measuring the octane number on the product side, upstream and downstream the exchanger.

#### Detection of Reformer Feed / Effluent Exchangers leak:

Presence of sulfur in the reformate allows to suspect a leak at Reformer Feed/Effluent Exchanger (R41-E-13110) (the small amount of sulfur present in feed 0.1 to 0.5 wt ppm is transformed in H<sub>2</sub>S in the Reactors (R41-R-131/132/133/134) and is mainly found in the recycle gas).

#### **4.3.3.2.2      Presence of nitrogen in the feed**

The maximum allowable nitrogen content in the feed is 0.5 ppm wt expressed as NH<sub>3</sub>.

The effect to the catalyst, the causes and the remedies to apply have been described in section 3.1.4.2.7 "Catalyst contaminants".

#### **4.3.3.2.3      Presence of sulfur in the feed**

The maximum allowable sulfur content in the feed is 0.5 ppm wt expressed as sulfur. It is worth noting that sulfur affects primarily the reformate yield. The octane number is also affected for high sulfur levels (up to 10 ppm wt).

The effect, the causes and remedies have been covered in section 3.1.4.2.7 "Catalyst contaminants".

#### **4.3.3.2.4      Presence of metals in the feed**

The presence of metal induces a permanent catalyst poisoning which results in a quick and noticeable drop in the octane number. It shows mainly through a shift in the ΔT across the reactors.

This is discussed under that item under section 4.3.3.4.

#### **4.3.3.2.5      Low chlorine content of the catalyst**

If the chlorine content is too low, the catalyst activity is reduced and the octane is lower than expected. There are sampling points S8-4020/ 4110 which enable to keep track of the chlorine content. The optimum figure is between 0.9 to 1.1% wt. of pure chlorine on the catalyst. This figure can be momentarily increased to make up for excessive chlorine losses, due to ammonia, for instance

#### **4.3.3.2.6      Partial by-pass of the catalyst**

If, for any reason, part of the catalyst is by-passed, the actual space velocity is higher than expected and the octane will drop. A higher temperature would be required to make-up for the octane loss. The causes of by-passing can be multiple: damaged internals, build-up of fines or scales at various places in the catalytic bed, etc.

It may develop into a hazardous situation because of the resulting channeling and the risk of exothermic hydrocracking reactions taking place in the area where space velocity is very low. By-passing and channeling are generally identified by an increased pressure drop across reactors and uneven, odd temperature profiles.

### **4.3.3.3    Loss of product yield**

A loss of product yield may be caused by one or several of the following:

- Presence of sulfur in the feed.
- Presence of metals in the feed.
- Too high chlorine content of the catalyst.

#### **4.3.3.3.1      Presence of sulfur in the feed**

The sulfur affects primarily the product yield. Any increase in sulfur above 0.5 ppm wt. reflects immediately in a lower product yield and a reduced  $\Delta T$  across the reactor. Refer to section 3.1.4.2.7 "Catalyst contaminants" for the causes, effects and remedies.

#### **4.3.3.3.2      Presence of metals in the feed**

This is discussed in the item related to decreased  $\Delta T$  in the First Reactor (R41-R-131) in section 4.3.3.4.

#### **4.3.3.3.3      Too high chlorine content of the catalyst**

A too high chlorine content (above 1.1 wt% of pure chlorine) promotes hydrocracking reactions which result in a lower products yield, a lower hydrogen purity, a lower hydrogen yield, but a higher octane.

A too high chlorine content will be detected through an increased yield of Depentanizer (R41-T-136) overhead gas and lower hydrogen recycle purity. To correct it, chlorine injection must be reduced.

#### **4.3.3.4 Unexpected ΔT reduction**

The temperature difference  $\Delta T$  (inlet - outlet) in the various Reactors (R41-R-131/132/133/134) is a very good indication of the catalyst condition.

Obvious reasons for a  $\Delta T$  decrease are:

- Feedstock quality: naphthene dehydrogenation is highly endothermic. A lower naphthene content shows up immediately on the  $\Delta T$  in the First Reactor (R41-R-131).
- H<sub>2</sub>/HC ratio increase (increased recycle). An increased recycle acts as a larger heat sink for the heat of the reaction.

Other reasons of a  $\Delta T$  decrease are the consequence of upsets, mentioned earlier, such as:

- Presence of sulfur in the feed.
- Presence of nitrogen in the feed.
- Too high chlorine content (which favors hydrocracking - exothermic reaction).

A loss of  $\Delta T$  in the First Reactor (R41-R-131) generally results from a sulfur upset in the unit feed. Poor operation of the Hydrotreating Reactor (R41-R-121) or of the NHT Stripper (R41-T-122) can then be suspected. Severity must be reduced, according to the H<sub>2</sub>S content in the recycle (for H<sub>2</sub>S > 5 ppm volume, reduce temperature to 480 °C).

In case of low  $\Delta T$  in Reactors 2 to 4, hydrocracking can be suspected. If such is the case, H<sub>2</sub> purity drops and LPG production increases .

Generally hydrocracking does not occur in the first reactor because the average temperature is lower. But the most worrying aspect of a decreased  $\Delta T$  is when it cannot be related to one of the above grounds and results from a permanent poisoning with metals.

Lead, arsenic and other metals are very severe catalyst poisons. The maximum allowable contents are shown in section 3.1.4.2.7 under permanent poisons of catalyst.

Due to the very high poisoning activity of the metals, the catalyst in the First Reactor (R41-R-131) is affected first, and the  $\Delta T$  through this reactor decreases. The endothermic reactions (naphthenes dehydrogenation) move then to the Second Reactor which exhibits an unexpected high  $\Delta T$ . Heavy metals generally result either from the

crude processed or from a poor operation of the upstream hydrotreating section. Reprocessing leaded gasoline (not a common occurrence today) can also cause catalyst poisoning.

Metals poisoning requires the dumping of the catalyst load.

#### **4.3.3.5 High hydrocracking rate and risk of temperature runaway**

Hydrocracking is suspected when H<sub>2</sub> purity drops, the amount of LPG and Depentanizer (R41-T-136) offgas increases with a simultaneous decrease of product yield.

Hydrocracking can be caused by:

- A fresh catalyst (too active) or an excessive acid function of the catalyst (i.e. high chlorine).
- A too high severity (either a too high temperature at the reactor inlet or a too low space velocity).
- Poor distribution (channeling) in the reactor which results in local high severity conditions.

The precautions to avoid hydrocracking are:

- Not to operate at capacity below the design turn-down ratio.
- Not to introduce feed for the first time on a fresh catalyst, at temperature higher than 400 °C. For a subsequent restart, the temperature limit can be increased to 440 °C.
- When raising throughput, to raise flow first and increase temperature afterwards.
- When lowering throughput, to lower temperature first and throughput afterwards.
- To raise temperature always cautiously: proceed by increment of 2deg. C/h.
- To monitor the differential pressure in the reactors. An increased differential pressure is the sign of poor distribution.

If hydrocracking is suspected:

- Lower the reactor inlet temperature down to 400 °C.
- Increase the feed rate to full capacity (to increase space velocity).
- Keep (or set) the recycle gas flow to the maximum.

#### **4.3.3.6 High pressure drop in the Reactors or the Regenerator**

##### **4.3.3.6.1 Reactors (R41-R-131/132/133/134)**

This problem is linked to an excessive catalyst attrition (broken particles, fines and dust). Excessive catalyst attrition is almost always associated with a too high velocity in the catalyst lift pipes. Operators attention is drawn to the fact that the increased pressure drop will show days or weeks after operating conditions have deteriorated and

the situation cannot be improved. The best, one can expect, while restoring the right operating conditions, is a pressure drop status quo.

Hence, it is advised to perform regular checks of the catalyst velocity : once a week on a routine basis when there is no change in operating conditions and each time operating conditions are changed (P, T, hydrogen gas molecular weight).

The process of the increase of the pressure drop is the following : broken catalyst particles are being trapped between the vertical wires of the center pipe and obstruct the open area. Then fines and dust also accumulate and dust starts building a cake around the center pipe. At this, point the pressure drop starts to increase significantly. Depending upon the amount of dust, the pressure drop increases more or less quickly.

It can take between one to six months to reach about 1 kg/cm<sup>2</sup>. The maximum allowable pressure drop is dependant upon the required severity of the operation and throughput, as the recycle gas rate will decrease significantly.

#### **4.3.3.6.2      Prevention**

The best prevention is to record, on a periodic basis, the lift conditions and the Reactor (R41-R- 131/132/133/134) pressure drop. The lift gas velocity must be adjusted to the recommended velocity as calculated in section 3.2.4.4.2 "Lift gas flow". One must keep in mind that when an excessive pressure drop occurs it is already too late to correct the cause. This is why maintaining the recommended catalyst velocity in the pipe is so important.

#### **4.3.3.6.3      Reactor cleaning**

The only way to reduce the pressure drop when it becomes unacceptable is to shut down the unit, unload the affected reactor and screen the catalyst with a 1.7 mm x 1.7 mm mesh with a screening machine. The catalyst must be stored in drums under an atmosphere of nitrogen

Depending upon the time available for this unplanned shutdown and also of the time to run until the next planned shutdown, the reactor may be inspected and cleaned. Special attention must be then given to the cleaning of the center pipe.

Then the screened catalyst **is** loaded again. Generally a catalyst make-up of 3 to 4% is required.

#### **4.3.3.6.4        Regenerator (R41-R-140)**

An excessive pressure drop may also develop in the Regenerator (R41-R-140) by the same process as for the Reactor(s) (R41-R-131/132/133/134).

As soon as the pressure drop reaches 1.0 kg/cm<sup>2</sup> instead of the normal figure of 0.2 kg/cm<sup>2</sup> a catalyst unloading of the Regenerator (R41-R-140) is recommended. Fortunately this operation can be conducted without shutting down the feed to the Aromizing unit (Section R41-3).

- stop catalyst circulation,
- isolate the Regenerator from the Reaction section,
- let the Regeneration loop cool down : shut down electrical heaters and continue nitrogen circulation if applicable,
- depressurize the Regenerator,
- unload the catalyst under the lower hopper,
- screen the catalyst.

Depending upon the downtime available and the time to run until the next planned shutdown, **Company** will decide to inspect the Regenerator (R41-R-140) or not, prior to reloading the catalyst.

#### **4.3.3.7    Failure of regeneration**

Regeneration may have to be shut down if:

- Both Regeneration Loop Compressor (R41-K-1465) and Air Compressors (R41-K-1470 A/B) failed (unlikely).
- A major leak occurred somewhere in the section.
- The Regeneration Loop Dryer (R41-DR-1465) failed.
- One of the Electrical Heaters in the Regeneration section failed.

The following measures must then be taken:

- Stop catalyst circulation.
- If the shutdown is expected to be of long duration, close manual special catalyst tight valves below the First, Second and Third Reactors (R41-R-131/132/133) as well as ON/OFF remote operated valves located under Fourth Reactor (R41-R-134) bottom ZV-4431, Regenerator (R41-R-140) bottom ZV-4031 and between First Upper Hopper (R41-D-1411) and Reduction Chamber (R41-D- 1412) ZV-4111.

- Stop air injection to the 2nd burning bed and to oxychlorination/calcination section.
- Switch off Electrical Heaters.
- Stop Caustic Recycle Pump (R41-P-1460A/B), Caustic Injection Pump in Caustic Package (R41-Z-1460), water to Washing Drum (R41-D-1460).
- Whenever possible, keep the Regeneration section under pressure.

#### **4.3.3.8 Failure of nitrogen lift system**

This system may have to be shut down if:

- Both compressors failed (unlikely).
- A major leak occurred and operation could not be sustained.
- The N<sub>2</sub> gas cooler failed (leak, cooling water default...)

The following measures must be taken:

- Stop catalyst circulation.
- Close manual special catalyst tight valves below the First, Second and Third Reactors (R41-R-131/132/133) as well as ON/OFF remote operated valves UVs located under Fourth Reactor (R41-R-134) bottom ZV-4431, Regenerator (R41-R-140) bottom ZV-4031 and between First Upper Hopper (R41-D-1411) and Reduction Chamber (R41-D-1412) ZV-4111.
- Stop air injection to the 1st and 2nd burning beds.

If the shutdown is expected to be of short duration (24 hours or so).

- Keep Regeneration Loop Compressor (R41-K-1465) on.
- Maintain temperature in the Regenerator (R41-R-140) beds.
- Keep washing system on (Caustic Recycle Pump (R41-P-1460A/B), Caustic Injection Pump in Caustic Package (R41-Z-1460), water injection pump (R41-P-1461A/B)).

If the shut down is expected to be longer, proceed with total shutdown of the regeneration section

#### **4.3.3.9 Failure of chlorine**

If chlorine injection in the regeneration cannot be continued, stop water injection.

- For a few hours only: keep running without any change, the chlorine loss will be compensated later.
- For up to 8 hours: reduce catalyst circulation rate.
- For more than 8 hours: proceed with regeneration partial shutdown and start adding chlorine in the feed.

#### **4.3.3.10 Failure of water injection in oxychlorination zone**

If water injection in the oxychlorination gas cannot be continued:

- For a few hours only: keep injecting chlorination agent, the chlorine pick-up will be increased.
- For up to 8 hours: reduce chlorination agent injection by about 20%.
- For more than 8 hours: adjust the chlorine injection to reach the target until the recovery of water injection.

#### **4.3.3.11 Failure of catalyst circulation**

If the expected downtime is less than 8 hours proceed with regeneration and catalyst circulation partial shutdown

If the expected downtime is more than 8 hours proceed with regeneration and catalyst circulation total shut down

#### **4.3.3.12 Washing section default**

Due to the corrosivity of the regeneration gas, any default of the washing section must be corrected shortly.

If the default cannot be fixed within a few hours, proceed with the total shutdown of the regeneration section

#### **4.3.3.13 Difficulties in controlling the regeneration temperature**

Refer to Figure 17- Principle of regeneration loop control.

##### **4.3.3.13.1 High temperature out of the first burning bed**

- Decrease R41-TC-40010A at Burning Heater (R41-E-1467) outlet set point to reduce the R41-TI-4000A at the inlet of the first burning bed to 470 °C.
- Check inlet O<sub>2</sub> content (must be < 0.8% vol). If required, decrease relevant R41-AC-4661 setpoint.
- Decrease catalyst circulation rate if any problem still occurs.

##### **4.3.3.13.2 High temperature out of the second burning bed**

- If temperature of the first burning bed allows it, increase O<sub>2</sub> content to 1st bed.
- Decrease catalyst circulation rate if any problem still occurs.

##### **4.3.3.13.3 Low temperature out of the second burning bed**

- Increase the inlet temperature to around 480 °C to the second burning bed by resetting R41-TC-40010A on first burning bed inlet.

- If it does not work (i.e. R41-TI-4004A at the outlet of 2nd bed is still below 480 °C) then oxychlorination step is not satisfactory. Low coke content must be suspected.
- Increase catalyst circulation if the problem still occurs.
- If low coke content is confirmed (lower than 3% wt on the catalyst) it is advised to stop regeneration for a few days.

#### **4.3.3.13.4      High temperature in the oxychlorination bed / black burning mode**

Not perfect combustion of the coke in the second bed, due to too high catalyst circulation rate, or oxygen analysis failure, etc. leads to coke entry in oxychlorination zone with an immediate temperature runaway in this area.

To avoid this occurrence, the Regenerator (R41-R-140) is operated in black burning mode i.e. (the R41-ZC- 40010 (Blackburning) switches automatically the Regeneration in black burning or mode) :

- R41-ZV-4721 air to calcination zones is closed, while
- R41-ZV-4720 air to 1st burning bed is open.
- R41-AC-4730 to 1st bed controls directly the air R41-FC-4721 through HS-4731 selector switch.
- Chloriding agent and water pumps are stopped.

If, in spite of this, temperature tends to follow its increase:

- stop catalyst circulation to avoid more coked catalyst to ingress in the oxychlorination zone.

When temperature in oxychlorination zone are again normal restart gently the catalyst circulation, then adjust it at previous conditions. Black burning conditions can be stopped when coke at the First Upper Hopper (R41-D-1411) catalyst sampler is lower than 0.2 wt%.

#### **4.3.3.13.5      Low temperature in the calcination / oxychlorination beds**

Three likely causes:

- Gas flow through the heaters exceeds the design figure.
- Heater resistance failure.
- Regenerator R41-PDC-4733 between burning and oxychlorination zones is set too low and part of the oxychlorination exhaust gas flows to the second burning zone and by-passes the Calcination Feed/Effluent Exchanger (R41-E-1468). This last cause is identified by:
  - An inlet gas flow to oxychlorination/calcination greater than effluent flow.
  - PDC-4733 reading nil (i.e. pressure in oxychlorination bed is equal or higher than pressure in the second burning bed).

The corrective action in this case is to adjust PDC-4733 set point.

#### **4.3.3.14 Shutdown of the Refrigeration System (R41-RU-13580 A/B)**

A shutdown of this system does not affect the Reaction section nor the Regeneration section. Its main effect is an increase of the molecular weight of the produced hydrogen, (also used as carrier gas for the lifts B, C and D) due to an increase of C3 to C5.

The points to watch are then:

- The hydrogen flow to the Hydrotreatment section (R41-2) and other users. Flow orifice coefficient must be corrected to maintain the requested hydrogen make up to the various users.
- The flow of gas to the lifts B, C and D must also be recalculated and adjusted if required. This gas flow impacts on the flow of catalyst.
- The temperature in the Reduction Chamber (R41-D-1412) must be carefully monitored, owing to the presence of heavier hydrocarbons at purification unit inlet. If required the inlet temperature to the reduction zone **is** lowered down to 420/430 °C.

#### **4.3.4 Troubleshooting procedure for R41-5**

During steady conditions, purity and recovery of hydrogen should be satisfactory. The pressure and flow indication of feed, product and tail gas can show some slight fluctuations, but the pattern should be the same during each sub-cycle. If a deviation from the regular pattern occurs, one should define exactly when it occurs.

##### **4.3.4.1 Checking process conditions**

Poor recovery or purity might result from e.g.:

- Excessive impurities in feed gas.
- End pressure of equalisations not reached.
- Excessive tail gas pressure.

##### **4.3.4.2 Checking tightness of valves**

When all valves of an adsorber are closed, the adsorber pressure should remain constant. If the adsorber pressure changes during isolation then this is caused by a leaking valve. From time to time one should verify adsorber pressure during isolation stages for all adsorbers. See also section 11.3 of document number V-202-1420-141-U-01-105, Revision 4.

Refer section 8 in the below document for more details on effect of various parameters during troubleshooting:

**V-202-1420-141-U-01-105 :**

**Operating Manual for POLYBED™ PSA Unit - 10-Bed PSA Unit R41-PK-1510**

## **4.4 Detailed Procedure for Normal Shut-down**

### **4.4.1 General**

Normal shutdown applies to a shutdown planned in advance for preventive maintenance or to unexpected events which are not of an emergency nature. Before initiating any planned shutdown, review all records to determine what inspections and repair work must be accomplished during the shutdown. Prepare a shutdown schedule, including plans for pre-arranging feed and product inventories during turnaround time. Notify all services and other dependent operating units of the schedule so that all activities can be properly coordinated. Arrange for all required parts, tools and services in advance, in particular adequate nitrogen for purging.

When shutting down, steps should be taken to prevent catalyst or equipment damage from expansion, contraction, thermal shock or unusual pressure surges. Purge with care all vessels, using inert gas and steam until all equipment is free of hydrocarbon liquids and gases. Purge thoroughly and check the atmosphere in the vessels before entering or starting repairs. Rigorously observe all safety precautions.

The general procedure to be followed for a total shutdown is the following:

- Lower the capacity and if necessary the severity.
- Switch the product to off-spec. or raw storage.
- Drain all hydrocarbons.
- Depressurize and purge.

Several shutdown cases are considered:

- Short duration shutdowns (i.e. less than 24 hours).

These shutdowns are typically less than 24 hours to carry out minor repairs without opening any major equipment.

- Long duration shutdowns.

This shutdown is required for major repair of some equipment or some sections of the unit. The procedure described above for short period shutdown is followed and completed with full cooling of equipment to ambient temperature. When required for entering the equipment, the whole unit is drained and inerted.

- Shutdowns to be followed by inspection of equipment.

#### Important notes

- Entry of personnel into vessels needs particular safety precautions. Vessels operating in presence of H<sub>2</sub>S may contain sulfides adhered to the surface of metal. These sulfides are pyrophoric and may release H<sub>2</sub>S. The

forced ventilation and permanent supervision is required on vessels subject to work of personnel inside these vessels.

- Nitrogen purge does not mean that vessel is ready for entering of personnel. Nitrogen is suffocating gas leading to death. Vessels must be fully vented and tested for oxygen content before admission of personnel entry. The "dead" spaces in vessels such as downcomers, separation weirs, etc. must be considered.

#### **4.4.2 Normal Shutdown procedure for R41-1**

##### **4.4.2.1 Short duration shutdown**

- Reduce Naphtha Splitter and LCN Splitter Section (R41-1) capacity to 50% of design.
- Isolate the columns (Naphtha Depentanizer R41-T-111, Naphtha Splitter R41-T-112, LCN Splitter R41-T-113), their feed and products lines by closing the corresponding FV block valves. Due to this the unit production is stopped.

Column	Feed FV	Column Bottom FV	Distillate / Side Cut FV
Naphtha Depentanizer R41-T-111	R41-FV-1120	R41-FV-1101	R41-FV-1154 R41-FV-1140 (C5 Rich Side Cut)
Naphtha Splitter R41-T-112	R41-FV-1101	R41-FV-1200A/B	R41-FV-1251
LCN Splitter R41-T-113	R240-FY-N001 via R41-HC-131	R41-FV-131	R41-FV-1351

- Keep all the columns on total reflux, reducing the respective reboiler temperature.
- 

Column	Reboiler	Temperature Controller	Steam to Reboiler Flow Controller
Naphtha Depentanizer R41-T-111	Naphtha Depentanizer Reboiler R41-E-111	R41-TC-1102	R41-FC-1105

Naphtha Splitter R41-T-112	Naphtha Splitter Reboiler R41-E-112 A/B	R41-TC-1205	R41-FC-1205
LCN Splitter R41-T-113	LCN Splitter Reboiler R41-E-113	R41-TC-1302	R41-FC-1305

The R41-1 section is now considered to be on standby with naphtha feed stopped, hydrocarbon levels in all of the vessels, and the columns on standby or total reflux.

#### **4.4.2.2 Long duration shutdown**

	<b>Action</b>	<b>Remarks</b>
1.	Proceed as per the steps for the short duration shutdown.	
2.	Decrease progressively the temperature of the LCN Splitter (R41-T-113) by reducing the reboiling steam flowrate using MP steam flow controller R41-FC-1305. When a minimum level is got in the LCN Splitter Reflux Drum (R41-D-1135), shut-off the steam to the LCN Splitter Reboiler (R41-E-113), stop the LCN Splitter Reflux Pumps (R41-P-1135A/B) and allow the LCN Splitter to cool down.	
3.	Decrease progressively the temperature of the Naphtha Depentanizer (R41-T-111) by reducing reboiling steam flowrate using MP steam flow controller R41-FC-1105. When a minimum level is got in the Naphtha Depentanizer Reflux Drum (R41-D-11150), shut-off the steam to the Naphtha Depentanizer Reboiler (R41-E-111), stop the Naphtha Depentanizer Reflux Pumps (R41-P-1115A/B) and allow the Naphtha Depentanizer (R41-T-111) to cool down. This step can be done in parallel with the shutdown of the LCN Splitter (R41-T-113) described above.	
4.	Then, decrease progressively the temperature of the Naphtha Splitter (R41-T-112), by reducing reboiling steam flowrate using MP steam flow controller R41-FC-1205. When a minimum level is got in the Naphtha Splitter Reflux Drum (R41-D-11250), shut-off the steam to the Naphtha Splitter Reboiler (R41-E-112A/B), stop the Naphtha Splitter Reflux Pumps(R41-P-1125A/B) and allow the Naphtha Splitter (R41-T-112) to cool down.	
5.	Maintain all the three columns under fuel gas pressure.	
6.	Shutdown the columns overheads air condensers (R41-E-1115, R41-E1125, R41-E-1135). Shutdown the Light Naphtha Trim Coolers (R41-E-1126A/B) and the LCN Trim Coolers (R41-E-1136A/B).	
7.	The extended period of shutdown requires the introduction of nitrogen to the reflux drums R41-D-11150, R41-D-11250 and R41-D-1135 in order to keep equipment under positive pressure.	
8.	The unit is now considered totally shutdown with hydrocarbon levels in all of the vessels and the columns under nitrogen pressure.	

#### **4.4.2.3 Shutdown followed by maintenance or inspection**

Shutdown for this purpose requires the complete removal of hydrogen and hydrocarbons from the equipment. The equipment must be purged with nitrogen before admission of air or must be steamed out depending on the design conditions of equipment. The first steps of shut down are same as used for long period shutdown described above.

#### **4.4.3 Normal Shutdown procedure for R41-2**

##### **4.4.3.1 Short period shutdown**

	<b>Action</b>	<b>Remarks</b>
1.	Reduce the Hydrotreatment Section (R41-2) capacity to 60% of design. It should not be necessary to adjust Hydrotreating Reactor (R41-R-121) temperature immediately for this short period before shutdown. Maintain maximum hydrogen recycle flow.	
2.	In case maintenance is not planned for NHT Stripper (R41-T-122) section, to maintain operation of Aromizing section R41-3, Hydrotreated Naphtha from storage (S220-TK-0700) is fed upstream of Stripper Feed/Bottom Exchangers R41-E-1221A/B/C (Line No: 8"-P-R41-0011)	
3.	Start cooling down the Hydrotreating Reactor R41-R-121 inlet temperature down to 200° C at a rate of 20° C/hour. Closed loop liquid recirculation under hydrogen at 200° C can be maintained as long as a sufficient concentration of H2S in the recycle gas is kept. To prevent any risk of catalyst reduction, it is recommended to closely monitor the H2S concentration in the recycle gas. Should it fall below 0.1 vol% then Hydrotreating Reactor (R41-R-121) bed temperature should be decreased further down to 180° C.	
4.	If required for maintenance, when Hydrotreating Reactor (R41-R-121) inlet temperature is at 200°C, shutdown the Feed Pump R41-P-1201A/B and shutdown the feed from section R41-1. Block-in feed flow control valves (R41-FV-2011 and R41-FV-2013)	
5.	Block-in level control valve of Separator Drum R41-D-12140 boot (R41-LV-2141).	
6.	When the level in the Separator Drum R41-D-12140 begins to fall and reaches 30%, shutdown the NHT Stripper (R41-T-122) feed from Separator Drum by closing R41-FV-2140.	
7.	Continue hydrogen circulation at maximum rate through the Hydrotreating Reactor R41-R-121 to strip off the hydrocarbons.	

At this stage the reaction section is considered to be on standby with the naphtha feed stopped and hydrogen circulating through the catalyst beds at reduced temperature. NHT Stripper (R41-T-122) is fed only from hydrotreated naphtha tank and bottom of NHT Stripper is routed to aromizing section.

If maintenance is required for NHT Stripper, feed to Aromizing section **is** stopped. Refer to operating instructions of R41-3 in 4.4.4 for shutdown procedure of R41-3 section.

	<b>Action</b>	<b>Remarks</b>
1.	Divert NHT Stripper bottom product to SR Naphtha tank (S030-TK-63/64) (Line No: 8"-P-R41-2112)	
2.	Cut feed from Hydrotreated Naphtha tank (S220-TK-0700) and block in valves.	
3.	As the level in the NHT Stripper begins to fall and reaches 30%, close valve R41-FV-2203 to SR naphtha tank.	
4.	At this point the operator can reduce the operating temperature of the NHT Stripper, shutdown the Stripper Reflux pump (R41-P-1225A/B) but maintain circulation through the Stripper Reboiler (R41-FR-122). The alternative is to leave the NHT Stripper operating on total reflux.	

#### **4.4.3.2 Long period shutdown**

	<b>Action</b>	<b>Remarks</b>
1.	Proceed as per the steps for the short duration shutdown.	
2.	A stripping procedure is established to remove hydrocarbon from the catalyst by using the recycle hydrogen.	
3.	After two hours of stripping the hydrocarbons from the catalyst beds in Hydrotreating Reactor (R41-R-121), reduce the Hydrotreating Reactor inlet temperature at a rate of 20 °C/h to 100° C. Monitor the Separator Drum R41-D-12140 level during stripping and drain to the hydrocarbon sewer if necessary.	
4.	When 100 °C is reached, shutdown the Reactor Feed Heater (R41-FR-12110), block in the fuel gas and steam purge the heater box of R41-FR-12110.	
5.	Keep hydrogen circulating until the temperature of the catalyst bed reaches 50° C.	
6.	When 50 °C is reached, shutdown the Recycle Compressor (R41-K-1215A/B), isolate and purge with nitrogen.	
7.	Maintain the reaction section pressure with nitrogen.	

8.	Shutdown the Reactor Effluent Air Condenser (R41-E1212) and Trim Condenser (R41-E-1213A/B)	
9.	For NHT Stripper (R41-T-122) column, if it has been maintained in total reflux operation, stop Stripper Reboiler (R41-FR-122). When the bottom temperature falls below 120° C stop the Stripper Reflux pump (R41-P-1225A/B) and let the NHT Stripper to cool down. Maintain a positive pressure with nitrogen if necessary.	
10.	Shutdown the Stripper Overhead Air Condenser (R41-E-1225) and the Stripper Trim Condensers (R41-E1226A/B). The extended period of shutdown requires the introduction of nitrogen in the Stripper Reflux Drum R41-D-12250 in order to keep equipment under positive pressure.	

The Naphtha Hydrotreatment section (R41-2) is now considered totally shutdown and under hydrogen/nitrogen pressure with low hydrocarbon levels in all the vessels.

#### **4.4.3.3 Shutdown followed by maintenance, inspection or catalyst unloading**

Shutdown for this purpose requires the complete removal of hydrogen and hydrocarbons from the equipment. The equipment of reaction section must be purged with nitrogen before admission of air. Other equipment must be steamed out. Proceed as follow for a long duration shutdown.

	Action	Remarks
1.	The first steps of shut down are the same as used for long period shutdown described above.	
2.	Drain all vessels and low points from hydrocarbons to the hydrocarbon sewer, taking care not to let hydrogen or fuel gas flow out.	
3.	Depressurize all sections to flare.	
4.	Isolate H <sub>2</sub> make-up and Stripper sections from the Reaction section.	
5.	Isolate with blinds all feed lines and product lines.	
6.	Isolate all PZV's and lines to flare.	
7.	Purge separately the Feed section and the Stripper section with low pressure steam as described in chapter 4.2.3 « First start-up of the unit / Complete inerting ». Purge down to	

	0.5 vol % hydrocarbons.	
8.	Purge the Recycle Compressor (R41-K-1215A/B) separately.	
9.	Pull a vacuum in the Reaction section and break with nitrogen as described in chapter 4.2.3 First start-up of the unit/Complete Inerting.	
10.	Drain all low points to the hydrocarbon sewer or blowdown.	
11.	Repeat the evacuation/nitrogen breaking steps until the H <sub>2</sub> + HC level has decreased below 0.5 vol. %.	
12.	Note that the porous catalyst will require time to displace the hydrocarbons. Proceed with caution around the Hydrotreating Reactor (R41-R-121) by allowing one hour before pulling the sample for testing.	
13.	Leave a residual nitrogen pressure of at least 0.1 kg/cm <sup>2</sup> g in the circuit.	
14.	When the atmosphere in the reaction section is completely inerted any equipment can be isolated for air purging and entry.	

#### 4.4.4 Normal Shutdown procedure for R41-3 & R41-4

The shutdown shall then be performed in planned stages. The operators of the upstream or downstream units **to** be informed of the shutdown to enable them to make the necessary adjustments and/or to plan their own shutdown.

The general procedure to be followed for a total shutdown is:

- To lower the severity and the capacity of the unit.
- To shut down the reaction section.
- To shut down the catalyst circulation and the regeneration sections.

**Note:** If no other source of hydrogen is available in the refinery, the Naphtha Hydrotreatment section (R41-2) will also have its capacity reduced first, then be shut down. Special care **is** taken during this period so as to keep the hydrotreated product on specifications.

Several shutdown cases are considered:

- Short duration normal shutdown (less than 24 hours).
- Long duration normal shutdown.

- Shutdown with catalyst unloading.
- Normal shutdown of the catalyst circulation and regeneration only.

#### **4.4.4.1 Short duration normal shutdown**

	<b>Action</b>	<b>Remarks</b>
1.	Start lowering Reactors (R41-R-131/132/133/134) inlet temperature to 470° C, by step of 5 °C.	
2.	One hour after the start of step 1, start reducing the feed flowrate using flow controller R41-FC-3110, step by step, down to 60% of the design capacity, which must be reached at 470 °C. Adjust flow increments in order to maintain the product quality within acceptable limit. At the same time the feed to the Hydrotreating Reactor (R41-R-121) is proportionally reduced and the reaction temperature adjusted. Stop DMDS injection feed to the Aromizing Section (R41-3).	
3.	Simultaneously with the preceding step, increase the reaction section pressure to approximately 3.5 kg/cm <sup>2</sup> g (at Separator Drum R41-D-13450). During this pressure increase, watch carefully the catalyst circulation, the N2 lift PDV-4041/4441 opening and adjust the bias if required to maintain catalyst circulation.	
4.	Stop the catalyst circulation and the regeneration loop as described in “Catalyst circulation and regeneration section” 4.4.4.4.	
5.	Stop the feed to the Naphtha Hydrotreatment Section (R41-2) and when the level in the bottom of the NHT Stripper (R41-T-122) starts to decrease, stop the feed to the Aromizing section. Close FV's (FV-2011 and FV-2013) at the discharge of Feed Pump and stop Feed Pump (R41-P-1201A/B). Line-up the product to the Closed Drain Drum (R41-D-1000). Shut-off the Reduction Heater (R41-E-1412) and close the H2 flow control valve (R41-FV-4160) to Reduction Chamber (R41-D-1412) and the differential pressure control valve (R41-PDV-41220) as well as the R41-HV-4170 at reduction gas outlet. Close H2 rich gas supply to all users.	
6.	Immediately after the feed cut off, shut down the H2 Rich Gas Compressors (R41-K-135/13550). Immediately open R41-PV-3550 on Second Interstage Drum (R41-D-13550) to HP Flare for smooth shutdown of H2 Rich Gas Compressors (R41-K-135). Shut block valves of H2 Rich Gas Compressors (R41-K-135/13550) suction & discharge and also close block valves in lines going to flare after shutdown of compressors. Lower	

	Reactor (R41-R-131/132/133/ 134) inlet temperatures at a rate of 35 °C/h.	
7.	When the level starts to decrease in the Separator Drum (R41-D-13450), stop the Separator Bottom pump (R41-P-13450A/B) to the HP Absorber section and isolate using the block valves of R41-FV-3452.	
8.	When the level starts to decrease in the HP Absorber Drum (R41-D-13580), isolate the block valves of (R41-FV-3580) liquid to the LPG Absorber Drum (R41-D-136100).	
9.	When the level starts to decrease in the LPG Absorber drum (R41-D-136100), stop the LPG Absorber Bottom pump (R41-P-13610A/B) to the Depentanizer Column (R41-T-136) and close the block valves of the R41-FV-3610.	
10.	Then isolate the bottom of the Depentanizer (R41-T-136) by closing the block valve of R42-FV-1110. Keep the column at total reflux conditions.	
11.	Simultaneously to steps 6 to 11, the Reactor (R41-R-131/132/133/134) inlet temperatures are lowered from 470° C to 400° C in two hours, then this temperature is maintained to allow the recycle gas to sweep the residual hydrocarbons from the catalyst. During this period, if the Separator Drum (R41-D-13450) level increases above 60%, drain the liquid to Closed Drain Drum (R41-D-1000).	

### **Stand-by status**

For a short duration shutdown, the unit **is** kept in the conditions reached above i.e.:

- Stripper Bottom Product Pump R41-P-122 A/B/C feeding the Aromizing section (R41-3) shut down.
- H2 Rich Gas Compressor (R41-K-135/13550) shut down.
- Catalyst circulation and catalyst regeneration partially shut down (i.e. catalyst circulation stopped, Regeneration Loop Compressor R41-K-1465 and N2 Compressors R41-K-1405A/B still on).
- Air compressor (R41-K-1470) running but air injection FV's (R41-FV-4720/4721) closed and blocked.
- Recycle compressor (R41-K-13450) is in operation.
- Fired Heaters (R41-FR-13110/13210/13310/13410) are on and Reactor (R41-R-131/132/133/134) inlet temperatures at 400 °C.
- Block valves closed on Separator Drum R41-PV-3450A/B to flare and on Second Interstage Drum R41-PV-3550 to flare.
- H2 Rich Gas to all users is closed including Reduction Chamber (R41-D-1412).
- Reaction section and HP Absorber sections (if possible) pressure maintained by H2 make up from storage.
- Depentanizer Column (R41-T-136) isolated, at total reflux.

- Deethanizer (R41-T-137) and Debutanizer (R41-T-138) feed is cut

#### **4.4.4.2 Long duration normal shutdown**

	Action	Remarks
1 -3	Proceed as per short duration shutdown.	
4	Stop catalyst circulation and regeneration (total shutdown) as described in "Catalyst circulation and regeneration section" in 4.4.4.4.	
5-11	Proceed as per short duration shutdown.	
12	<p>After the two hours of hydrogen sweeping, allow the catalyst beds to further cool down while decreasing Reactor (R41-R-131/132/133/134) outlet temperatures progressively to 200° C, then cut off the Fired Heaters (R41-FR-13110/13210/13310/13410). Stop refrigeration unit (R41-RU-13580 A/B). Isolate the absorption section.</p> <p>Continue circulating hydrogen with the Recycle Compressor (R41-K-13450) until the temperature in the reactor beds is 50° C. Shut down Recycle Compressor, close the suction and discharge block valves, depressurize to flare, and pressurize with nitrogen.</p> <p>Drain all low points and vessels to Closed Drain Drum (R41-D-1000).</p> <p>Decrease progressively the temperature of the Depentanizer column(R41-T-136), shut off the reboiler (R41-FR-13110-E) when temperature is below 120° C, stop the reflux and let the Depentanizer cool down by circulating through Reboiler pump (R41-P-136A/B).</p> <p>Stop the Reboiler Pump after Depentanizer cool down.</p>	

#### **4.4.4.3 Normal shutdown with catalyst unloading**

Catalyst may be unloaded either for inspection of reactor(s) or regenerator or because it is used and needs replacement.

First, the relevant sections of the unit must be freed from hydrocarbons. Then the catalyst **is** dumped:

- either under an atmosphere of nitrogen.
- or after a coarse decoking.

Proceed as per the long duration normal shutdown from steps 1 to 12.

	Action	Remarks
1 -12	Proceed as per long duration shutdown.	
13	Depressurize to Flare the Reaction R41-PV-3450A/B / R41-PV-3550 and HP Absorber	

	sections R41-PV-3650. Isolate with blinds the hydrogen makeup, the feed to the Reaction section, the bottom of the HP Absorber Drum (R41-D-13580), the H2 Rich Gas line to users and fuel gas.	
14	Pressurize then the sections up to 4 kg/cm <sup>2</sup> with nitrogen. Note that both compressors were already isolated and under nitrogen. Depressurize the unit to flare and low points to closed drain or blowdown. Renew this operation 3 times <b>until</b> (H <sub>2</sub> + HC) content of the gas in the reaction and HP Absorber sections drops to approximately 0.2 vol. %.	
15	Isolate now the Reaction section from the HP Absorber section by installing a blind at the Separator Drum (R41-D-13450) bottom. Blind also the PZVs and their by-pass in both sections, as well as PV to fuel gas and PV to flare. Separator drum PZV-3451A/B to atmosphere to be in line using swing elbow.	
16	Remove then the blind from the ejector suction line and pull the vacuum to the reaction section down to 0.5 kg/cm <sup>2</sup> abs. Break the vacuum by injecting nitrogen up to 0.1 kg/cm <sup>2</sup> g. Note that N <sub>2</sub> lift loop and Regeneration section are already under N <sub>2</sub> and are subject neither to N <sub>2</sub> sweeping nor vacuum.	

If the catalyst is at the end of life and **to** be replaced by a new one, the coked catalyst **is** dumped from the bottom of Reactors and Regenerator under nitrogen into drums. If the catalyst is to be reused after unloading (shutdown for inspection), the alternate procedure must be used.

**Note :** During these operations, the Regeneration section is kept under nitrogen atmosphere. Care should be taken to avoid stress corrosion by chlorine for the stainless steel equipment.

An alternate to the above procedure, is the coarse decoking of the catalyst in the regenerator, prior to unloading. Of course the oxychlorination will not be in service.

Another alternate to the dumping of coked catalyst from the unit called "On the fly procedure" is possible. It applies when the catalyst is to be replaced by a fresh one, but when no reactor(s) or regenerator inspection is planned. It consists in dumping the catalyst at the bottom of the lock hopper, while the reaction section is in service at low severity, and in replacing it, in the same vessel, by fresh catalyst, by means of the catalyst loading device, installed on top of the lock hopper. In such a case, the regenerator is used only to dry the fresh catalyst.

#### **4.4.4.4 Catalyst circulation and regeneration section**

Although the operation of the regeneration section on one hand and of the catalyst circulation on the other hand are quite independent, it is recommended to start up and shut down these sections in a proper sequence. Regeneration shutdown always lead to a simultaneous catalyst circulation shutdown in order to avoid coked catalyst entering the calcination zone. If not, special care **is** required upon the next start-up of the regeneration. (Refer Regeneration Startup in section 4.2.4.2.7)

In the case of catalyst circulation shutdown, if the operators take no action, the oxygen requirement for combustion progressively decreases and air **is** progressively and automatically shut-off through the action of the O2 analyzer (AE-4003) on the air FV's (R41-FV-4720/4721). There is no harm in this situation but the entire catalyst of the regeneration location **is** fully regenerated with almost no residual coke left and no gradient of coke content. The subsequent restart would be more troublesome.

**It is recommended to stop air injection to the regeneration, through operators action if the catalyst circulation shutdown is expected to last more than a couple of hours.**

Two levels of shutdown are considered: partial shutdown and total shutdown.

A partial shutdown is undertaken when the reason is specific to the regeneration loop and is expected not to exceed 24 hours. The policy is to maintain in operation most of the equipment not directly involved to allow for a quick restart.

A total shutdown of the regeneration and catalyst circulation can be caused:

- Either by a problem specific to the regeneration or catalyst circulation, of some duration (over 24 hours). In this case the operation of the Aromizing **section** can still be continued.
- Or by a total shutdown caused by other sections.

#### **4.4.4.4.1      Partial shutdown**

	<b>Action</b>	<b>Remarks</b>
1.	Stop the catalyst circulation while closing FV's (FV-4040/4140/4240/4340/4440) and PDV's (PDV-4041/4141/4241/4341/4441) to the five lift pots.	
2.	Close air injection to the Second Burning Bed using R41-FV-4720 and Oxychlorination/Calcination zones using R41-FV-4721	
3.	Keep the Air Compressor (R41-K-1470) running, using the blowoff valve to atmosphere	

	FV-4701.	
4.	Stop the Chlorination Agent Package (R41-Z-1469) and Oxychlorination Water Package (R41-Z-1468).	
5.	Keep Nitrogen Compressor (R41-K-1405A/B) in service.	
6.	Keep Regeneration Loop Compressor (R41-K-1465) running.	
7.	Keep the washing section (Caustic Recycle Pump R41-P-1460A/B, Washing Water pump R41-P-1461A/B, Caustic Injection Package R41-Z-1460) in normal operation.	

#### 4.4.4.4.2 Total shutdown

Action	Remarks
1. Stop the catalyst circulation while closing FV's (FV-4040/4140/4240/4340/4440) and PDV's (PDV-4041/4141/4241/4341/4441) to the five lift pots.	
2. Close air injection to the Second Burning Bed using R41-FV-4720 and Oxychlorination/Calcination zones using R41-FV-4721.	
3. Stop Air Compressor (R41-K-1470).	
4. Stop the Chlorination Agent Package (R41-Z-1469) and Oxychlorination Water Package (R41-Z-1468).	
5. Close the special tight manual valves below 1st, 2nd and 3rd Reactors (R41-R-131/132/133) and Shutdown Valves under the 4th Reactor R41-R-134 (R41-ZV- 4431), the Regenerator R41-R-140 (R41-ZV-431) and between the 1st Upper Hopper R41-D-1411 and the Reduction Chamber R41-D-1412 (R41-ZV-4111).	
6. Decrease Electrical Heaters (R41-E-1467/1469/1473) outlet temperature to about 350 °C. Then keep the Regeneration Loop Compressor (R41-K-1465) running to maintain about 300 °C in burning, oxychlorination and calcination beds.	
7. Maintain the pressure in regeneration loop.	
8. When burning and oxychlorination/calcination beds temperature are about 300 °C ,then: <ul style="list-style-type: none"> <li>- Stop the caustic make-up from (R41-Z-1460).</li> <li>- Stop the caustic circulation by stopping Caustic Recycle Pump R41-P-1460A/B.</li> <li>- Stop the H2O make-up to caustic circulation.</li> <li>- Stop the wash water injection by stopping Washing Water pump R41-P-1461A/B.</li> </ul>	
9. Stop Regeneration Loop Compressor (R41-K-1465).	

10.	Stop Nitrogen Compressor (R41-K-1405A/B).	
11.	Close block valves on R41-LV-460 (Washing Drum R41-D-1460 bottom outlet).	
12.	Keep the regeneration loop under N2 pressure.	
13.	Isolate the caustic recycle pumps,(R41-P-1460A/B) drain and wash them with BFW.	
14.	Let the catalyst cool down.	

Regeneration is now fully shut down

If the Aromizing **section** operation is to be continued:

- Reduce operation severity: drop reactor inlet temperature to 480° C. If product octane must be maintained, reduce feed flow as required.

#### **4.4.5 Normal Shutdown procedure for R41-5**

##### **4.4.5.1 Short duration normal shutdown**

Refer latest revision of section 9.2 in the below document:

**V-202-1420-141-U-01-105 - Operating Manual**

##### **4.4.5.2 Long duration normal shutdown**

Refer latest revision of section 9.3 in the below document:

**V-202-1420-141-U-01-105 - Operating Manual**

## **4.5 Emergency Shut-down Procedure And Restart Procedure**

### **4.5.1 General**

The plant is equipped with certain emergency shutdown controls which will automatically place the unit in a non-hazardous status should a major failure occur. The actions of the emergency shutdowns are aimed at protecting (a) the personnel and (b) the catalyst and equipment from heavy coking or serious damage. When the safe pattern of normal operation is interrupted, by unexpected failures or incidents emergency procedures are required to overcome the potential hazard, and if continued operation on a limited basis is impractical, the unit must be shut down safely.

The objectives which will govern the steps to be taken in such a situation are:

- To protect the operating personnel.
- To protect the catalyst.
- To protect the equipment.

The personnel protection results from:

- A satisfactory knowledge of the process, safe operating and shutdown procedures.
- The compliance with the safety rules in plant construction (safety distances, adequate orientation etc.)
- The installation of adequate fire and gas detection and firefighting equipment.
- Adequate operators safety awareness and safety training.

The following sections cover most situations operators may have to face:

The operation personnel must carefully study, in advance, the steps to be taken in such situations. Also it is important to note that the most likely shutdown causes are handled by automatic shutdown trips. These trips must always be operational, by-passing must be kept to a minimum e.g. during start-up, transient periods only. But in case of failure or bypass of these devices, the procedures below include all the actions to be undertaken, by the operators, assuming no action by the automatic devices.

#### **4.5.1.1 Automatic Emergency Shutdowns**

There are several automatic shutdown process interlocks used in the design of this unit to protect the catalyst and the equipment during an incident or failure. There are also several Emergency Shutdown Hand Switches. They are not automatic shutdowns but board mounted hand switches to be used at the discretion of the operator. Should an emergency situation occur such as a temperature runaway in the reactors, a fire or warning of a potential slug of water in the feed, the operator can activate this switch.

#### **4.5.2 Cause and Effect Diagrams**

Refer latest revision of Cause and Effect Diagrams Document No. **S-EP-R41-1223-8003** for detailed logic of shutdown systems. Also refer to section 8.7 for a list of cause and effect diagrams by vendor for respective equipment or package in vendor scope.

#### **4.5.3 Naphtha Splitter and LCN Splitter section R41-1**

##### **4.5.3.1 Feed Failure**

Not Applicable

##### **4.5.3.2 Utilities failure**

###### **4.5.3.2.1 Electrical Power failure**

This will shutdown the Naptha Depentanizer Air Condenser (R41- E-1115), Naptha Splitter Air Condenser (R41- E -1125), LCN Splitter Air Condenser (R41-E-1135), and Naptha Depentanizer Reflux Pumps(R41-P- 1115A/B), C5 Rich Cut Pumps (R41-P-1114A/B), Naptha Splitter Reflux Pumps (R41-P-1125A/B), Heavy Naphtha Pumps (R41-P-1120A/B), **Heavy LCN Pumps (R41-P-1130 A/B)**and LCN Splitter Reflux Pumps (R41- P-1135A/B).

- Immediately, shut-off steam to the columns' reboilers by closing steam supply control valves.
- Isolate the feed and product lines by closing the control valves and block valves.
- Isolate the columns.
- If necessary, inject nitrogen in the columns to maintain pressure.

###### **4.5.3.2.2 Instrument Air failure**

Unit control and shutdown valves will adopt their design "Failsafe" position in the event of an instrument air failure: AFC (air fail close), or AFO (air fail open). The valves are dedicated to placing the unit in a safe position.

Refer to attachment in section 8.4 for valve positions during instrument air failure.

###### **4.5.3.2.3 Steam failure**

Naptha Depentanizer Column Reboiler (R41-E-111), Naptha Splitter Reboiler (R41-E-112A/B) and LCN Splitter Reboiler (R41-E-113) use steam and their failure will lead to the loss of reboiler duty. Therefore, it results necessary to cut off the feed and then to shutdown the entire section R41-1.

###### **4.5.3.2.4 Cooling Water failure**

In the case of partial cooling water failure, it should be sufficient to reduce the feed flow to the columns and to maximize air cooling in order to maintain reasonable vessels and products temperatures. Otherwise, products will be sent to storage at too high temperatures. In the case of total cooling water failure the unit must be shutdown.

###### **4.5.3.2.5 Fuel Gas failure**

**Not Applicable.**

#### **4.5.3.3 Equipment Failure**

##### **4.5.3.3.1 Pump Failure or Shutdown**

Shutdown of the pumps R41-P-1115A/B, R41-P-1120A/B, R41-P-1125A/B, R41-P-1130A/B, R41-P-1135A/B can be caused:

- by a level upset (very low level) in the Naphtha Depentanizer Reflux Drum (R41-D-11150), Naphtha Splitter (R41-T-112), Naphtha Splitter Reflux Drum (R41-D-11250), LCN Splitter (R41-T-113) and LCN Splitter Reflux Drum (R41-D-1135) respectively
- by operator's decision in case of fire
- other major upsets in the unit

The failure of the pumps of the unit will cause bad separation performance of the columns, and its shutdown. Therefore, operator must be ready to react quickly in the following way:

- do not allow levels in the vessel bottom to decrease below the normal operating range and if this happens take immediate action to investigate and eliminate the cause.
- always keep the spare bottom pumps hot by continuously circulating a small slip stream from the main discharge through the pump casing (via the check valve bypass). Be ready to start a spare pump as soon as the duty pump fails.

##### **4.5.3.4 Fire/Major leak**

The following is only an overview of the steps to be taken during the discovery of a leak resulting in a fire. The following steps are from a process point of view mainly aimed at avoiding runaway reactions and protecting the equipment and catalyst, if any.

- Block in feed, product lines, shutdown the pumps progressively as the levels in the vessels begin to fall and then close fire valves at bottom of large capacities.
- Isolate the columns section.
- Depressurize the columns sections to flare.
- Drain all the vessels to the Closed Drain Drum or to blowdown.
- As the depressurized hot vessels cool down, watch the pressure and inject N<sub>2</sub> as necessary to avoid a vacuum.

##### **4.5.3.5 Other Upsets**

**Not applicable**

#### **4.5.3.6 Unit Restart**

Any unit restart procedure derives from the first start-up procedure. The unit status after the shutdown will dictate the point during restart where the general start-up procedure can be resumed.

For instance during a shutdown for a short duration, the unit would be kept on standby with columns which would have no feed but the reboilers would be on circulation at lower temperatures. In this case the restart procedure would begin at the oil-in step with levels already in the vessels.

For a long duration shutdown, the unit has been cooled down and all the columns left under nitrogen pressure.

The restart procedure will include the following steps:

- starting the columns at total reflux,
- filling up the unit with the feed at 50% flow,
- progressively increase temperature and flow to the normal operating figure.

#### **4.5.4 Naphtha Hydrotreatment section R41-2**

While performing emergency shutdown procedures, operators should be aware of catalyst preservation and avoid:

- An excessive catalyst temperature increase which can change the structure of the alumina (higher than 700 °C). To avoid damaging the catalyst structure, bulk temperature must never exceed 500 °C. Note that the design temperature of the Hydrotreating Reactor R41-R-121 (under design pressure) is much lower (371 °C).
- The presence of hydrocarbons without a sufficient hydrogen quantity which would result in a rapid deposit and the possible agglomeration of catalyst particles.

##### **4.5.4.1 Feed Failure**

A loss of feed may be due to Feed Pump (R41-P-1201A/B) failure with an unexpected delay in starting the spare pump or more commonly from leaks or other difficulties in the feed line requiring an interruption of the feed. A loss of feed from battery limits is not so severe due to the large hold-up in the Feed Surge Drum (R41-D-12010) (> 30 minutes at reduced capacity). A loss of feed at the Feed Pump is instantaneous and requires immediate action.

##### **Actions:**

- Notify the operators of the Aromizing Section (R41-3) immediately. The NHT Stripper (R41-T-122) bottom has hold-up time for feed to section R41-3 at design capacity. The operators of downstream units must take the necessary actions for loss of feed.
- Maintain H<sub>2</sub> circulation, reset the Hydrotreating Reactor (R41-R-121) inlet temperature to 250 °C.

- When the Separator (R41-D-12140) level starts to decrease, close and block-in the R41-FV-2140.
- When the level in the NHT Stripper R41-T-122 starts to fall, close and block-in valves to Aromizing section on the NHT Stripper bottom.
- Allow the NHT Stripper to operate on total reflux.

Maintain these conditions until feed is available again. Maintain pressure in the reaction and stripper section by hydrogen make-up. If interruption is to take place for several hours, short shutdown procedure should be implemented.

Do not leave catalyst under a hot hydrogen circulation for more than 12 hours, unless the H<sub>2</sub>S content in the recycle is maintained between 100-200 ppm vol. Note also that an increased H<sub>2</sub>S content while circulating hot hydrogen would be the sign of a catalyst desulfiding and would require the cooling down of the catalyst bed.

When flow to the reactors is re-established, start H<sub>2</sub> feed and return to previous operating temperatures if the feed is shortly recovered.

#### **4.5.4.2 Utilities failure**

##### **4.5.4.2.1 Electrical Power failure**

It is assumed that all electrical equipment in the section R41-2 will shutdown i.e. Recycle Compressor (R41-K-1215A/B), Stripper Air Condenser (R41-E-1225), Reactor Effluent Air Condenser (R41-E-1212), Hydrotreated Naphtha Air Cooler (R41-E-1222) and all pumps running on electric power (Feed Pump R41-P-1201A/B, Stripper Bottom Product Pump R41-P-122A/B/C, Stripper Reflux Pump R41-P-1225A/B).

- Immediately shut-off fuel to the Reactor Feed Heater R41-FR-12110 (normally automatically achieved due to compressor shutdown) and Stripper Reboiler R41-FR-122.
- Isolate the feed and product lines by closing the control valves and block valves.
- Block-in the Recycle Compressor R41-K-1215A/B.
- Isolate the NHT Stripper from the reaction section by closing the valve R41-FV-2140.
- Watch the skin temperatures of Hydrotreating Reactor (R41-R-121) and tube skin temperature of Reactor Feed Heater, if there is a runaway trend open the air damper and inject snuffing steam in Reactor Feed Heater.
- Maintain pressure in the reaction section. If necessary, inject fuel-gas or nitrogen in the NHT Stripper to maintain pressure.
- There is a potential for increased hydrocracking in the reactor which is idle with no flow. If power outage is suspected for a long duration, depressurize the reaction section to flare.

#### **4.5.4.2.2      Instrument Air failure**

Unit control and shutdown valves will adopt their design "fail-safe" position in the event of an instrument air failure: FC (fail close), or FO (fail open) or FL(Fail Lock).

The valves are dedicated to placing the Unit in a safe position.

Refer to attachment in section 8.4 for valve positions during instrument air failure.

#### **4.5.4.2.3      Steam Failure**

Not Applicable

#### **4.5.4.2.4      Cooling Water failure**

In the case of partial cooling water failure, it should be sufficient to reduce the feed flowrate to 60% of design capacity to maintain reasonable vessel and product temperatures. The NHT Stripper (R41-T-122) bottom should be carefully monitored to be sure the naphtha remains on spec. As the molecular weight of the recycle gas increases with higher separator temperature, the Recycle Compressor (R41-K-1215A/B) may shutdown on high load or high discharge temperature. In the case of total failure, it is recommended that the unit be shutdown immediately rather than waiting for the compressor to shutdown on high load or high temperature.

- Shutdown the Naphtha Feed Pumps (R41-P-1201A/B) and follow the procedure for loss of feed.
- Reduce the Reactor Feed Heater (R41-FR-12110) outlet temperature as necessary to lower the Separator (R41-D-12140) temperature
- Keep the H<sub>2</sub> Recycle Compressor (R41-K-1215A/B) in service as long as possible without risking the machine. This will strip the hydrocarbons off the catalyst.
- Allow the NHT Stripper to operate on total reflux with air cooling only.
- Maintain pressure in the reaction section with hydrogen make-up.

#### **4.5.4.2.5      Fuel gas failure**

The Reactor Feed Heater (R41-FR-12110) will shutdown.

- Cut naphtha feed immediately.
- Follow the same procedures as for loss of feed.
- Follow refinery safety practice for isolation and stream purge of the heater boxes.

#### **4.5.4.3      Equipment Failure**

##### **4.5.4.3.1      Recycle Gas Failure**

This refers to Recycle Compressor (R41-K-1215A/B) failure due to mechanical reasons and inability to start the standby compressor immediately.

**Actions:**

- Immediately stop the Reactor Feed Heater (R41-FR-12110). (normally carried out automatically)
- Simultaneously shutdown the naphtha Feed Pump (R41-P-1201A/B), close the discharge valves R41-FV- 2011 and R41-FV-2013 and block in.
- Close H<sub>2</sub> Make up valve R41-FV-2155.
- Watch the skin temperatures of Hydrotreating Reactor (R41-R-121) and tube skin temperature of Reactor Feed Heater, if there is a runaway trend open the air damper and inject snuffing steam in Reactor Feed Heater.
- Note that the catalyst bed thermocouples will not provide accurate temperature measurements, as there will be no flow across the thermocouples. As the feed contains unsaturated compounds, hydrocracking reactions may occur. It should be necessary to block in the reaction section and depressurize to flare. The estimated time between the Recycle Compressor shutdown and the depressurization is 20 minutes.
- Notify the Aromizing Section (R41-3) operators of the situation.
- When the separator (R41-D-12140) drum level starts to decrease, block in valve R41-FV-2140 on the NHT Stripper (R41-T-122) feed line.
- Close valve on the NHT Stripper bottom line to the Aromizing Section (R41-FV-3110) and allow the NHT Stripper to operate on total reflux.
- Let the Hydrotreating Reactor (R41-R-121) cool down. This could take several days due to lack of flow. Cool down can be assisted with a hydrogen make-up sweep, through the Recycle Compressor by-pass, provided the reaction pressure has been reduced.

**4.5.4.3.2        Stripper Reboiler failure**

This refers to Stripper Reboiler (R41-FR-122), which is fired heater failure or pump (R41-P-122A/B/C) failure without automatic restart of the standby.

**Actions**

In case of Stripper Reboiler shutdown, NHT Stripper bottom product should be diverted and capacity of the Naphtha Hydrotreatment section reduced.

- Naphtha with H<sub>2</sub>S cannot be sent to the Aromizing Section. Route the NHT Stripper bottom to the Straight Run Naphtha Storage tank (F56-TK-63/64) or back to the Feed Surge Drum R41-D-12010
- Inform the Aromizing Section (R41-3) operators of the situation.
- Reduce unit capacity to 50% of design as fast as possible.

- Work the unit at 50% capacity until the situation is back to normal.
- When H<sub>2</sub>S stripping is achieved and NHT Stripper bottom product specifications met, stabilized naphtha can be routed back to aromizing **section (R41-3)**.

#### **4.5.4.3.3 Stripper Reflux failure**

This refers to failure of the Stripper Reflux pumps (R41-P-1225A/B) without restart of the standby. Without reflux it will be difficult to maintain the NHT Stripper bottom on-spec.

##### **Actions**

- Reduce unit capacity to 50% of design as fast as possible and switch the NHT Stripper bottom back to the Feed Surge Drum R41-D-12010 or to the Straight Run Naphtha Storage tank (F56-TK-63/64).
- Notify the operators of the Aromizing Section (R41-3) of the situation and expected duration.
- Reduce the NHT Stripper bottoms temperature to minimize reflux, purge the level in the Stripper Reflux Drum (R41-D-12250) to flare, if necessary.
- If reflux **is** not available for a long duration, bypass the reaction section through the start-up bypass or shut-off the feed and follow the procedure for loss of feed.

#### **4.5.4.4 Fire/Major leak**

- Stop the fuel gas/oil supply to heaters R41-FR-12110 and R41-FR-122 by actuating the fuel gas emergency shutdown system from the control room
- Shutdown the naphtha feed pump R41-P-1201A/B and isolate the feed line
- Isolate stripper from reaction section by closing R41-FV-2014 and bloc-in.
- Block-in all products lines and H<sub>2</sub> make-up.
- Depending on the severity of the leak and location, shutdown the Recycle Compressor immediately and depressurize the reaction section to flare.
- Depressurize NHT Stripper section to flare.
- Drain all the vessels to the hydrocarbon sewer or to blowdown.
- As the depressurized hot vessels cool down, watch the pressure and inject N<sub>2</sub> as necessary to avoid vacuum.

If a fire has occurred then all the steps above will be taken while the fire fighting is taking place. Note however that the depressurizing step may move up higher in the sequence depending upon the gravity of the situation. If a small leak occurs in one of the fired heaters, the hydrocarbons will ignite immediately in this confined area. If this happens, open the stack damper (if possible) and maximize the draft to keep the fire under control within the heater box.

In case of extreme emergency, the reaction section can be depressurized to the flare, using the quick depressurization valve R41-ZV-2145 by actuating R41-ZC-2145. R41-ZC-2145 is activated by push buttons in the control room or on site (R41-HS-2145 A/B).

#### **4.5.4.5 Other Upsets**

**Not applicable**

#### **4.5.4.6 Unit restart**

Any unit restart procedure derives from the first startup procedure. The unit status after the shutdown will dictate the point during restart where the general startup procedure can be resumed.

For instance during a feed pump shutdown for a short duration, the unit would be kept on standby with the Recycle Compressor running at full capacity, the Reactor Feed Heater on and the Hydrotreating Reactor (R41-R-121) temperatures slightly lowered. In this case the restart procedure would begin at the oil-in step with levels already in the vessels.

For a long duration shutdown, the unit has been cooled down, the reaction section left under a pressure of hydrogen and the columns under a fuel-gas pressure or nitrogen pressure.

The restart procedure will include the following steps:

- starting the NHT Stripper column (R41-T-122) on total reflux
- repressurizing the reaction section to the normal operating pressure with hydrogen
- starting the Recycle Compressor(R41-K-1215A/B)
- Start feed pumps(R41-P-1201A/B) and feed liquid to the reaction at 60% of design flow rate
- Restart the Reactor Feed Heater (R41-FR-12110) and heating the reaction section. The catalyst temperature must not exceed 200° C
- Progressively increase temperature to the normal operating figure. Catalyst sulfiding is not required if the catalyst has not been replaced.

For a long duration shutdown, including catalyst replacement, the first startup procedure **to** be resumed all over again from the unit inerting, including the sulfiding procedure.

#### **4.5.5 Aromizing Reaction section R41-3 & Regeneration Section R41-4**

While performing emergency shutdown procedures, operators should be aware of catalyst preservation and avoid:

- An excessive grain temperature which can change the structure of the alumina (over 700° C). To keep grain temperature below 700° C, bed temperatures must never exceed the E.O.R operating temperature.
- The presence of hydrocarbons without a sufficient pressure of hydrogen which results in a rapid coke deposit and the possible formation of catalyst cakes which hamper the catalyst circulation and favors channelling.
- The quick depressurization of the reaction section which can damage the alumina support and induce the formation of catalyst dust and fines.

The general course of actions to be followed in an emergency situation is summarized below:

- Cut fuel gas to all reaction fired heaters (R41-FR-13110/13210/13310/13410).
- At the same time shut-off the liquid feed coming from Hydrotreatment section (R41-2).
- Maintain the reaction section pressure.
- Stop the H<sub>2</sub> Rich Gas Compressors (R41-K-135/13550) and isolate the reaction section from the HP Absorber section.
- Close the H<sub>2</sub> control valves to all users, close isolation block valves.
- Stop the catalyst circulation.
- Stop the catalyst regeneration.
- Isolate by block valves the control valves at the bottom of the vessels.
- Keep the Depentanizer column (R41-T-136) in total reflux.

Note that the Recycle Compressor (R41-K-13450) left running as long as possible.

##### **4.5.5.1 Feed Failure**

A loss of feed may result:

- Either from a feed pump (Stripper Bottom Product Pump R41-P-122A/B/C) failure coupled with an unexpected delay in starting the spare pump.
- Or more likely from problem with upstream Naphtha Hydrotreatment section (R41-2) which require to interrupt momentarily the feed.

When the feed is not available anymore, the following steps must be taken:

- The Recycle Compressor (R41-K-13450) being kept at its maximum capacity, decrease the Reactors (R-131/132/133/134) inlet temperature to 425° C (50° C/h), then maintain these conditions in order to sweep hydrocarbons from the catalyst.
- Stop DMDS injection (R41-Z-1201) to feed.
- Stop the H<sub>2</sub> Rich Gas Compressor (R41-K-135/13550), and close suction / discharge block valves.
- At the same time, isolate the Reaction section from the HP Absorber section while closing the FV-3502 on the antisurge line of the H<sub>2</sub> rich gas compressor (R41-K-135), then close block valves on the H<sub>2</sub> rich gas lines to all the users and to fuel gas.
- Shutdown the catalyst circulation and proceed with partial shutdown of the catalyst regeneration.
- Increase the Separator Drum (R41-D-13450) pressure to the value recommended for startup / shutdown.
- Shutdown the Reduction Heater (R41-E-1412) and close the H<sub>2</sub> rich gas FV-4160 to the Reduction Chamber (R41-D-1412) and the outlet valves PDV-4162 and HV-4170.
- When the levels start to decrease in the Separator Drum (R41-D-13450), HP Absorber Drum (R41-D-13580) and LPG Absorber Drum (R41-D-136100) and Depentanizer (R41-T-136), shut down the related pumps and isolate the control valves by block valves.
- Keep the Depentanizer at total reflux conditions and maintain these conditions until the feed is available again. If possible maintain the pressure of the reaction section by injecting H<sub>2</sub> rich gas from the H<sub>2</sub> header or from H<sub>2</sub> storage.

#### **4.5.5.2 Utilities failure**

##### **4.5.5.2.1 Electric Power failure**

The Recycle Compressor (K-13450) will remain operational in the case of power failure. All other electrical motors (pumps, compressors, cooler fans) are stopped. Electrical heaters are shutdown.

The following actions must be taken:

- Close the FV-3110 on the feed line and close the associated block valves.
- Shut-off fuel to all heaters (reactor heaters and reboiler heater).
- Isolate reaction section from the HP absorber section
- Close the block valves on the H<sub>2</sub> rich gas delivery to all users.
- Catalyst circulation has stopped by itself, owing to lack of N<sub>2</sub> lift gas and H<sub>2</sub> lift gas.
- Isolate the Reduction Chamber (R41-D-1412), close FV-4160 at inlet and PDV-4162 and HV-4170 at outlet.
- Keep the Recycle Compressor (R41-K-13450) running as long as possible.

Note however that the absence of cooling (air cooler fans down) will cause the temperature to rise and the machine to trip. Stop the Recycle Compressor before the trip temperature is reached.

The pressure will also tend to increase, open the PV-3450A/B to flare on the Separator Drum D-13450 outlet and the PV-3580 to PSA section (R41-5) on the HP Absorber Drum D-13580 outlet.

#### **4.5.5.2.2      Instrument Air failure (Or Power failure for Instruments)**

Where electrical instrumentation is used a power failure has the same effects as an instrument air failure:

- All the control valves and emergency safety valves (UV valves) will fail to their safe position.
- The Recycle Compressor (R41-K-13450) and the H<sub>2</sub> Rich Gas Compressor (R41-K-135 and R41-K-13550) will stop. Other compressors (Nitrogen Compressor (R41-K-1405A/B), Regeneration Loop Compressors (R41-K-1465)) are likely to stop also. In case of power failure all other motors (compressors, pumps, fans) will stop. Electrical heaters will shutdown.
- Ensure that all fired heaters are effectively shutdown and close the block valves on fuel gas lines to heaters.
- Watch heaters tube skin temperature: open dampers and inject snuffing steam if required.
- Isolate the reaction section from the HP absorber section
- Stop the pumps (Instrument Air failure).
- Close block valves on all control valves mainly but not limited to the following:
  - Feed FV's.
  - PV on H<sub>2</sub> delivery to users.
  - R41-PV-3450 to flare on H<sub>2</sub> rich gas compressor KO drum (R41-D-135).
  - R41-PV-3650 to fuel gas on LPG absorber drum(R41-D-136100).
  - LV (R41-FV-3450) on separator bottom.
  - LV (R41-FV-3580) on HP absorber drum bottom.
  - LV (R41-FV-3611) on depentanizer bottom.
  - LV (R41-FV-3851) on LPG to battery limit.
- Check that catalyst circulation is stopped and that the following remote operated valves are properly closed:
  - R41-ZV-4431 last reactor bottom
  - R41-KV-4010,4011,4020,4021 at lock hopper inlet (2) and outlet (2)
  - R41-ZV-4031 Regenerator bottom
  - R41-ZV-4111 1st Upper Hopper Outlet
- Close block valves of air injection FV's.

- Stop chlorination agent injection(R41-Z-1469) and oxychlorination water pumps (instrument air failure).
- Stop Caustic Recycle Pump (R41-P-1460A/B), Caustic Injection, Washing Water Pump (R41-P-1461A/B) (Instrument Air failure).
- If regeneration gas circulation cannot be continued (most likely case) shutdown electrical heaters (instrument air failure).

As soon as instrument air (or electrical power) is restored, start the Recycle Compressor K-13450 to cool down the heaters tubes and the catalytic beds to 400° C. Then proceed as per "Low severity operation" 0.

Unit control and shutdown valves will adopt their design "fail-safe" position in the event of an instrument air failure: FC (fail close), or FO (fail open). The valves are dedicated to placing the Unit in a safe position.

Refer to attachment in section 8.4 for valve positions during instrument air failure.

#### **4.5.5.2.3        Steam Failure**

Refer section 4.5.5.3.1 “Recycle Gas Compressor R41-K-13450 failure” which is caused by HP Steam failure.

#### **4.5.5.2.4        Cooling Water failure**

In the case of partial cooling water failure, it should be sufficient to reduce the severity and the feed flow rate to the reaction section as to maintain reasonable vessels and products temperatures. Watch carefully the pumps and compressors for possible overheating.

In the case of total failure the unit must be shut down:

- Cut-off fire to all the reactor fired heaters (FR-13110/13210/13310/13410).
- At the same time shut-off the feed FV-3110 and close the block valves.
- Stop DMDS injection to feed.
- Keep the recycle gas compressor (R41-K-13450) in service as long as it possible without risks for the machine, in order to cool down the heater tubes and the catalyst.
- Simultaneously with the heaters and feed cut-off:
  - Isolate H<sub>2</sub> rich gas delivery to all the users and to fuel gas.
  - Raise the Separator Drum (R41-D-13450) pressure to the value recommended for shutdown.
  - Shut-down the H<sub>2</sub> Rich Gas Compressor (R41-K-135 and R41-K-13550).
  - Cut-off Reduction Heater (R41-E-1412) power supply.
  - Close FV-4160 on the reduction gas inlet, close PDV-4162 and HV-4170 on the reduction gas outlet.
  - Close all the block valves on the Separator Drum bottom, HP and LPG Absorber bottoms.
- Whenever possible keep Depentanizer on total reflux.
- Shutdown the catalyst circulation and proceed with partial shutdown of the catalyst regeneration.

#### **4.5.5.2.5 Fuel gas failure**

All burners (Reactors preheater and heaters FR-13110/13210/13310/13410, Convection Reboiler coil FR-13110-E) will shut down.

Cut off feed immediately and proceed as per feed loss ("Feed Failure") 4.5.5.1, with however the following difference: in order to ensure the highest possible temperature for hydrocarbon sweeping with the recycle gas, air to the reactor heater burners (primary and secondary air) must be closed.

The Recycle Compressor (R41-K-13450) is shutdown when the reactor temperatures fall below 250° C.

#### **4.5.5.3 Equipment Failure**

##### **4.5.5.3.1 Recycle Compressor (R41-K-13450) failure (HP steam failure)**

Since the Recycle Compressor (K-13450) is HP steam driven, the measures below apply also to HP steam failure.

- Cut fuel gas to all reaction fired heaters (R41-FR-13110/13210/13310/13410).
- At the same time shut-off the feed using FV-3110 and close the corresponding block valves.
- Watch the heaters tube skin temperatures. If there is a runaway trend, open air dampers and inject snuffing steam.
- Stop DMDS (R41-Z-1201) injection.
- Increase the Separator Drum (R41-D-13450) pressure to the value recommended for startup / shutdown.
- Isolate the Reaction section from the HP Absorber section while closing the FV-3502 on the antisurge line of the H<sub>2</sub> rich gas compressor (R41-K-135), then close block valves on the H<sub>2</sub> rich gas lines to all the users and to fuel gas.
- At the same time, stop the H<sub>2</sub> Rich Gas Compressors (R41-K-135/13550) and close suction / discharge block valves.
- Shutdown the Reduction Heater (R41-E-1412) and close the H<sub>2</sub> rich gas FV-4160 to the Reduction Chamber (R41-D-1412) and the outlet valves PDV-4162 and HV-4170.
- Shutdown catalyst circulation and proceed with partial shutdown of the catalyst regeneration.
- When the levels start to decrease in the Separator Drum (R41-D-13450), HP Absorber Drum (R41-D-13580) and LPG Absorber Drum (R41-D-136100) and Depentanizer (R41-T-136), shut down the related pumps and isolate the control valves by block valves.
- Keep the depentanizer (R41-T-136) on total reflux conditions.

- Let the reactors cool down. If temperature decrease is higher than 50 °C/h refer section 4.5.5.5. This could take several days because of the lack of hydrogen circulation. Keep the pressure of the reaction section by injecting H<sub>2</sub> rich gas from the header or from H<sub>2</sub> storage.

**Note for restart:** Start the Recycle Compressor (K-13450) as soon as it is available. Assuming the temperature in the reactors has dropped below 440° C start the Fired Heaters (FR-13110/13210/13310/13410) again and adjust the inlet temperature to the different reactors at 440° C, then proceed as per oil in "Low severity operation at reduced capacity" (Refer Section 0)

If, at restart, the temperature in one or several reactors is still above 440° C, cool reactors first to 440° C through the recycle gas before firing the heaters again. Then proceed as per oil in "Low severity operation at reduced capacity"( Refer Section 0).

#### **4.5.5.3.2      H<sub>2</sub> Rich Gas Compressor (R41-K-135/13550) failure**

If H<sub>2</sub> Rich Gas Compressors fails and if the Aromizing section (R41-3) is the unique supplier of hydrogen to the Naphtha Hydrotreatment section (R41-2), then the Aromizing section (R41-3) must be shutdown. Proceed as per "Feed Failure" 4.5.5.1.

If another source of hydrogen is available for the Naphtha Hydrotreatment section (R41-2), then, in case of H<sub>2</sub> Rich Gas Compressors failure the hydrogen gas could be vented off at the Separator Drum D-13450 (through PV- 3450 to flare) and the capacity of the reformer reduced to 60%. The operation of the Recycle Compressor (K-13450) could enable to continue the operation of the unit. The liquid from the Separator Drum D-13450 could be routed to the Depentanizer Column (R41-T-136) through the Separator Drum Pumps (R41-P-13450A/B) and HP Absorber Drum (R41-D-13580). With no hydrogen gas to reduction and to hydrogen lifts, however, the catalyst circulation must be shut down as well as the regeneration. Hence this operating mode would be of limited duration.

#### **4.5.5.3.3      Absorber Feed Pumps (R41-P-13450A/B) or Depentanizer Feed Pumps (R41-P-13610A/B) failure**

This situation requires the same actions as loss of the feed to the unit. Refer to "Feed Failure" 4.5.5.1.

#### **4.5.5.3.4      Reboiler pumps (R41-P-136A/B) failure**

As it is impossible to send to storage or to other users unstabilized gasoline this is equivalent to the loss of feed, as the feed charge must be cut-off immediately. Refer to paragraph "Feed Failure" 4.5.5.1.

#### **4.5.5.4 Fire / Major leak**

The following are guidelines mainly aimed at avoiding runaway reactions, protecting the equipment and the catalyst.

##### **Major Leak**

In case of a major leak, from a process view point, the following actions must take place:

- Cut-off fuel to all fired heaters (FR-13110/13210/13310/13410) by actuating from the control room the fuel gas emergency shutdown system. Shut-off electrical heaters.
- Close the stack damper of all fired heaters (FR-13110/13210/13310/13410), stop draft fan units, if any, and inject snuffing steam.
- Close the feed FV's to the unit, close block valves and stop the feed pumps.
- Stop the H<sub>2</sub> Rich Gas Compressors (R41-K-135/13550).
- Depressurize the Depentanizer column (R41-T-136) and the HP Absorber section to fuel gas.
- Stop air to the regeneration section.
- Keep the Recycle Compressor (R41-K-13450) running as long as possible to cool down the fired heater coils and sweep the hydrocarbons from the catalyst, then shut the compressor down.
- Depressurize reaction section to flare.
- Decrease to the minimum the liquid level of all vessels, then stop all pumps and isolate all the units effluents by closing the control valves.
- When depressurized hot vessels cool down, watch the pressure and inject N<sub>2</sub> as necessary to avoid vacuum.

##### **Fire**

Generally speaking, all precautions to be taken and operations to be carried-out, are the same as the above while the fire fighting is taking place.

Note that if the leak occurs in one of the heaters, the hydrocarbons will ignite immediately in this confined area. In such a case, open the stack damper, maintain the draft fan units in service to keep the fire under control in the heater box.

#### **4.5.5.5 Other Upsets**

##### **4.5.5.5.1 Fast temperature decrease in the reaction section**

At hot temperature, the reactor volume is higher due to thermal dilatation. When the reaction section is shutdown, generally the catalyst circulation is stopped with a catalyst internal rearrangement leading to a lower void fraction

than during the catalyst moving phase. Then, the catalyst quantity inside the reactor is higher than at original start-up.

When the reactor cools down with a temperature ramp higher than 50° C/h, the vessel shrinks but neither the catalytic bed nor the internals in contact with the catalytic bed shrink at such rate resulting in high internal stress, since internal volume for the catalyst is not sufficient any more. This could lead to damaging internal reactor components.

If cool down temperature ramp could not be maintained below 50° C/hr, the best way to avoid such damages is to prevent the build up of high forces inside the reactor, by allowing catalyst circulation during the cooling down of the reaction section.

For that, the first priority is to keep as long as possible the catalyst circulation when emergency shutdown occurs. But due to the lack of hydrogen when the unit is shutdown or rapid pressure equilibrium between the reactors, the catalyst circulation is no more possible with the classical way. In any case, if some time is available before unit shutdown, whenever it is possible leave the lift pots empty so that there is already the possibility to move the catalyst.

Even in case of emergency shutdown of Nitrogen Compressor (K-1405A/B), the unit being equipped with a Nitrogen Storage Drum D-1406 linked to nitrogen network, it is still possible to send nitrogen to the 3 hydrogen lift pots through the start-up line and to the nitrogen lift pots. It allows catalyst circulation during emergency shutdown.

#### **4.5.5.6 Unit Restart**

##### **4.5.5.6.1 Restart of the entire unit (including regeneration section)**

Any unit restart procedure derives from the first startup procedure. The only difference results from the unit status after the shutdown which dictates the point where the general startup procedure can be resumed.

For instance, assume a shutdown of the feed pump of a short duration: the unit to be kept on stand-by with the Recycle Compressor (K-13450) running, the fired heaters (FR-13110/13210/13310/13410) still on, the reactors (R-131/132/133/134) temperature lowered, HP Absorber section blocked, the H<sub>2</sub> Rich Gas Compressor (K-135/13550) stopped and possibly (depending upon the expected duration) the Regeneration loop and catalyst circulation stopped (Refer to 4.5.5 "Emergency shutdown"). In this specific case operator will have to resume the first startup at "Oil in" 4.2.4.2.6.4, including, if required, the restart of the regeneration section.

More generally, in most cases of normal or emergency shutdowns of relatively long duration, the stand-by conditions are as follows:

- Feed and heaters are shut down, catalyst circulation and regeneration sections are stopped. The reaction section is isolated from the HP absorber section and cooled down under an atmosphere of hydrogen.
- Recycle compressor is stopped and isolated under nitrogen. The H<sub>2</sub> rich gas compressor is shut down and isolated.
- The depentanizer section is isolated from the HP absorber section. Both are under an atmosphere of hydrogen or fuel gas. Then, the restart procedure **to** be resumed in keeping the Depentanizer (T-136) at total reflux or catalyst heating up and reduction ( Section 4.2.4.2.6.3 “Catalyst heating up and reduction”). However the reduction step of 12 hours at 480 °C for water removal is not required.

Also the feed can be introduced again at a temperature of 440 °C, (no or very little water is expected).

Note also that the Aromizing section (R41-3) shutdown results (in the general case where no independent H<sub>2</sub> supply is available) in the shutdown of the Naphtha Hydrotreatment section (R41-2). The Aromizing section (R41-3) will be restarted with desulfurized dry naphtha.

An extreme case of unit restart is when coked catalyst has been unloaded and the reaction section was aerated (for inspection), in this case the restart procedure will start with a leak test, then as coked catalyst has been reloaded in the unit, catalyst drying will take place under hydrogen. In such a case, it is recommended to reload the catalyst in the reactor from where it was unloaded.

In case of restart of BFW by the pump R41-P-130A/B after trip due to Low Low trip, water will flow into dry tubes of Waste Heat Boiler R41-FR-130-SG. Temperature of the tubes shall be close to the flue gas temperature (at design heater case = 243°C), and this can lead potential risk:

- Thermal shock of tubes ( $T_{BFW} = 130^{\circ}\text{C}$  vs  $T_{\text{metal}} = 243^{\circ}\text{C}$ );
- Possible sudden vaporization of the water in tubes.

In order to mitigate the risks above, the recommendation is to smoothly control the BFW flowrate after the restart of the pump.

Consider a flowrate ramp-up of 3 minutes after the restart of the R41-P-130A/B.

Vendor advises that 3 minutes of flowrate ramp-up are adequate because it's enough to avoid Low Low trip maintaining the Normal level in the drum R41-D-130.

#### **4.5.5.6.2**      Restart of the Regeneration section alone

##### **4.5.5.6.2.1**    After a partial shutdown

In some cases of operating problems which affect the regeneration section only, and are expected to be corrected in a couple of days, the regeneration section alone plus the catalysts lifts may be partially shut down. This means that the regeneration section is isolated from the reaction section, air to burning zones cut off, but Regeneration loop compressor (K-1465) and Air compressors (K-1470) may still be running (Refer to 4.4.4.4 "Catalyst circulation and regeneration section").

Then the restart procedure is as follows:

- Make sure that the previous shutdown sequence was correct i.e. the circulation of catalyst has been stopped first and air to burning zone and oxychlorination/calcination after. If yes, proceed with next steps.
- Start the Regeneration loop compressor (K-1465) - if required - control flow in manual mode through spillback FV-466, switch to auto.
- Adjust flows to the burning beds, to oxychlorination and calcination through PDV-40090 A and B respectively between 2nd burning bed and oxychlorination outlet.
- Set bias between first reactor top and regeneration loop pressure at 0.7 kg/cm<sup>2</sup> - if required i.e. if compressor has to be restarted.
- Start the Air compressor (K-1470) if required.
- Check O2 analyzers in Regeneration section are ready for use.
- Set TIC (R41-TC-40010A) at burning gas heater outlet at 480 °C.
- Set TIC (R41-TC-4003) at second bed inlet at 480 °C.
- Set TIC (R41-TC-4006) at oxychlorination heater outlet at 510 °C.
- Set TIC (R41-TC-4007) at calcination heater outlet at 520 °C.
- Check that first burning zone inlet temperature is approximately 420 °C.
- Make sure that the caustic recycle pump and the washing system operate satisfactorily.
- Open the 2 FVs air valves (air flow to 2nd burning zone and to oxychlorination/calcination) and adjust set points to the previous ones.
- Switch on cascades between oxygen analyzers and FVs when the required O2 content has been reached (Refer to Figure 17: Principle of regeneration loop control in paragraph 4.2.4.2.7 "Regeneration startup").
- Open ON/OFF remote operated valve R41-KV-4013 on regenerator bottom pipe.

- Start the catalyst lifts. First from last reactor to regenerator, etc. (See 4.2.4.2.4.4 “Catalyst circulation”). Set R41-PDIC-4431 on the lift from the last reactor to the regenerator at its design value.
- When  $\Delta T$  in the first burning zone increases adjust burning heater outlet temperature at 470 °C.
- When the oxychlorination zone reaches 450 °C start water and chlorine injection.
- Adjust the TIC set point, at burning heater outlet, to maintain the inlet temperature to the first burning zone between 470 and 480 °C. 2nd bed inlet temperature must be around 480 °C.

If at the previous shutdown the air injection was stopped prior to stopping the catalyst circulation, some coked catalyst has entered the calcination zone. Special caution must be taken at restart: At the beginning air must be directed exclusively to the burning zone and none to the calcination zone, i.e. R41-ZV-4004 is closed to oxychlorination / calcination zones and R41-ZV-4003 is open to 1st burning bed. Only when the catalyst contained in the calcination/oxychlorination zone has been replaced with catalyst from the burning zone can air be directed to the calcination zone again (Refer 4.2.4.2.7 “Regeneration startup”).

#### **4.5.5.6.2.2      Restart after a total shutdown of the regeneration section**

If the regeneration section has been fully shut down:

- Either alone.
- Or as a result of a shutdown of the entire unit .

Then operators must refer:

- Either to Regeneration start up (Refer 4.2.4.2.7 “Regeneration startup”).
- Or to Oil in (paragraph 4.2.4.2.6.4 “Oil in”).

#### **Important:**

Under normal steady conditions and design feeds the unit typically operates with a coke content on the catalyst between 4 to 6% wt. However, the Aromizing unit can be maintained on stream without the regeneration section for some period of time.

In this case, the limiting factor being the coke deposit, the lower the severity, the longer this period. It is then recommended to reduce reactors inlet temperatures to approximately 480 °C and flow to approximately 60% with maximum recycle rate, in order not to significantly exceed the 6% wt coke deposit. The period without regeneration might then last up to two weeks.

However, regeneration with coke deposit higher than 6% wt. have been carried out. In this case, operators must bear in mind that the coke burning capacity (kg/h) of the unit is limited. Consequently upon restart of the regeneration they must adjust the catalyst circulation rate taking account of:

- i) the maximum coke burning capacity
- ii) the actual wt% coke deposit

Moreover, they must carefully watch the temperature increase in the burning zones.

Example: Coke burning capacity 80 kg/h

Actual coke deposit 10% wt

Maximum catalyst circulation. Qcata (kg/h)

$$Q_{cata} = 80 * 100 / 10 : 800 \text{ kg/h}$$

It is recommended to start with a lower circulation rate (say 80% of the maximum rate) and increase progressively, according to the temperature increase in burning beds.

#### **4.5.6 PSA section R41-5**

Refer latest revision of the below document for Emergency shutdown and restart procedures.

**V-202-1420-141-U-01-105 - Operating Manual**

##### **4.5.6.1 Utilities failure: Instrument Air Failure**

Unit control and shutdown valves will adopt their design "Failsafe" position in the event of an instrument air failure: AFC (air fail close), or AFO (air fail open). The valves are dedicated to placing the unit in a safe position.

Refer to attachment in section 8.4 for valve positions during instrument air failure.

## **4.6 Catalyst Specifications and Special Procedures**

### **4.6.1 Naphtha Hydrotreatment section R41-2**

#### **4.6.1.1 Manufacturer**

Catalyst and inert balls are manufactured by Axens in their facilities located at SALINDRES 30340 FRANCE.

Head office address:

Axens

89, boulevard Franklin Roosevelt

B.P. 50802

92508 RUEIL MALMAISON CEDEX – FRANCE

Phone: 33 (0) 1 47.14.21.00 Fax: 33 (0) 1 47.14.25.00

#### **4.6.1.2 Catalyst specifications**

##### Catalysts

Type : HR-538 (Cobalt and molybdenum on alumina support)

Quantity : 72 m<sup>3</sup>

##### Alumina balls

Type : Synthetic or shamva mullite

Shape, size : Balls ¾ inch, Quantity : 7.4 m<sup>3</sup>

Shape, size : Balls ¼ inch, Quantity : 2.1 m<sup>3</sup>

##### Catalytic bed protection

- Type : ACT 069, Quantity : 2.1 m<sup>3</sup>
- Type : ACT 078, Quantity : 2.1 m<sup>3</sup>
- Type : ACT 108, Quantity : 2.1 m<sup>3</sup>
- Type : ACT 139, Quantity : 2.1 m<sup>3</sup>

#### **4.6.1.3 Packaging, Handling and Storage**

##### Packaging

The catalysts can be delivered in steel cylindrical drums having the characteristics given in the technical data sheets.

##### Handling recommendations

Drums must be handled with care to avoid catalyst breakage. The drums must not be rolled and must not be allowed to fall.

Rain, snow, sand can damage the catalyst and its containers. Therefore adequate shelter for the catalyst during storage, transport and loading must be arranged. Before loading operation, the catalyst loading equipment must be safely installed and checked ready for operation. Reactors and internals must be previously inspected for dimension conformity and cleanliness.

During catalyst loading and unloading operations personnel must take the following precautions:

- Outside the reactors wear a dust mask, protective clothing, goggles, gloves and a helmet.
- When inside the reactors for short periods, wear a safety harness. A second man must be in attendance outside the vessel. Always, apply the General Safety Rules.

As a general rule, no one is allowed to enter a vessel before the atmosphere has been proven suitable and all vessel nozzles are blinded. In addition, personnel working in the reactor during the catalyst loading must wear an air mask covering the entire face.

#### **4.6.1.4 Catalyst sulfiding reactions**

The metals of catalyst HR-538 are in their oxide form. It must undergo a treatment to recover the active sulfide form. This is the purpose of the catalyst sulfiding.

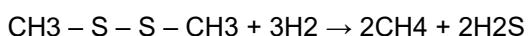
Sulfiding is achieved:

- Either by injection of a sulfiding agent (DMDS) in an hydrogen stream which is circulated on the catalyst (dry process).
- Or by injection of the sulfiding agent (DMDS) in a circulation of hydrogen and raw feed (wet process).

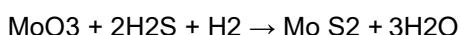
For naphtha pretreater catalyst, wet sulfiding is preferred because it is easily combined with the oil-in and warm-up of the catalyst.

The required amount of DMDS is determined from the decomposition of DMDS into H<sub>2</sub>S which sulfurizes the catalyst metals according to the following reaction:

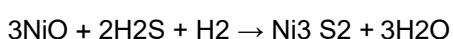
- DMDS decomposition



- Sulphiding of molybdenum oxide



- Sulphiding of the nickel oxide



The total amount of DMDS required by the stoichiometry is the following:

- HR-538 : 0.126 kg/kg of catalyst.

Axens recommends to order some more, say 50%, to account for possible mishaps.

The sulfiding procedure is already described (Refer to section 0 Catalyst sulfiding HR-538).

The main steps are:

- Injection of DMDS in the raw feed, when the reactor temperature is 180° C, required for the thermal decomposition of the DMDS
- A temperature step at 220° C with a minimum duration of four hours and till a significant amount of H<sub>2</sub>S appears in the recycle gas (0.2% volume).
- The total amount of DMDS is injected in about 25 hours. However this period can be longer as the DMDS injection flow rate may have to be reduced:
  - to keep the reactor ΔT at 30° C maximum,
  - to maintain the H<sub>2</sub>S content in the recycle gas between 0.2% and 2% volume.
- A temperature step close to 330° C is maintained for duration of 8 hours and till the required amount of DMDS has been injected. The duration of this high temperature step is mandatory, even if, owing to some delays or upsets in the previous phase, it resulted in an injected amount of DMDS in excess of the calculated figure.

#### **IMPORTANT REMARK:**

**Note that hot hydrogen must never be circulated without hydrogen sulfide on the catalysts HR-538. If it occurred the catalyst could be desulfurized. Should such a situation arise, decrease the reactor inlet temperature down to 200° C.**

##### **4.6.1.5 HR 538 Catalyst unloading**

Catalyst may be unloaded for various reasons:

- The catalyst is used (not regenerable).
- The catalyst is still active but must be dumped for the inspection of reactor.

##### **4.6.1.5.1 Used Catalyst Unloading for Disposal**

Prior to unloading, the catalyst must undergo H<sub>2</sub> stripping and cooling steps. When dumped, if the catalyst warms up due to ambient air oxidation, it can be watered. If there is no need to enter the reactor R41-R-121, it **is** left under a nitrogen pressure. Otherwise, a man equipped with an adequate breathing apparatus must enter to clean the reactor from the remaining catalyst prior to aerating.

##### **4.6.1.5.2 Unloading for reactor inspection**

For reactor inspection of R41-R-121 loaded with the active catalyst, the unloading must be carefully performed under inert gas and the catalyst is packed in good quality drums.

Procedure for catalyst unloading is described here after:

- To avoid catalyst oxidation in ambient air, the catalyst must be free of hydrocarbons by stripping and unloaded under a nitrogen atmosphere.
- Hot N<sub>2</sub> stripping at 150 °C for reactor R41-R-121 is carried out for 8 hours prior to unloading to strip the hydrocarbons.
- Depressurization of the reactor section to flare and drain-off the liquid HCs to sewer.
- Purging of the reactor section until HC+H<sub>2</sub> content is below 0.2%. This is done by pressurizing with nitrogen and then depressurizing to atmosphere.
- Ensure the catalyst bed temperature is uniformly below 50 °C.
- Isolate the reactor.
- Unload the catalyst through the catalyst draw-off nozzle (bottom flange). The reactor should be continuously swept with cold nitrogen from the reactor top to the catalyst drawoff nozzles during unloading

People equipped with a special breathing apparatus must enter the reactor to remove any residual catalyst prior to aerating. The usual safety measures, including safety harnesses and other man in attendance with a spare breathing equipment must be provided when this operation takes place.

When unloading has been completed, open manholes and aerate the vessel thoroughly to remove all traces of nitrogen. When the atmosphere in the vessel meets the vessel entry permit regulations, it can be entered for final inspection.

#### **4.6.1.6 Austenitic Steel Protection**

Since sulfides are present during operation of the Unit, when the unit is exposed to moist air during shutdown, the potential for stress corrosion cracking in the equipment fabricated from austenitic stainless steel will exist.

##### **4.6.1.6.1 Polythionic Acid Attack**

Once a unit has been placed on stream, even if the sulfur content of the feed stock is low, all items made of austenitic stainless steel should be considered to contain a layer of iron sulphide scale. Even though these layers of scale in many cases may be very thin, they represent a potential hazard to the underlying steel.

The action of water and oxygen on this sulfide scale forms weak sulphurous type acids, commonly referred to as polythionic acids, which can attack austenitic stainless steels and cause intergranular corrosion and cracking.

These stainless steels are vulnerable to this type of corrosion, particularly in areas of residual tensile stresses and in areas where intergranular chromium carbides may exist, such as the heat-affected zones adjacent to welds. Therefore, special precautions should be taken to protect austenitic stainless steel from this corrosive environment.

#### **4.6.1.6.2      Protection against Polythionic Acid Attack**

Protection against polythionic acid attack can be accomplished by preventing the corrosive environment from forming or by providing an agent, which will neutralize any corrosive acids as they are formed.

#### **4.6.1.6.3      Preventing the formation of Polythionic Acids**

Since these acids are formed by the action of water and oxygen with hydrogen sulfide or sulfide scale, elimination of either liquid phase water or oxygen will prevent these acids from being formed. Since there will usually be an equilibrium amount of water vapor present during the normal operation of a unit, during shutdown periods this water vapor can be prevented from condensing by maintaining the temperature of the austenitic stainless steel equipment above the dew point of water.

Under normal operations there should be essentially no oxygen present in the system. The only other time any significant amount of oxygen might enter the system would be during a shutdown period when the system is depressurized and the equipment is opened and exposed to air. Under these conditions a suitable purge of nitrogen should be established through the equipment involved to prevent any air from entering the system, and maintained until the system is again closed. If possible, the equipment should be blinded or blanked-off during this period and kept under a slight positive pressure of nitrogen.

#### **4.6.1.6.4      Neutralization**

Whenever austenitic stainless steel cannot be adequately protected by maintaining temperatures above the dew point of water or by an adequate nitrogen purge, a protective neutralizing environment should be established in this equipment prior to exposure to air. An effective neutralizing environment can be provided by washing with a dilute soda ash solution.

The solution should contain 2%wt. Soda Ash ( $\text{Na}_2\text{CO}_3$ ) in water. Water used to prepare the solution should contain no more than 50ppm in chlorides. The resulting solution should not contain more than 150ppm of chloride according to NACE RP 0170-93.

Sodium Nitrate (0.5%wt) should also be added to the solution to give added protection against chloride attack. Do not exceed this amount.

The only equipment of the Unit which the above precautions apply is the Reactor Feed Heater (R41-FR-12110).

## **4.6.2 Aromizing Reaction section R41-3 & Regeneration Section R41-4**

### **4.6.2.1 Manufacturer**

Aromizing® catalyst is manufactured by Axens in their facilities located at Salindres 30340 France.

Axens HEAD OFFICE ADDRESS:

89 boulevard Franklin Roosevelt

BP 50802

92508 Rueil Malmaison France Cedex

Phone : + 33 1 47 14 21 00 Fax : + 33 1 47 14 25 00

### **4.6.2.2 Catalysts specifications:**

#### **4.6.2.2.1 Catalyst for Aromizing section reactors (Section R41-3)**

Catalyst used for the four aromizing reactors(First Reactor R41-R-131, Second Reactor R41-R-132, Third Reactor R41-R-133 and Fourth Reactor R41-R-134) in section R41-3 is described below.

Type : AR 701

Form : Spheres

Diameter : 1.8 mm

Platinum : 0.3 wt%

Loss of ignition at 900 °C : 3 wt%

Surface Area : 200 m<sup>2</sup>/g

Total Pore volume : 60 cm<sup>3</sup>/ 100g

Moving Bed Density : 650 kg/m<sup>3</sup>

Static Bed Density : 670 kg/m<sup>3</sup>

AR 701 is a multi-metallic, platinum-tin, aromizing (reforming) catalyst, developed for the production of C6-C8 aromatics from naphtha with maximum selectivity. AR 701 provides :

- High activity
- Exceptional mechanical strength leading to minimal abrasion during catalyst transfer through lifts between reactor/regenerator.
- High regenerability due to low surface area decrease after numerous regenerations.
- Superior chloride retention owing to the combined effect of its special carrier and promoters. Refiners therefore benefit by adding less chloride and requiring less chloride clean up.

- Low coke due to its multi-metallic formulation. Refiners therefore have opportunities to increase operation severity (higher throughput, feed severity) without facing coke burning limitations.

#### 4.6.2.2.2 Adsorbent for Hydrogen Rich Gas Chloride Adsorbers R41-R-13590A/B (Section R41-3)

Type	: SAS857
Form	: White alumina beads
Diameter	: 2 to 5 mm
Surface area	: 100 m <sup>2</sup> /g
Sock loading density	: 0.83 kg/l
Dense loading density	: 0.88 kg/l
Particle crushing strength	: 8 min. daN

SAS 857 is formulated for HCl removal from gas streams.

#### 4.6.2.2.3 Adsorbent for Depentanizer Feed Chloride Adsorbers R41-R-13610A/B (Section R41-3)

Type	: SAS858
Form	: White alumina beads
Diameter	: 1.4 to 2.8 mm
Surface area	: 100 m <sup>2</sup> /g
Sock loading density	: 0.83 kg/l
Dense loading density	: 0.88 kg/l
Particle crushing strength	: 8 min. daN

SAS 858 is formulated for HCl removal from liquid hydrocarbon streams.

#### 4.6.2.3 Packaging, handling and storage

Catalyst can be delivered either in drums or in big bags. Catalyst must be handled with care to avoid breakage of the catalyst beads. During the loading, the loading sleeve **is** adjusted to allow a free fall no higher than 1 meter, above the catalyst level. Catalyst drums must not be rolled and big bags must be carefully handled to avoid catalyst attrition.

Catalyst delivered in sealed still drums **to be** stored in an enclosed and ventilated warehouse. Storage time under such a condition is two years without any damage for the catalyst and for the packaging. Outdoor storage is possible, provided original packaging is stored under water tight cover and raised above the naturally flood-free ground: Such storage is not recommended and should be minimized to reduce as much as possible the risk of water damage.

Catalyst delivered in big bag **to be** normally loaded in the reactor as soon as it arrives on site. Short duration storage can be envisaged provided, it is in a covered and dry warehouse.

#### PACKAGING

<b>DRUM (see Note 1)</b>	
Description	Steel drum (UN standard). Air tight cover. Thickness: 0.8 mm Tare: 14.5 kg
Dimensions	Diameter: 0.6 m – Height: 0.9 m Standard capacity: 217 liters.
Netweight	105 kg
<b>BIG BAG</b>	
Description	External skin: fiber glass spliced propylene Internal skin: 80 micron polyethylene
Dimensions	Square section 80 x 89 cm. Cylinder diameter: 110 cm. Height: empty 160 cm, full: 120 to 150 cm.
Netweight	700 kg

Note 1: The cover of each drum is secured by a plastic seal, on which a kg/cm<sup>2</sup> code mentions the drum serial number. During catalyst loading collect these seals and hand them over to the customer.

Other handling and storage recommendations are similar to section R41-2 given in 4.6.1.3

#### **4.6.2.4 Coked catalyst unloading**

As mentioned in 4.4.4.3 "Normal shutdown" with catalyst unloading, the catalyst can be dumped from the reactors and/or from the regenerator without previous coke combustion. In such case, the catalyst must be unloaded under nitrogen. This procedure applies for:

- A partial catalyst unloading caused by the inspection of one of the reactors or the regenerator.
- A total catalyst unloading for catalyst replacement, at the end of catalyst life.

The catalyst in the reaction section has been swept with hot hydrogen to remove the hydrocarbons, then it has been cooled to 50 °C. The reaction section and HP absorber section have been depressurized to flare and liquids drained to blow-down. (H<sub>2</sub> + HC) content in both sections has been reduced to less than 0.2 % vol. (Refer to 4.4.4 “Normal shutdown”).

For the catalyst unloading proceed as follows:

- Keep the reaction section and the regenerator under a slight positive pressure of N<sub>2</sub> (0.05/0.1 kg/cm<sup>2</sup> gage).
- Disconnect the seal leg under each lower hopper upper valve and connect a sleeve.
- If the catalyst has reached the end of life, it will be stored in drums. During the drum filling-up, a small flow of nitrogen will be injected in the drum.
- If the catalyst is to be reloaded, it will be screened to remove fines and scales before being stored in labeled drums under nitrogen. These drums have to be identified in order to be reloaded in the same equipment.
- After the complete unloading of the catalyst, the reactor inlet elbows can be removed, then air flushing can take place to remove the nitrogen. When the atmosphere into the reactors has been proven suitable, inspection and cleaning can take place. The few remains of catalyst dusts and scales must be discarded.

Note: Coked catalyst must be unloaded with a slight nitrogen flush and stored in drums without any internal plastic bag.

#### **4.6.2.5 Coarse decoking of the catalyst prior to unloading**

The procedure consists of burning the coke of the whole catalyst load, using the regenerator, before dumping the catalyst.

Prior to the burning, the feed has been cut-off and nitrogen is being circulated in the reaction section. The coke burning cannot be total because combustion will be difficult to sustain when the coke level drops to below 2% wt.

This procedure is longer (about 4 days) than the unloading of coked catalyst but it is safer: the risk of coke ignition is remote. If only one reactor (regenerator) needs be unloaded for inspection purpose, the time required may be found prohibitive. The procedure is justified mainly when unloading the whole catalyst prior to its replacement.

Once the catalyst has been cooled down and the (H<sub>2</sub> + HC) content reduced to less than 0.2% vol. in the reaction and HP absorber section (Refer to 4.4.4 “Normal shutdown”), a procedure similar to the one used for catalyst dry out will be used.

The regeneration section is brought to start-up conditions i.e. Regeneration Compressor (K-1465) running, N2 flow established to the various burning, oxychlorination and calcination zones, heaters on, and temperature of regeneration gas set at approximately 400 °C, with the washing section on stream. But FVs on air injection are closed and catalyst circulation still stopped.

In the reaction section, the Recycle Compressor K-13450 is in service at its maximum capacity for N2 circulation. The H2 rich gas compressor K-13550 is also in service in full recycle through the Antisurge valve, the pressure being set at 9-10 kg/cm<sup>2</sup> (g):

- Fire the reaction section fired heaters (FR-13110/13210/13310/13410) and bring the Reactor (R- 131/132/133/134) inlet temperatures to 300 °C (40deg. C/h).
- Start catalyst circulation.
- When the catalyst circulation is in steady conditions, start the air injection to the burning zones. Set the catalyst flow in function of the temperature rise (DT) in the burning zones.
- Note that as the catalyst is not being re-used, the oxychlorination and the calcination are not needed, and these zones can be kept at about 400 °C.
- Keep the regeneration in service as long as there is a small DT in the burning beds with the catalyst circulation at its maximum and 1st burning zone inlet O2 analyser at 0.7 vol. % O2 and 2nd burning zone outlet O2 analyser at 0.35 vol. % O2.
- When there is no more DT in the burning beds, stop the regeneration, the catalyst circulation and the H2 rich gas compressor.
- Decrease the reactors inlet temperature down to 200 °C, cut-off fire to the reaction fired heaters (FR-13110/13210/13310/13410), and cool down the catalyst beds to 50 °C.
- Then stop the Recycle Compressor (K-13450) and depressurize the reaction section.
- The catalyst can be unloaded from the reactors using the same procedure as per "Coked catalyst unloading". except that there is no need to use nitrogen blanketing in the drums.

When the temperature in the regenerator reaches 50 °C, the catalyst can also be unloaded.

#### **4.6.2.6 On-the-fly catalyst replacement**

This procedure has the advantage of allowing the replacement of the whole catalyst hold-up with fresh catalyst while the unit is running, but obviously cannot be performed if reactors (regenerator) inspection is needed.

This operation is to be carried out on a 24 hours basis and lasts about a week. 4 riggers, 1 foreman, 1 crane operator, 1 fork lift operator are needed.

Material wise 1 crane, 1 mobile hopper, 1 stationary hopper to be positioned above the lock hopper, 1 fork lift, 1 platform to unload the new catalyst drums, and sleeves are necessary. The Lock Hopper (D-1402) is equipped with a catalyst loading nozzle on top and with an unloading connection on the bottom pipe.

The procedure consists of:

- Filling the lock hopper -above the regenerator - with coked catalyst, as per the normal transfer between the surge drum and regenerator.
- Withdrawing the coked catalyst from the lock hopper to drums.
- Loading the fresh catalyst in the lock hopper.
- Proceeding with the transfer of the fresh catalyst to the regeneration upper section.

The details of the operation are as follows:

- The reaction section is in service, preferably at low severity and capacity. The catalyst circulation and the regeneration are also in operation.
- The transfer system is switched to manual mode. When the lock hopper is full, it is isolated and depressurized to atmosphere, then the catalyst is unloaded from the bottom of the lock hopper via the connection on the catalyst leg and transferred through a sleeve to the drums located at ground level. These drums (with no internal plastic bag) are filled-up under nitrogen.
- Then from the catalyst loading device, which has been previously loaded with the exact amount of catalyst and isolated from atmosphere, the lock hopper is loaded with fresh catalyst. The use of a dedicated device of the exact volume of one drum of catalyst and isolable from atmosphere limits the losses of nitrogen and avoids too much moisture to enter the lock hopper. However, other solutions are allowed (stationary hopper with sleeve for instance).

The lock hopper pressure is then equalized with the regenerator and the fresh catalyst is transferred into the regenerator.

As the fresh catalyst is introduced into the regenerator, it must be dried. The regeneration beds temperatures are adjusted to this purpose.

- As the fresh catalyst replaces the coked catalyst in the burning zone, AIC's will tend to close air FCV's. When  $\Delta T$ 's in both burning bed become negative, inhibit the high oxygen content interlock. Keep unchanged the conditions of the reduction chamber check the good operation of the regeneration loop dryer.
- Run the regeneration loop compressor at 50% capacity to allow the burning, oxychlorination and calcination heaters outlet temperatures to be increased.
- Set the burning heater outlet temperature in order to reach 400deg. C in the burning beds.
- Set the oxychlorination and calcination heaters outlet temperatures in order to reach 500 °C - 510 °C in the oxychlorination/calcination zone.
- Maintain oxygen content in the circulating nitrogen at 2 to 5 % volume (to avoid metal sintering).
- It is recommended to decrease, one after the other, the Reactor Inlet Temperatures down to ~ 500 °C as fresh catalyst is entering each reactor.
- Chlorine injection in the feed during this operation is optional to maintain performance if required.
- The above conditions must be maintained until the amount of catalyst withdrawn corresponds to the catalyst inventory of the unit plus 1 batch. Check the last batch of catalyst withdrawn. When the coke content of the incoming catalyst to the upper surge drum is lower than 3% wt then catalyst replacement is considered to be completed and, the regeneration section can be placed on stand-by, in black burning mode, AIR FCV's closed. Otherwise the regeneration conditions are restored (do not forget to reduce O<sub>2</sub> in the section down to 0.8% vol. before introducing coked catalyst in the regenerator).
- The two last batches will be carefully collected and their physical property checked (particle size, specific area, metallic phase dispersion). Depending on the results they can be re-used as make-up.

#### **4.6.2.7 Spent catalyst handling and further treatment**

##### **4.6.2.7.1 Handling**

Spent catalyst can be under of the following forms:

- Carbon burn catalyst: i.e. prior to unloading, the catalyst has been subject to a controlled combustion of the coke deposit. Of course, prior to the carbon burn, hydrocarbons have been swept off the catalyst and the section of the unit involved has been made inert.
- Coked catalyst: only hydrocarbon sweeping and inerting has been performed prior to unloading. In this case unloading must be performed under an inert atmosphere with the catalyst filled drum flushed with a slight nitrogen flow.

Coke free catalyst, provided the burning has been performed thoroughly, presents no more hazard than fresh catalyst for which a MSDS is given in attachment.

Coked catalyst presents no specific hazard provided its temperature is below 50 °C. Higher temperature may induce metal oxidation and ignition of the coke deposit. The higher the temperature and the remaining active area, the greater the risk of ignition. This is the reason for the catalyst filled drum to be nitrogen flushed.

#### **4.6.2.7.2      Further treatment-Noble metal recovery.**

Catalyst metal being a noble metal (Pt) it must be recovered from the used catalyst. This recovery is only applicable after combustion of the coke deposited on the spent catalyst. No oxychlorination is needed in this case. Axens, the manufacturer of the catalyst, can make all necessary arrangement to have this task performed under the best technical and commercial conditions, at the request of the Company.

#### **4.6.2.8    Catalyst circulation - special procedure in case of incident**

##### **4.6.2.8.1      Lift pot plugging**

A lift pot may plug at the beginning of the operation by construction debris or, during the operation, if catalyst agglomerates are formed in the upstream reactor (hydrocracking reactions).

The consequence of the lift pot plugging is the automatic shutdown of the catalyst circulation (high level in the upstream upper hopper, low level in the downstream upper hopper).

The symptoms of plugging are:

- The total lift gas flow is unchanged.
- The PDV on secondary lift gas line tends to open as the level of the downstream upper hopper decreases:
  - either the DP of the lift pipe goes to a maximum if the lift pipe is full of catalyst,
  - or the DP of the lift pipe goes to zero if the lift pipe is empty.

In both cases the catalyst is not circulating.

Note also that plugging of the primary injection conical strainer can decrease and even stop the catalyst circulation since the transmitter related to the lift pipe DP will show a differential pressure higher than the real one, and will tend to close the PDV.

To clean a lift pot, apply the following procedure (See Figure 25 - Lift Pot Unplugging):

- Keep the regenerator in service at reduced capacity, set PDC of the lift A (Regenerator to 1st reactor) in manual at about 0.1 kg/cm<sup>2</sup>. Of course during the period of lift pot unplugging, the level of the first upper hopper will increase.
- Close the special tight manual valve under the reactor upstream the plugged lift pot.
- Stop the lifts not involved in the plugging when the level in the upper hoppers are at 80%.
- Open fully the PDV of the plugged lift during one minute to try to empty the lift pipe.
- Close the PDV (secondary lift gas) manually and close the block valves.
- Close the FV (primary lift gas) manually and close the block valves.
- Close the special tight manual valves on the lift pipe. The lift is now completely isolated.
- Depressurize the lift pot.
- Remove the primary injection nozzle and collect the catalyst in a bucket.
- Check the nozzle and clean the conical strainer.
- Inspect visually the internal of the lift pot to check if it is clean.
- Connect a nitrogen nozzle to the drain valve of the PDV and flush the secondary injection several times.
- Reinstall the primary injection nozzle and strainer. Tighten the flanges.
- Pressurize the lift pot with nitrogen several times to purge the oxygen.
- Open the special tight manual valve on the lift pipe.
- Open the FV in manual mode to obtain the previous value and switch to auto mode.
- Slowly open the special tight manual valve under the reactor. The lift pot will be filled-up and a small deviation will show on the upstream upper hopper.
- Open the PDV in manual mode to obtain the previous DP value and switch to auto mode.
- Start the other lifts.
- Stabilize the catalyst circulation and when all the levels reach their normal value put all the upper hopper LIC's in cascade on the corresponding PDIC's.

#### **4.6.2.8.2      Balance drum filter plugging**

After several upsets of the upstream lift, catalyst scales or fines may plug the filter inside one of the balance drum. The consequence of the filter plugging is a pressure increase in the upstream upper hopper. As the lift PDV will open to maintain the  $\Delta P$ , the pressure in the upstream lift pot will also increase and the  $\Delta P$  in the seal leg between the lift pot and its lower hopper will decrease (See Figure 26). Catalyst circulation will consequently be reduced.

To clean the filter apply the following procedure:

- Keep the regenerator in service at reduced capacity, set the PDIC of lift A in manual at about 0.1 kg/cm<sup>2</sup>. Of course during the period of the balance drum filter unplugging the level of the 1st upper hopper will increase.
- Close the special catalyst tight valve under the reactor upstream of the considered balance drum.
- Stop the lifts not involved in the plugging when the level in the upper hoppers are at 80%.
- Isolate the balance drum by double block valves. Depressurize the vessel, open hand hole, and clean the filter.
- Reinstate the filter and the handhole.
- Restart catalyst circulation.
- Reset cascades between upper hopper level control and PDV.

## 4.7 Sampling Points

### 4.7.1 R41-1

The following are the list of sample points in R41-1:

Item	Location	Service	Analysis	Method	Frequency
S7-1200	FV-1200	Heavy Naphtha to R41-2	Composition	IFP 9301	As required (8)
			Distillation	ASTM D 86	1 per day
			Specific gravity	ASTM D 1298 / D 4052	1 per day
			Total sulfur content (1)	ASTM D 5453 / D 2622	1 per day
			Total chlorine content	ASTM D 4929	As required (8)
			Total nitrogen content	ASTM D 4629	As required (8)
			Bromine number (2)	ASTM D 1159	As required (8)
			Bromine index (2)	ASTM D 2710	As required (8)
			Arsenic content	IFP 9312	As required (8)
			Copper content	ASTM D 6732	As required (8)
			Lead content	IFP 9406	As required (8)
			Mercury content	IFP 9606	As required (8)
			Other metals contaminants (5)	AAS (3) – ICP-MS(4)	As required (8)

S7-1101	FV-1101	R41-T-111 Naphtha Depentanizer Bottom	Composition	IFP 9301	As required (8)
			Distillation	ASTM D 86	As required (8)
			Specific Gravity	ASTM D 1298 / D 4052	As required (8)
S5-1150	FV-1150	R41-D-11150 Naphtha Depentanizer reflux	Composition	IFP 9301	As required (8)
			Distillation	ASTM D 86	As required (8)
			Specific Gravity	ASTM D 1298 / D 4052	As required (8)
S3 1151	PV-1151	R41-D-11150 Naphtha Depentanizer Reflux Drum Off gas	Composition	IFP 9622	As required (8)
S5-1140	FV-1140	C5 Rich cut to Storage	C6 content	Gas Cromatograph	As required (8)
			Soecific Gravity	ASTM D 1298 / D 4052	As required (8)
			True Vapor Pressure	ASTM D 2879	As required (8)
S5-1250	FV-1250	R41-T-112 Naphtha Splitter reflux	Distillation	ASTM D287	1 per day
			API gravity	ASTM D287	1 per day
			Reid Vapor Pressure	ASTM D323	1 per day
			DVPE	ASTM D5191	1 per day
			Sulphur	ASTM D5453	1 per day
S5-135	FV-135	LCN Splitter reflux	Benzene	IFP 9301	1 per day

S7-131	FV-131	Heavy LCN to R41-2	Same analysis as for Heavy Naptha with the following frequencies		
			Total nitrogen content	ASTM D 4629	1 per day
			Bromine number (2)	ASTM D 1159	1 per day
			Bromine index (2)	ASTM D 2710	1 per day

#### 4.7.2 R41-2

The following are the list of sample points in R41-2

Item	Location	Service	Analysis	Method	Frequency
S7-2203	P-R41-2095	Hydrotreated Naptha	Same analysis as for hydrotreatment feed plus the following specific analysis		
			Doctor test	ASTM D 4952	As required (8)
			Reid Vapor Pressure	ASTM D 323	As required (8)
			Total sulfur content (6)	ASTM D5453 / D4045	1 per day
S3-2150	H-R41-2036	Recycle gas	Composition	IFP 9622	As required
			Hydrogen sulfide	Draeger tube CH 29101 or 28101 (7)	1 per day
S3-2251	R41-PV-2250	Sour Gas from R41-D-12250	Composition	IFP 9622	1 per day
			Density	online analyzer	Continuous
			Hydrogen sulfide	Draeger tube CH 28101 or 81 012110 (7)	1 per day
			Mercury content	ASTM D 6350	1 per day

S5-2250	FV-2250	Stripper Reflux	Composition	IFP 9301	As required (8)
			Total sulfur content (6)	ASTM D5453 / D4045	As required (8)
			Specific gravity	ASTM D 1298 / D 4052	As required (8)
			Distillation	ASTM D 86	As required (8)
S7-2010	P-R41-2000	Hydrotreatment Feed	Composition	IFP 9301	As required (8)
			Distillation	ASTM D 86	1 per day
			Specific gravity	ASTM D 1298 / D 4052	1 per day
			Total sulfur content (1)	ASTM D 5453 / D 2622	1 per day
			Total chlorine content	ASTM D 4929	As required (8)
			Total nitrogen content	ASTM D 4629	1 per day
			Bromine number (2)	ASTM D 1159	1 per day
			Bromine index (2)	ASTM D 2710	1 per day
			Arsenic content	IFP 9312	As required (8)
			Copper content	ASTM D 6732	As required (8)
			Lead content	IFP 9406	As required (8)
			Mercury content	IFP 9606	As required (8)
			Other metals contaminants (5)	AAS (3) – ICP-MS(4)	As required (8)

S5-2141	LV-2141	Sour Water from R41-D-12140	Sulfide in water	ASTM D4658-	As required (8)
			NH3	ASTM D1945	As required (8)

#### **Notes for section R41-1 and R41-2**

- (1) ASTM D 5453 is recommended on usual basis. Total sulfur by ASTM D 2622 could be used if necessary for cross-checking.
- (2) Bromine number (g Br<sub>2</sub> / 100g) for high olefin content ; Bromine index (mg Br<sub>2</sub> / 100g) for low olefin content
- (3) Adaptation test of AAS = graphite furnace electrothermal atomic absorption spectrometry
- (4) ICP- MS = Inductively Coupled Plasma with mass spectrometer detection
- (5) Axens can provide support to help for external analysis in IFP laboratories or other specialised laboratories. Specification below available methods quantification limit can be back calculated based on the spent catalyst analysis.
- (6) ASTM D 5453 is recommended on usual basis. Total sulfur by ASTM D 4045 could be used if necessary for cross-checking.
- (7) Depending upon concentration
- (8) Analysis not normally required but may needed to evaluate performance or for possible troubleshooting studies

#### **4.7.3 R41-3**

The following are the list of sample points in R41-3

Item	Location	Service	Analysis	Method	Frequency
S7-3610	P-3166	Stabilized reformate	Composition	IFP 9302	1 per day
			Distillation	ASTM D 86	1 per day
			Specific Gravity	ASTM D 1298 / D 4052	1 per day
			Bromine index (1)	ASTM D 2710	Required if to storage
			Existing gum	ASTM D 381	Required if to storage

<b>Item</b>	<b>Location</b>	<b>Service</b>	<b>Analysis</b>	<b>Method</b>	<b>Frequency</b>
			Potential residue	ASTM D 873	Required if to storage
S3-3591	H-3087/3088	R41-R-13590 A/B Outlet	HCl	Draeger tube 67 28181	As required (1)
S3-3590	H-3103	R41-R-13590 A/B Intlet	HCl	Draeger tube 67 28181	As required (1))
S3-3651	PV-3650	Fuel gas	Composition	IFP 9909	1 per day
S7-3612	P-3159/3160	R41-R-13610 A/B Outlet	HCl	Draeger tube 67 28181	As required (1)
S7-3611	P-3119	R41-R-13610 A/B Intlet	HCl	Draeger tube 67 28181	As required (1)
S5-3650	FV-3650	Depentanizer Reflux	Composition	IFP 9301	As required (1)
			Specific gravity	ASTM D 1298 / D 4052	As required (1)
S3-3653	G-3145	Fuel gas	Composition	IFP 9909	1 per day
S7-3700	FV-3700	Deethanizer Bottom	Composition	IFP 9301	As required (1)
			Specific gravity	ASTM D 1298 / D 4052	As required (1)
S5-3750	FV-3750	Deethanizer Reflux	Composition	IFP 9301	As required (1)
			Specific gravity	ASTM D 1298 / D 4052	As required (1)
S3-3751	PV-3750	Fuel gas	Composition	IFP 9909	1 per day
S4-3450	G-3274	Recycle gas	H2 purity	Online analyser	
			Composition	IFP 9908	1 per day
			Water	Online analyser	
			Hydrogen Sulfide	Draeger tube 67 28041	1 per day
			HCl	Draeger tubeCH29501	1 per day
S5-3850	FV-3850	LPG	LPG sampling method	ASTM D 1265	1 per day
			Composition	IFP 9909	
			Density	ASTM D 1657	1 per week
			Doctor test	ASTM D 4952	As required (1)

<b>Item</b>	<b>Location</b>	<b>Service</b>	<b>Analysis</b>	<b>Method</b>	<b>Frequency</b>
			Copper strip	ASTM D1838	As required (1)
			Total sulfur content (2)	ASTM D 6667 / D 4468	1 per day
			Total chlorine Content (3)	ASTM D 4929 / UOP 930	As required (1)
			H2S and RSH	ASTM D 6228	1 per day
			HCl	Draeger tube CH29501	As required (1)
			C5	IFP 9909	1 per day
			RVP	ASTM D323 / D5191	1 per day
S5-3800	FV-3800	C5	Benzene	IFP 9301	1 per day
S2-3003	BBD-5530	Blowdown from D-130	pH	ASTM D 1293	1 per week
			Conductivity	ASTM D 1125	1 per week
			Phosphates	ASTM D4327	1 per week
			Chloride	ASTM D 512	1 per week
			Total dissolved solid	ASTM D 5907	1 per week
			Hardness	ASTM D 1126	1 per week
S2-3004	MS-6340	Blowdown from E-136	pH	ASTM D 1293	1 per week
			Conductivity	ASTM D 1125	1 per week
			Phosphates	ASTM D4327	1 per week
			Chloride	ASTM D 512	1 per week
			Total dissolved solid	ASTM D 5907	1 per week
			Hardness	ASTM D 1126	1 per week

**Notes for section R41-3**

(1) Analysis not normally required but may needed to evaluate performance or for possible troubleshooting studies

#### 4.7.4 R41-4

The following are the list of sample points in R41-4

Item	Location	Service	Analysis	Method	Frequency
S3-4650	G-4000	Regeneration loop dryer inlet	O2	Online Analyzers IFP 9810 or Refinery GC Analyser	As required (9)
			CO	IFP 9810 or Refinery GC Analyser or Draeger tube CH 19701	As required (9)
			CO2	IFP 9810 or Refinery GC Analyser or Draeger tube CH 23501	As required (9)
			HCl	Draeger tube 67 28181	As required (9)
			SO2	Draeger tube 67 27101	As required (9)
S-4651	G-4021	Regeneration loop dryer outlet	H2O	Moisture analyzer	As required (9)
S3-4161	H-4077	H2 effluent to H2 rich gas KO drum	Composition (10)	Moisture analyzer	As required (9)
S3-4160	H-5001	H2 from PSA	Hydrogen Purity	Gas Cromatography	1 per day
			C1-C5	Gas Cromatography	1 per day
			Olefins	Gas Cromatography	2 per week
			CO+CO2	Draeger tube	2 per week
			H2S	Draeger tube	2 per week
			NH3	Draeger tube	2 per week
			Alogens	Draeger tube	2 per week
S3-4051	H-7520	N2	O2	IFP 9810	As required (9)
			H2	IFP 9810	As required (9)
S6-4601	LV-4601	Washing drum water purge to Neutralization pit	Same analysis and frequency as per S6-4601 Neutralization solution		

S6-460	LV-460	Neutralisation solution	Total sodium	ASTM D 4191	1 per shift
			Alkalinity	ASTM D1121	1 per shift
			Total Solids	ASTM D 5907	1 per day
			pH (4)	pH paper	1 per shift
S8-4020/ 4110	D-1402 / D- 1411	Catalyst (8)	Carbon content	310 CA 220	1 per day for spent catalyst
			Chlorine content	CA 207 / IFP 9303 (5)	1 per day for regenerated and spent catalyst
			Sulfur content	310 CA 220 / IFP 9303 (5)	As required (9)
			Other metals contaminants	ASTM D 7260 (6) or WDX RF (7)	As required (9)
			Specific surface area	ASTM D 3663	As required (9)
S6-4800	RO-4800	Neutralisation solution	Total sodium	ASTM D 4191	1 per shift
			Alkalinity	ASTM D1121	1 per shift
			Total Solids	ASTM D 5907	1 per day
			pH (4)	pH paper	1 per shift

#### Notes for section R41-3 and R41-4

- (1) Bromine index (mg Br<sub>2</sub> / 100g) for low olefin content.
- (2) ASTM D 6667 is recommended on usual basis. Total sulfur by ASTM D 4468 could be used if necessary for cross-checking.
- (3) ASTM D 4929 part B: Oxidative combustion and microcoulometry detection using LPG injection loop.
- (4) To check online analyzer
- (5) To be used on usual basis. WDXRF method IFP 9303 could be used if necessary for cross-checking. WDXRF = Wave-Length Dispersive X-Ray Fluorescence.
- (6) Adaptation test of ASTM D7260 by ICP (Inductively Coupled Plasma)
- (7) Matrix matched calibration.
- (8) From usual practice, only carbon, sulfur and chloride determination are performed in refinery laboratory. Other determinations are seldom required, Axens can provide support to help for external analyses in IFP laboratories or other specialised laboratories.
- (9) Analysis not normally required but may be needed to evaluate performance or for possible troubleshooting studies
- (10) Values to be monitored are the following:
  - H<sub>2</sub> content: 99% vol minimum;

- C2+ content: 0.5% vol maximum;
- HCl: 20 – 80 ppm vol;
- H<sub>2</sub>O: 30 – 100 ppm vol.

#### 4.7.5 R41-5

The following are the list of sample points in R41-5

Item	Location	Service	Analysis	Method	Frequency
S3-5101	H-5004	PSA inlet gas	Composition	Gas Cromatograph	1 per day
			C1-C5	Gas Cromatography	1 per day
			HCl	Draeger tube	2 per week
			CO+CO <sub>2</sub>	UOP 603 or equivalent or Draeger tube	2 per week
			H <sub>2</sub> S	Draeger tube	2 per week
			NH <sub>3</sub>	Draeger tube	2 per week
S3-5102	H-5001	H <sub>2</sub> from PSA	Hydrogen Purity	Gas Cromatography	1 per day
			C1-C5	Gas Cromatography	1 per day
			Olefins	Gas Cromatography	2 per week
			CO+CO <sub>2</sub>	UOP 603 or equivalent or Draeger tube	1 per day
			H <sub>2</sub> S	Draeger tube	2 per week

S3-5102	H-5001	H2 from PSA	NH3	Draeger tube	2 per week
			Alogens	Draeger tube	2 per week
			C5+	Gas Cromatography	2 per week
S3-5103	G-5007	Tail gas	Composition	Gas Cromatograph	1 per week

#### **Notes for section R41-5**

For sampling instructions of unit R41-5 refer section 8.15 in the below document:

**V-202-1420-141-U-01-105\_4C\_0010 - Operating Manual**

#### **4.7.6 R41-9**

**The following are the list of sample points in R41-9**

Item	Location	Service	Analysis	Method	Frequency
S5-2210	P-R41-0010	Hydrotreatment Feed	Composition	IPF 9301	As required (2)
			Distillation	ASTM D 86	1 per day
			Specific gravity	ASTM D 1298 / D 4052	1 per day
			Total sulfur content (1)	ASTM D 5453 / D 2622	1 per day
			Total chlorine content	ASTM D 4929	As required (2)
			Total nitrogen content	ASTM D 4629	1 per day
			Bromine number (2)	ASTM D 1159	1 per day

S5-2210	P-R41-0010	Hydrotreatment Feed	Bromine index (2)	ASTM D 2710	1 per day
			Arsenic content	IFP 9312	As required (2)
			Copper content	ASTM D 6732	As required (2)
			Lead content	IFP 9406	As required (2)
			Mercury content	IFP 9606	As required (2)
			Other metals contaminants (5)	AAS (3) – ICP-MS(4)	As required (2)
S5-2212	P-R41-0009	Non Aromatic Purge	Composition	IFP 9301	As required (2)
S5-131	P-R41-0008	LCN Feed	Composition	IFP 9301	As required (2)
			Distillation	ASTM D 86	1 per day
			Specific gravity	ASTM D 1298 / D 4052	1 per day
S5-1120	P-R41-0004	SR Run Naphtha	Composition	IFP 9301	As required (2)
			Distillation	ASTM D 86	1 per day
			Specific gravity	ASTM D 1298 / D 4052	1 per day
S5-9067	CD-R41-8014	Closed Drain Minimum Flow Line	H2O	Moisture analyzer	As required (2 )

#### Notes for section R41-9

- (1) ASTM D 5453 is recommended on usual basis. Total sulfur by ASTM D 2622 could be used if necessary for cross-checking.
- (2) Analysis not normally required but may be needed to evaluate performance or for possible troubleshooting studies

#### **4.7.7 Description of IFP/Axens analytical methods**

IFP 9301	Petroleum Naphta Detailed Analysis Capillary gas chromatography
IFP 9406	Lead content (feed, desulphurized heavy naphtha)
IFP 9606	Mercury content (feed, desulphurized heavy naphtha)
IFP 9810	Catalytic cracked gas - Analysis of Hydrogen, Nitrogen, Oxygen, Carbon oxides, Hydrogen sulphide, ammonia and hydrocarbons. Gas Chromatography
IFP 9312	Petroleum products analysis Determination of Arsenic (feed, desulphurized heavy naphtha)
IFP 9622	Hydrotreating gas analysis of hydrogen, hydrocarbons, air, water and hydrogen sulphide gas chromatography
IFP 9302	Stabilized reformate effluent Detailed analysis Capillary gas chromatography
IFP 9303	Alumina-based catalysts Determination of chlorine and sulfur Wave length dispersive x-ray fluorescence
IFP 9860	Petroleum products P.Cresol, Phenols and thiophenols UV Spectrophotometry
IFP 9908	Reforming gas analysis of hydrogen and low hydrocarbons content gas chromatography
IFP 9909	Reforming gas analysis of hydrocarbons and low hydrogen content gas chromatography
310 CA 207	Determination of chloride ions in used catalyst Potentiometric titration
310 CA 220	Determination of total sulfur and carbon in used catalyst Infra-red analysis of combustion products

#### **Analysis Methods and Frequency**

1. The methods nominated “ASTM D-” are copyrighted by ASTM International (“ASTM”), 100 Barr Harbor Drive, West Conshohocken, PA 19428-2959 USA; <http://astm.org/>  
Current copies of these methods (“Active Standards”) must be obtained from this organization.
2. The frequencies given above are routine related to a normal operation. During start-up and test runs more analyses **is** required.

## **4.8 Analytical**

### **4.8.1 Introduction**

During start up and performance testing many more samples to be taken than are indicated here to obtain the required information.

After the plant commences normal operation, the sampling schedule may change both in frequency and samples taken due to a better knowledge of the process and confidence.

### **4.8.2 Sampling Procedure And Frequency**

Reference P&IDs:

- Piping & Instrumentation diagram R400 Sampling Details (1/4) Common (D-EP-R400-1225-1010)
- Piping & Instrumentation diagram R400 Sampling Details (2/4) Common (D-EP-R400-1225-1011)
- Piping & Instrumentation diagram R400 Sampling Details (3/4) Common (D-EP-R400-1225-1012)
- Piping & Instrumentation diagram R400 Sampling Details (4/4) Common (D-EP-R400-1225-1013)

Refer to section 4.7 for sampling procedure & frequency.

### **4.8.3 Sampling Procedure And Safety Precautions**

Samples must be taken and labelled properly. When taking samples and analyzing, following the appropriate procedures is of great importance in order to evaluate the performance of the unit.

#### **Basic Steps**

These are some of the steps and guides to be followed when samples are being taken. After being notified that a sample must be taken, the following steps must be followed:

- Make certain that the labels to be used for sample identification are correct.
- The appropriate containers for each sample must be available, and must be clean and dry.
- When sampling requires the use of a rope, use cotton rope rather than nylon in order to avoid static.
- When sampling a high risk product such as acid or caustic, full protection garment is to be used by operator. Operator must be familiar with the location of the nearest safety showers and eye washers.

- When sample is to be taken from a tank, the operator must eliminate the static risk before climbing the tank by touching bare hand a steel step of the ladder for his body to be grounded.
- Locate yourself upwind from the sample in order to avoid inhaling vapor or smoke.
- Avoid splattering of the sampled product and immediately clean any spillages.
- Do not allow any product to spill to grade or the container to be overfilled. Do not let any container open to avoid rain water to cause an overfill.
- Replace any cap or flange that had been removed for sample taking.

### **General Sampling Guides**

For the good operation of a process unit, it is of vital importance keeping track of the quality of the streams that enter and exit the unit. This can be achieved by specific analysis and product sampling. The samples to be taken must be representative of what is happening in a process and they need to be taken following procedures that ensure homogeneity and safety in the sampling. The procedures explained below are general guidelines that do not intend to modify or supersede the standard refinery practices Required Equipment And Materials

- Adequate personal protection equipment (clothing, boots, gloves, helmet, goggles, face masks, ear protection, portable H<sub>2</sub>S detectors...).
- Firefighting equipment (fire water network, first aid kit...)
- Communication devices (portable radios with extra battery).
- Tools if required.
- Sampling containers (cylinders, bottles, cans...).
- Labeling material for sample identification.
- All personnel must be familiarized with the location and operation of safety and firefighting equipment, the escape routes and the emergency evacuation.

#### **4.8.3.1 General Procedures**

- In case the sample connection has a cooling device, water flow should be adjusted to cool as much as possible but still maintain product fluidity.
- Flush the facilities to process for applicable sample points or to flare/closed drain. Flushing to be done for the duration of 2 to 5 minutes.
- Once the facilities is flushed, block and proceed to take the sample. If using bottles for sampling, care must be taken with potential splattering so aprons and face masks tol be used. In case of using pressure

- containers for sampling, once installed, proceed to let the fluid flow by opening the outlet valves and then the inlet valves. After 1 or 2 minutes, close the outlet valves and then close the inlet valves.
- Before removing the sample container, depressurize the facilities to flare or to closed drain system in order to remove material accumulated between the inlet valves and the container. Once done this, take the container with the sample.

#### 4.9 DOPAK® Sampling

The sampling systems handling benzene and very toxic services, DOPAK® system for sampling is considered (This upgradation from conventional type to DOPAK® system has been done based on instruction by COMPANY through Letter L-PMT-RP2-1376 and further technical alignment L-PMT-RP2- 1563. Reference Change Order request No. 067 – Dopak Benzene Analysing system)

DOPAK® sampling systems is provided for 29 samplers working in benzene and very toxic service.

It allows the operator to be shielded from contact with the product being sampled. Also local spillage can be avoided and volatile substances are prevented from escape into the atmosphere. Safety in the widest sense is highly improved.

The below mentioned are the list of sampling systems for which DOPAK® system is considered.

PROCESS CONDITIONS											SAMPLER CONFIGURATION
POS	Type	P&ID	Tag	PHASE	Vapor pr. (Bar)	NACE	Op. Temp °C	DT °C	Op. Pr Bar	DP Bar	Dopak Sampler type
1	S3	1208	2150	GAS		YES	46	76	21.2	27.0/ FV	S32 1000/0-1 G (G1) W83
2	S3	1215	2251	GAS		YES	40	136	9.7	13.5/HV@ 149°C	S32 1000/0-1 G (G1) W83
3	S4	1312	3450	GAS			129	159	6.2	9.4	S32 1000/0-1 G (G1) W83
4	S5	1207	2141	LIQUID	0.1	YES	46	120	21.7	27.8	S23 900-1000-1 W83 (D1)

5	S5	1215	2250	L/G	10.7	YES	40	70	15.5	20.2	S32 1000/0-1 LG (F3) W83
6	S5	1901	2212	L/G	3.1		50	160	14.7	16.2	S32 1000/0-1 LG (F3) W83
7	S5	1901	131	L/G	1.8		61	100	6.7	7.7 / HV@149°C	S32 1000/0-1 LG (F3) W83
8	S7	1112	131	LIQUID	0.7		71	101	8.5	11.2	S23 900-1000-1 W83 (D1)
9	S7	1322	3612	L/G	25.4		106	136	27.9	38.9	S32 1000/0-1 LG (F3) W83
10	S7	1322	3611	L/G	25.4		106	136	27.9	38.9	S32 1000/0-1 LG (F3) W83
11	S7	1323	3610	L/G	1		107	137	13.7	17.6/HV@149°C	S32 1000/0-1 LG (F3) W83
12	S7	1101	1110	L/G	1.1		107	137	4.0	7.1	S32 1000/0-1 LG (F3) W83
13	S7	1104	1150	L/G	1		85	115	10.0	16	S32 1000/0-1 LG (F3) W83

## **Equipment Information**

## **5 EQUIPMENT INFORMATION**

### **5.1 General Equipment Information**

In this section, all the equipment are listed with individual name and tag numbers.. For additional information of each equipment refer to "Equipment List of Naphtha Reformer" Doc.No. S-EP-R41-1224-0001

<b>Equipment Type</b>	<b>Tag Number</b>	<b>Equipment Name</b>
<b>Reactors</b>		
	R-121	Hydrotreating Reactor
	R-131	First Reactor
	R-132	Second Reactor
	R-133	Third Reactor
	R-134	Fourth Reactor
	R-13590A/B	Hydrogen Rich Gas Chloride Adsorbers
	R-13610A/B	Depentanizer Feed Chloride Adsorbers
	R-140	Regenerator
<b>Columns</b>		
	T-111	Naphtha Depentanizer
	T-112	Naphtha Splitter
	T-113	LCN Splitter
	T-122	NHT Stripper
	T-136	Depentanizer Column
	T-137	Deethanizer Column
	T-138	Debutanizer Column
<b>Vessels</b>		
	D-11150	Naphtha Depentanizer Reflux Drum
	D-11250	Naphtha Splitter Reflux Drum
	D-1135	LCN Splitter Reflux Drum
	D-12140	Separator Drum
	D-1215	Recycle Compressors Ko Drum
	D-12010	Feed Surge Drum
	D-12250	Stripper Reflux Drum
	D-12160	Sour Water Drum
	D-1750	Fuel Gas Ko Drum
	D-13450	Separator Drum

<b>Equipment Type</b>	<b>Tag Number</b>	<b>Equipment Name</b>
	D-135	H2 Rich Gas Compressor Ko Drum
	D-1353	First Interstage Drum
	D-13580	HP Absorber Drum
	D-136100	LPG Absorber Drum
	D-13550	Second Interstage Drum
	D-13650	Depentanizer Reflux Drum
	D-13750	Deethanizer Reflux Drum
	D-13850	Debutanizer Reflux Drum
	D-130	Steam Drum
	D-1301	Continuous Blowdown Drum
	D-1751	Fuel Gas Ko Drum
	D-1401	Upper Surge Drum
	D-1402	Lock Hopper
	D-1403	First Lower Hopper
	D-1404	First Lift Pot
	D-1405	Nitrogen Compressor Ko Drum
	D-1406	Nitrogen Storage Drum
	D-1411	First Upper Hopper
	D-1412	Reduction Chamber
	D-1413	Second Lower Hopper
	D-1414	Second Lift Pot
	D-1421	First Balance Drum
	D-1422	Second Upper Hopper
	D-1423	Third Lower Hopper
	D-1424	Third Lift Pot
	D-1431	Second Balance Drum
	D-1432	Third Upper Hopper
	D-1433	Fourth Lower Hopper
	D-1434	Fourth Lift Pot
	D-1441	Third Balance Drum
	D-1442	Fourth Upper Hopper
	D-1443	Fifth Lower Hopper
	D-1444	Fifth Lift Pot
	D-1460	Washing Drum

<b>Equipment Type</b>	<b>Tag Number</b>	<b>Equipment Name</b>
<b>Air Fin Coolers</b>	D-1472	Air Dryer Drum
	D-1501	PSA Feed Coalescer
	D-181	LP Flare Ko Drum
	D-182	HP Flare Ko Drum
	D-1630	MP Condensate Flash Drum
	D-1640	LP Condensate Flash Drum
	D-1000	Closed Drain Drum
<b>Exchangers</b>		
	E-1115	Naphtha Depentanizer Air Condenser
	E-1125	Naphtha Splitter Air Condenser
	E-1135	LCN Splitter Air Condenser
	E-1212	Reactor Effluent Air Condenser
	E-1225	Stripper Air Condenser
	E-1222	Hydrotreated Naphtha Air Cooler
	E-13410	Reactor Effluent Air Cooler
	E-1351	First Interstage Air Cooler
	E-1353	Second Interstage Air Cooler
	E-13650	Depentanizer Air Cooler
	E-1363	Sr Naphtha Tank Rundown Air Cooler
	E-1114A/B	C5 Rich Cut Trim Coolers
	E-111	Naphtha Depentanizer Reboiler
	E-1116	Naphta Depentanizer Trim Cooler
	E-1126A/B	Light Naphtha Trim Coolers
	E-112A/B	Naphtha Splitter Reboilers
	E-1111A/B	Naphtha Depentanizer Feed/Naphtha Splitter Bottom Exchangers
	E-1112	Naphtha Preheater
	E-1136A/B	Light LCN Trim Coolers
	E-113	LCN Splitter Reboiler
	E-1131A/B	LCN Splitter Feed/Bottom Exchangers
	E-12110A/G	Reactor Feed / Effluent Exchangers
	E-12110B/H	Reactor Feed / Effluent Exchangers
	E-12110C/J	Reactor Feed / Effluent Exchangers
	E-12110D/K	Reactor Feed / Effluent Exchangers

<b>Equipment Type</b>	<b>Tag Number</b>	<b>Equipment Name</b>
	E-12110E/L	Reactor Feed / Effluent Exchangers
	E-12110F/M	Reactor Feed / Effluent Exchangers
	E-1213A/B	Reactor Effluent Trim Condensers
	E-1226A/B	Stripper Trim Condensers
	E-1221A/B/C	Stripper Feed / Bottom Exchangers
	E-1223A/B	Hydrotreated Naphtha Trim Coolers
	E-13110	Reformer Feed/Effluent Exchanger
	E-1342A/B	Reactor Effluent Trim Coolers
	E-1352 A/B	First Interstage Trim Cooler
	E-13550A/B	HP Absorber Feed Coolers
	E-1356	H2 Rich Gas / Hp Absorber Feed Exchanger
	E-1357	HP Absorber Feed / Bottom Exchanger
	E-1354	Second Interstage Trim Cooler
	E-1366 A/B/C/D	Depentanizer Trim Coolers
	E-136	Depentanizer Bottom Steam Generator
	E-1362	Depentanizer Feed Bottom Exchanger B
	E-13610	Depentanizer Feed Bottom Exchanger A
	E-1364 A/B	Sr Naphtha Tank Rundown Trim Coolers
	E-1375	Deethanizer Condenser
	E-137	Deethanizer Reboiler
	E-13850	Debutanizer Condenser
	E-138	Debutanizer Reboiler
	E-1381	Deethanizer Feed / Debutanizer Bottom Heat Exchanger
	E-1382A/B	C5 Cut Trim Coolers
	E-1301	Blowdown Cooler
	E-1405	Nitrogen Loop Trim Cooler
	E-1406	Nitrogen Storage Trim Cooler
	E-1416	Reduction Exchanger
	E-1417	Hydrogen Lift Gas Exchanger
	E-1468	Calcination Feed / Effluent Exchanger
	E-1466	Burning Feed/Effluent Exchanger
	E-1460	Regeneration Loop Trim Cooler
	E-152	Tail Gas After Cooler
	E-1465	Regeneration Compressor Trim Cooler

<b>Equipment Type</b>	<b>Tag Number</b>	<b>Equipment Name</b>
	E-1451 A/B	Demineralized Water Cooler
<b>Furnaces</b>		
	FR-12110	Reactor Feed Heater
	FR-122	Stripper Reboiler
	FR-13110	Preheater
	FR-13210	First Interheater
	FR-13310	Second Interheater
	FR-13410	Third Interheater
	FR-130-SG	Reformer Furnace Convection Section Waste Heat Boiler
	FR-13110E	Convection Reboiler Coil
<b>Pumps</b>		
	P-1115A/B	Naphtha Depentanizer Reflux Pumps
	P-1114A/B	C5 Rich Cut Pumps
	P-1125A/B	Naphtha Splitter Reflux Pumps
	P-1120A/B	Heavy Naphtha Pumps
	P-1135A/B	LCN Splitter Reflux Pumps
	P-1130A/B	Heavy LCN Pumps
	P-1201A/B	Feed Pumps
	P-1225A/B	Stripper Reflux Pumps
	P-122A/B/C	Stripper Bottom Product Pumps
	P-13450A/B	Separator Bottom Pumps
	P-13610A/B	LPG Absorber Bottom Pumps
	P-13650A/B	Depentanizer Reflux Pumps
	P-1366A/B	Depentanizer Distillate Pumps
	P-136A/B	Depentanizer Reboiler Pumps
	P-1375A/B	Deethanizer Reflux Pumps
	P-13850A/B	Debutanizer Reflux Pumps
	P-130A	BFW Circulation Pumps
	P-130B	BFW Circulation Pumps
	P-1460A/B	Caustic Recycle Pumps
	P-1461A/B	Washing Water Pumps
	P-1480 A	Caustic Sump Pit Pump
	P-181A/B	LP Flare Condensate Pumps
	P-1030 A/B/C	Intermediate Sys Lift Station Pump

<b>Equipment Type</b>	<b>Tag Number</b>	<b>Equipment Name</b>
<b>Compressors</b>	P-1040 A/B	SYS Lift Station Pumps
	P-182A/B	HP Flare Condensate Pumps
	P-1640A/B	Hot Condensate Pumps
	P-1000	Closed Drain Pump
	P-1010A/B	OWS Lift Station Pumps
	P-1020A/B/C	SYS Lift Station Pumps
	P-1001	Oily Water Drain Pump
<b>Compressors</b>	K-1215A/B	Recycle Compressors
K-1215 A/B (Sub items)	K-1215 A/B (Sub items)	R41-KM-1215 A/B-P-04 - Jacking oil pump R41-K-1215 A/B-PD-01 Pulsation Suppressor Inlet (Left side) R41-K-1215 A/B -PD-02 Pulsation Suppressor Outlet (Left side) R41-K-1215 A/B -PD-03 Pulsation Suppressor Inlet (Right side) R41-K-1215 A/B -PD-04 Pulsation Suppressor Outlet (Right side) LO console R41-K-1215 A/B-P01 Main Lube oil Pump Driven By Comp Crankshaft R41-K-1215 A/B-P-02 Aux Oil Pump Driven by Electric Motor R41-K-1215 A/B-E-02 Oil Cooler R41-K-1215 A/B-F-01 A/B Oil Filter (Duplex) R41-K-1215 A/B-E-01 Oil Electric Heater CCW Console (COMMON for R41-K-1215 A/B) R41-K-1215 -D-01 Cooling Water Reservoir R41-K-1215 -P-03A Main Cooling Water Pump Driven by Electric Motor R41-K-1215 -P-03B Auxiliary Cooling Water Pump Driven by Electric Motor R41-K-1215 -E-03 Electric Heater R41-K-1215 -E-04 A/B Heat Exchanger (Duplex) R41-K-1215 -F-02 A/B Filter (Duplex)
		K-13450
		Recycle Compressor
		Steam turbine for Recycle Compressor R41-ST-13450
		LO Unit
		K-13450-D-01 Oil reservoir
		R41-K-13450-P-01 A/B Oil (LO & CO) Pumps
		R41-K-13450-E-02 A/B Oil Cooler
		R41-K-13450-F-01 A/B Duplex Oil Filters
		R41-K-13450-D-03 Accumulator
		R41-K-13450-E-03 Oil Electrical Heater
		R41-K-13450-D-02 LO Rundown Tank
		R41-K-13450-E-01 Gland Condenser for R41-ST-13450

<b>Equipment Type</b>	<b>Tag Number</b>	<b>Equipment Name</b>
		<p>R41-K-13450-EJ-01 Ejector  R41-K-13450-SL-01 Ejector Silencer  R41-K-13450-D-05 Condensate Seal Tank</p> <p>Seal Gas System  R41-K-13450-F-02 A/B Primary Seal Gas Filter  R41-K-13450-F-03 A/B Buffer Gas Filter</p> <p>R41-K-13450-E-04 Main Surface Condenser</p> <p>Vacuum System Package :  R41-K-13450-E-05/06 Ejector Condensers (Inter/After)  R41-K-13450-EJ-02 A/B Stage 1 Ejectors  R41-K-13450-EJ-03 A/B Stage 2 Ejectors  R41-K-13450-EJ-04 Start-up Ejector  R41-K-13450-SL-02 Ejector Silencer</p> <p>R41-K-13450-P-02 A/B Condensate Transfer Pumps</p>
	K-135	<p>H2 Rich Gas Compressor (1st Stage)</p> <p>H2 Rich Gas Compressor (2nd Stage)</p>
	K-135 (Sub items)	<p>Steam Turbine for H2 Rich gas Compressor R41-ST-135</p> <p>Common LO Unit for K-135 &amp; K-13550  R41-K-135-D-01 Oil reservoir  R41-K-135-P-01 A/B Oil (LO &amp; CO) Pumps  R41-K-135-E-02 A/B Oil Cooler  R41-K-135-F-01 A/B Duplex Oil Filters  R41-K-135-D-03 Accumulator  R41-K-13550-D-03 Accumulator  R41-K-135-E-03 Oil Electrical Heater  R41-K-135-D-02 LO Rundown Tank</p> <p>R41-K-135-E-01 Gland Condenser for R41-ST-135  R41-K-135-EJ-01 Ejector  R41-K-135-SL-01 Ejector Silencer  R41-K-135-D-04 Condensate Seal Tank</p> <p>Seal Gas System  R41-K-135-F-02 A/B Primary Seal Gas Filter  R41-K-135-F-03 A/B Buffer Gas Filter</p> <p>R41-K-135-E-04 Main common Surface Condenser</p> <p>Common Vacuum System Package:  R41-K-135-E-05/06 Ejector Condensers (Inter/After)  R41-K-135-EJ-02 A/B Stage 1 Ejectors</p>

<b>Equipment Type</b>	<b>Tag Number</b>	<b>Equipment Name</b>
		R41-K-135-EJ-03 A/B Stage 2 Ejectors R41-K-135-EJ-04 Start-up Ejector R41-K-135-SL-02 Ejector Silencer
	K-13550	R41-K-135-P-02 A/B Common Condensate Transfer Pumps
		H2 Rich Gas Compressor (3rd Stage)
	K-13550 (Sub items)	Steam Turbine for H2 Rich Gas Compressor R41-ST-13550  R41-K-13550-E-01 Gland Condenser for R41-ST-13550 9 R41-K-13550-EJ-01 Ejector R41-K-13550-SL-01 Ejector Silencer R41-K-13550-D-03 LO Rundown Tank R41-K-13550-D-01 Condensate Seal Tank  Seal Gas System for 2nd & 3rd stage R41-K-13550-F-02 A/B Primary Seal Gas Filter R41-K-13550-F-03 A/B Bufferl Gas Filter For common items see K-135 sub items
	B-14150	Elutriation Blower
	K-1405A/B	Nitrogen Compressors
	K-1405A/B (sub items)	R41-K-1405 A/B-PD-01 Pulsation Suppressor Inlet R41-K-1405 A/B-PD-02 Pulsation Suppressor Outlet R41-K-1405 A/B-E-01 Electric Heater for Lube Oil R41-K-1405 A/B-P-01 A Main Lube Oil Pump Driven by Comp. Crankshaft R41-K-1405 A/B-P-01 B Auxiliary Lube Oil Pump Driven by Electric Motor R41-K-1405 A/B-F-01 Lube Oil Filter R41-K-1405 A/B-E-02 Lube Oil Cooler
	K-1465	Regeneration Loop Compressor
	K-1465 A/B (Sub items)	LO Unit R41-K-1465-D-01 Oil reservoir R41-K-1465-P-01 A/B Oil (LO & CO) Pumps R41-K-1465-E-01 A/B Oil Cooler R41-K-1465-F-01 A/B Duplex Oil Filters R41-K-1465-E-02 Oil Electrical Heater R41-K-1465-D-02 LO Rundown Tank  Seal Gas System R41-K-1465-F-02 A/B Primary Seal Gas Filter R41-K-1465-F-03 A/B Buffer Gas Filter
	K-1470	Air Compressors
	K-1470 A/B	R41-K-1470-E-01 1st Stage Intercooler

<b>Equipment Type</b>	<b>Tag Number</b>	<b>Equipment Name</b>
	(Sub items)	R41-K-1470-E-02 2nd Stage Intercooler Lube Oil System R41-K-1470-D-01 Lube Oil reservoir R41-K-1470-P-01A/B Lube Oil Pumps (Main shaft driven and Aux Mot driven) R41-K-1470-E-04 Oil Cooler R41-K-1470-F-02A/B Duplex Lube Oil Filters R41-K-1470-E-05 Lube Oil Electrical Heater  R41-K-1470-E-03-After cooler R41-K-1470-SL-01:Blow Off Valve Silencer R41-K-1470-F-01 Inlet Air Filter
	K-152A/B	PSA Tail Gas Compressors
	K-152 A/B (Sub items)	R41-K-152 A/B-D- 02 - Seal Oil Reservoir R41-K-152 A/B-P- 03A/B - Seal Oil Pump R41-K-152 A/B SL - Discharge Silencer R41-K-152 A/B-B- 01A/B - Ventilation Fan A/ Ventilation Fan B Oil Separator Skid R41-K-152 A/B-D-01 - SEPARATOR R41-K-152 A/B-P-01A/01B - Oil Pump R41-K-152 A/B-E-02 - Heater R41-K-152 A/B-P- 04 - Fill Pump Oil Cooler Skid R41-K-152 A/B-E-01 A/B - Oil Cooler R41-K-152 A/B-F-01 A/B - Oil Filter Lube Oil Skid R41-K-152-D-03 - Oil Reservoir for Electric Motor Lube oil system R41-K-152-P-02 A/B - LO pumps (main and auxiliaries) for Electric Motor Lube oil system R41-K-152-E-03 - Oil Cooler for Electric Motor Lube oil system R41-K-152-F-02 A/B - Oil Filters for Electric Motor Lube oil system R41-K-152-E-04 - Oil Electrical Heater for Electric Motor Lube oil system
<b>Packages</b>		
	Z-1201	DMDS Package: R41-Z-1201-T1 Sulphiding Agent Drum R41-Z-1201-P1A / P1B Sulphiding Agent Injection Pumps
	Z-1225	Corrosion Inhibitor Injection Package: R41-Z-1225-T1 Corrosion Inhibitor Drum R41-Z-1225-P1A / P1B Corrosion Inhibitor Injection Pumps
	Z-1312	H2O Injection Package: R41-Z-1312-T1 Water Injection Tank

<b>Equipment Type</b>	<b>Tag Number</b>	<b>Equipment Name</b>
		R41-Z-1312-P1A / P1B Water Injection Pumps
	Z-1313	DMDS Injection Package: R41-Z-1313-T1 Sulphiding Agent Drum R41-Z-1313-P1A / P1B Sulphiding Agent Injection Pumps
	Z-1314	Chloride Injection Package R41-Z-1314-T1 Chloriding Agent Drum R41-Z-1314-P1A / P1B Chloriding Agent Injectin Pumps
	Z-1301	Phosphate Injection Package R41-Z-1301-T1 Phosphate Injection Tank R41-Z-1301-P1A / P1B Phosphate Injection Pumps
	PK-1461	Recirculation Package (future)
	Z-1460	Caustic Package R41-Z-1460-T1 Caustic Solution Tank R41-Z-1460-P1A / P1B Caustic Injection Pumps
	Z-1469	Chlorination Agent Package R41-Z-1469-T1 Chlorination Agent Drum R41-Z-1469-P1 Chlorination Agent Injectin Pumps
	Z-1468	Oxychlorination Water Package R41-Z-1468-T1 Oxychlorination Water Tank R41-Z-1468-P1A / P1B Oxychlorination Water Pumps
	PK-1510	PSA Unit Package
	PK-1510 (Sub items)	R41-PK-1510-T-01-A to R41-PK-1510-T-01-J Adsorber Vessels R41-PK-1510-T-02 Tail Gas Drum R41-PK-1510-F-01 Hydrogen Filter
	RU-13580A/B	Refrigeration Packages A/B
	RU-13580 A/B (Sub items)	R41-RU-13580-K-01 A/B Screw Compressors R41-RU-13580-P01 A/B & P02 A/BScrew Pumps for Compressor Two Compressor Lube Oil Consoles Two MV Motor Lube Oil consoles R41-RU-13580-F-01A/B & F02 A/B Oil Filter R41-RU-13580-E-03 & E04 Oil Cooler R41-RU-13580-D-02 Oil Separator R41-RU-13580-E-06 Oil Separator Electric Heater R41-RU-13580-E-01 HP Absorber Chiller R41-RU-13580-E-02 Refrigerant Condenser R41-RU-13580-D-01 Refrigerant Accumulator R41-RU-13580-E-05 Economizer R41-RU-13580-D-05 & D-06 Motor Bearing Oil Tank R41-RU-13580-E-07 & E-08 Motor Bearing Oil Cooler R41-RU-13580-F03 A/B & F04 A/B Motor Bearing Oil Filter R41-RU-13580-P03 A/B & P04 A/B Lube Oil Pumps for MV Motor
		Miscellaneous
	DR-1465	Regeneration Loop Dryer
	DR-1465 (Sub	R41-DR-1465-D02 A/B Adsorber

<b>Equipment Type</b>	<b>Tag Number</b>	<b>Equipment Name</b>
	items)	R41-DR-1465-D01 Inlet Coalescer R41- DR-1465-E01 Regeneration heater R41- DR-1465-E02Regeneration Cooler R41-DR-1465-D03 Regeneration K O Drum
	DR-1472	Air Dryer
	DR-1472 (Sub items)	R41-DR-1472-D-01A/B Dryer vessels R41-DR-1472-F-01 Pre filter R41-DR-1472-F-02 After filter
	E-14150	First Upper Hopper Finned Tube Exchanger
	E-1412	Reduction Heater
	E-1467	Burning Heater
	E-1469	Oxychlorination Heater
	E-1473	Calcination Heater
	F-13110A/B	Feed Filters
	F-1405	Upper Surge Drum Fines Filter
	F-14150	First Upper Hopper Fines Filter
	F-1465	Regeneration Loop Filter
	F-1720A/B	Instrument Air Filters
	M-1460	Caustic Static Mixer
	M-1464	Chlorination Agent Static Mixer
	Z-1461 (Part of M-1460)	Caustic Spray Injection Nozzle
	Z-1480	Caustic Sump Pit
	Z-1010	OWS Lift Station Sump
	Z-1020	Sys Lift Station Sump
	Z-1030	Intermediate Sys Lift Station
	Z-1040	Sws Lift Station
	EJ-1215	Start-Up Ejector
	231-G-101	Emergency Diesel Generator
	239-G-101	Emergency Diesel Generator

## 5.2 Standby Equipment

Below table illustrate the standby equipment for Naphtha Reformer Unit.

K-1215B	NHDT Recycle compressor B
K-1215-P-03B	Auxiliary Closed Cooling Water Pump for NHDT Recycle Compressor A & B
K-1215A-P-02	Auxiliary Lube Oil Pump for NHDT Recycle Compressor A
K-1215B-P-02	Auxiliary Lube Oil Pump for NHDT Recycle Compressor B
KM-1215B-P-04	NHDT Recycle compressor B Motor Jacking oil pump
K-13450-P-01B	Oil (LO & CO) Pump for Recycle Compressor
K-13450-P-02B	Condensate Transfer Pump
K-135-P-01B	Oil (LO & CO) Pump for 1st & 2nd Stg H2 Rich Gas Compressor
KT-135-P-02B	Common Condensate Transfer Pump
K-1405B	Nitrogen Compressor B
R41-K-1405 A-P01B	Auxiliary Lube Oil Pump Driven by Electric Motor
R41-K-1405 B-P01B	Auxiliary Lube Oil Pump Driven by Electric Motor
K-1465-P-01B	Oil (LO & CO) Auxiliary Lube Oil Pump for Regeneration Loop Compressor
K-1470-P-01B	Auxiliary Lube Oil Pump for Air Compressor
P-1115B	Naphtha Depentanizer Reflux Pump B
P-1114B	C5 Rich Cut Pump B
P-1125B	Naphtha Splitter reflux Pump B
P-1120B	Heavy Naphtha Pump B
P-1135B	LCN Splitter Reflux Pump B
P-1130B	Heavy LCN Pump B
P-1201B	Feed pump B
P-1225B	Splitter reflux Pump B
P-122C	Stripper Bottom Product Pump C
P-13450B	Separator Bottom Pump B
P-13610B	LPG absorber Bottom Pump B
P-13650B	Depentanizer reflux Pump B
P-1366B	Depentanizer Distillate Pump B
P-136B	Depentanizer reboiler Pump B
P-1375B	Deethanizer reflux Pump B
P-13850B	Debutanizer reflux Pump B
P-130B	BFW Circulation Pump
P-1460B	Caustic Recycle Pump B
P-1461B	Washing water Pump B

P-181B	LP Flare Condensate Pump B
P-182B	HP Flare Condensate Pump B
P-1640B	Hot Condensate Pump B
P-1010B	OWS Lift Station Pump B
P-1020C	SYS Lift Station Pump C
P-1030C	Intermediate SYS Lift Station Pump C
P-1040B	Sanitary Lift Station Pump B
Z-1201-P-01B	DMDS Injection Package Metering Pump B
Z-1225-P-01B	Corrosion Inhibitor Injection Package Metering Pump B
Z-1312-P-01B	H2O Injection Package Metering Pump B
Z-1313-P-01B	DMDS Injection Package Metering Pump B
Z-1314-P-01B	Chlorine Injection Package Metering Pump B
Z-1301-P-01-B	Phosphate Injection Package Metering Pump B
Z-1460-P-01B	Caustic Package Metering Pump B
Z-1469-P-01B	Chlorination Agent Injection Package Metering Pump B
Z-1468-P-01B	Oxychlorination Water Injection Package Metering Pump B
RU-13580-P-01B	Ref. Pkg Compr A Lube Oil Pump B
RU-13580-P-02B	Ref. Pkg Compr B Lube Oil Pump B
RU-13580-P-03B	Ref. Pkg Motor A Lube Oil Pump B
RU-13580-P-04B	Ref. Pkg Motor B Lube Oil Pump B
K-152A-P-01B	Stand-by Lube Oil Pump for PSA tail Gas Compressor A
K-152A-P-03B	Seal oil Stand-by Pump for PSA tail Gas Compressor A
K-152B-P-01B	Stand-by Lube Oil Pump for PSA tail Gas Compressor B
K-152B-P-03B	Seal oil Stand-by Pump for PSA tail Gas Compressor B
K-152A-P-04	Lube Oil Fill Pump for PSA tail Gas Compressor A
K-152-P-02B	Stand-by Lube Oil Pump for PSA tail Gas Compressor A & B Motor B
K-152B-P-04	Lube Oil Fill Pump for PSA tail Gas Compressor B
K-152A-B-01B	Ventilation fan B for PSA tail gas compressor A
K-152B-B-01B	Ventilation fan B for PSA tail gas compressor B

### **5.3 Operation and Logic Narrative / Control Operating Philosophy - Vendor Document Reference**

S.No.	Equipment	Document Number	Preparation for initial start-up	Start-up Procedure	Normal Operation	Shutdown Procedure	List of Consumables required for Start-up
A	Recycle Compressor (R41-K-1215 A/B)	V-202-1420-130-M-01-457(520)	II-1	II-2	II	II-4	IV-4
B	Stripper Reboiler (R41-FR-122)	V-202-1420-144-K-01-1065	6.3	6.7	6	6.9	NA
C	Reactor Feed Heater (R41-FR-12110)	V-202-1420-144-K-01-1267	6.3	6.7	6	6.9	NA
D	Pre-Heater (R41-FR-13110)	V-202-1420-144-K-01-0342	6.3	6.7	6	6.10	NA
E	1 <sup>st</sup> Inter Heater (R41-FR-13210)		6.3	6.7	6	6.10	NA
F	2 <sup>nd</sup> Inter Heater (R41-FR-13310)		6.3	6.7	6	6.10	NA
G	3 <sup>rd</sup> Inter Heater (R41-FR-13410)		6.3	6.7	6	6.10	NA
H	Reformer Heater WHB (R41-FR-130)	V-202-1420-144-K-01-0342	6.3	6.7	6	6.10	NA
I	Recycle Compressor (R41-K-13450)	V-202-1420-126-H-01-008(038)	6.2 (1)	6.2 (2)	6.3 (2)	6.4 & 6.5 (2)	10.13
J	H2 Rich Gas Compressor (R41-K-135/13550)	V-202-1420-126-H-01-208 (235)	6.2	6.2	6.3	6.4 & 6.5	10.13
K	Air Compressor (R41-K-1470)	V-202-1420-129-C-02-257 (282)	3-36	4-4	4	4.5	7
L	Regeneration Loop Compressor (R41-K-1465)	V-202-1420-126-H-01-608 (636)	6.2	4.3	6.3	6.4	10.13
M	N2 Compressor (R41-K-1405)	V-202-1420-130-S-03-614	2.1 & 3.1	2.3 & 3.3	2.5 & 3.5	2.6 & 3.6	NA
N	Refrigeration Package (R41-RU-13580 A/B)	V-202-1420-142-I-01-488	6	6.3	3.7	3.8	10.3
O	PSA Package (R41-PK-1510)	V-202-1420-141-U-01-105	7	7	8	9	5

P	PSA TAIL GAS COMPRESSORS (R41-K-152A/B)	V-202-1420- 131-M-02-806	NA	1.1	4	5	NA
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## Safety Systems

## **6 SAFETY SYSTEMS**

### **6.1 General Safety Instructions**

The refinery fire and safety regulations should be complied with at all times.

The following general points should be remembered:

#### **6.1.1 Administrative Procedure**

- Upon entering the unit, personnel should always report to the operating shift supervisor in the control room, providing him with identification and the reason for their presence on the unit. The supervisor must always be aware of who is on the unit, in addition to the shift operating staff, and why.
- No unauthorised person should be allowed to remain on the unit.
- Before maintenance work is carried out, the maintenance supervisor must be in possession of a relevant work permit which the operating shift supervisor has cleared for execution. Before work commences, any special safety equipment must be provided and precautions which the permit invokes must be carried out. Maintenance areas should be roped off and warning signs posted to reduce casual access and to inform personnel that work is being carried out. Temporary equipment should always be grounded so that the possibility of static electricity is minimized.
- All operating staff should be aware of the day to day operational instructions posted in the control room, especially any restrictions on operations caused by maintenance work, etc. Work tasks performed on the unit must always be based on precise and clear instructions. If verbal or written instructions seem ambiguous and/or unclear, operators must obtain clarification before proceeding with the work. Actions taken on the basis of misunderstandings can lead to unsafe conditions which put at risk the safety of personnel and equipment.
- The lines blind list must be kept up to date, especially during periods of maintenance work. Where work involves the isolation of sections of the unit, isolation valves and blinds should be clearly labelled or tagged to define the extent of live lines and vessels and to warn against inadvertent operation.
- No work to be started in any area or on any equipment without consent of the person-in-charge.
- All shift personnel must be aware of the particular hazards associated with the various chemicals, process liquids and vapours present in the unit, and of the initial first aid treatment to be applied if exposure is accidentally experienced. The locations of eyewashes, showers, and utility stations must be known by

everyone. All operating staff should be fully conversant with the relevant material handling procedures for the unit.

- The location of emergency equipment and the range of equipment provided should be known by all the shift operating crew. Items such as face masks, respirators, goggles, fire blankets, spare protective clothing, first aid equipment, etc., should be kept in known secure locations and be easily accessible in the event of an emergency.
- Each shift should include at least one person who is fully conversant with first aid procedures and whose normal station on the refinery is known by members of the unit shift operating crew.
- First aid instructions should be posted at strategic positions within the unit.
- All telephone points should be clearly labelled with emergency telephone numbers e.g. Fire and safety manager, medical centre manager, etc. The locations of all telephones should be known by everyone
- Fire drills should be regularly carried out to remind personnel of the locations of fire main valves, fire hydrants, hoses, monitors and fire extinguishers. The equipment must be routinely checked for correct operation and good condition.

#### **6.1.2 General Behaviour**

- Operators of vehicles comply with all traffic requirements, particularly speed limits.
- All persons in vehicles wear seat belts at all times.
- When ascending or descending stairways, use the handrail and take only one step at a time.
- Smoking is permitted in designated areas, only matches and lighters are prohibited in restricted areas
- Eating or resting is permitted in designated areas only.
- Use proper manual lifting techniques, or obtain assistance or mechanical lifting aids when lifting loads.
- Climbing or standing on equipment, piping, valves, or unstable surfaces (e.g., chairs or barrels) to perform work is prohibited.
- Running in work areas is prohibited, except during emergencies.
- Non - approved electrical / electronic devices (e.g.,cellular phones, pagers, and instruments)are not be used in classified areas unless properly permitted.
- Horseplay or fighting on the premises is prohibited.

#### **6.1.3 Personal Protective Equipment**

Hazards should be avoided through engineering or administrative controls. If those controls are not available or are unfeasible, personal protective equipment should be used to put a barrier between you and the hazards.

- All personnel should wear appropriate protective clothing when they are on the unit.

- Finger rings, wristwatches, jewelry, loose clothing, unsecured long hair, and other loose accessories are not worn within an arm's reach of rotating equipment or electrical switchgear.
- Approved hard hats without defects to be worn in designated areas. Metallic hard hats are prohibited.
- Approved safety footwear to be worn in field operations, process areas, and other designated areas.
- Approved safety eyewear with side protection to be worn where designated.
- Approved additional hazard-specific eye / face protection (e.g., goggles and / or a face shield) to be worn where foreign objects may injure the eye or face (e.g., grinding, welding, drilling, or scraping).
- Proper personal protective equipment (ppe) prescribed by the material hazard bulletin (mhb) or material safety data sheet (msds) to be worn when handling chemicals or hazardous materials.
- Approved hearing protection to be worn in high noise areas (i.e., 85 decibels [dba] or higher).
- Proper hand protection (e.g., gloves) to be worn when performing tasks that may present a hand injury risk.
- Proper self contained breathing apparatus (scba) for non-respirable environment or confined space entries to be used. The scba to be certified and the user properly trained in using the equipment.
- Approved fall protection measures (e.g., safety harnesses or scaffolding) are used if the working height is greater than 1.8 m (6 ft) emergencies.

#### Types of Personal Protective Equipment:

- Hearing protection – Use when exposed to noise at or above, 90 decibels (dB) TWA.
- Hard hats – Wear when exposed to bumping into or struck-by hazards
- Gloves and arm protection – Cover hands and arms when exposed to chemicals, heat, cold, radiation agents or abrasive surfaces
- Respirators – Should be used when exposed to harmful inhalation hazards due to chemicals. Respirators have intended uses; ensure the respirator operator are using is properly selected for the hazard to which operator are exposed. For example, dust respirators are used for silica exposure when cutting block; organic cartridge respirators are appropriate for trichloroethylene found in paints and resins.
- Safety harnesses with lanyards – Should be implemented when exposed to fall hazards.
- Eye and face protection - Glasses are intended to be used to protect from impact hazards; e.g., when using saws. Goggles protect the eyes from splash hazards. Face shields are intended to protect the face from splash hazards and should be worn with safety glasses or goggles.
- Welding hoods – Should be worn when performing cutting, welding or brazing.
- Steel-toe shoes – Should be worn when moving or working around potential falling heavy objects.

#### **6.1.4 Work Practices**

- All electrical conductors to be considered energized unless properly locked, tagged, cleared, and tried.
- De-energize all circuits before beginning work. Use safety process, “isolation, lockout, and use of hold tags” to prevent the electrical circuits from being inadvertently energized.
- Use proper PPE including insulated rubber gloves for high voltage work. Additionally, mats and blankets may be required to provide insulation from other elements that are energized or grounded.
- Personnel should not wear rings, wristwatches, other jewelry, glasses with metal frames, or other similar metallic objects while working within arm’s length of energized electrical equipment.
- Do not cause electrical interlocks to be inoperative by removing, modifying, or destroying them.
- Blown fuses to be removed with approved fuse pullers and replaced only with the proper type and rated fuses.
- Metal ladders are not to be used when working on or near electrical equipment or conductors; use only nonconductive ladders. Never use defective electrical equipment, defective extension cords, or shop-made extension cords.
- When opening or closing a disconnect switch, personnel will stand to the side, turn head away from switch, and throw switch with a quick upward or downward single motion.
- Extension cords are not to be used in place of permanent wiring.
- Ground fault circuit interrupters (gfcis) or ground isolation systems to be used for all portable electrical tools, temporary wiring, and in potentially damp areas.
- Maximum voltage for portable electrical hand tools should not exceed 125v.
- Only individuals qualified for the type of electrical work to be undertaken will repair or install electrical equipment, or work around live circuits (e.g.,switchman).
- Individuals who need to identify and possibly de energize an electrical circuit will attend specialized electrical safety training.
- Qualified personnel authorized to work on electrical circuits are trained in first aid and basic life support (bls)
- Regular inspection routines should be established to check the unit for leaks and other signs of potential danger, to examine equipment sealing and cooling systems, to check lubrication systems and reservoirs and to ensure that all protective guards on equipment, etc., are correctly placed.
- Do not apply compressed air or other gases to yourself or others
- Operating equipment having a “danger, do not operate” (hold) tag is prohibited.
- No work to be started in any area or on any equipment without consent of the person-in-charge.

- Whenever a safety device is removed from service and/or defeated, the appropriate supervisor and affected parties to be notified, the device tagged, and the action properly documented.
- All block valves on pressure relief systems in service is chain-locked or car-sealed open.

#### **6.1.5 House keeping**

- Good housekeeping efforts are part of enhancing fire prevention and accident prevention standards. One of the easiest ways to prevent accident is to maintain a neat and orderly job site.
- Maintain good housekeeping in your work area at all times.
- The operations staff should maintain the unit in a clean condition on a day to day basis. Accumulated dirt, oil and grease spills, which always present a fire hazard, should be cleared up rather than be allowed to evaporate, etc., tools and equipment should not be left lying around in between shifts where they will obstruct accessways, or cause accidents. The walkways should always be clear of any temporary equipment.
- All firefighting equipment should be maintained on a regular basis and should not be moved from the proper location. If temporary works dictate the need for local extinguishers, water hoses, etc., then these items must be provided in addition to those normally available on the unit.
- Erect barricades / flagging around hazardous work, areas such as holes in decking and floor surfaces, trenches, road crossings, and overhead hazardous work.
- Use only proper tools and equipment maintained in a safe working condition. Homemade tools are prohibited. Tools and safety equipment used by contractor must be inspected and certified by inspectors/inspection agencies authorized by the company.
- All fire extinguishers and other emergency equipment to be in good condition, inspected regularly, and kept clear of any obstruction.
- All chemical or hazardous material containers to be properly labeled and stored. Drums are stored in secondary containment areas.
- Materials must be stacked and placed away from foot traffic.
- Materials and equipment should not be stored within 1.8 m (6 ft) from the edge of the roof.
- Tools and equipment must be put properly in their respective place.
- Where necessary, wheels on rolling equipment to be wedge locked.
- Trash and scraps are fire hazards and must be collected and disposed off immediately.
- Keep exits and entrances always clear.
- Store all liquids (including flammable liquids) in approved, clearly labeled containers in designated storage areas only.

- Keep lighting sources clean and clear.
- Keep sprinklers, fire alarms and fire extinguishers clear of obstruction.
- All operating machinery and electrical switchgear have all safety guards, switches, and alarms in place and functional
- Water, foam, dry powder and C02 fire extinguishers must be clearly labelled to ensure that the correct type of extinguisher is used in the event of fire.
- Dry powder and foam extinguisher inventories should not be kept for longer than the recommended storage life to ensure extinguisher effectiveness when the need arises.

#### **6.1.6 Fire protection**

Response procedures in case of fire

- Summon help/sound alarm.
- Only trained personnel **has to** operate fire extinguishers and equipment.
- Ensure that all personnel are evacuated per the local emergency response plan.
- Isolate all fuel sources and / or threatened facilities and close doors; do not attempt to extinguish gas fires.
- Do not fight fires beyond the incipient (initial) stage or beyond your level of training. Locate the firefighting equipment and approach the fire from the upwind side.
- Never operate an extinguisher in such a manner that any part of your body is located directly above the fill cap.
- Test the extinguisher before attempting to extinguish fire.
- After the fire is extinguished, stand by to ensure that there is no reignition.

#### **Fire prevention guidelines**

- Class a fire materials (e.g., paper and wood) storage **to** be minimized in process and electrical areas.
- Trained personnel **has to** visually inspect all fire equipment monthly.
- Report and repair all hydrocarbon liquid or gas leaks immediately.
- In the event of a hydrocarbon liquid or gas leak, remove sources of ignition immediately (e.g., shutdown engines).
- Do not use gasoline as a cleaning agent.
- Always fill portable gasoline containers on the ground and never place gasoline containers inside vehicle passenger compartments.

- When transferring hydrocarbons (flammable liquids) from a line or vessel to another container, the source container and the receiving container **is** electrically bonded to prevent ignition due to static electricity.
- Plastic cups/buckets **are not to** be used for collection of hydrocarbon samples.
- **Do not smoke, use cellular phones, other electrical devices while refueling or within electrically classified areas.**

#### **6.1.7 Material sampling**

- In taking samples of any material in the unit regardless of its physical state, there are two basic principles which should be followed:
- Use common sense and observe all reasonable safety precautions to ensure that no injury to personnel can result. Maintain equipment during sampling at its operating condition and check that the continuity of the process is not upset.
- Correctly use the appropriate sampling equipment. Confirm that its condition, cleanliness and purging are satisfactory so that a meaningful, representative sample is obtained and is properly identified. Use the correct sampling procedure as described in the laboratory procedures manual.

Unless these principles are followed, a sample **is** valueless.

Erroneous test results may lead to incorrect decisions concerning the operation of the plant which in turn could lead to unsafe or uneconomical operation. Accurate analyses are of little value unless the samples are truly representative of the stream.

When sampling gases, enough gas should be passed through the sample bomb to ensure the displacement of all purge gas and to equalise the temperatures of the sample stream and the sample so that the sample composition is not distorted by condensation or flashing.

When sampling liquids, allow sufficient sample volume for expansion. Ensure that the sample composition is representative of the source material, undistorted by flash vaporization.

## **6.2 Plant safety features**

### **6.2.1 Safety Showers/Eye-Washes - Equipment, List & Locations**

On the basis of characteristics of the hazardous substances (skin corrosive / skin irritant / dermal toxic etc..) processed in the unit and through the identification of high exposure risk area (handling / loading of catalyst,

chemicals filling operation etc..) an assessment of the need and positioning of safety showers and eye wash stations has been carried out according to specification Safety Shower and eyewash station criteria S-EP-R400-137Z-0004.

The result of this assessment and the location of the safety showers and eye wash stations is shown in the following document:

- D-EP-R41-1225-0020 - R41 - Naphtha Reformer Unit Safety Shower/Eye Wash Station Layout
- Refer to document No. V-202-1420-324-R-06-018 for Safety Shower/Eye Wash Data Sheet

Safety showers and eye wash facilities can be used to provide:

- Dilution of substances after skin or eyes exposure
- Rinsing substances after skin and eyes exposure
- Cooling after exposure to hot liquids or vapours
- Extinguishing in case clothing set on fire

Furthermore Eye-wash station installed in the Battery Rooms inside the buildings for the risk related to H<sub>2</sub> release during battery recharge.

From each potential source the travel distance to the nearest safety shower is within 15 meters.

The safety showers and eyewash station are free standing and free from any obstruction. Also between the source of the risk and the Safety shower no obstructions are allowed.

The safety shower and eye wash system is branched from the drinking water system, during each shift the facilities to be flushed to guarantee temperature control.

The facility is furnished with systems to mitigate potential infections for contamination with biological agents(e.g. Legionella, etc..) caused by the exposure with flush water.

### **6.2.2 Fire And Gas Detection**

The Fire and Gas Detectors are provided throughout the process area on the basis of hazardous streams processed in the unit and the related hazard of fire and gas dispersion. It has been designed in order to meet the following safety goals:

- provide an early detection of flammable/toxic gas leakage;
- early detect the presence of a fire;
- alert personnel in field and in buildings of the detected hazard by means of audible and visual alarms;
- initiate manual and/or automatic remedial actions to avoid escalation of hazardous conditions.

Based on the assessment of the hazardous properties of the processed fluids in the unit type of detectors considered for this unit are the following:

- Smoke detectors, point-type
- Smoke detectors for in duct installation, point-type
- Smoke detector, beam-type
- High Sensitivity Smoke Detectors (HSSD), point type
- Heat detectors, point-type, rate compensated or rate of rise;
- Thermo-sensitive cables;
- Flame Detectors.
- Flammable Gas Detectors (HC / H<sub>2</sub> gas detector)
- Toxic Gas Detector (H<sub>2</sub>S Gas detector)
- Oxygen Depletion Detectors
- Gas Detector Calibration

The position and quantities of the F&G detectors have been assessed and shown in the following drawings, for process area and buildings rooms/premises:

DOCUMENT NUMBER	TITLE
D-EP-R41-1241-0001	FIRE AND GAS DETECTION SYSTEM DRAWING - UNIT 410
D-EP-R41-1241-0002	FIRE AND GAS DETECTION SYSTEM DRAWING - SUBSTATION 239
D-EP-R41-1241-0003	FIRE AND GAS DETECTION SYSTEM DRAWING - PIB 31

Location and quantities of flammable / toxic gas detectors in process area have been verified assessing the behaviour of identified gas release scenarios and the extension of gas dispersion considering different wind directions.

Methodology and results are reported in "Dispersion study (for gas detectors location verification)", doc. T-EP-R400-137Z-002.

The actions to be taken in case of specific alarms generated by the detectors, as for example unit shut down, firefighting systems activation, building HVAC system management etc.., are included in the "Fire & Gas Detection system General criteria", doc. S-EP-R400-1241-0001.

### **6.2.3 Hazardous Areas Layout**

Area Hazardous Classification of the unit area is based on API RP 505, considering flammable substances and operating conditions of the process equipment present.

Analysis of the substances and calculation of the extent of classified area is provided in the following documents:

- Doc. N. D-EP-R400-138-0001 - Hazardous Area Classification General Drawing
- Doc. N. D-EP-R41-138-0001- Hazardous Area Classification Unit 410 Plant Drawing
- General process area is classified as Zone 2, gas group IIC being most stringent, Zone 1 is foreseen in pit and area below ground.

Furthermore suitable procedures and Work Permit shall be put in place for Maintenance activities to have adequate apparatus / device / activities for the classified area they have to be executed.

### **6.2.4 Fire Fighting And Fire Protection Equipment**

Fire hazardous equipment protected by fixed fire-fighting systems, as well as the relevant typology of protection, spray/deluge system or fire water monitor is listed in "Fire Fighting Hazard Identification list", doc. no. S-EP-R400-1226-0003.

Fire hazardous equipment are identified and protected according to the requirements defined in "Basis of Design for Fire Protection System", doc. n. S-EP-R400-1226-0001.

The quantity of fire-fighting equipment (monitors and spray/deluge systems) provided in the unit are:

<b>Fire-fighting Equipment</b>	<b>Quantity for Unit R41</b>
Fire Water Monitor	40
Spray/Deluge System	23

#### **6.2.4.1 Fire Protection**

##### **Active Fire Protection**

Active fire protection is provided throughout the process area, in order to minimize the consequences of a fire scenario through cooling and/or fire extinguishment.

The Unit is provided with active fire protection facilities, personnel fire protection facilities as well as support facilities as indicated below:

- Hydrants, fire water hose reels and fire water monitors is provided in accordance with specification S-PM-G000-1241-0001 Rev.6; General Specification for Fire Protection System  
SAES-B-017; Firewater System Design  
SAES-B-019; Portable, Mobile and Special Fixed Fire Fighting Equipment

- Fixed water spray systems (deluge systems) for protection of dedicated equipment.
- Semi-Fixed foam systems for protection of selected tanks.
- Dry Riser Units, installed near stairways of multi-level structures, (equipment handling flammable and/or combustible substances and on distillation columns and reactors structures).
- Appropriate number of portable facilities including hand and wheeled fire extinguishers are provided as per specification

S-PM-G000-1241-0001 Rev.6; General Specification for Fire Protection System  
SAES-B-019; Portable, Mobile and Special Fixed Fire Fighting Equipment

The position and quantities of the firefighting devices installed in the unit are shown in the following drawings:

DOCUMENT NUMBER	TITLE
D-EP-R41-1225-7001	P&ID FIREWATER NETWORK - UNIT 410
D-EP-R400-1225-7001	P&ID FIREFIGHTING EQUIPMENT DETAIL (HOSE REEL & HYDRANT)
D-EP-R400-1225-7002	P&ID FIREFIGHTING EQUIPMENT DETAIL (MONITOR & DRY RISER)
D-EP-R400-1225-7003	P&ID FIREFIGHTING EQUIPMENT DETAIL (DELUGE INSTALLATION)
D-EP-R400-1225-7004	P&ID FIREFIGHTING SPRAY NOZZLE INSTALLATION DETAIL
D-EP-R400-1225-7005	P&ID FIRE WATER AND FOAM SYSTEM DETAIL FOR STORAGE TANK
D-EP-R41-1225-7002	P&ID SPRAY SYSTEM DISTRIBUTION - UNIT 410
D-EP-R400-1225-7006	OVERALL LAYOUT OF FIREWATER SYSTEM - UNIT 410 & 420
D-EP-R41-1226-0001	CONCEPTUAL LAYOUT OF FIREWATER SYSTEM - UNIT 410
D-EP-R41-1226-0002	LAYOUT OF MONITOR COVERAGE - UNIT 410
D-EP-R41-1226-0003	FIRE RISK AREA - UNIT 410
T-EP-R400-1226-0001	DELUGE SYSTEM CALCULATION REPORT
S-EP-R400-135Z-2001	MATERIAL REQUISITION (TECHNICAL SUPPLY SPECIFICATION) FOR FIREFIGHTING/SAFETY EQUIPMENT
S-EP-R400-1226-0002	FIREFIGHTING HAZARD IDENTIFICATION LIST

### **Passive Fire Protection**

Passive fire protection is an additional protective measures which are necessary to protect an equipment from fire, even if the design, location, spacing and drainage are of considerable importance in minimizing equipment involvement in a fire. To improve the capacity of equipment & its support structure to maintain their structural integrity during a fire and to shield essential operating systems when they are exposed to fire.

Fire hazardous equipment are identified and protected according to the requirements defined in Fireproofing General Criteria - S-EP-R400-13B4-0001.

The Fire Proofing provided in the unit are shown in the following drawings:

DOCUMENT NUMBER	TITLE
S-EP-R400-13B4-0002	FIREPROOFING DATA SHEET UTILITIES
S-EP-R41-13B4-0001	FIREPROOFING DATA SHEET UNIT 410
S-EP-R41-13B4-0002	FIREPROOFING ITEM AND STRUCTURE TO BE FIREPROOFED - UNIT R41
D-EP-R41-1378-7001	R41 - NAPHTHA REFORMER UNIT - FIREPROOFING DRAWING

#### **6.2.4.2 Fire-Fighting System for Building**

Fire-fighting equipment provided for each building:

BUILDING DESCRIPTION	SPRINKLERS	HOSE REELS	PORTABLE EXTINGUISHERS
PIB 31 (Naphtha)	NO	NO	YES
PIB 32 (Aromatics)	NO	NO	YES
SS 231 (R42 Aroma South)	NO	NO	YES
SS 237 (R42 Aroma North)	NO	NO	YES
SS 239 (R41 Naphtha)	NO	NO	YES

#### **6.2.5 Emergency Escape Route**

In the unit plot plan, escape routes have been identified on the basis of the definitions given in "Escape Route General Criteria", doc. N. S-EP-R400-137Z-0001.

Unit Safety Equipment & Escape Routes Layout are as mentioned below,

- D-EP-R400-137Z-0001 - R400-Overall Plot Plan - Escape Route Layout
- D-EP-R41-137Z-0001 - R41-Naphtha Reformer Unit Escape Route Layout
- D-EP-R41-137Z-0002 - Escape Route Layout Of Building - SS231
- D-EP-R41-137Z-0003 - Escape Route Layout Of Building - SS239
- D-EP-R41-137Z-0004 - Escape Route Layout Of Process Interface Building – 31

represents the emergency evacuation routes, when operators have to evacuate to the safest and nearest safe place of each unit during a main risks event (as fire, explosions, toxic vapour clouds, etc.).

#### **6.2.6 Sampling in High pressure lines**

On high pressure lines, extreme caution must be taken when opening any sample or bleed valve.

Improper opening or shut-off of some valves on interconnecting lines may result in exceeding pressure limits on vessels, exchangers, valves and lines

### **6.3 Plant Hazardous Substances Requiring Special Precautions**

In the process plant area several different substances are present that can, when released and in contact with the human body, become a hazard for the personnel (for toxicity or carcinogenicity, or skin/eyes irritating characteristics), environment or result in potentially flammable/explosive scenarios.

The list of Hazardous, toxic and flammable substances handled in Unit R41 are listed below:

- Hydrogen
- Fuel Gas
- Fuel Gas rich in H<sub>2</sub>
- LPG
- Light Naphtha
- Heavy Naphtha
- Methane
- Ethane
- Propane
- Butane
- IsoButane
- Cracked Naphtha
- Reformate
- Pentane
- IsoPentane
- Hexane
- IsoHexane
- Naphtha
- C5 Fuel Oil

The list of Toxic substances are:

- Hydrogen Sulfide
- Ammonia
- Benzene Service (Benzene > 5wt%)
- DMDS

Each operator should be aware of the nature of the substances present in the process area.

Furthermore, he should be informed about the relevant risk to his own health and take all the protective measures necessary to operate in the process area.

#### **6.3.1 Safe Handling Of Volatile, Corrosive And Toxic Materials**

Refinery Management and Unit 410 Operation Managers should ensure consistent, safe practices are followed for handling of chemicals substances.

Line Manager shall ensure:

- All hazardous chemicals or materials must be properly labeled and stored.
- Do not use chemicals or materials from unlabeled containers. The need for adequate labeling extends far beyond the immediate requirements of the individual users, since they may not be present in case of fire or explosion, or when containers are broken or spilled. Proper labeling is extremely important as it is impossible to dispose of unlabeled chemicals.
- Spills to be cleaned immediately.
- Avoid direct contact with any chemical. The first step in using any chemical should be a review of the Material Safety Data Sheet (MSDS) supplied by the manufacturer. Pay specific attention to the potential hazards and safety equipment required for working with the material. Be familiar with the proper emergency procedures recommended for the chemical in case of accidental exposure/release.
- Employee must wear proper eye, face shield and hand protection. Always review emergency procedure before use. MSDS indications on PPE are mandatory
- Do not eat, drink, smoke or chew in an area where hazardous chemicals are present or any exposure to any hazardous chemical is likely. Wash properly exposed skin after using hazardous chemicals.
- Operators involved in operations that require handling of hazardous chemicals must know where safety showers and eye wash stations are located and how they operate. Flush eyewash stations and showers before handling hazardous chemicals / materials to ensure proper operation and clean water in an emergency.
- Supervisors are responsible for determining the potential hazards of non-routine tasks, identifying the proper personnel protective equipment, communicating these hazards to employees, and ensuring that the proper procedures are prepared and followed.
- Volatile chemicals to be managed in properly ventilated conditions or using extraction meanings (cupboards, extraction arms, etc.).

- Dangerous (irritant, oxidant carcinogenic etc.) volatile chemicals to be handled only wearing the proper PPE for breathing apparatus. Direct contact with such substances/materials to be avoided as well.
- Flammable and explosives volatile chemicals to be handled only were proper meanings are in place to grant the safety of the operators; risk analysis and MSDS indications to be followed to identify the required precautions

Information is provided in MSDS for the safe storage and transport of the substance including any special requirements, codes or restrictions which apply. Recommendations are outlined for clean-up of spillage and disposal of waste. Firefighting methods and associated protective equipment are specified.

#### **6.3.1.1 Corrosives**

Corrosives (liquids, solids, and gases) are chemicals that cause visible destruction or irreversible alterations to living tissue by chemical action at the site of contact. Corrosive effects can occur not only to the skin and eyes, but also to the respiratory tract through inhalation and to the gastrointestinal tract through ingestion. Corrosive liquids have a high potential to cause external injury to the body, while corrosive gases are readily absorbed into the body through skin contact and inhalation. Corrosive solids and their dusts can damage tissue by dissolving rapidly in moisture on the skin or within the respiratory tract when inhaled. In order to minimize these potential hazards, precautionary procedures must be observed when handling corrosives.

Contact with the skin or eyes represent the greatest risk when dealing with corrosives. Match the hazard presented by the material with the protective equipment recommended by the MSDS. Always wear resistant gloves and eye protection when dealing with corrosives. In some cases, respiratory protection may be desirable.

Corrosives give often strong reactions; Check the MSDS and compatibility tables to avoid improper usage / disposal.

#### **Handling**

- Be aware of the nearest eyewash station and safety shower for your work location.
- When acids or alkalis are used, some form of containment to control spills must be employed. Included among these methods are bench top spill diapers and resistant trays.
- When diluting, always add ACID to WATER, never add water to acid. Allow the acid to run down the inside of the container and mix slowly by gentle rotation.
- Be aware of the methods, materials and procedure for cleaning corrosive spills.
- Appropriate spill clean-up material should be available in areas where corrosive chemicals are used and stored.

- Protective carriers to be used when transporting corrosive chemicals

### **Storage**

- Store corrosives in a cool, dry and well-ventilated area away from direct sunlight.
- Use storage materials that are resistant to corrosion.
- Store corrosive materials near, but not on the floor to minimize danger of falling splashes etc.
- Isolate corrosives from the following:
  - Organics
  - Flammables
  - toxic materials
- Separate containers to facilitate handling. Organic acids and bases are to be stored separately from strong oxidizing agents to prevent interaction of fumes and corrosion of storage cabinets.

### **General First Aid Considerations for Corrosives**

In the event that a corrosive contacts the skin, immediately remove any contaminated clothing and flush the area with copious amounts of water. Use care not to rub or damage the skin. Seek medical attention.

In the event that a corrosive chemical contacts the eyes, immediately flush the eyes with large amounts of clean water, including under the eyelids for at least 15 minutes. Seek immediate medical attention.

If a corrosive material is ingested, seek immediate medical attention.

#### **6.3.1.2 Toxic Chemicals**

Toxic materials may enter the body through the skin, inhalation, and/or ingestion. Care should be taken to prevent these means of entrance when handling toxic materials. A large number of common substances are acute respiratory hazards and should not be used in a confined area in large amounts. They should be used only in a hood or under ventilation / extraction. Some of these include; ammonium hydroxide, carbon monoxide, chlorine, fluorine, hydrochloric acid, hydrogen sulfide, and sulfur dioxide, ammonia, amines, solvents. Toxic substances may form as by-products of certain reactions.

### **Handling and Storage**

- Isolate, segregate, and clearly label all toxic chemicals.
- Adequate room ventilation must be provided at the work site area. Ventilation/extraction meanings must be used whenever possible.

- The appropriate personal protective equipment must be worn as directed by the label or MSDS.
- Limit exposure time.
- Practice good personal hygiene.
- hand washing
- wearing a lab coat

Proper disposal procedures to be in place to avoid improper usage of toxic materials.

### **6.3.2 Toxic Service and Very Toxic Service**

In Unit R41 there are a certain numbers of toxic substances that are defined below.

Refer to Isolation Philosophy – S-PM-G000-1222-0602, “Emergency Shutdown, Isolation philosophy and Depressuring” in SAF-11 and HSE Design Philosophy S-PM-G000-1240-002.

#### **6.3.2.1 Toxic Service**

The process gases or liquid streams containing CO, H<sub>2</sub>S and NH<sub>3</sub> (continuous flow during normal operation only) exceeding the IDLH values (Refer to Table below) are classified as toxic services. Based on IDLH values of these substances in the process stream, special engineering measures such as material selection, equipment design, QC testing, provision of gas detection system and venting to safe atmosphere has been implemented in design.

In addition to that fluids containing more than 5% of a chemical with a NFPA 704 Health Category Rating 3 or above is considered as toxic services (limited to isolation of plant or equipment) as per Isolation Philosophy – S-PM-G000-1222-0602 and “Emergency Shutdown, Isolation philosophy and Depressuring” in SAF-11.

Only Caustic service system falls in this category and identified with piping class 37. For this piping valves, low fugitive valve Rate B as per project specification S-PM-G000-136-0004 is considered

The threshold values of the following toxic substances are as shown in the following Table.

**Threshold Values (ppm mol)**

<b>Substance</b>	<b>TLV-TWA</b>	<b>TLV-STEL</b>	<b>IDLH</b>
CO	25 ppm	-	1,200 ppm
H <sub>2</sub> S	10 ppm	15 ppm	100 ppm
NH <sub>3</sub>	25 ppm	35 ppm	300 ppm

Note) TLV-TWA : Threshold Limit Value – Time Weighted Average

TLV-STEL : Threshold Limit Value – Short-Term Exposure Limit

IDLH : Immediately Dangerous to Life and Health

The maximum concentration levels at working locations to be maintained below its TLV-TWA value during normal operations and below STEL values during emergency operations. The IDLH threshold values at point of leak at workplace, which still allows personnel to escape unharmed in time as IDLH values are based on the effects that might occur as a consequence of a 30-minute exposure.

Plant areas where process gases or liquid streams exceed the following values (i.e., 3 times IDLH) are provided with gas detection system.

Gases or Liquid Streams Requiring Gas Detection System  
(equal to, or greater than in stream - ppm mol)

Substance	In Process Gas or Liquid Stream
CO	3,600 ppm
H2S	300 ppm
NH3	900 ppm

#### **6.3.2.2 Very Toxic/Lethal Service**

The process gases or liquid streams (continuous flow during normal operation only) exceeding the following values (i.e., 10 times IDLH) are classified as very toxic/lethal,

Very Toxic/Lethal Service (equal to, or greater than in stream - ppm mol)

Substance	In Process Gas or Liquid Stream
CO	12,000 ppm
H2S	1,000 ppm
NH3	3,000 ppm

Lethal services (limited to isolation) are the fluids H2S, CO and NH3 in excess of 20% volume

Wet sour: Process streams containing an aqueous phase with a partial pressure of H2S in the gas phase greater than 0.3 kPa absolute (0.05 psia).

Several streams in Unit R41 section 2 contain hydrogen sulfide, a very toxic substance classified 3 according to the NFPA 30 toxicity hazard rating. The list of the considered equipment/streams, with the relevant process conditions and H2S content is given in table below.

### **6.3.2.3 Hydrogen sulphide**

Hydrogen sulfide is one of the more dangerous materials in our industry. In its handling, two types of hazards must be taken into account, its extreme toxicity and its explosive nature when mixed with air or sulfur dioxide. The maximum safe concentration of hydrogen sulfide is about 13 ppm. Although at first this concentration can be readily recognized by its odor, hydrogen sulfide may partially paralyze the olfactory nerves to the point at which the presence of the gas is no longer sensed.

Therefore, though the odor of the gas is strongly unpleasant, it is neither a reliable safeguard nor a warning against its poisonous effects. Hydrogen sulfide in its toxic action attacks nerve centers. Early symptoms of poisoning are slight headache, burning eyes, and clouded vision.

A concentration of 100 ppm of hydrogen sulfide in air causes coughing, irritation and loss of smell after 2-15 minutes and drowsiness after 15-30 minutes.

A concentration of 1000 ppm of hydrogen sulfide in air can make one unconscious at once with early cessation of respiration and death in a few minutes.

Hydrogen sulfide is a combustible material and, when mixed with air or sulfur dioxide, may be explosive. It is essential, therefore, to avoid such mixtures in the processing of hydrogen sulfide. The explosive range of hydrogen sulfide in air is from 4.5 - 45 %. The ignition temperature of such mixtures is around 250° C.

**Some precautions against poisoning to be taken in working with hydrogen sulfide are:**

- Closed-in areas should be well ventilated preferably with forced draft.
- Equipment containing hydrogen sulfide should be tightly sealed. Any leaks should be repaired immediately.
- At seals or stuffing boxes where leaks might occur during normal operation, means should be provided for venting the escape gas to a safe location.
- Vessels should be purged of hydrogen sulfide before being opened
- Masks furnishing purge air should be worn by personnel who are likely to be exposed to the gas.
- Personnel who may be exposed to even low concentrations of this gas should frequently retire to areas of fresh air.
- As a good safety measure, personnel should learn to recognize the early symptoms of hydrogen sulfide poisoning.

### **Detection of hydrogen sulfide**

A simple test with lead acetate solution on white paper will detect the presence of hydrogen sulfide. Depending on the concentration the paper will turn yellow or brown.

Adequate Draeger tubes can be used in the same way.

### **Personal protection**

Gas mask of appropriate type or positive air mask should be used.

### **First aid**

A person unconscious in an atmosphere which may be contaminated with hydrogen sulphide should be assumed to have hydrogen sulfide poisoning. This is a serious medical emergency and requires immediate attention. The affected individual should be removed to clean atmosphere, care being taken that rescuers too are not overcome by hydrogen sulfide. Artificial respiration should be resorted to immediately, if necessary, and the victim should be kept warm and at rest. **Countermeasures**

In order to control and mitigate the H<sub>2</sub>S risk, following measures are implemented in design and operating manual:

- Limit the access to process areas of Unit R41 to personnel adequately trained to deal with a H<sub>2</sub>S emergency;
- Installed H<sub>2</sub>S detectors and alarms in the area of the Unit R41;
- Design of rotating machines (R41-P-1225A/B and R41-K-1215A/B) taking into account the presence of H<sub>2</sub>S.

#### **6.3.2.4 Carbonyls**

Formed by combining the (CO) group and metal, in particular Ni, Fe, Co, Mo, under certain operating conditions, in presence of carbon monoxide.

During regeneration step of catalyst it is possible to produce small quantities of metal carbonyl, but exact quantities cannot be precised. HDT catalyst can contain traces of nickel, cobalt or molybdenum carbonyl.

### **Physical properties**

Some of the carbonyls, nickel in particular, are very toxic, so their formation must be avoided in the interest of safety. Whenever workers are going to enter or open a catalytic reactor, stringent precautions should be followed to assure that carbonyls are not present. Even in closed systems where there is no safety hazard, carbonyl formation should be prevented, since it may remove metal from the catalyst and cause loss of activity.

The toxicity of carbonyls depends in part, but not always, on their easy decomposition which releases carbon monoxide.

Symptoms are due in part to CO and in part to direct irritating action of the carbonyl.

Concentration as low as 1 ppb is toxic for an exposition time of 8 hours.

They react with water or steam to produce toxic or flammable vapors and can react vigorously with oxidizing materials.

### **Detection of carbonyls**

Infrared spectrometry can be used to detect carbonyls in the range of 1 to 10 ppb.

The flame of a Bunsen burner or alcohol lamp can be used as a simple and effective test for carbonyls; metal carbonyls will impart a readily observable luminosity to flames, even if the concentration of the carbonyl is as low as 1 ppm.

### **Personnel protection**

If it is necessary for the personnel to enter a reactor where the presence of nickel carbonyl is suspected, they should be equipped with self-contained air masks and skin protection.

#### **6.3.2.5 Pyrophoric Materials – iron sulphide**

Used catalyst, which is coated with iron sulphide, is pyrophoric and has to be handled under nitrogen blanket conditions. Due to the presence of H<sub>2</sub>S, iron sulphide is also present in other parts of the unit. This substance is subject to ignition when exposed to air. Any vessel, filter, screen where iron sulphide is collected should be kept water-wet until cleaned or safely disposed of.

#### **6.3.3 Hydrogen Service**

Process streams containing hydrogen with a partial pressure of 350 kPa-abs and higher are classified as Hydrogen service. Hydrogen services are identified with Piping Class with "R" digit. Manual valve in this service is considered as low fugitive rate B as per project specification S-PM-G000-136-0004

Hydrogen is a flammable gas which, in concentrations from 4.1 to 74% volume in air, is explosive.

Care must be taken to purge the air out of the unit as required before start-up and to purge hydrogen out of the unit for shut-down.

Tightness tests are to be made before all start-ups on every vessel containing or likely to contain hydrogen.

Each operator must continually inspect equipment and flanges for leaks. All leaks require immediate action.

### **IMPORTANT NOTE:**

The pressure reduction results in heating of hydrogen, contrary to hydrocarbons or other gases which are cooled down (Joule-Thomson effect). When heated above its ignition temperature by pressure release from high pressure, the hydrogen gas starts to burn in presence of air.

#### **6.3.4 Benzene Service**

Process fluids having > 5 wt % Benzene are classified as Benzene service. Benzene services are identified with Piping Class with "B" digit. Manual valve in benzene service is considered as low fugitive rate B as per project specification S-PM-G000-136-0004. Sampling point in Benzene services are provided with Dopak system to allow the operator to be shielded from contact with the product being sampled. Also local spillage can be avoided and volatile substances are prevented from escape into the atmosphere. Also double mechanical seal for centrifugal and rotary pumps has been considered

#### **6.3.5 Chemical products**

Main chemical products used in the Unit during start-up and normal operation are as follows:

- DMDS
- Corrosion Inhibitor
- Sulfiding agent
- Chloriding agent
- Sodium hydroxide.

#### **6.3.6 Catalysts**

- HR 538, ACT 069, ACT 078, ACT 108, ACT 139 and Inert Balls.
- Axens Procatalyse catalyst AR701
- Axens adsorbents SAS 857 and SAS 858

Refer to Material Safety Data Sheets for detailed information on these chemicals & catalysts

### **6.4 Occupational Exposure Levels**

Occupational Exposure Levels adopted are those of the American Conference of Governmental Industrial Hygienists (ACGIH) (2009). These levels, examples of which are summarized in below Table, must not be exceeded in areas where people may be present and at ground level within the plant boundaries.

The value of the following table (referred in the air dilution) must be ensured for all personnel working in the project units. Where a value could not be respected, proper actions **are** provided in terms of design or in terms of proper procedures (i.e. access restriction)

Table from American Conference of Governmental Industrial Hygienists (ACGIH)  
Occupational Exposure Levels (2009)

Material Name	ACGIH TLV <sup>(a)</sup> (ppm unless otherwise specified)	
	TWA <sup>(b)</sup>	STEL <sup>(c)</sup>
Acetic acid	10	15
Acetone	500	750
Acrolein	-	0.1 ceiling
Acrylic acid	2	-
Ammonia	25	35
Benzene	0.5	2.5
Aliphatic hydrocarbon gases - Alkane (C1 – C4) Butane, ethane, liquefied petroleum gas, propane.	1000	-
Caprolactam (CPL)	5 mg/m <sup>3</sup> <sup>(d)</sup>	-
Carbon dioxide	5000	30000
Carbon monoxide	25	-
Cumene	50	-
Cyclohexane	100	-
Cyclohexanone	20	50
Cyclohexanone oxime as PNOS <sup>(e)</sup>	3 mg/m <sup>3</sup> (respirable) 10 mg/m <sup>3</sup> (inhalable)	
Ethanol (EtOH)	-	1000
Ethylene glycol	-	100 mg/m <sup>3</sup> ceiling <sup>(f)</sup>
Ethylene oxide	1	-
Ethylene vinylacetate copolymer (EVA) as PNOS <sup>(e)</sup> <sup>(f)</sup>	3 mg/m <sup>3</sup> (respirable) 10 mg/m <sup>3</sup> (inhalable)	
Ethylene propylene diene monomer rubber (EPDM) as PNOS <sup>(e)</sup>	3 mg/m <sup>3</sup> (respirable) 10 mg/m <sup>3</sup> (inhalable)	
5-Ethylidene-2-norbornene (ENB)	-	5 ceiling
Gasoline	300	500
Hydrogen peroxide (H <sub>2</sub> O <sub>2</sub> )	1	-
Hydrogen sulphide	10 (1) <sup>(g)</sup>	15 (5) <sup>(g)</sup>
Isobutylene as PNOS <sup>(e)</sup> <sup>(f)</sup>	3 mg/m <sup>3</sup> (respirable) 10 mg/m <sup>3</sup> (inhalable)	
Methacrylic acid	20	-
Methanol (AcOH)	200	250
Methyl acrylate (MA)	2	-
Methyl tert-butyl ether (MTBE)	50	-
Methyl methacrylate (MMA)	50	100
Poly-Methyl methacrylate (pMMA) as PNOS <sup>(e)</sup>	3 mg/m <sup>3</sup> (respirable) 10 mg/m <sup>3</sup> (inhalable)	

Material Name	ACGIH TLV <sup>(a)</sup> (ppm unless otherwise specified)	
Nylon 6 (PA-6) as PNOS <sup>(e)</sup>	3 mg/m <sup>3</sup> (respirable) 10 mg/m <sup>3</sup> (inhalable)	
Nitrogen dioxide	3	5
Phenol	5	-
Propylene oxide (PO)	2	-
Sodium hydroxide (NaOH)	-	2 mg/m <sup>3</sup> ceiling
Sulphur dioxide	-	0.25
Terephthalic acid (PTA)	10 mg/m <sup>3</sup>	-
Toluene	20	-
Vinyl acetate, monomer (VAM)	10	15
para-Xylene (PX)	100	150

Notes:

a Threshold Limit Value.

b The time-weighted average concentration for a conventional 8-hour workday and a 40-hour workweek, to which it is believed that nearly all workers may be repeatedly exposed, day after day, without adverse effect.

c Short term exposure limit. It represents the concentration to which it is believed that workers can be exposed continuously for a short period of time without suffering from 1) irritation, 2) chronic or irreversible tissue damage, or 3) narcosis of sufficient degree to increase the likelihood of accidental injury, impair self-rescue or materially reduce work efficiency, and provided that the daily TWA is not exceeded.

d Both particle and vapor phases should be considered.

e Particles (insoluble or poorly soluble) Not Otherwise Specified. These values are recommended by ACGIH (TLVs and BEIs, 2009, Appendix B, Page 74) and have been reviewed and agreed with Licensors.

f Aerosol only.

g For Hydrogen sulphide, changes of TWA (from 10 to 1 ppm) and STEL (from 15 to 5 ppm) are proposed at present.

## 6.5 MSDS

The list of **Toxic, Hazardous** materials and catalysts materials handled in Unit 410 are detailed out in section **6.3.2**.

For the details of Material Safety data sheet for all these materials refer to MSDS Collection Report S-EP-R400-137Z-0003, Appendix A & B.

## 6.6 Dispersion of Hydrocarbons from vents

Dispersion study has been conducted for Units R41 to evaluate the hazards from dispersion of toxic and/or flammable gases.

- Dispersion from atmospheric vents in the Units R41
- Dispersion from streams/equipment in Unit R41 which contain Hydrogen Sulphide (H<sub>2</sub>S) in excess of 0.1% mol.

The results of the analysis are compared with acceptable contaminant concentration values in order to ensure the compliance with project requirements.

For more details refer to Dispersion Study Report (Document no. T-EP-R400-137Z-0002)

The list of the atmospheric vents evaluated, with the relevant data, is given in Tables below. The identification has been carried out through a review of the P&IDs (Listed in doc. D-EP-R400-1225-1001/2), and the stream composition from Heat and Material Balance (Doc S-BD-R41-1222-0101/0201/0301/0401/0501)

### 6.6.1 Atmospheric Vents

#### R41 Naphtha Reformer Unit

Item TAG	Equipment	Temp (°C)	Pressure (kg/cm <sup>2</sup> G)	Composition (% mol)					Service	Vent size (inch)	Vent height (m)
				N2	CO2	O2	H2O	HCL			
D-1412	REDUCTION CHAMBER	480	0.8 (Note 1)	100					Start-up only	2"	42
D-135	H2 RICH GAS COMPRESSOR KO DRUM (Note 2)	46	0.8 (Note 1)	100					Start-up only	12"	26.5
D-1460	WASHING DRUM (top)	45	atm	74.44	23.59	0.82	1.15		Discontinuous	2"	13.5
E-1466	BURNING FEED/EFFLUENT EXCHANGER (Note 3)	490	0.8 (Note 1)	82.25	16.87	0.45	0.42	0.01	Discontinuous	12"	39.3
E-1468	CALCINATION FEED / EFFLUENT EXCHANGER (Note 3)	465	0.8 (Note 1)	81.09	13.18	4.90	0.77	0.06	Discontinuous	4"	38.6
D-1402	LOCK HOPPER	46	0.8 (Note 1)	100					Discontinuous	2"	60
D-1406	NITROGEN STORAGE DRUM	46	0.8 (Note 1)	100					Discontinuous	2"	16.8
K-1405A/B	NITROGEN COMPRESSORS	152	0.8 (Note 1)	100					Discontinuous	2"	4
Z-1480	CAUSTIC SUMP PIT	30	atm	Note 4					Discontinuous	2"	3

Note 1 Pressure estimated in the vent line downstream the PSV

Note 2 The vent is operated with nitrogen during start-up. When flammable enters the equipment the stream is switched to flare.

Note 3 The vent on the tube side of the exchanger has been considered. Similar conditions and results hold for the vent on the shell side.

Note 4 Hydrogen Chloride concentration in the vapor < 5 ppm (TLV-C)

It is observed that intermittent H<sub>2</sub>S emissions from catalyst sulfiding are possible during start-up only, however they are routed to the flare, hence are not reported in the atmospheric vent list of R41.

### 6.7 Noise

The plant design must guarantee compliance with International Regulation - IFC (International Finance Corporation of World Bank Group) General EHS and Company regulation SAES-A-105: Noise Control. The applicable values are reported here below:

NOISE EXPOSURE LIMITS	
exposure limit values	90 dB(A)

Areas of the plant where it is not practical, using accepted noise abatement techniques, to comply with the work area sound pressure level limits shall be designed as “Restricted Areas”. In “Restricted Areas” suitable warning signs shall be erected.

The maximum allowable sound pressure level for a ‘Restricted Area’ shall be between 90 dB(A) and 95 dB(A).

For details refer to “Noise study report” doc no. T-EP-R400-1244-0004.

## **6.8 Fugitive Emission**

Fugitive emissions are emissions of gases or vapors from pressurized equipment due to leaks and other unintended or irregular releases of gases,. As well as the economic cost of lost commodities, fugitive emissions contribute to air pollution and climate change.

Fugitive emissions present other risks and hazards. Emissions of volatile organic compounds such as benzene pose a long term health risk to workers and local communities. In situations where large amounts of flammable liquids and gases are contained under pressure, leaks also increase the risk of fire and explosion.

Leaks from pressurized process equipment generally occur through valves, pipe connections, mechanical seals, or related equipment. Fugitive emissions also occur at evaporative sources such as storage tanks. Because of the technical difficulties and costs of detecting and quantifying actual fugitive emissions at a site or facility, and the variability and intermittent nature of emission flow rates, bottom-up estimates based on standard emission factors are generally used for annual reporting purposes

To minimize and control leaks at process facilities operators carry out regular leak detection and repair activities. Routine inspections of process equipment with gas detectors can be used to identify leaks and estimate the leak rate in order to decide on appropriate corrective action. Proper routine maintenance of equipment reduces the likelihood of leaks. Manual valves in Lethal, benzene and hydrogen services is considered as low fugitive rate B as per project specification S-PM-G000-136-0004

For details refer to “Fugitive Emission Study” doc no. T-EP-R400-1233-6004.

## Support Systems

## **7 SUPPORT SYSTEMS**

### **7.1 Control Building / Room Description**

The PCS systems are installed in an in-door environment in various control building / room described in this section.

#### **7.1.1 Central Control Room**

Central control rooms are the principle locations for the plant personnel to perform plant operations. PCS systems installed in central control rooms are normally for process information presentation to the operation personnel for plant operation, PCS system engineering and maintenance.

Central Control Room 3 (CCR-3) covers the phase-II petrochemical plant and new utilities.

#### **7.1.2 Emergency Control Centre (ECC)**

This is the existing Disaster Control Centre located in administration building for complex disaster control. A new emergency control center console (ECCCON) is located in this location.

#### **7.1.3 Fire Station (FS)**

The FS covers the whole phase-II facility for fire alarm monitoring. A new Fire Station Console (FSCON) is located in new Fire Station.

### **7.2 Process Interface Building (PIB)**

Process Interface Building (PIB) is the interface building between the PCS and Field Instrumentation Equipment. CCR3 communicate with a number of PIBs via redundant optical network links. The PIB covers one or more Risk Areas. Each PIB contains the marshalling cabinets, control system cabinets and Emergency Console for the PCS and I/O associated with the Risk Areas. All PCS I/O together with its related process and control equipment such as marshalling Cabinet, PDP and network and any other associated control equipment for Risk Areas is totally independent of each other. For each Risk Area within the PIB, the PCS, including DCS, SIS, FGAS, VMS, FFVMS and CCS is segregated from another Risk Area. Other sub-system equipment related to plant operation and control including telecommunication and fire alarm panel is installed in each PIB.

In case of loss of other Risk Areas or loss of communication link with CCR3, the PCS system for the dedicated Risk Area can be locally operated from the PIB on the Emergency Console and monitored from the Operator Shelter Workstation (OSWS).

### **7.3 Substation (SS)**

The substation (SS) is the interface between the electrical control system and the field installed electrical equipment. NO PCS systems are installed in substation. I/O signals for motor control or electrical equipment require interfacing with PCS system are hardwired by multi-core cables to respective PIB and is segregated by the Risk Area.

PCS system remote node are installed in substation and communicate I/O signals via remote node bus to PCS controllers in PIB.

## **Drawings and Reference Documents**

## **8 DRAWINGS AND REFERENCE DOCUMENTS**

### **8.1 Leak Test Procedure**

Document Type	Document Number
TIGHTNESS TEST AND INERTING PROCEDURE R41 FLARE DISTRIBUTION (HIGH PRESSURE AND LOW PRESSURE) SECTION	S-EP-R400-173-0013
TIGHTNESS TEST AND INERTING PROCEDURE R41 FUEL GAS DISTRIBUTION SECTION	S-EP-R400-173-0014
TIGHTNESS TEST AND INERTING PROCEDURE - NAPHTHA SPLITTER SECTION	S-EP-R400-173-0015
TIGHTNESS TEST AND INERTING PROCEDURE - NAPHTHA HYDROTREATMENT SECTION	S-EP-R400-173-0016
TIGHTNESS TEST AND INERTING PROCEDURE NHT REACTOR FEED HEATER FR-12110 FUEL GAS SECTION	S-EP-R400-173-0019
TIGHTNESS TEST AND INERTING PROCEDURE NAPHTHA STRIPPER REBOILER HEATER FR-122 FUEL GAS SECTION	S-EP-R400-173-0021
TIGHTNESS TEST AND INERTING PROCEDURE - AROMIZING REACTION SECTION AND CATALYST REGENERATION SECTION	S-EP-R400-173-0025
TIGHTNESS TEST AND INERTING PROCEDURE REACTOR FEED HEATER FR-13110/13210/13310/13410 FUEL GAS SECTION	S-EP-R400-173-0026
TIGHTNESS TEST AND INERTING PROCEDURE - HP ABSORPTION AND LPG RECOVERY SECTION	S-EP-R400-173-0030
TIGHTNESS TEST AND INERTING PROCEDURE R41 HYDROGEN DISTRIBUTION SECTION	S-EP-R400-173-0035
TIGHTNESS TEST AND INERTING PROCEDURE R41 CLOSED DRAIN SECTION	S-EP-R400-173-0036

### **8.2 Start-up Drawings**

#### **8.2.1 Drying Out Drawings**

Section	Attachment
R41-2	<i>Attachment 1</i>
R41-3 & R41-4	

### **8.2.2 R41-2 Start-up Drawings**

<b>Section</b>	<b>Attachment</b>
Startup Naphtha Circulation	<b>Attachment</b>
Pressurization	<b>2</b>
Sulfiding	

### **8.3 Blind List**

<b>Section</b>	<b>Attachment</b>
R41 (All Sections)	<b>Attachment</b> <b>3</b>

### **8.4 Valve position during Instrument Air Failure**

<b>Section</b>	<b>Attachment</b>
R41 (All Sections)	<b>Attachment</b> <b>4</b>

## 8.5 PFD

Section	Document Number
Symbology PFD	D-EP-R400-1223-4000 to 40010
R41-1	D-EP-R41-1223-4101 to 4118
R41-2	D-EP-R41-1223-4201 to 4204
R41-3	D-EP-R41-1223-4301 to 4312
R41-4	D-EP-R41-1223-4401 to 4404
R41-5	D-EP-R41-1223-4312
R41-9	D-EP-R41-1223-4901 to 4905, 4909, 4921

## 8.6 P&ID

Document Type/ Section	Document Number	
Specification for P&ID Symbol & Identification	S-EP-R400-137-125	
P&IDs List	D-EP-R400-1225-1001	
P&IDs Legend	D-EP-R400-1225-1003 to 1043	
R41-1	Main Process	D-EP-R41-1225-1101 to 1113
	Packages	N/A
R41-2	Main Process	D-EP-R41-1225-1201 to 1219
	Packages	D-EP-R41-1225-122 to 1230
R41-3	Main Process	D-EP-R41-1225-1301 to 13450
	Packages	D-EP-R41-1225-1346 to 1392
R41-4	Main Process	D-EP-R41-1225-1401 to 1432
	Packages	D-EP-R41-1225-1433 to 1457
R41-5	Main Process	D-EP-R41-1225-1501 to 1504
	Packages	D-EP-R41-1225-1505 to 1521
R41-9	Main Process	D-EP-R41-1225-1901 to 1918
	Packages	D-EP-R41-1225-1919 to 1926
Distribution P&ID	D-EP-R41-1225-1701 to 1781	

## 8.7 Cause and Effect Diagram

Section / Equipment	Document Number
Unit R41 C&ED	S-EP-R41-1223-8003
R41-K-1215	V-202-1420-130-M-01-523
R41-K-13450	V-202-1420-126-H-01-039
R41-K-135	V-202-1420-126-H-01-236
R41-K-13550	V-202-1420-126-H-01-441
R41-K-1465	V-202-1420-126-H-01-637
R41-K-1405	V-202-1420-130-S-03-615

R41-K-1470	V-202-1420-129-C-02-281
R41-K-152	V-202-1420-131-M-02-878
R41-PK-1510	V-202-1420-141-U-01-111
R41-RU-13580	V-202-1420-142-I-01-423
R41-DR-1472	V-202-1420-143-C-03-018
R41-AS-0001 FOR ANALYSER SHELTERS AND ANALYSERS	V-202-1420-286-Y-02-075
R41-AS-0002 FOR ANALYSER SHELTERS AND ANALYSERS	V-202-1420-286-Y-02-076

## 8.8 Control Narratives and DCS Graphic Printout

Section / Equipment	Document Number
DCS Graphic Printout	V-EP-RP02-PKGE-0116
R41-1	S-EP-R41-1223-2000
R41-2	S-EP-R41-1223-2005
R41-3	S-EP-R41-1223-2006
R41-4	S-EP-R41-1223-2007
R41-5	S-EP-R41-1223-2008
R41-9	S-EP-R41-1223-2009
DCS - PIB31	S-EP-R41-1371-2010
CCS - PIB31	S-EP-R41-1371-2012
R41-K-1215	V-202-1420-130-M-01-520
R41-K-13450	V-202-1420-126-H-01-038
R41-K-135	V-202-1420-126-H-01-235
R41-K-13550	V-202-1420-126-H-01-440
R41-K-1465	V-202-1420-126-H-01-636
R41-K-1405	V-202-1420-130-S-03-614
R41-K-1470	V-202-1420-129-C-02-282
R41-K-152A/B	V-202-1420-131-M-02-806
R41-RU-13580	V-202-1420-142-I-01-422
R41-PK-1510	V-202-1420-141-U-01-125
R41-DR-1472	V-202-1420-143-C-03-008
R41-DR-1465	V-202-1420-148-C-05-746
R41-FR-122	V-202-1420-144-K-01-1065
R41-FR-12110	V-202-1420-144-K-01-1267
R41-FR-13110/13210/13310/13410	V-202-1420-144-K-01-0342
R41-F-1405	V-202-1420-139-P-05-013
R41-F-14150	V-202-1420-139-P-05-013

## **8.9 DCS and SIS**

<b>Section</b>	<b>Document Number</b>
DCS Logic Diagrams	D-EP-R41-1371-40020
SIS Logic Diagrams	D-EP-R41-1371-4005

## **8.10 Instrument Installation Schedule**

<b>Section</b>	<b>Document Number</b>
Control valves	S-EP-R41-1374-1009
Flow Instruments	S-EP-R41-1373-2007
Level Instruments	S-EP-R41-1373-3005
Miscellaneous Instruments	S-EP-R41-1373-9001
Pressure Instruments	S-EP-R41-1373-1004
Safety Relief Valves	S-EP-R41-1374-2002
Temperature Instruments	S-EP-R41-1373-4004

## **8.11 List of Summaries**

<b>Title</b>	<b>Document Number</b>
UTILITY SUMMARY FOR NAPHTHA REFORMER UNIT	S-EP-R41-1223-5000
EQUIPMENT LIST FOR NAPHTHA REFORMER UNIT	S-EP-R41-1224-0001
FLARE LOAD SUMMARY FOR NAPHTHA REFORMER UNIT AND AROMATIC COMPLEX	S-EP-R400-1223-8001
EFFLUENT SUMMARY FOR NAPHTHA REFORMER UNIT	S-EP-R41-1223-6000
MSDS COLLECTION REPORT	R400-ZA-E-85010

## **8.12 Catalyst and Chemical Summary**

<b>Section</b>	<b>Document Number</b>
Unit R41 Catalyst Specification	S-EP-R41-13C1-5007
Unit R41 Chemicals Specification	S-EP-R41-13C2-5006
Unit R41 Inert Ceramic Ball Specification	S-EP-R41-13C1-5008

## **8.13 Fire Water System**

<b>Section</b>	<b>Document Number</b>
Overall Layout Of Firewater System	D-EP-R400-1225-7006
Hazardous Area Classification General Drawing	D-EP-R400-138-0001
R400-Overall Plot Plan - Escape Route Layout	D-EP-R400-137Z-0001
R41 Conceptual Layout Of Firewater System	D-EP-R41-1226-0001
R41 – P&ID - Firewater Network	D-EP-R41-1225-7001
P&ID Spray System Distribution - R41	D-EP-R41-1225-7002
Fire And Gas Detection System Drawing - Unit R41	D-EP-R41-1241-0001
R41 - Hazardous Area Classification Unit R41 Plant Drawing	D-EP-R41-138-0001
R41 - Fireproofing Drawing	D-EP-R41-1378-7001
R41 - Escape Route Layout	D-EP-R41-137Z-0001

## **8.14 Plot Plan**

<b>Section</b>	<b>Document Number</b>
OVERALL PLOT PLAN	D-EP-R400-1225-0001
R41 - PLOT PLAN (1/4)	D-EP-R41-1225-0001
R41 - PLOT PLAN (2/4)	D-EP-R41-1225-0002
R41 - PLOT PLAN AREA 1	D-EP-R41-1225-0004
R41 - PLOT PLAN AREA 2	D-EP-R41-1225-0005
R41 - PLOT PLAN AREA 3	D-EP-R41-1225-0006
R41 - PLOT PLAN AREA 4	D-EP-R41-1225-0007
R41 - PLOT PLAN AREA 5 (1/2)	D-EP-R41-1225-0008
R41 - PLOT PLAN AREA 5 (2/2)	D-EP-R41-1225-0009
R41 - PLOT PLAN AREA 6	D-EP-R41-1225-0010
R41 - PLOT PLAN AREA 7	D-EP-R41-1225-0011
R41 - PLOT PLAN (4/4)	D-EP-R41-1225-0013
R41 - PLOT PLAN (3/4)	D-EP-R41-1225-0012

**8.15 Installation, Operation and Maintenance Manual- List of Vendor Reference Documents**

Equipment Tag	Service	Installation, Operation and Maintenance Manual
<b>REACTORS</b>		
R41-R-121	HYDROTREATING REACTOR	V-202-1420-105-H-01-093
R41-R-131	FIRST REACTOR	V-202-1420-108-F-01-405
R41-R-132	SECOND REACTOR	V-202-1420-108-F-01-406
R41-R-133	THIRD REACTOR	V-202-1420-108-F-01-407
R41-R-134	FOURTH REACTOR	V-202-1420-108-F-01-408
R41-R-13590A/B	HYDROGEN RICH GAS CHLORIDE ADSORBERS	V-202-1420-109-A-05-545
R41-R-13610A/B	DEPENTANIZER FEED CHLORIDE ADSORBERS	V-202-1420-109-A-05-546
R41-R-140	REGENERATOR	V-202-1420-108-F-01-409
<b>COLUMNS</b>		
R41-T-111	NAPHTHA DEPENTANIZER	V-202-1420-112-Z-01-580
		V-202-1420-110-B-01-375 (for Internals)
R41-T-112	NAPHTHA SPLITTER	V-202-1420-109-A-05-551
		V-202-1420-110-B-01-357 (for Internals)
R41-T-113	LCN SPLITTER	V-202-1420-112-Z-01-581
		V-202-1420-110-B-01-358 (for Internals)
R41-T-122	NHT STRIPPER	V-202-1420-109-A-05-552
		V-202-1420-110-B-01-359 (for Internals)
R41-T-136	DEPENTANIZER COLUMN	V-202-1420-109-A-05-553
		V-202-1420-110-B-01-360 (for Internals)
R41-T-137	DEETHANIZER COLUMN	V-202-1420-112-Z-01-582

		V-202-1420-110-B-01-361 (for Internals)
R41-T-138	DEBUTANIZER COLUMN	V-202-1420-112-Z-01-583
		V-202-1420-110-B-01-362 (for Internals)
<b>VESSELS</b>		
R41-D-11150	NAPHTHA DEPENTANIZER REFLUX DRUM	V-202-1420-112-Z-01-585
R41-D-11250	NAPHTHA SPLITTER REFLUX DRUM	V-202-1420-112-Z-01-586
R41-D-1135	LCN SPLITTER REFLUX DRUM	V-202-1420-113-Z-01-488
R41-D-12140	SEPARATOR DRUM	V-202-1420-109-A-05-564
R41-D-1215	RECYCLE COMPRESSORS KO DRUM	V-202-1420-113-Z-01-489
R41-D-12010	FEED SURGE DRUM	V-202-1420-112-Z-01-587
R41-D-12250	STRIPPER REFLUX DRUM	V-202-1420-113-Z-01-490
R41-D-12160	SOUR WATER DRUM	V-202-1420-113-Z-01-491
R41-D-1750	FUEL GAS KO DRUM	V-202-1420-113-Z-01-492
R41-D-13450	SEPARATOR DRUM	V-202-1420-109-A-05-565
R41-D-135	H2 RICH GAS COMPRESSOR KO DRUM	V-202-1420-112-Z-01-588
R41-D-1353	FIRST INTERSTAGE DRUM	V-202-1420-113-Z-01-493
R41-D-13580	HP ABSORBER DRUM	V-202-1420-112-Z-01-589
R41-D-136100	LPG ABSORBER DRUM	V-202-1420-112-Z-01-590
R41-D-13550	SECOND INTERSTAGE DRUM	V-202-1420-113-Z-01-494
R41-D-13650	DEPENTANIZER REFLUX DRUM	V-202-1420-112-Z-01-591
R41-D-13750	DEETHANIZER REFLUX DRUM	V-202-1420-113-Z-01-495
R41-D-13850	DEBUTANIZER REFLUX DRUM	V-202-1420-113-Z-01-496
R41-D-1301	CONTINUOUS BLOWDOWN DRUM	V-202-1420-113-Z-01-497
R41-D-1751	FUEL GAS KO DRUM	V-202-1420-113-Z-01-498
R41-D-1401	UPPER SURGE DRUM	V-202-1420-108-F-01-410

R41-D-1402	LOCK HOPPER	V-202-1420-108-F-01-411
R41-D-1403	FIRST LOWER HOPPER	V-202-1420-108-F-01-412
R41-D-1404	FIRST LIFT POT	V-202-1420-108-F-01-413
R41-D-1405	NITROGEN COMPRESSOR KO DRUM	V-202-1420-113-Z-01-499
R41-D-1406	NITROGEN STORAGE DRUM	V-202-1420-109-A-05-566
R41-D-1411	FIRST UPPER HOPPER	V-202-1420-108-F-01-414
R41-D-1412	REDUCTION CHAMBER	V-202-1420-108-F-01-415
R41-D-1413	SECOND LOWER HOPPER	V-202-1420-108-F-01-416
R41-D-1414	SECOND LIFT POT	V-202-1420-108-F-01-417
R41-D-1421	FIRST BALANCE DRUM	V-202-1420-108-F-01-418
R41-D-1422	SECOND UPPER HOPPER	V-202-1420-108-F-01-419
R41-D-1423	THIRD LOWER HOPPER	V-202-1420-108-F-01-420
R41-D-1424	THIRD LIFT POT	V-202-1420-108-F-01-421
R41-D-1431	SECOND BALANCE DRUM	V-202-1420-108-F-01-422
R41-D-1432	THIRD UPPER HOPPER	V-202-1420-108-F-01-423
R41-D-1433	FOURTH LOWER HOPPER	V-202-1420-108-F-01-424
R41-D-1434	FOURTH LIFT POT	V-202-1420-108-F-01-425
R41-D-1441	THIRD BALANCE DRUM	V-202-1420-108-F-01-426
R41-D-1442	FOURTH UPPER HOPPER	V-202-1420-108-F-01-427
R41-D-1443	FIFTH LOWER HOPPER	V-202-1420-108-F-01-428
R41-D-1444	FIFTH LIFT POT	V-202-1420-108-F-01-429
R41-D-1460	WASHING DRUM	V-202-1420-118-H-02-224
R41-D-1472	AIR DRYER DRUM	V-202-1420-113-Z-01-500
R41-D-1501	PSA FEED COALESCER	V-202-1420-113-Z-01-513
R41-D-181	LP FLARE KO DRUM	V-202-1420-112-Z-01-592

R41-D-182	HP FLARE KO DRUM	V-202-1420-109-A-05-567
R41-D-1630	MP CONDENSATE FLASH DRUM	V-202-1420-113-Z-01-501
R41-D-1640	LP CONDENSATE FLASH DRUM	V-202-1420-113-Z-01-502
R41-D-1000	CLOSED DRAIN DRUM	V-202-1420-112-Z-01-593
<b>AFC</b>		
R41-E-1115	NAPHTHA DEPENTANIZER AIR CONDENSER	V-202-1420-116-G-02-006
R41-E-1125	NAPHTHA SPLITTER AIR CONDENSER	V-202-1420-116-G-02-500
R41-E-1135	LCN SPLITTER AIR CONDENSER	V-202-1420-116-G-02-501
R41-E-1212	REACTOR EFFLUENT AIR CONDENSER	V-202-1420-116-G-02-502
R41-E-1225	STRIPPER AIR CONDENSER	V-202-1420-116-G-02-503
R41-E-1222	HYDROTREATED NAPHTHA AIR COOLER	V-202-1420-116-G-02-504
R41-E-13410	REACTOR EFFLUENT AIR COOLER	V-202-1420-116-G-02-505
R41-E-1351	FIRST INTERSTAGE AIR COOLER	V-202-1420-116-G-02-506
R41-E-1353	SECOND INTERSTAGE AIR COOLER	V-202-1420-116-G-02-507
R41-E-13650	DEPENTANIZER AIR COOLER	V-202-1420-116-G-02-508
R41-E-1363	SR NAPHTHA TANK RUNDOWN AIR COOLER	V-202-1420-116-G-02-509
<b>EXCHANGERS</b>		
R41-E-1114A/B	C5 RICH CUT TRIM COOLERS	V-202-1420-121-D-02-257
R41-E-111	NAPHTHA DEPENTANIZER REBOILER	V-202-1420-118-H-02-074
R41-E-1116	NAPHTHA DEPENTANIZER TRIM COOLER	V-202-1420-121-D-02-279
R41-E-1126A/B	LIGHT NAPHTHA TRIM COOLERS	V-202-1420-121-D-02-258
R41-E-112A/B	NAPHTHA SPLITTER REBOILERS	V-202-1420-121-D-02-259
R41-E-1111A/B	NAPHTHA DEPENTANIZER FEED/NAPHTHA SPLITTER BOTTOM EXCHANGERS	V-202-1420-118-H-02-075
R41-E-1112	NAPHTHA PREHEATER	V-202-1420-121-D-02-260
R41-E-1136A/B	LIGHT LCN TRIM COOLERS	V-202-1420-121-D-02-261

R41-E-113	LCN SPLITTER REBOILER	V-202-1420-121-D-02-262
R41-E-1131A/B	LCN SPLITTER FEED/BOTTOM EXCHANGERS	V-202-1420-121-D-02-263
R41-E-12110A/G	REACTOR FEED / EFFLUENT EXCHANGERS	V-202-1420-118-H-02-070
R41-E-12110B/H	REACTOR FEED / EFFLUENT EXCHANGERS	V-202-1420-118-H-02-070
R41-E-12110C/J	REACTOR FEED / EFFLUENT EXCHANGERS	V-202-1420-118-H-02-070
R41-E-12110D/K	REACTOR FEED / EFFLUENT EXCHANGERS	V-202-1420-118-H-02-070
R41-E-12110E/L	REACTOR FEED / EFFLUENT EXCHANGERS	V-202-1420-118-H-02-070
R41-E-12110F/M	REACTOR FEED / EFFLUENT EXCHANGERS	V-202-1420-118-H-02-070
R41-E-1213A/B	REACTOR EFFLUENT TRIM CONDENSERS	V-202-1420-118-H-02-076
R41-E-1226A/B	STRIPPER TRIM CONDENSERS	V-202-1420-121-D-02-264
R41-E-1221A/B/C	STRIPPER FEED / BOTTOM EXCHANGERS	V-202-1420-118-H-02-077
R41-E-1223A/B	HYDROTREATED NAPHTHA TRIM COOLERS	V-202-1420-121-D-02-265
R41-E-13110	REFORMER FEED/EFFLUENT EXCHANGER	V-202-1420-101-A-01-041
R41-E-1342A/B	REACTOR EFFLUENT TRIM COOLERS	V-202-1420-118-H-02-078
R41-E-1352 A/B	FIRST INTERSTAGE TRIM COOLER	V-202-1420-121-D-02-266
R41-E-13550A/B	HP ABSORBER FEED COOLERS	V-202-1420-118-H-02-079
R41-E-1356	H2 RICH GAS / HP ABSORBER FEED EXCHANGER	V-202-1420-121-D-02-267
R41-E-1357	HP ABSORBER FEED / BOTTOM EXCHANGER	V-202-1420-118-H-02-080
R41-E-1354	SECOND INTERSTAGE TRIM COOLER	V-202-1420-118-H-02-208
R41-E-1366 A/B/C/D	DEPENTANIZER TRIM COOLERS	V-202-1420-118-H-02-210
R41-E-136	DEPENTANIZER BOTTOM STEAM GENERATOR	V-202-1420-118-H-02-212
R41-E-1362	DEPENTANIZER FEED BOTTOM EXCHANGER B	V-202-1420-118-H-02-213
R41-E-13610	DEPENTANIZER FEED BOTTOM EXCHANGER A	V-202-1420-118-H-02-215
R41-E-1364 A/B	SR NAPHTHA TANK RUNDOWN TRIM COOLERS	V-202-1420-121-D-02-268
R41-E-1375	DEETHANIZER CONDENSER	V-202-1420-121-D-02-269

R41-E-137	DEETHANIZER REBOILER	V-202-1420-120-D-02-309
R41-E-13850	DEBUTANIZER CONDENSER	V-202-1420-121-D-02-270
R41-E-138	DEBUTANIZER REBOILER	V-202-1420-121-D-02-271
R41-E-1381	DEETHANIZER FEED / DEBUTANIZER BOTTOM HEAT EXCHANGER	V-202-1420-121-D-02-272
R41-E-1382A/B	C5 CUT TRIM COOLERS	V-202-1420-121-D-02-273
R41-E-1301	BLOWDOWN COOLER	V-202-1420-123-D-02-037
R41-E-1405	NITROGEN LOOP TRIM COOLER	V-202-1420-121-D-02-274
R41-E-1406	NITROGEN STORAGE TRIM COOLER	V-202-1420-121-D-02-275
R41-E-1416	REDUCTION EXCHANGER	V-202-1420-118-H-02-071
R41-E-1417	HYDROGEN LIFT GAS EXCHANGER	V-202-1420-118-H-02-072
R41-E-1468	CALCINATION FEED / EFFLUENT EXCHANGER	V-202-1420-121-D-02-276
R41-E-1466	BURNING FEED/EFFLUENT EXCHANGER	V-202-1420-121-D-02-277
R41-E-1460	REGENERATION LOOP TRIM COOLER	V-202-1420-118-H-02-073
R41-E-1465	REGENERATION COMPRESSOR TRIM COOLER	
R41-E-152	TAIL GAS AFTER COOLER	V-202-1420-121-D-02-278
R41-E-1451 A/B	DEMINERALIZED WATER COOLER	V-202-1420-123-D-02-039
<b>FURNACES</b>		
R41-FR-12110	REACTOR FEED HEATER	V-202-1420-144-K-01-1261
R41-FR-12110-E	REACTOR FEED HEATER CONVECTION SECTION	V-202-1420-144-K-01-1261
R41-FR-122	STRIPPER REBOILER	V-202-1420-144-K-01-1059
R41-FR-13110	PREHEATER	V-202-1420-144-K-01-0105
R41-FR-13210	FIRST INTERHEATER	V-202-1420-144-K-01-0105
R41-FR-13310	SECOND INTERHEATER	V-202-1420-144-K-01-0105
R41-FR-13410	THIRD INTERHEATER	V-202-1420-144-K-01-0105
R41-FR-130-SG	REFORMER FURNACE CONVECTION SECTION Waste Heat Boiler	V-202-1420-144-K-01-0105

R41-FR-13110E	CONVECTION REBOILER COIL	V-202-1420-144-K-01-0105
<b>PUMPS</b>		
R41-P-1115A/B	NAPHTHA DEPENTANIZER REFLUX PUMPS	V-202-1420-134-F-03-369
R41-P-1114A/B	C5 RICH CUT PUMPS	V-202-1420-134-F-02-828
R41-P-1125A/B	NAPHTHA SPLITTER REFLUX PUMPS	V-202-1420-134-F-02-856
R41-P-1120A/B	HEAVY NAPHTHA PUMPS	V-202-1420-134-F-02-857
R41-P-1135A/B	LCN SPLITTER REFLUX PUMPS	V-202-1420-134-F-02-829
R41-P-1130A/B	HEAVY LCN PUMPS	V-202-1420-134-F-02-830
R41-P-1201A/B	FEED PUMPS	V-202-1420-134-F-03-386
R41-P-1225A/B	STRIPPER REFLUX PUMPS	V-202-1420-134-F-02-831
R41-P-122A/B/C	STRIPPER BOTTOM PRODUCT PUMPS	V-202-1420-134-F-03-476
R41-P-13450A/B	SEPARATOR BOTTOM PUMPS	V-202-1420-134-F-03-404
R41-P-13610A/B	LPG ABSORBER BOTTOM PUMPS	V-202-1420-134-F-03-422
R41-P-13650A/B	DEPENTANIZER REFLUX PUMPS	V-202-1420-134-F-02-832
R41-P-1366A/B	DEPENTANIZER DISTILLATE PUMPS	V-202-1420-134-F-03-458
R41-P-136A/B	DEPENTANIZER REBOILER PUMPS	V-202-1420-134-F-03-440
R41-P-1375A/B	DEETHANIZER REFLUX PUMPS	V-202-1420-134-F-02-833
R41-P-13850A/B	DEBUTANIZER REFLUX PUMPS	V-202-1420-134-F-02-834
R41-P-1460A/B	CAUSTIC RECYCLE PUMPS	V-202-1420-138-F-03-810
R41-P-1461A/B	WASHING WATER PUMPS	V-202-1420-134-F-02-835
R41-P-1480 A	CAUSTIC SUMP PIT PUMP	V-202-1420-135-W-01-462
R41-P-181A/B	LP FLARE CONDENSATE PUMPS	V-202-1420-134-F-02-836
R41-P-1030 A/B/C	INTERMEDIATE SYS LIFT STATION PUMP	V-202-1420-135-W-01-450
R41-P-1040 A/B	SWS LIFT STATION PUMPS	V-202-1420-152-F-05-316
R41-P-182A/B	HP FLARE CONDENSATE PUMPS	V-202-1420-134-F-02-837

R41-P-1640A/B	HOT CONDENSATE PUMPS	V-202-1420-136-F-03-662
R41-P-1000	CLOSED DRAIN PUMP	V-202-1420-135-W-01-404
R41-P-1010	OWS LIFT STATION PUMPS	V-202-1420-135-W-01-426
R41-P-1020A/B/C	SYS LIFT STATION PUMPS	V-202-1420-135-W-01-438
R41-P-1001	OILY WATER DRAIN PUMP	V-202-1420-135-W-01-426
<b>COMPRESSORS</b>		
R41-K-1215A/B	RECYCLE COMPRESSORS	V-202-1420-130-M-01-457
R41-K-13450	RECYCLE COMPRESSOR	V-202-1420-126-H-01-008
R41-K-135	H2 RICH GAS COMPRESSOR (1ST STAGE)	V-202-1420-126-H-01-208
	H2 RICH GAS COMPRESSOR (2ND STAGE)	V-202-1420-126-H-01-208
R41-K-13550	H2 RICH GAS COMPRESSOR (3RD STAGE)	V-202-1420-126-H-01-408
R41-B-14150	ELUTRIATION BLOWER	V-202-1420-133-I-02-204
R41-K-1405A/B	NITROGEN COMPRESSORS	V-202-1420-130-S-03-624
R41-K-1465	REGENERATION LOOP COMPRESSOR	V-202-1420-126-H-01-608
R41-K-1470	AIR COMPRESSORS	V-202-1420-129-C-02-257
R41-K-152A/B	PSA TAIL GAS COMPRESSORS	V-202-1420-131-M-02-807
<b>PACKAGES</b>		
R41-Z-1201	DMDS PACKAGE	V-202-1420-137-I-04-303
R41-Z-1225	CORROSION INHIBITOR INJECTION PACKAGE	V-202-1420-137-I-04-356
R41-Z-1312	H2O INJECTION PACKAGE	V-202-1420-137-I-04-358
R41-Z-1313	DMDS INJECTION PACKAGE	V-202-1420-137-I-04-359
R41-Z-1314	CHLORIDE INJECTION PACKAGE	V-202-1420-137-I-04-360
R41-Z-1301	PHOSPHATE INJECTION PACKAGE	V-202-1420-137-I-04-357
R41-Z-1460	CAUSTIC PACKAGE	V-202-1420-137-I-04-361
R41-Z-1469	CHLORINATION AGENT PACKAGE	V-202-1420-137-I-04-363

R41-Z-1468	OXYCHLORINATION WATER PACKAGE	V-202-1420-137-I-04-362
R41-PK-1510	PSA UNIT PACKAGE	V-202-1420-141-U-01-105
R41-RU-13580	REFRIGERATION PACKAGES A/B	V-202-1420-142-I-01-488
		V-202-1420-142-I-01-408
R41-DR-1465	REGENERATION LOOP DRYER	V-202-1420-148-C-05-708
		V-202-1420-148-C-05-750
R41-DR-1472	AIR DRYER	V-202-1420-143-C-03-037
<b>MISCELLANEOUS</b>		
R41-E-14150	FIRST UPPER HOPPER FINNED TUBE EXCHANGER	V-202-1420-149-B-03-009
R41-E-1412	REDUCTION HEATER	V-202-1420-124-V-01-067
R41-E-1467	BURNING HEATER	V-202-1420-124-V-01-068
R41-E-1469	OXYCHLORINATION HEATER	V-202-1420-124-V-01-069
R41-E-1473	CALCINATION HEATER	V-202-1420-124-V-01-070
R41-F-13110A/B	FEED FILTERS	V-202-1420-139-P-05-004
R41-F-1405	UPPER SURGE DRUM FINES FILTER	V-202-1420-139-P-05-038
R41-F-14150	FIRST UPPER HOPPER FINES FILTER	V-202-1420-139-P-05-039
R41-F-1465	REGENERATION LOOP FILTER	V-202-1420-139-P-05-042
R41-F-1720A/B	INSTRUMENT AIR FILTERS	V-202-1420-139-P-05-045
R41-EJ-1215	START-UP EJECTOR	V-202-1420-140-T-08-192
R41-231-G-101	EMERGENCY DIESEL GENERATOR	V-202-1420-147-C-06-119
R41-239-G-101	EMERGENCY DIESEL GENERATOR	V-202-1420-147-C-06-319

## 8.16 List of General Criteria

Document Number	Title
S-PM-G000-1222-0001	BASIC ENGINEERING DESIGN DATA(BEDD)
S-PM-G000-1222-0602	ISOLATION PHILOSOPHY
S-PM-G000-1222-0603	SPARING PHILOSOPHY
S-PM-G000-1222-0604	PROCESS CONTROL & OPERATION PHILOSOPHY
S-PM-G000-1222-0605	EMERGENCY SHUTDOWN PHILOSOPHY
S-PM-G000-1222-0606	EMERGENCY DEPRESSURING PHILOSOPHY
S-PM-G000-1222-0607	OVERPRESSURE PROTECTION PHILOSOPHY
S-PM-G000-1222-0608	DRAINAGE PHILOSOPHY
S-PM-G000-1222-0609	FLARE DESIGN PHILOSOPHY
S-PM-G000-1222-0610	COMPRESSOR CONTROL PHILOSOPHY
S-PM-G000-1240-0001	ENVIRONMENTAL DESIGN BASIS
S-PM-G000-1240-0002	HSE DESIGN PHILOSOPHY
S-BD-R41-1222-0101	PROCESS BOOK FOR R41-1
S-BD-R41-1222-0201	PROCESS BOOK FOR R41-2
S-BD-R41-1222-0301	PROCESS BOOK FOR R41-3
S-BD-R41-1222-0303	ADDENDUM TO PROCESS BOOK FOR R41-3
S-BD-R41-1222-0401	PROCESS BOOK FOR R41-4
S-BD-R41-1222-0501	PROCESS BOOK FOR R41-5
S-EP-R400-1386-0059	GENERAL SPECIFICATION FOR TELECOMMUNICATION SYSTEMS
D-EP-R400-1371-2001	PCS AND TPV SYSTEM ARCHITECTURE

V-EP-PRII-CORE-0102	SYSTEM DESIGN DOCUMENT (PCS)
S-EP-R400-1222-0040	SAFETY CRITERIA
S-EP-R400-1241-0001	FIRE AND GAS DETECTION SYSTEM
S-EP-R400-13B4-0001	FIREPROOFING GENERAL CRITERIA
S-EP-R400-137Z-0001	ESCAPE ROUTE GENERAL CRITERIA
S-EP-R400-137Z-0002	SAFETY SIGN CRITERIA
S-EP-R400-137Z-0004	SAFETY SHOWER AND EYE WASH STATION CRITERIA
T-EP-R400-1222-0001	ENVIRONMENTAL PHILOSOPHY
S-EP-R400-1226-0001	BASIS OF DESIGN FOR FIRE PROTECTION SYSTEM

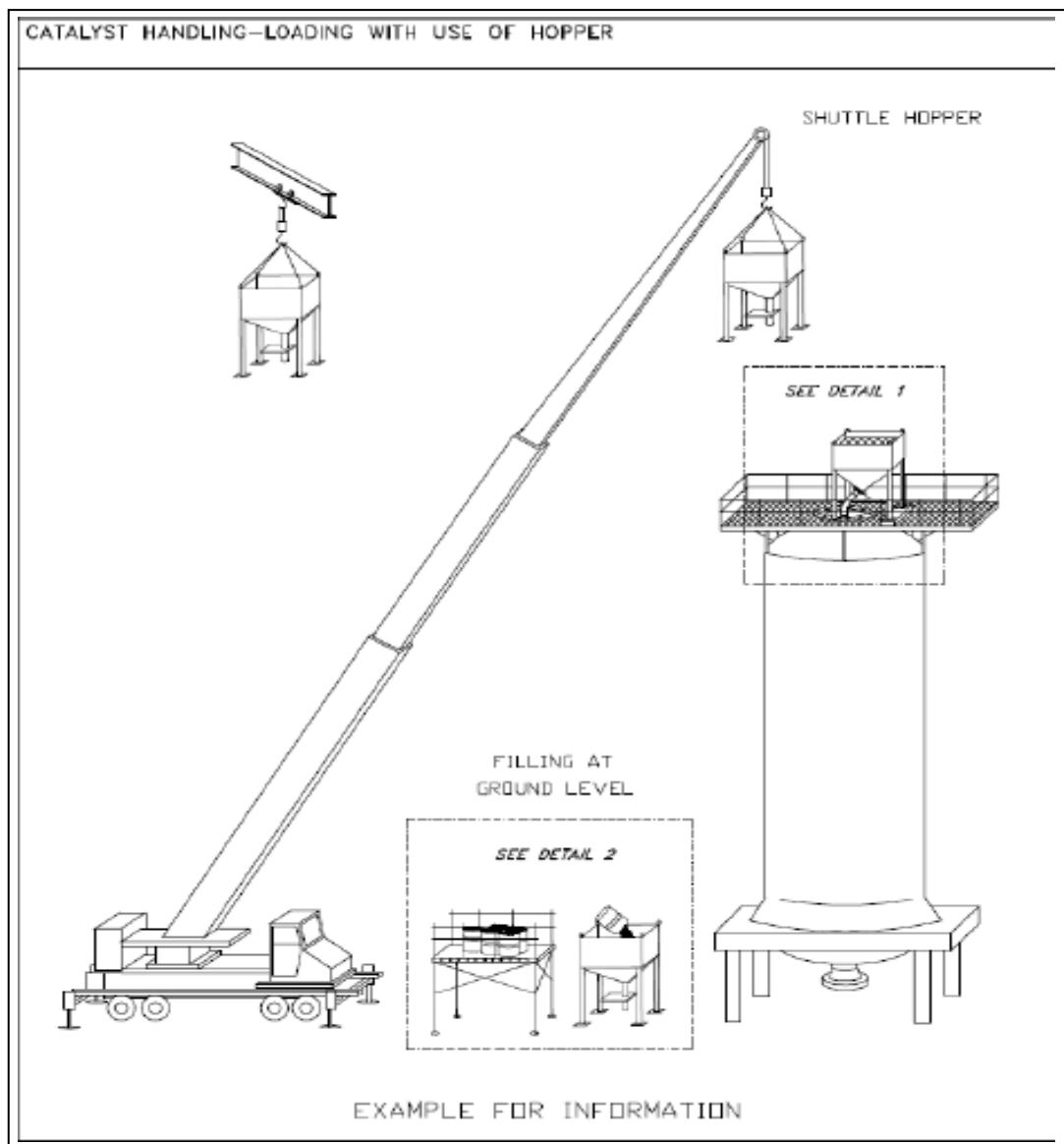
## 8.17 List of Operating Instructions, Precommissioning, Commissioning and start-up documents

Title	Document Number
OPERATING INSTRUCTION R41-1	S-EP-R41-1283-0101
OPERATING INSTRUCTION R41-2	S-EP-R41-1283-0102
OPERATING INSTRUCTION R41-3 and R41-4	S-EP-R41-1283-0103
PRE-COMMISSIONING AND MECHANICAL COMPLETION PLAN	S-EP-R400-17Z-0001
COMMISSIONING PLAN	S-EP-R400-173-0001
START-UP PLAN	S-EP-R400-171-0001
PRE-COMMISSIONING MANUAL	S-EP-R400-172-0002

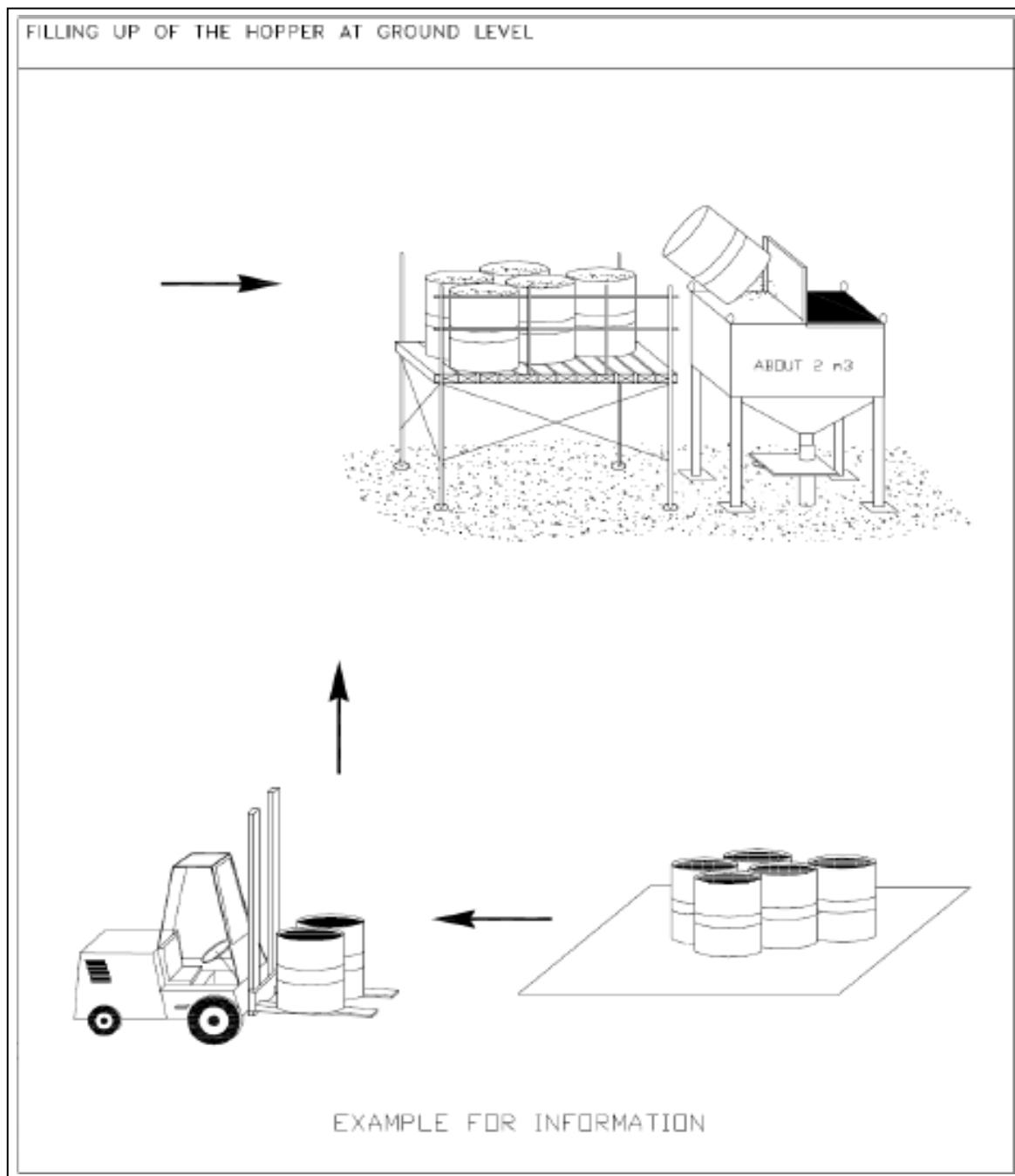
## 8.18 Catalyst Loading Drawings

### 8.18.1 Catalyst Loading for Naphtha Hydrotreatment Section (R41-2)

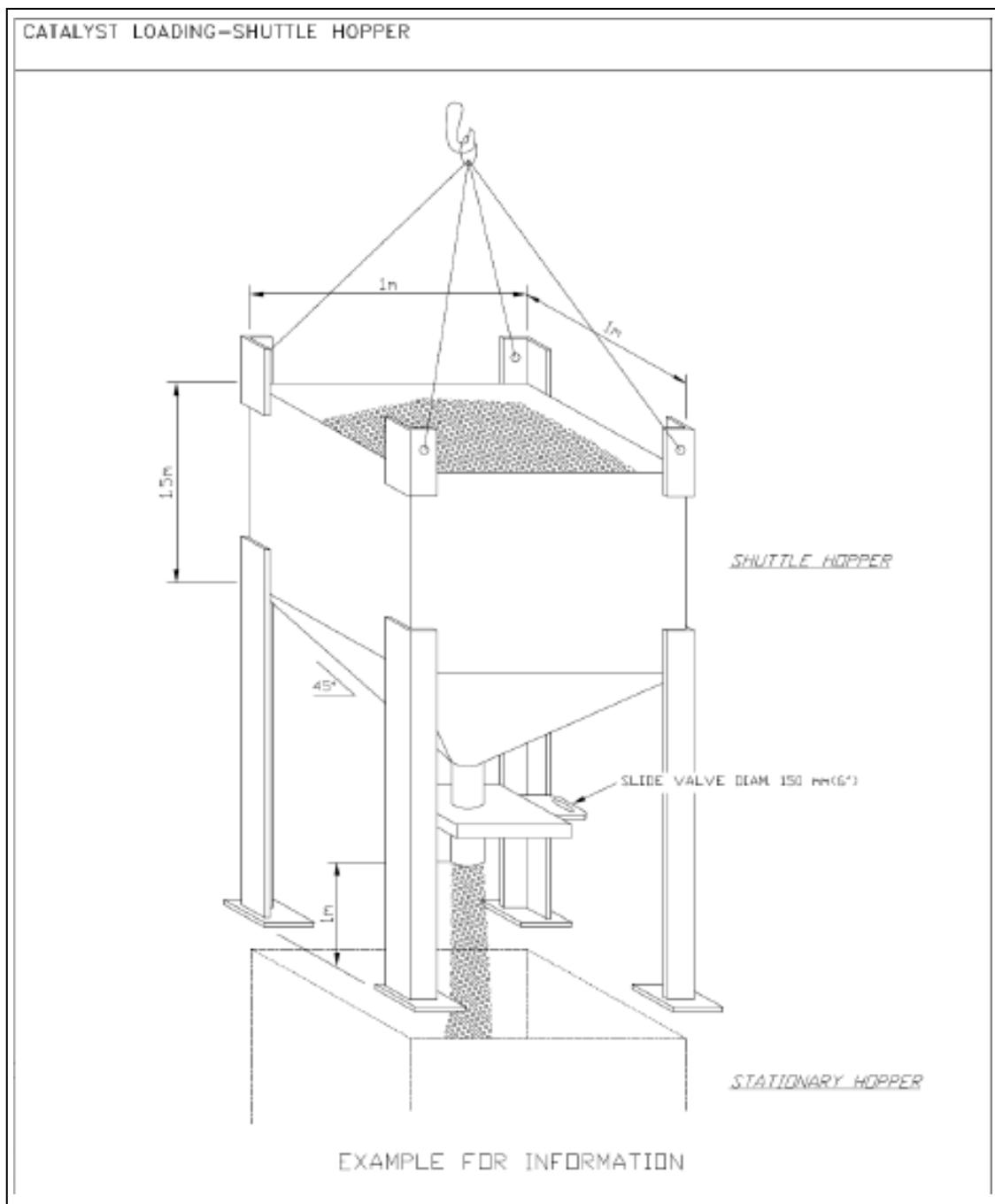
#### 8.18.1.1 Catalyst Handling-Loading with use of Hopper



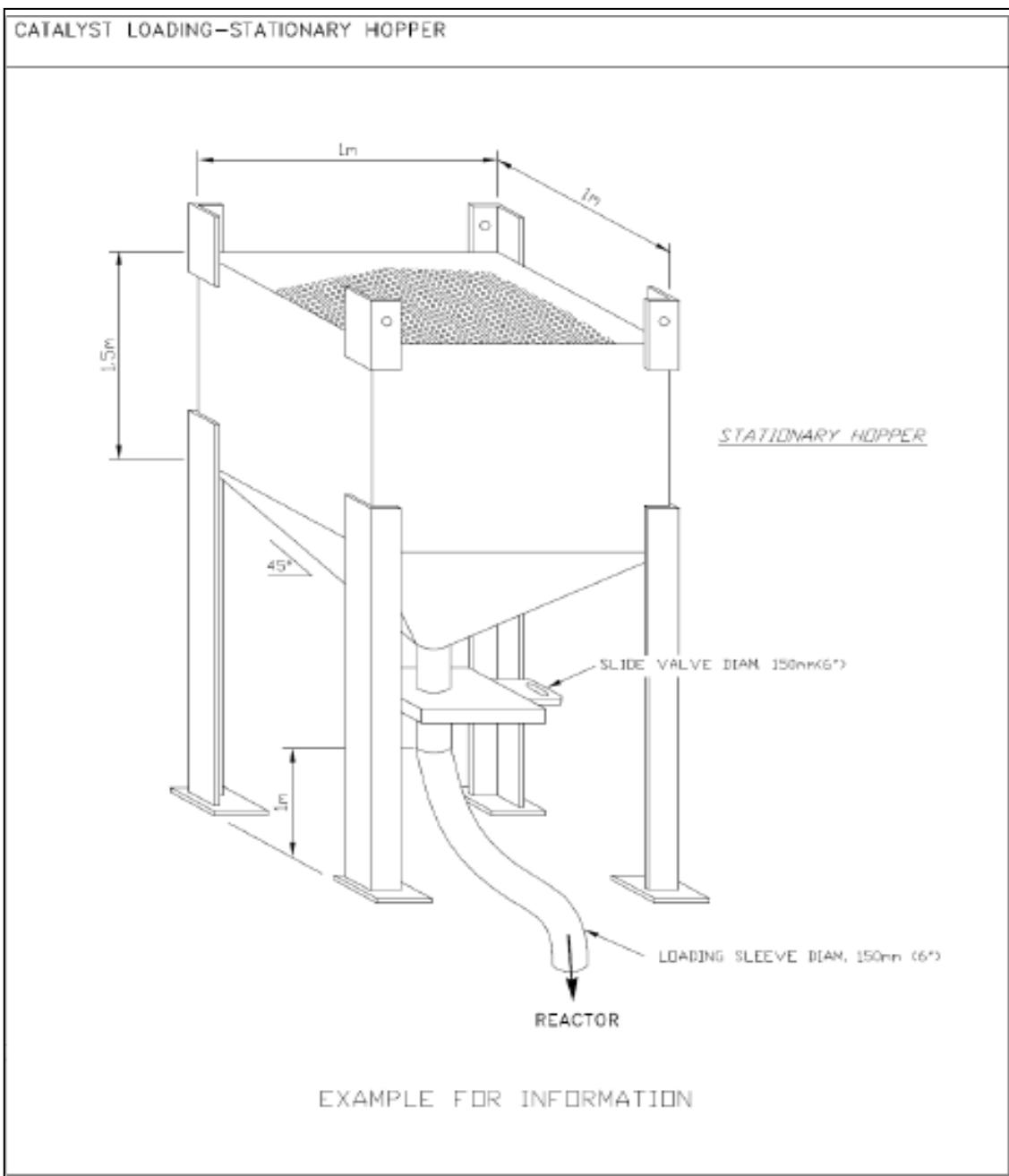
**8.18.1.2 Filling up of the Hopper at ground level**



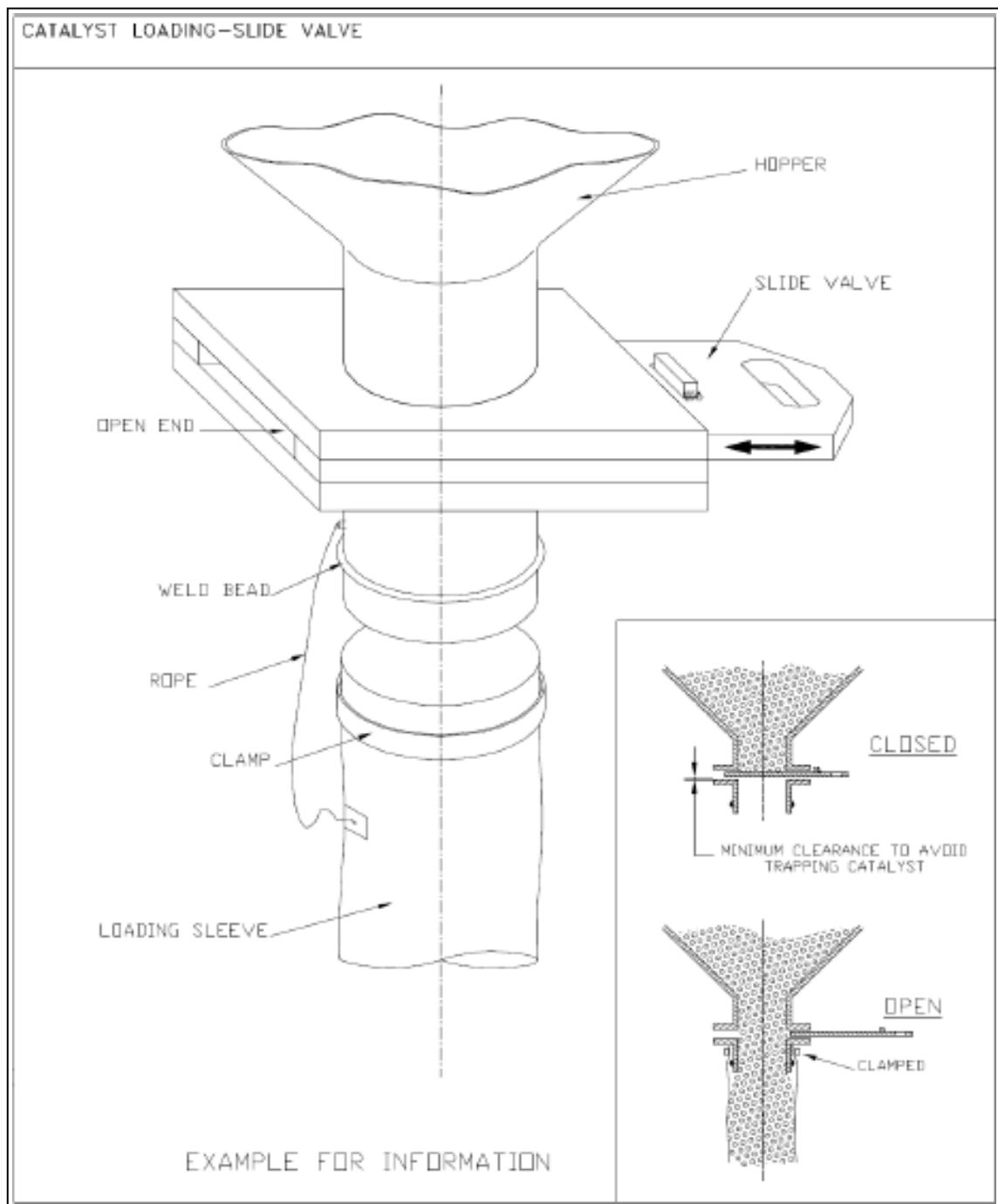
### **8.18.1.3 Catalyst Loading – Shuttle Hopper**



#### **8.18.1.4 Catalyst Loading – Stationary Hopper**



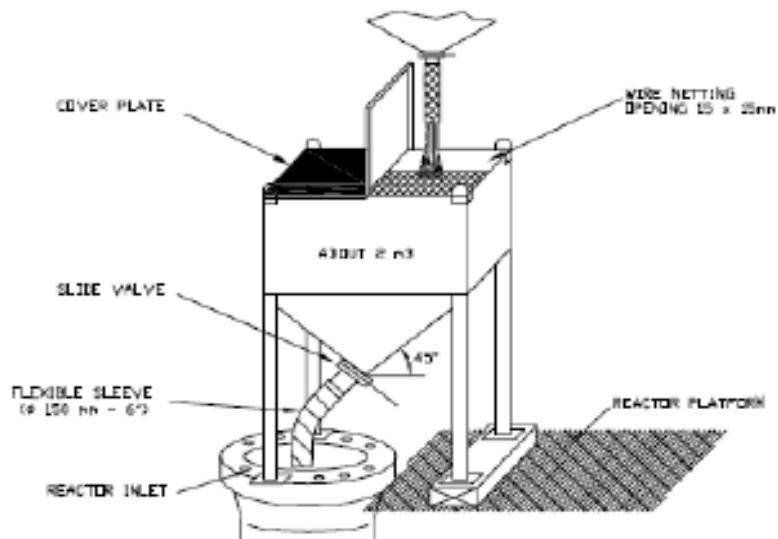
#### **8.18.1.5 Catalyst Loading – Slide Valve**



**8.18.1.6 Hopper Located on top of Reactor – Under Air / Hopper filling at ground level**

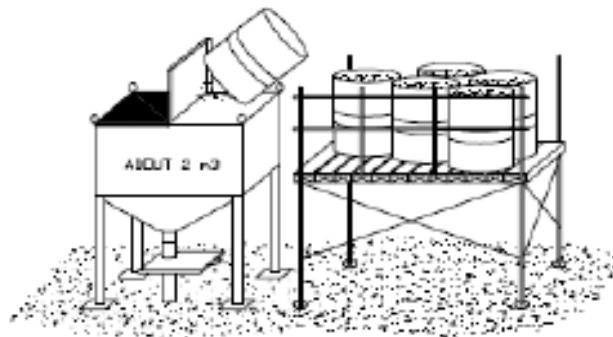
HOPPER LOCATED ON THE TOP OF REACTOR – UNDER AIR  
HOPPER FILLING AT GROUND LEVEL

DETAIL 1



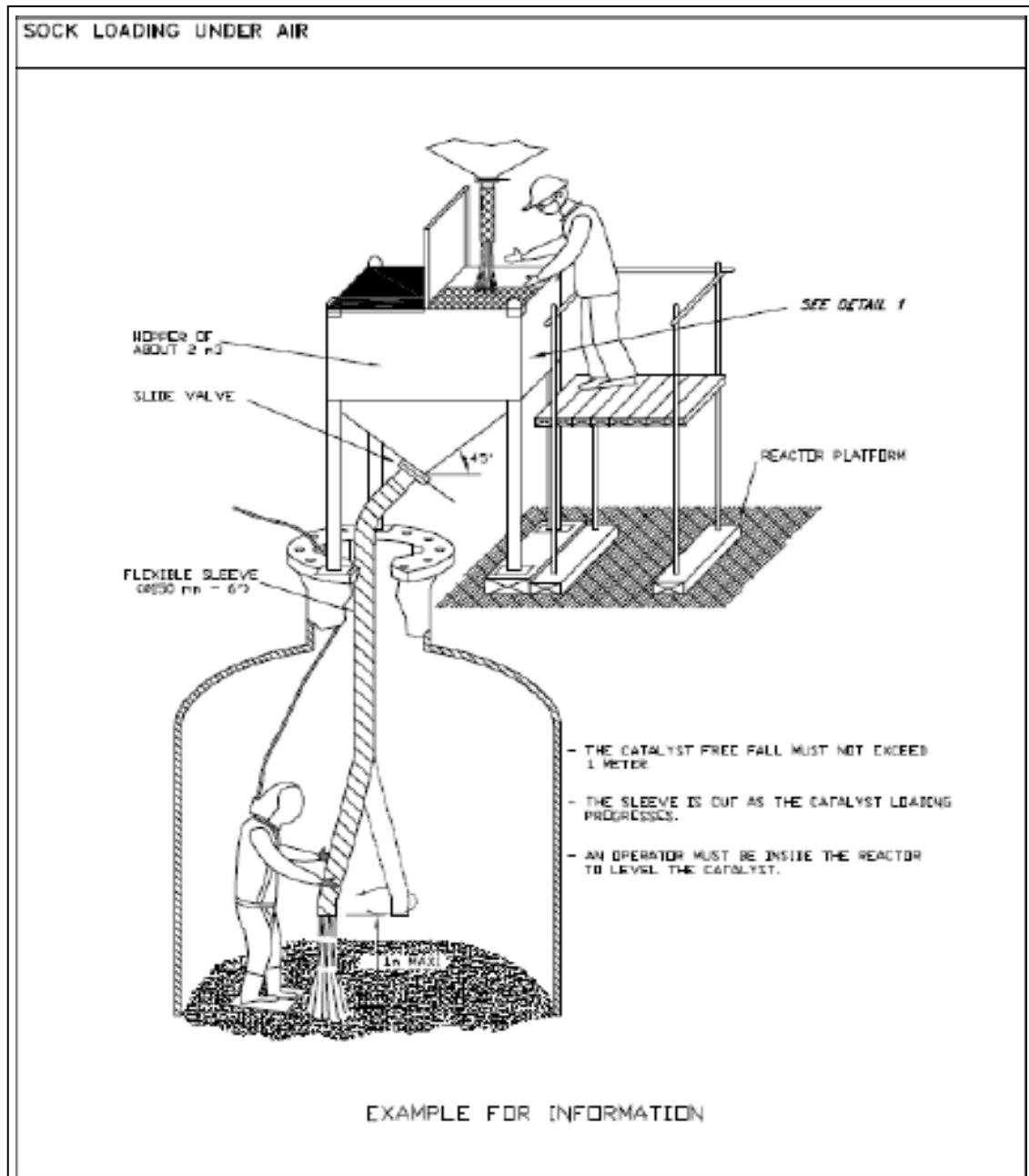
EXAMPLE FOR INFORMATION

DETAIL 2



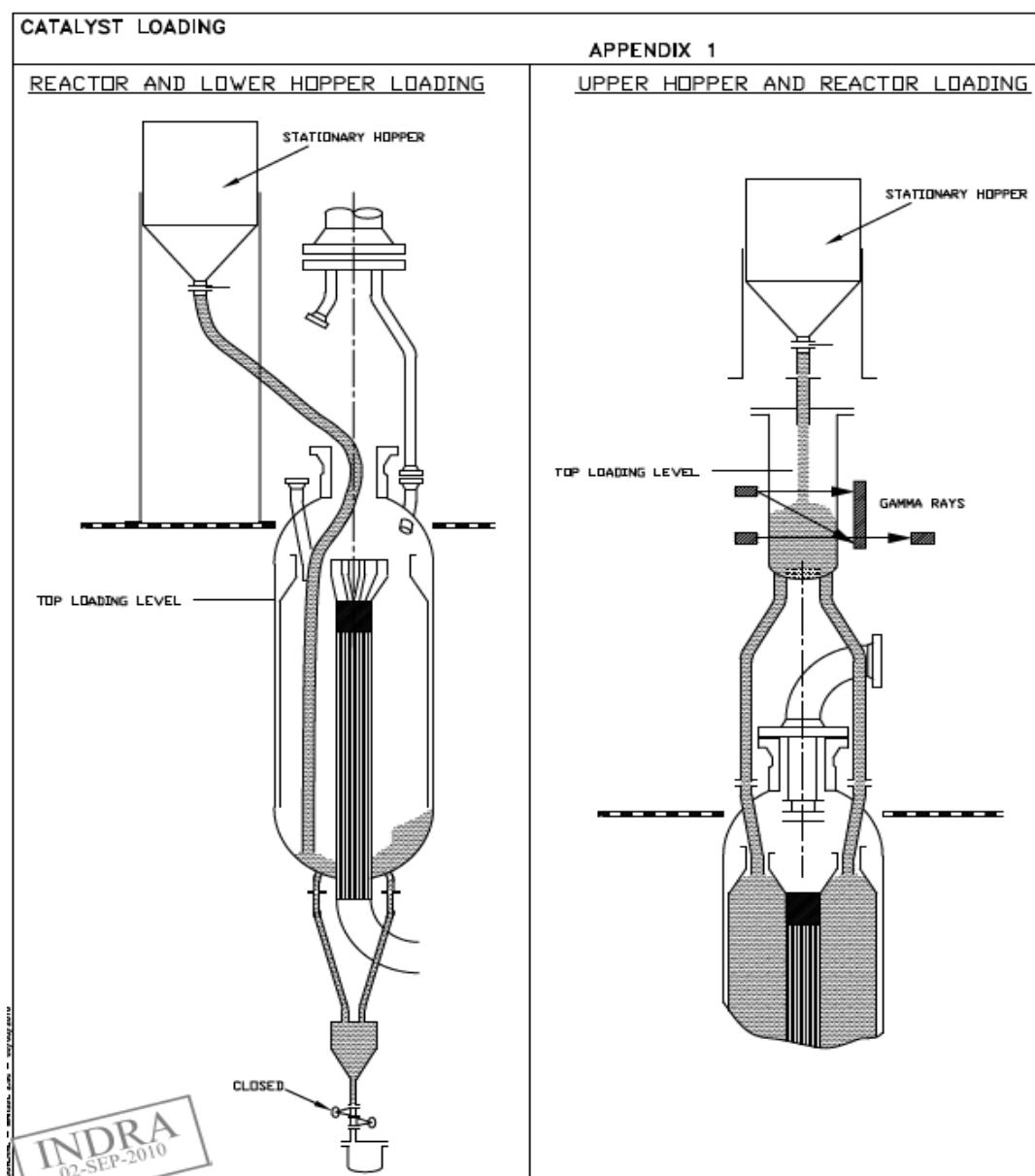
EXAMPLE FOR INFORMATION

### **8.18.1.7 Sock loading under air**



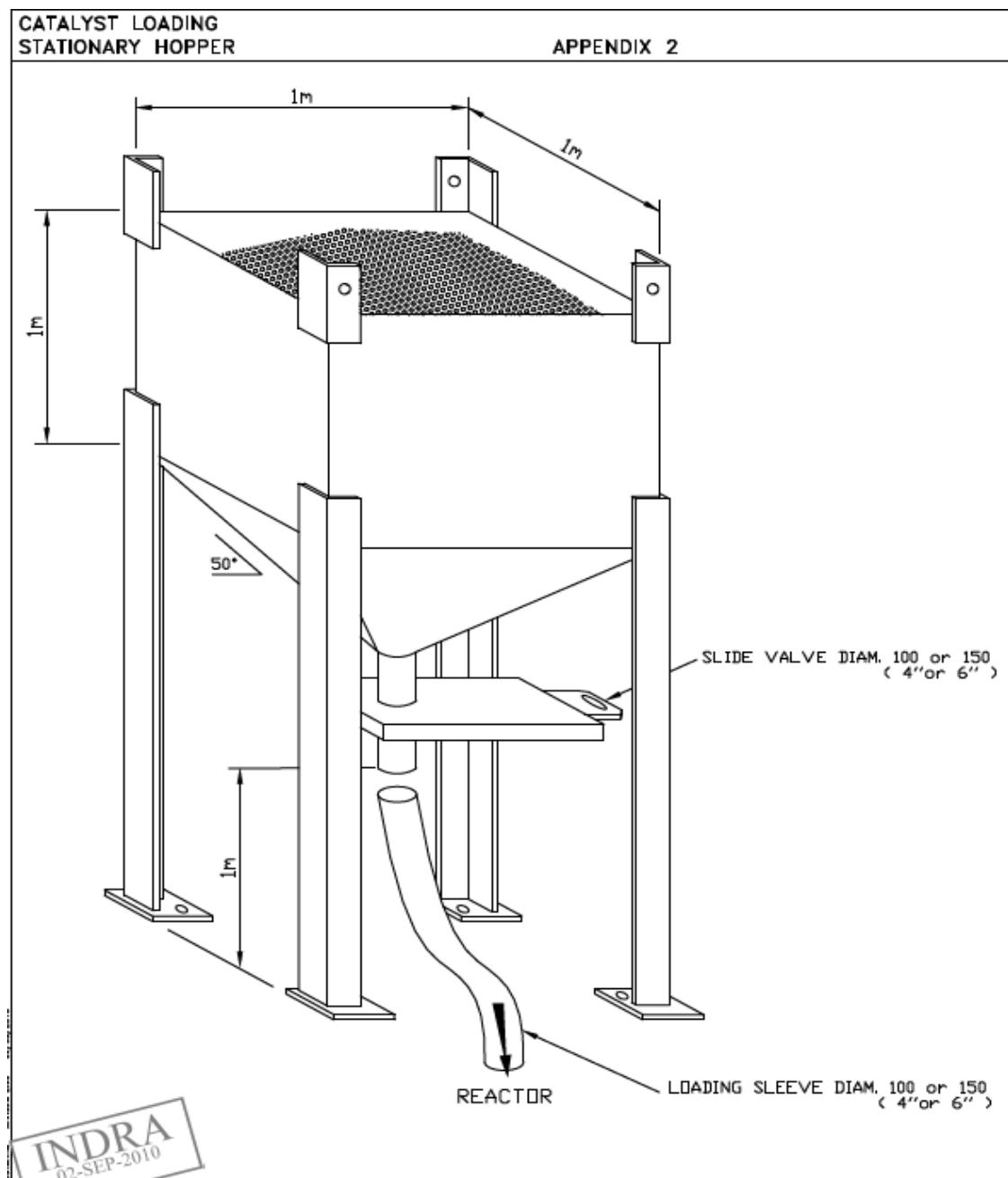
## 8.18.2 Catalyst Loading for Aromizing Reaction & Regeneration Section (R41-3 & R41-4)

### 8.18.2.1 Appendix 1: Catalyst Loading



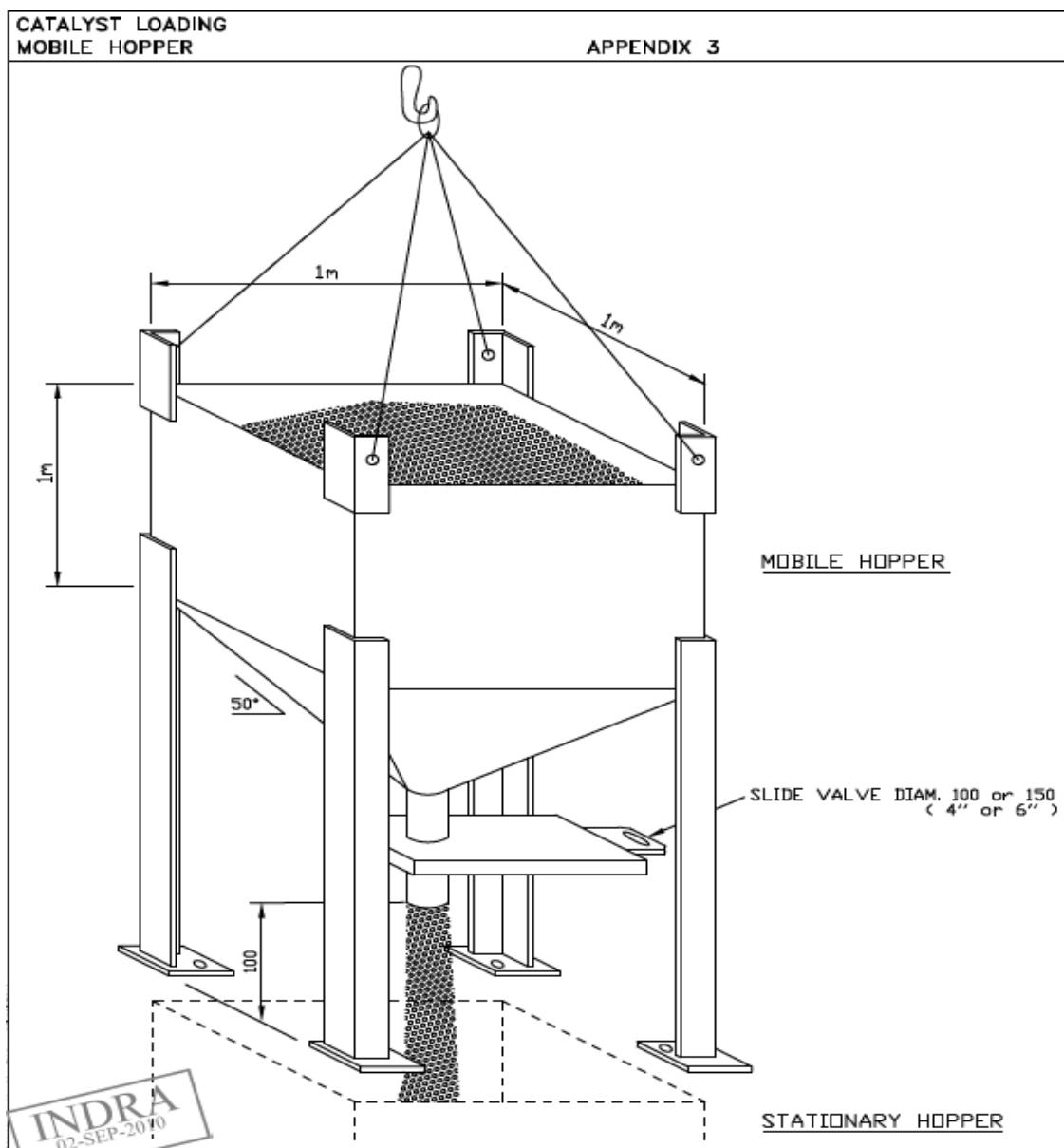
Appendix 1: Catalyst Loading

### **8.18.2.2 Appendix 2: Catalyst Loading-Stationary Hopper**



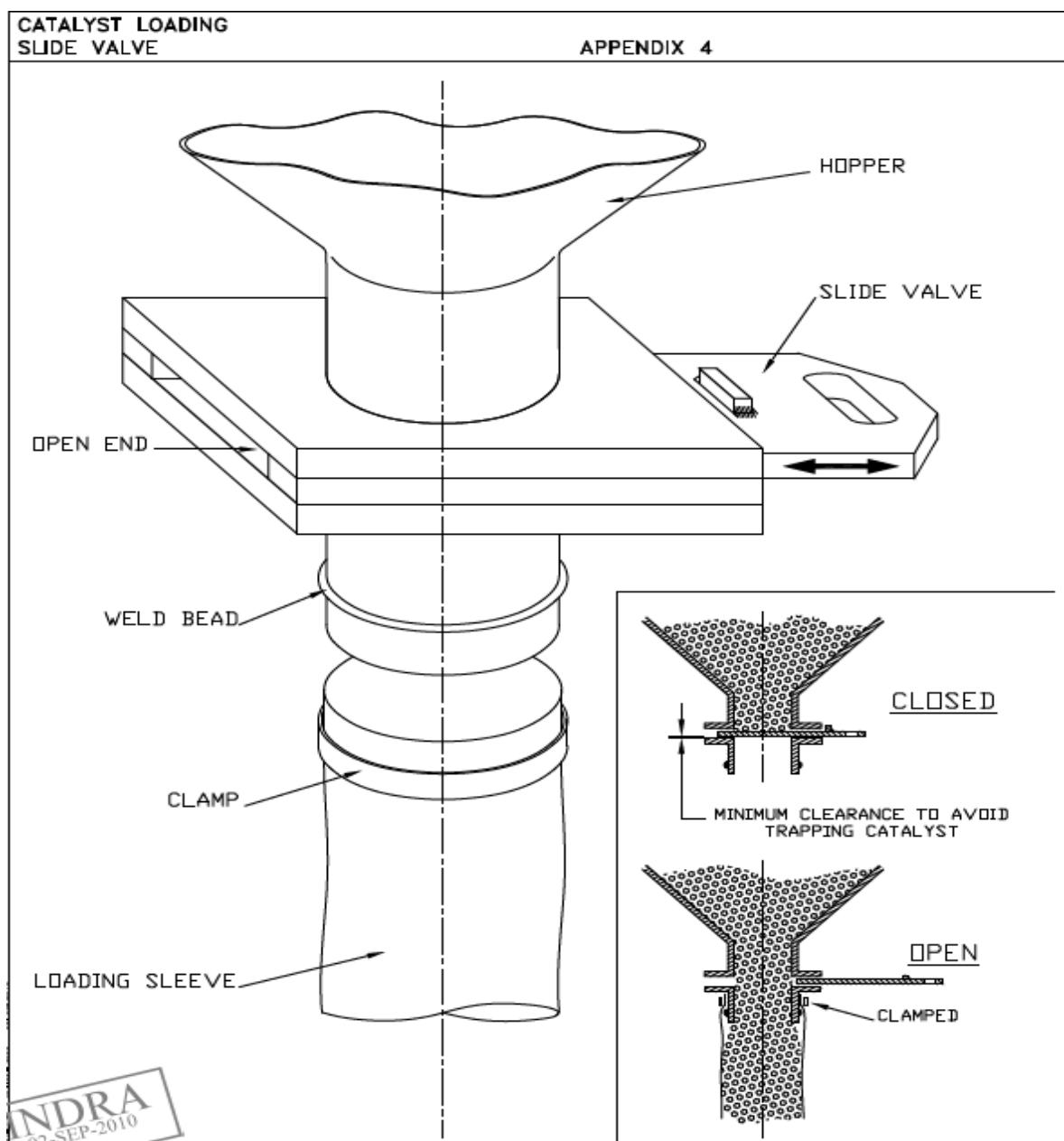
*Appendix 2: Catalyst Loading-Stationary Hopper*

### **8.18.2.3 Appendix 3: Catalyst Loading-Mobile Hopper**



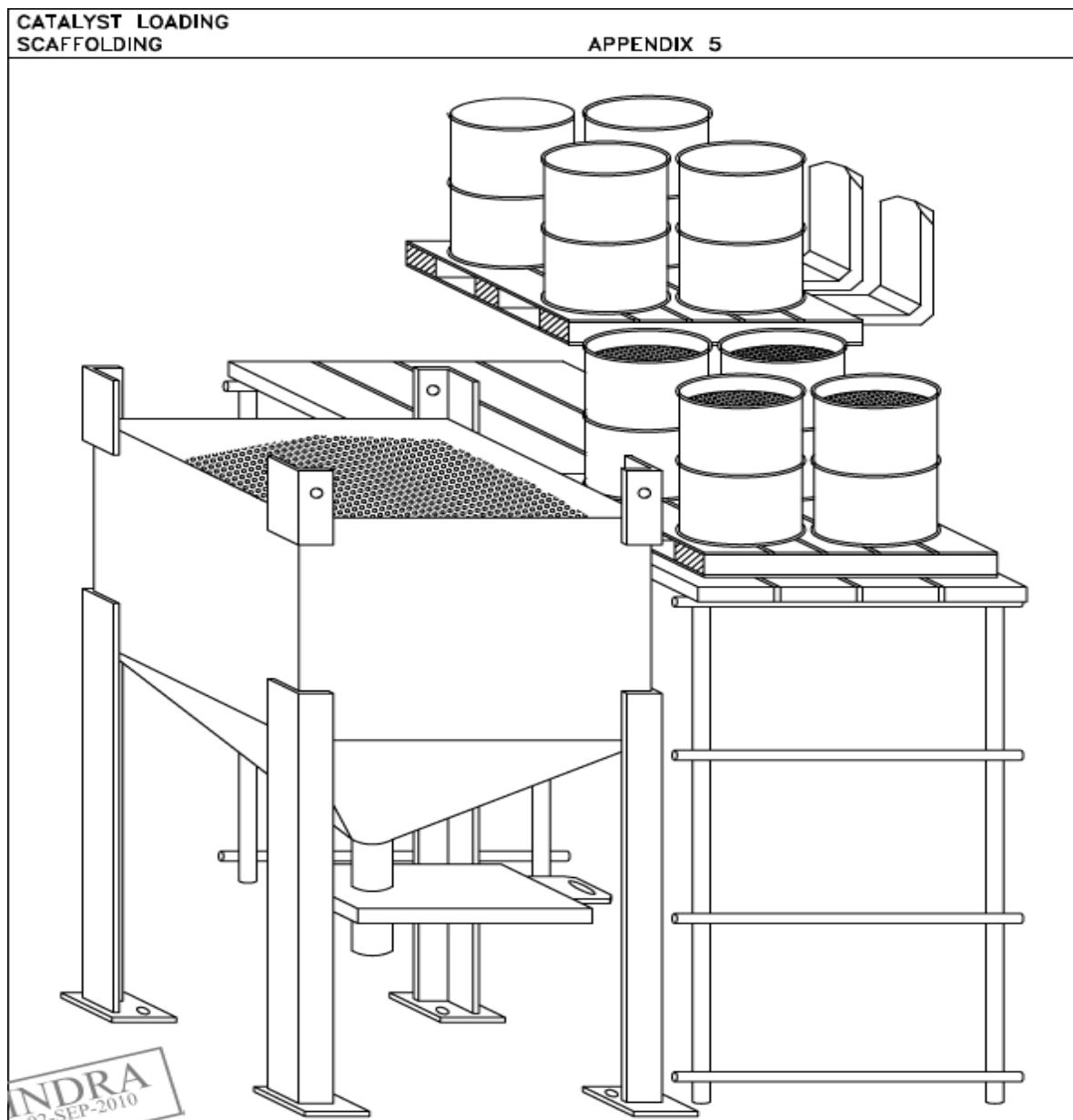
*Appendix 3: Catalyst Loading-Mobile Hopper*

**8.18.2.4 Appendix 4: Catalyst Loading - Slide Valve**



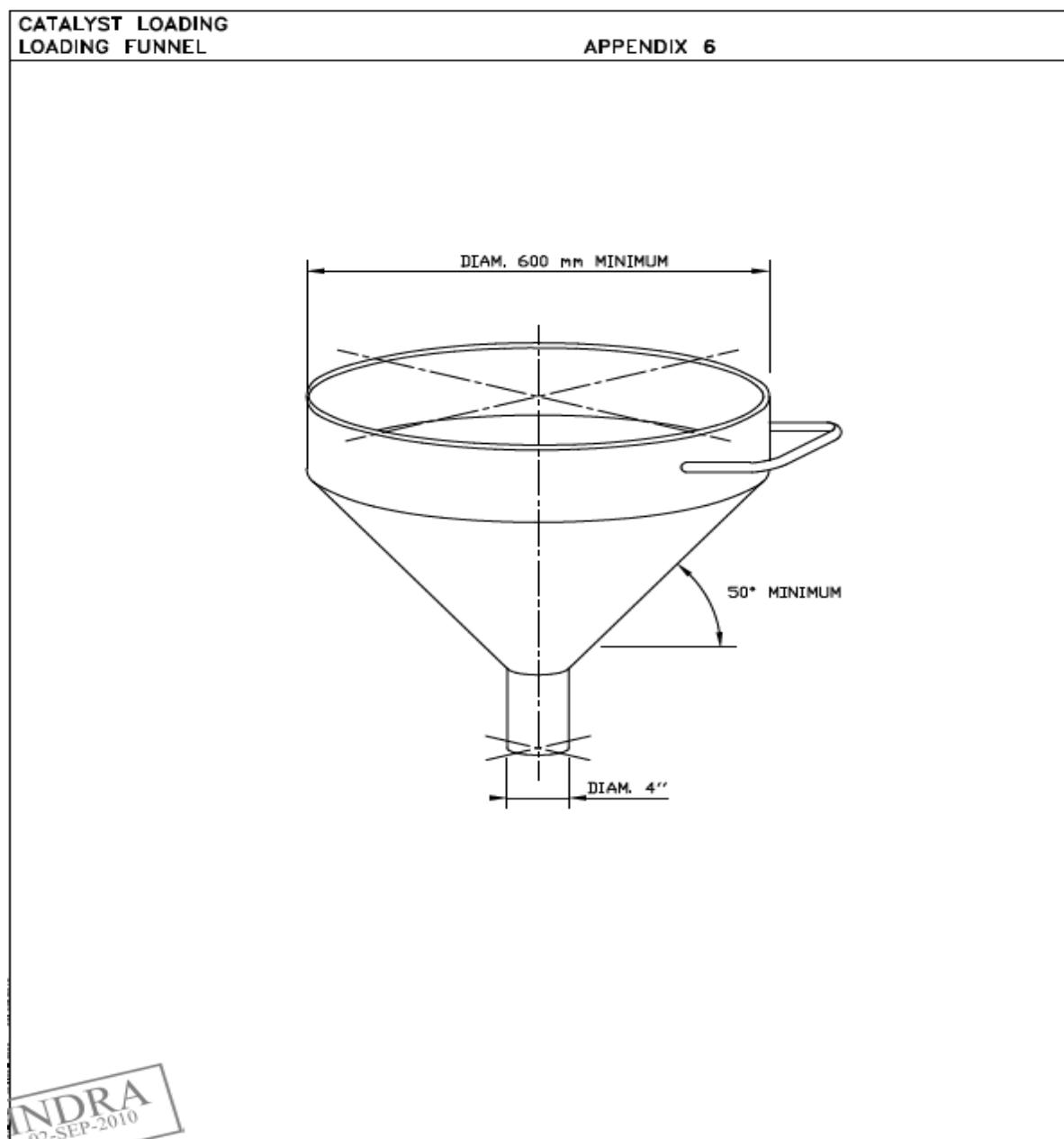
*Appendix 4: Catalyst Loading - Slide Valve*

**8.18.2.5** Appendix 5: Catalyst Loading - Scaffolding



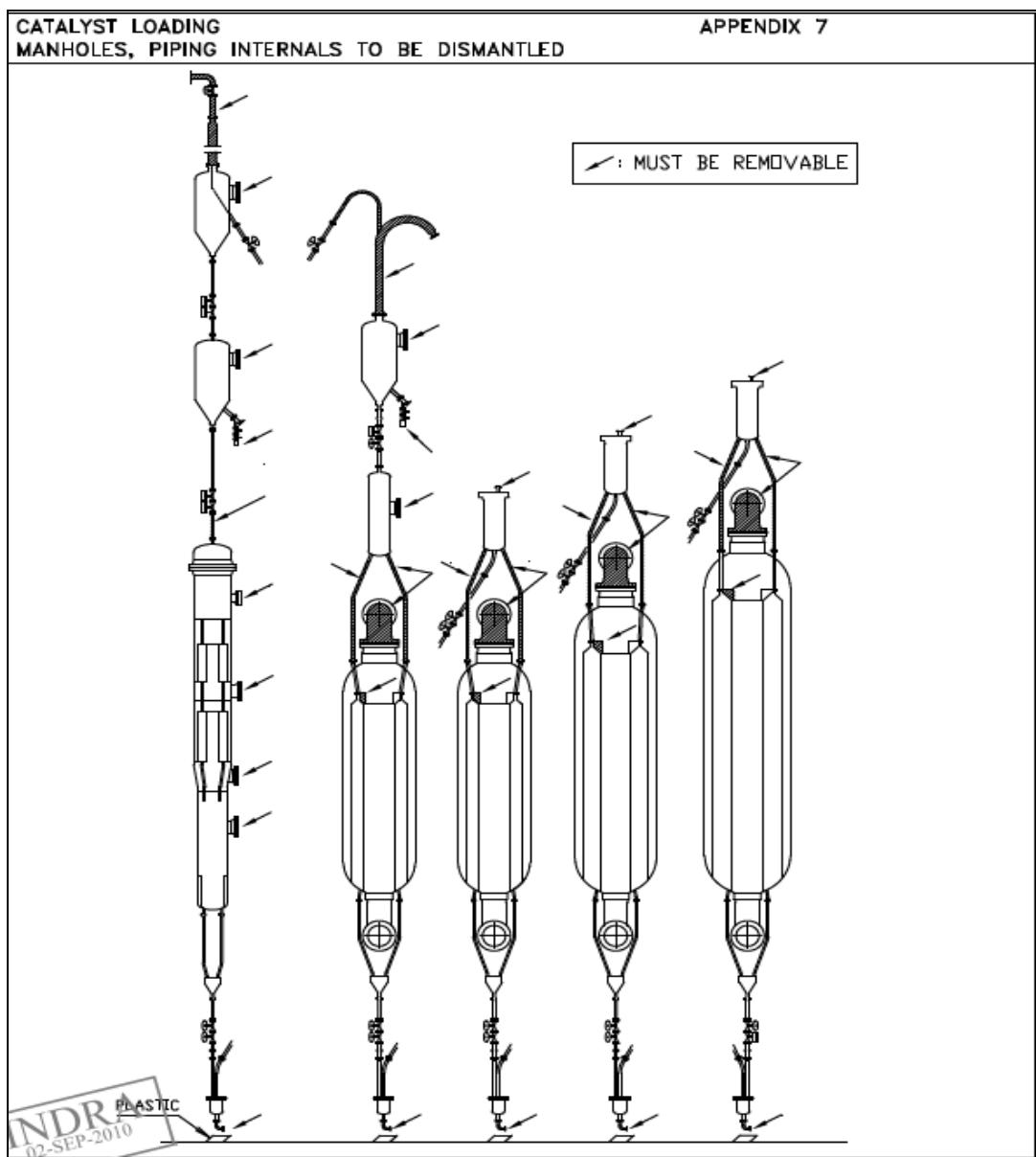
*Appendix 5: Catalyst Loading - Scaffolding*

**8.18.2.6 Appendix 6: Catalyst Loading - Funnel**



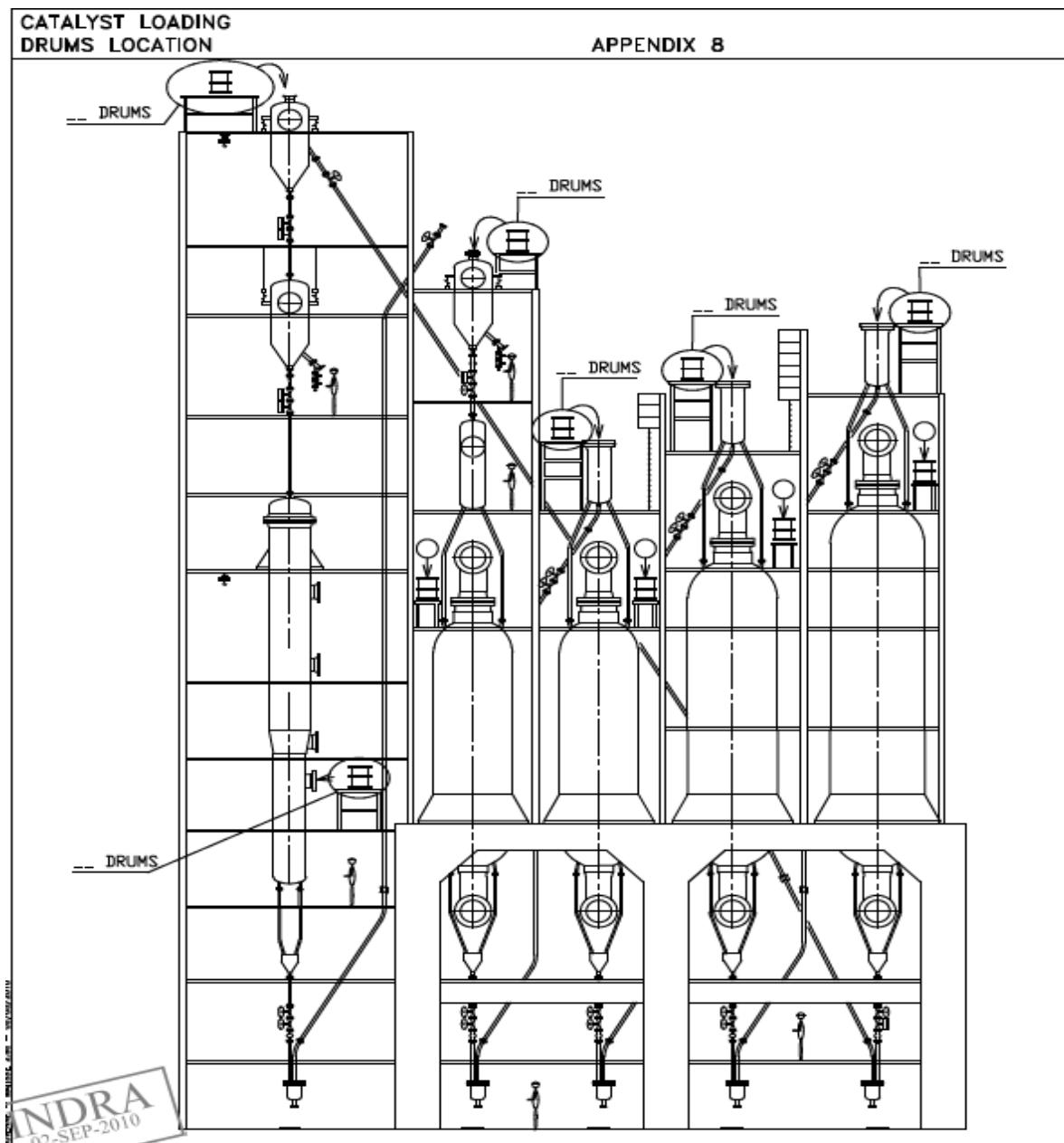
*Appendix 6: Catalyst Loading - Funnel*

**8.18.2.7 Appendix 7: Catalyst Loading - Manholes, Piping Internals to be Dismantled**



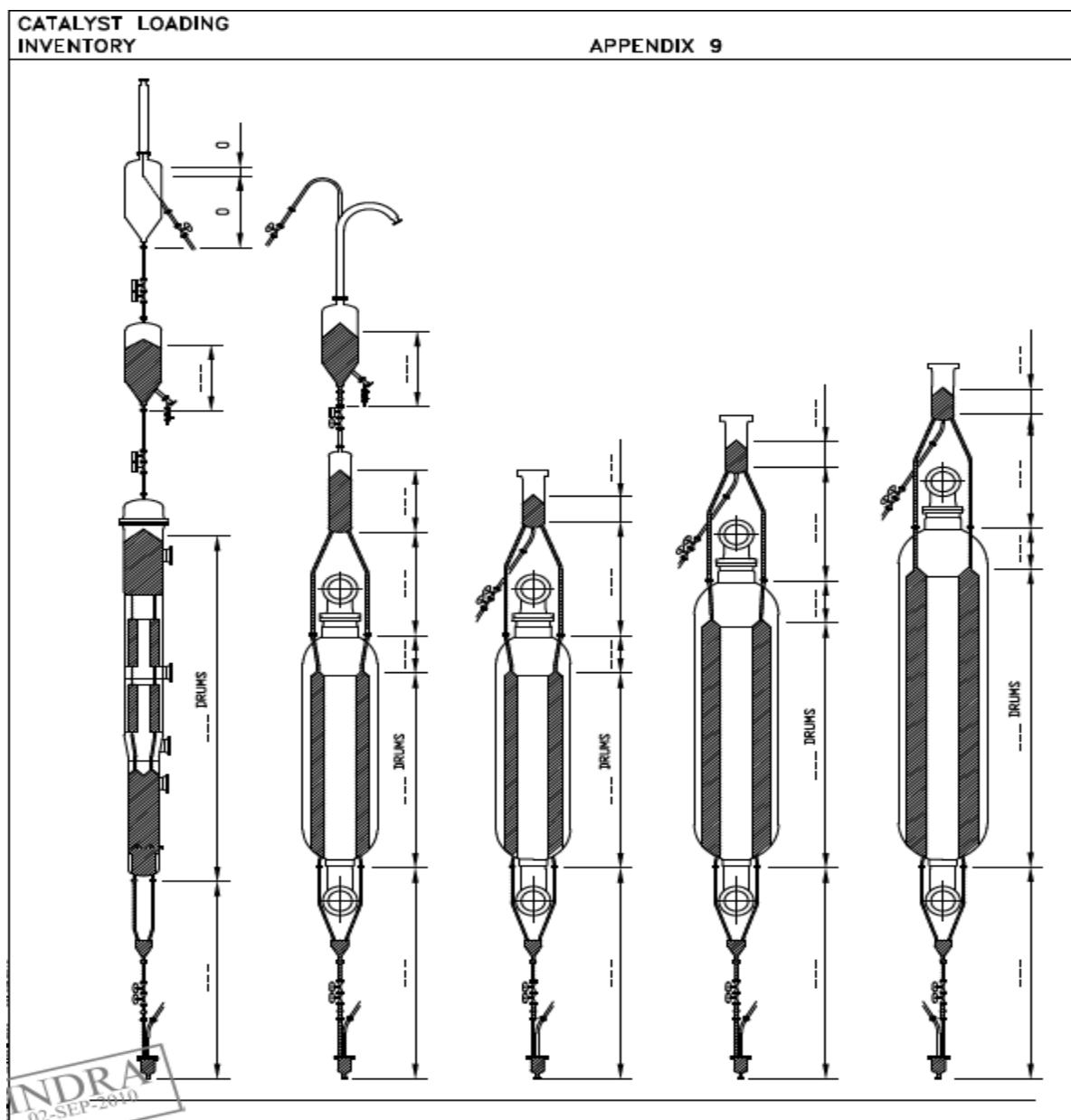
*Appendix 7: Catalyst Loading - Manholes, Piping Internals to be Dismantled*

**8.18.2.8 Appendix 8: Catalyst Loading - Drums Location**



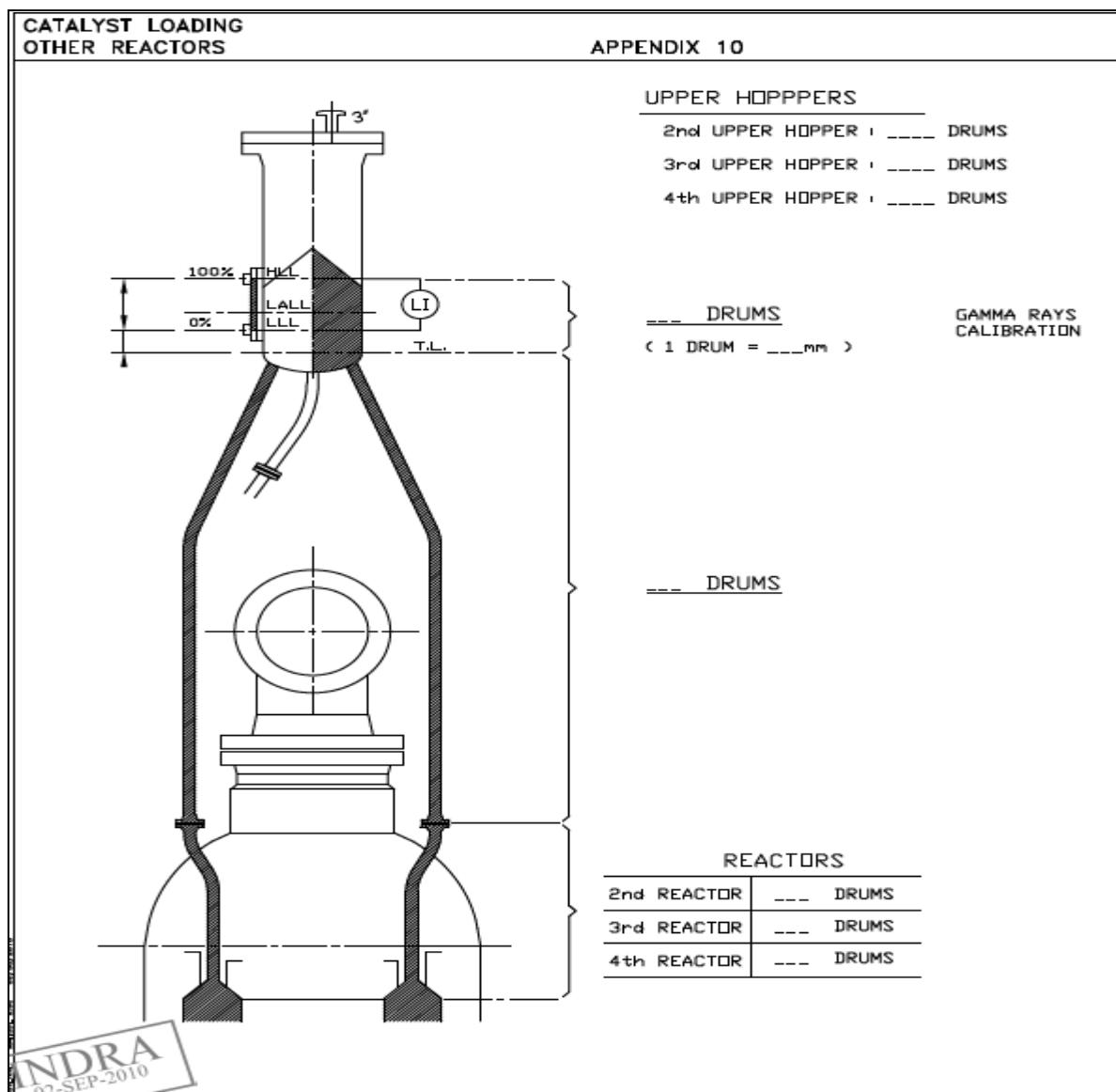
*Appendix 8: Catalyst Loading - Drums Location*

**8.18.2.9 Appendix 9: Catalyst Loading - Inventory**



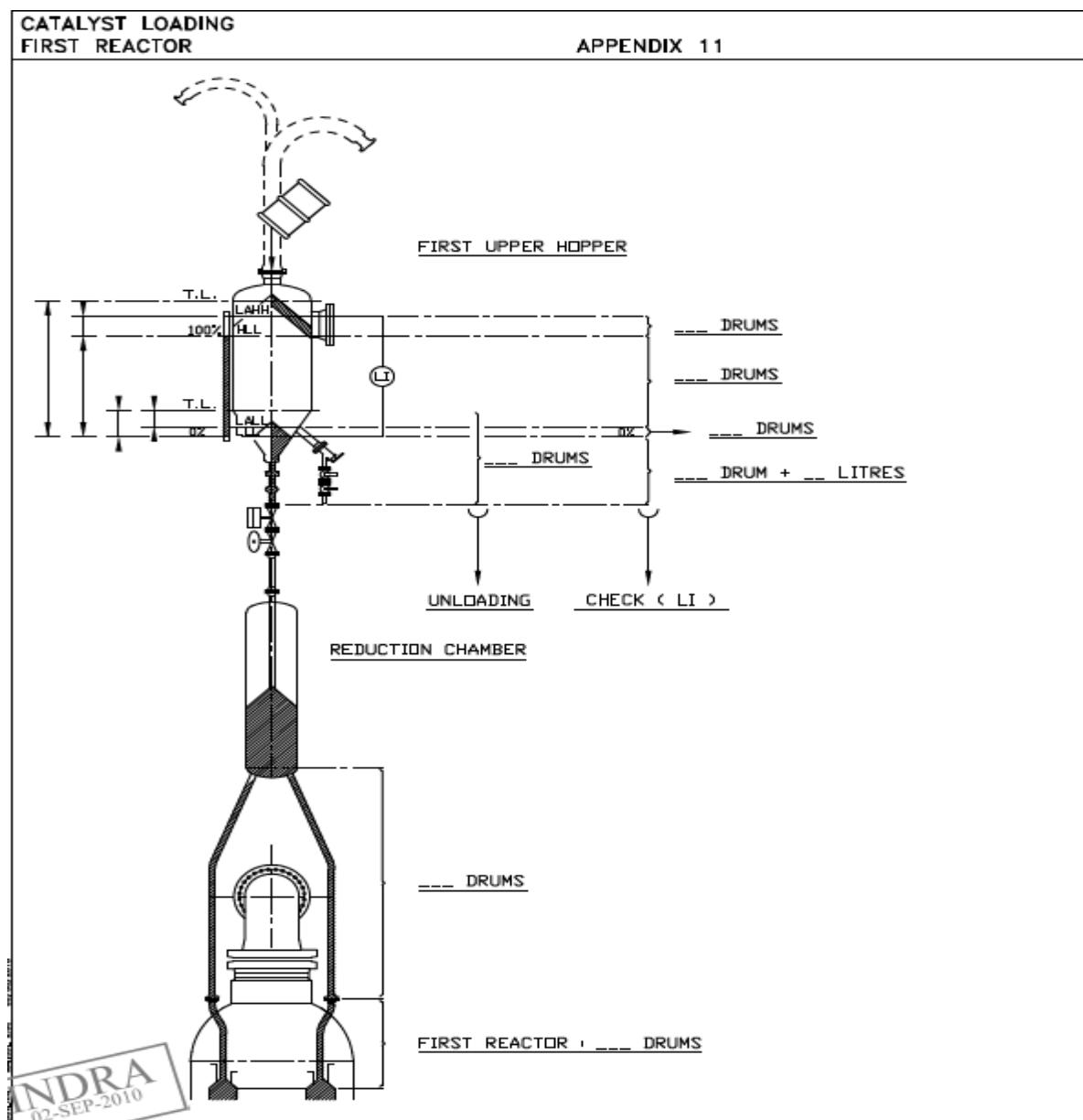
Appendix 9: Catalyst Loading - Inventory

**8.18.2.10 Appendix 10: Catalyst Loading - Other Reactors**



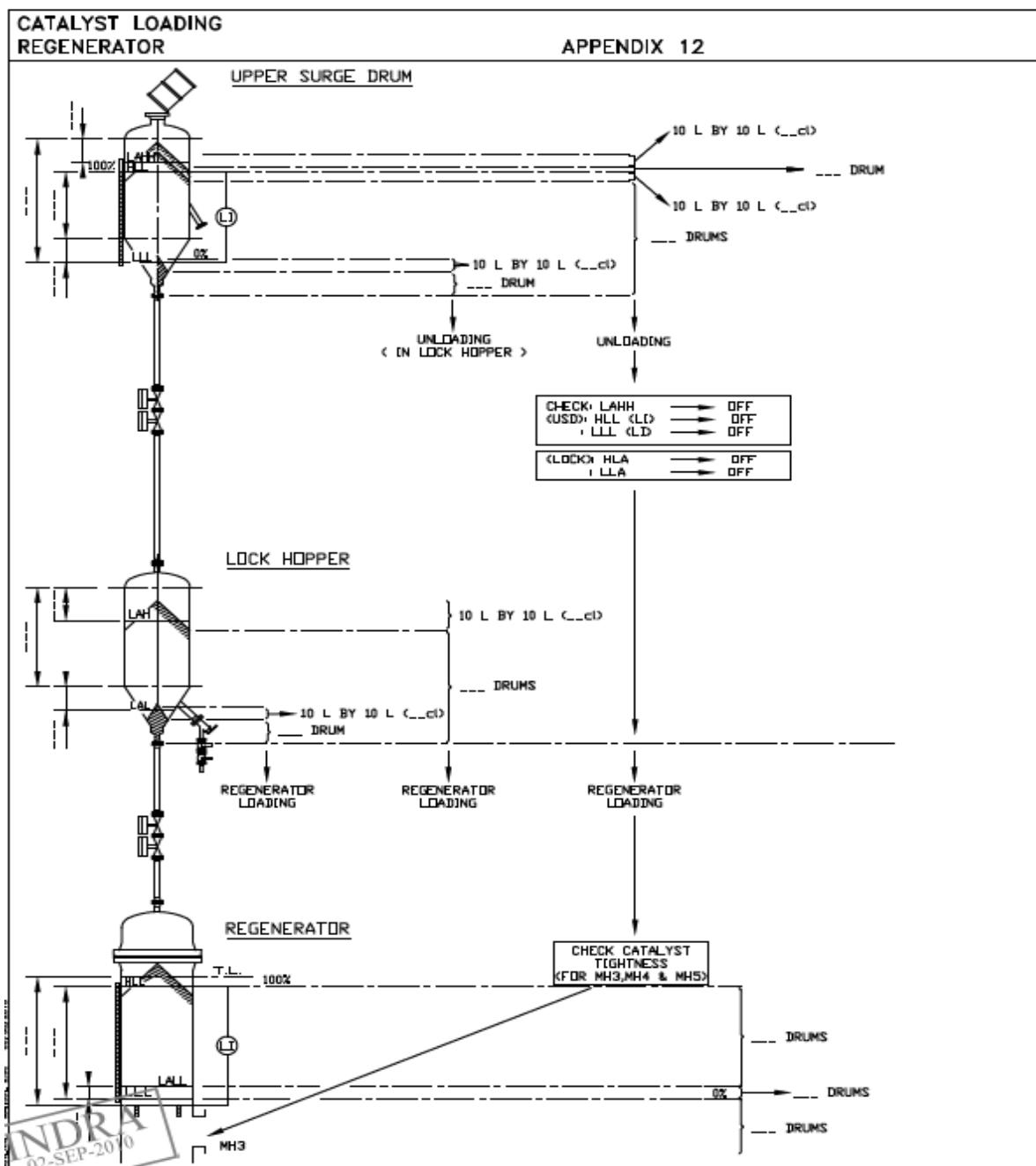
Appendix 10: Catalyst Loading - Other Reactors

### **8.18.2.11 Appendix 11: Catalyst Loading - First Reactor**



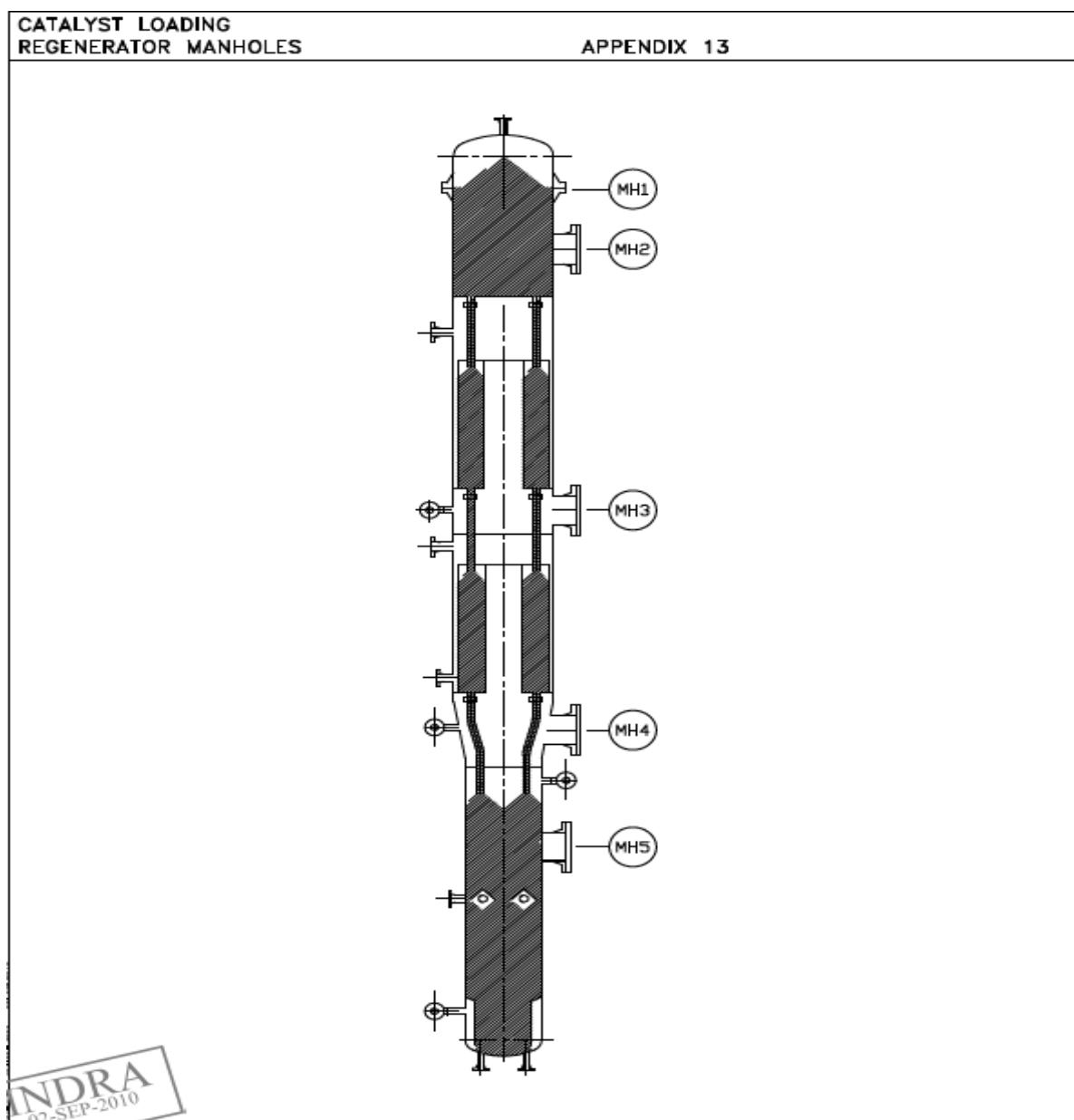
Appendix 11: Catalyst Loading - First Reactor

### 8.18.2.12 Appendix 12: Catalyst Loading - Regenerator



Appendix 12: Catalyst Loading - Regenerator

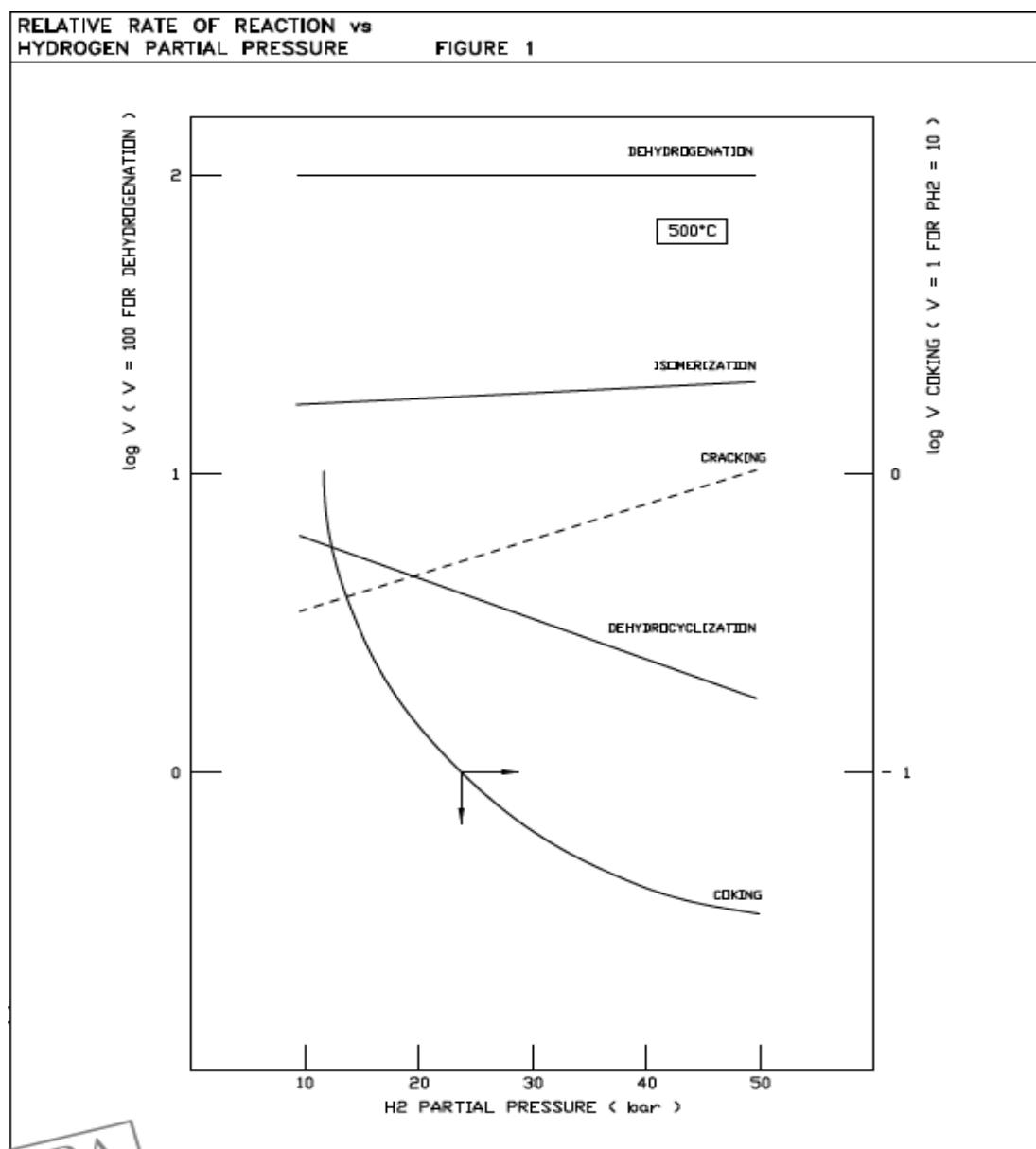
**8.18.2.13 Appendix 13: Catalyst Loading Regenerator - Manholes**



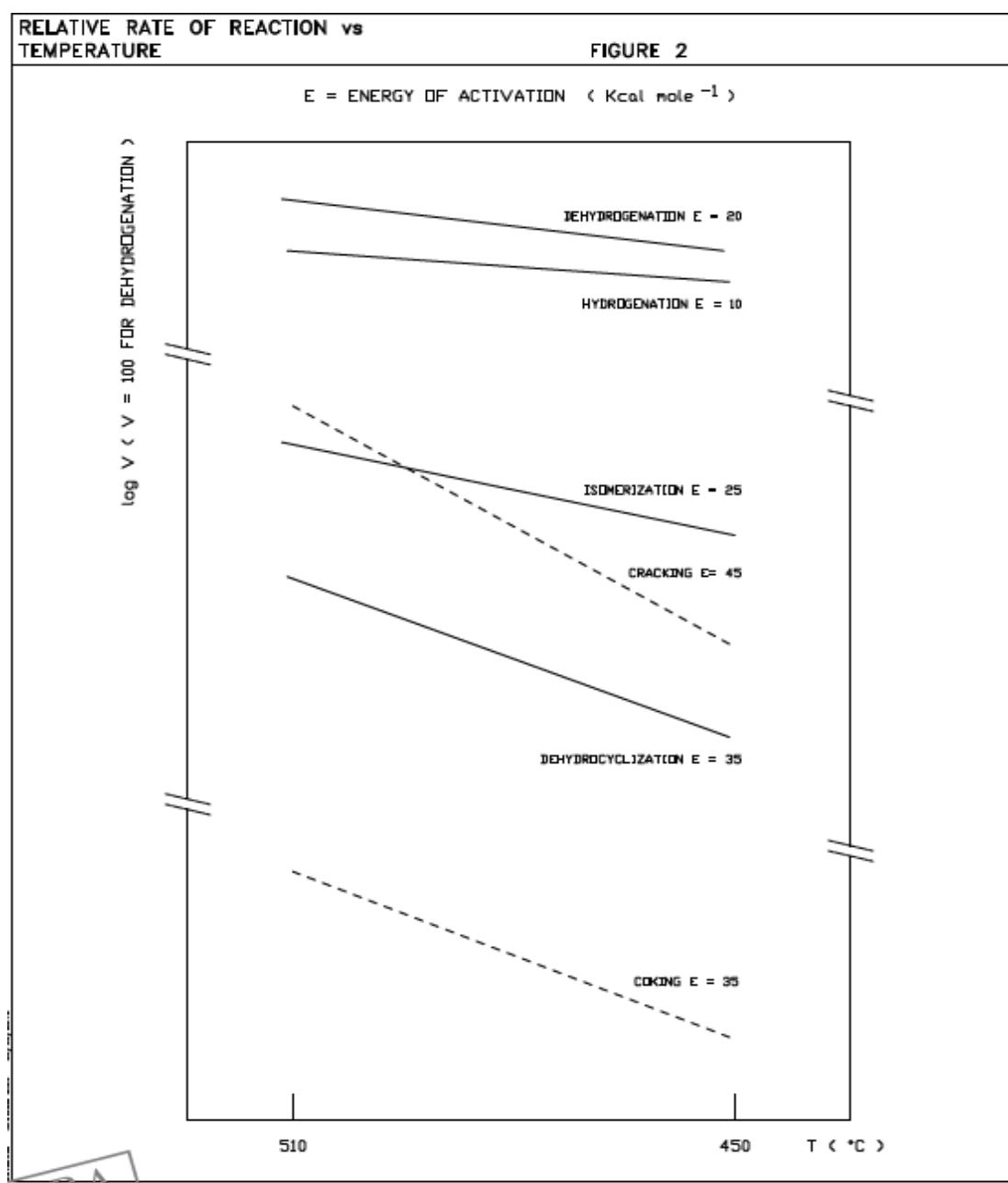
Appendix 13: Catalyst Loading Regenerator - Manholes

## 8.19 List of Figures

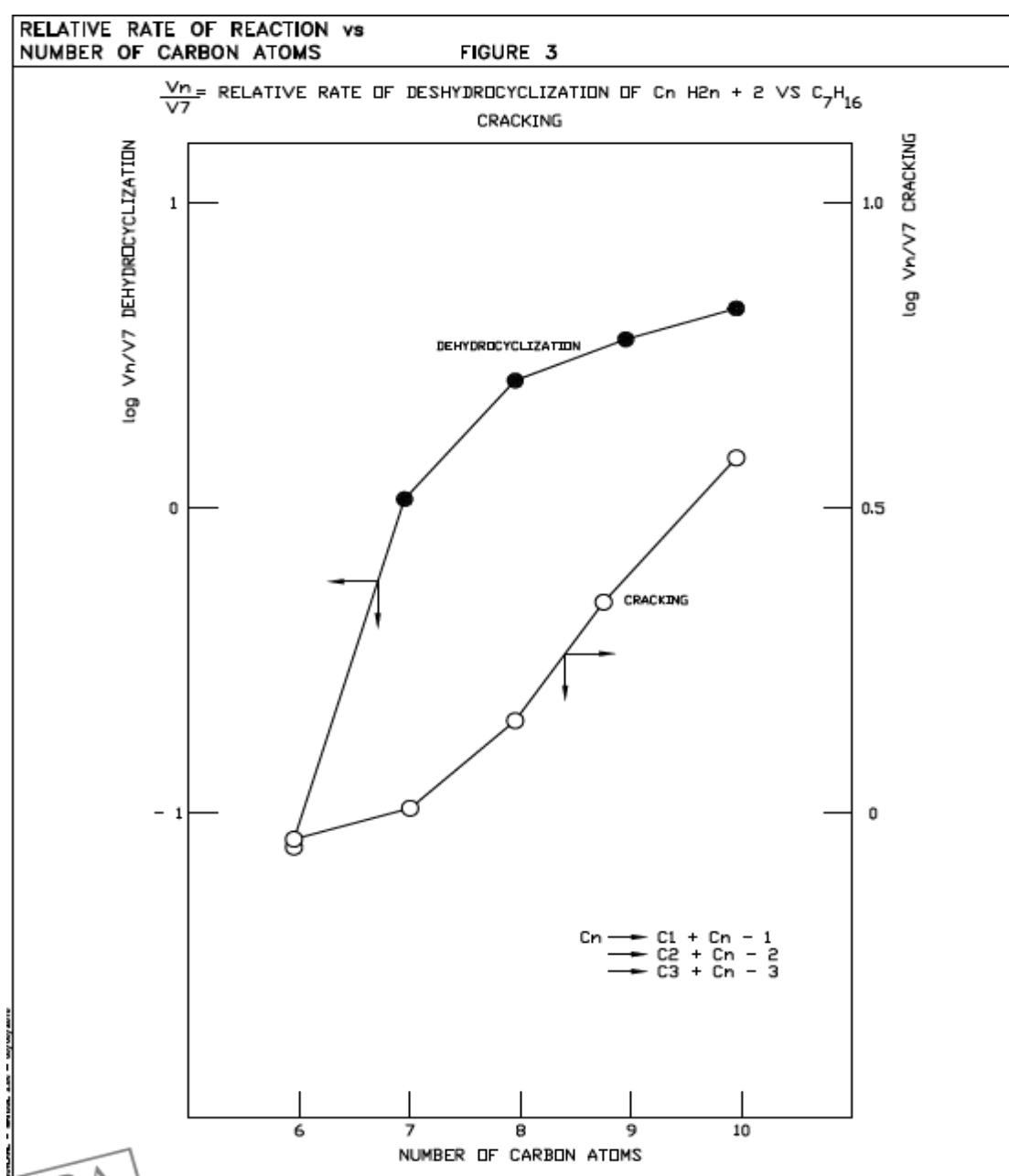
### 8.19.1 Figure 1 - Relative Rate of Reaction Vs Hydrogen Partial Pressure



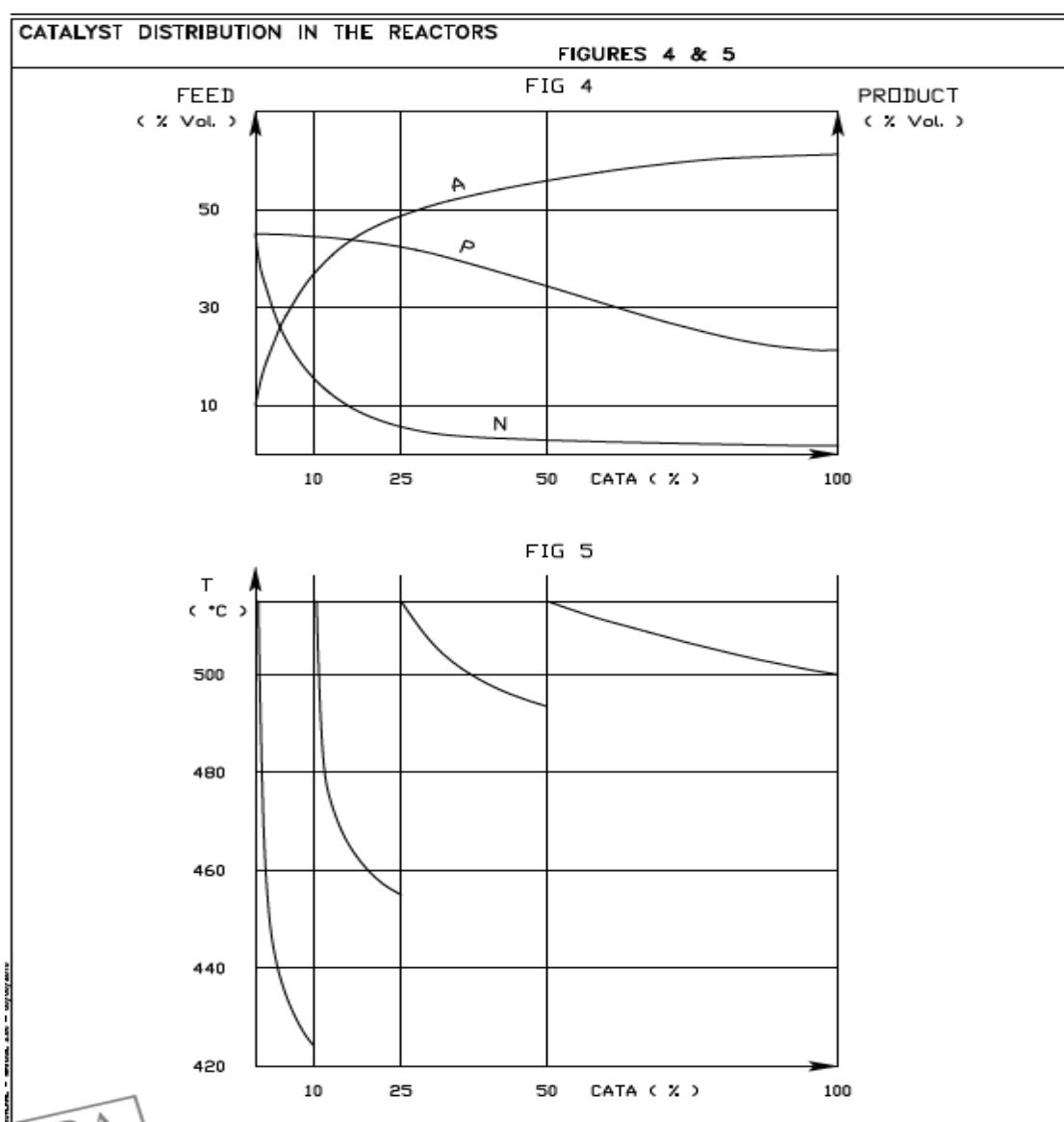
### 8.19.2 Figure 2 - Relative Rate of Reaction Vs Temperature



**8.19.3 Figure 3 - Relative Rate of Reaction Vs Number of Carbon Atoms**

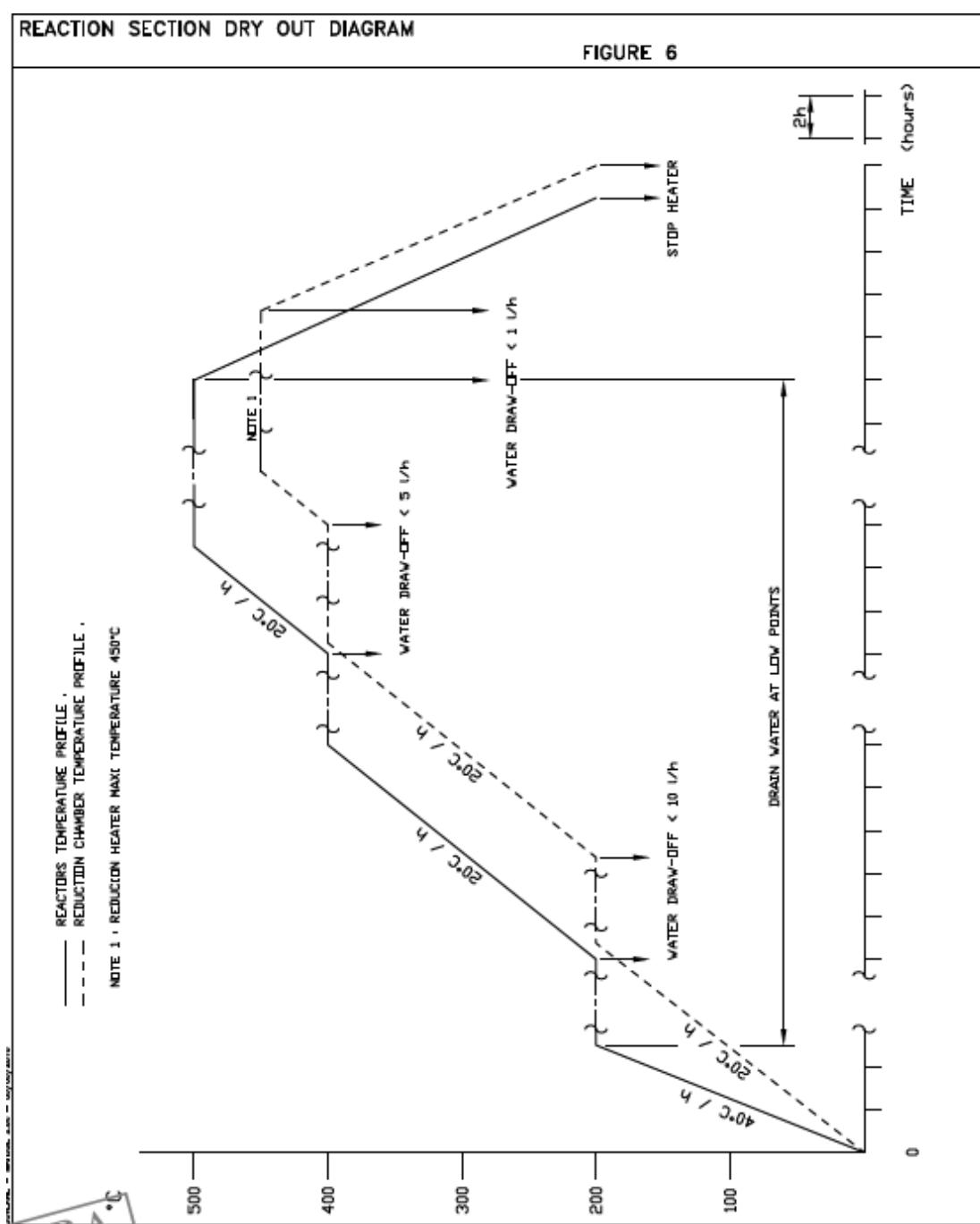


#### 8.19.4 Figure 4 - Catalyst Distribution Vs Feed Vol%

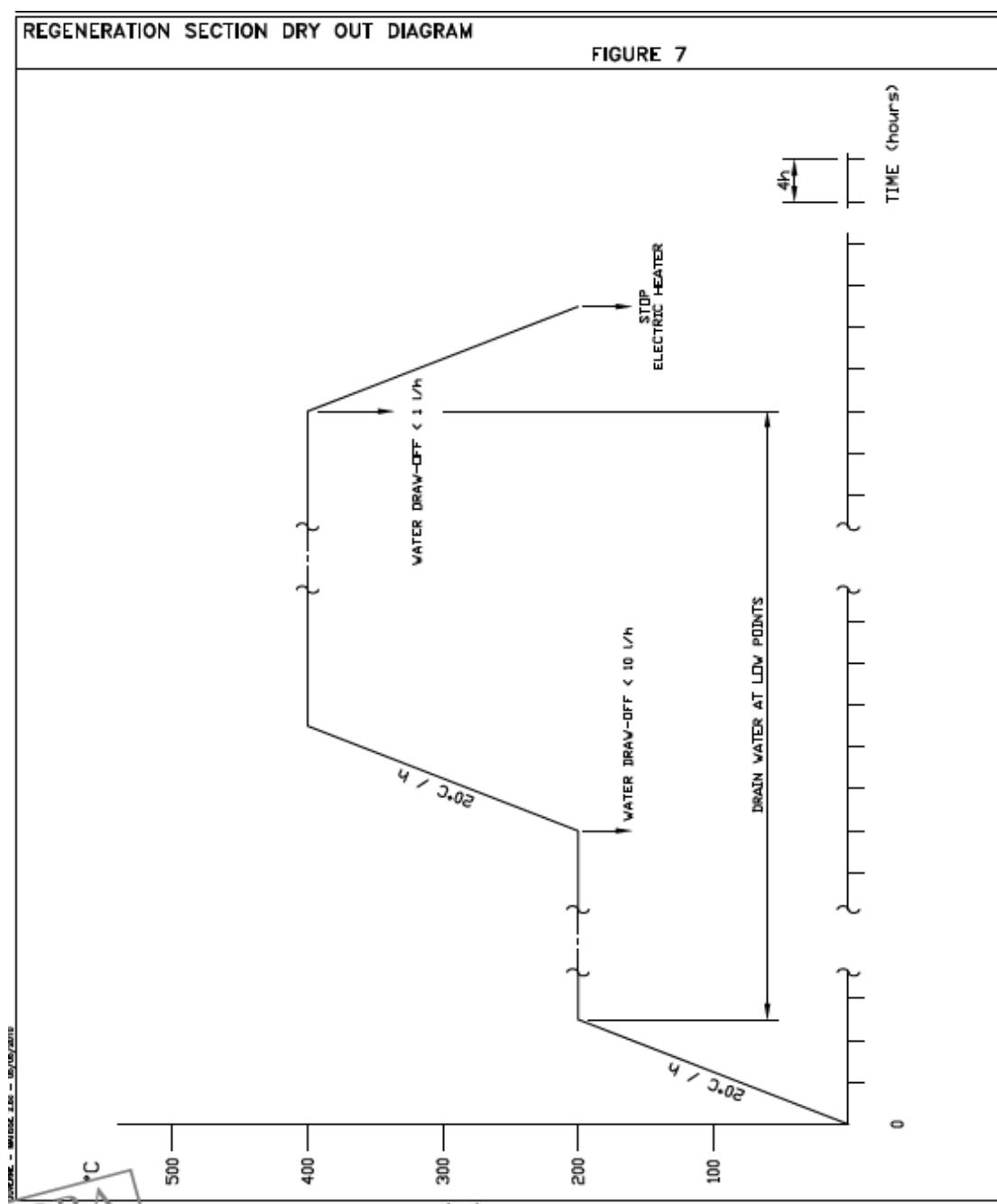


#### 8.19.5 Figure 5 - Catalyst Distribution Vs Temperature

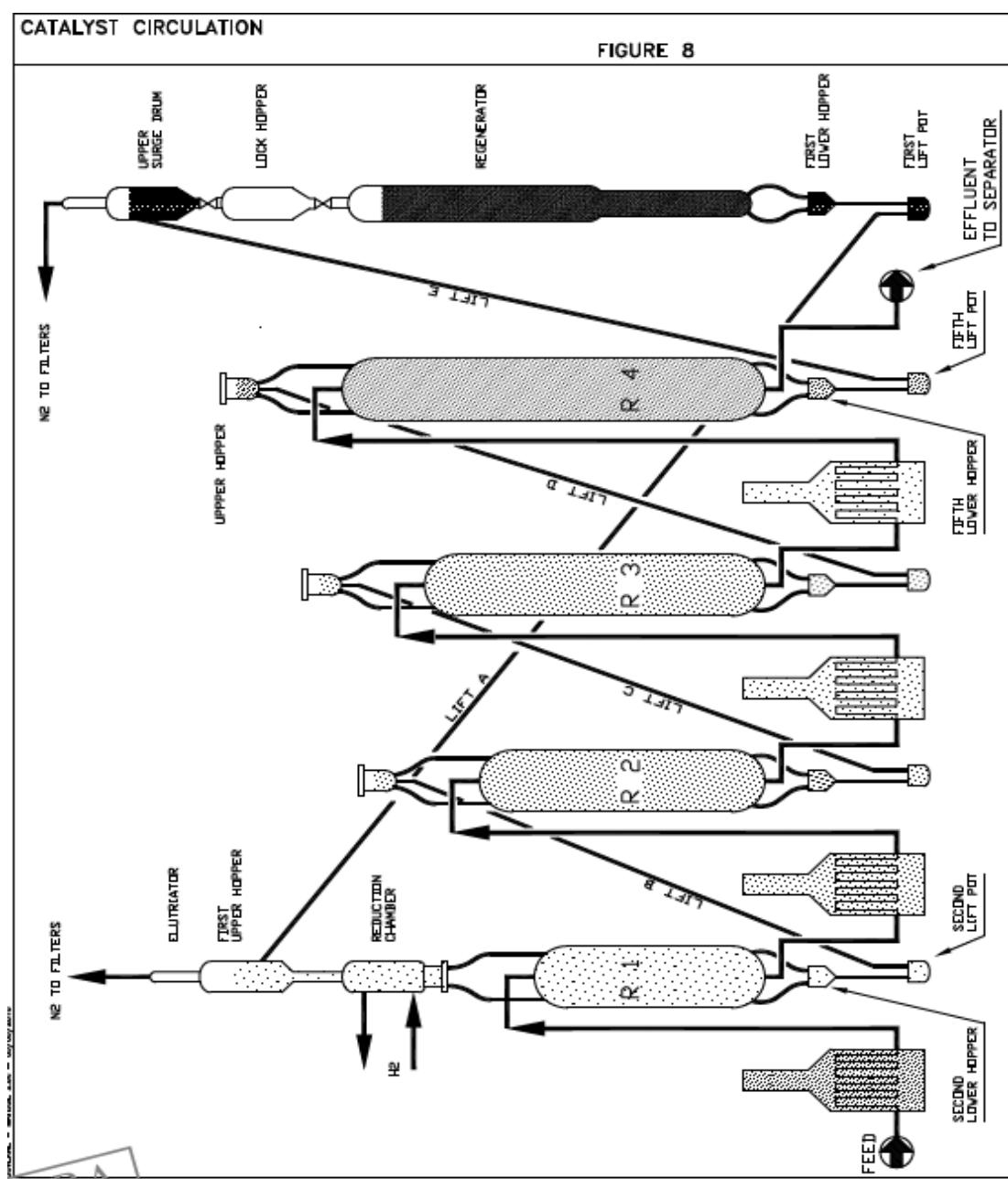
### 8.19.6 Figure 6 - Reaction Section Dryout Diagram



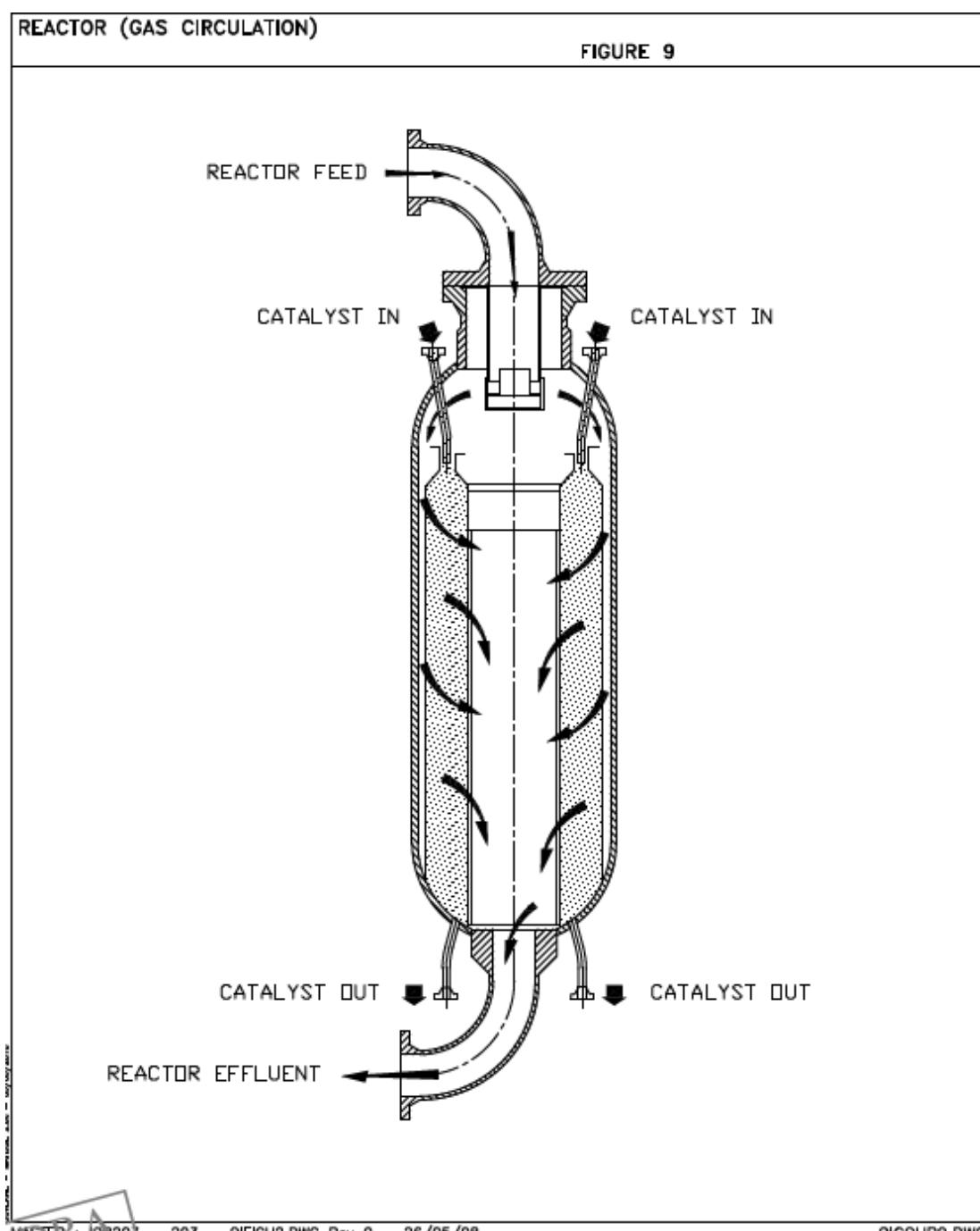
**8.19.7 Figure 7 - Regeneration Section Dryout Diagram**



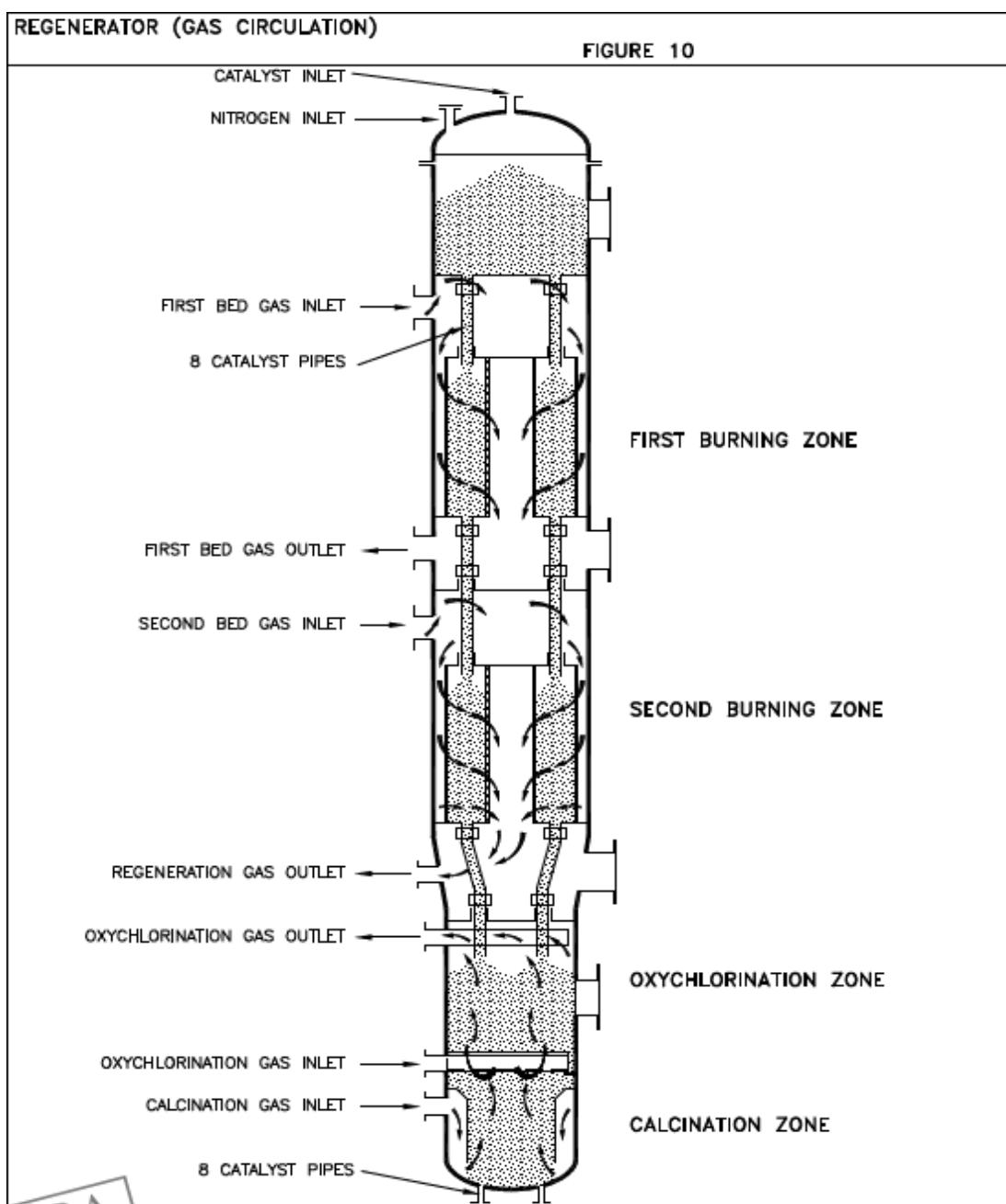
### 8.19.8 Figure 8 - Catalyst Circulation



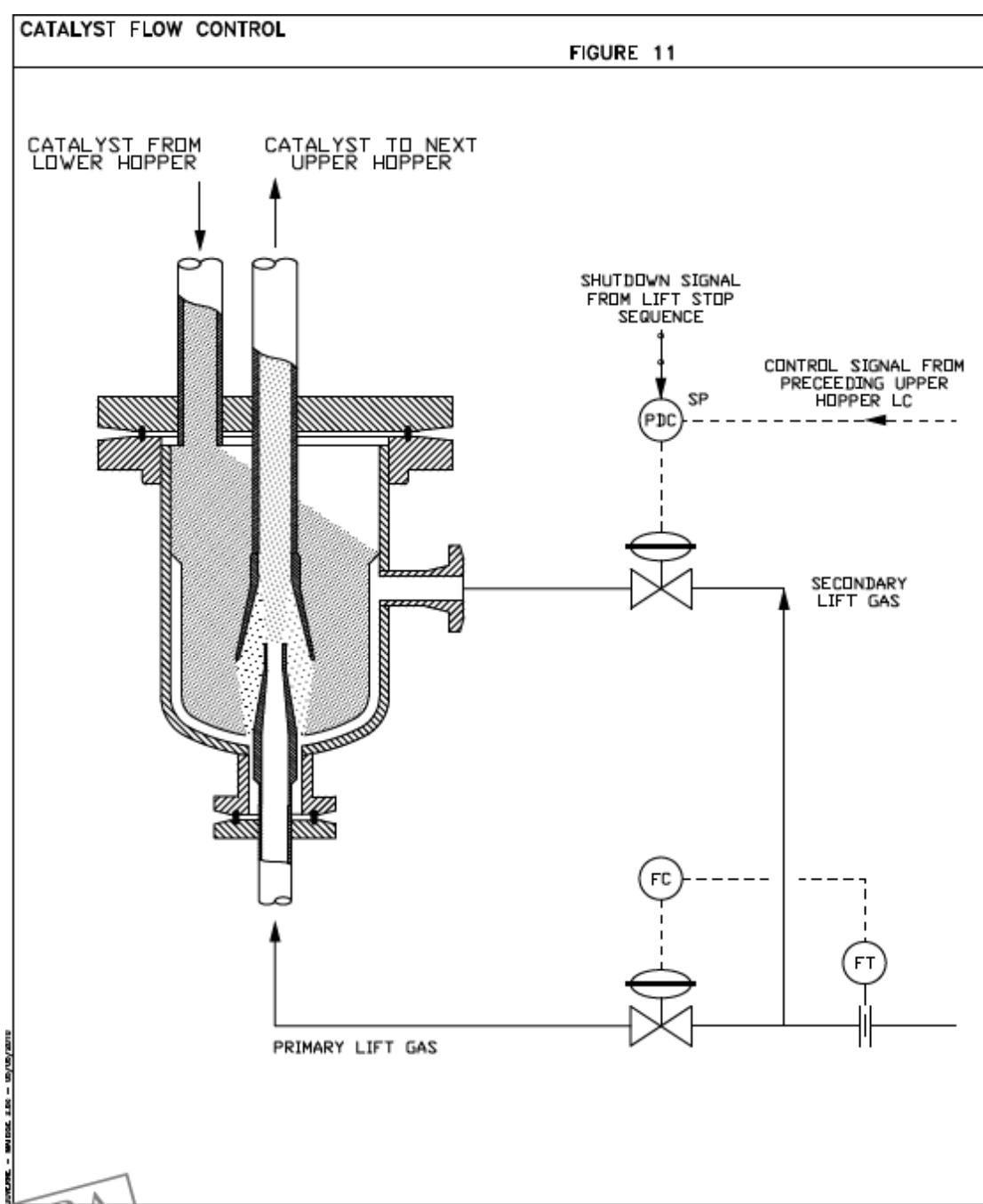
**8.19.9 Figure 9 - Reactor Gas Circulation (R41-R-131/132/133/134)**



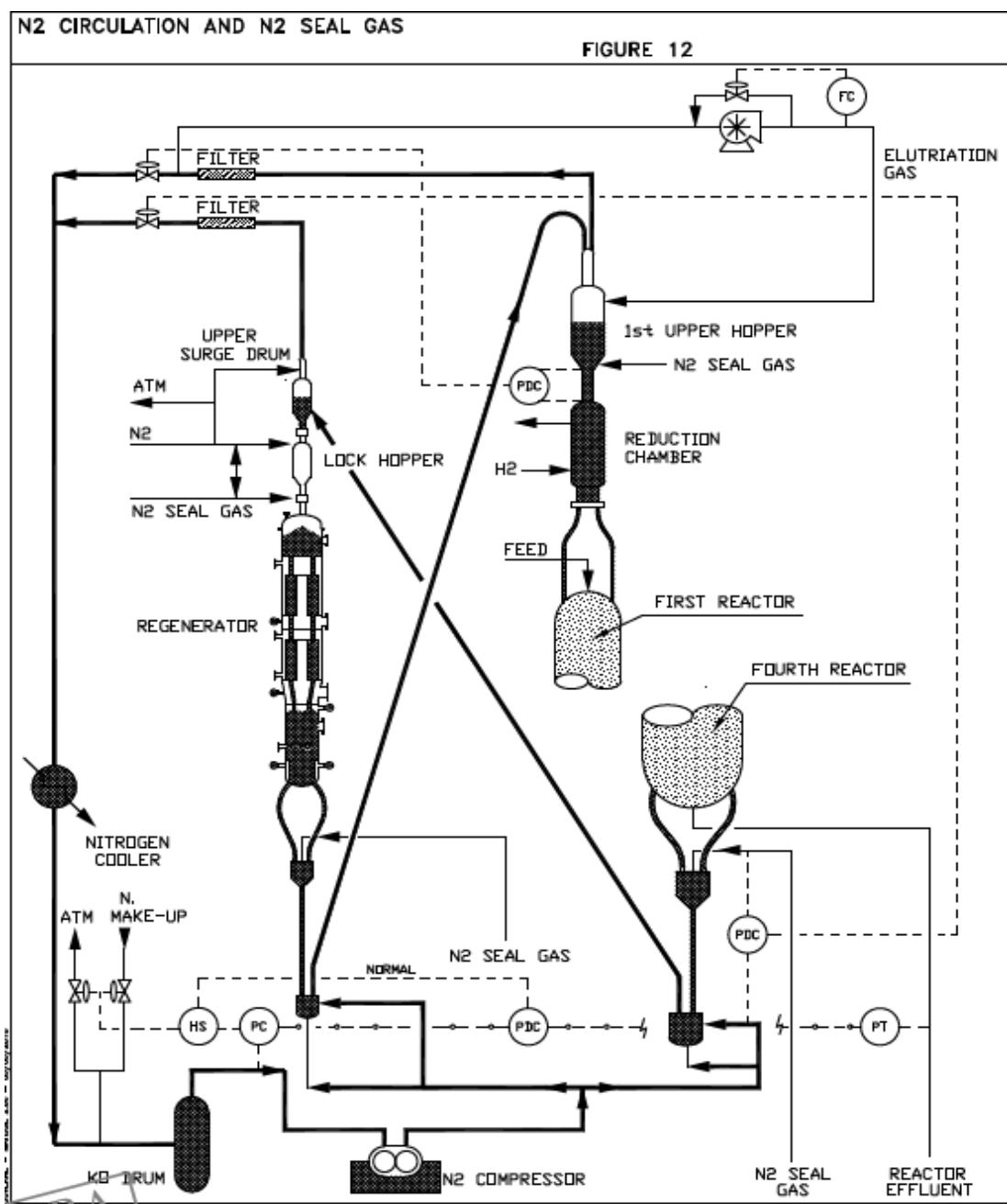
**8.19.10 Figure 10 - Regenerator Gas Circulation (R41-R--140)**



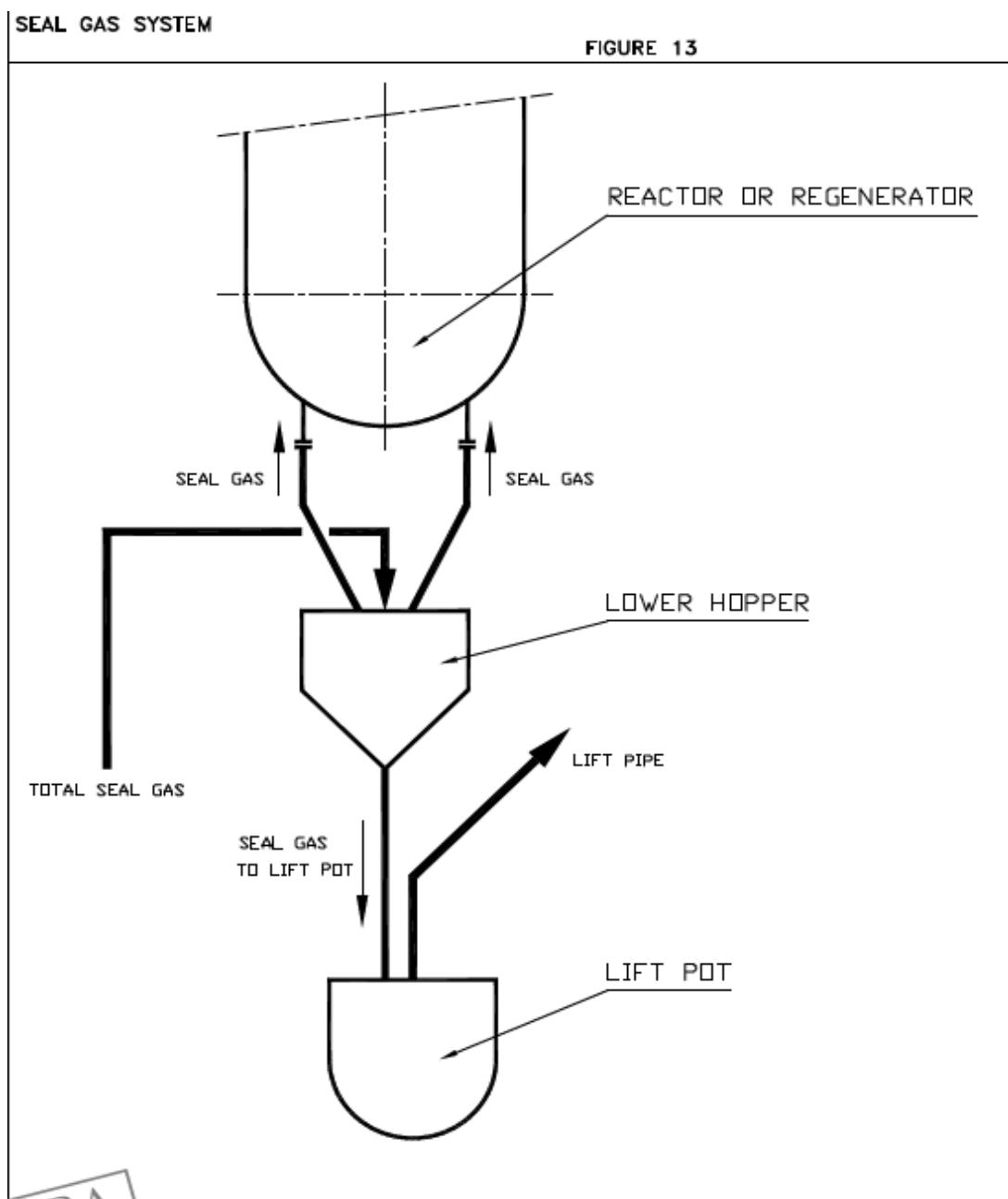
**8.19.11 Figure 11 - Catalyst Flow control in Section R41-4**



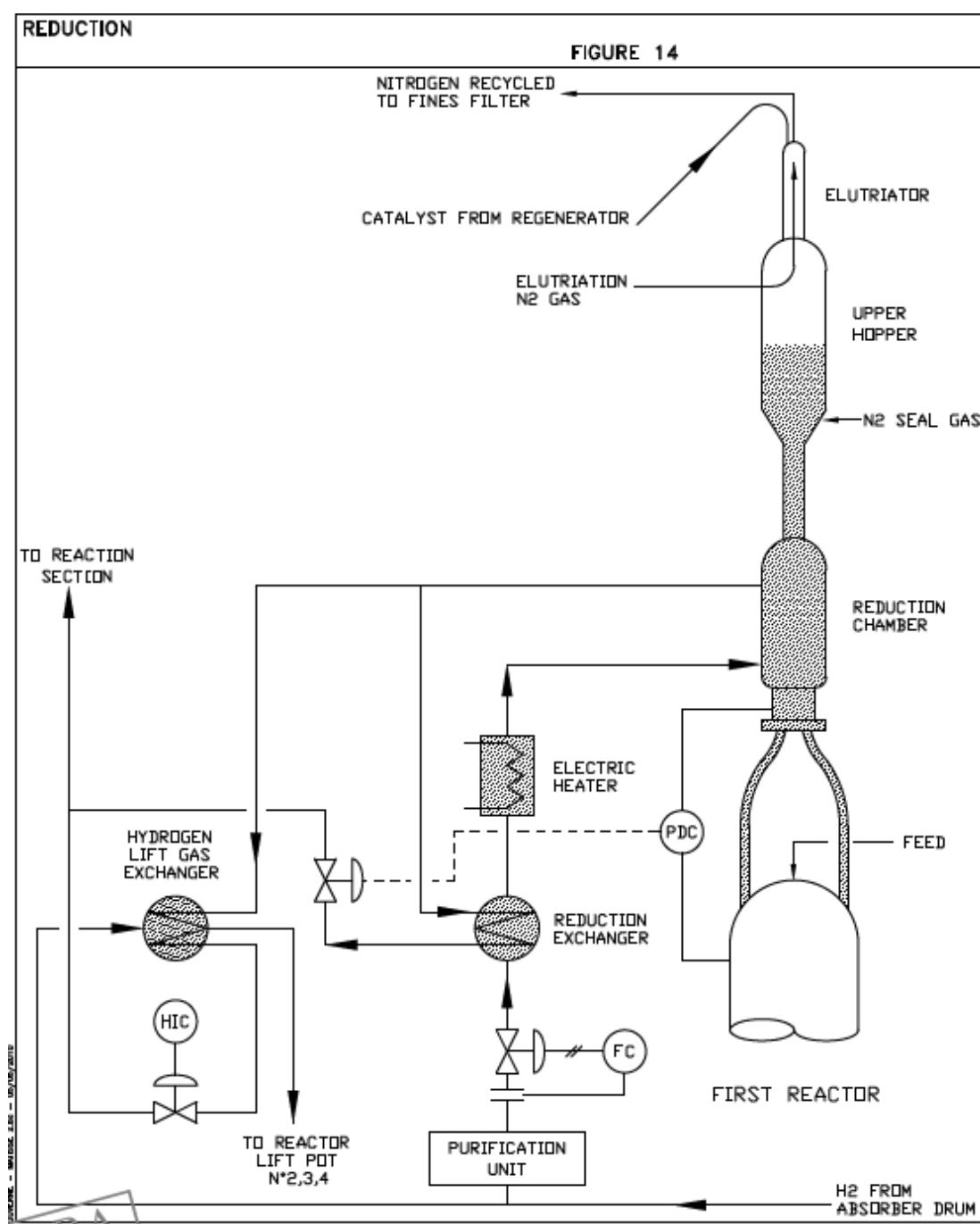
**8.19.12 Figure 12 - Nitrogen Circulation and Nitrogen Seal Gas**



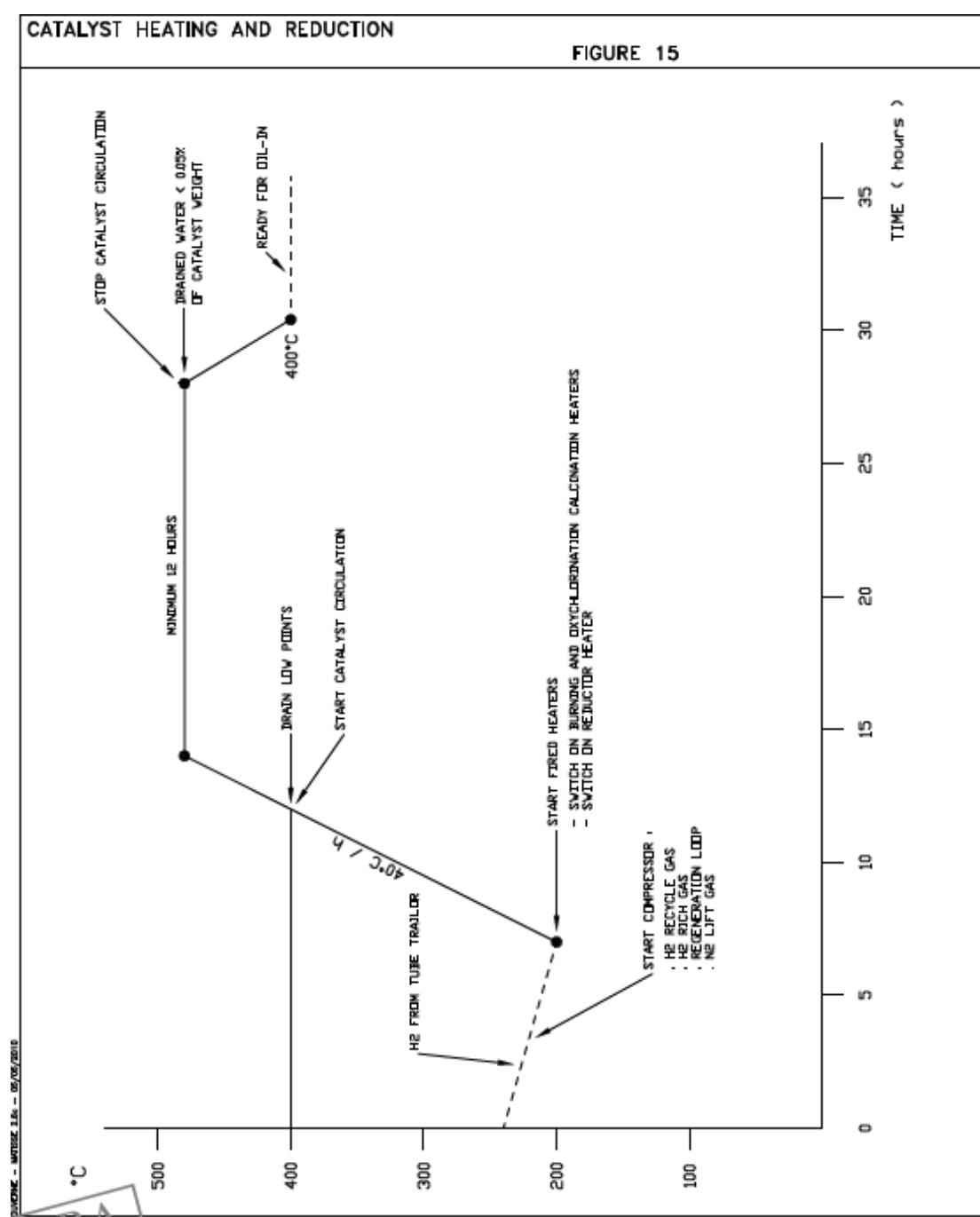
**8.19.13 Figure 13 - Seal Gas System**



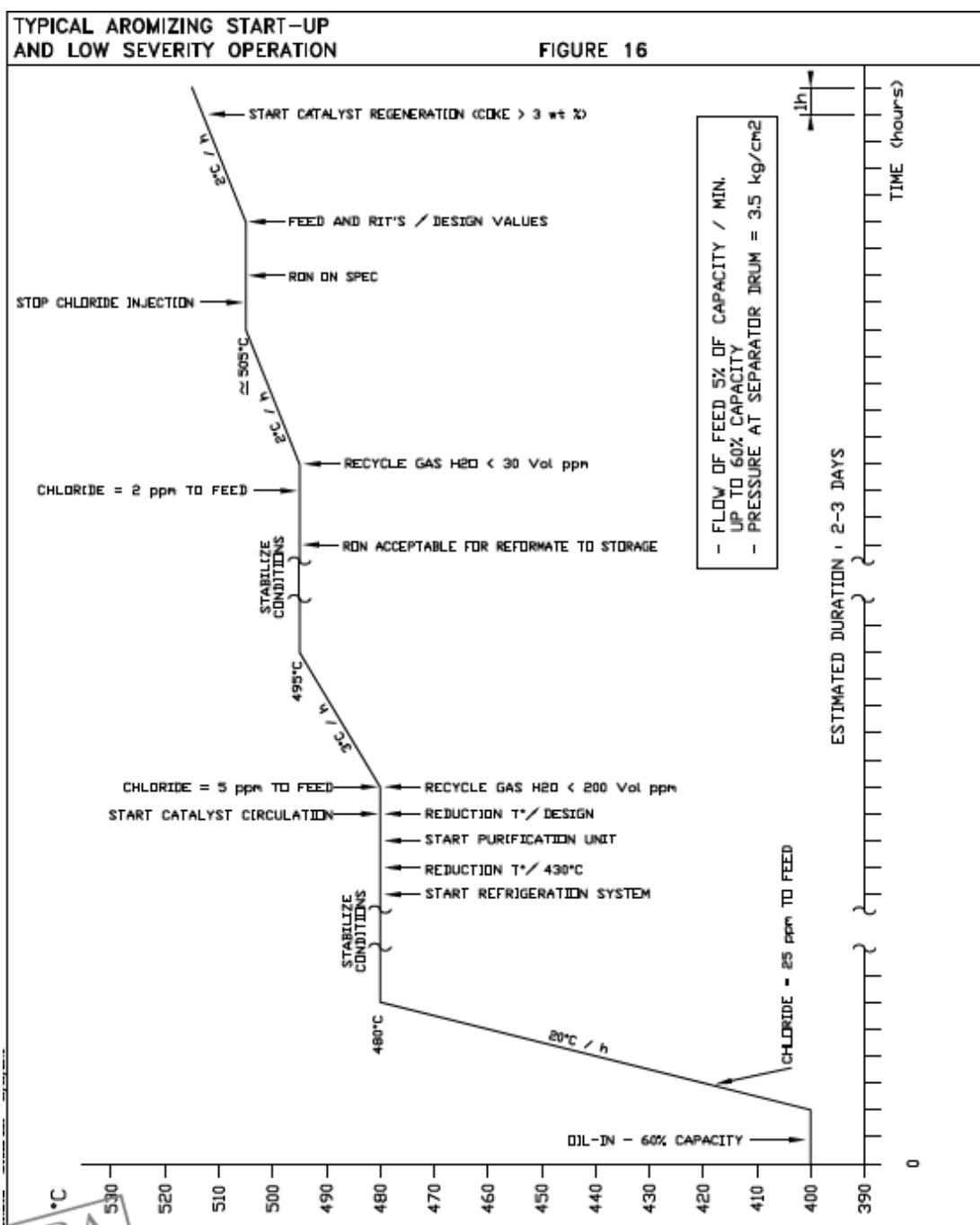
**8.19.14 Figure 14 - Catalyst Reduction**



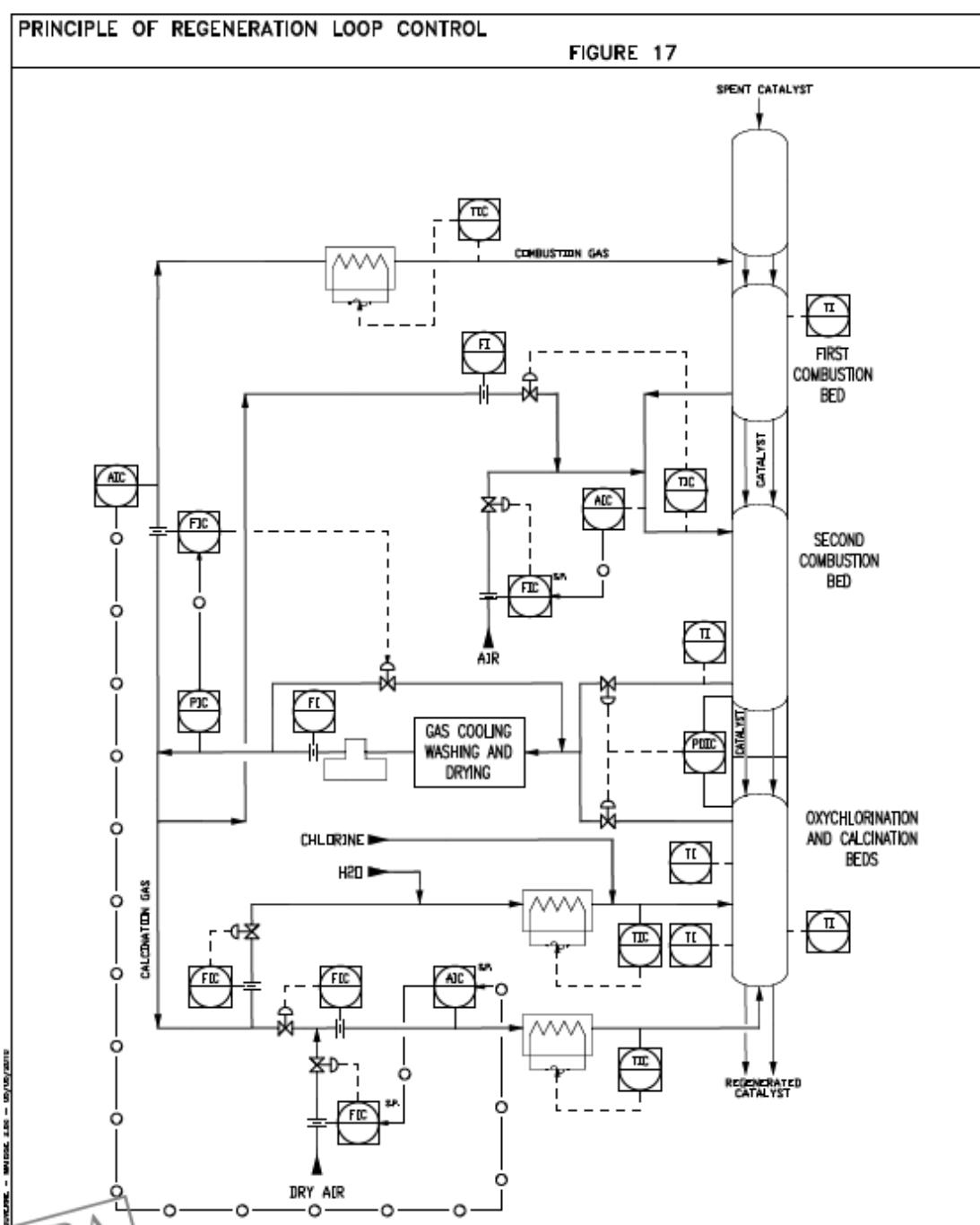
### 8.19.15 Figure 15 - Catalyst Heating and Reduction



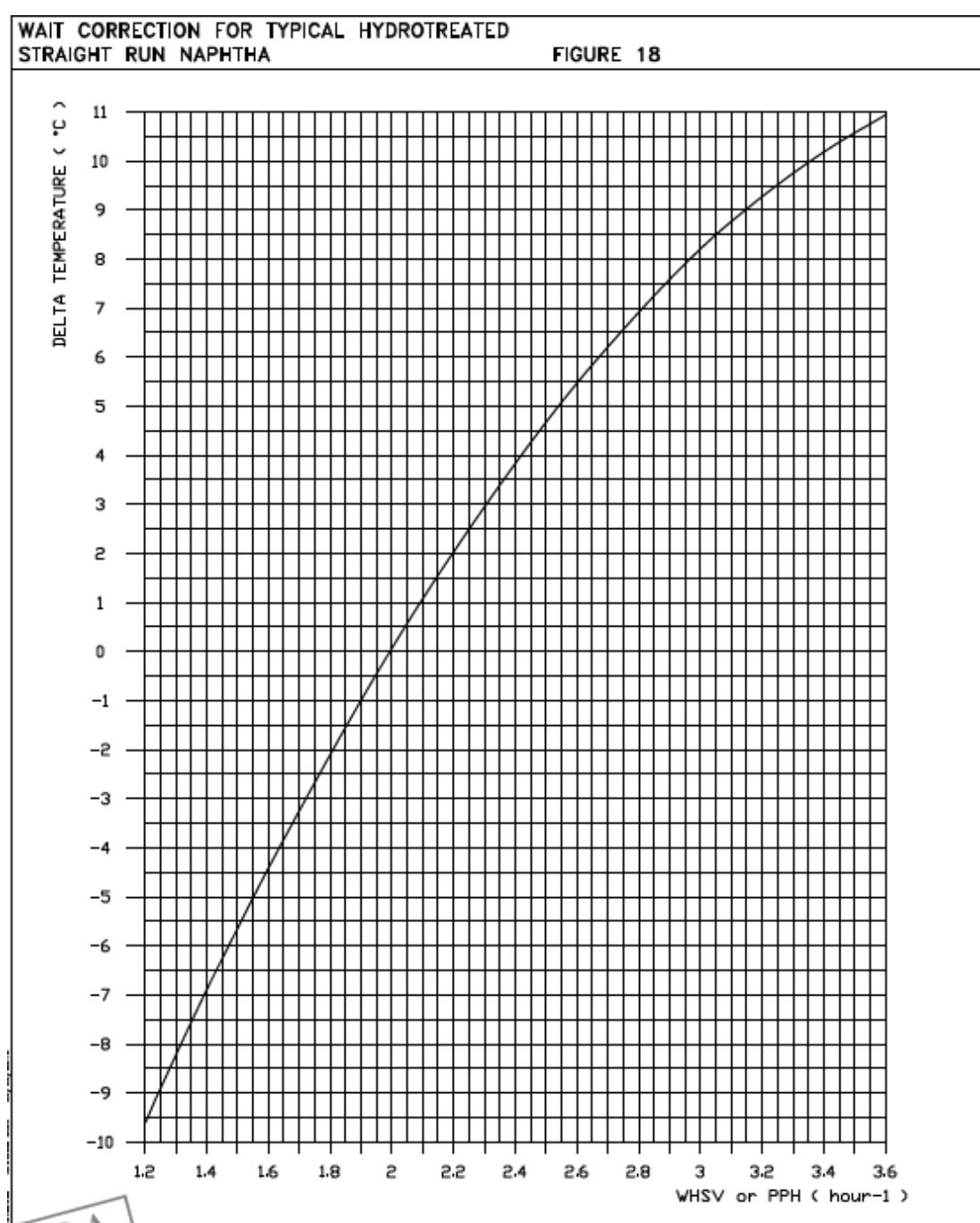
### 8.19.16 Figure 16 - Aromizing Start-Up and Low Severity Operation



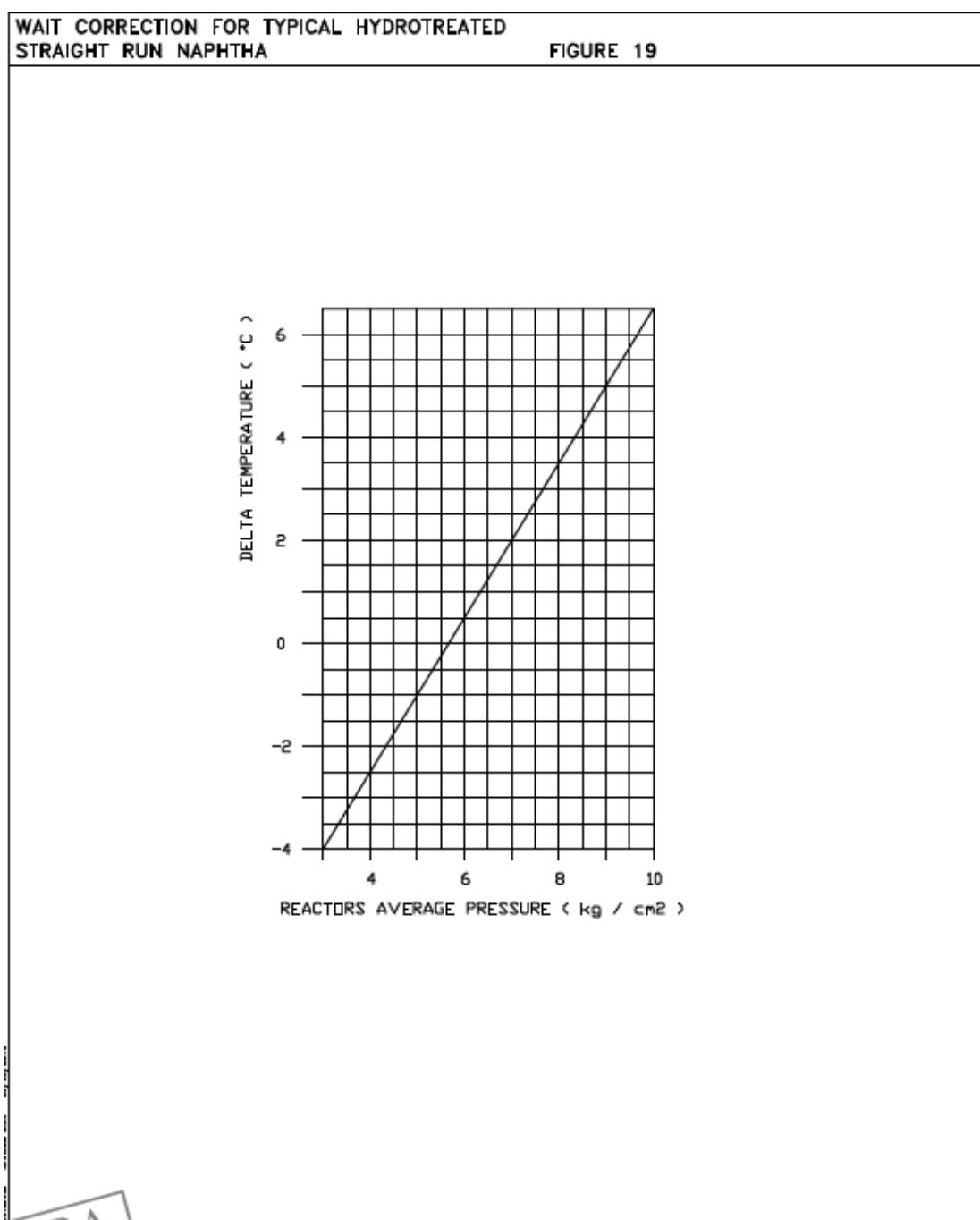
**8.19.17 Figure 17 - Principle of Regeneration Loop Control**



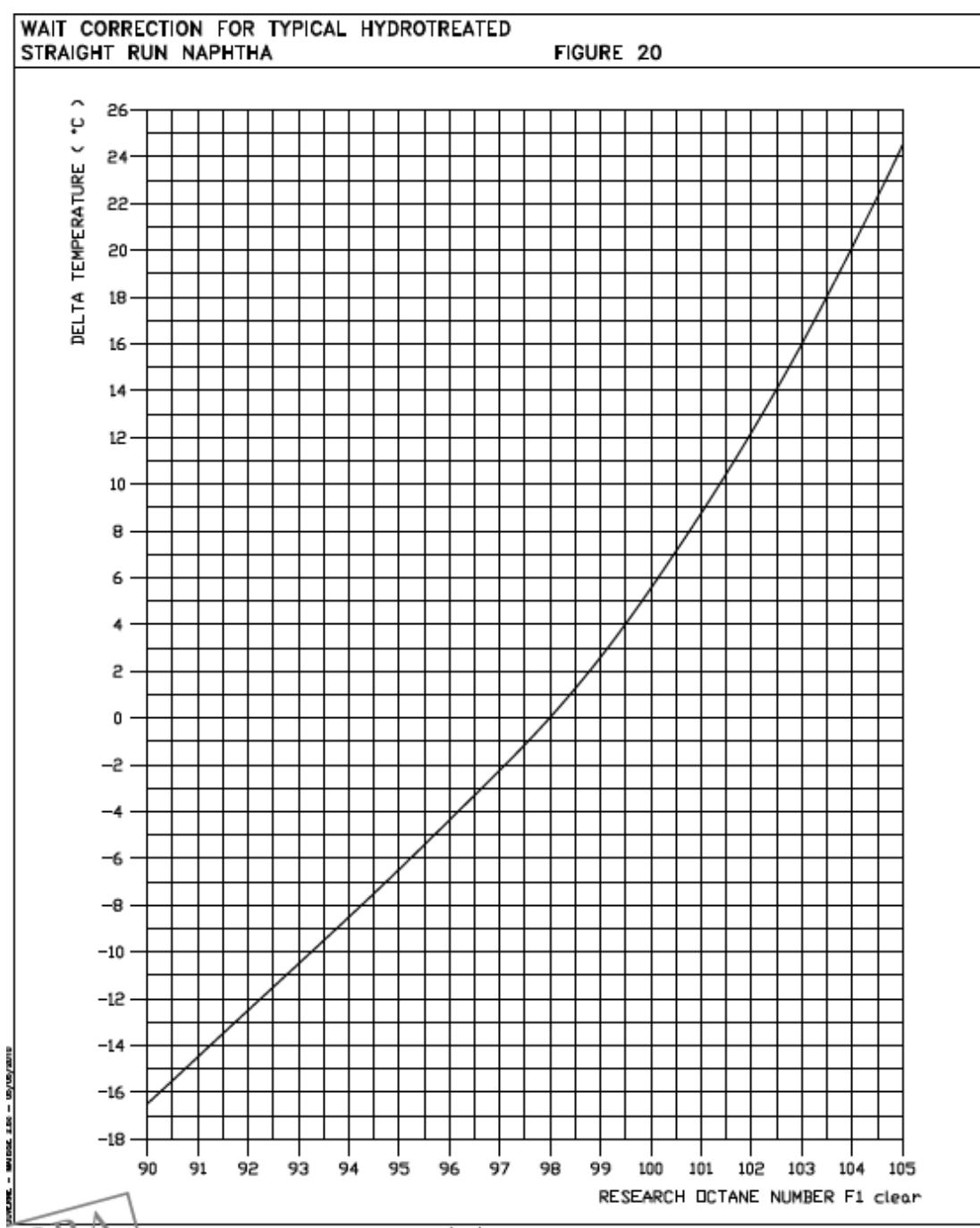
**8.19.18 Figure 18 - WAIT Correction for typical Hydrotreated SR Naphtha -1**



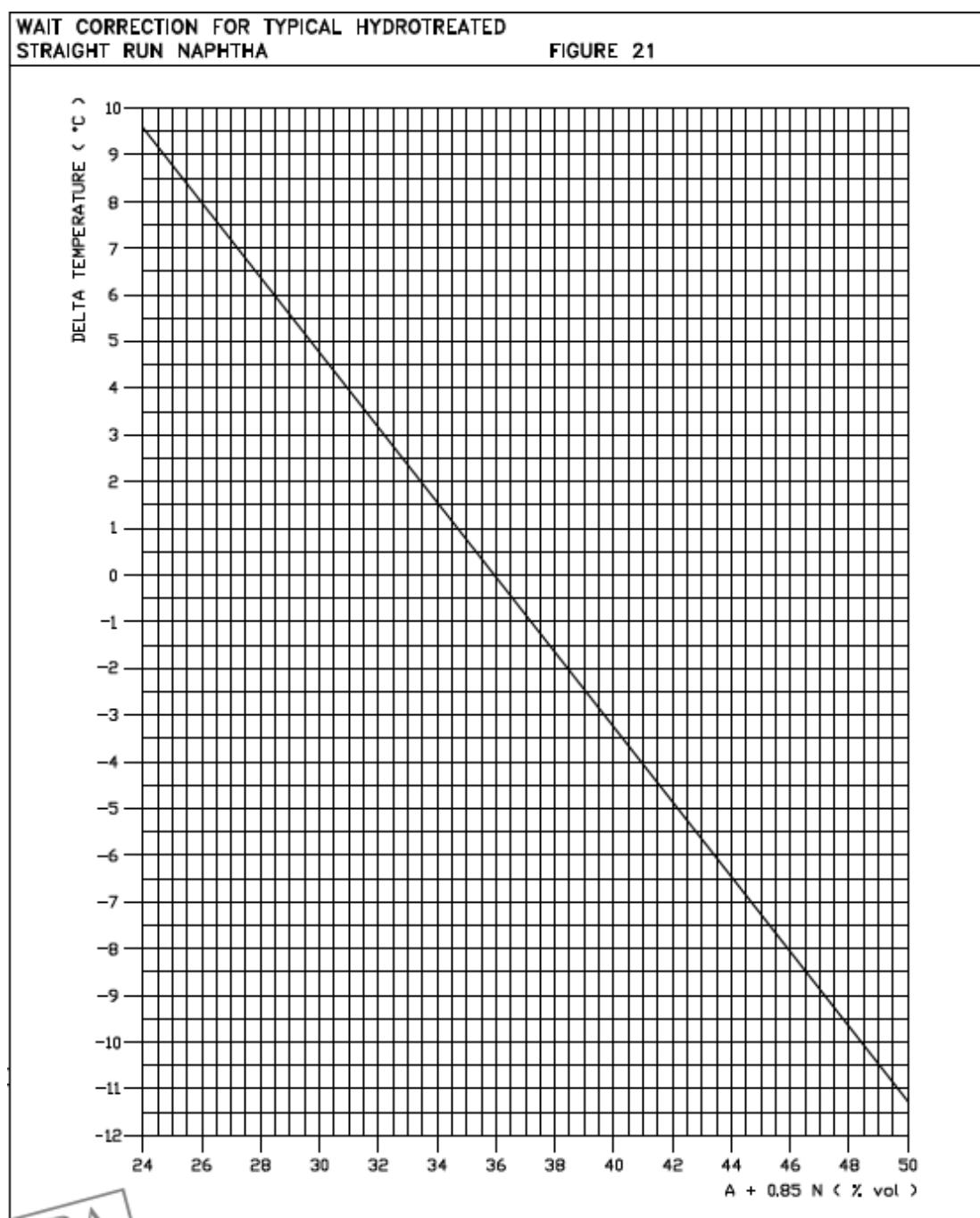
**8.19.19 Figure 19 - WAIT Correction for typical Hydrotreated SR Naphtha -2**



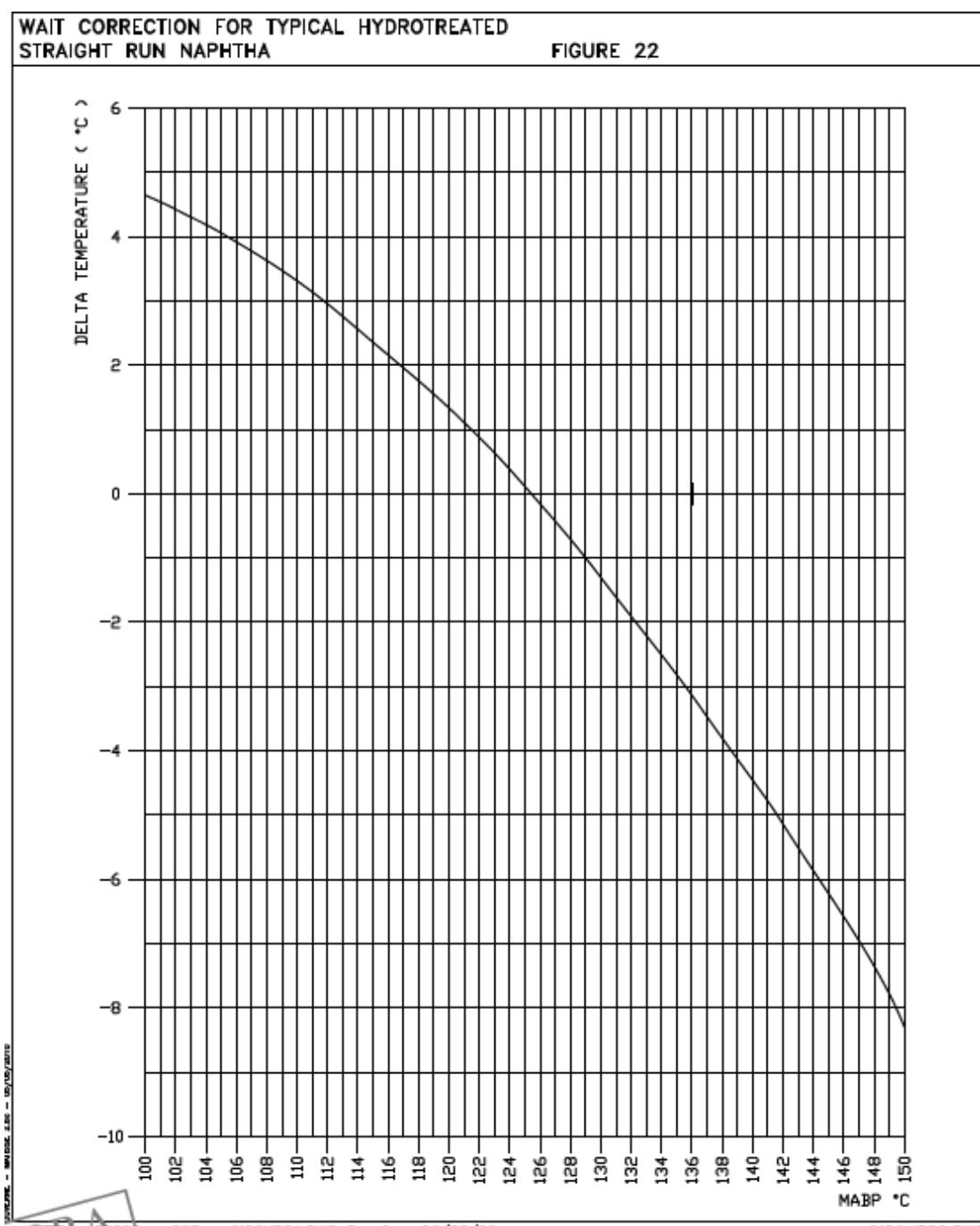
**8.19.20 Figure 20 - WAIT Correction for typical Hydrotreated SR Naphtha -3**



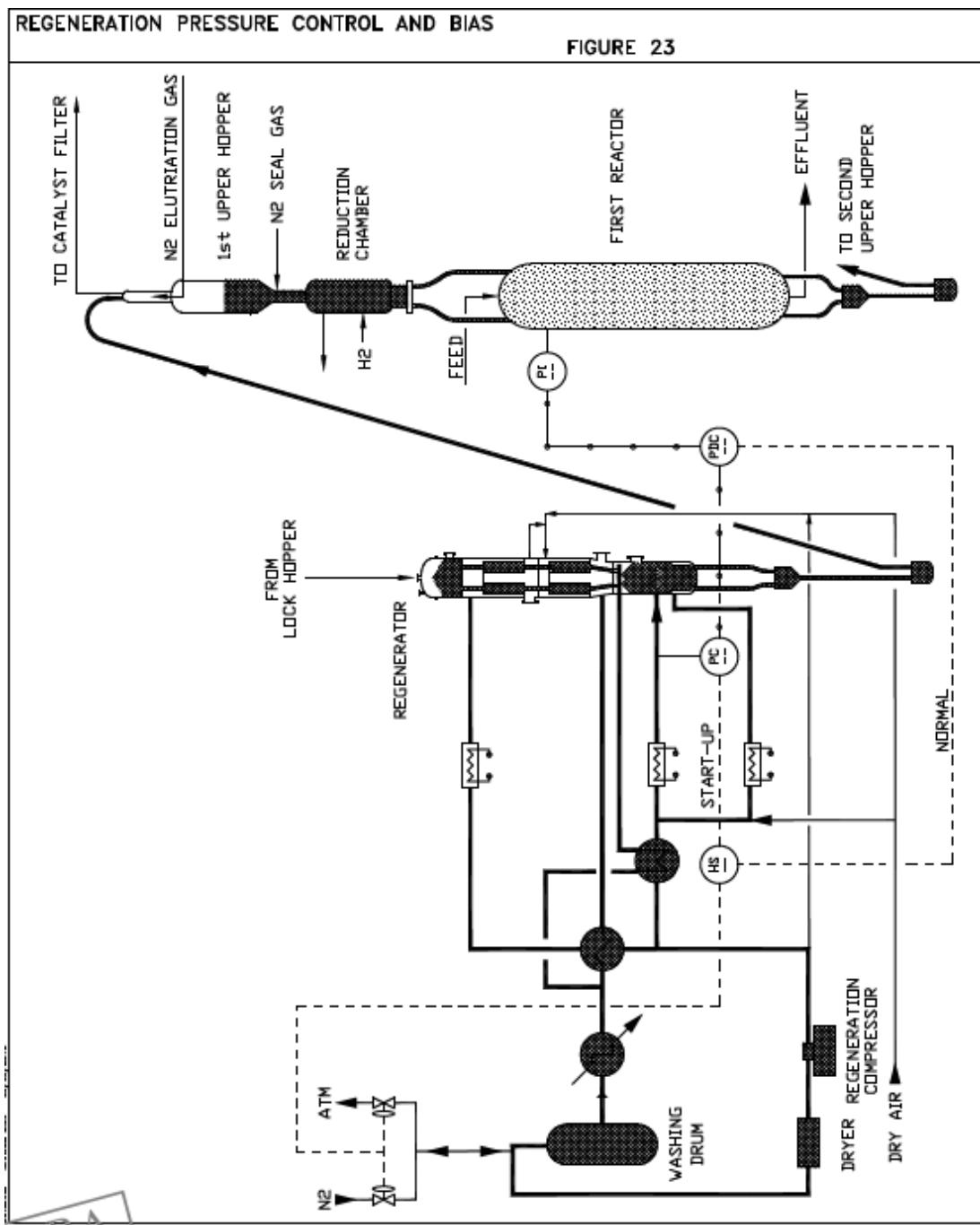
**8.19.21 Figure 21 - WAIT Correction for typical Hydrotreated SR Naphtha -4**



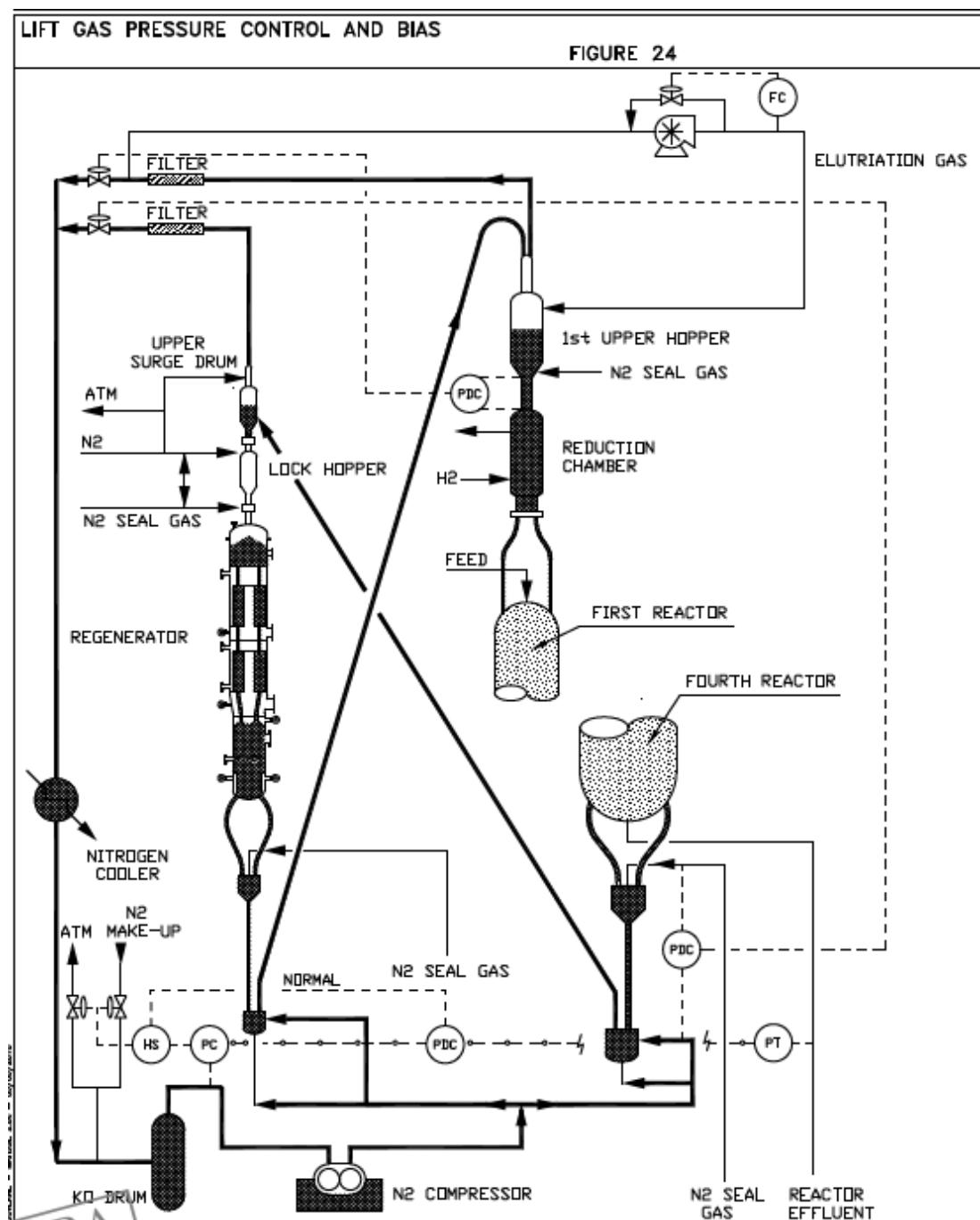
**8.19.22 Figure 22 - WAIT Correction for typical Hydrotreated SR Naphtha -5**



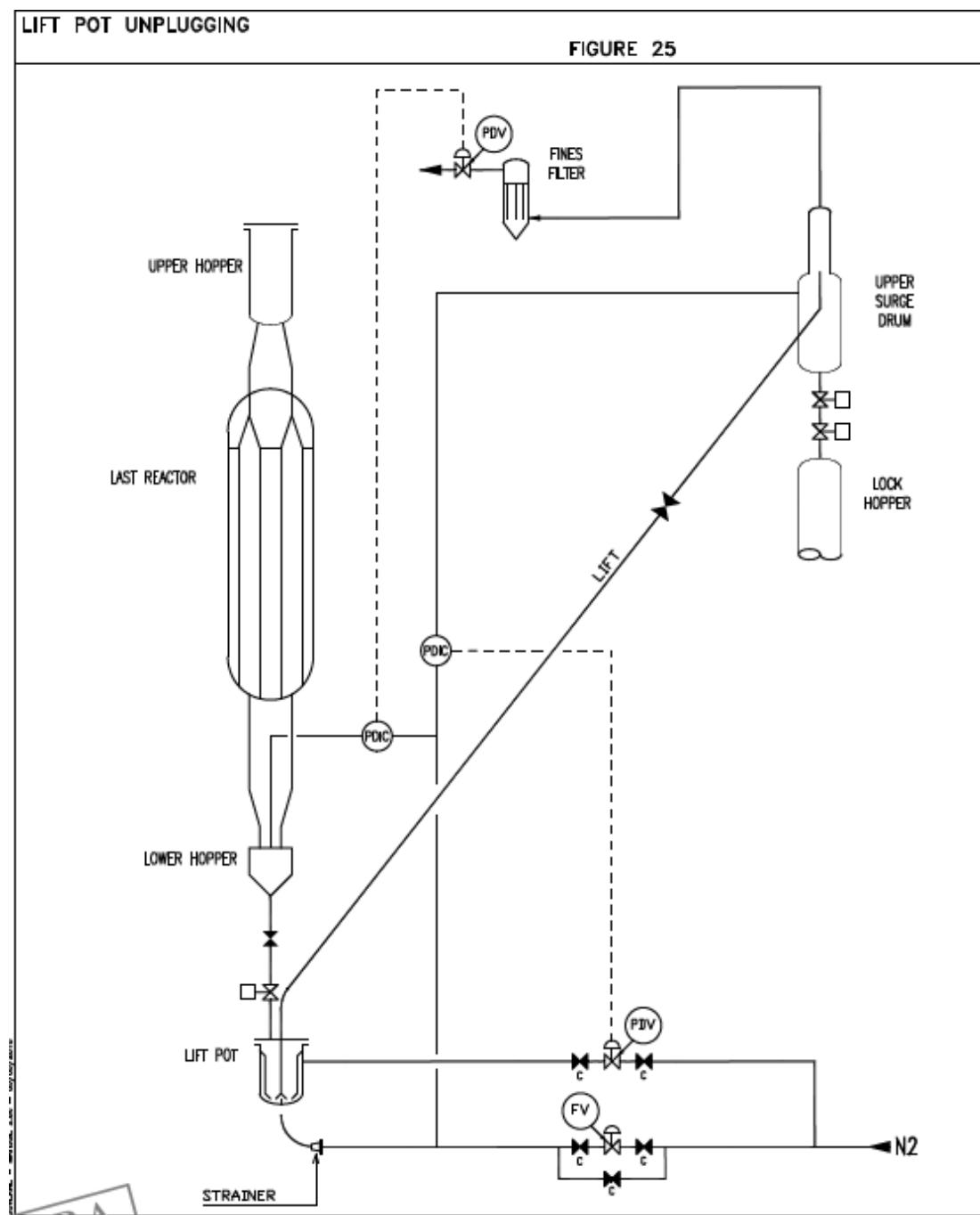
**8.19.23 Figure 23 - Regeneration Pressure Control and BIAS**



**8.19.24 Figure 24 - Lift Gas Pressure Control and BIAS**



**8.19.25 Figure 25 - Lift Pot Unplugging**



**8.19.26 Figure 26 - Lift Pot Unplugging**

