THE OIL & GAS ENGINEERING GUIDE

Hervé Baron

Editions TECHNIP

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Preface

When the author, an alumni of IFP School, contacted me in 2008 to express his desire to share his experience with students, I readily accepted. Such is the practice of IFP School: to involve working professionals among its faculty, to bridge the gap between the academic and professional worlds. This transfer of living knowledge is the foundation of our curriculum.

What I did not expect, though, was that he would take this opportunity to write a book!

What started as a one-day lecture gave rise to a book summarizing 15 years of professional experience.

In doing so, I know that the author took a great deal of pleasure. Not only in the sense that he was producing something useful, but also in the consolidation of the various aspects of his experience as well.

Writing this book was an opportunity for him to stand back from details and derive principles. This resulted in a clear synthesis offering an overall view to the newcomer.

I wish this work great success. I also wish the author to grow in his teaching skills, capturing the audience as he does by covering the subject matter simply as a recollection of first hand experiences.

Jean-Luc Karnik, Dean, IFP School

Acknowledgments

The author wishes to address a special thank to:

- Jean-Luc Karnik, Dean of IFP school, for the opportunity he offered him to give lectures there, which is how this work originated,
- Michel Angot, for his review and significant contribution to this work.

The author also wishes to thank his many colleagues who helped him put this work together:

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The engineering documents shown herein come from real projects executed by Saipem and Technip. The author wishes to thank these two companies for their authorization to publish these documents.

Finally, the author wishes to thank Groupe H. Labbe (www.labbe-france.fr), for their authorization to reproduce pictures of equipment manufactured in their premises.

Reader's feed back:

Not being a specialist of all subject matters described in this work, the author submitted its various sections to the review of senior engineers in each discipline. This will not have removed all errors or avoided omissions. The author will be grateful to the reader that will point them out, comment on the book or make any suggestion for improvement.

Correspondence to the author shall be addressed to: oilandgasengineering@gmail.com.

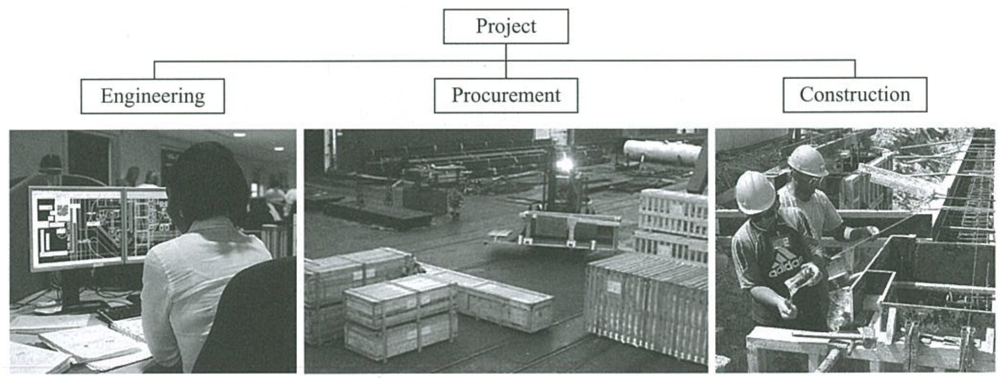
Table of Contents

Usual Engineering Abbreviations

3D	3 Dimensions
CWI	Civil Works Installation drawing
EPC	Engineering, Procurement and Construction
ESD	Emergency Shut Down
Ex	Explosion protection
FEED	Front End Engineering Design
F&G	Fire and Gas
HAZOP	HAZard and OPerability study
HVAC	Heating, Ventilation and Air Conditioning
HSE	Health, Safety and Environment
IFA	Issue For Approval
IFC	Issue For Construction
IFD	Issue For Design
IFR	Issue For Review
ISO	piping Isometric drawing
MTO	Material Take-Off
PFD	Process Flow Diagram
P&ID	Piping & Instrumentation Diagram
PCS	Process Control System
QRA	Quantitative Risk Analysis

Introduction

The execution of a turn-key Project for an industrial facility consists of three main activities: Engineering, Procurement and Construction, which are followed by Commissioning and Start-Up.



Engineering designs the facilities, produces the list, specifications and data sheets of all equipment and materials, and issues all drawings required to erect them at the construction site.

Procurement purchases all equipment and materials based on the lists and specifications prepared by Engineering.

Finally, Construction installs all equipment and materials purchased by Procurement as per the erection drawings produced by Engineering.

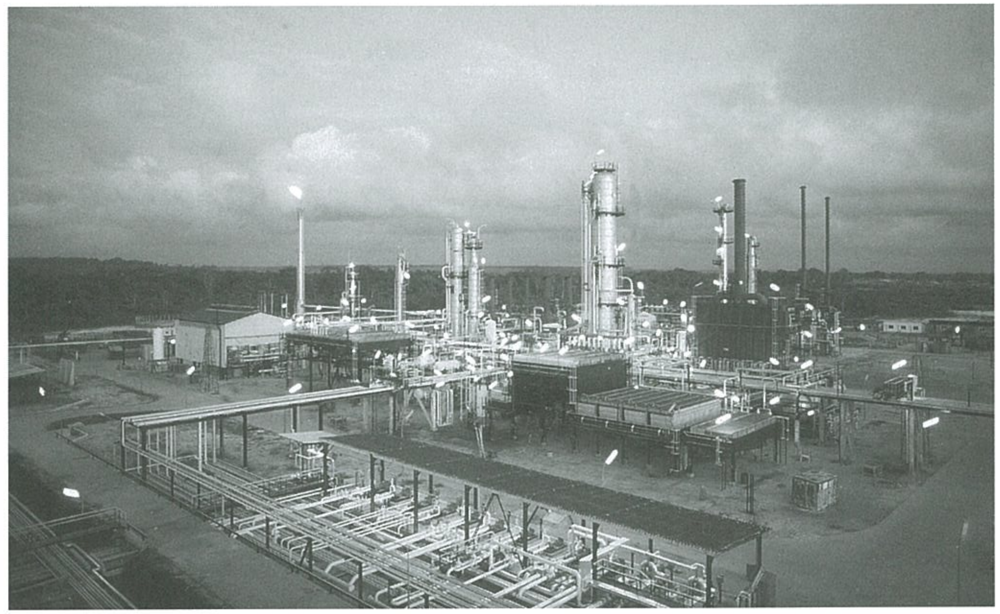
Engineering design is the first, and most critical part, of the execution of a Project. It is indeed engineering that writes the music that will then be played by all project functions: Procurement procures equipment/material as specified by Engineering, Construction erects as shown on engineering drawings.

Engineering is the task of translating a set of functional requirements into a full set of drawings and specifications depicting every detail of a facility.

Engineering involves a variety of specialities, which include Process, Safety, Civil, Electrical, Instrumentation & Control to name a few, and a large number of tasks, from high level conceptual ones to the production of very detailed fabrication and installation drawings.

Cost pressures in the past decade have resulted in the transfer a number of tasks from high cost countries to low cost centres. This does not make it easy for today's engineers entering an Engineering and Construction Contractor to get an overall view of Engineering activities.

This work's purpose is to meet this need. It describes in a synthetic yet exhaustive way all activities carried out during the **Engineering** of Oil & Gas facilities, such as refineries, oil platforms, chemical plants, etc.



The work stays on the level of principles rather than going into detailed practices.

In this sense, what is described here is not the practice of a particular Engineering Company but is, to a very large extent, common to all and can be found on any Project.

All illustrative documents (drawings, diagrams, text documents) are actual Engineering deliverables which were used on executed Projects.

Chapter 1

Project Engineering

Engineering of a facility is done in two different steps, a conceptual one, the Basic Engineering, and an execution one, the Detailed Engineering. These two steps are almost always done by different contractors. The Basic Engineering is usually done under an engineering services contract while detailed design is normally part of the facility's Engineering, Procurement and Construction (EPC), also called turn-key, contract.

The scope of **Basic Engineering**, also called **Front End Engineering Design (FEED)**, is to define the facility at a conceptual rather than a detailed level. It entails defining the process scheme, the main equipment, the overall plot plan, the architecture of systems, etc. Basic Engineering stops with the issue of the main documents defining the plant, mainly the Piping and Instrumentation Diagrams, the overall layout of the plant (plot plant), the specification of the main equipment, the Electrical distribution diagram and the Process Control system architecture drawing.

The basic engineering documents serve as the technical part of the call for tender for turn-key execution of the project.

Detailed Engineering takes place during the actual project execution phase. It consists of producing all documents necessary to purchase and erect all plant equipment. It therefore entails producing the specification and bill of all quantities for all equipment and materials. It also entails producing all detailed installation drawings.

Detailed Engineering integrates vendor information (actual equipment data after design by vendor), as purchasing of equipment actually takes place in this phase, whereas Basic Engineering takes place ahead of equipment purchasing.

The depth of details required in installation related Engineering activities, such as Civil, Steel Structure, Piping, Electrical and Instrumentation, etc. will depend on the split of responsibility that has been agreed with the construction contractor.

It is very common, for instance, that pipes with a diameter below 2" are excluded from the Engineer's scope. Their routing, the material take-off and the procurement of the associated material are under the responsibility of the construction contractor.

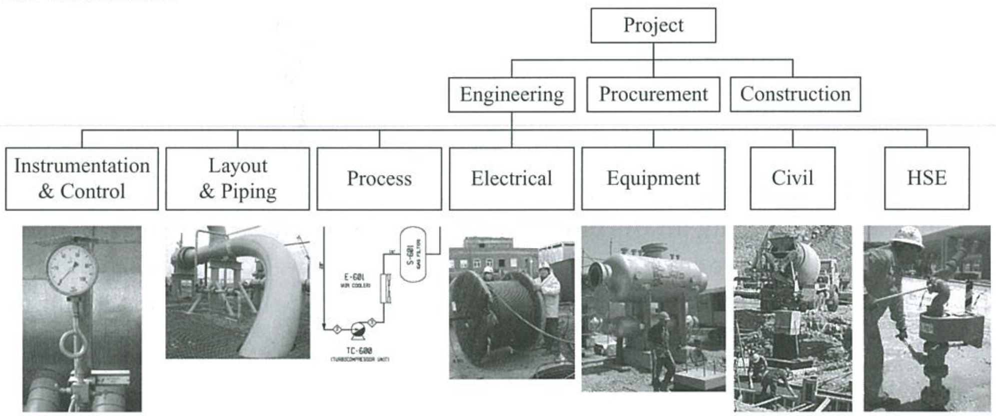
The **Engineering Execution Plan** contains a split of responsibility matrix who defines who does what between the Engineer and the Construction Contractor.

RESPONSIBILITY MATRIX						
ACTIVITY	STUDY / EXPERTISE ACTIVITY	ENGINEERING / PROCUREMENT / SUPPLY				
		STUDIES	REQUISITIONS	STUDIES	MTO's	SUPPLY
		ENGINEER	ENGINEER	SHIPYARD	SHIPYARD	SHIPYARD
PIPING						
	Plot Plan and Equipment general lay out	X				
UTILITIES PIPING	Utilities upstream of modules			X	X	X
	Utilities Headers inside modules lay out	X			X	X
	Utilities Headers Prelim. Weight report	X				
2" and above	Utilities Headers inside modules drwgs	X				
below 2"	Utilities smaller lines inside modules lay out			X	X	X
	Utilities MTO's inside modules			X	X	X
	Weight report	R		X		
PIPING CLASS	900# Piping Class Specification	X				
	900# Valves, Relief Valves Specifications	X				
	All other Piping Class Specifications	R		X		

X – Responsible
R – Review / Comment

Additionally, Engineering tasks can be distributed between Engineering centres in different parts of the world.

Engineering is split into various disciplines, the main ones being shown on the chart here.



The disciplines are coordinated by the project engineering manager who, like an architect for a building project, ensures consistency between the trades.

Engineering activities are of a various nature. Some disciplines, such as Process, are not much concerned by the geographical layout of the plant: They only produce diagrams (representation of a concept) and do not produce drawings (scaled geographical representation of the physical plant).

Other disciplines are very much concernend with these physical drawings, as shown on the matrix below.

	Engineering Discipline					
Activity	Process	Equipment	Civil	Piping	Instrumentation & control	Electrical
Diagrams	X				X	X
Geographical drawings			X	X	X	X
Architecture drawings					X	X
Calculations	X	X	X	X		X
Equipment or material specification, data sheet & requisition		X		X	X	X
Site works specification			X	X	X	X

Thousands of documents and drawings are issued by Engineering on a typical Project.

These documents can nevertheless be grouped in categories. For instance, although Piping issues as many large scale drawings as required to cover the whole plant area, all are of the same type: "Piping General Arrangement Drawing".

All commonly issued engineering documents are listed in the Index at the end of this work. An example of each one is included in the corresponding discipline section.

There are many inter-dependencies between these documents. For instance, piping routing drawings are issued after the process diagram is defined, etc. These inter-dependencies will be described in the schedule section.

The typical schedule of issue of engineering documents is shown in Appendix. A given document will usually be issued several times, at different stages. Typically, a document is first issued for internal review (IFR) of the other disciplines, then to the client for approval (IFA), then for design (IFD) and ultimately, for construction (IFC).

Most of the documents will also undergo revisions to incorporate the necessary changes or additional details as the design progresses.

A document numbering system is put in place. Document numbers include, besides a serial number, discipline and document type codes. This allows quick identification of the issuing discipline and nature of document.

An **Engineering Document Register** is maintained to show at any time the list and current revision of all documents.

Engineering document register

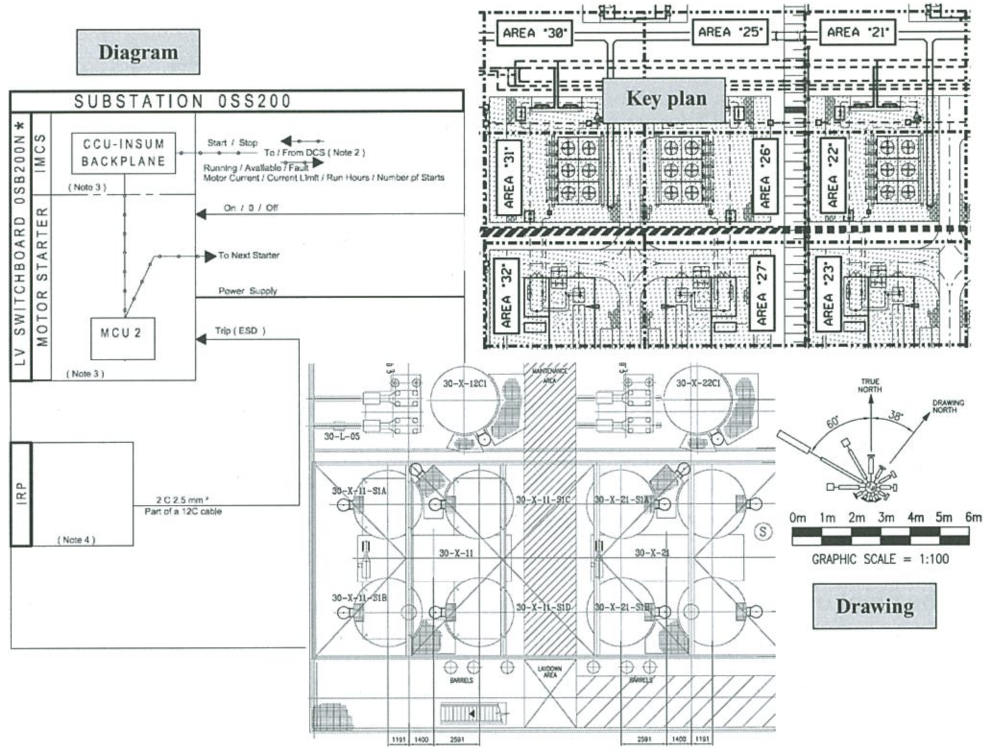
Document number			Document title	Document revision
A	1	48104	Service building instrument. rooms cables routing	B
A	2	48102	Trouble shooting diagrams	D
A	3	48134	F&G system architecture drawing	E
A	4	50100	Instrument index	B
A	7	50003	Spec for instrument installation works and service	C
A	8	50960	Instrument Data sheets for temperature switches	B
A	9	50110	Requisition for pressure relief valves	B
M	1	62059	General plot plan	B
M	2	62020	Piping details standard	C
M	2	62070	Piping general arrangement Area 1	D
M	4	60100	Special items list	D
M	5	62250	Piping isometrics booklet	C
M	6	60000	Pipes and fittings thickness calculation	A
M	6	62351	Calculation note CN1 - piping stress analysis	A
M	7	60001	General piping specification	C
M	8	60103	Data sheets for station piping material	B
M	9	60200	Requisition for pipes	F

Discipline code	
A	Instrumentation & Control
C	Civil engineering
E	Electrical
G	Project general documents
J	Mechanical
K	Safety
M	Piping & Layout
P	Processes
S	Steel Structures
V	Vessels – Heat exchangers
W	Materials – Welding

Document code	
1	Installation drawings
2	Detail drawings
3	Diagrams
4	Lists – Bill of Quantities
5	Isometrics
6	Calculation notes
7	Specifications
8	Data sheets
9	Requisitions

Drawings are mainly of 3 types, as follows:

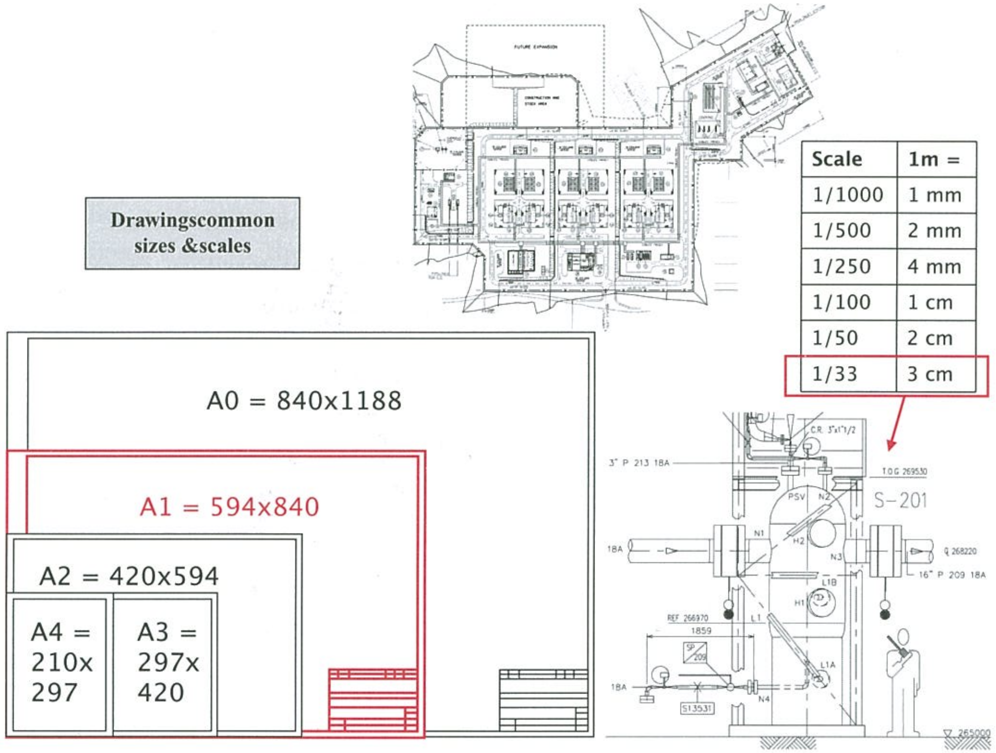
- diagrams, such as Piping & Instrumentation Diagrams, which show a concept,
- drawings, such as Piping General Arrangements Drawings, which show a scaled geographical representation of the plant. The representation may be a plan (top), an elevation (front, side, back) or a cross section view.
- key plans, which shows the division of the plant territory in multiple drawings of a particular type, covering all plant areas at high enough a scale.



A3 is the common size for diagrams and A1 for drawings (in order to cover the maximum surface area in the later case). A0 is not often used as it does not easily unfold at the job Site.

Overall drawings, such as the overall plot plan are issued with a scale of 1/500 or 1/100, depending on size of plant, while detailed installation drawings issued by Piping and Civil for each plant are issued with a 1/50 scale.

Drawingscommon sizes &scales

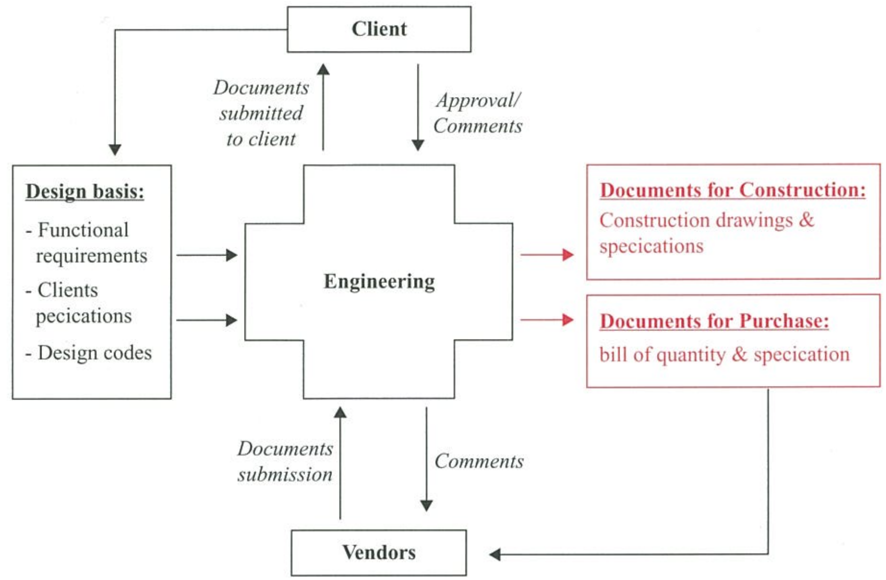


Scale	1m =
1/1000	1 mm
1/500	2 mm
1/250	4 mm
1/100	1 cm
1/50	2 cm
1/33	3 cm

Engineering is the integrator of vendor supplied equipment. Such integration is highly dependant on information from the vendors (size of equipment, power consumption, etc.). One of the challenges faced by Engineering is the management of such an integration, which requires timely input of vendor information not to delay design development.

The plant owner is involved in the Engineering process as they need to review and approve the design and check the compliance to their requirements.

The main information flows are depicted in the diagram that follows.



Managing the flow of information at the interfaces (between disciplines and with vendors) is highly critical, as will be explained in the conclusion to this work.

Chapter 2

Getting started

Design of a new process facility starts by the definition, as per its owner requirements, of its *function*. In short, what is the process to be performed: liquefaction of natural gas, separation and stabilisation of crude oil, etc., the required capacity, the feed stock and products specifications and the performance (availability, thermal efficiency, etc.).

A typical duty for an oil platform would be:

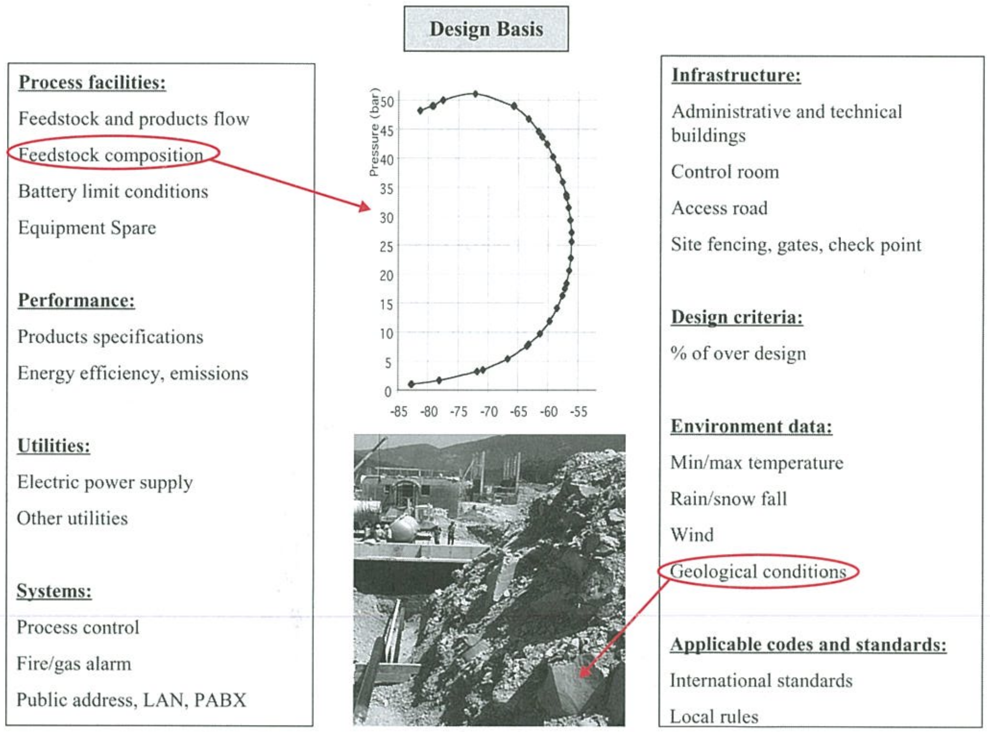
> "The facilities will be designed to handle production rates of 200 kbpd (annual average) of oil production and a peak of 15 Msm3/d of gas production.
>
> The full wellstream production from the subsea wells will be separated into oil, water, and gas phases in a three-stage flash separation process with inter-stage cooling designed to produce a stabilized crude product of 0.9 bara true vapor pressure. Water will be removed in the flash separation/stabilization process in order to reach of 0.5 vol.% BS&W oil specification. The produced gas will be compressed, dehydrated and be injected into the reservoir to maintain pressure as well as conserve the gas."

On top of the functional requirements, come a number of Client specifications, technical requirements for equipment for instance, that will ensure that the facility will last and have the required availability. For instance, design and mechanical requirements will be specified for pumps, so as to limit wear and need for maintenance, to ensure uninterrupted operation over a specified service life.

The Client requirements are found in the Contract Engineering Basis, which describes "what" and "how" to deliver from a technical perspective.

It includes both project specific functional requirements, which include the scope of work and the design basis, and general requirements, such as Client's design standards and specifications.

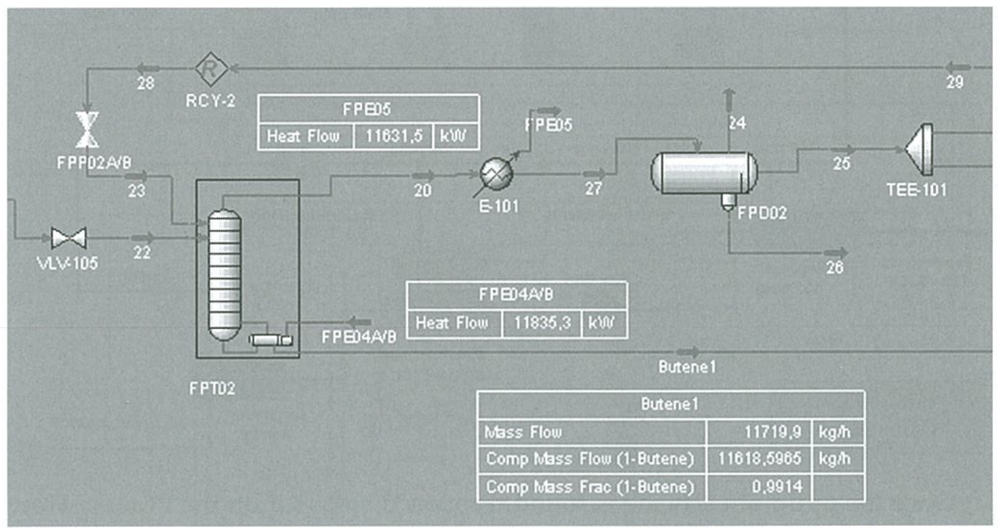
In order for all engineering disciplines to work with a concise document summarizing the main design bases, the Engineering Manager issues the **Engineering Design Basis** document which gives reference information such as feedstock composition, environmental data, performance requirements, applicable specifications, etc.



Chapter 3

Process

How to process the inlet fluid(s) to produce the required product(s), i.e., the Process, will be defined by performing **Process simulations**. These simulations use thermodynamic models to simulate fluid behaviours under the different process operations: phase separation, compression, heat exchange, expansion, etc.



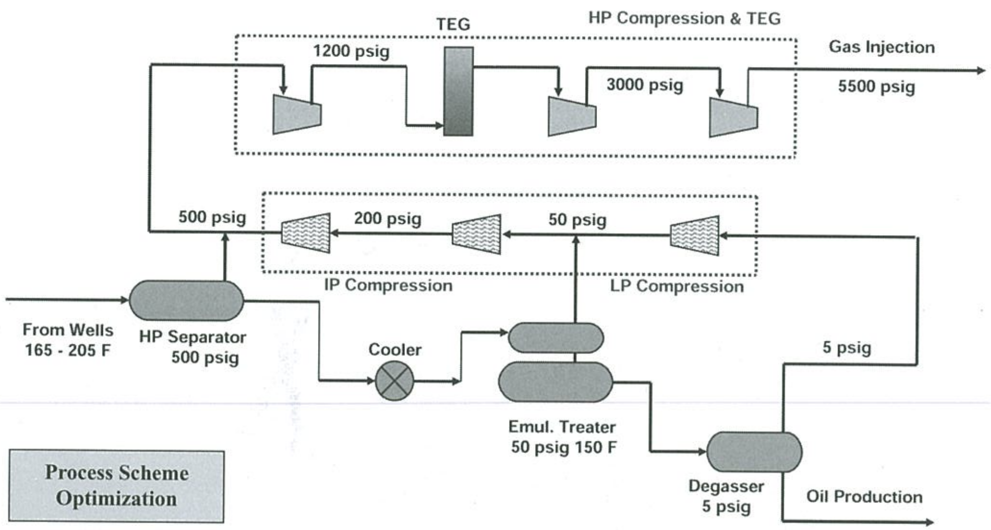
The software also calculates the duty of the equipment. For instance, the software will calculate the required capacity of the compressor to bring gas of such composition from a given inlet pressure to a given discharge pressure. Such calculation is difficult to make manually as petroleum fluids contain a large variety of components. The software incorporates thermodynamic models, which include the properties of all these components, and calculates the difference in enthalpy between the compressed and non-compressed gas, hence the required compressor capacity.

Such mechanical duty will in turn determine the size of the driver (gas turbine for instance) by applying typical compressor efficiency, losses in gear box, etc.

Various schemes are simulated to find the optimum process scheme. This optimisation is done to match a few constraints, e.g., the ratio of outlet to inlet pressure in a gas compressor is around 2.5 (above that the gas temperature becomes too high), gas turbines come in a range of stepped – not continuous – sizes, e.g., 3/5/9/15/25 MW.

Running process simulations will allow to try several scenarios and optimize the process, i.e., reduce the number of equipment, energy consumption, etc.

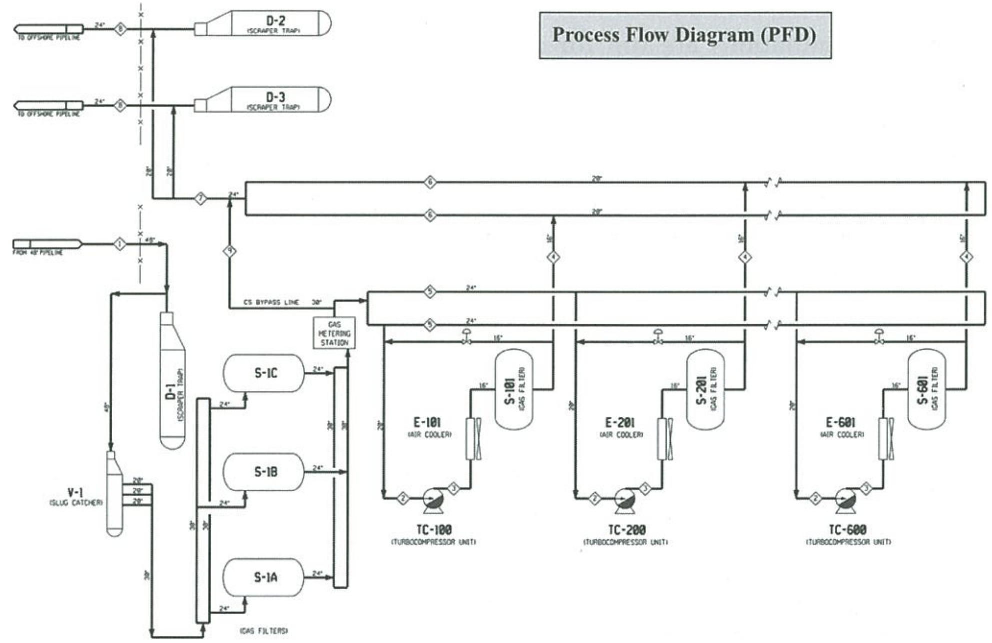
In the case of crude oil stabilisation for instance, pressure levels will be optimized, in order to reduce the number of separators while keeping pressures at values that allow easy gas re-compression (for injection back into the reservoir).



Process Scheme Optimization

Once the optimum scheme is found, Process displays it on the **Process Flow Diagrams (PFDs)** that show the process equipment, e.g., separator, heat exchanger, compressor, etc., and their sequence.

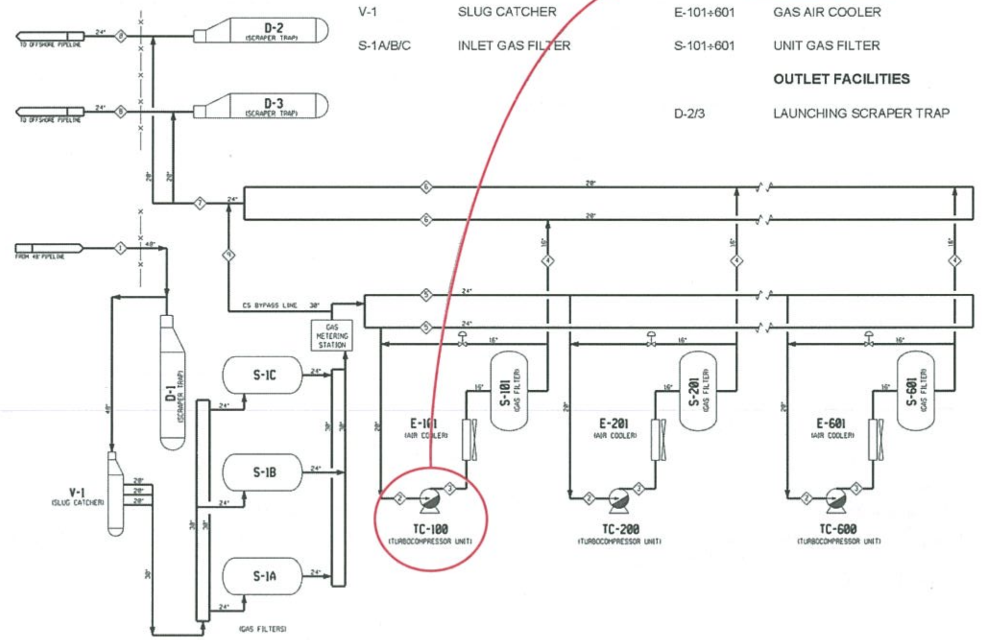
Process Flow Diagram (PFD)



The Process **Equipment list** is the register of all Process equipment. It is derived from the PFDs.

Equipment list

	INLET FACILITIES		GAS COMPRESSION SYSTEM
D-1	RECEIVING SCRAPER TRAP	TC-100÷600	TURBO COMPRESSOR UNIT
V-1	SLUG CATCHER	E-101÷601	GAS AIR COOLER
S-1A/B/C	INLET GAS FILTER	S-101÷601	UNIT GAS FILTER
			OUTLET FACILITIES
		D-2/3	LAUNCHING SCRAPER TRAP

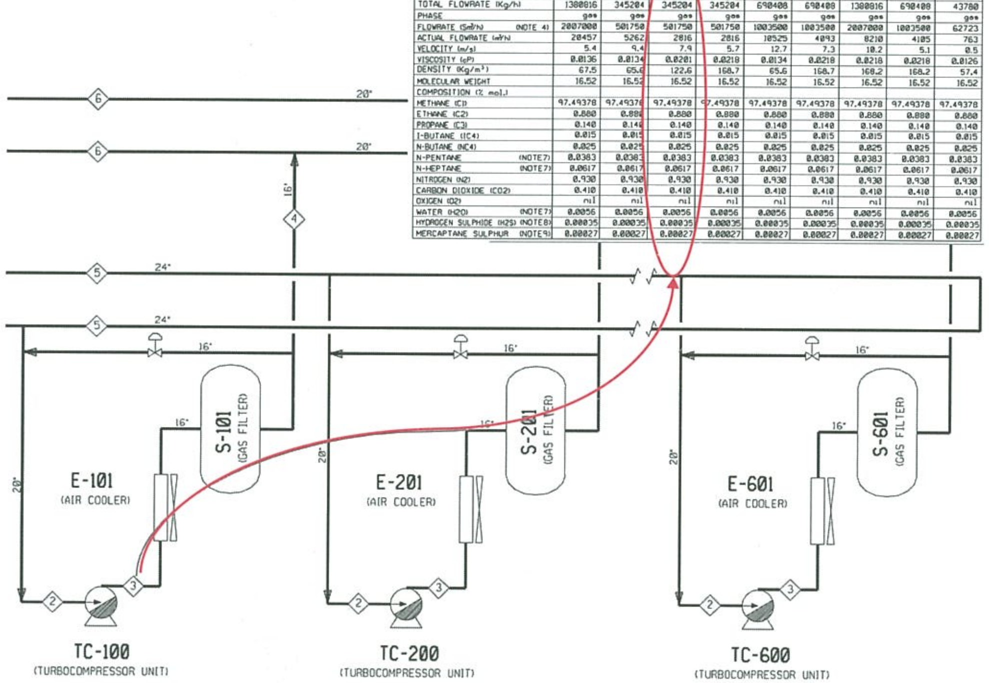


Process simulations are run for all operating cases, such as initial year of operation, plateau level, operating case at field end of life when water to oil ratio has increased significantly, etc.

This determines the required capacity of each equipment. Minimum and maximum duties are identified covering the full range of operating cases. The range of operating conditions for each line (pressure, temperature, flow) is also identified, which will allow adequate line specification and sizing.

The results are tabulated in the **heat and material balance**, which shows the flow, composition and condition of each stream.

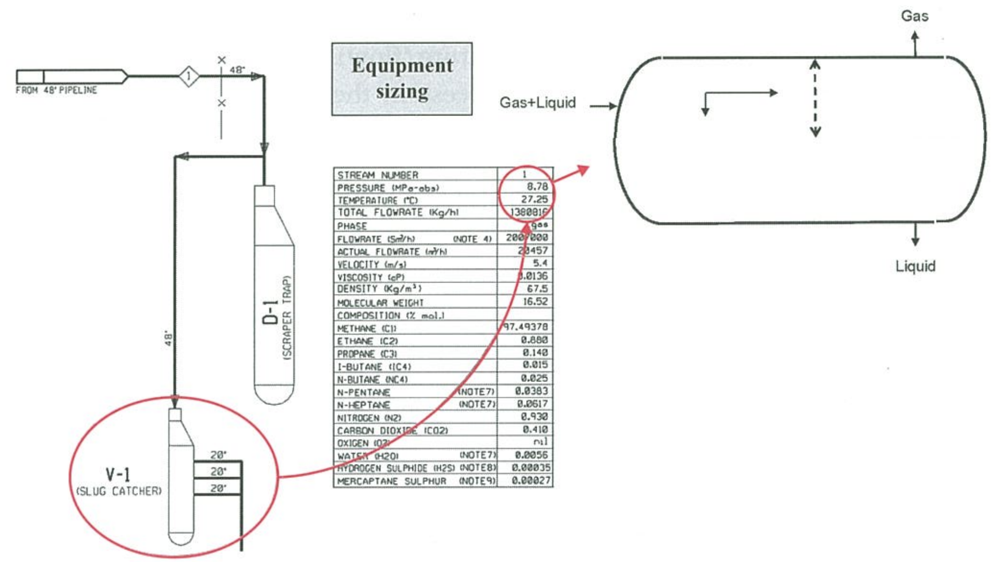
Heat & Material balance



STREAM NUMBER	1	2	3	4	5	6	7	8	9
PRESSURE (MPa-abs)	8.78	8.52	25.1	25.06	8.52	25.06	24.95	24.95	7.10
TEMPERATURE (°C)	27.25	26.4	130	50.0	26.4	50.0	49.8	49.8	12.0
TOTAL FLOWRATE (Kg/h)	1380816	345204	345204	345204	690408	690408	1380816	690408	43780
PHASE	gas	gas	gas	gas	gas	gas	gas	gas	gas
FLOWRATE (Sm³/h) (NOTE 4)	2007000	501750	501750	501750	1003500	1003500	2007000	1003500	62723
ACTUAL FLOWRATE (m³/h)	20457	5262	2816	2816	10525	4093	8210	4105	763
VELOCITY (m/s)	5.4	9.4	7.9	5.7	12.7	7.3	10.2	5.1	0.5
VISCOSITY (cP)	0.0136	0.0134	0.0201	0.0218	0.0134	0.0218	0.0218	0.0218	0.0126
DENSITY (Kg/m³)	67.5	65.6	122.6	168.7	65.6	168.7	168.2	168.2	57.4
MOLECULAR WEIGHT	16.52	16.52	16.52	16.52	16.52	16.52	16.52	16.52	16.52
COMPOSITION (% mol.)									
METHANE (C1)	97.49378	97.49378	97.49378	97.49378	97.49378	97.49378	97.49378	97.49378	97.49378
ETHANE (C2)	0.880	0.880	0.880	0.880	0.880	0.880	0.880	0.880	0.880
PROPANE (C3)	0.140	0.140	0.140	0.140	0.140	0.140	0.140	0.140	0.140
I-BUTANE (IC4)	0.015	0.015	0.015	0.015	0.015	0.015	0.015	0.015	0.015
N-BUTANE (NC4)	0.025	0.025	0.025	0.025	0.025	0.025	0.025	0.025	0.025
N-PENTANE (NOTE7)	0.0383	0.0383	0.0383	0.0383	0.0383	0.0383	0.0383	0.0383	0.0383
N-HEPTANE (NOTE7)	0.0617	0.0617	0.0617	0.0617	0.0617	0.0617	0.0617	0.0617	0.0617
NITROGEN (N2)	0.930	0.930	0.930	0.930	0.930	0.930	0.930	0.930	0.930
CARBON DIOXIDE (CO2)	0.410	0.410	0.410	0.410	0.410	0.410	0.410	0.410	0.410
OXIGEN (O2)	nil	nil	nil	nil	nil	nil	nil	nil	nil
WATER (H2O) (NOTE7)	0.0056	0.0056	0.0056	0.0056	0.0056	0.0056	0.0056	0.0056	0.0056
HYDROGEN SULPHIDE (H2S) (NOTE8)	0.00035	0.00035	0.00035	0.00035	0.00035	0.00035	0.00035	0.00035	0.00035
MERCAPTANE SULPHUR (NOTE9)	0.00027	0.00027	0.00027	0.00027	0.00027	0.00027	0.00027	0.00027	0.00027

Process then performs the **sizing of equipment** as per the required process duty, e.g., size of gas compressor according to required gas flow and gas gravity, size of cooling water pump as per process fluid cooling requirements and calorific value, etc. and Site conditions, e.g., temperature of available cooling medium (air/sea water).

Equipment sizing

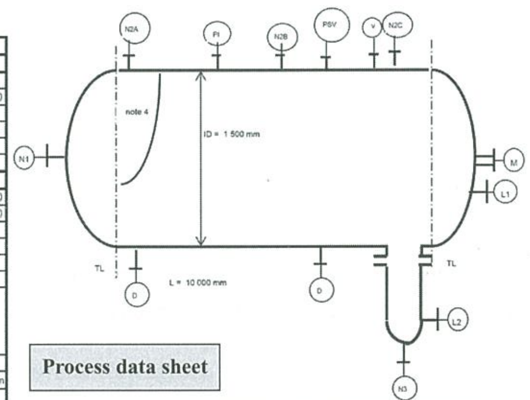


STREAM NUMBER	1
PRESSURE (MPa-abs)	8.78
TEMPERATURE (°C)	27.25
TOTAL FLOWRATE (Kg/h)	1380816
PHASE	gas
FLOWRATE (Sm³/h) (NOTE 4)	2007000
ACTUAL FLOWRATE (m³/h)	20457
VELOCITY (m/s)	5.4
VISCOSITY (cP)	0.0136
DENSITY (Kg/m³)	67.5
MOLECULAR WEIGHT	16.52
COMPOSITION (% mol.)	
METHANE (C1)	97.49378
ETHANE (C2)	0.880
PROPANE (C3)	0.140
I-BUTANE (IC4)	0.015
N-BUTANE (NC4)	0.025
N-PENTANE (NOTE7)	0.0383
N-HEPTANE (NOTE7)	0.0617
NITROGEN (N2)	0.930
CARBON DIOXIDE (CO2)	0.410
OXIGEN (O2)	nil
WATER (H2O) (NOTE7)	0.0056
HYDROGEN SULPHIDE (H2S) (NOTE8)	0.00035
MERCAPTANE SULPHUR (NOTE9)	0.00027

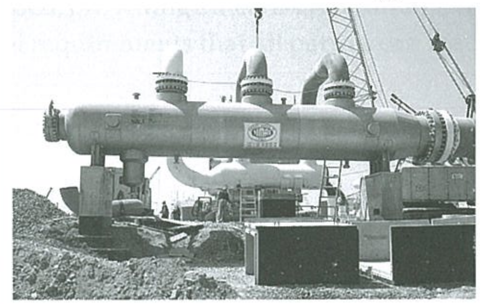
The process duty of each equipment is specified in a **Process data sheet**.

SERVICE	Slug Catcher	COLONNE / *COLUMN*
CONDITIONS OPERATOIRES / *OPERATING CONDITIONS*		
FLUIDE / *FLUID*	Natural Gas	
PRESION DE SERVICE / *OPER. PRESSURE*	9.7	MPa(a)
TEMPERATURE DE SERVICE / *OPER. TEMPERATURE*	30	°C
MASSE VOLUMIQUE LIQ. / *LIQ. DENSITY*	1000	kg/m³
ABRASION, CORROSION, CAUSE / *EROSION, CORROSIVE DUE TO*	note 3	
INFLAMMABLE - EXPLOSIF / *FLAMMABLE - EXPLOSIVE*	Flammable	
DONNEES DE CONSTRUCTION / *CONSTRUCTION DATA*		
PRESSION DE CALCUL / *DESIGN PRESSURE*	10.11	MPa(a)
VIDE : DEPRESSION DE CALCUL / *DESIGN VACUUM PRESSURE*		MPa(a)
TEMPERATURE DE CALCUL / *DESIGN TEMPERATURE*	-20/50	°C
CAPACITE / *CAPACITY*	18	m³
MATERIAU / *MATERIAL*	CS	
SUREPAISSEUR DE CORROSION / *CORROSION ALLOWANCE*	3	mm
DETENSIONNEMENT / *STRESS RELIEVE*	OUI / *YES* ☐	NON / *NO* ☐
REVETEMENT INTERNE / *LINING*	note 6	
EPAISSEUR REVETEMENT / *LINING THICKNESS*		mm
CALORIFUGE / *INSULATION*	OUI / *YES* ☐	NON / *NO* ☒
CONSERVATION CHALEUR / *HEAT CONSERVATION*	☐	
PROTECTION PERSONNEL / *PERSONNEL PROTECTION*	☐	
EQUIPEMENT INTERNE / *INTERNALS*		
CODE DE CONSTRUCTION / *REFERENCE CODE*	ASME VIII div1	

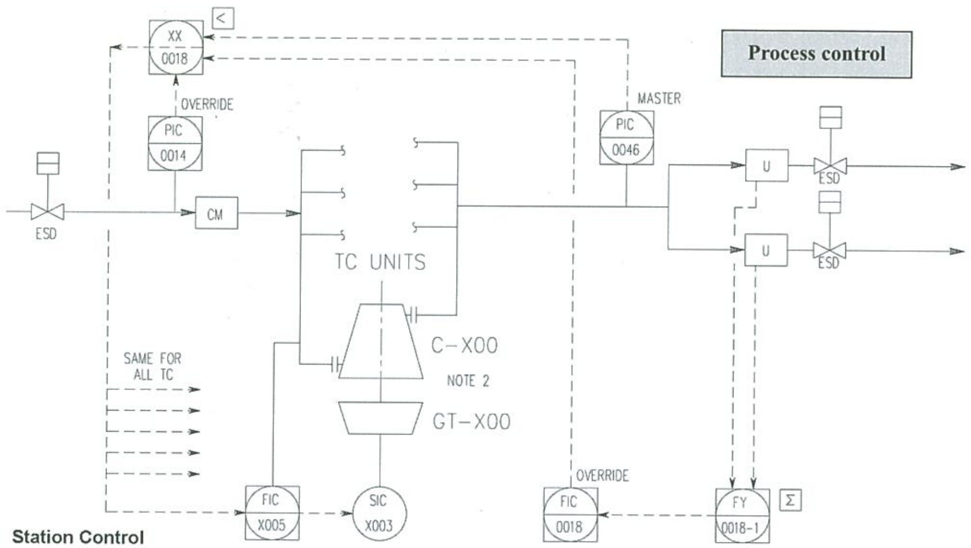
TUBULURES / *NOZZLES*			
REPERE / *MARK*	Nb	DN / *SIZE*	SERVICE
PSV	1	3"	Relief Valve
N1	1	48"	Inlet
N2A/B/C	3	24" (note 7)	Gas Outlets
N3	1	4"	Liquid Outlet
V	1	2"	Vent
D	2	2"	Drains
PI	1	2"	Pressure Gauge
L1 / L2	2	3"	Standpipe
M	1	24"	Manhole



Process data sheet



The PFDs also show how the process will be controlled, by indicating the required controls (of pressure/temperature/flow) throughout the process scheme. This is further described by Process in the **Process Description and Operating Philosophy**.

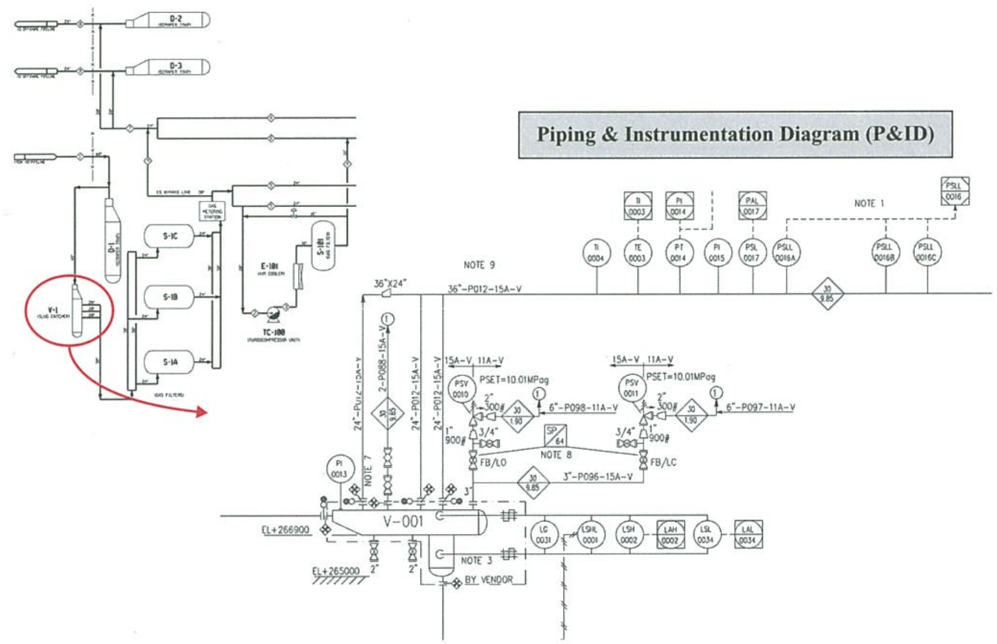


Station Control

Control of the station shall be carried out, manually or automatically, by adjusting the revolutions of the units, controlling the most critical of the following parameters:

- suction gas pressure (override);
- discharge gas pressure (master);
- gas flow rate (override).

As the process diagram is further detailed, PFDs are translated into **Piping and Instrumentation Diagrams (P&IDs)**.

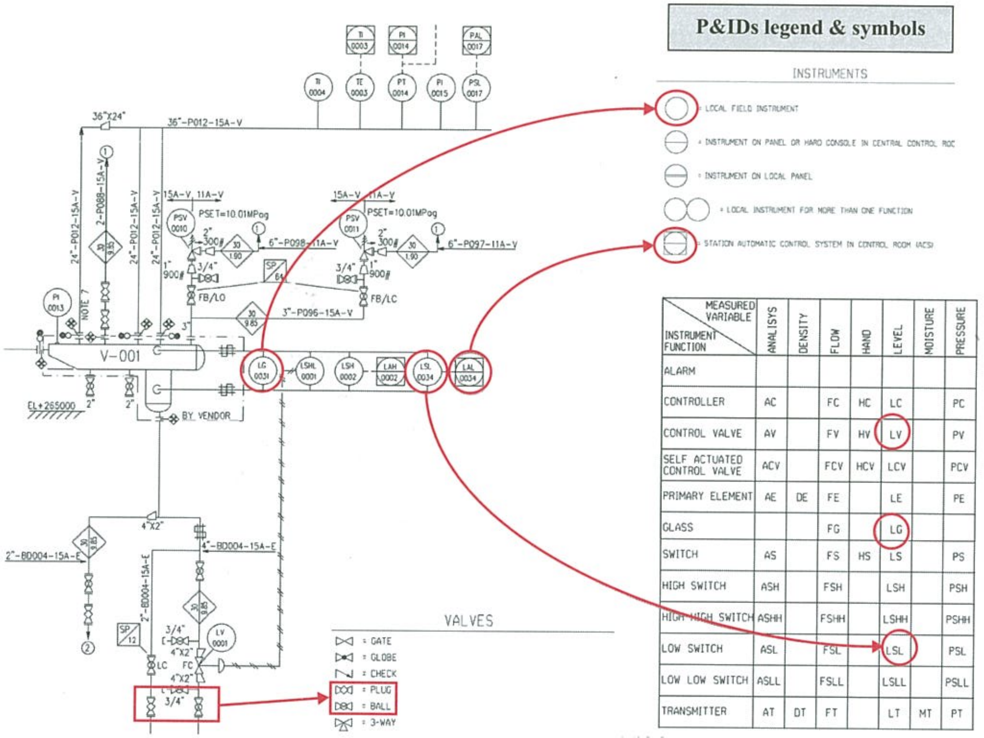


P&IDs show in details the equipment, piping, valves (manual/motorized), instrumentation, process control and emergency shutdown devices.

P&IDs do not only include all lines, instruments, valves required during normal operation, but also the ones required for maintenance, plant start-up and all operating cases.

They will include, for instance, equipment isolation valves, depressurization and drainage lines. They will also include a recycle line required for operation of the plant at low throughput, etc.

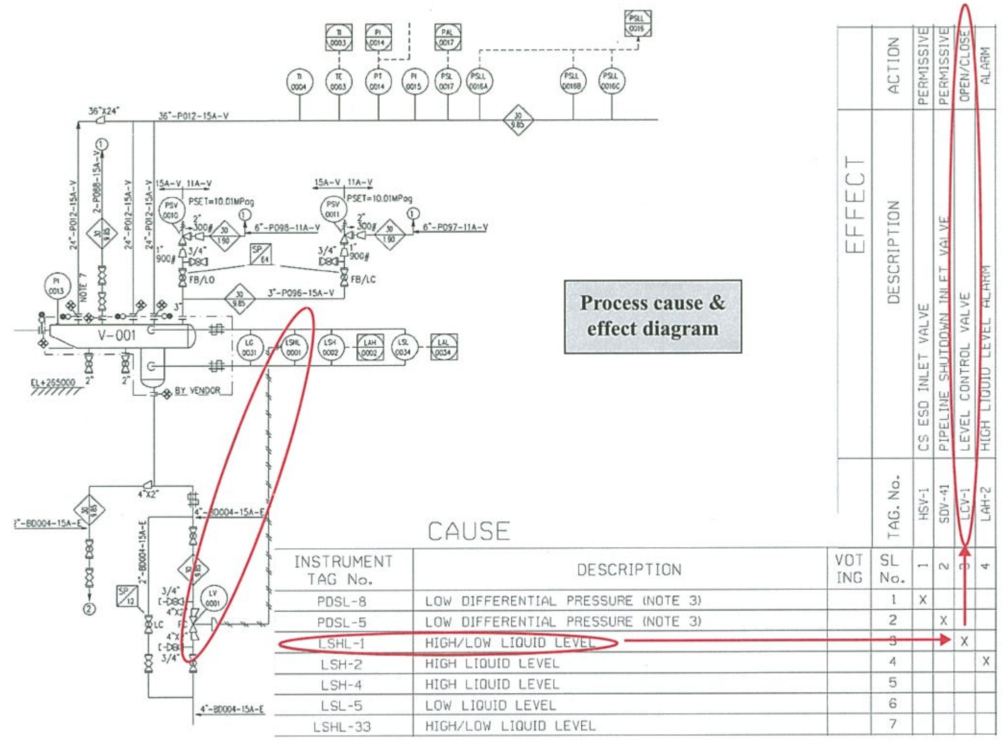
The **Legend and Symbols P&ID** shows the meaning of the graphical elements and symbols used on the P&IDs. For instrumentation, an international symbols and identification standard is generally used, providing a means of communicating instrumentation, automation and control requirements that all parties can readily understand.



MEASURED VARIABLE / INSTRUMENT FUNCTION	ANALISYS	DENSITY	FLOW	HAND	LEVEL	MOISTURE	PRESSURE
ALARM							
CONTROLLER	AC		FC	HC	LC		PC
CONTROL VALVE	AV		FV	HV	LV		PV
SELF ACTUATED CONTROL VALVE	ACV		FCV	HCV	LCV		PCV
PRIMARY ELEMENT	AE	DE	FE		LE		PE
GLASS			FG		LG		
SWITCH	AS		FS	HS	LS		PS
HIGH SWITCH	ASH		FSH		LSH		PSH
HIGH HIGH SWITCH	ASHH		FSHH		LSHH		PSHH
LOW SWITCH	ASL		FSL		LSL		PSL
LOW LOW SWITCH	ASLL		FSLL		LSLL		PSLL
TRANSMITTER	AT	DT	FT		LT	MT	PT

The P&IDs are developed by Process as per the various Operating, Safety and Maintenance requirements:

- Equipment isolation philosophy: valves and bypass to be provided,
- Requirements for start-up and shutdown, i.e., additional bypass/ pressurization, drain lines, etc.,
- Equipment sparing/redundancy philosophy, e.g., 2 pumps, each 100%, one operating and one spare,
- Process controls, which are directly shown on P&IDs by means of dotted lines between controlled process parameter (pressure, flow, temperature) and control valve. Process automations (ON/OFF controls) are described in specific diagrams called **Process Cause & Effects Diagrams**.



EFFECT

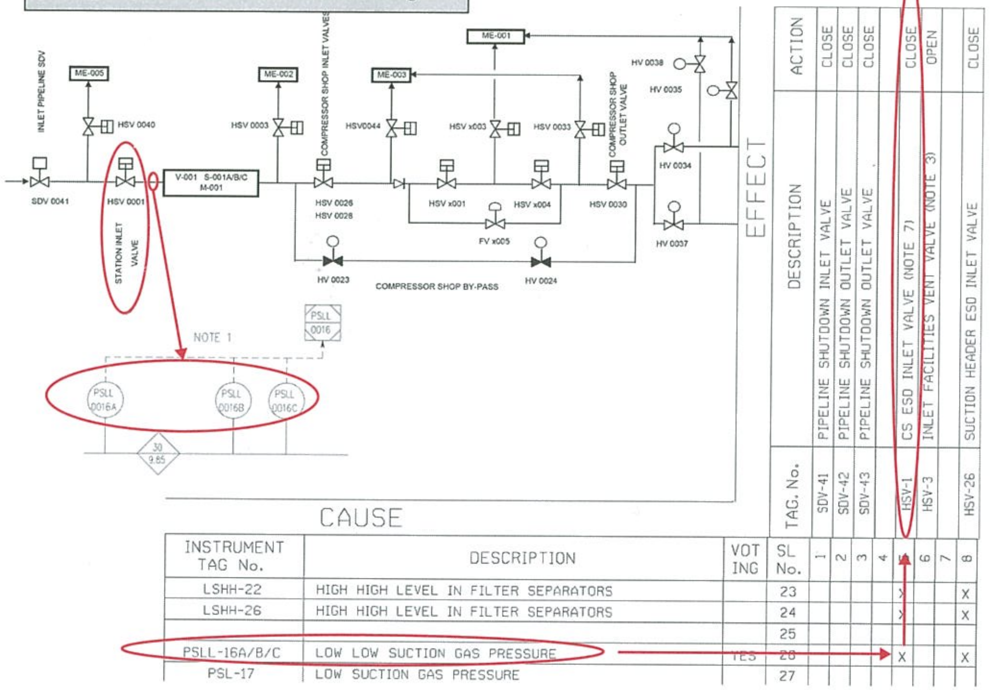
			1	2	3	4
		TAG. No.	HSV-1	SDV-41	LCV-1	LAH-2
		DESCRIPTION	CS ESD INLET VALVE	PIPELINE SHUTDOWN INLET VALVE	LEVEL CONTROL VALVE	HIGH LIQUID LEVEL ALARM
		ACTION	PERMISSIVE	PERMISSIVE	OPEN/CLOSE	ALARM

CAUSE

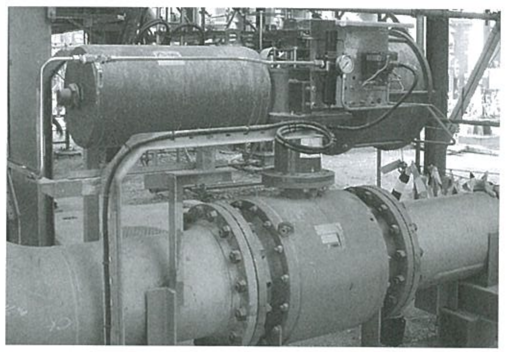
INSTRUMENT TAG No.	DESCRIPTION	VOTING	SL No.	1	2	3	4
PDSL-8	LOW DIFFERENTIAL PRESSURE (NOTE 3)		1	X			
PDSL-5	LOW DIFFERENTIAL PRESSURE (NOTE 3)		2		X		
LSHL-1	HIGH/LOW LIQUID LEVEL		3			X	
LSH-2	HIGH LIQUID LEVEL		4				X
LSH-4	HIGH LIQUID LEVEL		5				
LSL-5	LOW LIQUID LEVEL		6				
LSHL-33	HIGH/LOW LIQUID LEVEL		7				

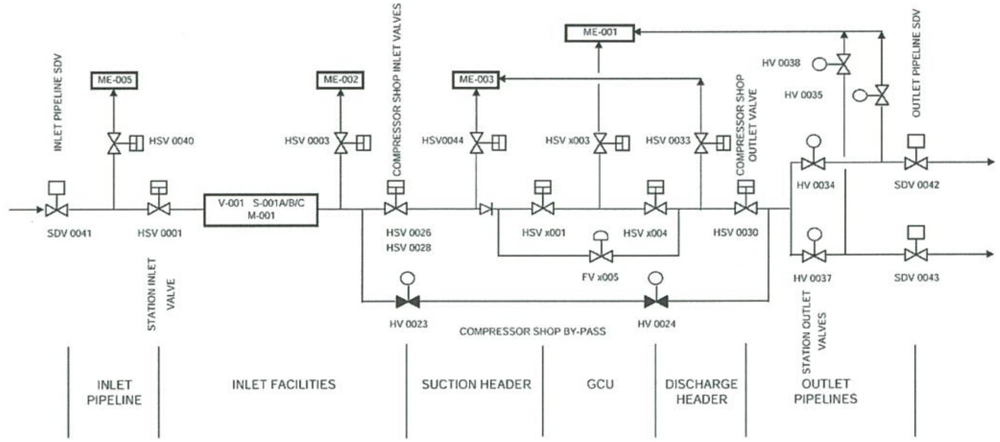
- Process safety automations: sensors initiate process shutdown in case of upset of process parameters. Their detailed logic of operation is shown on the **Emergency Shutdown (ESD) Cause & Effect Diagrams**.

Emergency Shutdown cause & effect diagram



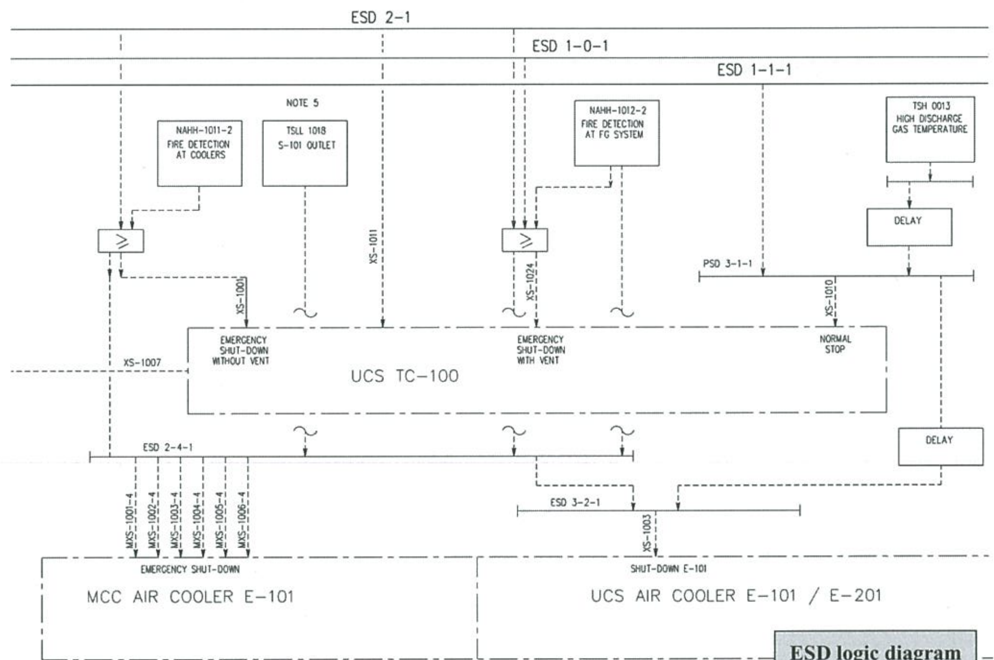
- Plant emergency isolation and depressurization requirements. To ensure it can be returned to a safe condition in case of emergency, the plant is split into sections that can be isolated from each other. Such isolation is achieved by means of emergency shutdown valves (ESDVs). Each section can also be depressurized. The split into sections, which determines the number of isolation and depressurisation valves to be provided and their location, is shown on the **ESD simplified diagram**.





Besides the individual process safety automations described above, Process designs the system to safely bring the plant to a stand still in an emergency. This is done in various degrees, called ESD levels, from the shutdown of a local process unit, to the shutdown or even shutdown and depressurisation of all facilities.

The ESD levels are cascaded: the overall plant shutdown initiates each of the individual unit shutdown, as shown on the **ESD logic diagrams**.



ESD logic diagram

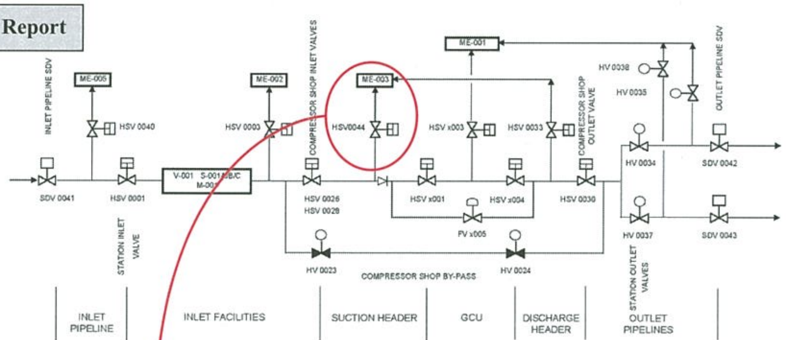
The definition of the levels, the initiating causes and the actions implemented for each one, are described in the **Emergency Shutdown and Depressurisation Philosophy**.

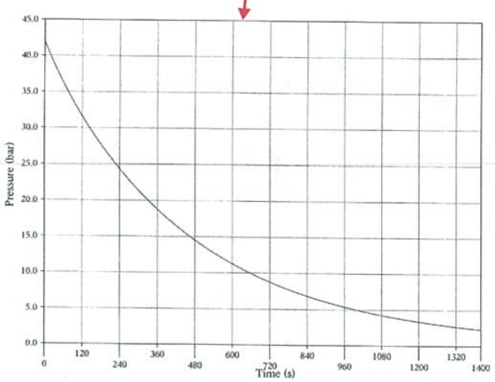
Process discipline is also in charge of designing the relief system. A relief system is used to safely release overpressure in case of process upset, or to completely depressurize the plant in case of emergency such as a major leak, etc. Process designs the relief system: diameter of relief lines, design pressure of liquid collection vessel (flare knock-out drum), capacity of flare tip, etc. to cover all relief scenarios.

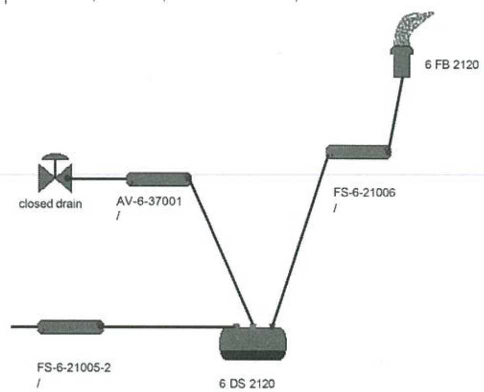
Relief system design criteria are given by codes or client requirements, such as the requirement to depressurize the plant to 7 bars in less than 15 minutes in an emergency.

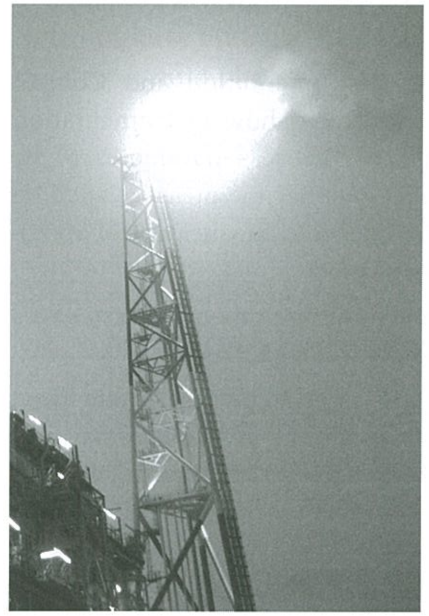
The **Flare Report** details the relief calculations and results, including the levels of low temperature reached in the pressure vessels and relief lines during depressurization. Very fast depressurization from high pressures to very low pressure in a few minutes leads to very low temperature. The depressurization case determines the low design temperature of the pressure vessels and the flare system. It may dictate the use of special materials such as low temperature carbon steel, or even stainless steel.

Flare Report

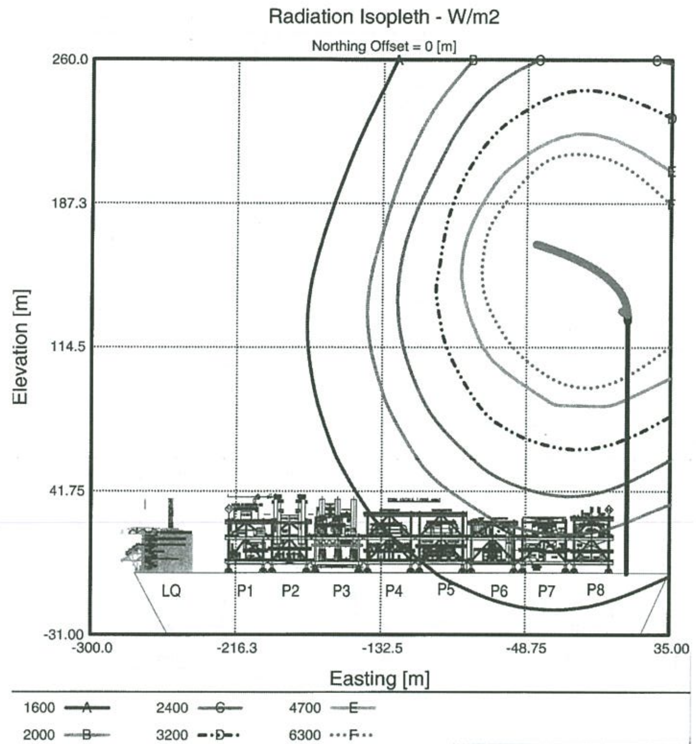


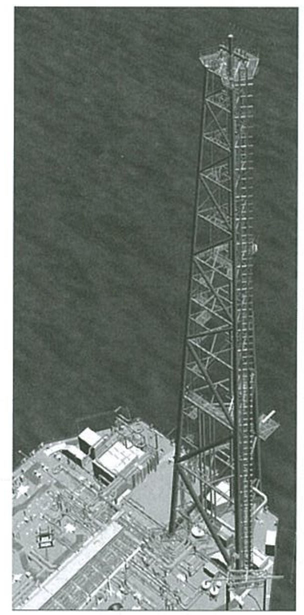






Flare heat radiation calculations are done as part of the flare study, to define the height of the flare stack. The required stack height is the one that gives low enough a level of heat radiation at grade/closest operating areas levels.





The PIDs are the main vehicle by which the Process design will be shown to the Client, to whom they are issued for approval.

They are also the basis on which Piping, Instrumentation and Control disciplines will develop their design. For instance, they show Instrumentation discipline the detailed requirements: not only the process parameter to be measured (Flow, Pressure, Temperature), but also whether the measure shall be available locally in the field only or on central console in the control room, whether the value must be recorded (to keep history), etc.

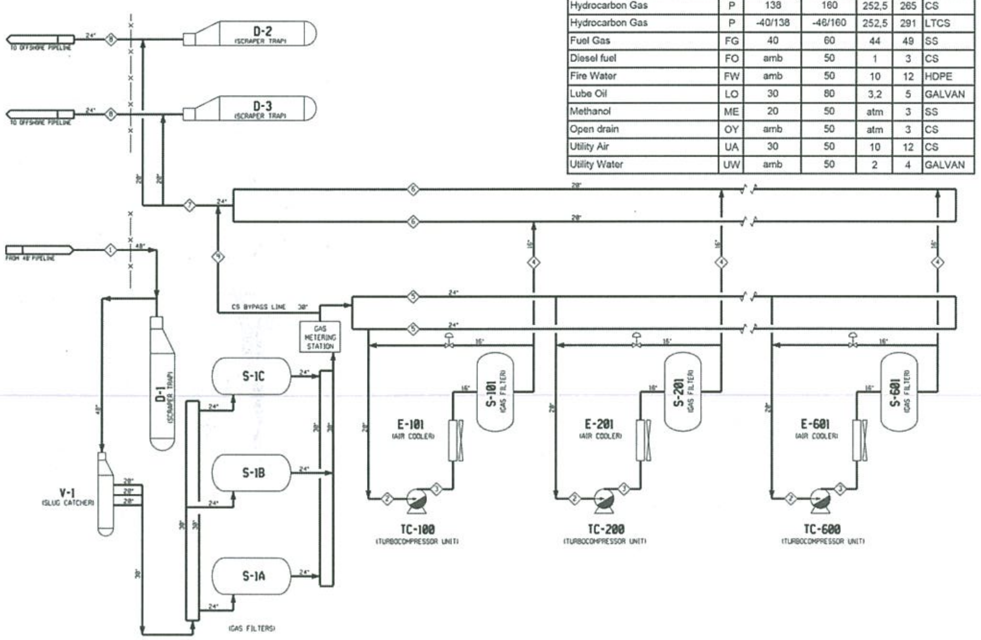
P&IDs also record the precise interface with vendor equipment and packages (piping connections, exchanged instrument and control signals, etc.).

The P&IDs are living documents, which are amended with inputs from numerous parties. These inputs are sourced from Client, HAZOP review, all disciplines, Vendors e.g., size of control valves once sized, equipment and packages interface information, etc.

While developing the P&IDs, Process groups the various fluids, based on their operating conditions (pressure, temperature) and corrosiveness in the **Process fluid list**.

Process fluid list

FLUID	SYMBOL	OPERATING CONDITIONS T °C MAX/DESIGN		OPERATING CONDITIONS bar(g) MAX/DESIGN		MATERIAL
Hydrocarbon Gas	P	30	50	97	98,5	CS
Hydrocarbon Gas	P	138	160	252,5	265	CS
Hydrocarbon Gas	P	-40/138	-46/160	252,5	291	LTCS
Fuel Gas	FG	40	60	44	49	SS
Diesel fuel	FO	amb	50	1	3	CS
Fire Water	FW	amb	50	10	12	HDPE
Lube Oil	LO	30	80	3,2	5	GALVAN
Methanol	ME	20	50	atm	3	SS
Open drain	OY	amb	50	atm	3	CS
Utility Air	UA	30	50	10	12	CS
Utility Water	UW	amb	50	2	4	GALVAN

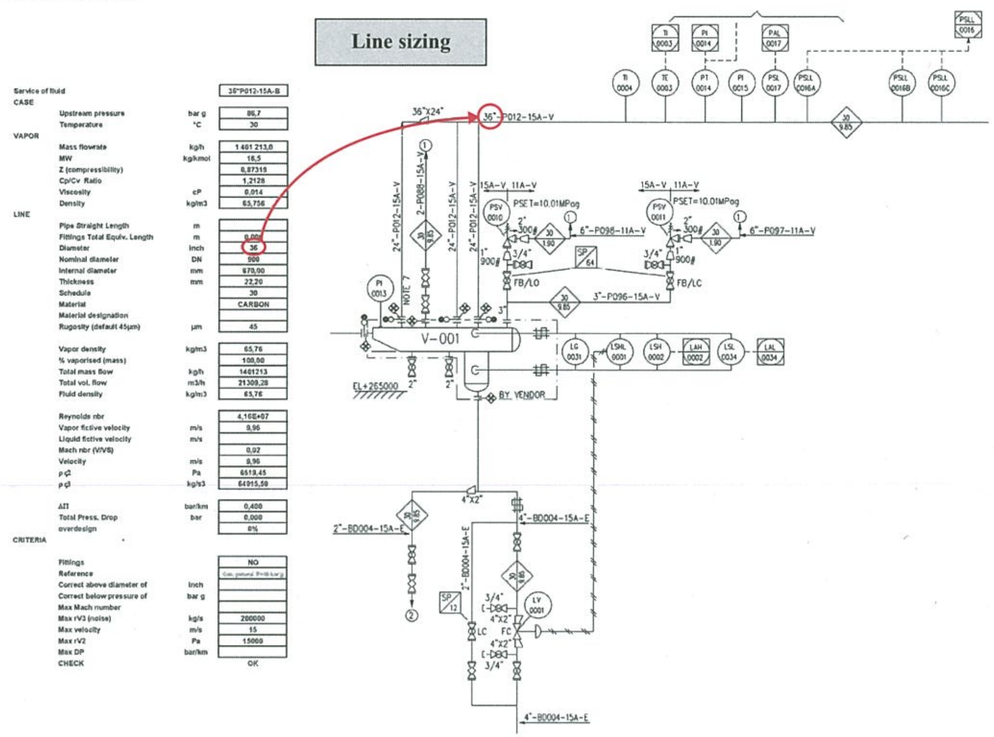


Process also numbers each line and maintains the corresponding register, called **Process Line List**. It shows the process information for each line, namely, fluid type, fluid phase, operating and design temperature and pressure, etc.

Line Number Fluid Code	Line Number Unit Code	Line Number Seq No.	Line Size	Class	P&ID Dwg. No.	Line Connection From	Line Connection To	Fluid Phase	Operating Condition Press barg	Operating Condition Temp degC	Density kg/m3	Design Condition Press barg	Design Condition Temp (Max.) degC	Design Condition Temp (Min.) degC	Full Vacuum (Y/N)
GN	71	61106	22	3C3AS1	D-80-212	LNG STORAGE	UNIT 93	V	27,6	55	18,2	34,5	100		N
GN	71	61106	20	3C3AS1	D-80-212	LNG STORAGE	UNIT 93	V	27,6	55	18,2	34,5	100		N
GN	71	61106	12	3C3AS1	D-80-212	LNG STORAGE	UNIT 93	V	27,6	55	18,2	34,5	100		N
LNG	71	60001	32	3R0JLL	D-80-302	668-P001 A/B/C	LNG RUNDOWN HEADER	L	11,1	-159	439	30	80	-167	N
LNG	71	60001	22	3R0JLL	D-80-302	668-P001 A/B/C	LNG RUNDOWN HEADER	L	11,1	-159	439	30	80	-167	N
DOW	72	63000	0,75	1P1	D-72-204	72-P061A	DOW	L	0	48	1000	2	82		N
DOW	72	63001	0,75	1P1	D-72-204	72-P061B	DOW	L	0	48	1000	2	82		N
DOW	72	63002	0,75	1P1	D-72-204	72-P062A	DOW	L	0	48	1000	2	82		N
DOW	72	63003	0,75	1P1	D-72-204	72-P062B	DOW	L	0	48	1000	2	82		N

Process calculates the diameter of lines, based on hydraulic requirements (maximum pressure drop allowed or erosion criteria), shows the details of the calculation in **Calculations notes** and indicates the resulting line diameters on the P&IDs.

Line sizing



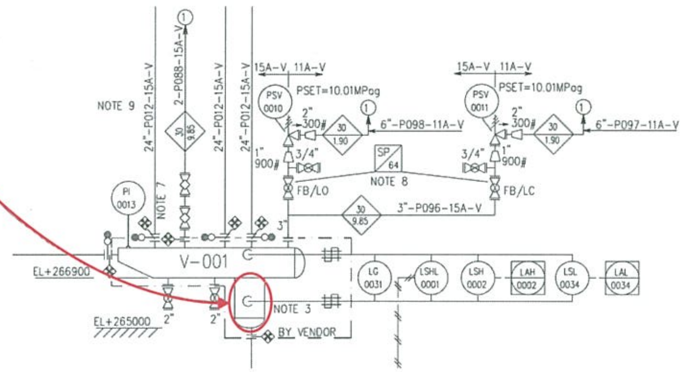
Finally, Process issues the **Operating Manual**, containing a detailed description of the facilities, instructions for start-up, operation and maintenance.

4.1.1.3.3 Slug catcher lining-up and liquid sealing

Operating manual

Refer to the following Piping & Instrument Diagram:
- *P-3-08512 : Liquid disposal system*

- Fill bottom of boot with diesel oil through connection of one of non installed instruments (LSH or LSL) at least up to LSL-0001 (Level Switch Low) in order to avoid gas blow-by through drain line as transported gas expected quality is dry. Blind the connection again. Check that LV is still closed.
- Ensure that all spectacle blinds (one at drum inlet, three at drum outlet) around slug catcher are in open position.
- Close the two 2" plug valves on vent line.
- Close the two 2" plug valves on each drain.
- Ensure that mechanical interlock between the PSV is in right position, i.e. the closure of one isolation valve



The operating manual provides reference information such as the capacity of all vessels, set-points of controllers, alarms, safety switches, etc.

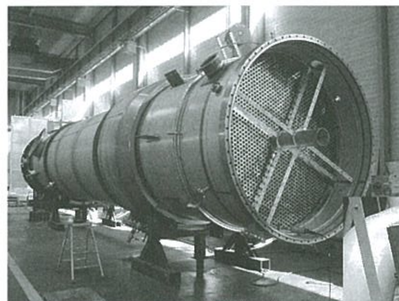
TAG	Position	Control device	PID	Unit (1)	Set point	Alarm low	Alarm high	Range (2)	Comment
	Inlet facilities								
PCV0001	Pilot gas for level valves	LVs	8513	bar	11				See note 11 on P-3-08513
LSHL0001	Slug catcher D-001 boot	LV-0001	8512	mm	-150/50				
LAH0002	Slug catcher D-001 boot		8512	mm			200		
LAL0034	Slug catcher D-001 boot		8512	mm		-450			
PIC0014	Header inlet filters separators S-001		8550	bar	67				Act as override only
PAL0017	Inlet gas filters S-001 inlet header		8512	bar		64.5		50 - 70	
LAH0007	Inlet gas filter S-001A upstream		8513	mm			290	-250 to	Level 0 is bottom vessel axis level.

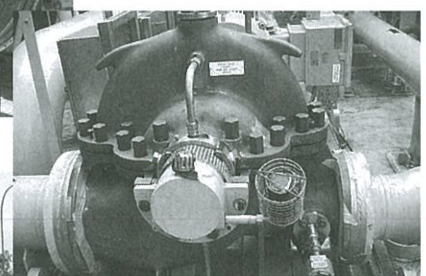
The operating manual contains information about *systems* (process, utility, emergency shutdown) operation. Information on the operation and maintenance of individual equipment are found in the equipment vendor documentation instead.

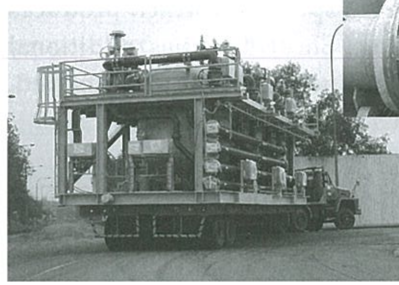
Chapter 4

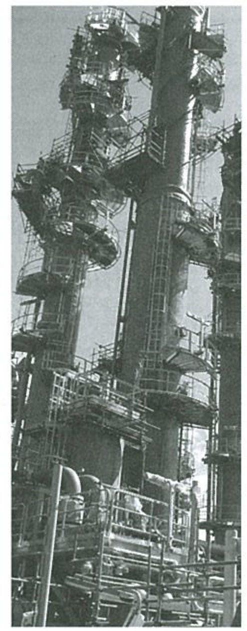
Equipment/Mechanical

Equipment, also called Mechanical, discipline includes various specialities, such as pressure vessels, heat exchangers, fired equipment, rotating equipment and packages.









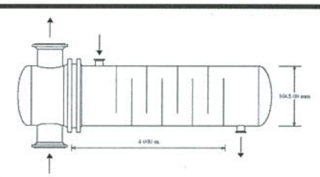
Heat exchangers are designed and sized by Engineering, as they are of a standard non-proprietary design (shell and tube, etc.). A computer software is used to model the heat transfer for the specified geometry (number of tubes, position of baffles, etc.). The input and results of the calculation are recorded on a **calculation sheet**.

Rating - Horizontal Multipass Flow TEMA BEU Shell With Single-Segmental Baffles

Process Data		Hot Shellside		Cold Tubeside	
Fluid name		Condensate		Product Gas	
Fluid condition			Sens. Liquid		Sens. Gas
Total flow rate	(kg/s)		150.817		809.563
Weight fraction vapor, In/Out	(--)	0.000	0.000	1.000	1.000
Temperature, In/Out	(Deg C)	129.30	39.90	24.40	39.98
Temperature, Average/Skin	(Deg C)	84.6	48.84	32.2	40.15
Wall temperature, Min/Max	(Deg C)	34.07	69.44	33.65	64.65
Pressure, In/Average	(kPa)	500.007	496.549	7530.11	7512.40
Pressure drop, Total/Allowed	(kPa)	6.916	100.000	35.423	50.000
Velocity, Mid/Max allow	(m/s)	0.27		9.19	
Mole fraction inert	(--)				
Average film coef.	(W/m2-K)		751.36		2280.27
Heat transfer safety factor	(--)		1.000		1.000
Fouling resistance	(m2-K/W)		0.000200		0.000200

Overall Performance Data				
Overall coef., Reqd/Clean/Actual	(W/m2-K)	404.25 /	501.27 /	410.71
Heat duty, Calculated/Specified	(MegaWatts)	32.7979 /		
Effective overall temperature difference	(Deg C)	31.6		
EMTD = (MTD) * (DELTA) * (F/G/H)	(Deg C)	36.51 *	0.8668 *	1.0000

See Runtime Messages Report for warnings.



Exchanger Fluid Volumes		
Approximate shellside	(L)	3872.5
Approximate tubeside	(L)	12521.2

The design and sizing of other equipment, such as compressors, etc. is proprietary and done by their vendors.

The Process data is completed by the Equipment specialist, which produces the **Mechanical data sheet**. The Mechanical Data Sheet specifies additional requirements besides the process duty, such as codes and standards to be applied, performance, energy efficiency, type and materials of construction, etc.

Process data sheet

SERVICE :	NATURAL GAS COMPRESSOR			
NOMBRE REQUIS / *NUMBER REQUIRED*	TOTAL / *TOTAL :*	6	*RUNNING*	
OPERATION : CONTINUE / *CONTINUOUS*	X			
PROPRIETES DU FLUIDE / *FLUID PROPERTIES*				
CAS DE MARCHE / *RUNNING CASE*	mas.mol	DESIGN CASE		
FLUIDE/*FLUID* — COMPOSANTS / *COMPOUNDS*	MW			
	MOLAR PERCENT			
COMPONENT	DESIGN	ALTERNATIVE		
Methane CH4	97,528	97,721		
Ethane (C2H6)	0,880	0,095		
Propane (C3H8)	0,140	0,025		
I-Butane (C4H10)	0,015	0,005		
N-Butane (C4H10)	0,025	0,005		
I-Pentane (C5H12)	0,018	0,045		
N-Pentane (C5H12)	0,020	0,050		
Hexane (C6H14)	0,022	0,000		
Heptane + (C7H16)	0,013			
Nitrogen (N2)	0,930	1,746		
Carbon Dioxide (CO2)	0,410	0,290		
Oxygen (O2)	Nil	Nil		
COMPRESS. (Z)/*COMPRESSIBILITY* ASP/REF / *SUCT/DISCH*	0.876/1.013			
Cp/Cv ASP/REFOULEMENT / *SUCTION/DISCHARGE*	1.582/1.485			
TOXIQUE/*TOXIC*		*FLAMMABLE*	X	
CORROSIF / EROSIF, A CAUSE DE / *CORROSIVE / EROSIVE, BECAUSE OF :*				
DONNEES DE FONCTIONNEMENT / *OPERATING CONDITIONS*				
ASPIRATION / *SUCTION*	PRESSION ABS / *ABS. PRESS*	MPa(a)	8,52	
	TEMPERATURE	°C	30	
	MASSE VOLUMIQUE / *DENSITY*	kg/m³	63,97	
	DEBIT VOL. / FLOWRATE VOL			
	NORMAL	m³/s	-	
	CALCUL / *DESIGN*	m³/s	5,99	
	DEBIT MASSIQUE, NORMAL *MASS FLOW, NORMAL*	kg/s	383,03	
	TEMPERATURE MAXI SERVICE *MAX OPERATING TEMP.*	°C	note 7	
	PRESSION ABSOLUE MAXI *ABSOLUTE PRESSURE MAXI*	MPa(a)		
REFOULT : PRESSION ABS / *DISCH. ABS PRESS*		MPa(a)	25,5	
REGULATION DE DEBIT / *FLOW VARIATION*		%		

Mechanical data sheet

LOCATION: (2.1.8) _

X INDOOR	X HEATED	UNDER ROOF
OUTDOOR	UNHEATED	PARTIAL SIDES
X GRADE	MEZZANINE	_

X ELEC. AREA CLASSIFICATION (2.1.14) II A T3

CL GR DIV

WINTERIZATION REQD.(2.1.8)

TROPICALIZATION REQD.(3.4.6.6)

SITE DATA:

X ELEVATION (m): 270 m

BAROMETER (Bar abs): _

X RANGE OF AMBIENT TEMPS (°C): -19/42

NOISE SPECIFICATIONS: (2.1.9) _

X APPLICABLE TO MACHINE: 95dBA inside, 80dBA outside building

ACOUSTIC HOUSING: YES X NO

ATIONS:

MPR. FOR GEN. REFINERY SERV.

CONSTRUCTION FEATURES

TYPE FABRICATION WELDED

MATERIAL ASTM A 182F22

MAX. YIELD STRENGTH (N) >310 N/mm²

BRINNEL HARDNESS: MAX./MIN. 207 /

X SHAFT: _

MATERIAL 40 NICrMo7 (equivalent to AISI 4340)

DIA. @ IMPELLER (mm) 163 / 182

DIA. @ COUPLING (mm) 120

SHAFT END: X TAPERED CYLINDRICAL

MAX. YELD STRENGTH (BAR) 7350

SHAFT HARDNESS (BNH) (Rc) <=270 HB

STRESS AT COUPLING (BAR) _

PAINTING: _

X MANUFACTURER'S STD.

OTHER: SUBJECT TO CLIENT APPROVAL

SHAFT SEALS: _

X SEAL TYPE (2.8.3) DRY GAS SEALS

X SETTLING OUT PRESSURE (BARG) 153,7

SPECIAL OPERATION (2.8.1) _

SUPPLEMENTAL DEVICE REQUIRED FOR CONTACT SEALS (2.8.3.2) TYPE: _

X BUFFER GAS SYSTEM REQUIRED (2.8.7)

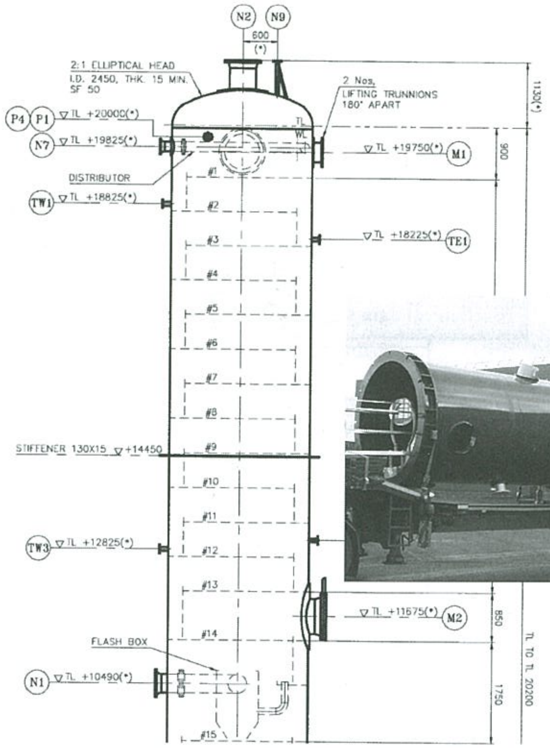
X TYPE BUFFER GAS COMPRESSED AIR

Pressure vessels, on the other hand, are specified in details to the manufacturer: type and position of internals, dimensions, number, size and elevations of nozzles, etc. which come from process requirements. For a gas/oil/water separator for instance, the section of the vessel will be sized to reduce the gas velocity enough to achieve proper gas/liquid separation, the liquid section volume will be defined so as to provide enough residence time to achieve adequate oil/water separation, e.g., 3 minutes for light oil and 8 minutes for heavy oil, etc.

For a distillation column, the distance between trays will be defined by the process licensor, which will in turn set the elevation of the column, nozzles, etc.

The detailed arrangement of the vessel is specified to the manufacturer by means of a **vessel guide drawing**.

Vessel guide drawing



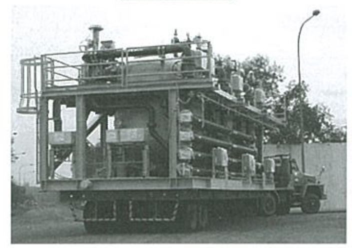
This guide drawing is also issued to Piping for routing of connected pipes. The orientations of nozzles are not defined on the guide drawing. Instead, they are defined by Piping following the piping routing studies.

A **supply specification** is prepared, describing the entire scope and limits of supply and listing all applicable specifications. The piping specification, for instance, should be referenced if the supply includes piping, the electrical specification should be included if the supply includes electrical equipment, etc.

Many pieces of equipment are indeed not purchased on their own, such as a pressure vessel or a heat exchanger, but as a package. A package is a set of equipment, purchased as a functional unit, e.g., a water treatment unit. It comes complete with all equipment, piping, instrumentation, cables, etc. already installed on one or several "skids" (frames). This approach, which consists of purchasing a part of the plant already pre-fabricated, reduces construction time at Site, as assembly is carried out at the vendor's premises instead.

The scope of supply of the package vendor in all disciplines must be precisely defined. For a package made of several parts, for instance, the party who is supplying the interconnections (pipes, cables) between the parts must be specified. A detailed matrix, such as the one shown below for Instrumentation, is the most efficient way to precisely define the split of responsibilities and battery limits.

Packages



TYPICAL SCOPE OF SUPPLY

C : CONTRACTOR PC : PACKAGE CONTRACTOR B.L. : BATTERY LIMITS

DESIGNATION	DESIGN		SUPPLY		INSTALLATION	
	C	PC	C	PC	C	PC
1 feeder 230 VAC, 50 Hz for instrum.	X		X		X	
1 instrument air supply at B.L.	X		X		X	
Electrical distribution		X		X		X
Air distribution		X		X		X
Junction boxes at B.L.		X		X		X
Air connection at B.L.		X		X		X
Interconnecting principles	X	X				
Instruments inside of B.L.		X		X		X
Instruments outside of B.L.	X		X		X	

The specification and the data sheet are attached to a document called a **Material Requisition**, which is the document Engineering issues to Procurement for Purchasing the equipment. The requisition precisely defines the equipment/material to be supplied and the exact scope of supply and services, e.g., what calculations are to be done by the vendor. It also specifies the quality control requirements, the documentation to be supplied by the vendor and its delivery schedule. The documents required from vendors are of different types:

- Study documents, such as P&IDs, calculation notes, general arrangement drawings, etc.
- Interface documents, showing all connections at the supply's battery limits in all disciplines: anchor bolts and loads on foundation, piping connections, electrical and instrumentation connections, etc.

  The interface documents and their timely submission are of primary importance to Engineering, for integration of the equipment/package into the overall plant. Provision of these documents must be synchronised with the engineering schedule. Penalties are specified for late submission of critical documents by the vendor.
- Documents required at the construction site: preservation procedure, list of components (packing list), lifting instructions, commissioning and start-up instructions.

- Documents to be retained by the plant owner: manufacturing records, operating and maintenance manual, list, references and drawings of spare parts.

Supply specification

2.1 General Requirements

The Supplier shall provide for the design of all equipment supplied according to the requirements stated in this specification.

The gas compressor unit (GCU) shall be designed for continuous duty at the operating conditions specified here below and considering that the unit shall be operated in unattended, automatic remote control.

Time required to put the unit into operation, from stand-by ready to start, shall not exceed 25 minutes.

Equipment supplied shall be of reliable and proven design, experimental (prototype) equipment are not acceptable.

The GCU Supplier shall give:
- reference list (types of fuel, duty, site/year of installation, operating hours, etc.)
- reliability statistic data
- tests results (shop and on site)

for the main critical components and parameters (turbine, DLE system, gearbox, pressure and head of gas compressor, dry seals, degradation turbine parameters). The design Supplier experience relevant to the whole package (turbine+gear+gas compressor+accessories) shall be proven.
For the main critical components of the GCU, Customer expects reference running hours more than 3000 hrs.

The life of main equipment shall be not less than 30 years of exercise.

The gas compressor unit shall be supplied in blocks; pre-fabricated part of a unit, weight and dimensions of each block shall be suitable for an easy transport by railways and motorways within Russia.
Supplier shall provide devices to prevent the possibility of damage to the equipment or its parts during loading-unloading operations, installation and assembly on site by usual hoisting and lifting means.

The supply will be designed based on international standards and the supplier will provide the GOSSTANDARD (GOST R) and GOSGORTECHNADZOR (GGTN) certificates. These certificates will allow proper importation and will be used for installation of the supply.

More detailed requirements relevant to the equipment to be supplied are specified in section 4 of this specification.
International SI system shall be followed for measurement units.

2.2 Installation Requirements

For noise attenuation, gas turbine and its auxiliaries shall be housed inside a skid-mounted enclosure.
The whole gas compressor unit shall be installed inside a building for protection from atmospheric agents and noise abatement; all sources of noise shall be silenced so that the noise limits specified in this specification are performed.
Unit installations shall be suitable for easy inspection and maintenance operations; all provisions and fixed facilities necessary shall be supplied.
Unit building shall be provided with lifting means suitable to move the pieces for maintenance operations.

Material Requisition

1. LIST OF MATERIALS

ITEM	QUANTITY	TAG N°	DESIGNATION
1	6	TC100/TC200 TC300/TC400 TC500/TC600	TURBO COMPRESSORS
2	1		SET OF STAR-UP & COMMISSIONING SPARE PARTS FOR ITEM1
3	1		SET OF SPECIAL TOOLS FOR ITEM1
4	1		SET OF 2 YEARS SPARE PARTS

2. APPLICABLE DOCUMENTS	DOCUMENTS NUMBER*	REV
2.1. PROJECT GENERAL SPECIFICATIONS		
Technical Specification Centrifugal Compressor	J-7-30001 (MA-E-30001)	REV. 2
Data Sheets Centrifugal Compressor	J-8-30101 (MA-E-30101)	REV. 2
Data Sheets Gas Turbine	J-8-30102 (MA-E-30101)	REV. 1
General spec. for L.V. Switchboards for Packaged Unit	E-7-40011 (EA-E-40011)	REV. A
Data Sheet for T[illegible]	[illegible]	[illegible]
Turbocompress[illegible]		

3. QA PROGRAM STANDARD AND INSPECTION REQUIREMENTS FOR VENDORS

QA PROGRAM

THE FOLLOWING QUALITY ASSURANCE PROGRAM (QA PROGRAM) SHALL BE IMPLEMENTED AND DOCUMENTED IF THE BIDDER IS AWARDED THE PURCHASE ORDER FOR THIS REQUISITION :

ISO 9001 { X }
ISO 9002 { }
ISO 9003 { }
NONE { }

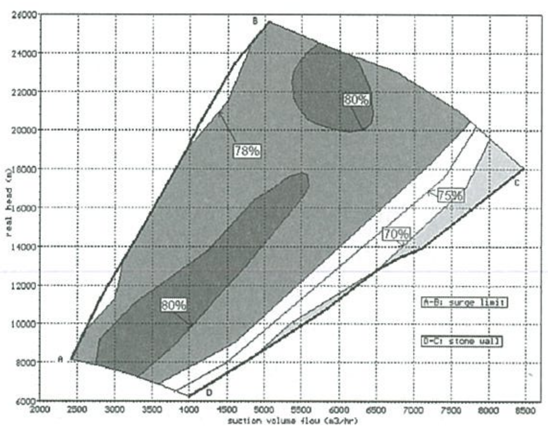
COMPANY INSPECTION LEVEL REQUIREMENTS
(FOR INFORMATION ; RELEVANT REQUIRED SERVICES TO BE SPECIFIED IN THE REQUISITION)

LEVEL 0 { } NO INSPECTION REQUIRED
LEVEL 1 { } FINAL INSPECTION ONLY PRIOR TO SHIPMENT
LEVEL 2 { } INCLUDES "IN PROGRESS" SURVEILLANCE, MEETINGS (REGULAR OR NOT), ALL WITNESS AND HOLD POINTS, FINAL INSPECTION AND RELEASE FOR SHIPMENT OR FINAL ACCEPTANCE
LEVEL 3 { X } RESIDENT INSPECTOR CONTINUOUSLY MONITORING THE WORK

ITEM	DESIGNATION	INSTALMENT 0	1	2	3	4	5
	4.2. PROCESS AND PERFORMANCE DOCUMENTS						
	TURBO COMPRESSOR	0	1	2	3	4	5
1	DIMENSIONAL OUTLINE DRAWINGS OF TURBOCOMPRESSOR SET*	A		B	C	D	E
2	GENERAL ARRANGEMENT DWG OF TURBOCOMPRESSOR BUILDING WITH INSIDE AND OUTSIDE INSTALLATIONS*	A		B	C	D	E
3	AIR INLET AND EXHAUST SYSTEMS ARRANGEMENT DRAWINGS*	A		B	C	D	E
4	LUBE OIL AIR COOLER ARRANGEMENT DRAWINGS*	A		B	C		E
5	TURBOCOMPRESSOR SET FOUNDATION PLAN WITH STATIC AND DYNAMIC LOADS*	A		B	C	D	E
6	FOUNDATION PLAN WITH STATIC AND DYNAMIC LOADS FOR TURBOCOMPRESSOR BUILDING AND OTHER AUX.EQUIPMENT	A		B	C	D	E
7	CUSTOMER MECHANICAL CONNECTIONS LIST AND PLAN WITH MAX. ALLOWABLE LOADS*			B	C	D	

Upon receipt of the inquiry the vendors will perform their own design.

For a compressor, for instance, this will entail defining the number and design of the impellers to match all operating cases with maximum efficiency. The vendor will submit such performance data in their proposal.



Once the bids are received from vendors, technical appraisal is carried out to both confirm compliance to requirements and to compare the offers from the various vendors.

The detailed technical analyses of the bids are shown in the **Technical Bid Tabulation** document. It covers scope of supply and services, compliance to performance guarantees, design and fabrication codes and standards, inspection and quality requirements, supplier's references in similar supplies, etc. For each item, the specified requirements are shown together with what is offered by each vendor.

Technical Bid Tabulation

			Requirements	Supplier 1	Supplier 2
1 -SCOPE OF SUPPLY SUMMARY (continued)					
1.6 Piping / Structure / Painting / Misc.					
Piping:					
Interconnecting piping between skids or equipement (fuel, lube oil, water, steam, etc...):			included	included	included
Painting					
Non insulated equipment (motor, valves, steel structures, platforms, etc...)			Max. at shop		up to final coat
Boiler block			Max. at shop	sandblasting & primer + insulation at shop	Primer + insulation/lagging at shop
1 -SCOPE OF SUPPLY (continued)					
1.7 Services					
Shop inspection and tests (as a minimum)				included	
Superheater			As per ASME	Hydrotested before shipping	Hydrotested before shipping
Boiler			As per ASME	Hydrotested before shipping	Hydrotested before shipping
1 -SCOPE OF SUPPLY (continued)					
1.8 Codes & standards					
Boiler presure parts & safety valves			ASME I	ASME I with S stamp	ASME
Pressure parts materials			ASME I	ASME I with S stamp	ASME
2 -OPERATING CONDITIONS					
2.1 Design conditions					
Feed Water Temperature @ BL	(MCR/Peak Load)	°C	120	120	120
Feed Water Pressure	(Mini required / Mecha desi	barg	68 / 90	65 / 90	Yes
2.2 Guaranteed performances					
Steam Flow	(MCR)	t/h	240	240	240
Steam Outlet Temperature at BL		°C	384 +/- 5	384 +/- 5	384 +/- 6
Steam Outlet Pressure at BL		barg	41,3 +/- 1	41,3 +/-1	41,3
3 - CONSTRUCTION DATA					
3.1 General					
Boiler area dimensions	W x L (w/o eco / w eco)	m	By Vendor	~16000x25000 / ~17000x25000	~24076x27147 / ~25231x26916
Boiler dimensions	W x L x H	m	By Vendor	12500 x 15500 x 10500	8670 x 19000 x 10250
3.2 Steam Drum					
Pressure	operating / design	barg	As per ASME	47,5 / 54,0	tbd / 56,54
Temperature	operating / design	°C	By Vendor	262 / 295	382 / 343
Length (TL-TL)		mm	By Vendor	14200	14833

Following this detailed technical analysis, including clarification meetings held with suppliers, the technical acceptability of each bid is advised by Engineering to Procurement.

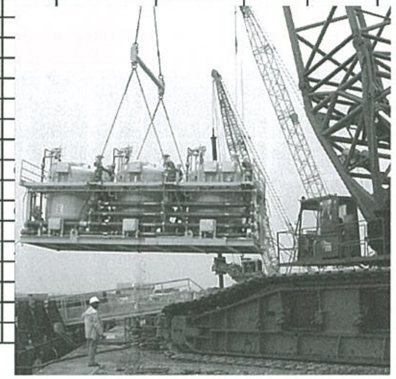
Once the equipment is purchased, and before proceeding with fabrication, the vendor submits its design documents to Engineering for review and approval. Vendor documents are checked by Engineering for compliance with the purchase order specifications. Comments from the various disciplines are consolidated. The document is returned to the vendor with a code, result of the review, instructing the vendor either to proceed or to revise its design and resubmit it for further review.

COMMENT STATUS : THE APPROVAL OF THIS DOCUMENT DOES NOT RELIEVE THE SUPPLIER OF ITS CONTRACTUAL RESPONSABILITIES			
1	NO COMMENT OR FORMAL COMMENTS PROCEED WITH FABRICATION RESUBMIT WITH UPPER REVISION STAMPED APPROVED FOR CONSTRUCTION	4	FOR INFORMATION REFERENCE ONLY
2	APPROVED AS NOTED PROCEED WITH FABRICATION IN ACCORDANCE WITH COMMENTS RESUBMIT CORRECTED DOCUMENTS FOR APPROVAL WITH UPPER REVISION	5	FINAL DOCUMENT
3	DISAPPROVED DO NOT FABRICATE RESUBMIT CORRECTED DOCUMENT FOR APPROVAL WITH UPPER REVISION	CHECKED BY :	DATE :

Vendor documents provide information on the equipment, such as dimensions, weight, electrical and other utilities consumption, etc. which Engineering incorporates in the overall plant design.

A register is maintained of all equipment: the **Equipment Summary**. Such register is used, for an on-shore project, by the contractor at Site to know how many equipment will have to be installed for its planning purposes and what is the capacity of the cranes required to lift these equipment in order to mobilize the proper cranes.

PROCESS EQUIPMENT SUMMARY												
SYSTEM No	ITEM No	Qty of Equip	DESCRIPTION	Design Conditions (gage press.)		Orientation	Vessels Dimensions		P&ID (or Dwg) No.	Unit Est. Shipping Weight	Grade level	MATERIAL note 3
				DP	DT		ID	T-T				
				MPa	°C		mm	mm		ton		
1			PROCESS									
1.1			INLET FACILITIES									
	D-001	1	Receiving scraper trap	10.01	50	H	1400	9800	P-3-08511	20	261000	CS
	V-001	1	Slug catcher	10.01	50	H	1500	10000	P-3-08512	30	261000	CS
	S-001A/B/C	3	Inlet gas filter	10.01	50	H	1450	3210	P-3-08513	40	261000	CS
	M-001	1	Gas metering station package	9.85	50							
	U-060	1	Analyser house	9.85	50							
1.2			OUTLET FACILITIES									
	D-002	1	Launching scraper trap	26.5	70	H	750					
	D-003	1	Launching scraper trap	26.5	70	H	750					
	T-050	1	Methanol tank	ATM	50	H	1600					
	P-051A/B/C	3	Methanol injection pump	26.5	50							
	P-052	1	Methanol portable pump	0.07	50							



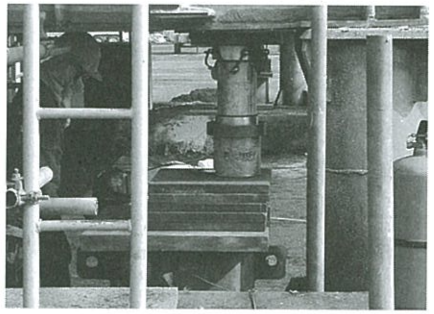
On an Off-Shore project, the equipment summary helps to prepare the **weight report**.

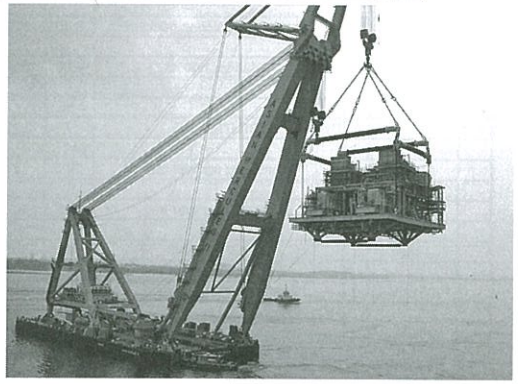
A **lifting study** is also produced, based on the weight derived from the Material Take-Off in each discipline, to estimate the weight and the centre of gravity. It serves to validate or not the lifting feasibility by the selected crane. In the case where the load exceeds the hook capacity, a weight management is required, to modify the arrangement of the module or to decide to remove a part of the module and reduce the weight for the lifting phase.

Weight report

Detail for module X		Reported weight (te)		Center of Gravity East	North	Elevation
Riser protec. / Acc. ladders	Boarding access ladders	1098	171	100,0	222,6	86,0
	Riser Protector		915			
	Cathodic protection		12			
Mooring Equipment		493	493	97,0	242,1	101,1
Instrumentation & electrical Equipment	Instrumentation equipment	99	13	100	100	87,5
	Electrical Equipment		49			
	Electrical cable integration		32			
	Electrical cable tray / support		5			
Riser inst. winch support and Casings	Paint on riser / caisson	501	14			
	Fire water caisson		66	100	100	83,75
	SW lift caisson		43	66,4	215	83,75
	Suction Hoses		126			
	Riser instalation winch support		252	136,1	NA	102,4
	Total	2190		95,5	249,3	87,9

(*) Gross Estimation of the centre of gravity





Chapter 5

Plant layout

Once the plant equipment is defined, upon completion of the Process Flow Diagrams (PFDs), Plant layout (also called installation) discipline performs installation studies, which consists of defining the topographical organisation of the facility.

An industrial facility is usually split into 3 zones: Process, Utilities and Offsite.

- The process units are where the feedstock is processed into products,
- Utilities units deal with electrical power generation, production and handling of utility fluids such as steam, heating/cooling medium, water, compressed air, nitrogen, etc. and treatment of the waste fluids, such as rain and oily water, drains, waste gas, etc.,
- Offsites consist of product storage, shipping facilities and of buildings.

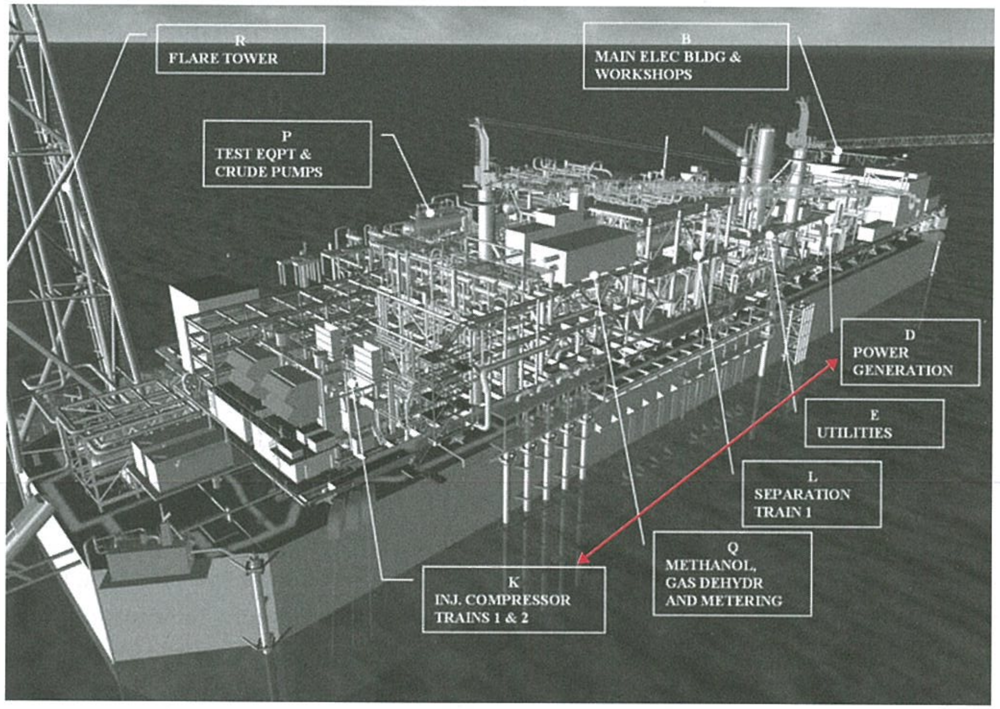
An Off-Shore facility will also include living quarters (LQ) and a helicopter landing pad, located as far as possible from the process units.

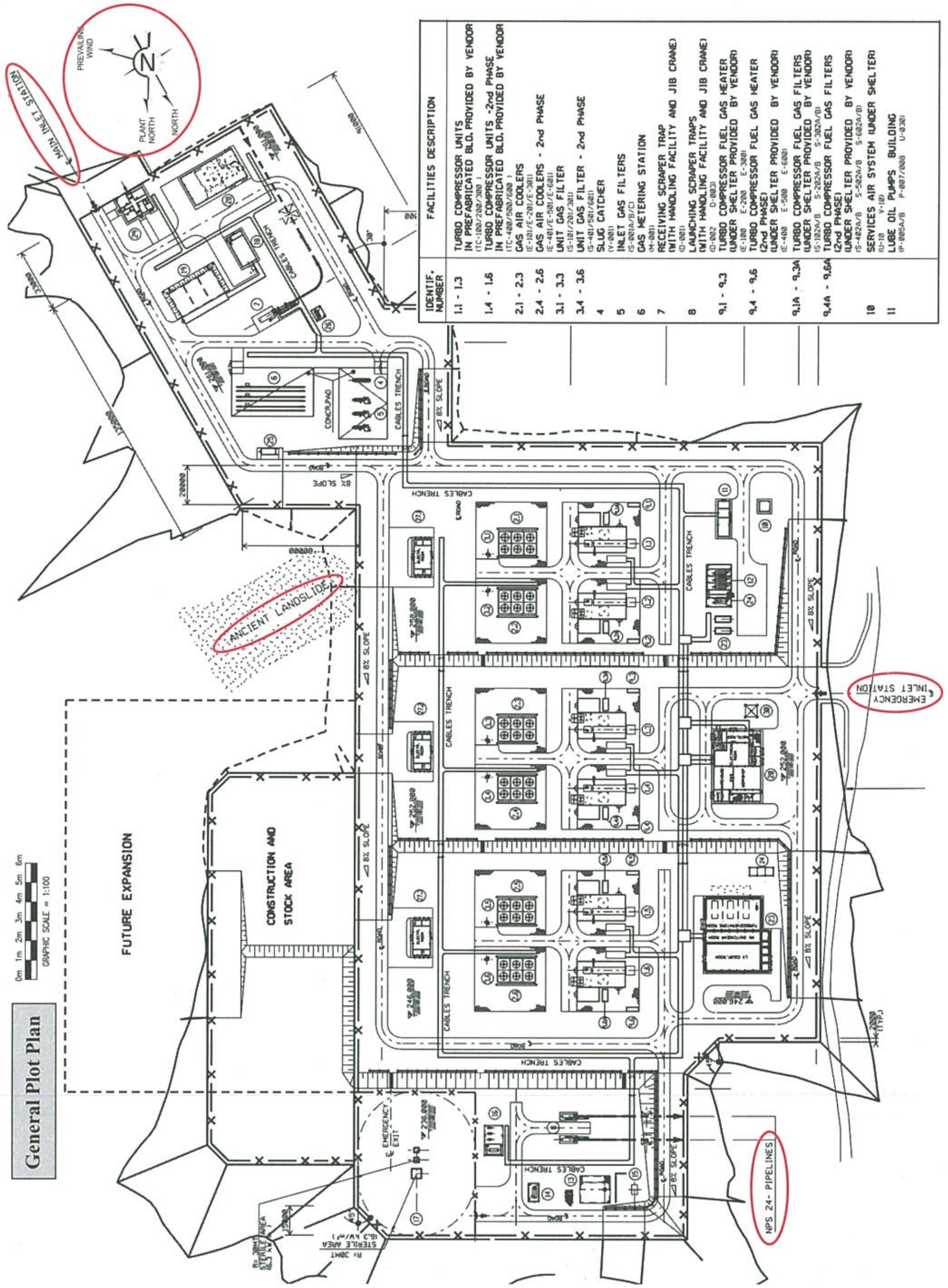
The site where the plant is to be built will impact its layout. A restricted land plot size will drive a vertical stacking rather than an horizontal spread of the plant equipment, a sloped relief will decide a terraced arrangement to minimize the earthworks, uneven soil geotechnical properties will impose constraints for location of heavy or critical installations (large storage tanks, turbo-machinery, etc.).

The plant layout takes into account the plant environment: location of access/ exit roads, external connecting networks: pipelines, electrical grid, water supply, etc. It is depicted on the **General Plot Plan**, which is the base graphical document used to locate all items of equipment, structures, buildings, roads and boundaries for the overall plant complex.

The location of the various units, and that of equipment within units, is determined following a number of principles, primarily related to safety.

Hazardous units, such as gas compression units, are located far away from vital units, such as power generation, and manned areas, such as living quarters.





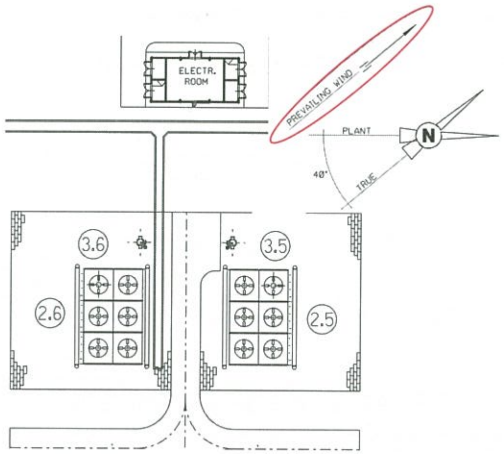
General Plot Plan

Units are classified in terms of risk of releasing flammable materials (leak) or igniting them (explosion, fire). The risk level mainly derives from operating conditions: the higher the pressure and the temperature, the higher the risk.

Risk are classified in High (HH), Intermediate (IH) and Moderate Hazard (MH).

(in m)	MH	IH	HH
MH	15	30	60
IH		30	60
HH			60

Minimum distances between units are specified by codes, as per the combination of risks. This will ensure, for instance, that flammable vapour released by one unit diffuses to a concentration below the explosive limit when it reaches another unit where a source of ignition exists.



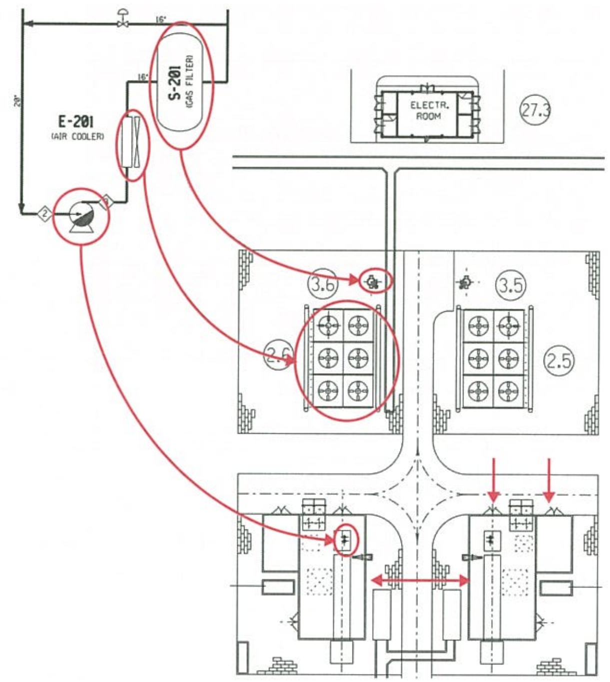
Additionally, units at risk of releasing flammable substances are located away and downwind of equipment that could be source of ignition.

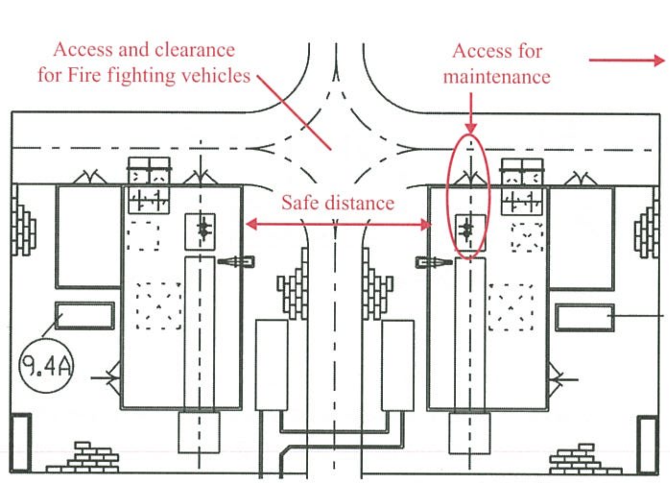
Electrical sub-stations, for instance, will be located upwind of gas coolers. Should a leak occur in the gas coolers, the gas cloud will not reach the electrical sub-station which houses spark generating equipment that could ignite the gas cloud.

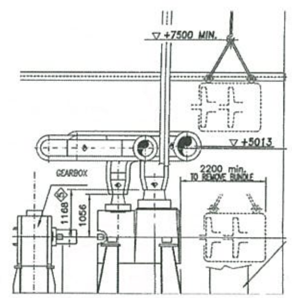
Within units, the positions of equipment naturally follow their sequence in the process flow to minimize the length of inter-connections.

Free space is provided around equipment for proper operator access and for maintenance (removal of parts, truck/crane access).

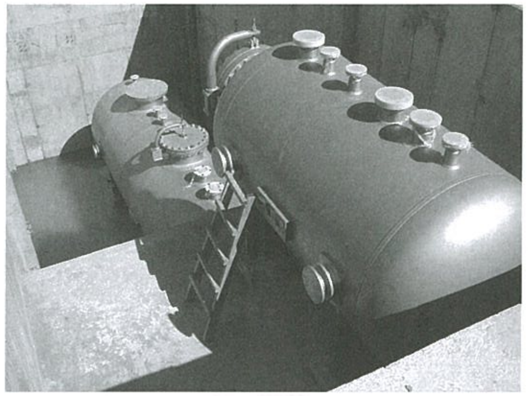
Special attention is given to free space/access for personnel evacuation and fire fighting. Enough space is provided between and around equipment.





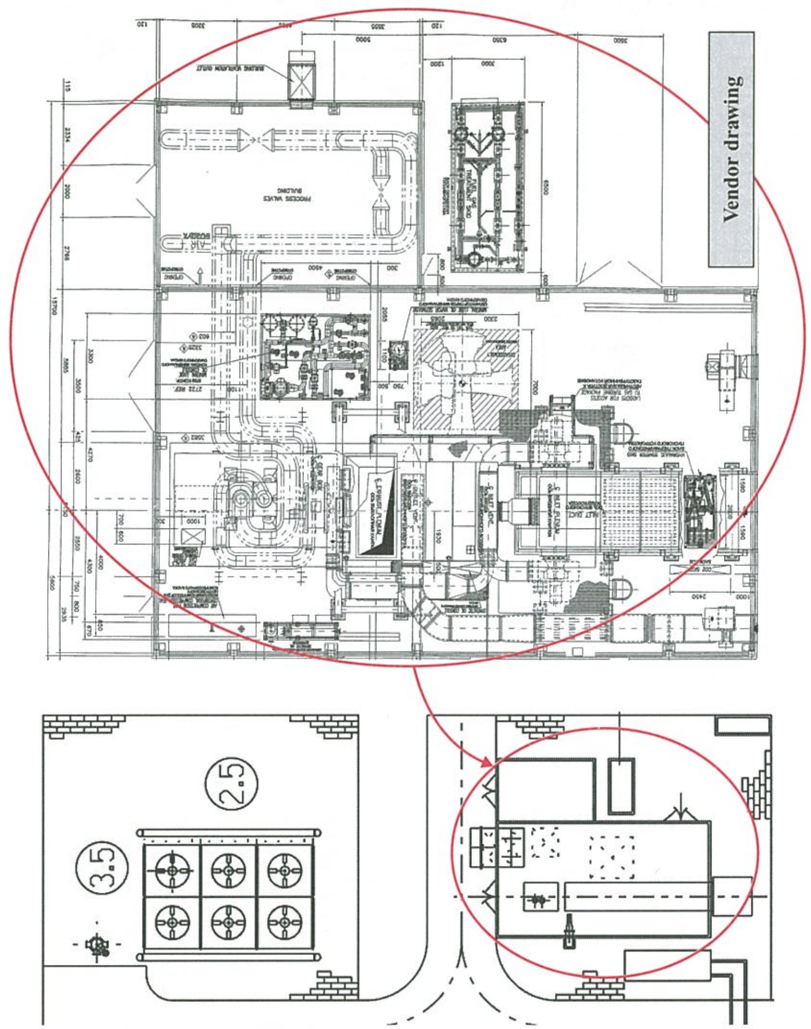


An optimum spacing is found with respect to cost. The size of the plant footprint has indeed a direct impact on the quantities to be purchased and installed: length of pipes, pipe-racks, electrical and instrumentation cables, sewage, fire fighting, roads, paved areas, etc.



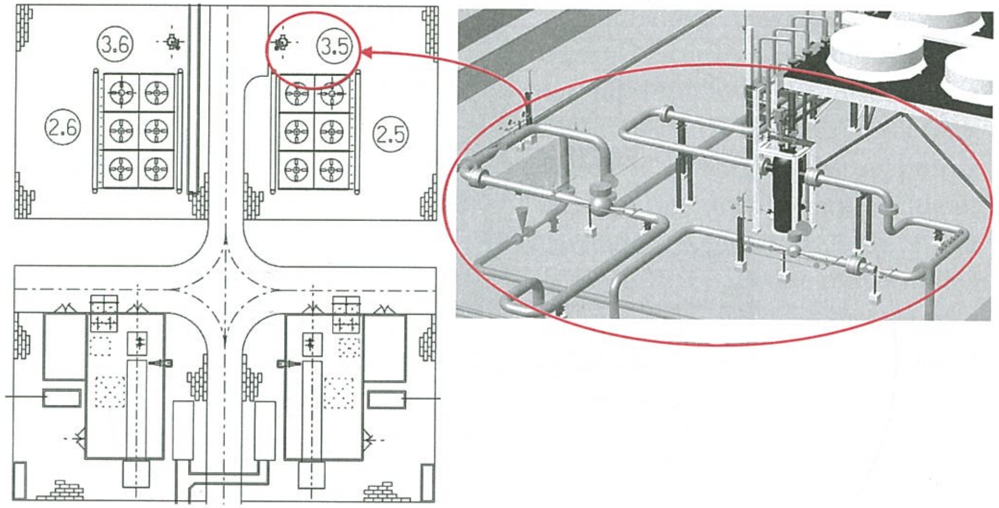
Equipment elevations may be dictated by process reasons. A pump, for instance, shall be placed at a lower elevation than the vessel from which it is fed, to ensure proper supply to the pump without cavitation. Another example is that of vessel that is used to collect drains by gravity. It must be located at a lower elevation than the vessel(s) it drains from.

Equipment dimensions will not be available initially. It will become available once the equipment supplier has finalized its design and purchased its sub-equipment. Not only the size of the main equipment should be considered while elaborating the Plot Plan, such as a turbo-compressor unit, but also their auxiliaries, e.g., fuel gas unit, lube oil skid, etc.

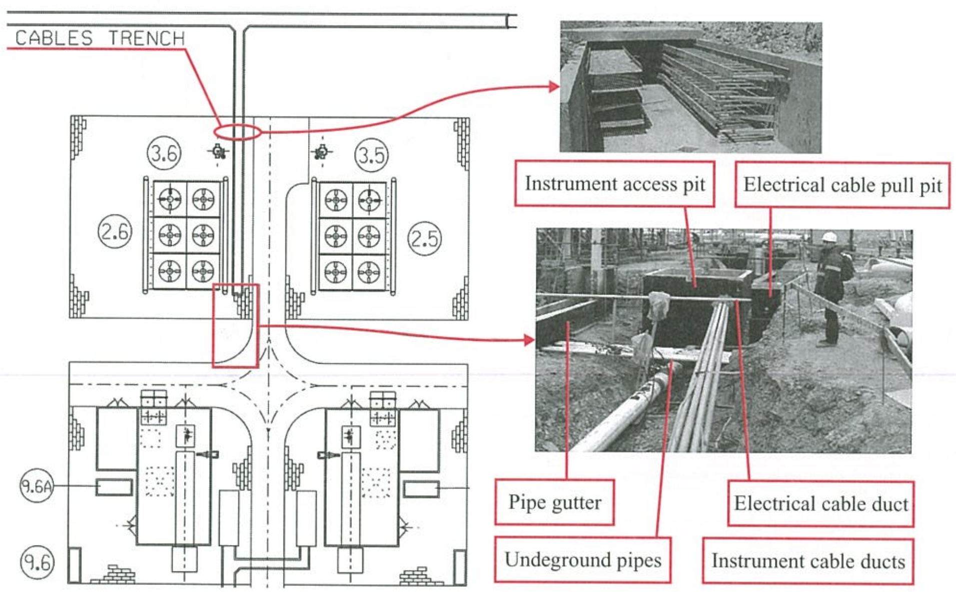


Experience is required to account for all equipment, and estimate their size with accuracy before actual information is available from vendors, in order to be able to freeze the plot plan at an early stage.

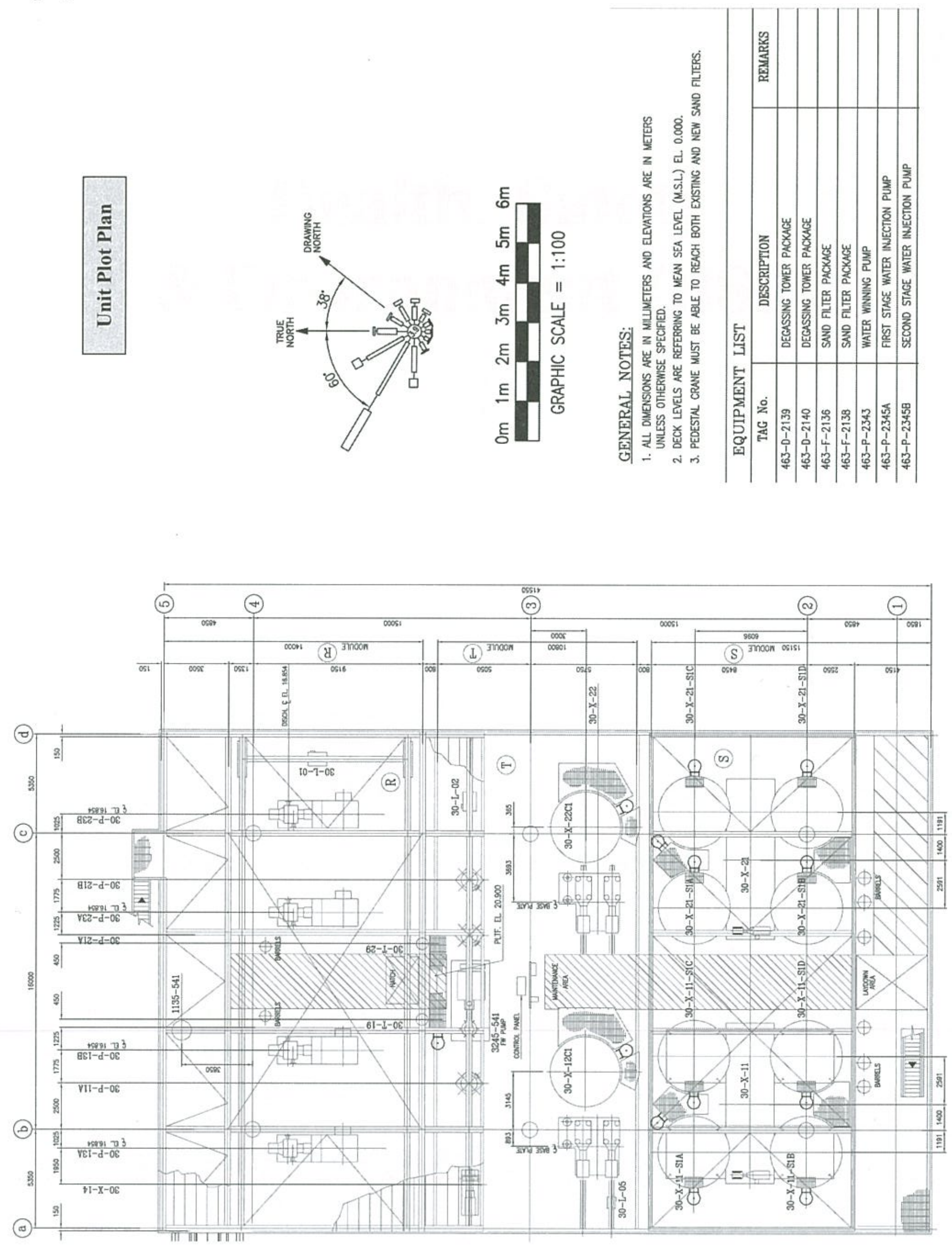
Such freeze of the plot plan is essential as it is a pre-requisite for the start of Site activities.



Space for routing of *all* networks (all process and utility pipes, Electrical and Control cables, fire fighting, sewage, pits...) must be duly considered in the Plot Plan. This is the reason why defining a correct layout requires a lot of experience. One indeed needs to have a vision of the entire plant, including all pipes, networks, accesses, etc., before they appear on the drawing boards, thanks to one's experience on previous facilities. All such items will indeed come later on as the design develops and will occupy space that must have been reserved.



The position of equipment is shown on the **Unit Plot Plan**, by means of coordinates or distance to axis of reference datum point, e.g., inlet nozzle on equipment.



Chapter 6

Health, Safety & Environment (HSE)

Health, Safety and Environment (HSE), also called Loss Prevention Engineering or simply "Safety", works at preventing or minimizing the consequences of accidents linked to the operation of the plant. It is also in charge of ensuring that it complies with legal requirements in terms of release to the environment (gaseous emissions, waste water, noise, solid wastes, etc.).

The first field in which safety is involved is that of the plant process itself. It leads an audit, called a **HAZOP Review** (HAZard and OPerability Review), which is a systematic review of all possible process upsets, verifying that the design incorporates adequate safeguards to allow the process to come back to normal or to safely shut down.

HAZOP reviews are usually carried by Safety with the help of a third party, to avoid conflicts between safety requirements, Contractor and Client's interests. The reviewing team includes Process, Operations, Instrumentation & Control specialists, as many aspects are to be jointly considered.

A systematic method is used for the review: at each point of the process (in each line, in each equipment) the causes and consequences of possible process (pressure/temperature/flow) upsets are identified and evaluated.

The likelihood of an undesirable event happening is evaluated, taking into account the safeguards already included in the design, such as safety automations, alarm, operating instructions.

The consequence that would result from the undesirable event is determined and its severity is ranked using criteria such as the ones shown in the table below.

The risk is then finally evaluated as a combination of the likelihood to happen (frequency) and the severity.

HAZOP Review

RISK LEVEL

[1] Several/Continuous: more than 1 per year
[2] Single: once between 1 and 10 years
[3] Likely: once between 10 and 100 years
[4] Unlikely: once between 100 and 1000 yrs
[5] Very unlikely: less than once in 1000 yr

RISK MATRIX

FREQUENCY

F5	I	I	L	L	L
F4	H	I	L	L	L
F3	H	H	I	L	L
F2	H	H	I	L	L
F1	H	H	H	I	L
	S1	S2	S3	S4	S5

HAZARD CATEGORY

SEVERITY

	1 Major	2 Significant	3 Moderate	4 Minor	5 Negligible
1 Personnel	Multiple Fatalities	Single Fatality	Severe injury	Lost Time injury	No Significant Effect
2 Property Damage/ Business Interruption	Major	Significant	Moderate	Minor	Negligible
3 Environmental	Significant/ Long Term	Significant / Short Term	Minor/ Long Term	Minor/ Short Term	No Measurable Effect

High risks (H) are events with severe consequences and high likelihood to happen. High risks are unacceptable.

The HAZOP team identifies high risks, for which it records that the design must be improved. Precise tracking of the status and expediting of these requested improvements will be made throughout the Engineering phase in order to ensure their implementation.

A typical example of a reviewed item would be the scenario of overflow of a liquid containing vessel.

The team would identify the possible cause (miss operation during filling), consequence (release of product to atmosphere through vessel overflow pipe), existing safeguards (liquid level indicator, operating instructions, high level alarm).

The Frequency of occurrence will be estimated considering likelihood of error by operator, malfunction of the level sensor, etc.

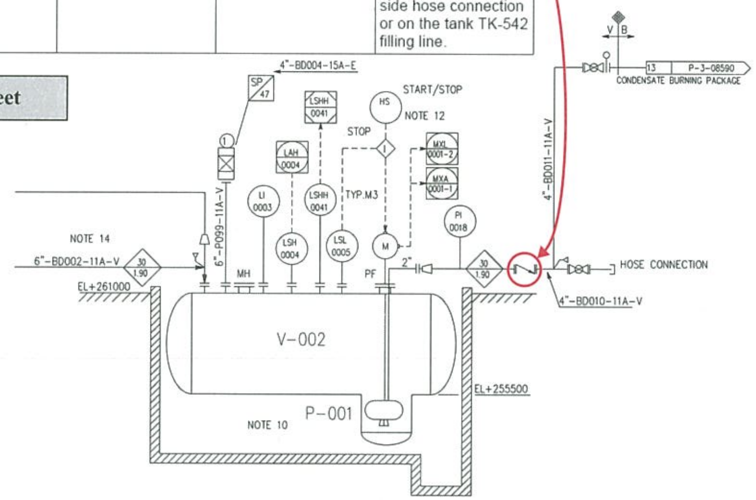
The Severity will depend on the type of product released to atmosphere (personnel and/or environmental hazard).

Should Frequency * Severity (risk) be found high, the HAZOP team would prescribe an action from the design team (a check to be done, a calculation to be made, a change to the design such as the addition of a safeguard, etc.).

The form below shows a typical HAZOP worksheet, issued after the review as part of the **HAZOP report**. The first item does not require any action by the design team. The second item requires an action (addition of a non-return valve), which Engineering has implemented as shown on the P&ID.

DEVIATION	CAUSE	CONSEQUENCE	SAFEGUARDS	ACTION
195 Flow Reverse	2. Reverse flow through the spare pump.	Less chemicals injection. Potential polymerization and fouling in the debutanizer T-601 and E-602A/B. Freq: [5] Ctgy: [1] [2] [3] Svrty: [5] [3] [4] Risk: [L] [L] [L]	Operating instructions. Pump technology (positive displacement pump).	No further action required, existing safeguards considered adequate.
196 Flow Reverse	3. Tank refilling.	Potential nitrogen back-flow through the filling line.		Ensure there is a non-return device either on the tank side hose connection or on the tank TK-542 filling line.

HAZOP Action sheet



Early incorporation of additional requirements resulting from the HAZOP is essential to minimize the amount of design reworks they generate.

Second only to process safety is the safe layout of the facility. Explosion and fire hazards exist in Oil & Gas facilities due to the flammable and explosive inventories handled. Adequate design considerations, in particular in the field of layout (relative positions of equipment) and spacing (minimum distances between equipment), can reduce the risk or consequence of such events.

Explosion and fire damage can indeed be significantly reduced with proper layout as explosion overpressure and fire radiation intensity rapidly decrease with distance. Minimum distances are specified between units and equipment based on the risk levels.

Safety will also review the layout of the plant to ensure sufficient space is provided for escape of personnel in case of emergency and for access for fire fighting.

Please refer to the Plant Layout section for details of safety considerations in plant layout.

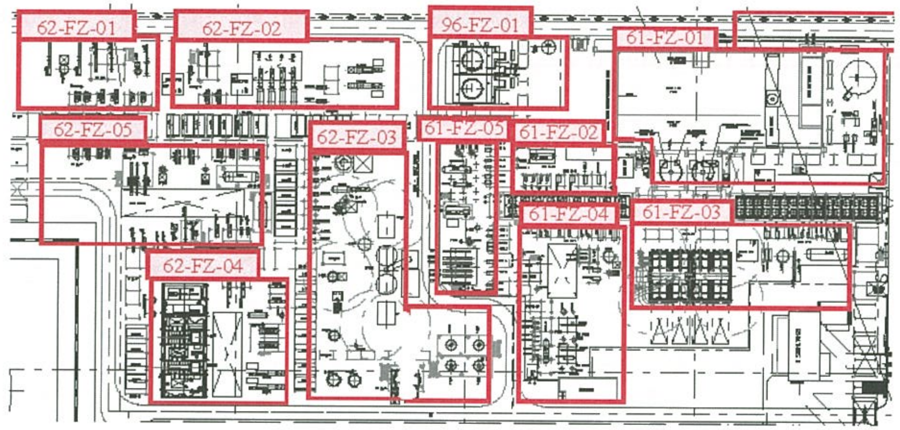
The Fire Fighting system of the plant is designed by Safety. Such system comprises both passive and active fire fighting means.

Active fire fighting system consist of the fire water system, a pressurized water ring feeding hydrants, fire monitors (for manual fire fighting) and the deluge system (for automatic fire fighting).

The deluge system consists of spray nozzles (sprinklers) arranged around the equipment, that will automatically spray water on the equipment upon detection of fire. The detection itself is done by fusible plugs located around the equipment, that melt when subject to heat.

The purpose of the water spray is not to extinguish the fire but to cool down the equipment, for instance a pressure vessel, to prevent the steel from loosing its strength at elevated temperature which could lead to the collapse of the vessel and loss of containment.

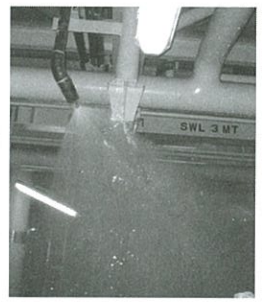
The quantity of fire fighting water is determined in the **fire water demand calculation note**. The plant area is first divided into fire zones.

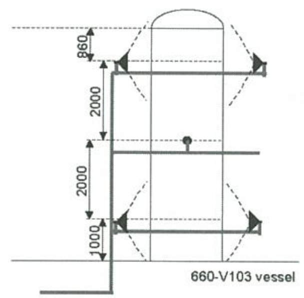


The water demand calculation is then calculated on the basis of a fire in one of the fire zone, with all fire fighting equipment in operation in this fire zone.

The deluge water demand is calculated from the number of sprinkler nozzles, itself a function of the the surface areas of the protected vessels.

Fire Water Demand Calculation note

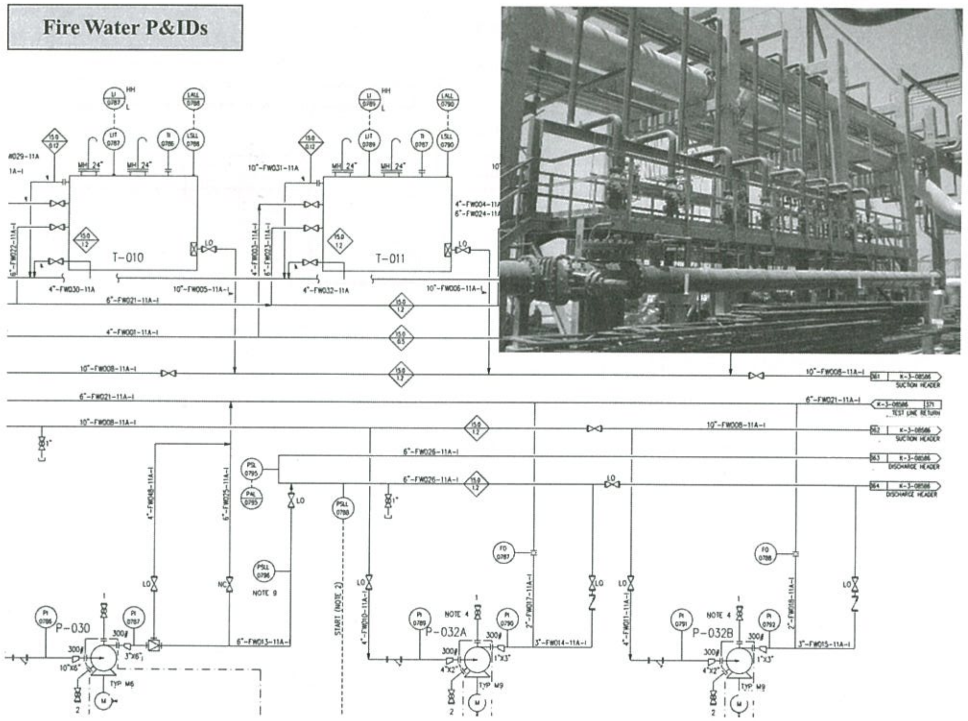




Item	Calculated flow rate	Selected flow rate
Maximum flowrate for deluge system	1117 m^3/h	745 m^3/h
Flowrate for monitors (6)	684 m^3/h	456 m^3/h
Flowrate for hoses (4)	228 m^3/h	228 m^3/h
Common facilities area (Unit 660) total firewater demand		**1429 m^3/h**

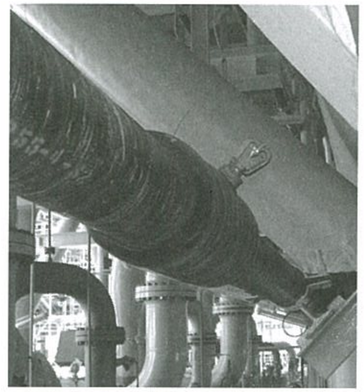
The fire water system is depicted by the Safety on the **Fire Water Piping & Instrumentation Diagrams (P&IDs)**.

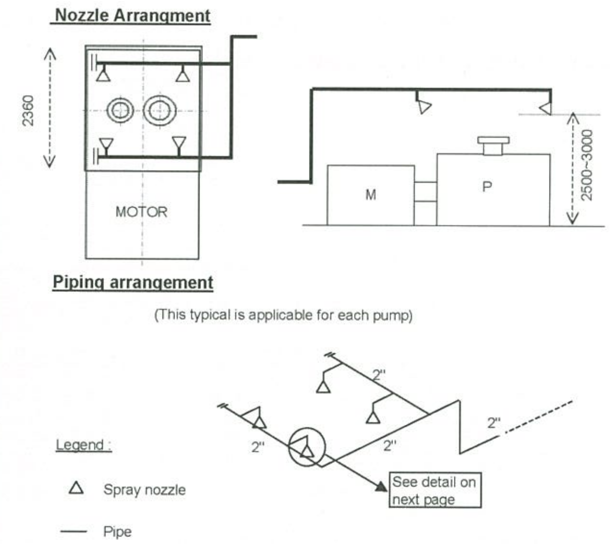
Fire Water P&IDs



Arrangement of deluge nozzles around equipment is shown on the **Deluge system arrangement drawings**.

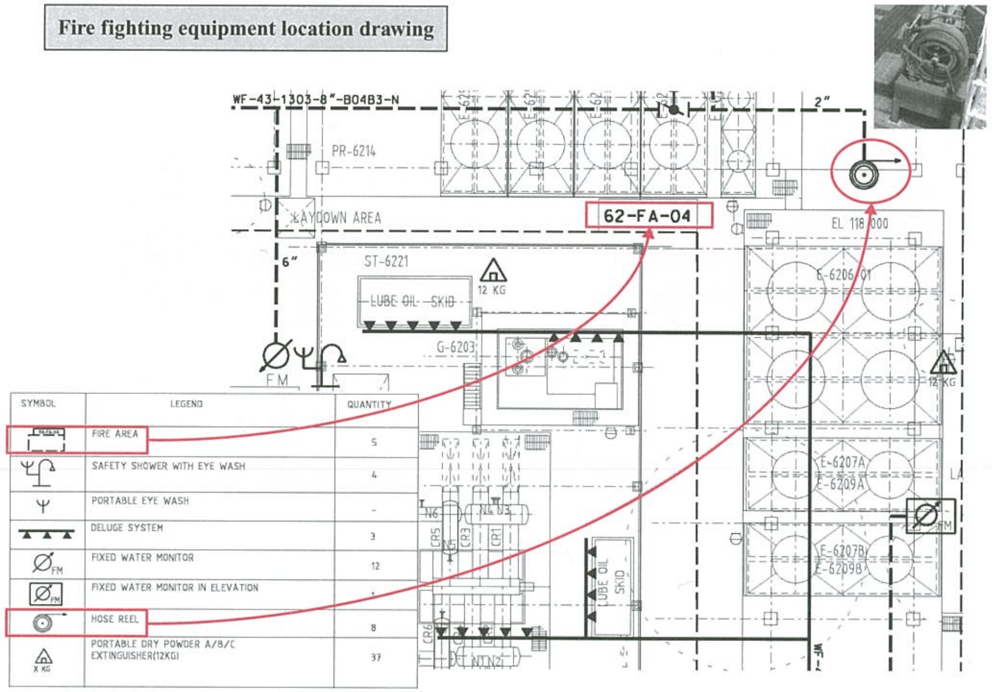
Deluge system arrangement drawings





The location of the fire fighting equipment is shown on the **Fire fighting equipment location drawings**.

Fire fighting equipment location drawing



Passive fire fighting, by means of fireproofing, is applied to structures supporting equipment and pipes. Protection of such structures will prevent/ delay the fall of critical equipment or pipes therefore avoiding the escalation of the incident.

In order to define which structures shall be fireproofed, Satey proceeds as follows:

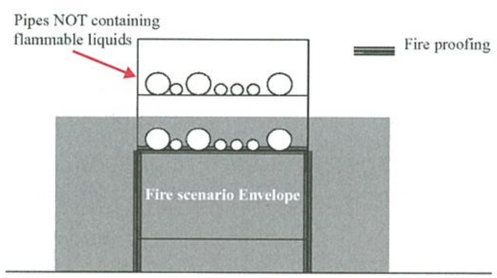
It first establishes the list of equipment generating a fire hazard, such as equipment containing a significant volume of flammable liquid, etc.

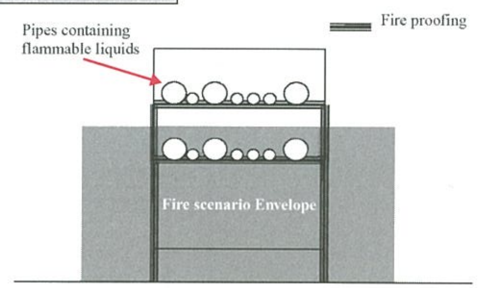
Each such equipment creates a "fire scenario envelope" in its surroundings. The various envelopes are consolidated and structures located inside the overall envelope are identified.

Not all structures within the envelope shall be fireproofed, but only the ones supporting equipment and pipe whose collapse could lead to incident escalation or large damage. This would include for instance a large and heavy tank, even if merely containing water, located at height.

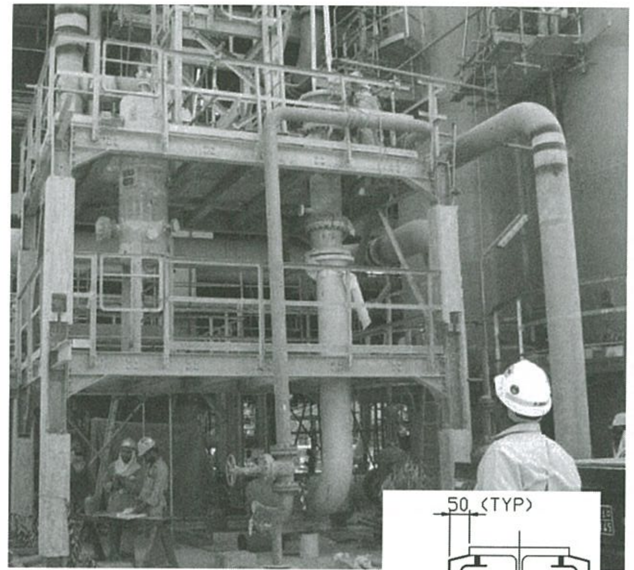
Extent of fireproofing of the structures is defined by means of typical drawings such as the ones shown here.

Passive fire protection typical drawings

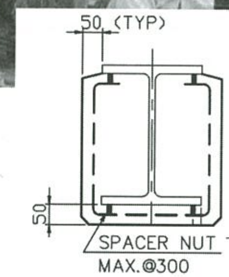


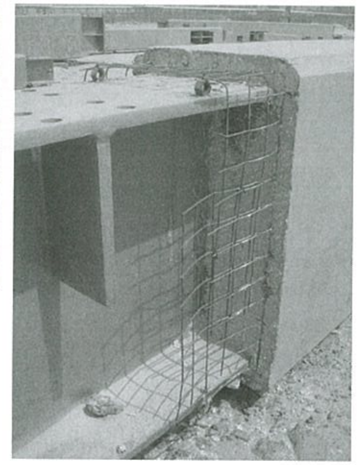


Fire proofing can be done by applying a special coating, or concrete, in which case requirements are addressed to the civil engineer who develops the required standard drawings.



Fire proofing

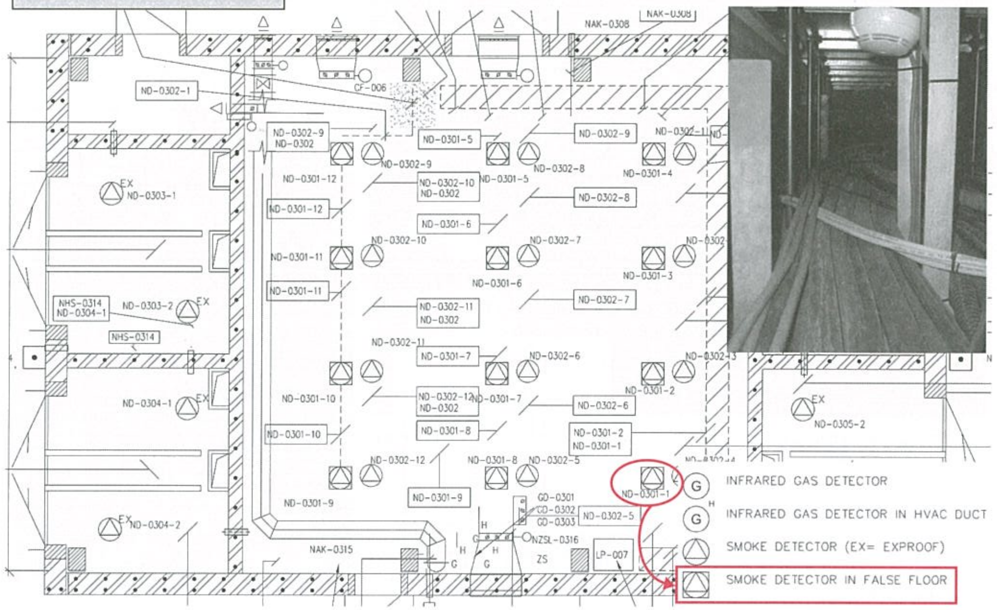




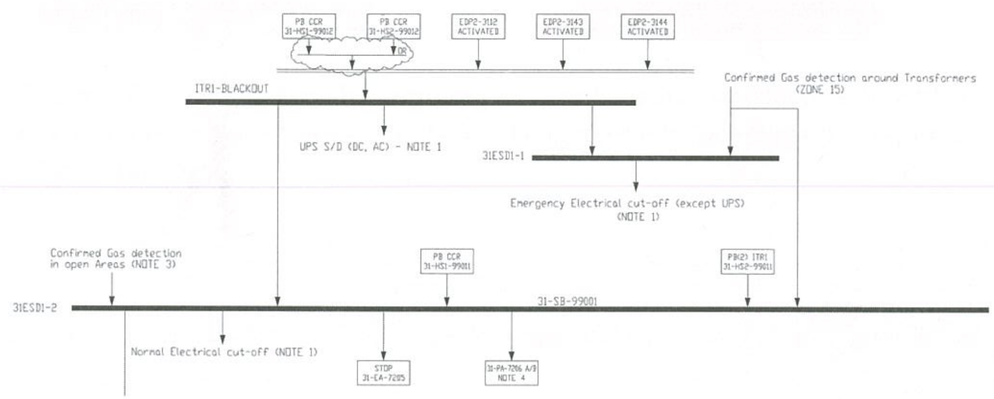
Fire fighting includes a Fire and Gas detection system, which activates alarms and performs automatic actions, such as electrical isolation, in case of fire and gas detection.

Safety defines the number, location and type of Fire and Gas detectors both in process areas and inside buildings and shows the same on the **Fire & Gas detection layout drawings**.

Fire & Gas detection layout



Safety defines the emergency actions, such as process shutdown, electrical isolation, etc. upon fire or gas detection. These actions and their initiators are shown on the **ESD logic diagrams**.



The detailed logic is shown on the **Fire and Gas Matrix**.

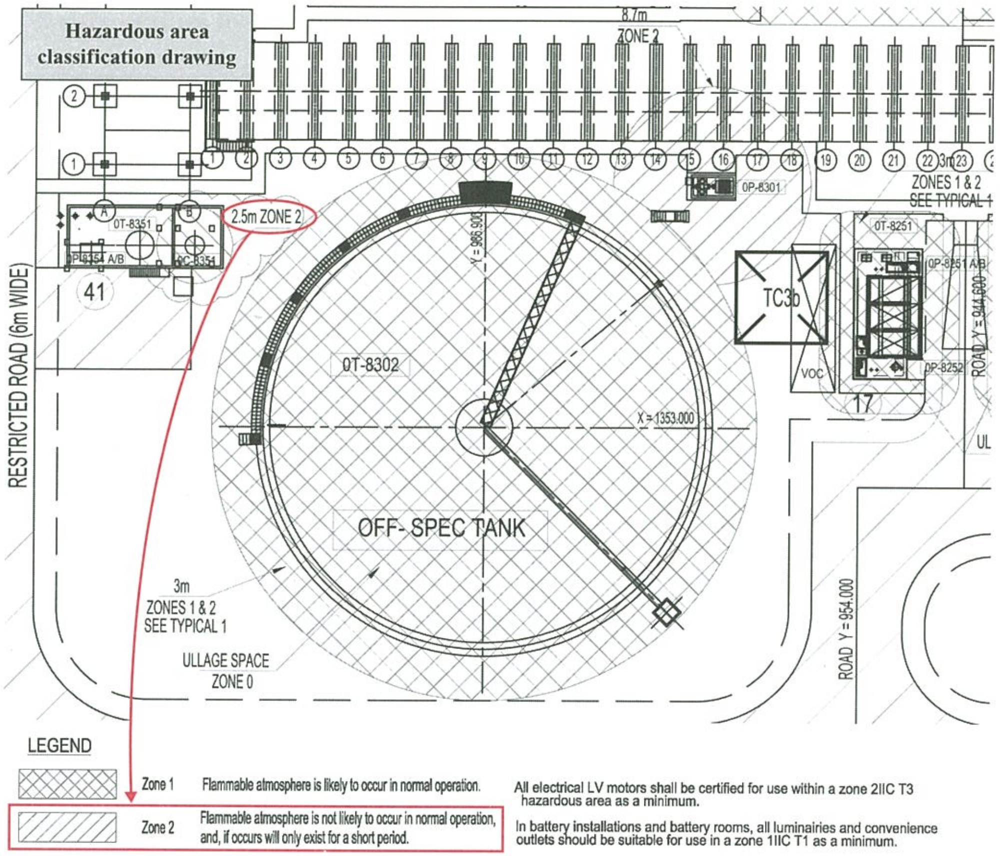
CAUSES				EFFECTS							
Location	Causes	Voting	Setpoint	Local F&G panel	Master F&G panel	Gate house F&G panel	Fire building F&G panel	Audible and visible Fire alarm	Audible and visible Gas alarm	SD-2	Close electrical substation 27.1 fire dampers and stop HVAC
Compressor unit 27.1 - Electrical substation											
Transformers	Optical smoke detector	1 out of 2		X	X	X	X				
		2 out of 2		X	X	X	X	X			
	Manual Fire Alarm Station	1 out of 1		X	X	X	X	X			
HVAC inlet	Infrared gas detection	1 out of 3	10% LFL	X	X	X	X				
		1 out of 3	20% LFL	X	X	X	X				
		2 out of 3	10% LFL	X	X	X	X		X		
		2 out of 3	20% LFL	X	X	X	X		X		X
Electrical room and false floor	Optical smoke detector	1 out of 2		X	X	X	X				
		2 out of 2		X	X	X	X	X			X
	Manual Fire Alarm Station	1out of 1		X	X	X	X	X			

In the example shown above, detection of gas in the air inlet of the building ventilation system will cause the ventilation fan to stop and the damper (shutter of the ventilation duct) to close. Indeed, the equipment located inside buildings is not designed to work in an explosive atmosphere.

Safety identifies the areas of the plant where explosive atmospheres could form. This is based on the identification of known sources of release and potential sources of leaks.

Sources of release include storage tanks, vents of equipment and instruments, etc. Potential sources of leaks include flanged connections in pipework etc. The extent of the explosive atmosphere around the source is assumed using a set of rules, for instance a radius of 3 meters around an instrument vent, etc.

Hazardous area classification drawings are prepared showing areas where an explosive atmosphere could be present, along with the likeliness of presence (Zone 0/1/2).



Electrical equipment located in hazardous areas must be of a special design so that they are not a source of ignition. Such special design provides various degree of protection against the risk of being a source of ignition.

The required degree of protection is determined based on the classification (zone 0 > 1 > 2) of the area where the equipment is located.

Protection could be achieved by different designs such as:

- explosion proof, referred to as "d": the equipment is enclosed inside a heavy duty enclosure that would contain an explosion and avoid its propagation,
- increased safety, referred to as "e": the equipment is designed not to generate any spark,
- intrinsic safety, referred to as "i": the amount of energy created by a spark in the equipment is not high enough to ignite the explosive atmosphere,
- etc.

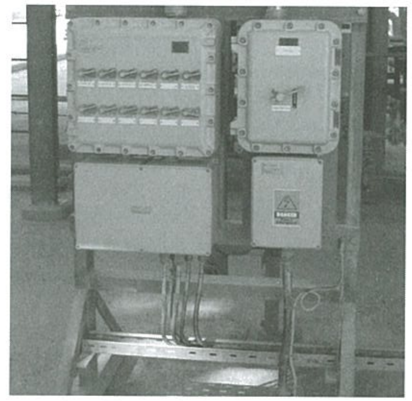
Besides this level of explosion protection, Safety specifies the composition of the explosive atmosphere to which the equipment could be exposed. The nature of the explosive atmosphere has indeed a direct impact on the minimum ignition energy. An atmosphere of hydrogen, such as the one that could develop in a battery room during charging, requires much less energy to ignite than a natural gas atmosphere for instance. The nature of the atmosphere is specified by reference to a gas group, e.g., IIC for hydrogen, etc.

Finally, Safety specifies the maximum temperature authorized on the equipment surface. Indeed, the explosive atmosphere will ignite if it comes in contact with a temperature above its self-ignition temperature. This again depends on the composition of the explosive atmosphere: methane self-ignition temperature is around 600°C whereas that of ethylene is 425°C.

The maximum equipment surface temperature is specified by means of a temperature class, e.g., T3 means maximum surface temperature of 200°C.

Electrical equipment protected against explosion is clearly marked by means of an international code encompassing the information above:

Explosion proof



Increased Safety

The **Quantitative Risk Analysis (QRA)** is a systematic way to assess the hazardous situations associated with the operation of the plant. The analysis is related to release of hazardous materials to atmosphere that can cause damage to people or equipment, e.g., due to explosion, fire, etc.

Each accidental event is plotted inside a risk matrix, according to its frequency and severity.

Action is required for any event falling in the "Intolerable Risk Area" of the matrix. Its frequency or consequences must be reduced to bring it into the "ALARP (As Low As Reasonably Practicable)" or "Acceptable" risk areas, through risk reduction measures.

The first step of the QRA is to perform a hazard identification.

In the example that follows, the hazard reviewed is that of an explosion due to leak from piping. The cause could be material detects, construction errors, corrosion, maintenance overlook, etc.

The plant is divided into individual isolable sections of similar hazardous material, process conditions and location. The section considered here is the building housing a compressor.

The inventory of each component from which the leak could originate (pipes, flanges, pumps, valves, instruments…) is made. Frequency of leak of individual components is taken from statistical data found in the literature, for various leak size, e.g., 5% of component bore size, etc.

The sum of the individual component leak frequencies and sizes give the overall plant section leak frequency and size.

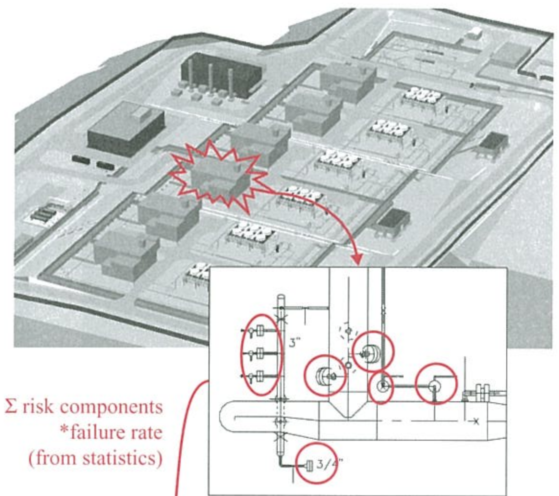
Quantitative Risk Analysis (QRA)

Case study: Gas leak from random piping component rupture

Cause: installation error, corrosion, material defect…

Possible consequence: Dispersion without ignition / jet fire / flash fire / explosion

Section considered: Compressor building



Step 1:

Identification and characterisation of initiating events

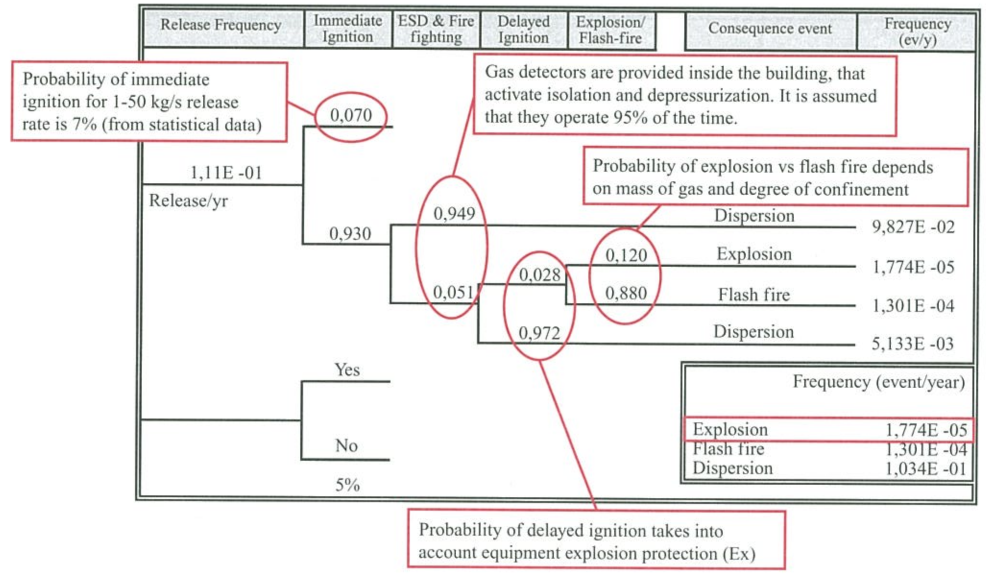
Gas leak inside compressor buidling due to component rupture	Hole size (% of component section)		
	5%	20%	Full
Frequency (event/year)	1,11E -01	5,06E -04	6,83E -05
Outflow rate (kg/s)	5,7	90,8	2270,0

Release of hazardous material to atmosphere can give rise to different effects, such as simple dispersion without harm or on the contrary fire, explosion, etc. This depends on a number of factors, such the presence of ignition sources, the degree of confinement, etc. It is the purpose of the second step of the QRA to evaluate the probability of each possible consequence.

The various scenarios are shown on event trees. The frequency of each event is factored by the probability of the subsequent one, resulting in the frequency of the various possible ultimate consequences.

Quantitative Risk Analysis (QRA)

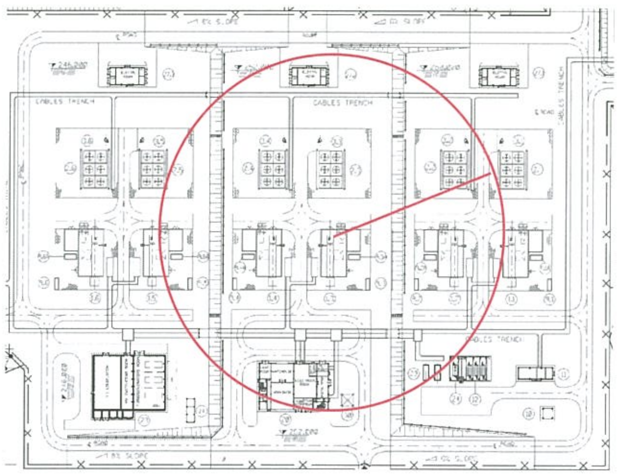
Step 2:
Event tree analysis



The third step of the QRA is to evaluate the effects of each accidental scenario. Consequences are expressed in terms of reference values of overpressure, heat radiation, etc.

Quantitative Risk Analysis (QRA)

Step 3:
Consequence evalutation



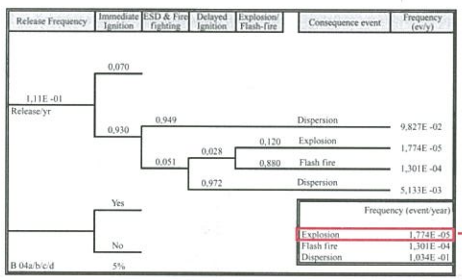
Overpresssure (bar)	0.2	0.1	0.01
Distance (m)	96	167	1270

CONSEQUENCE CLASS	QUANTITATIVE CRITERIA	EFFECTS
MINOR	≤ 0.1 bar locally (within 10m)	No effect, no damage
SIGNIFICANT	≤ 0.1 bar locally (within 50m)	Limited damage to plant and operators
SEVERE	> 0.1 bar within plant	Damage to plant and operators
MAJOR	> 0.1 bar on populated areas	Damage to plant, operators & public

The risk is ranked in a class of consequences and plotted on the Risk Matrix to check its acceptability.

Quantitative Risk Analysis (QRA)

Final step:
classification of risk



Unacceptable risk area– **Design change necessary**

As Low As Reasonably Practicable – **Plant Management measures**

1.OE -02				
1.OE -03				
1.OE -04 Unlikely				
1.OE -05 Rare				
1.OE -06	Minor	Significant	Severe	Major

CONSEQUENCE CLASS	QUANTITATIVE CRITERIA	EFFECTS
MINOR	≤ 0.1 bar locally (within 10m)	No effect, no damage
SIGNIFICANT	≤ 0.1 bar locally (within 50m)	Limited damage to plant and operators
SEVERE	> 0.1 bar within plant	Damage to plant and operators
MAJOR	> 0.1 bar on populated areas	Damage to plant, operators & public

The Quantitative Risk Assessment results in requirements, such as blast resistance of buildings, reinforcement of structures supporting safety critical elements, etc., which are incorporated in the design.

The impact of the plant on the environment is specified and evaluated by the HSE discipline.

An **ENVID** (ENVironmental aspects IDentification) review is performed to identify all environmental aspects of the plant, i.e., all equipment having a potential impact on the environment.

Aspect	Health	Air	Water		Raw material	Waste
		Gaseous emissions	Resource Consumption	Liquid effluents	Petroleum/gas /Chemicals	
Relief (flare/vent)	Noise*	CO, NO_X, PM, SO_2, VOC				
Power generation		CO, NO_X, PM, SO_2			Fuelgas	
Gas compression	Noise*	Fugitive VOC			Gas	
Fresh water	Potable		X			
Cooling water	Legionella		X	Effluent Water Temperature	Biocides, pH Control	
Effluent water (open drains/ treatment Plant)				Hydrocarbons, Suspended Solids		Biosludges, Oily sludge

The review covers, for each aspect, the corresponding environmental concerns (noise, NOX emission, energy consumption, waste generation…) and the measures that are implemented in the design to control the environmental impact.

The **Health and Environment Requirements specification** states the requirements for each of the identified environmental aspect: regulatory standards, limits for all emissions (contaminants in discharged water, pollutants in gaseous discharges, etc.), design dispositions to limit/monitor pollutants for each type of emission/effluent discharge, ambient air quality, noise limits, disposition for disposal of hazardous wastes, etc.

Effluent Quality Criteria for Discharge into Sea Organic Species				
Parameter	Symbol	Units	Monthly Average	Maximum Allowable
Oil & Grease		mg/l	5	10
Phenols		mg/l	0.1	0.5
Total Organic Carbon	TOC	mg/l	50	75
Halogenated hydrocarbons and Pesticides		mg/l	***	

The above requirements are fed back into the design (water segregation and treatment system, height of exhaust stacks) and addressed to equipment vendors (limits of NOx for gas turbines, etc.).

Later in the Project, an **Environmental Impact Assessment** is performed to verify that the design complies with the above requirements.

It includes an analysis of the dispersion of atmospheric pollutants released by the plant to evaluate the impact of the plant on the surrounding air quality. It entails an inventory of all sources of atmospheric emissions (machinery exhausts, etc.), and the modelling of the atmospheric dispersion according to local meteorological data. It results in the calculation of the levels of ground concentration of atmospheric pollutants at various distances from the plant, e.g., within the facility, in nearby populated areas, etc.

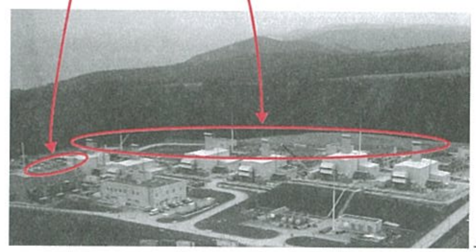
Environmental Impact Assessment (Air quality dispersion analysis)

Sources description

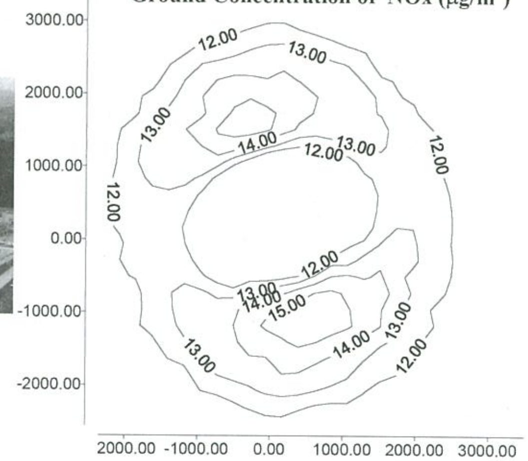
SOURCE NAME	Stack Height (m)	Stack. diam. (m)	Flue gas temp. (°K)	Flue gas velocity (m/s)	Q_{WET} (Nm^3/h)	NO_X (g/s)	CO (g/s)
Turbocompressor TC-100	15	2.9	775	28	206000	2.87	8.60
Turbocompressor TC-200	15	2.9	775	28	206000	2.87	8.60
Turbocompressor TC-300	15	2.9	775	28	206000	2.87	8.60
Turbocompressor TC-400	15	2.9	775	28	206000	2.87	8.60
Turbogenerator TG-001	15	1.38	806	28	45000	0.63	1.88
Turbogenerator TG-002	15	1.38	806	28	45000	0.63	1.88

Coordinates of the sources

	X (m)	Y (m)
Turbocompressor TC-100	127	365
Turbocompressor TC-200	127	331
Turbocompressor TC-300	127	268
Turbocompressor TC-400	127	235
Turbogenerator TG-001	182	177
Turbogenerator TG-002	190	177

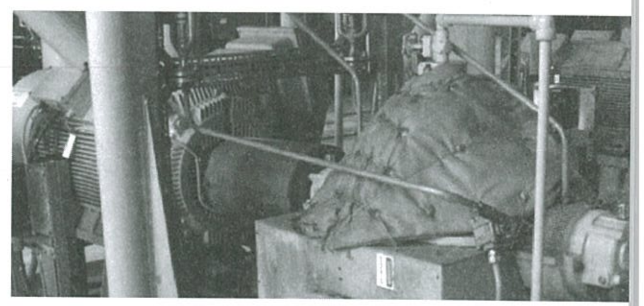


Ground Concentration of NOx ($\mu g/m^3$)



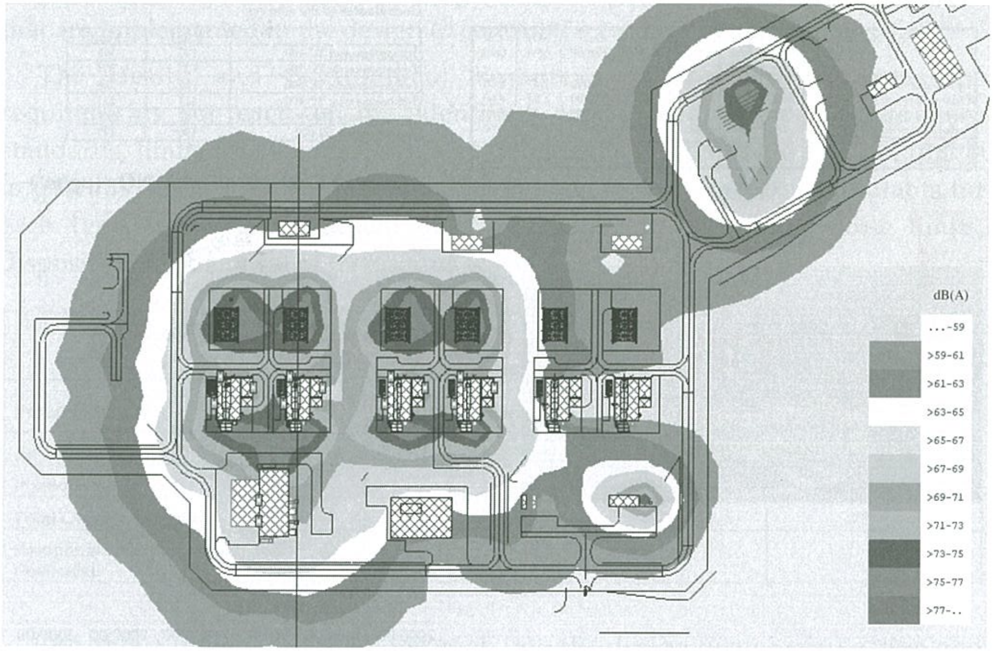
The scope of the Environmental Impact Assessment covers emissions in normal operation only. Accidental emissions and their impact on the facilities or populations is out of the scope and is covered in the Quantitative Risk Assessment.

The environmental impact assessment also includes a **Noise study**. It starts with the inventory of all noise sources. Noise levels are then obtained from reference data base during preliminary studies, then from each equipment vendor after purchase. A computer is used to run a model of the noise dispersion. Both noise sources and barrier elements with noise screen effect such as buildings, are entered in the model. The noise level at each location of the plant is evaluated. Verification is done that noise levels in working areas, and at the facility's boundaries, are within the safe/legal limits.



The noise study records the bases and results of noise calculations. Equipment noise insulation requirements are derived from the noise study. The results of the noise study are shown on the **Noise map**.

Noise Map



Finally, the Environmental Impact Assessment includes a waste management study. The wastes generated by the plant are inventoried and the possible options for recycling, treatment or disposal are studied based on existing local waste recycling/treatment/disposal facilities. This study allows to size the temporary waste storage area required on site.

Chapter 7

Civil engineering

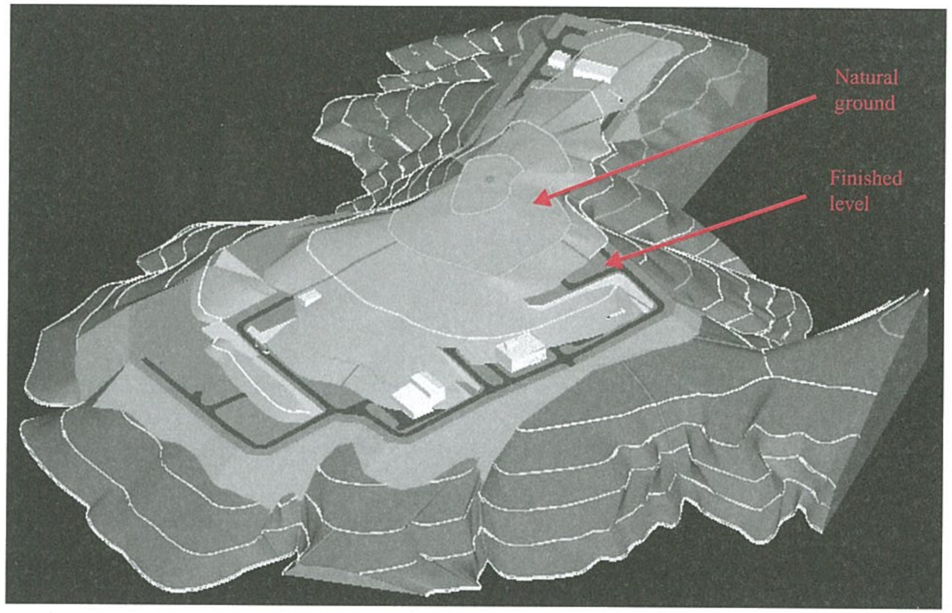
The first step of civil engineering for an On-Shore plant is to know the Site and the type of soil on which the plant will be built. A survey is required to collect topographical, hydrological, geological and geotechnical data. A **Soil Investigations Specification** is prepared by the Geotechnical Engineer to define the scope of this survey. It will include soil investigations, by means of geotechnical and geophysical methods, to collect a good understanding of the type of soil and its variability over the plant area. The type of soil determines the type of equipment required for excavations (excavators/explosives) and the type of foundations (shallow/deep) required for the plant equipment.

It will also include the identification of any local geo hazards, such as seismic hazard, collapsible soil, underground cavities, etc. and the definition of the soil geotechnical parameters to be used for the sizing of the foundations, such as soil bearing capacity.

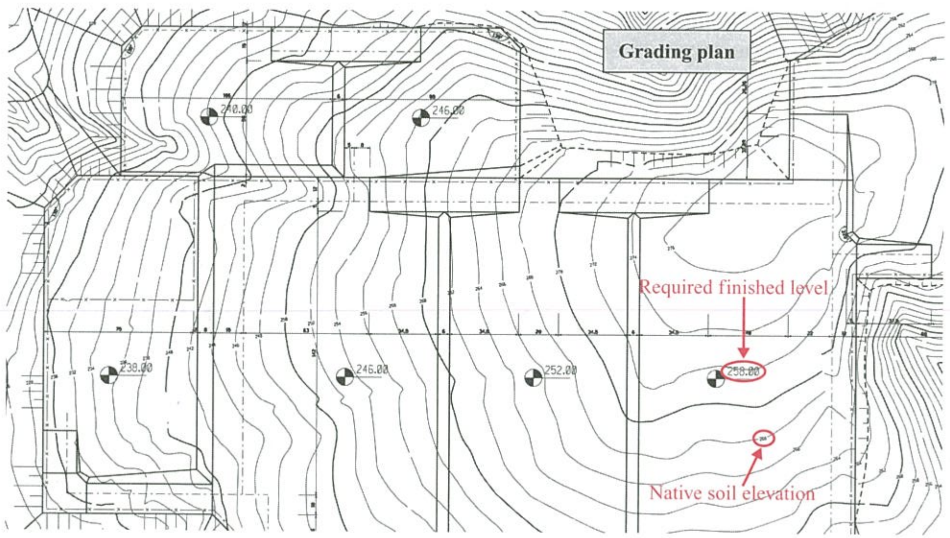
Specific studies are performed underneath critical structures, such as large storage tanks, tall columns, etc.

The geotechnical engineer will also provide specific recommendations to the engineer with respect to, for instance, reinforcement of slopes to be done in backfilled areas, etc.

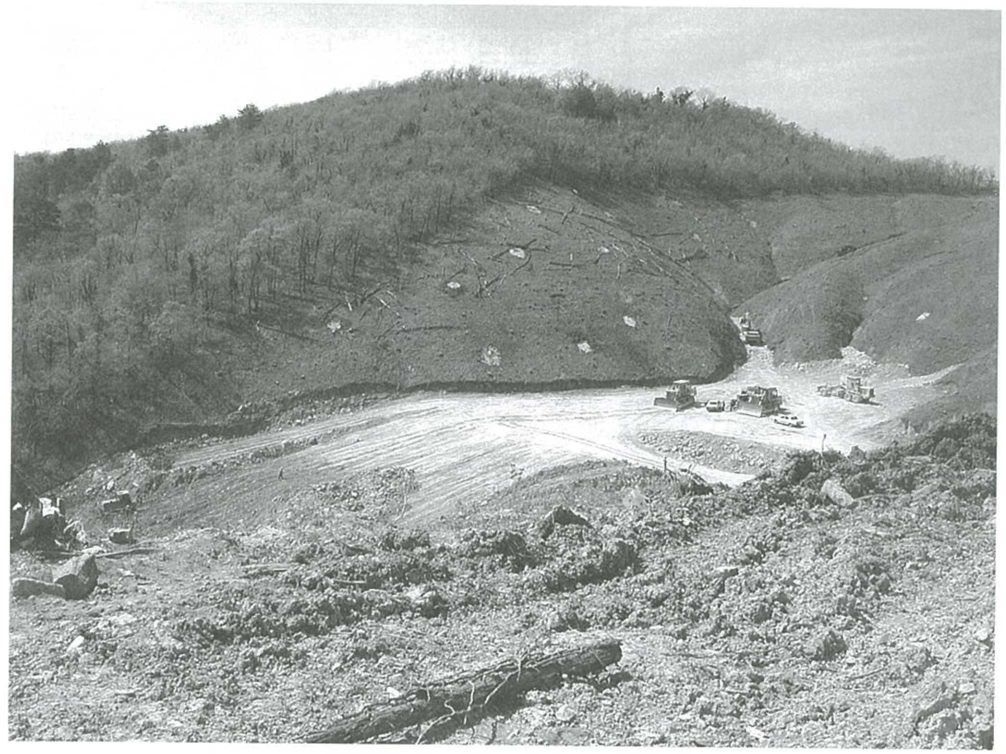
Once the overall layout (General Plot Plan) of the facility is defined, the first Site activities can start. These are the earthworks, which consist of levelling the site up to the required elevation.



Earthworks drawings are produced, such as the **Grading Plan**, showing the natural ground elevation and the final desired elevation.

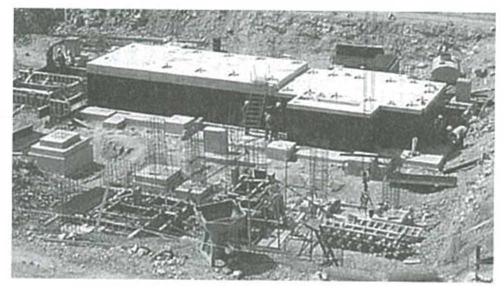


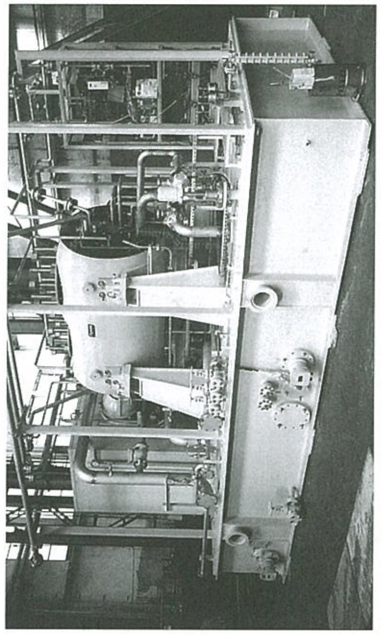
Earthworks equipment will then excavate/fill in order to reach the required finished level.

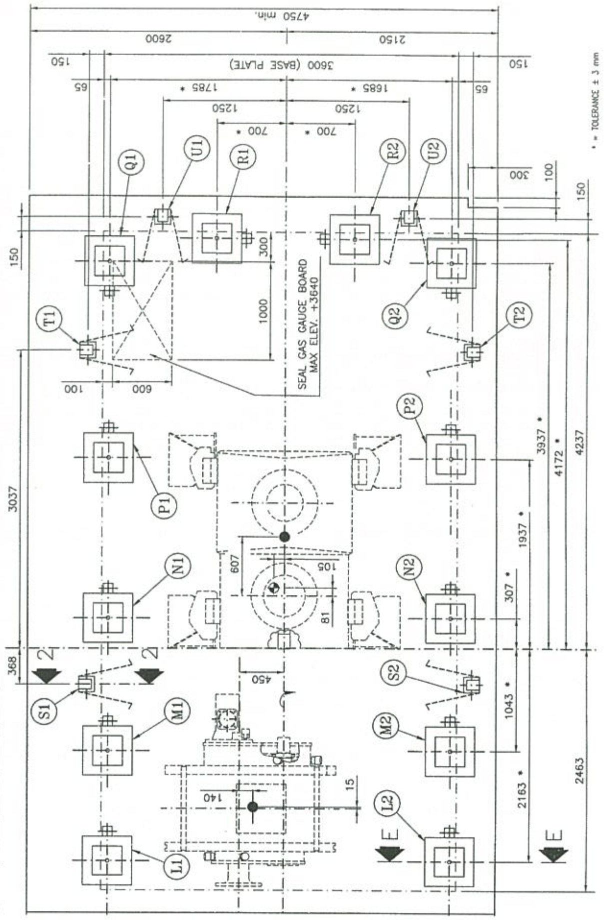


Once the Site is levelled, local excavation can be done and foundations of main equipment can be cast. Indeed, the main equipment foundations are the deepest undergrounds to be installed hence they have to be installed first.

Design of equipment foundation requires Vendor information such as footprint, location of anchor bolts, static and dynamic loads, etc. The vendor determines these loads, which are the basis for the sizing of the foundation.

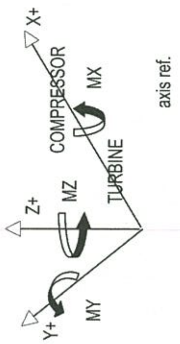






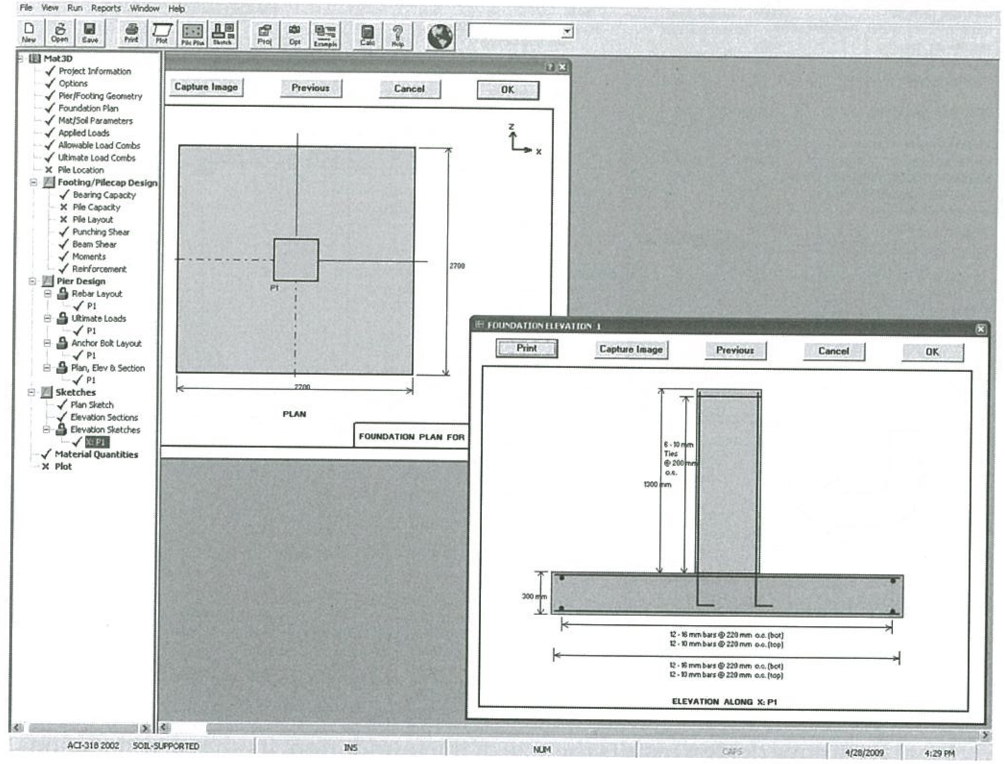
FOUNDATIONS LOADS

STATIC LOADS				OPERATING LOADS									
				live loads					pressure loads				
fX	fY	mX	mY	fZ	fX	fY	mX	mY	fZ	fX	fY	mX	mY
	17	-64		413	27	37	-166	76	270	-37	62	75	-25
10	100	392		-2009	26	92	-389	76	540		345	480	
-42	184	-680	-31	-1875	430	137	-568	80	786		522	930	
28	160	-583	12	-1022	430	88	-344	81	600		429	728	
	144	-537	13	-3030	27	100	-433	76	563		355	563	
	845	-336		-26	24	86	-358	72	416		260	300	
	223	-738		-297	25	14	-78	74	257	40	69	30	27
21	40	-97	69	75	30	18	-70	136		-427	-22	90	-966
-20	32	-79	-67	43			-34		-14	485	-16	68	1161
-19		-22	59	-15	20	28	-133	151	177	-865	-29	160	-2260
-10	17	-47	-32	-12			-29	50	152	735	-10	58	1830
	-53	88		118	24	29	-146	72	52	-72	-128	300	-32
	-88	308		-268	23	20	-132	70	394		-49	324	17
-56	-144	499	-34	1170	418		100	77	853	136	-180	668	23
-14		59		-1640	418		-56	76	600	40	-300	773	-35
		70	11	-437	23		-72	70	610	11	-200	724	32



Vendor information

The civil engineer designs the foundation using a computer software.



The type (piles, etc.) and size of the foundation depend on soil characteristics (bearing capacity, etc.). The bases of design and results of calculations are recorded in the **foundation calculation note**.

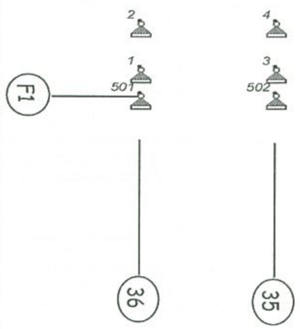
DESIGN CODE	ACI 318 - 2002			FOOTING DESIGN INFORMATION	
CONCRETE PARAMETERS:		E-W Dim (mm)	2600.00		
Compressive Strength (N/sq mm)	28.00	N-S Dim (mm)	2600.00		
Unit Weight (kN/cu m)	24.00	Thickness (mm)	550.00		
REINFORCING STEEL PARAMETERS:		Bottom Steel (Bot)	11 - 16 mm bars @ 225 mm o.c. (bot)		
Yield Strength (N/sq mm)	420.00			Max Long Bar Size	20
Unit Weight (kN/cu m)	78.50			Min Long Bar Size	20
Modulus of Elasticity (kN/sq mm)	210.00			Max Tie Bar Size	10
				Min Tie Bar Size	10
SOIL PARAMETERS:				Max Ftg Bar Size	25
				Min Ftg Bar Size	12
Allowable Net Bearing Capacity (kN/sq r	350.00			Temp & Shrinkage Steel Ratio	0.0009
Unit Weight (kN/cu m)	18.00				
MINIMUM FOUNDATION CRITERIA:				**BUOYANCY CRITERIA:**	
Depth of Footing Below Grade (mm)	1450			Consider Buoyancy:	No
Minimum Soil Cover (mm)	900.00			Consider soil for buoyancy:	No
Grade Elevation (mm)	3000.00			Water table below grade (r	0

APPLIED LOADS

P8

Load Case	Axial (kN)	Shear E-W (kN)	Mom N-S (kN m)	Shear N-S (kN)	Mom E-W (kN m)
1 - Dead	63.99	-0.63	0.00	-3.65	0.00
2 - PDL	232.12	-4.64	0.00	-11.98	0.00
3 - POL	123.68	-6.98	0.00	-1.88	0.00
4 - TL	0.00	0.00	0.00	0.00	0.00
5 - PTL	0.00	0.00	0.00	0.00	0.00
6 - TF	166.61	-27.75	0.00	-34.21	0.00
7 - Wind_X	45.48	-0.90	0.00	-20.89	0.00

Foundation calculation note



BEARING CAPACITY/STABILITY RATIO

Load Comb	Max Pressure (kN/sq m)	All Pressure (kN/sq m)	S.R. N/S.	S.R. E/W	All S.R.	Rem
1 - Dead + PDL	84.97	376.09	25.83	76.61	2.00	
2 - Dead + PDL + PTL + BL	84.97	376.09	25.83	76.61	2.00	

MAXIMUM SHEAR - E-W DIRECTION

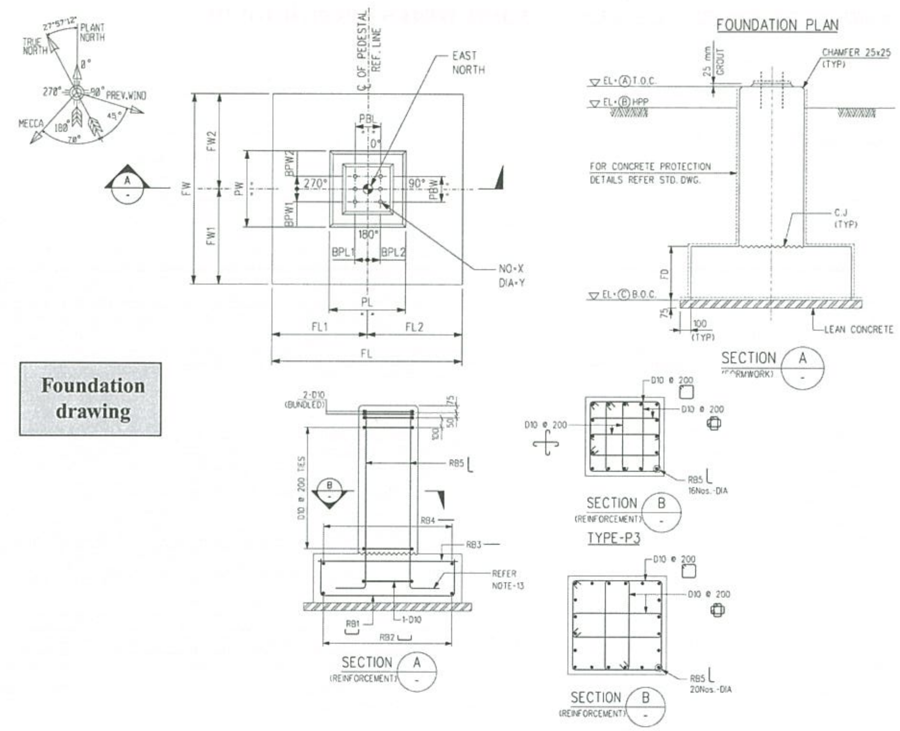
Load Comb	Left Dist (m)	Max Shear (kN)	Shear Stress (kN/sq m)	All Stress (kN/sq m)	Rem
1 - 0.9Dead + 0.9PDL + 0.45POL + 1.28Wind_X + 1.6BL	0.59	93.88	78.99	659.07	
2 - 0.9Dead + 0.9PDL + 0.45POL + -1.28Wind_X + 1.6BL	0.59	65.84	55.40	659.07	
3 - 0.9Dead + 0.9PDL + 0.45POL + 1.28Wind_Z + 1.6BL	0.59	158.35	133.24	659.07	

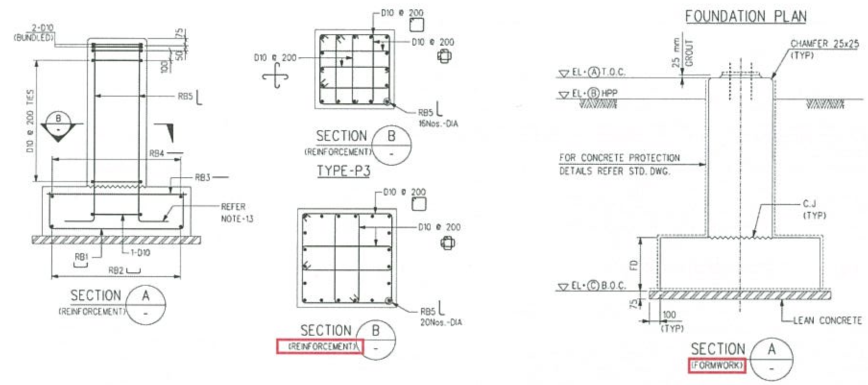
From the above design results the size of the foundation, its shape, dimensions, depth, and amount of re-inforcement.

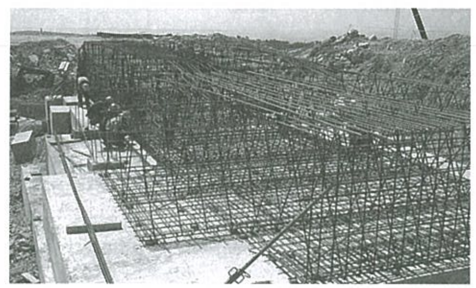
Foundation drawings are produced, which show the dimensions and depth of the foundation, the position, number and size of re-inforcing bars, and the position of anchor bolts to be cast in the foundation.

Reinforcement drawings and **Formwork drawings** are usually issued as separate drawings.

Foundation drawing







Besides drawings, Civil issues **Civil works specifications**, for each trade, e.g., site preparation, concrete works, roads, buildings, etc. which define the materials to be used, how the work shall be done, the inspections and testing requirements, etc.

Civil works specification

3 MATERIALS

3.1 Special requirements

3.1.1 Cement

Cement characteristics shall conform to BS 12, BS 146, BS 1370, BS 4027, BS 4246, BS 6588 or equivalent Russian code.
The type of cement to be used and the relevant strength shall be specified on the design drawings and/or in other contract documents.

3.1.2 Water

The water used for making concrete or cleaning out shuttering, curing concrete or similar purposes shall be taken from the mains supply wherever possible, and shall comply with the requirements of BS 3148: or equivalent Russian code. Where water is not available from the mains the Customer's approval shall be obtained before use.

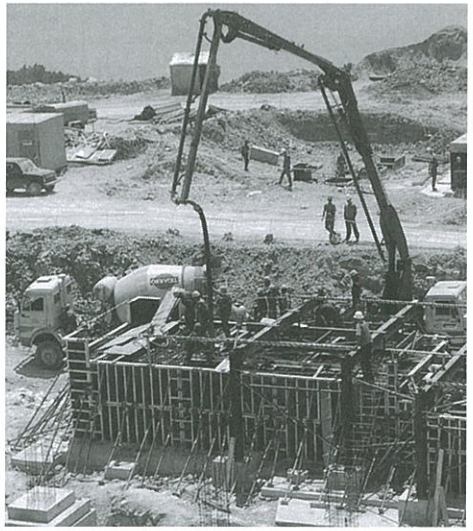
3.1.3 Sand (Fine aggregate)

Sand shall come from rivers, quarries, from natural sources or crushing of compact siliceous, quartz, granitic or calcareous rock. The sand shall be clean, free from silt and any other foreign matter that may affect the strength and/or the normal curing time of the concrete.
The grain size shall be well graded within the following range:

Sieve (BS 410)	% Passing (by mass)
10 mm	100
5 mm	95-100
2.36 mm	80-100
1.18 mm	50-85
600 µm	25-60
300 µm	10-30
150 µm	2-10

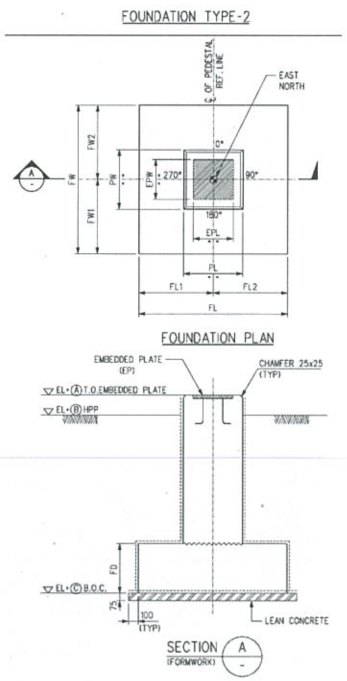
The content in fines (passing through a sieve of 75 µm) shall not exceed the following values:

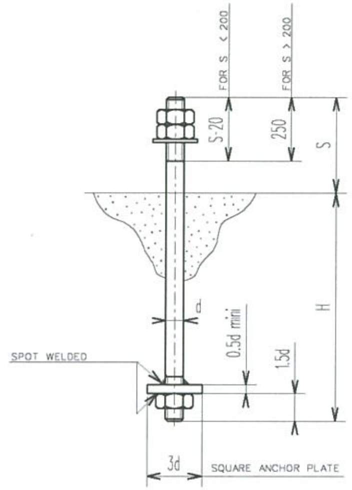
- 3% by mass for natural sand
- 5% by mass for sand produced by crushing.



Pre-fabrication is done to the maximum possible extent in order to reduce installation time. Concrete indeed requires around 2 weeks to dry before it can be buried. For the case of a foundation cast in-situ for instance, the excavation, which occupies a large footprint, needs to remain open for such period of time, which prevents surface works to proceed. Pre-fabrication of the foundation would avoid that and allow immediate backfill after installation.

Besides specific concrete constructions which are one-off and customized to a particular equipment, civil also produces generic concrete items. **Civil standard drawings**, such as the one showing standardized pipe support foundations here, are issued for that purpose. Such standardisation allows mass production at the pre-fabrication yard.





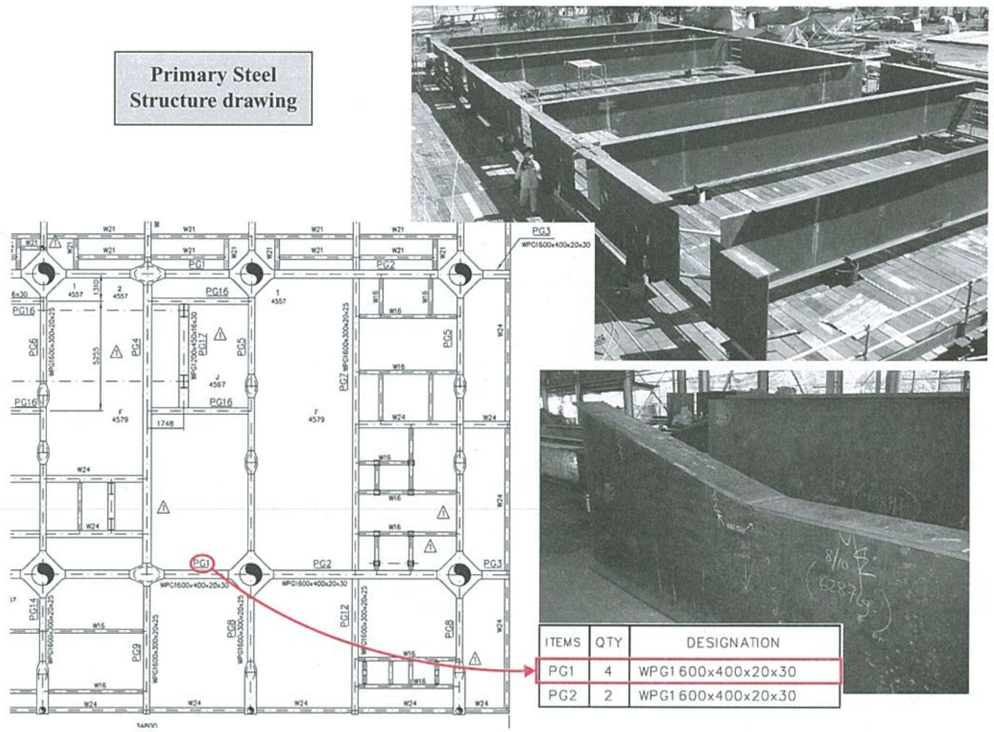
Civil also issues **Construction standards**, such as the one shown here for anchor bolts, which show repetitive arrangements.

Similarly to foundations for an On-Shore facility, deck structural drawings are produced for an Off-Shore facility.

The deck structure is made of the primary structure, which comprises the main girders making the deck frames, and the connection between the decks (legs), the secondary structure, made of beams supporting equipment, and tertiary structure, made of small beams supporting plating.

Layout studies determine the number, size and elevation of deck levels and the main equipment location. Together with equipment weights, it allows the Structure discipline to perform its design, calculations and to issue the **Primary Steel Structure drawings**.

Primary Steel Structure drawing

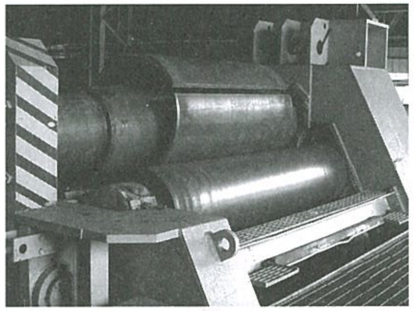


ITEMS	QTY	DESIGNATION
PG1	4	WPG1 600x400x20x30
PG2	2	WPG1 600x400x20x30

The primary structure (welded plate girders forming the deck frame, deck legs, etc.) is made out of steel plates that are a long lead item. Indeed, such steel has special properties (high strength, through thickness properties), requires special tests and must come from a mill that has been duly qualified.

The primary steel structure material take-off is therefore issued early in the project to quantity all necessary steel plates.

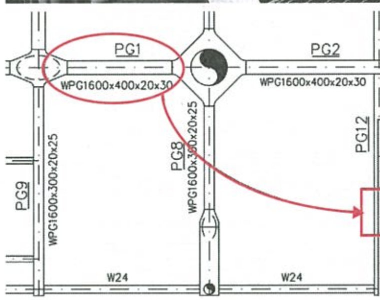
Structural steel specification



Material Selection for Deck Structure			
Structural Category	Item Description	Yield Type	Toughness Class
A	NODES/JOINT CANS Deck legs, Trusses, Girders, Flareboom	I II III	NA 2 2
B	PRIMARY MEMBERS Deck legs, Truss chords, Truss diagonals, Girders, Flarebooms, Blast walls	I II III	0 1 2
C	SECONDARY MEMBERS Bracing, Floor Deck plate	I	0

Yield Type	Specified Minimum Yield Strength Mpa	Toughness Classes		
		0 (No testing)	1 Test @ LAST	2 Test @ 30°C below LAST
I	240/248	20 J	20 J	20 J
II	344	N/A	35 J	35 J
III	412	N/A	45 J	45 J

Structural Steel Selection for Yield Type III Steels		
Toughness Class	Preferred	Alternatives
1	API 2W Gr 60 ASTM A131 Gr EH40 (shapes)	ASTM A633 Gr. E (plate) ASTM A572 Gr 60 (plate and shapes)
2	API 2W Gr.60 (plate) ASTM A131 Gr EH40 (shapes)	BS 7191 450 EM (plate) API 572 Gr 60 (shapes)



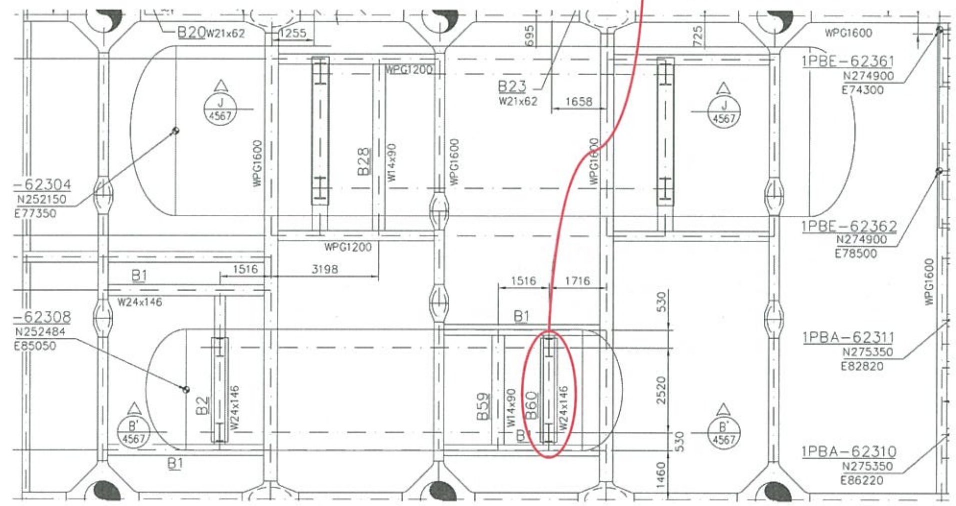
Primary Steel Structure MTO

Item	Qty	Description		Thk.	Material	Unit Surface (m²)	Total Surface (m²)	Unit Weight (Kg)	Total Weight (Kg)	Category	Yield Type
		Main girder WPG 1600 x 400 x 20 x 30									
PG1	4										
PG1a	16	Top & Bottom Flange	Plate	30	API 2W Gr. 60	1.228	19.648	235.50	4627	B	III
PG1b	4	Web	Plate	20	API 2W Gr. 60	13.757	55.027	157.00	8639	B	III
PG2	2										
PG2a	4	Top & Bottom Flange	Plate	30	API 2W Gr. 60	3.132	12.528	235.50	2950	B	III
PG2b	2	Web	Plate	20	API 2W Gr. 60	13.757	27.514	157.00	4320	B	III

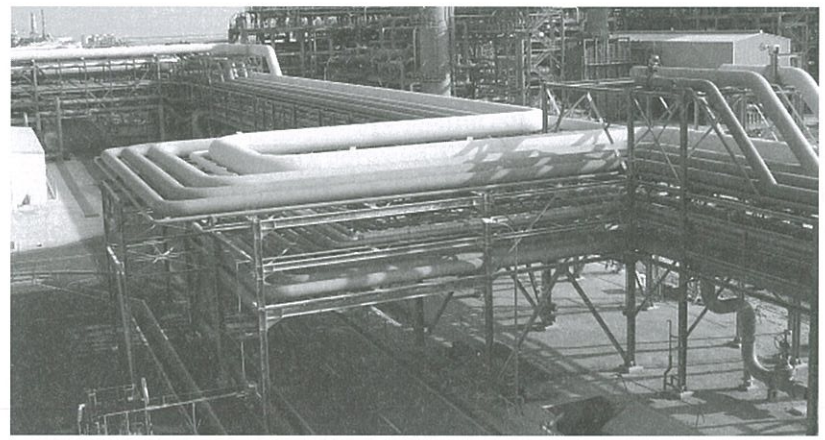
Secondary structure drawings are issued next, which show the main equipment support beams, and the associated bill of material, which has of a shorter lead time than primary steel.

Secondary Steel Structure drawing

MATERIAL LIST									
ITEMS	QTY	DESIGNATION	MATERIAL	L.A.V. UNIT	L.A.V. TOTAL	WEIGHT UNIT	WEIGHT TOTAL	CAT	TYP
B1	4	W24x146	ASTM A131DH/EH36	4.980	19.920	217	4323	B	II
B2	1	W24x146	ASTM A131DH/EH36	4.734	4.734	217	1027	B	II
B60	1	W24x146	ASTM A131DH/EH36	3.564	3.564	217	773	B	II



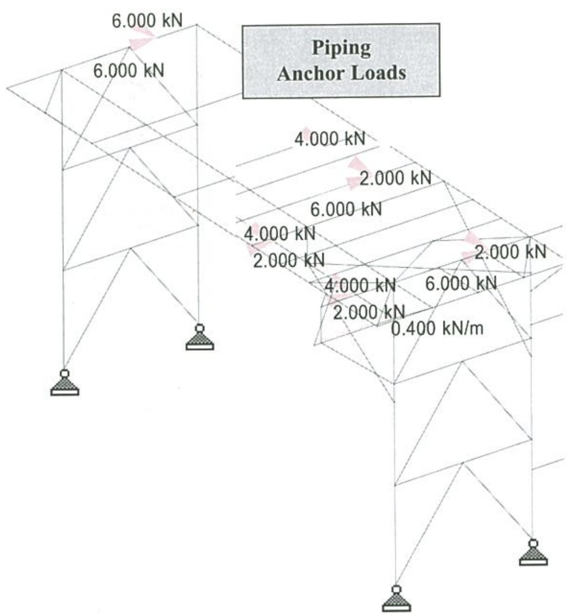
In On-Shore facilities, besides equipment supporting structures, long stretches of large steel structures supporting pipes, called pipe-racks, are found.



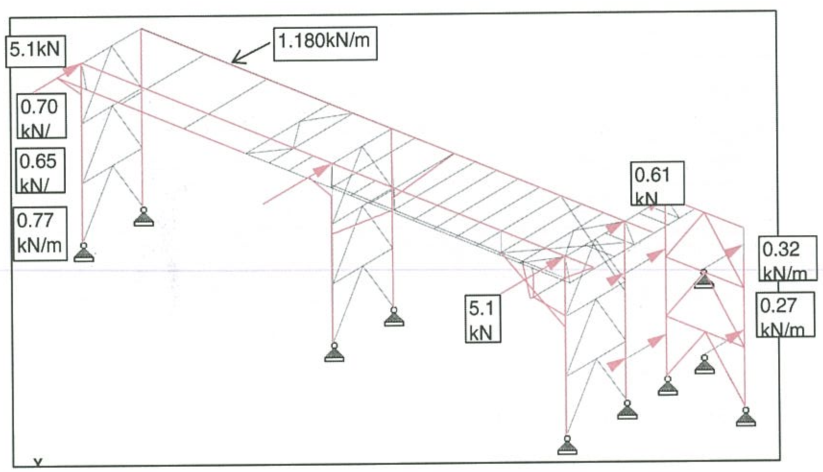
Requirements for these structures (location, width, number and elevation of levels, etc.) and input for their design (number of pipes to be supported, weight, operating loads) are defined by Piping.

Good communication between Piping and Civil is essential to optimize their design and include contingencies in order to avoid changes at a later stage, when piping studies will have progressed.

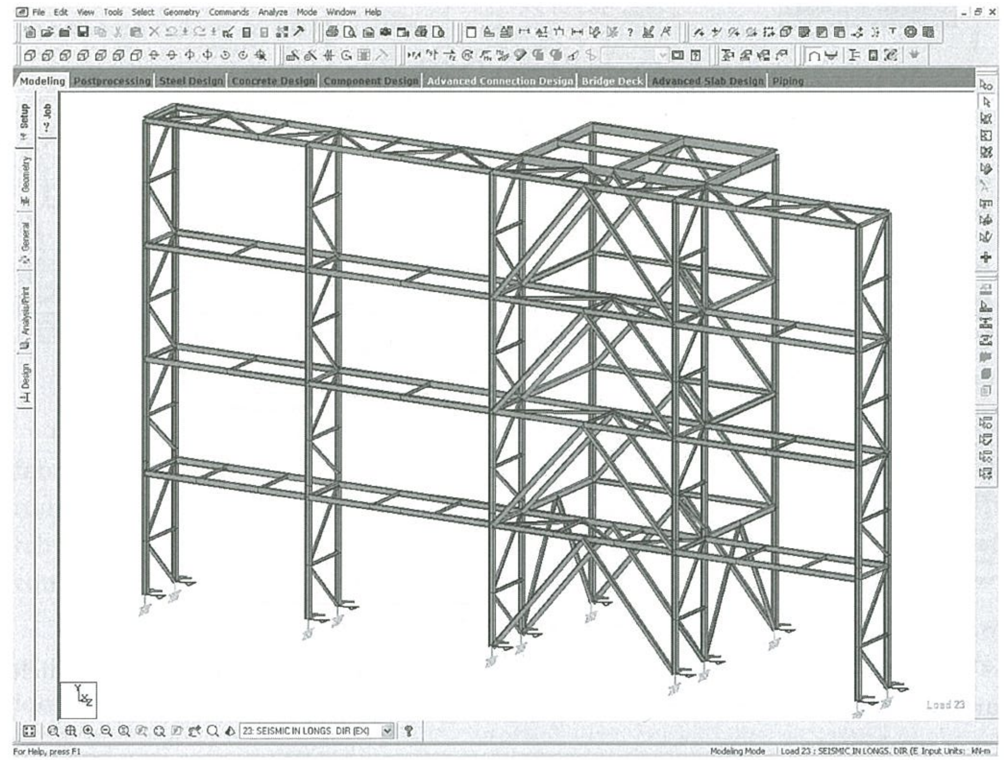
Large piping operating loads, such as loads at piping fixed points, thermal loads from low or high temperature lines (subject to high expansion), etc. are calculated by Piping Stress analysis group and advised to Civil. Other piping loads are estimated by Civil.



To these piping loads are added external loads such as seismic and wind loads.

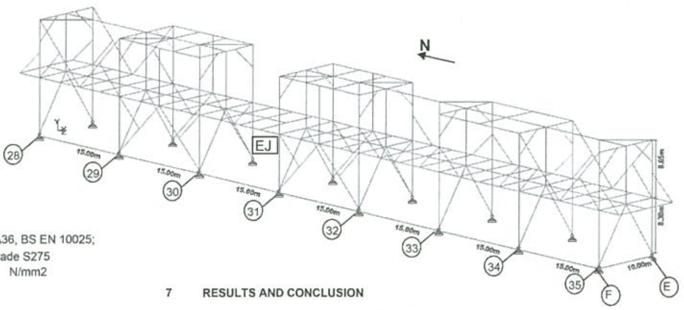


The structure is designed using a 3D modelling and calculation software.



Design of the structure includes sizing of main members, selection of connection type (pin/moment) between the members, provision of secondary members, such bracings for stability, etc. It results in a **structural calculation note**, which shows the design input and results (stress ratios in structure members, deflection of members).

Calculation note



Basic Design Data

Grade of Steel = ASTM A36, BS EN 10025; 1993 Grade S275

Yield strength of steel f_y = 265 N/mm2

Anchor Bolts

Anchor bolts grade = ASTM A307
Allowable Tensile stress = 138 N/mm^2
Allowable Shear stress = 69 N/mm^2

Wind loads

Basic wind speed V = 41 m/s
Exposure category = C
Importance factor I = 1.0
Topographic factor K_{zt} = 1.0

Seismic load

Seismic zone = 1
Seismic zone factor Z = 0.075
Soil profile type = S_b
Importance factor I = 1.0

7 RESULTS AND CONCLUSION

Maximum lateral displacement of top-most tier at EL19.400m as obtained from "STAAD OUTPUT"

Elevation (m)	Node	Load case	Max. displace. in X- dir. (mm)	Max. displace. in Z-dir. (mm)	Ht. Above Base Pl. (H) (mm)	Allowable Deflection (H/200) (mm)	Ratio : (Ht./Disp.)
19.4	96	913	35.68		16950	84.75	475.06
19.4	60	111		16.122	16950	84.75	1051.4

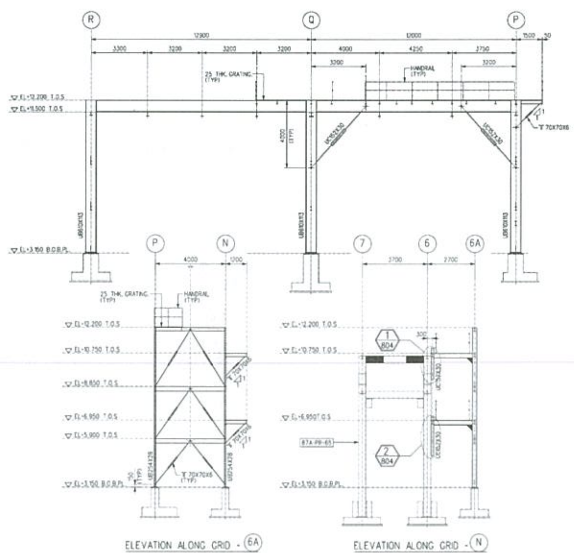
From above table, It is observed that lateral displacements are well within the allowable limit.

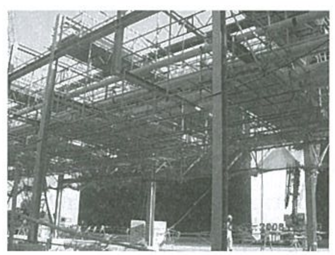
Maximum stress ratio as obtained from Staad Output is as follows

Description	Member	Max. Stress Ratio
GRID F - 29 to 30, 31 to 32	UB610X229X113	0.499
GRID E - 29 to 30, 31 to 32	UB914X305X253	0.882
GRID 33 to 34	UC254X254X73	0.415
PLAN BRACINGS AT EL. 19.400	UC203X203X46	0.458
PLAN BRACINGS AT EL. 19.400	2/UA90X90X8	0.538

STEEL Pipe Rack Structure 84-PR-65 is thus safe.

The civil designer then prepares the **steel structure design drawings**, which are issued to the manufacturer of steel.

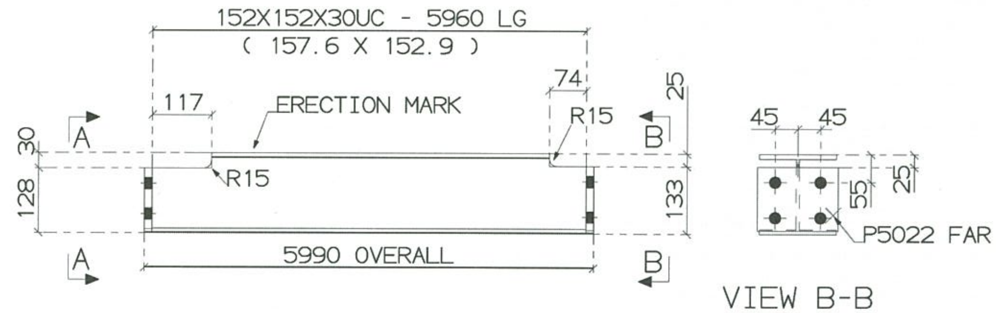




Steel structure design drawings

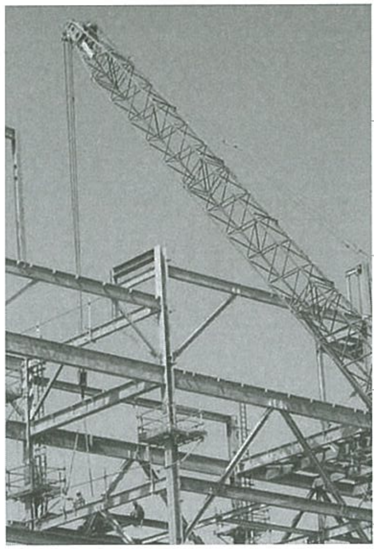
BILL OF QUANTITY				
ITEM No.	DESCRIPTION	D/M	UNIT	QUANTITY
A.3	PIPE RACKS (NON-FIREPROOFED)			
A.3.1	HEAVY (MORE THAN 75 kg/m)	M.1	Ton	10.71
A.3.2	MEDIUM (BETWEEN 30-75 kg/m)	M.1	Ton	14.17
A.3.3	LIGHT (LESS THAN 30 kg/m)	M.1	Ton	6.78
A.9	HANDRAILS	M.2	Ton	
A.10	LADDERS AND LADDER CAGES	M.2	Ton	
	TOTAL STEEL WORK		Ton	31.66

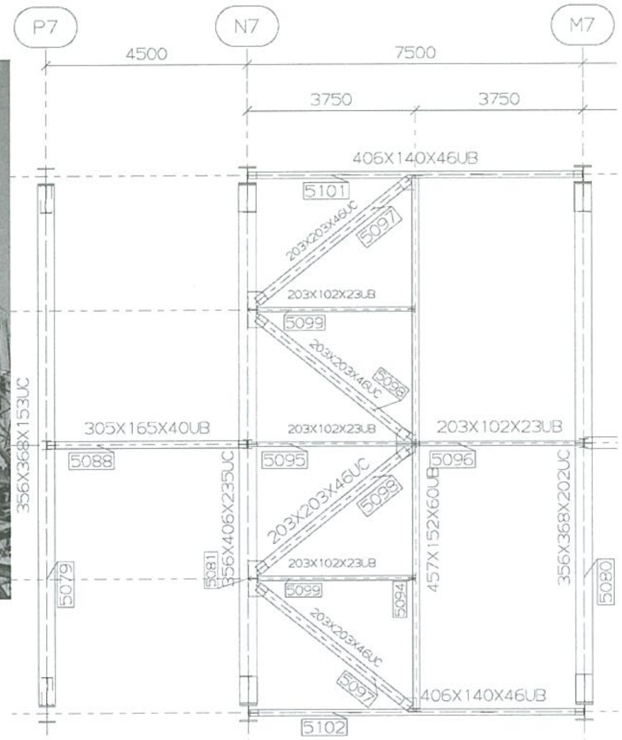
The steel structure manufacturer models the structure in all details, including all connections between steel members, and issues shop drawings, such as the one shown below, to its fabrication shop.



One shop drawing is produced for each structural member, showing all fabrication details, such as exact dimensions, position of gussets, positions and number of holes for bolts, etc. There is also usually a direct transfer of all fabrication data from the design office 3D model software to the numerical control fabrication machinery.

The manufacturer issues the **Erection drawings**, which show the overall view of the structure, together with the arrangement of the various steel members, identified by their piece marks.



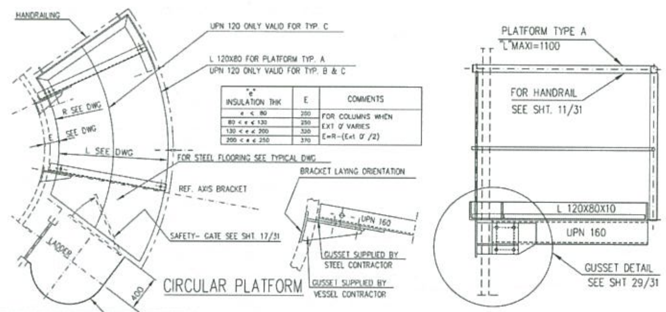


Erection drawings

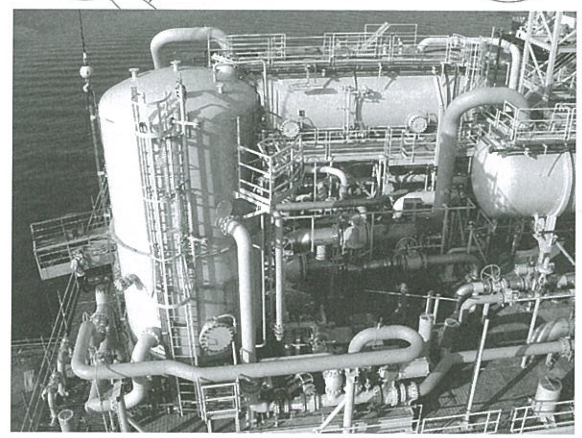
Identification is key. A given steel structure may come in as many as one thousand pieces, reaching the erection Site by several different truck loads, spread during storage before erection in very extended lay down areas.

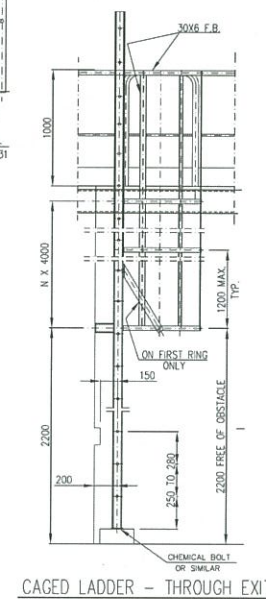
On top of equipment and piping supporting structures, civil provides small platforms for operator access (to equipment, instrument, valves, etc.).

Corresponding access requirements (location, elevation, dimensions of operating stages) are identified and defined by Piping installation discipline. Civil discipline implements these requirements by designing the corresponding small structures. A standard design is produced, which will be applied to all these repetitive items, and to the associated handrails, stairs, ladders, etc.



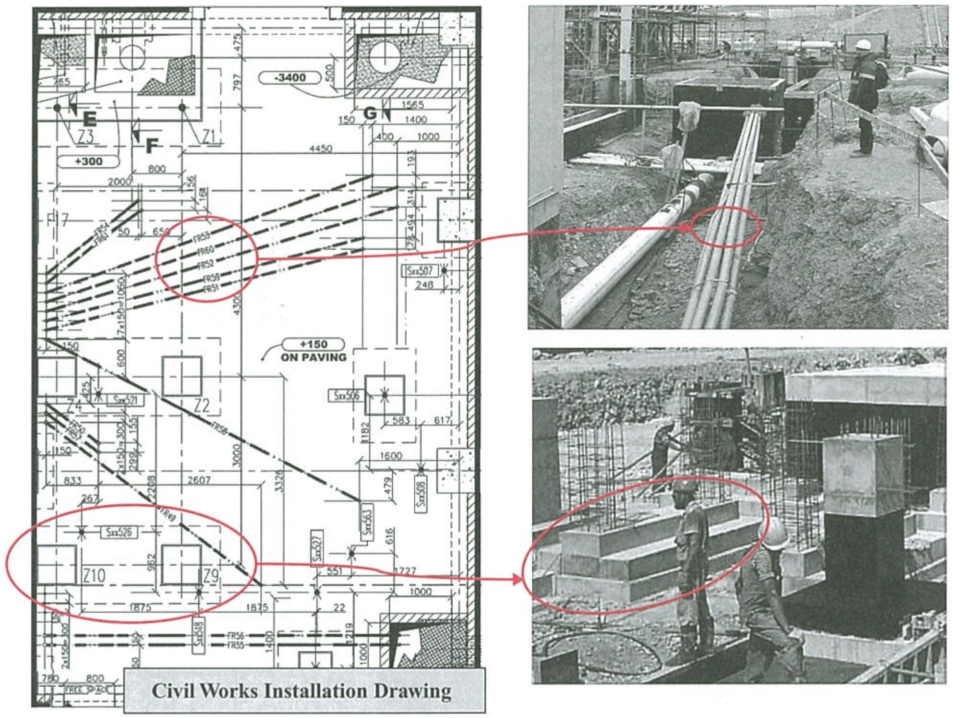
Steel Structure standard drawings





Civil Works Installation (CWI) drawings show the layout of all underground objects and networks. These are very detailed drawings showing, for each area, the location and elevation of the numerous underground objects: foundations (of equipment, structures, buildings, pipe supports, etc.), networks (process and utility services, cables, sewage, pits, roads, etc.).

Production of the CWI drawings ensures coordination of all underground objects in order to anticipate and prevent interferences.



Civil Works Installation Drawing

Priorities exist among the various underground objects and networks. The civil engineer locates the priority ones first, the next priorities will be located in the remaining available space. The sequence is as follows:

- Main equipment and pipe-racks foundations come first, as the main equipment positions are determined by the facility layout and cannot be changed,
- Gravity underground piping, such as sewage, comes second, as it must be sloped hence there is no flexibility in its routing. The space occupied by access pits, provided for cleaning at every change of direction shall also be accounted for,
- Underground pressure piping comes next, as its length must be minimized to reduce costs,
- Then come cables. Width and routes of cable trenches are advised by the corresponding disciplines (Electrical/Instrumentation/Telecom). The space occupied by cable pulling pits, duct banks at road crossing is also considered.

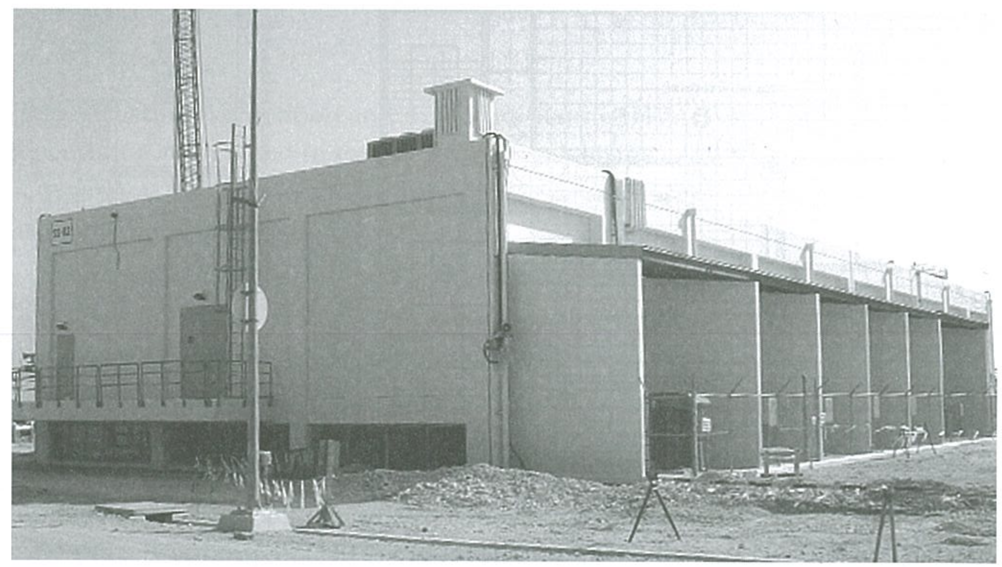
Civil Works Installation drawings are issued multiple times, to allow Site works to proceed step-wise. As the design progress, underground objects and networks are progressively designed, positioned and shown on the CWI drawings. Site installation starts by the deepest underground items. Accordingly, the CWI are first issued with the main equipment foundation only, then with added rain water collection and underground piping networks, then with cable trenches, pipe supports, etc. and lastly with paving.

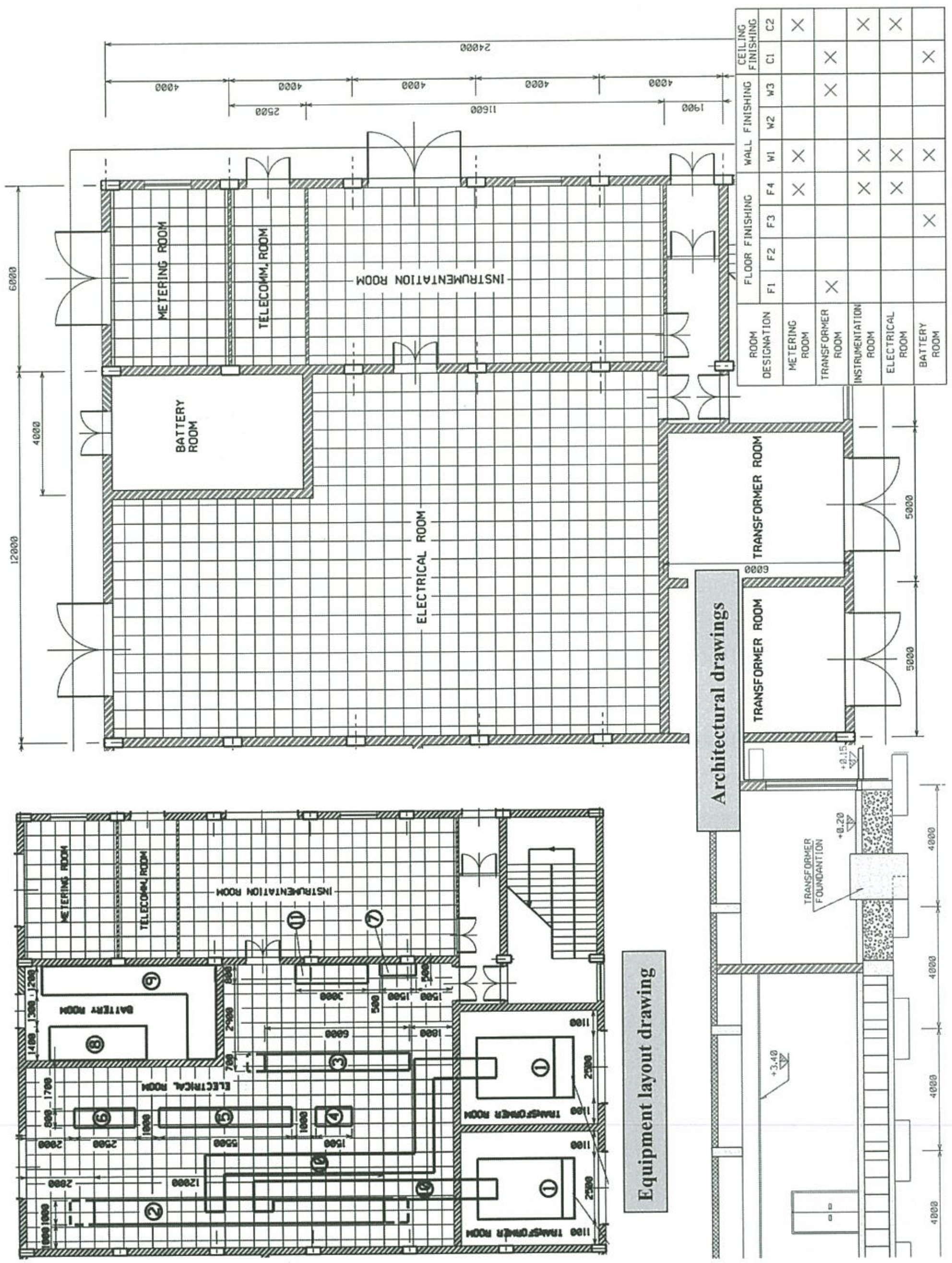
Before Civil can issue the paving drawings, all undergrounds must be defined and included. Indeed, after paving is cast, no underground can be installed. This requires the civil engineer to collect information from all disciplines. Civil will, for instance, collect information about pipe support location and loads and incorporate the corresponding foundations or re-inforcements in the paving drawings.

Building design also falls within the scope of the civil engineer. It starts by the architectural definition of the building, i.e., size/number of rooms, etc. which comes from the building function.

An Electrical sub-station, for instance, will be sized according to the number and size of housed switchboards, including provision for future ones. It will also be specified a false floor for cable routing, wall and floor openings for cable penetrations, etc.

The architectural requirements are grouped and shown on the Architectural drawings.



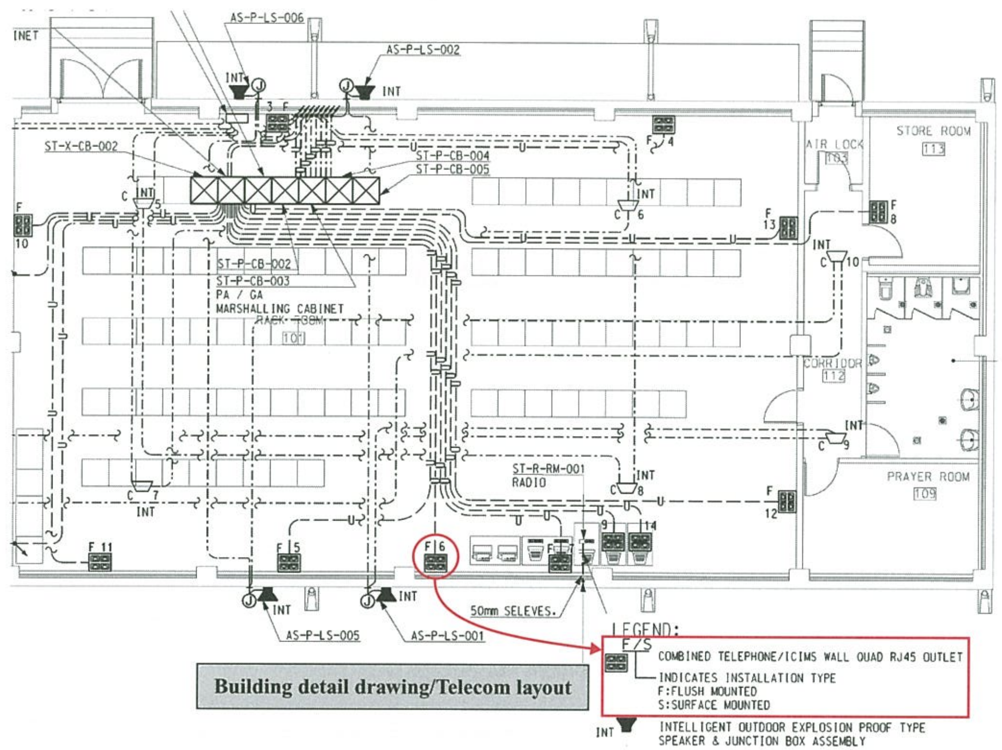


Architectural drawings

Equipment layout drawing

The building detailed design follows from the architectural requirements. Drawings in all trades, with a very high level of details, are produced.

Production of **building detail drawings**, such as the layout of Telecom equipment and cables, is usually sub-contracted to the building construction contractor.



Building detail drawing/Telecom layout

The Heating, Ventilation and Air Conditioning (HVAC) system is also part of the building design and in the Civil engineer's scope.

The HVAC system of a building is designed to provide the required climate inside the building/room.

Examples of climate control requirements are:

- forced ventilation, for mechanical equipment generating heat,
- heating (winter) & air-conditioning (summer) for rooms where personnel could be present,
- ventilation (heat evacuation) and air-conditioning (humidity control) in electrical equipment rooms,
- overpressure maintenance in electrical sub-stations located inside process units (to prevent dust/flammable gas to enter the building).

These requirements are further refined, for each room of each building, depending on its function:

- temperature to be maintained in permanently vs temporarily manned rooms (control room, offices vs corridors, change rooms, etc.),
- temperature to be maintained in equipment rooms.

The design of the HVAC system will depend on the above requirements, the environmental conditions (min/max temperature, humidity) at the plant location and the heat emissions from the equipment housed in the building (electrical cabinets and cables, mechanical equipment).

Heating, Ventilation & Air Conditioning (HVAC)

Climatic Data

Warm season

Design Temperature for Ventilation Systems	+ 26.2 °C
Design Temperature for Air Conditioning Systems	+ 30.8 °C
Absolute Maximum Temperature	+ 41.0 °C
Specific Enthalpy for Air Conditioning System Design	+ 66.8 kJ/kg
Relative Humidity	60 %

Internal Design Condition

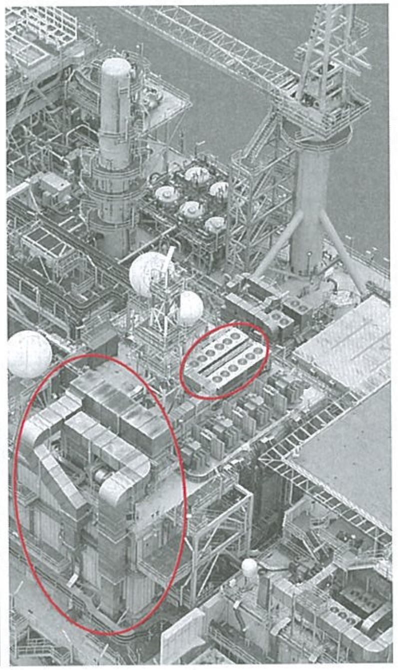
Warm season

Rooms with permanent working personnel + 24 °C

For Technological Control Rooms the following optimal rates shall be maintained round a year:

Temperature	22 ± 2 °C
Relative Humidity	50 ± 10 %

ESTIMATED HEAT EMISSION FROM EQUIPMENT (W/m^2 OF FLOOR AREA)	
CONTROL ROOMS	350
OFFICES, LABORATORIES, CLINIC	-
ELECTRICAL SWITCH ROOMS	50
KITCHENS	250
DINING AREAS	50
MAINTENANCE AREAS	15



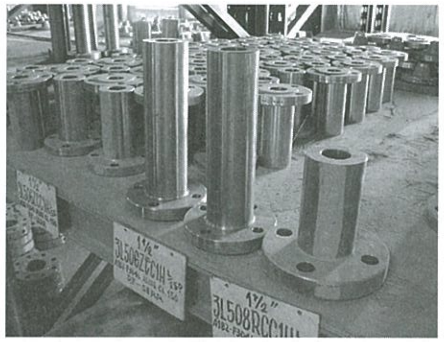
The HVAC of an industrial facility with a large number of buildings even in a non-extreme climate can be a significant electric power consumer. In such cases, HVAC power consumption impacts the sizing of the power generators.

In such cases, the buildings HVAC power consumption must be precisely evaluated at an early stage in the Project.

Heat emissions from equipment will not be available at this stage and will be estimated. A preliminary sizing of the HVAC equipment is done on this basis, resulting in an estimated power consumption. Such estimate is critical as a significant underestimate might lead to improper sizing of the power generators.

Chapter 8

Material & Corrosion



Materials & Corrosion discipline specifies the materials to suit the various service conditions. It also specifies how these materials will be protected against internal (from fluid) and external (atmospheric) corrosion.

Equipment and pipes material selection is done on the basis of required material strength (ability to withstand pressure), adequacy with fluid temperature and resistance to corrosion from the carried fluid.

The most common material encountered is Carbon steel, which is cheap and widely available. It comes in different grades. High strength grades are used for high pressure service, to reduce the wall thickness. For very low temperature, such as depressurization lines and cryogenic service, alloy steels, such as stainless steel, are required.

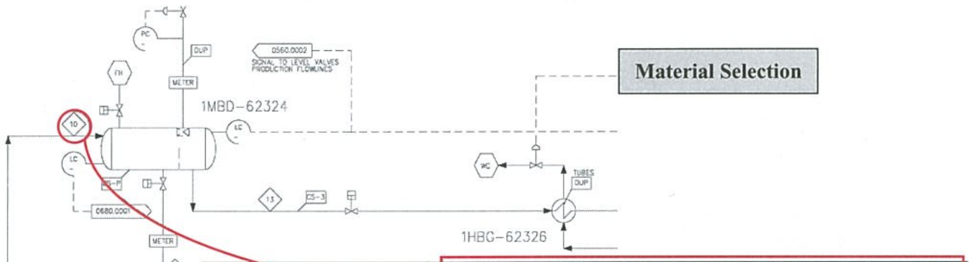
On Off-Shore platforms, where sea water is used for fire fighting, the fire water distribution ring is usually made of GRE (Glass Reinforced Epoxy). Highly alloyed steel, such as super duplex stainless steel, is used for strength at connections to fire water pumps.

Material selection is done on the basis of the calculated corrosion rate.

Steel pipes handling well stream effluent in Oil and Gas production facilities, for instance, are subject to corrosion by acid water. Indeed, the effluent from the wells contains a mixture of oil, water and gas. Gas contains CO_2, which makes the water acid. Acid water corrodes steel.

The total corrosion rate, i.e., loss of thickness, over the design life of the facility is calculated, based on the CO_2 pressure, the fluid temperature, etc.

If such loss is only a few mm, then ordinary carbon steel "CS" is selected, with an increased thickness, called a corrosion allowance "CA", typically up to 6 mm only.



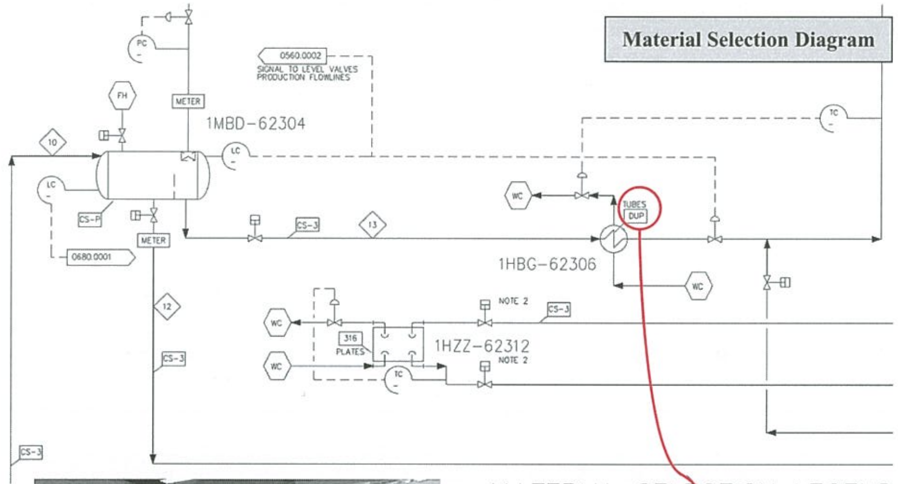
Origin / Termination	Press (Barg)	Mole CO2	CO2 pp (Barg)	Temp (C)	R (mm/y)	Corrected corrosion rate	Material + CA (mm)
Feed to HP separator	36,5	0,0042	0,15	96	3,25	0.06mm/yr	CS+3
To HP compressor inlet cooler	36,5	0,0086	0,31	96	5,93	3mm/yr	Duplex SS
Outlet to produced water treatment	36,5	0,0001	0,00	96	0,31	0.06mm/yr	CS+3
HP separator to crude oil cooler	36,5	0,0009	0,03	96	1,31	0.02mm/yr	CS+3
Feed to IP separator	3,5	0,0009	0,00	66	0,07	0.06mm/yr	CS+3

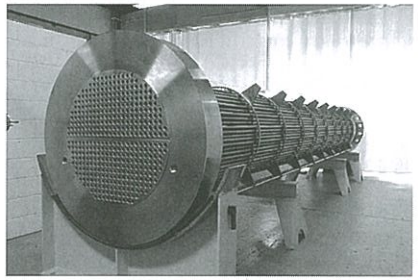
If the corrosion rate is high, a corrosion resistant alloy steel must be selected instead, such as stainless steel.

In some cases, it is possible to inhibit corrosion by injecting a chemical, called corrosion inhibitor, to decrease the corrosion rate. In such cases the pipes can remain in carbon steel but adequate corrosion monitoring, usually by means of weight loss coupons and corrosion probes, must be put in place to ensure inhibition is effective.

Carbon steel is not suitable where clean service is required and must be galvanized to ensure cleanliness.

Material selection is specified by the Material and Corrosion Engineer and shown on the **Material Selection Diagrams**.





MATERIAL SELECTION LEGEND:
1. CS-1 DENOTES CARBON STEEL W/ 0.8 mm CORROSION ALLOWANCE.
2. CS-2 DENOTES CARBON STEEL W/ 1.6 mm CORROSION ALLOWANCE.
3. CS-3 DENOTES CARBON STEEL W/ 3.2 mm CORROSION ALLOWANCE.
4. CS-4 DENOTES CARBON STEEL W/ 6.4 mm CORROSION ALLOWANCE.
5. CS-5 DENOTES 316L CLAD CS-3.
6. CS-P DENOTES CARBON STEEL WITH PHENOLIC LINED
7. 316L DENOTES 316L TYPE STAINLESS STEEL.
8. DUP DENOTES 2205 DUPLEX STAINLESS STEEL.

Materials have very different ability to withstand temperature and corrosion. Many of them, however, have the same visual apppearance. In order to avoid confusion, for instance use of the wrong type of alloy during piping fabrication, which could lead to catastrophic line rupture, adequate marking and inspection of materials is put in place.

Marking is specified in the piping material purchase specification. On top of that, Positive Material Identification (PMI) is carried out at Site for alloy steels. PMI determines the chemical composition of the steel, allowing to differentiate two identically looking alloys.

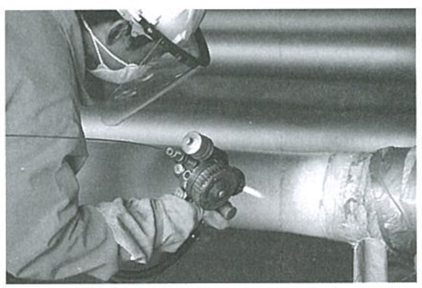
DAILY POSITIVE MATERIAL IDENTIFICATION REPORT FOR PIPING			
ISOMETRIC No. : F65A775RBD1016 3ROJL	✓ FOR ACCEPT	× FOR REJECT	REPORT No : T7-7539 PAGE No : 01

MATERIAL TYPE	WELD METAL TYPE	PMI EQUIPMENT :
A : 304L B : 304H C : 316L D : NiCrMo4 E : Other Alloy	A : 308L B : 308H C : 316L D : NiCrMo4 E : Other Alloy	NITON XLI/XLT

SPOOL NO.	W.No. ~~SW~~ / FW ✓	BASE METAL 1	WELD METAL	BASE METAL 2	EXAMINED BY	DATE
	06	A ✓	A ✓	A ✓	AK	30-03-09

Mo	Nb	W	Ni	Fe	Mn	Cr	V	Ti
0.24 ± 0.07	0.03 ± 0.03	0.01 ± 0.28	8.46 ± 1.39	68.87 ± 2.15	2.26 ± 1.01	18.59 ± 1.25	0.25 ± 0.46	0.26 ± 0.57
0.26 ± 0.06	0.00 ± 0.01	0.00 ± 0.22	8.98 ± 1.13	67.51 ± 1.73	2.05 ± 0.78	19.31 ± 1.02	0.00 ± 0.51	0.55 ± 0.52
0.23 ± 0.09	0.02 ± 0.03	0.00 ± 0.36	8.79 ± 1.81	71.85 ± 2.81	0.63 ± 1.10	17.69 ± 1.57	0.22 ± 0.55	0.00 ± 1.10
0.28 ± 0.06	0.01 ± 0.01	0.00 ± 0.24	8.29 ± 1.11	70.00 ± 1.75	2.64 ± 0.80	18.20 ± 0.99	0.01 ± 0.29	0.00 ± 0.65

The corrosion engineer also specifies the protection of structures and pipes against external (atmospheric) corrosion.



Protection of outdoor steel from corrosion is achieved by coating. The coating can be a metallic coating, such as Zinc (galvanizing) or Aluminium (very severe environment). For less severe requirements, steel is painted, after thorough surface preparation (sand blasting).

Painting is done following a painting system. The painting system defines the number of layers, the composition and the thickness of each layer. Different painting materials are used for pipes in low temperature and high temperature service.

The **painting specification** defines the surface preparation and paint system to be used for each application. Reference is made to an International code for the definition of the colors.

No.	Pipework Category	Painting System
1.	Pipes, factory bends, tees and other fittings with service temperature up to 80°C	*Epoxyvinyl System* Primer: inorganic zinc primer, DFT 75 µm min. Intermediates: two coats of epoxyvinyl paint, DFT 80+100 µm. Top coat for final color: epoxy paint, DFT 40 µm min. Total DFT 295 µm min.
2.	Pipes, factory bends, tees and other fittings with service temperature over 80°C	*Silicone System* Primer: inorganic zinc primer, DFT 75 µm min. Intermediates: two coats of silicone paint, DFT 25+25 µm. Top coat for final color: silicone paint, DFT 25 µm min. Total DFT 150 µm min.

Protection of submerged steel, e.g., internals of vessels, Off-Shore platform jacket, sealines, is done by means of sacrificial metallic attachments.

Such attachments, made of a less noble metal than steel, corrode first and, as they are electrically connected to the protected steel, prevent the corrosion of the latter. Sacrificial anodes are usually in zinc. They can be replaced once consumed.

Protection against corrosion of steel buried in the ground, e.g., underground piping services, is also achieved by coating. A mechanically stronger coating than painting is required for such application, usually in the form of a polymer applied at the factory on the straight pipes, fittings, etc. Field joints are coated at Site. The **coating specification** defines the requirements of the coating, such as surface preparation, number, material and thickness of layers.

Buried steel pipes are usually protected against corrosion by an additional system, called the **cathodic protection** system.

Cathodic protection consists of maintaining the steel pipe at a low negative potential. This is done by flowing an electric current between the pipe and an anode buried close to it. Anodes are surrounded by material of low resistance, such as coke, in order to ensure the flow of the electric current. Reference electrodes measuring the pipe potential are provided to control that the pipe is effectively protected.