FLUOR®

sasol
reaching new frontiers

SASOL CHEMICALS (USA) LLC

LAKE CHARLES CHEMICALS PROJECT (LCCP)

LCCP ZIEGLER EXPANSION

PROCESS CONTROL NARRATIVE
SECTION 5500 – ALCOHOL PREPARATION

DOCUMENT NUMBER:
L2CC-030-70-EN-5500

FLUOR
IFC – Issued for Construction
May 15, 2018

Strictly Confidential

Fluor Project No: L2CC
WBS No: 030

REV	DATE	PAGES	DESCRIPTION	ORIG.	CHKD	FLUOR APPROVED BY	CLIENT APPROVED BY
5	03-23-18	79	Re-Issued for Construction	PSP	AJD	RPD	
4	8-Feb-17	71	Issued for Construction	SMB	AJD	RPD	
3	4-Nov-16	71	Issued for Construction	SMB	AJD	RPD	
2	21-July-16	72	Issued for Construction	SMB	AJD	RPD	
1B	27-Aug-15	66	Issued for HAZOP	SMB	MNC	RPD	
1A	04-Apr-15	58	Issued For Design	SMB	KRM	RPD	
1	08-Dec-14	52	Issued For Design	SMB	KRM	RPD	

SASOL CHEMICALS (USA) LLC

LAKE CHARLES CHEMICALS PROJECT (LCCP)

LCCP ZIEGLER EXPANSION

PROCESS CONTROL NARRATIVE
SECTION 5500 – ALCOHOL PREPARATION

DOCUMENT NUMBER:
L2CC-030-70-EN-5500

Strictly Confidential

Fluor Project No: L2CC
WBS No: 030

REV	DATE	PAGES	DESCRIPTION	ORIG.	CHKD	FLUOR	CLIENT
5	03-23-18	79	Re-Issued for Construction	PSP	AJD	RPD	
4	8-Feb-17	71	Issued for Construction	SMB	AJD	RPD	
3	4-Nov-16	71	Issued for Construction	SMB	AJD	RPD	
2	21-July-16	72	Issued for Construction	SMB	AJD	RPD	
1B	27-Aug-15	66	Issued for HAZOP	SMB	MNC	RPD	
1A	04-Apr-15	58	Issued For Design	SMB	KRM	RPD	
1	08-Dec-14	52	Issued For Design	SMB	KRM	RPD	
						APPROVED BY	

RECORD OF REVISIONS

Revision No.	Date	Description
1	12/8/2014	Incorporated comments from P&ID and narrative review. Added Hydrolysis reactor level to flow control mode selector. Added 4.3.9 Dehydrator Tower Feed Controller. Updated ram and flush sequence. Updated spare pump control for P030-5514 and P030-5520. Added 4.3.19 Tank Emissions Counter. Updated I-30-9013 and removed I-16. Added references to I-30-5521 and I-30-5522. Added I-30-5523.
1A	4/2/2015	Transferred S-5500 Utilities from L2CC-030-70-EN-8500 to this narrative, sections 3.3.5, 3.3.6, 4.4, 5.11, 5.12, 5.13, and 5.14. Updated the P&ID and PFD reference list. Added vibration interlocks for air coolers and condensers, 5.16 through 5.29. Updated instrument tag numbers. Updated Appendix II.
1B	8/27/2015	Removed “030” or “006” from instrument tag numbers. Updated controls based on Client requirements.
2	7/21/2016	Updated per S5500 PH/LOPA. Updated per changes caused by LCCP-SAS-30-PR-EDI-0039. Added SIS interlocks SI-30-5501/5502/9007/9008/9009. Updated per EDI PHA/LOPA. Update based on latest P&IDs.
3	4-Nov-16	Minor Updates. Updated reset requirements.
4	8-Feb-17	Added section for additional requirements and referenced all SIS C&Es
5	23-Mar-18	Following updates made based on Software FAT clarifications with client and any new FDCNs past last IFC cycle. - Section 3.3.3 Ethanol purge flow control description - Section 4.3.1 Tagging typos - Section 4.3.2 Ramping recovery control - Section 4.3.3 Hydrolysis water feed composition calculation to use an External Reset Feedback (BKCAL_IN) along with some tagging changes - Section 4.3.4 Tank definitions and respective level indications updated - Section 4.3.5 Removed built-in maintenance timer - Section 4.3.6 Note about references on AYC loop coefficients and engineering range for the controller added - Section 4.3.7 Feedback ratio control using FFC53201 added using an rolling average PV equation - Section 4.3.8 Engineering switch details added - Section 4.3.9 Alternate control tray and units for QC/FC defined - Section 4.3.10 Definitions of constraints to ramp logic improved - Section 4.3.13 Tagging and interface calculation updated - Section 4.3.16 Reflux equation constant values updated - Section 4.3.19 Variable stroke actuator turndowns and P030-5517A/B pump speeds defined - Section 4.3.20 (old) Ethanol Tower Accumulator Purge Deleted - Section 4.3.20 (new) Flush/Collection drum out flow local panel control defined - Section 4.3.21 (previously 4.3.22) - Section 4.4 Simple Loops – Valve actions and split ranges updated - Section 4.5.2 Ram Flush Sequence – Bypassed controllers updated, reference to I-30-5511 added - Section 5.1 – I-30-5511 Interlock bypass changed to manual, and reset condition added

		- Section 5.8 – I-30-5519 Spare pump switching and auto-start logic updated for both possible options

TABLE OF CONTENTS

1.0 HOLDS 6
2.0 REFERENCE DOCUMENTS 7
2.1 P&IDs 7
2.2 Process Flow Diagrams 9
2.3 Cause and Effect Diagram 9
2.4 Other references 9
3.0 PROCESS DESCRIPTION 10
3.1 Purpose 10
3.2 General Description 10
3.3 Detailed Description 10
3.4 Overall Diagram (Sketch is for reference only) 16
4.0 CONTROL STRATEGIES 17
4.1 General 17
4.2 Advanced Process Control Strategies (multiple inputs and outputs) 17
4.3 Complex Control Strategies (multiple inputs single outputs) 18
4.4 Simple loops 54
4.5 Sequential Control Strategies 60
5.0 PROCESS INTERLOCKS 61
5.1 I-30-5511: Alkoxide Low-Low Flow Isolation 61
5.2 I-30-5512: Hydrolysis Reactor (R030-5501) High-High Interface Level 61
5.3 I-30-5513: Ram and Flush Sequence 61
5.4 I-30-5515: Butanol Stripper (W030-5504) High-High Pressure 61
5.5 I-30-5516: Ethanol Tower (W030-5502) High-High Pressure 62
5.6 I-30-5517: Dehydrator Tower (W030-5501) High-High Pressure 62
5.7 I-30-5518: Butanol Tower (W030-5503) High-High Pressure 62
5.8 I-30-5519: P030-5514 and P030-5520 Spare Pump 63
5.9 I-30-5520: S-5500 Flush/Collection Drum (D030-5513) Low-Low Pressure 63
5.10 I-30-5521: Hot Demin Water Pumps (P030-5522A/B) Low-Low Level 63
5.11 I-30-5522: Hot Demin Water Drum (D030-5521) High-High Level 64
5.12 I-30-5523: Condensate Collection Drum (D030-5520) Low-Low Level 64
5.13 I-30-5524: Condensate Collection Drum (D030-5520) High-High Level 64
5.14 I-30-5525: Surface Drainage Sump Pump 64
5.15 I-30-5526: High-High Fan Vibration 65
5.16 I-30-5527: High-High Fan Vibration 65
5.17 I-30-5528: High-High Fan Vibration 65
5.18 I-30-5529: High-High Fan Vibration 65
5.19 I-30-5530: High-High Fan Vibration 65
5.20 I-30-5531: High-High Fan Vibration 66
5.21 I-30-5532: High-High Fan Vibration 66
5.22 I-30-5533: High-High Fan Vibration 66
5.23 I-30-5534: High-High Fan Vibration 66

5.24 I-30-5535: High-High Fan Vibration......67
5.25 I-30-5536: High-High Fan Vibration......67
5.26 I-30-5537: High-High Fan Vibration......67
5.27 I-30-5538: High-High Fan Vibration......67
5.28 I-30-5539: High-High Fan Vibration......67
5.29 I-30-5540: Low Recycle Butanol Flow......68
5.30 I-30-5541: Butanol Stripper Bottoms Pump......68
5.31 I-30-5542: Butanol Tower High-High Level......68
5.32 I-30-5543: Loss of Nitrogen Sweep......68
5.33 I-30-5544: Refrigerated Vent Knockout Drum......69
5.34 I-30-5545: Low-Low level P030-5516A/B Pump Protection......69
5.35 I-30-5546: P030-5512A/B Autostart......69
5.36 I-30-5547: Eductor Control......69
5.37 I-30-5548: High-High Level in D030-5513......70
5.38 I-30-5550: P030-5527 Bearing Flush......70
5.39 I-30-9011: Hydrolysis Water Storage Tank (T030-5501) High-High Level......70
5.40 I-30-9012: Hydrolysis Water Storage Tank (T030-5501) Low-Low Pressure......71
5.41 I-30-9013: Crude Alcohol Storage Tank (T030-5503) and Section 550 Recycle Butanol Storage Tank (FB-552) High-High Level......71
5.42 I-30-9014: Crude Alcohol Storage Tank (T030-5503) Low-Low Pressure......72
5.43 I-30-9015: Alcohol / Water Draw Pump (P030-5518) Low-Low Flow......72
5.44 I-30-9016: Swing Tank Storage Tank (T030-5502) High-High Level......72
5.45 I-30-9017: Swing Tank Storage Tank (T030-5502) Low-Low Pressure......74
5.46 I-30-9018: Flare Knockout Drum Backflow to T030-5501 Protection......75
5.47 I-30-9019: Flare Knockout Drum Backflow to T030-5502 Protection......75
5.48 I-30-9020: Flare Knockout Drum Backflow to T030-5503 Protection......75
5.49 Additional requirements......75
APPENDIX......77
I. Existing Ziegler DeltaV Links Required for Expansion Project......77
II. Existing Ziegler DeltaV Configuration Modification Required for Expansion Project......78

1.0 HOLDS

Section	Description	Due Timeframe
	ABB to DeltaV Level and Temperature displays from tanks in the ABB system.	Final configuration
	Further Development Needed: Control over rides in S-5500 which prevent high, high-high, and high-high-high levels in process vessels. These overrides can help ensure that the negative consequences of a complete and sudden process shutdown are experienced only very rarely, or never.	Prior to Startup of Plant

2.0 REFERENCE DOCUMENTS

2.1 P&IDs

Drawing	Description
L2CC-030-25-PI-5510	Utility – Cooling Water
L2CC-030-25-PI-5511-01	S-5500 Nitrogen KO Drum
L2CC-030-25-PI-5512-01	S-5500 Cold Demin Water Distribution
L2CC-030-25-PI-5512-02	S-5500 Hot Demin Water Distribution
L2CC-030-25-PI-5512-03	S-5500 Hot Demin Water Storage System
L2CC-030-25-PI-5513-01	Utility – 30# Steam Distribution
L2CC-030-25-PI-5520	Condensate Collection Drum and Pumps
L2CC-030-25-PI-5521	150# To 30# Steam Desuperheater
L2CC-030-25-PI-5523	S-5500 Utility – 150# Steam Distribution
L2CC-030-25-PI-5524	Utility System – S-5500/6000 Instrument Air and Plant Air
L2CC-030-25-PI-5525	Alcohol Preparation S-5500 Hydrolysis Water Filters & Heaters
L2CC-030-25-PI-5526	Alcohol Preparation S-5500 Hydrolysis Reactor Feed
L2CC-030-25-PI-5527	Alcohol Preparation S-5500 Hydrolysis Reactor
L2CC-030-25-PI-5528	Alcohol Preparation S-5500 Wet Crude Alcohol Cooler
L2CC-030-25-PI-5529	Alcohol Preparation S-5500 1st Stage Mixing Drum
L2CC-030-25-PI-5530	Alcohol Preparation S-5500 1st Stage Phase Separator
L2CC-030-25-PI-5531	Alcohol Preparation S-5500 2nd Stage Mixing Drum
L2CC-030-25-PI-5532	Alcohol Preparation S-5500 2nd Stage Phase Separator
L2CC-030-25-PI-5533	Alcohol Preparation S-5500 Alcohol Recirculation Pumps
L2CC-030-25-PI-5534	Alcohol Preparation S-5500 Butanol Stripper Tower
L2CC-030-25-PI-5535	Alcohol Preparation S-5500 Butanol Stripper O/H Condenser
L2CC-030-25-PI-5536	Alcohol Preparation S-5500 Butanol Stripper Bottoms Pumps
L2CC-030-25-PI-5537	Alcohol Preparation S-5500 Butanol Stripper Bottoms Slurry Cooler
L2CC-030-25-PI-5538	Alcohol Preparation S-5500 Dehydrator Feed Water Separator
L2CC-030-25-PI-5539	Alcohol Preparation S-5500 Dehydrator Tower Feed Preheater
L2CC-030-25-PI-5540	Alcohol Preparation S-5500 Dehydrator Tower
L2CC-030-25-PI-5541	Alcohol Preparation S-5500 Dehydrator Tower O/H Condenser & Accumulator
L2CC-030-25-PI-5542	Alcohol Preparation S-5500 Dehydrator Tower Bottoms Pumps
L2CC-030-25-PI-5543	Alcohol Preparation S-5500 Dehydrator Water Phase/Ethanol Feed Pumps

Drawing	Description
L2CC-030-25-PI-5544	Alcohol Preparation S-5500 Butanol Tower
L2CC-030-25-PI-5545	Alcohol Preparation S-5500 Butanol Tower O/H Condenser & Accumulator
L2CC-030-25-PI-5546	Alcohol Preparation S-5500 Butanol Tower Bottoms Pumps
L2CC-030-25-PI-5547	Alcohol Preparation S-5500 Butanol Tower Reflux Pumps
L2CC-030-25-PI-5548	Alcohol Preparation S-5500 Ethanol Tower
L2CC-030-25-PI-5549	Alcohol Preparation S-5500 Ethanol Tower O/H Condenser & Accumulator
L2CC-030-25-PI-5550	Alcohol Preparation S-5500 Ethanol Tower Bottoms Pumps
L2CC-030-25-PI-5551	Alcohol Preparation S-5500 Ethanol Tower Reflux Pumps
L2CC-030-25-PI-5552	Alcohol Preparation S-5500 Ethanol Tower Bottoms Cooler
L2CC-030-25-PI-5553	Alcohol Preparation S-5500 Ammonia Absorber Tower
L2CC-030-25-PI-5554	Alcohol Preparation S-5500 Surface Drainage Header
L2CC-030-25-PI-5555	Alcohol Preparation S-5500 Flush Collection Drum
L2CC-030-25-PI-5556	Alcohol Preparation S-5500 Refrigerated Vent Knockout Drum
L2CC-030-25-PI-5557	Alcohol Preparation S-5500 Refrigerated Vent Knockout System
L2CC-030-25-PI-5558	Alcohol Preparation S-5500 Flush Collection Drum Pumps
L2CC-030-25-PI-5559	Alcohol Preparation S-5500 Blowdown Header
L2CC-030-25-PI-5580	Utility System – S-5500/6000 Plant Water and EW/SS
L2CC-038-25-PI-5611	Alumina Spray Dryer/Handling S-5500 Alumina Slurry Surge Drum T038-5604
L2CC-030-25-PI-9060-01	Hydrolysis Water Storage T030-5501
L2CC-030-25-PI-9060-02	Hydrolysis Water Storage S-5500 Hydrolysis Water Feed Pumps
L2CC-030-25-PI-9061-01	Crude Alcohol Storage T030-5503
L2CC-030-25-PI-9061-02	Crude Alcohol Storage S-5500 Dehydrator Tower Charge Pumps
L2CC-030-25-PI-9062-01	S-5500 Recycle Butanol Swing Tank and Pumps
L2CC-030-25-PI-9065	S-5500 Alkoxide Charge Pumps to Hydrolysis Reactor
L2CC-006-25-PI-9067	S-5500 Recycle Butanol Feed Pumps P030-5505A/B
LCCC-074.9-PI-123-D	South Tank Farm Alkoxide & Alco 16-18 Tanks FB-657/720
LCCC-074.9-PI-131-D	South Tank Farm Butanol Tank T6-527
LCCC-074.9-PI-144-D	South Tank Farm Recycle Butanol / Hydrolysis Condensate Tank FB-552
LCCC-074.9-PI-189-D	South Tank Farm Hydrolysis Water / Recycle Butanol Pumps

2.2 Process Flow Diagrams

Drawing	Description
L2CC-030-25-PF-5501	Process Flow Diagram Section 5500 Hydrolysis Reactor
L2CC-030-25-PF-5502	Process Flow Diagram Section 5500 1st AND 2nd Stage Mixing and Separation
L2CC-030-25-PF-5503	Process Flow Diagram Section 5500 Butanol Stripper
L2CC-030-25-PF-5504	Process Flow Diagram Section 5500 Crude Alcohol Feed System
L2CC-030-25-PF-5505	Process Flow Diagram Section 5500 Dehydrator Tower
L2CC-030-25-PF-5506	Process Flow Diagram Section 5500 Butanol Tower
L2CC-030-25-PF-5507	Process Flow Diagram Section 5500 Ethanol Tower
L2CC-030-25-PF-5508	Process Flow Diagram Section 5500 Miscellaneous Support Systems
L2CC-030-25-UF-5509-01	Utility Flow Diagram S-5500 Condensate Collection
L2CC-030-25-PF-5510	Process Flow Diagram S-5500 Hot Demin Water System

2.3 Cause and Effect Diagram

Drawing	Description
L2CC-70-25-EN-5501	Process Interlock Cause and Effect Diagrams Section 5500 Alcohol Preparation
L2CC-70-25-EN-5502	Safety Interlock Cause and Effect Diagrams Section 5500 Alcohol Preparation

2.4 Other references

Document	Description
L2CC-030-70-EN-0100	LCCP Ziegler Expansion Safety Requirement Specification (SRS)

3.0 PROCESS DESCRIPTION

To improve readability, the numeric portion of the tag name of all instrument and control tags below is shown as five digits instead of the full eight digits. The first three digits, which are not shown, are implied as either Area 006, 030, or 038 and can be determined by the unique Section numbers for all of the Ziegler Plant. For a more comprehensive explanation of the numbering for the Ziegler Sections, refer to L2CC-000-00-PR-0002.

3.1 Purpose

The 5500 Section includes the Hydrolysis Reactor (R030-5501), mixing and separation vessels which extract heavy alcohol from slurry, Butanol Stripper Tower (W030-5504), Dehydrator Tower (W030-5501), Butanol Tower (W030-5503), Ethanol Tower (W030-5502), Ammonia Absorber Tower (W030-5505), and associated equipment whose purpose is to react the alkoxide feed with water to produce alcohols and alumina slurry. This equipment then separates the products into ethanol, butanol, alumina slurry, and C6+ crude alcohol streams.

3.2 General Description

Stripped aluminum alkoxide is reacted with hydrolysis water consisting of Demineralized water, condensate, ammonia, and low levels of alcohol to form ALFOL® alcohol and aqueous alumina slurry. Crude alcohol produced from this reaction contains approximately 12 weight percent water and a small amount of entrained slurry. The alumina slurry produced from this reaction contains approximately 80 weight percent water, 10 percent entrained/dissolved alcohol, and about 10 percent alumina solids. The water, ethanol, and butanol are removed from the C6+ crude alcohol by distillation. A two-stage extraction system separates C6+ alcohol from alumina slurry. Residual C2/C4 alcohol in the slurry is removed from the alumina slurry in the butanol stripper.

3.3 Detailed Description

Refer to overall block diagram in 3.3.4 for the following descriptions. For detailed explanation of the controls, refer to section 4 (Control Strategies).

3.3.1 Hydrolysis, Extraction, Mixing, and Separation Vessels

Solvent-free aluminum alkoxide is pumped, on flow control (FC53130), from existing storage tank, FB-657 into an agitated Hydrolysis Reactor (R030-5501) via alkoxide Charge Pumps (P030-5501A/B). The alkoxide enters the reactor through one of two available injection nozzles into the aqueous phase to ensure it reacts rapidly with hydrolysis water to form crude alcohol and alumina. The injection nozzles are equipped with ram valves designed to push through any coating that builds up on the inside of the nozzle; the process of clearing this build-up is activated by the Ram-and-Flush sequence. The ram valves are designed to allow alkoxide to flow during the ram and flush sequence.

The hydrolysis water consists of steam condensate, demineralized water, and recycled water from the fractionation system (Dehydrator Tower O/H Accumulator water phase and Ammonia Absorber Tower) and is introduced through a nozzle 180 degrees opposite the alkoxide injection nozzles. Demineralized water or condensate is required to prevent process contamination of the alumina product with iron, calcium, and other impurities found in groundwater. Hydrolysis water is stored in the new Hydrolysis Water Storage Tank (T030-5501).

A 0.5% – 1.5% concentration of ammonia (manually sampled) is required in the hydrolysis water to prevent the formation of emulsions in the reactor and separator vessels. Ammonium hydroxide is recovered from the Ethanol Tower O/H Accumulator (D030-5510) vapor in the Ammonia Absorber Tower (W030-5505) using demin water to absorb the ammonia-laden vapor. The ammonium hydroxide liquid from the base of the tower is recycled back to the process, normally flowing to the suction of the dehydrator O/H accumulator water phase pumps (P030-5513A/B) and then to the hydrolysis reactor. Fresh ammonium hydroxide is stored in existing storage drum (D6-529), which provides ammonia storage for both sections 550 and 5500.

The total hydrolysis water (made of several streams) is calculated and flow-controlled (FYC53123), to the Hydrolysis Water Steam Ring/Direct Steam Injection Heater (X030-5519) where it is contacted with 350 psig saturated steam (which also contributes to the hydrolysis water makeup) to heat the water before entering Hydrolysis Reactor (R030-5501). The water flow is set according to the alkoxide-to-water ratio controller (FFC53123) that gets its setpoint from the Butanol Stripper Tower (W030-5504) bottoms %solids controller (AYC53259), which uses lab analysis data. Fouling of the mass flow meter is the reason for updating the controller automatically.

When hydrolysis water reacts with stripped alkoxide, crude alcohol (ranging from C2 to C20+) and alumina are created. The range of the alcohol produced forms a Poisson distribution with the medium weight alcohols (about C10) at the center of the graph. Excess reaction water is added to produce alumina slurry with 10% solids after the alcohol has been extracted.

In section 3000, ethylene groups are added to ATE to make aluminum alkyls of various chain lengths. The number of groups added is referred to as the M value. The lower the M value, the more to left of the graph of the distribution of alcohol production shifts (i.e. more C6 and less C20+). Also the lower the M value, the higher the % solids exiting the Butanol Stripper Tower bottoms at a fixed ratio of hydrolysis water to stripped alkoxide. Production of TAP alcohol has a similar effect.

With the exception of ethanol and butanol, the alcohols produced from the hydrolysis reaction are relatively insoluble in the alumina water/slurry phase. Therefore, the S-5500 Hydrolysis Reactor (R030-5501) is designed to separate the wet crude alcohol and alumina phases within the vessel.

Using nitrogen, pressures of approximately 80 psig (PC53138) on the Hydrolysis Reactor (R030-5501), 60 psig (PC53174) on the 1st Stage Separator Drum (D030-5502), and 40 psig (PC53198) on the 2nd Stage Separator Drum (D030-5504) are maintained to enable transfer of the alumina slurry from vessel to vessel via pressure differential. The alumina slurry from the Hydrolysis Reactor (R030-5501) is transferred directly, via interface level-to-flow control (LC53200 to FC53201), to the butanol extraction system / alumina purification system. The crude alcohol is transferred, via level-to-flow control (LC53136 to FC53163), to the Wet Crude Alcohol Storage Tank (T030-5503) in the tank farm area after cooling by the Wet Crude Alcohol Product Cooler (X030-5516).

Pumping is required to transfer the alcohol stream from the 2nd Stage Separator Drum (D030-5504) to the 1st Stage Mixing Drum (D030-5503); the alcohol phase is level-controlled (LC53199), via pumps P030-5503A/B. Alcohol from the 1st Stage Separator Drum (D030-5502) is pumped to the Hydrolysis Reactor (R030-5501) on alcohol level-to-flow control (LC53175 to FC53221) via pumps P030-5503B/C. Pump P030-5503B is a common spare for both streams.

3.3.2 Alumina Slurry Purification

The alumina/water slurry phase from the Hydrolysis Reactor (R030-5501) contains dissolved and entrained alcohol which must be removed during alumina purification to reduce carbon content, alcohol production losses, air emissions, and potentially explosive spray dryer conditions. Ethanol and butanol can be easily removed from the slurry by steam stripping, but the C6+ alcohol removal requires a two-step process involving: a two-stage counter-flow extraction operation using recycle butanol to extract the C6+ alcohol, followed by steam stripping to remove residual ethanol and butanol.

Alumina slurry is on slurry/alcohol interface level-to-slurry flow control (LC53147 to FC53131) under nitrogen pressure from the Hydrolysis Reactor (R030-5501) to the 1st Stage Mixing Drum (D030-5503). In the 1st Stage Mixing Drum (D030-5503), the slurry mixes with the recycle butanol wash stream from the 2nd Stage Separator Drum (D030-5504), which is flowing counter-currently to the slurry stream. The effluent from the 1st Stage Mixing Drum (D030-5503) separates in the 1st Stage Separator Drum (D030-5502).

The alumina slurry is transferred from the 1st Stage Separator Drum (D030-5502) to the 2nd Stage Mixing Drum (D030-5501) on interface level control (LC53176). In the 2nd Stage Mixing Drum (D030-5501), the slurry is mixed with heated fresh recycle butanol from the Recycle Butanol Tank (FB-552) on flow control (FFC53215). The amount of recycle butanol is a critical control parameter; it should be based on the amount of %Al in the feed alkoxide. For control purposes, the surrogate for % aluminum in alkoxide feed is the slurry flow from the second-stage mixing drum. The alcohol/slurry mixture from the 2nd Stage Mixing Drum (D030-5501) is transferred to the 2nd Stage Separator Drum (D030-5504).

The alcohol phase from the 2nd Stage Separator Drum (D030-5504) which is pumped by 2nd Stage Alcohol Pumps (P030-5503A/B) to the 1st Stage Mixing Drum (D030-5503) is part of the counter-flow extraction process. The slurry in 2nd Stage Separator Drum (D030-5504) is controlled by alcohol/slurry interface level-to-feed flow control (LC53200 to FC53201) under nitrogen pressure to the top tray of the Butanol Stripper Tower (W030-5504).

Desuperheated 30 psig steam is used to strip butanol and lighter components from the slurry. The steam is desuperheated with demineralized water to about 5°F above saturation. Excessive steam superheat condition evaporates water, which causes thickening of the slurry leading to increased tray fouling in the Butanol Stripper Tower (W030-5504). The amount of superheat is calculated as the difference between the stripper bottoms temperature (TI53234C) and the desuperheater steam outlet temperature (TI53234). TYC53234 controls the amount of superheat by adjusting the flow of water (FC53230) to the de-superheat station, Z030-5502. Operator sets the total desuperheated steam flow rate via the controller (FYC53229). The latter represents the sum of the steam flow (FC53229) and the water flow (FC53230).

The Butanol Stripper O/H Cyclone (D030-5505) removes entrained liquid and alumina particles from the butanol stripper overhead vapor stream and combines them with the fresh feed stream to Butanol Stripper Tower (W030-5504). The overhead stream is condensed and sub cooled in Butanol Stripper O/H Condenser1 (X030-5515) and combined with the dehydrator tower overhead stream in the Dehydrator O/H Accumulator (D030-5509). The alcohol-free slurry from the Butanol Stripper Tower (W030-5504) bottoms is pumped on level-to-flow-to-speed control (LC53237 to FC53259 to SC53251/53252) by the Butanol Stripper Bottoms Pumps (P030-5504A/B) through a cooler and to the Stripped Alumina Slurry Surge Drum (T038-5604).

3.3.3 Alcohol Fractionation

Crude alcohol containing approximately 12 weight percent water is fed by flow control (FC53288) to the Dehydrator Tower (W030-5501) from Wet Crude Alcohol Storage Tank (T030-5503). Prior to entering the column, the alcohol feed is filtered to remove entrained slurry, passes through the Dehydrator Feed Water Separator (D030-5508) to remove free-phase water, and is preheated during startup in the Dehydrator Tower Feed Preheater (X030-5501).

The Dehydrator Feed Water Separator (D030-5508) is always liquid full and operates on interface level control (LC53284) to recycle the water phase to the Hydrolysis Water Tank (T030-5501) automatically. The purpose of the Dehydrator Tower (W030-5501) is to remove water and ethanol from the wet crude alcohol stream. High purity butanol from the Butanol Tower (W030-5503) is set by ratio control (FFC53294) with the Dehydrator Tower feed; this stream is used as the reflux of the Dehydrator Tower to minimize C6+ alcohol carryover.

Water-free and ethanol-free crude alcohol bottoms from the Dehydrator Tower (W030-5501) are pumped to the Butanol Tower (W030-5503) on level-to-flow control (LC53309 to FC53331) by the Dehydrator Bottoms Pumps, P030-5507A/B. A 99%+ butanol product is distilled overhead, condensed in the Butanol Tower O/H Condenser[1] (X030-5507), and collected in the Butanol Tower O/H Accumulator (D030-5511). From the Butanol Tower O/H Accumulator the Butanol Tower Reflux Pumps (P030-5512A/B):

- supply reflux to the Dehydrator Tower (W030-5501) based on flow ratio control (FFC53294) as a primary flow
- supply reflux to the Butanol Tower (W030-5503) based on butanol tower internal reflux control (FYC53379) as a primary flow
- send butanol to storage (either to recycle butanol storage FB-552 or crude alcohol storage T030-5503) based on level to flow control (LC90106 to FC53378) as the secondary flow. LC53368 has high and low accumulator level overrides to maintain proper control of the accumulator. Each override is an individual PID controller that reports to a middle selector along with LC90106. The selected output becomes the setpoint of FC53378.
- send butanol production to product storage FB-527, FB-15-5, and FB-602B based on level to flow control (LC53368 to FC53380) as excess flow.

The butanol-free, Butanol Tower (W030-5503) bottoms are cooled and transferred by level-to-flow control (LC53357 to FC53377) to the Crude Alcohol Storage Tank (FB-671) for processing in System S-6000.

The Dehydrator Tower overhead stream is condensed/sub-cooled in the Dehydrator Tower O/H Condensers[1] (X030-5502) and combined with the butanol stripper overhead stream in the Dehydrator Tower O/H Accumulator (D030-5509) where they are separated into alcohol and aqueous phases. The aqueous phase (containing normally around 11% alcohol) is level to flow controlled (LC53316 to FC53341), combined with Ammonia Absorber Tower (W030-5505) bottoms, and recycled to the Hydrolysis Reactor (R030-5501). Normally, the Ammonia Absorber Tower bottoms flows to the suction of the dehydrator tower accumulator water phase pumps.

The Dehydrator Tower O/H Accumulator (D030-5509) alcohol phase (containing up to 23% water) is pumped via Ethanol Tower Feed Pumps, P030-5510A/B, on level-to-flow control (LC53317 to FC53391) as feed to the Ethanol Tower (W030-5502). The ethanol tower sidedraw product is ethanol (with 12% water and other contaminants) that is filtered and transferred by P030-5517A/B on flow-to-speed/stroke control (FC53430 to SC53433/53434) to existing storage tank (FB-506C) where it is combined with ethanol from DA-552 of the existing Ziegler train. The ethanol from both trains is used as fuel in the hot oil heaters BA-802 and H030-8003. Sidedraw flow receives its setpoint from a pressure compensated temperature controller (TYC53403), sensed about 10 stages below the sidedraw tray). The setpoint of TYC53403 is adjusted manually based on lab sample results.

The Ethanol Tower overhead vapor consists primarily of ethanol, water, and ammonia. The stream is partially condensed in the Ethanol Tower O/H Condenser (X030-5504) and collected in the Ethanol Tower O/H Accumulator (D030-5510). The vapor from the accumulator is vented through the Ethanol Tower Vent Condenser (X030-5511) to the Ammonia Absorber Tower (W030-5505). The ammonia vapor is absorbed with demineralized water in the Ammonia Absorber Tower (W030-5505) and returned to the suction or discharge of the Dehydrator Accumulator Water Phase Pumps

(P030-5513A/B) during normal operations. This maximizes ammonia recovery while minimizing ethanol recycled to the Hydrolysis Reactor (R030-5501). The Ammonia Absorber Tower liquid also can be pumped to other locations.

The vent stream from the Ammonia Absorber Tower (W030-5505) is combined with vents from:

- Dehydrator Tower Feed Water Separator (D030-5508)
- Dehydrator Tower O/H Accumulator Drum (D030-5509)
- Butanol Tower Overhead Accumulator (D030-5511)

The combined stream is routed to S-5500 Refrigerated Vent Knock Out D030-5512, where any residual liquid is condensed out. The vapor is then sent to S-5500 normal vent ejectors (K030-5502A/B), using natural gas as the motive force, to Vent Knockout drum D030-6019. Either one or two ejectors are in operation depending on the demand from upstream equipment, based on suction pressure. The refrigeration package has been deleted.

Flush/Collection Drum (D030-5513) and Surface Drainage Sump (D030-5522) are routed to atmosphere.

The liquid in the Ethanol Tower O/H Accumulator (D030-5510) is pumped to the reflux section of the Ethanol Tower by Ethanol Tower Reflux Pumps (P030-5511A/B) via level-to-flow control (LC53420 to FC53432). Some of the overhead material (due mainly to octane buildup) is also purged manually through FC-53431 to the supplemental BOD tank at the Air Separation Unit (ASU), based on sample results.. The ethanol bottoms stream (a combination of butanol, ethanol, and water, called recycle butanol) is combined with some of the Butanol Tower (W030-5503) overhead product, cooled in the Ethanol Tower Bottoms Cooler (X030-5506), and transferred via Ethanol Tower Bottoms Pumps (P030-5508A/B) on level-to-flow control (LC53412 to FC53429) to the existing Recycle Butanol Tank (FB-552).

3.3.4 Miscellaneous

The following liquid (alcohol/water) drains from process equipment clearing are routed to the Flush/Collection Drum (D030-5513):

- Hydrolysis Reactor Water Feed Pumps (P030-5502A/B)
- Refrigerated Vent Knock-Out Drum (D030-5512)
- Dehydrator Tower O/H Accumulator (D030-5509)
- Dehydrator Feed Water Separator (D030-5508)
- Dehydrator Tower Feed Filters (D030-5550A/B)
- Dehydrator Tower Charge Pumps (P0305506A/B)
- Ethanol Tower Bottoms Pump (P030-5508A/B)
- Ethanol Tower and Reboiler (W030-5502 X030-5505)
- Butanol Tower Reflux Pumps (P030-5512A/B)
- Recycle Butanol Pumps (P030-5521A/B)
- Alcohol / Water Tank Draw Pump (P030-5518)

The Flush/Collection Drum (D030-5513) is located below grade and collects drainage from hydrolysis vessels. Curbed areas around the Butanol Tower reflux pumps (W030-5503), Ethanol Tower (W030-5502) and bottoms pumps, dehydrator feed filters, the pump pad for the Hydrolysis Reactor (R030-5501) water, and Dehydrator Tower (W030-5501), and recycle butanol feed pumps all drain to D030-5522. Drainage collected in D030-5522 can be pumped to T030-5501 or D030-5513. Other surface areas are not curbed; small flows (such as sample line purging, seal drips, etc.) and rain above grade flow to the wastewater treatment system. Flush/Collection Drum (D030-5513) contains internal agitators to keep the contents mixed.

Flush/Collection Drum (D030-5513) level is controlled by setting a flow to the selected destination, which can be the 1st Stage Mixing Vessel (D030-5503), the Wet Crude Alcohol Tank (T030-5503), and/or the Hydrolysis Water Tank (T030-5501). A local control station provides the outside operator with information needed to ensure contents are pumped to the proper locations based on level, flow, and density of the pumped fluid. It is critical to operate the drum at a slight positive pressure to prevent backflow of drum contents to the atmospheric drain lines.

Tanks T030-5501/02/03 have a split-range tank blanketing system that provides an inert atmosphere inside the tanks as the contents are pumped into and out of the tanks. The vent is normally routed to the flare through S-6000 vent knockout drum (D030-6019). However, if the knockout drum has high-high pressure, interlock I-30-9011/9016/9013 (refer to L2CC-030-70-EN-5500) blocks the vent to D030-6019.

Recycle Butanol Swing Tank (T030-5502) has the capability to be a backup tank for existing Butanol storage (FB-552), Hydrolysis water tank (T030-5501) and Crude Alcohol tank (T030-5503).

3.3.5 Cold and Hot Demin Water Systems

The Ziegler Unit requires hot and cold demineralized water for the process and flushing. Demin water at ambient temperature, cold demin, is received from the OSBL header and distributed to Section 5500 and the spray dryers. Hot demin water is produced by heating cold demin water using 150# steam in the Demin Water Exchanger, X030-5521. Hot demin water is used for equipment/instrument flushes, utility station and providing feed water to keep the spray dryer operating when alumina slurry is not available. Hot demin water is stored in the Hot Demin Water Storage Drum, D030-5521.

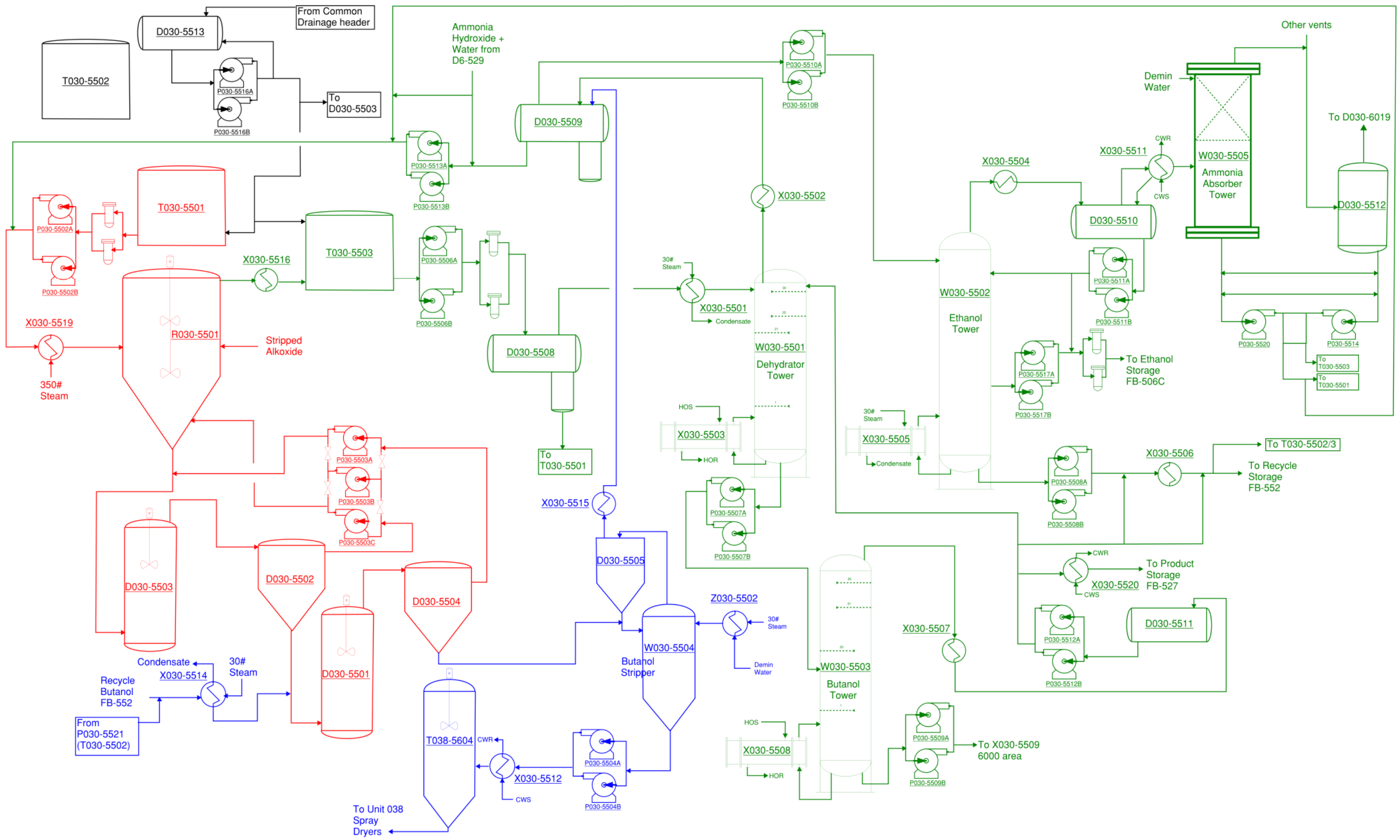
3.3.6 Condensate System

The Ziegler Unit requires condensate to de-superheat 350-psig steam to 150-psig steam, and to de-superheat 150-psig steam to 30-psig steam. To produce condensate for the system, steam Condensate from Section 2000 is collected and pumped to Section 5500 where it is collected along with condensate from the S-5500 Condensate Collection Drum D030-5520. If liquid level in this drum falls then steam is fed to it and cooled down in the S-5500 Overhead Condenser X030-5522 to recover and maintain the normal condensate level and avoid the S-5500 Condensate Pumps P030-5525A/B stop.

3.3.7 Notes

(1) For air-cooled condensers X030-5515, X030-5502, X030-5507, and X030-5504: primary control adjusts the fan speed to achieve a target outlet temperature. The condensers are designed with multiple stages. The first stage is the vapor stage; at the end of this stage, the vapor should be fully condensed. The last stages are more efficient at cooling, so in colder weather the outlet temperature will lower the fan speed to the point where the first stage vapor is not fully condensed. This will cause the condenser to become choked. Each condenser will be equipped with a temperature transmitter on the rear header box to ensure that complete condensation has been achieved by the end of the first pass. If the rear header box temperature is not low enough, it will override the primary temperature control and force the outlet temperature lower.

3.4 Overall Diagram (Sketch is for reference only)



Color Legend:

Hydrolysis / Extraction   Alumina Slurry Purification   Alcohol Fractionation   Miscellaneous

4.0 CONTROL STRATEGIES

To improve readability, the numeric portion of the tag name of all instrument and control tags below is shown as five digits instead of the full eight digits. The first three digits, which are not shown, are implied as either Area 006, 030, or 038 and can be determined by the unique Section numbers for all of the Ziegler Plant. For a more comprehensive explanation of the numbering for the Ziegler Sections, refer to L2CC-000-00-PR-0002.

4.1 General

During startup and shutdown of certain parts of section 5500, operator has the ability to bypass overrides in order to minimize process upsets.

4.2 Advanced Process Control Strategies (multiple inputs and outputs)

The crystallite size controller, %alumina controller and ram and flush controllers are advance process control strategies but were left with complex controls because of logical order.

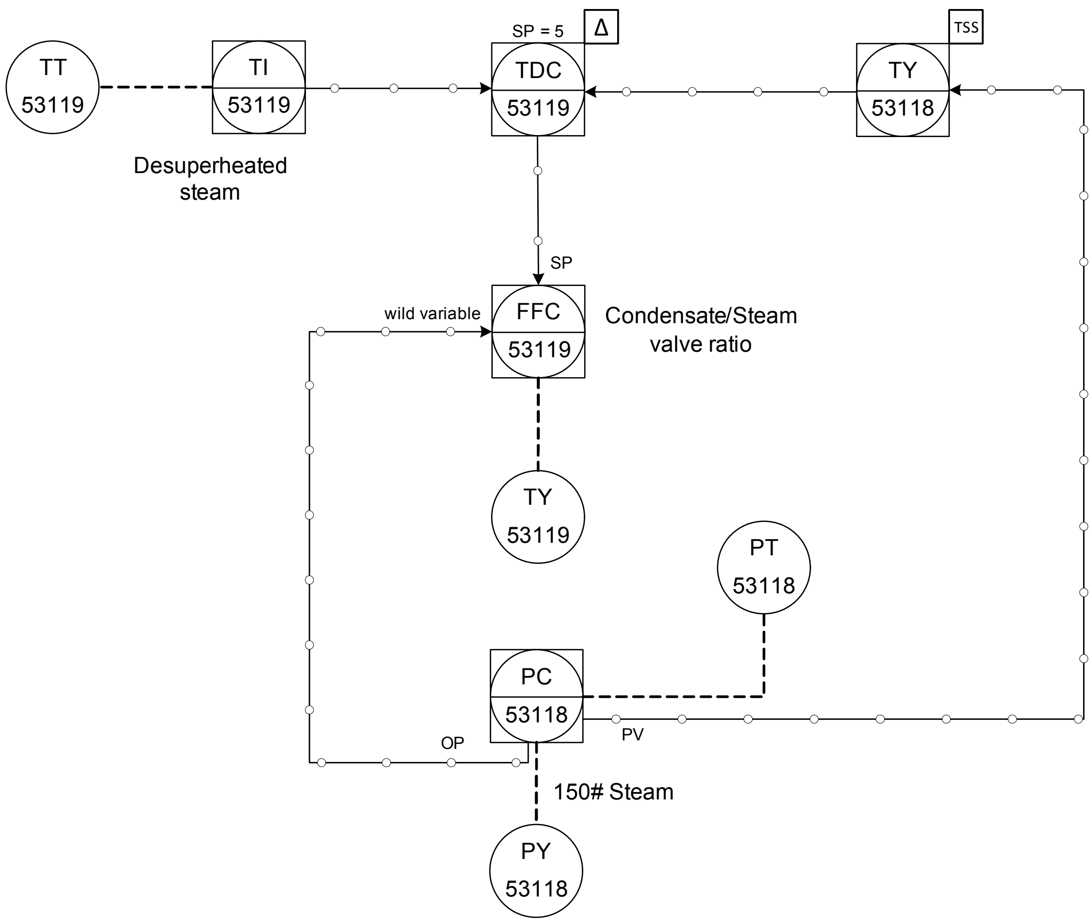
4.3 Complex Control Strategies (multiple inputs single outputs)

4.3.1 30# Steam De-Superheater

Reference P&IDs: L2CC-030-25-PI-5521

150# steam is letdown across a pressure control valve (PV-53118) and sent to de-superheater K-5501. PC53118 measures and controls the pressure downstream of PV-53118, and downstream of K-5501. There, condensate is added to cool the steam to the proper level of superheat (~5° F). TI53119 measures the temperature of the de-superheated steam. TY53118 calculates the theoretical saturated steam (TSS) temperature at measured letdown pressure, PC53118. The calculation is based on published steam tables as implemented using the TSS block within the DCS.

Ratio controller, FFC53119, uses PV-53118 position as its wild variable and sets condensate valve TV-53119 in ratio with it. TDC53119 calculates the difference between the actual steam temperature and saturated steam temperature, thus the amount of superheat within the 30# steam. TDC53119 adjusts the setpoint of FFC53119 to control the superheat condition to a safe, efficient, value, typically 5° F.



4.3.2 Alkoxide Feed ramp control

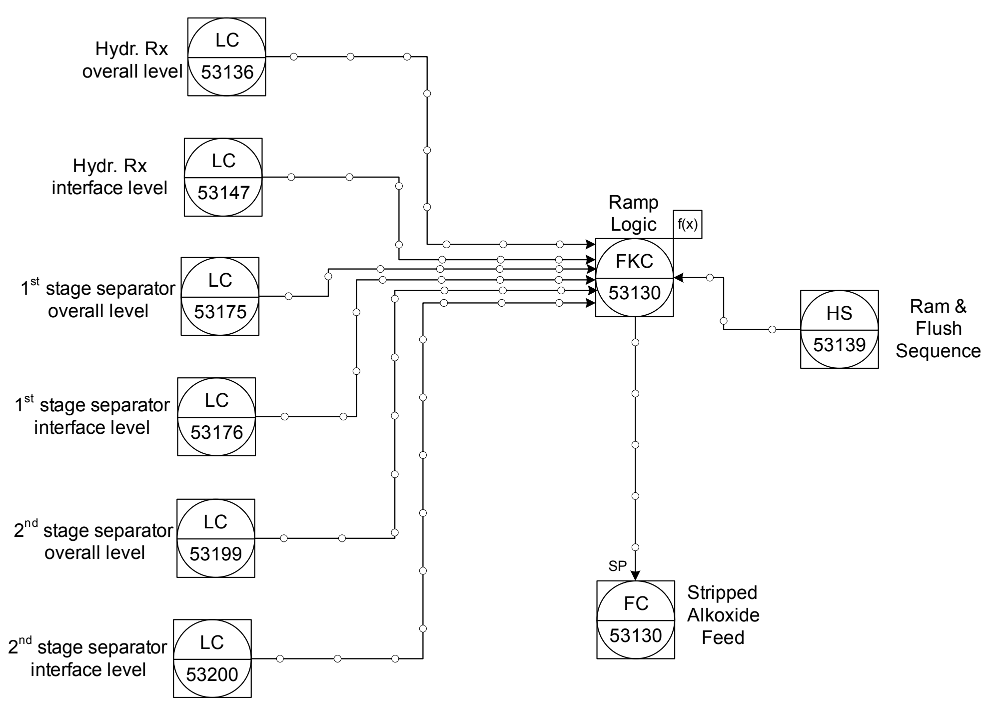
Reference P&IDs: L2CC-030-25-PI-5526, L2CC-030-25-PI-5527, L2CC-030-25-PI-5530, L2CC-030-25-PI-5532

The alkoxide feed has feed ramp controller. The operator specifies the final setpoint in lbs/hr and the ramp rate in lbs/hr/min. When activated, the controller changes the setpoint according to the specified ramp rate. The logic observes various level deviation constraints. If any of these are active, it suspends the ramp. Only high deviations are considered on Ramp Up, while only low deviations are considered on Ramp Down. If the Ram & Flush operation has been requested, ramping also is suspended. After ramping is suspended, the ramp begins again automatically when the constraint is cleared.

The following constraints are considered in the ramping logic:

a. LC53136 – Hydrolysis reactor overall level deviation
b. LC53147 – Hydrolysis reactor interface level deviation
c. LC53175 – 1st stage separator overall level deviation
d. LC53176 – 1st stage separator interface level deviation
e. LC53199 – 2nd stage separator overall level deviation
f. LC53200 – 2nd stage separator interface level deviation
g. HS53139 – Ram & Flush sequence activation/interlock

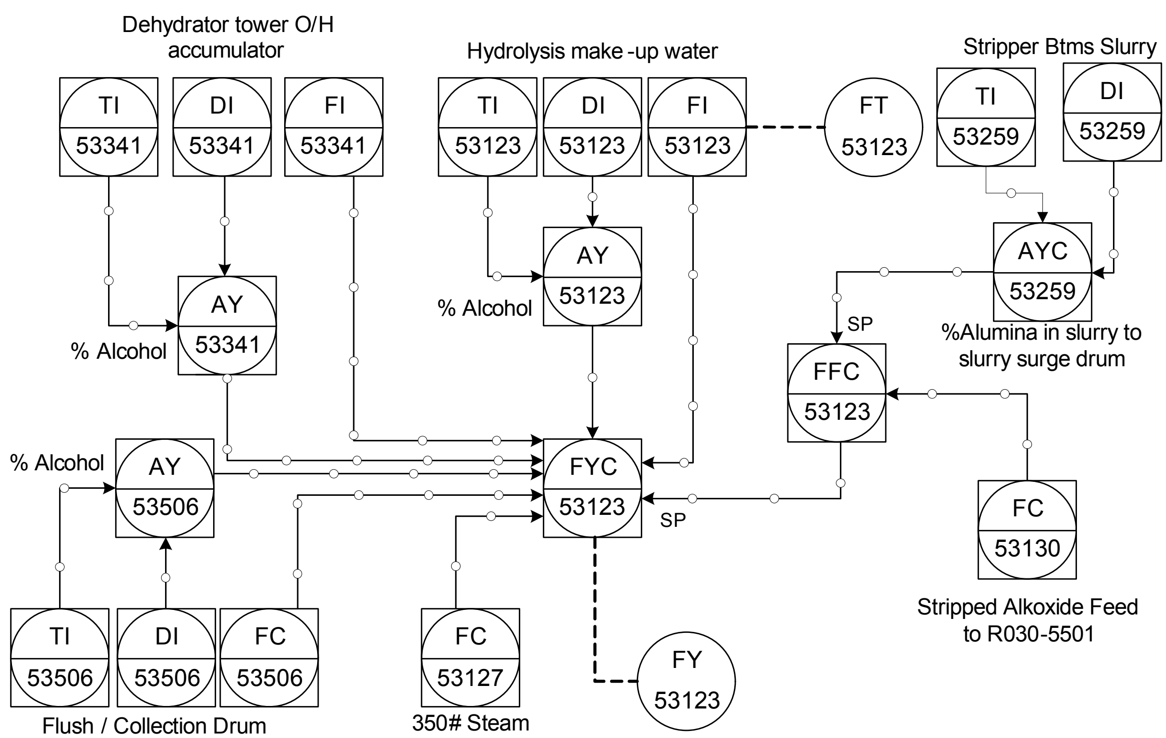
Once the controller reaches the final setpoint, the ramp controller releases the feed flow controller to its normal mode (Auto for operator control, or Cascade to the stripped alkoxide storage inventory controller, section 4.3.4). The controller will display the current setpoint, the ramp rate, and the final setpoint. The ramp rate in lbs/hr/min and the ending setpoint in lbs/hr are entered by the operators and have minimum and maximum limits.



4.3.3 Hydrolysis water feed to hydrolysis reactor

Reference P&IDs: L2CC-030-25-PI-5525, L2CC-030-25-PI-5526, L2CC-030-25-PI-5536, L2CC-030-25-PI-5543, L2CC-030-25-PI-5558

The hydrolysis reactor carries out the reaction of aluminum alkoxide with hydrolysis water to produce alcohol and alumina. An excess of hydrolysis reaction water provides a way to transport the alumina as slurry downstream of the reactor. However, too much water wastes energy in the spray dryers in the removal of the unnecessary water.



Make-up hydrolysis water (from T030-5501) is adjusted by total hydrolysis water flow controller, FYC53123. FC53341 controls the combined flow rate of the dehydrator tower O/H accumulator and the ammonia absorber stream (which contains the ammonia hydroxide required to prevent the formation of emulsions). Flows from the dehydrator overhead accumulator (FC53341), the flush collection drum (FC53507), live steam to the steam ring heater (FC53127), and make-up water (FI53123) all contribute to the total hydrolysis water. FC53341, FC53507, and FI53123 may contain some alcohol, so AY53341, AY53506, and AY53123 respectively, are used to calculate the concentration of alcohol in the stream. This is incorporated into the total water calculation; the alcohol content is excluded from the total water result. The make-up water valve is manipulated by FYC53123 to control the total hydrolysis water flow.

A regression model calculates the percentage of alcohol in the water streams based on their temperature and density as follows:

$$\mathrm{AY53xxx} = \mathrm{K3} - \mathrm{K2} * \mathrm{TI53xxx} - \mathrm{K1} * \mathrm{DI53xxx}$$

Where:

$\mathrm{K1} = 498.4208$
$\mathrm{K2} = 0.1651348$
$\mathrm{K3} = 510.7517$
$\mathrm{AY53xxx}$ = concentration of Alcohol, percent
$\mathrm{TI53xxx}$ = temperature of stream, °F
$\mathrm{DI53xxx}$ = density of stream, Spec Gravity

$$\mathrm{FYC53123.PV} = \mathrm{FC53127.PV} + \mathrm{FC53507.PV} * \left(1 - \frac{\mathrm{AY53506.PV}}{100}\right) + \mathrm{FI53341} * \left(1 - \frac{\mathrm{AY53341.PV}}{100}\right) + \mathrm{FI53123.PV} * \left(1 - \frac{\mathrm{AY53123.PV}}{100}\right)$$

Where:

$\mathrm{FYC53123.PV}$ = Total Water Flow to Hydrolysis Reactor
$\mathrm{FC53127.PV}$ = Flow of Steam to steam ring heater
$\mathrm{FC53507.PV}$ = Water from Flush Collection Drum
$\mathrm{AY53506.PV}$ = Alcohol content of Water from Flush Collection Drum
$\mathrm{FI53341.PV}$ = Water from Dehydrator OH Accumulator
$\mathrm{AY53341.PV}$ = Alcohol content of Water from Dehydrator OH Accumulator
$\mathrm{FI53123.PV}$ = Makeup Hydrolysis Water
$\mathrm{AY53123.PV}$ = Alcohol content of Makeup Hydrolysis Water

The setpoint of the total hydrolysis water, FYC53123, is adjusted in proportion to the stripped alkoxide feed rate by FFC53123, the water/feed ratio controller. This ratio ultimately affects the dilution of the alumina slurry.

The equation for the ratio is:

$$\mathrm{FFC53123.PV} = \mathrm{FYC53123.PV}/\mathrm{FC53130.PV} \qquad \text{(PV measurement)}$$

$$\mathrm{FYC53123.SP} = \mathrm{FFC53123.SP} * \mathrm{FC53130.PV} \qquad \text{(Controller OP)}$$

Where:

$$\text{FFC53123.PV} = \text{Total Hydrolysis Water / Alkoxide Feed Ratio}$$
$$\text{FYC53123.PV} = \text{Total Water Flow to Hydrolysis Reactor}$$
$$\text{FC53127.PV} = \text{Alkoxide Feed Flow to Hydrolysis Reactor}$$

The % of Al_2O_3 in the alumina slurry leaving the system (at the Butanol Stripper Bottoms) is calculated and controlled by AYC53259, which adjusts the setpoint of FFC53123. The calibration of mass flow meter FT-53259 is expected to shift over time due to coating. The calculation uses sample data from LIMS to compensate the DCS data for the shift. The exact equation used in the compensation needs to be provided by the plant. It is done by the PIMS system, not in the DCS.

The base equations for the Stripper Bottoms % Al_2O_3 are (adapted from the existing Ziegler plant's AYC55580):

$$\text{Y1} = \text{K2} - \text{K3} * \text{TI53259.PV} \qquad \text{(intermediate calculation)}$$
$$\text{AYC53259.PV} = (\text{K4}/\text{DI53259.PV}) * (\text{DI53259.PV} - \text{Y1})/(1 - \text{Y1}/\text{K1}) \qquad \text{(PV measurement)}$$

Where:

$$\text{AYC53259} = \text{Stripper Bottoms \% } Al_2O_3$$
$$\text{DI53259} = \text{Stripper Bottoms density}$$
$$\text{TI53259} = \text{Stripper Bottoms temperature}$$
$\text{K1} = 4.0$ (constant term)
$\text{K2} = 1.0422539$ (constant term)
$\text{K3} = 0.0005855$ (constant term)
$\text{K4} = 100$ (conversion to %)

AYC53259 uses expanded External Reset Feedback (BKCAL_IN) as follows:

```
IF (FFC53123.BKCAL_OUT > AYC53259.OP) THEN
    AYC53259.BKCAL_IN = MAX(FFC53123.BKCAL_OUT, AYC53259.OP − K1)
ELSE
    AYC53259.BKCAL_IN = MIN(FFC53123.BKCAL_OUT, AYC53259.OP + K1)
ENDIF
```

Where:

$\text{K1} = 1.0$ (expanded ext. feedback amount, in % of output scale)

4.3.4 Stripped Alkoxide Inventory Control

Reference P&IDs: L2CC-030-25-PI-5527, L2CC-030-25-PI-5530, L2CC-030-25-PI-5532, L2CC-030-25-PI-5534, L2CC-030-25-PI-9055, L2CC-030-25-PI-9056, 074.9-PI-124-D, 074.9-PI-126-D

In section 5500, the stripped alkoxide feed to the hydrolysis reactor has two automated modes of operation beyond the normal operator-initiated Ramp mode described in Section 4.3.1. The automation is aimed at achieving a specified target of crude alcohol production rate vs. balancing crude alcohol production against the stripped alkoxide production from the Hotside.

Switch HS53130 selects whether the Balancing mode is in service:
0 = OFF (i.e. the automation controls to a specific production target using FYC53377)
1 = ON (i.e. the automation controls to balance with the Hotside production using FY53131)

The strategy is a collection of constraint override controllers that resolve to a final setpoint for the alkoxide feed flow controller, FC53130. The balancing portion is supported by a calculation of the net changes of intermediate material within the Hotside tankage. That calculation result is presented in the FY53131 loop, and used whenever the Hotside Balancing mode is ON.

The equations for FY53131 Balance Mode control are:

$$\mathrm{FY53131.PV} = k_1(\mathrm{FY53131\text{-}1.PV}) + k_2(\mathrm{FY53131\text{-}2.PV}) + k_3(\mathrm{FY53131\text{-}3.PV}) + k_4(\mathrm{FY53131\text{-}4.PV})$$

Where:
$\mathrm{FY53131\text{-}1.PV} = \mathrm{FB\text{-}405\ (Growth\ Product)\ Net\ Inventory\ Change}$
$\mathrm{FY53131\text{-}2.PV} = \mathrm{D030\text{-}4003\ (POGP)\ Net\ Inventory\ Change}$
$\mathrm{FY53131\text{-}3.PV} = \mathrm{D030\text{-}4004\ (OGP)\ Net\ Inventory\ Change}$
$\mathrm{FY53131\text{-}4.PV} = \mathrm{FB657\ (Stripped\ Alkoxide)\ Net\ Inventory\ Change}$
$k_1 = \text{factor for FB405 (Growth Product) Net Inventory Change} = 0.1$
$k_2 = \text{factor for D030-4003 (POGP) Net Inventory Change} = 0.0$
$k_3 = \text{factor for D030-4004 (OGP) Net Inventory Change} = 0.0$
$k_4 = \text{factor for FB657 (Stripped Alkoxide) Net Inventory Change} = 0.9$
$k_1 + k_2 + k_3 + k_4 = 1$

The Net Inventory Change for each tank is calculated as the net change in level (in lbs) averaged over one hour, reported as PPH. A dead time block is used to delay the level reading for one hour. The equation is:

$$\text{Net Inventory Change} = c * (\text{Tank Level.PV} - \text{Delayed Tank Level})$$

Where:
$\text{Tank Level.PV} = \text{current tank reading, \%}$
$\text{Delayed Tank Level} = \text{onehour delayed tank reading, \%}$
$c = \text{conversion factor for tank volume, lbs/\%}$

The tanks involved are:

Tag	Tank	Service	Level Tag	Factor, lbs/%
FY53131-1	FB-405	Growth Product	LI90351	61165.
FY53131-2	D030-4003	POGP	LI91182	17282.
FY53131-3	D030-4004	OGP	LI91193	16876.
FY53131-4	FB-657	Stripped Alkoxide	LI90366	11172.

All tank inventories are converted from level % to mass in pounds for consistent accounting. The k factors must sum to one to account for the inventory properly. Note that each tank is individually assessed for inventory movement. However, the two intermediate tanks (POGP and OGP) are normally omitted from the calculation, thus their k factors are zero. Most of the weight is given to the stripped alkoxide inventory due to its proximity to S-5500.

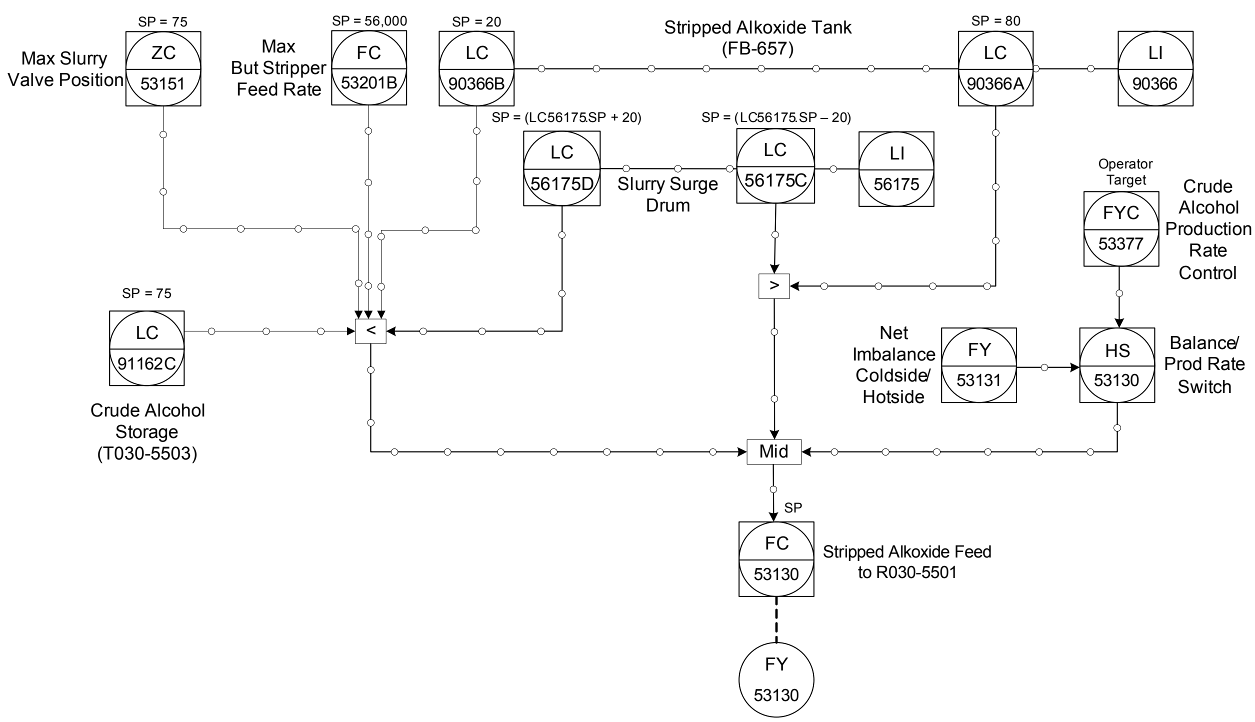
Whenever Balancing mode is OFF, the strategy uses the output of the production rate controller loop (FYC53377). This mode is useful for hitting a desired production target or maximizing production if S-5500 is a bottleneck. The goal of the production rate controller is to feed S-5500 the proper amount to achieve an overall production target, as specified by the SP of FYC53377. The PV of FYC53377 is the one-minute moving average of the Butanol Tower bottoms flow (FC53377.PV), i.e. the crude alcohol product flow.

FYC53377 is a PID feedback loop tuned with moderately low gain and a long reset time (e.g. 4000 sec). Because it uses low gain, a special algorithm must be applied to the normal BKCAL signal from FC53130.PV used for External Reset Feedback. This algorithm, shown below, provides for greater latitude on the movement of the FYC53377 output than otherwise would be allowed. In the equations, PV is FC53130.PV, OP is FYC53377.OP, BKCAL is the signal to be applied to the BKCAL pin of FYC53377's PID block, and AL is the configured additional latitude (typically 1% of the output scale).

$$\text{IF } (\text{PV} > OP) \text{ THEN BKCAL} = \text{MAX}(\text{OP}, \text{PV} - \text{AL})$$
$$\text{IF } (\text{PV} \leq \text{OP}) \text{ THEN BKCAL} = \text{MIN}(\text{OP}, \text{PV} + \text{AL})$$

Constraints on Alkoxide storage tank level, intermediate crude Alcohol storage tank level, maximum Butanol Stripper feed rate, downstream Slurry Surge Drum level, and various slurry valve positions are considered.

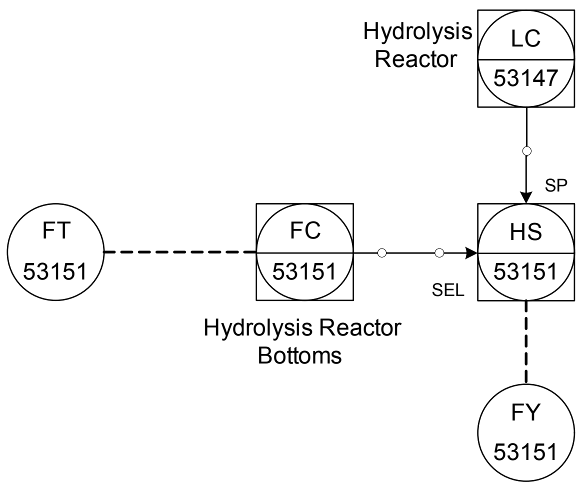
Note: To simplify the P&IDs, the inventory control strategy is not shown on the P&IDs.



4.3.5 Hydrolysis Reactor Level to Flow Control Mode Selector

Reference P&IDs: L2CC-030-25-PI-5527

The normal control for the hydrolysis reactor level control is level (LC53147) to flow (FC53151) cascade. However, the existing mass flow meter tends to clog occasionally so a selector switch (HS53151) enables the BYPASS parameter of FC53151's PID block to allow LC53147 to operate FV-53151 directly.



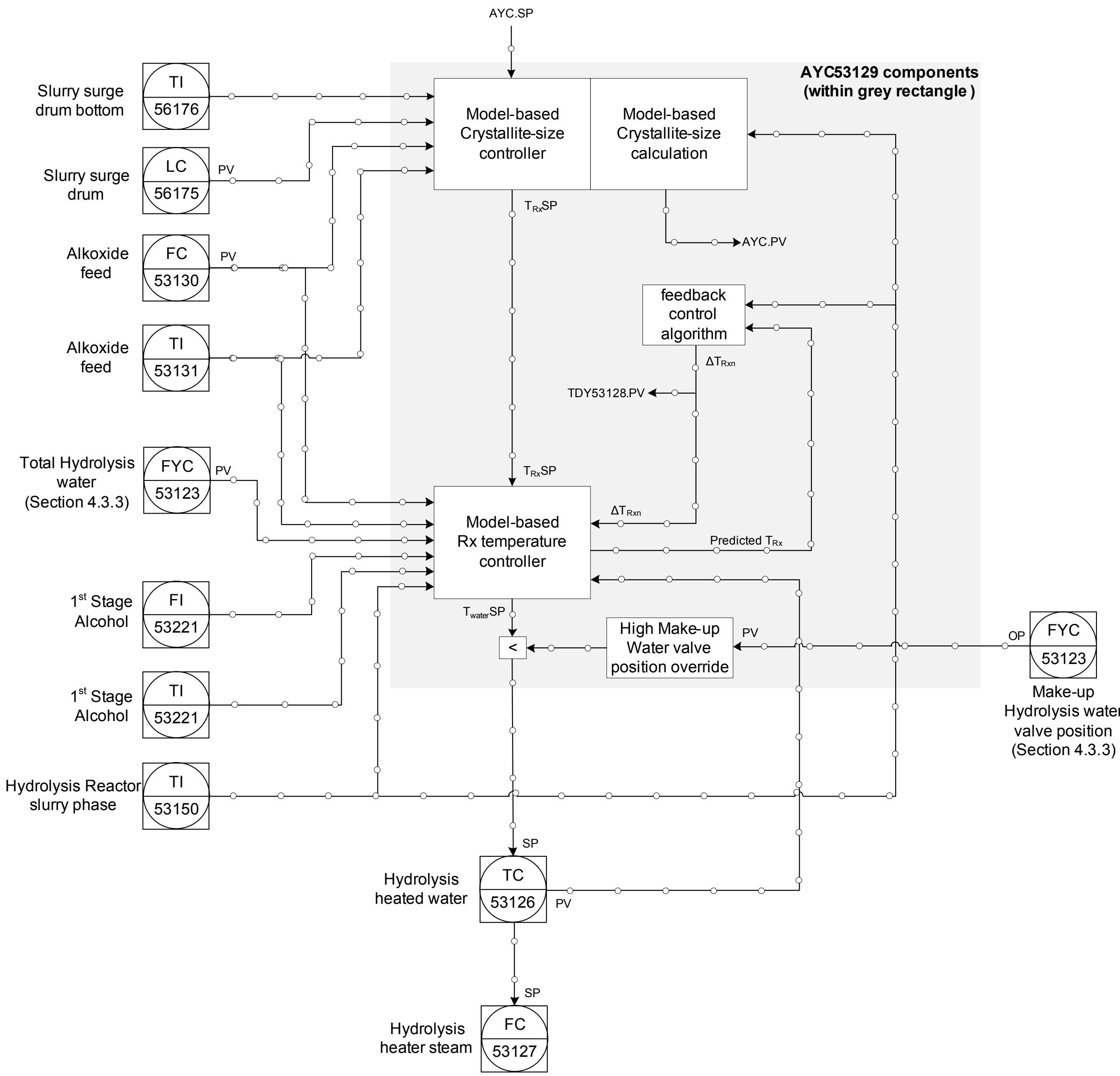
4.3.6 R030-5501 Crystallite Size Control

Reference P&IDs: L2CC-030-25-PI-5525, L2CC-030-25-PI-5526, L2CC-030-25-PI-5527, L2CC-030-25-PI-5533, L2CC-038-25-PI-5611

Alumina slurry produced in the 5500 area is transferred to spray dryers (Unit 038) where the alumina is dried and sold. One of the primary variables affecting product quality is the crystal size of the alumina. Primary factors influencing crystal size are residence time and temperature within the hydrolysis/extraction drums and the slurry surge drum. The longer the residence time and higher the temperature, the larger the crystal size will become. An empirical model was built to predict crystal size based on these parameters. AYC53129 uses the model directly to set a target hydrolysis reactor temperature, which ultimately sets the hydrolysis water temperature. An internal feedback loop allows the controller to meet its internal reactor temperature target and, thus, meet the crystal size target.

The size of the crystallite is measured in a laboratory using process samples. The operator uses the sample results to adjust the setpoint of the controller, when necessary, although the model should be calibrated to maintain its accuracy.

The following diagram shows the internal details of the AYC53129 Control Module. The equations for the various blocks are given in the pages following the diagram.



The crystallite size control is based upon two models, both running inside the AYC loop. The first model is an empirical one that relates crystallite size to hydrolysis reactor temperature (T_{Rx}), slurry surge drum temperature (T_{SSD}), slurry surge drum level (L_{SSD}), and alkoxide feed rate (F_{feed}). The coefficients in this model are based on DC-551 in Z1. They need to be re-evaluated for R-5501 once Z2 comes into operation and historical data are gathered.

$$\mathrm{AYC.PV} = K_{TRx} * T_{Rx} + K_{Tssd} * T_{SSD} + \frac{K_{Feed}}{F_{feed}} + K_{Lssd} * L_{SSD} - K_e$$

Where:
K_{TRx} = Hydrolysis reactor temperature coefficient = 0.192
K_{Tssd} = Slurry surge drum temperature coefficient = 0.0659
K_{Feed} = Alkoxide feed flow coefficient = 130000
K_{Lssd} = Slurry surge drum level coefficient = 0.0686
K_e = Empirical crystallite size constant = 10.128

Essentially, this equation transforms the task of controlling crystallize size into one of controlling reactor temperature. Given there is no explicit control of hydrolysis reactor temperature, a model-based controller is employed. It is based upon a simple energy balance around the reactor with an additional internal feedback loop. The model includes a term that represents the temperature rise generated by the hydrolysis reaction, and this is the term that is used for feedback correction of the model.

The energy balance combines the enthalpy of the three streams that enter the reactor (alkoxide feed, hydrolysis water, and 1st stage phase alcohol) to calculate bulk reactor temperature. The equation follows:

$$\widehat{T_{Rx}} = \frac{C_{pw} * T_{water} * F_{water} + C_{pf} * T_{feed} * F_{feed} + C_{ps} * T_{stage1} * F_{stage1}}{C_{pw} * F_{water} + C_{pf} * F_{feed} + C_{ps} * F_{stage1}} + \Delta T_{Rxn}$$

Where:
$\widehat{T_{Rx}}$ = predicted bulk temperature of hydrolysis reactor slurry phase
C_{pw} = heat capacity of hydrolysis water = 1.00
C_{pf} = heat capacity of alkoxide feed = 0.55
C_{ps} = heat capacity of 1^{st} stage phase alcohol = 0.72
T_{water} = temperature of hydrolysis water (TC53126)
T_{feed} = temperature of alkoxide feed (TI53131)
T_{stage1} = temperature of 1^{st} stage phase alcohol (TI53221)
F_{water} = flow of hydrolysis water (FYC53123)
F_{feed} = flow of alkoxide feed (FC53130)
F_{stage1} = flow of 1^{st} stage phase alcohol (FI53221)
ΔT_{Rxn} = temperature rise from heat released in hydrolysis reaction (TDY53128)
T_{SSD} = slurry surge drum temperature (TI56176)
L_{SSD} = slurry surge drum level (LC56175)

The above equation for T_{Rx} is used to predict the bulk reactor temperature based on actual conditions of the three incoming streams plus the assumed heat of reaction. The latter is adjusted gradually via feedback by comparing the predicted bulk temperature with the actual until the two agree exactly. The assumed heat of reaction changes very slowly over time, so the model generally predicts the temperature very accurately when incoming conditions change.

The two equations are inverted to transform them into control equations as follows:

$$T_{Rx}\mathrm{SP} = \left(\frac{1}{0.192}\right) * \mathrm{AYC.SP} - \left(\frac{0.0659}{0.192}\right) * T_{SSD} - \left(\frac{130000}{0.192 * F_{feed}}\right) - \left(\frac{0.0686}{0.192}\right) * L_{SSD} + \left(\frac{10.128}{0.192}\right)$$

$$T_{water}\mathrm{SP} =$$

$$\frac{(T_{Rx}SP - \Delta T_{Rxn}) * (C_{pw} * F_{water} + C_{pf} * F_{feed} + C_{ps} * F_{stage1}) - C_{pf} * T_{feed} * F_{feed} - C_{ps} * T_{stage1} * F_{stage1}}{C_{pw} * F_{water}}$$

The combination of these two equations allows the setpoint of the hydrolysis water temperature to be calculated directly from the crystallite size setpoint. Internally, a feedback algorithm must be used to maintain reactor temperature, thus maintaining crystallite size. The algorithm evaluates the difference between the actual and predicted bulk temperature, and applies a small percentage of this difference to the assumed heat of reaction term. Eventually the two temperatures match and no further adjustment is required. The small percentage is an engineering tuning parameter. The algorithm is classified as an integral-only type. The result of the feedback calculation ΔT_{Rxn} shall be clamped between 0 and 60.

$$\Delta T_{Rxn} = \Delta T_{Rxn} + k * (T_{Rx} - \widehat{T_{Rx}}) * \Delta t$$

Where: $T_{Rx} = \text{actual bulk temperature of hydrolysis reactor slurry phase (TI53150)}$
$k = \text{integral tuning gain} \cong 0.001$
$\Delta t = \text{execution interval of the CM in seconds}$

Where the alkoxide feed flow appears in the denominator, divide-by-zero protection must be provided. This is done by limiting the feed flow to a small number at a minimum (e.g. 10 lbs/hr) before it is used.

Where used in the control equation, the operator-entered crystallite size setpoint (AYC53129.SP) is ramped internally to avoid rapid changes to the steam ring heater should the operator make large changes to the loop setpoint. Large setpoint changes are common when changing alumina campaigns. Maintain an internal SP in Y1 as follows:

$\text{IF(AYC53129.MODE.ACTUAL} \neq \text{AUTO) THEN Y1} = \text{AYC53129.PV;}$
ELSE
$\quad Y2 = \text{MAX(AYC53129.SP}, Y1 - 0.005 * \Delta t);$
$\quad Y1 = \text{MIN}(Y2, Y1 + 0.005 * \Delta t);$
ENDIF

Where: $Y1 = \text{AYC.SP to be used in the } T_{Rx}SP \text{ equation on the previous page}$

An override control algorithm is built into the loop to limit the water temperature setpoint if the hydrolysis water flow valve exceeds 70%. This is not done in a separate loop, but is performed by a special algorithm within the AYC loop. The equation follows.

$Y3 = 100 * (T_{water}SP - K1)/(K2 - K1);$ (in %)

$\text{OVRD.OP} = Y3 - K3 * \text{MAX(0.0, FYC53123.OP} - K4);$ (in %)

$\text{Final AYC.OP} = \text{OVRD.OP}/100 * (K2 - K1) + K1;$ (in Eng. Units)

Where: $K1 = \text{Engineering units range Low value for TC53126} \cong 100$
$K2 = \text{Engineering units range High value for TC53126} \cong 275$
$K3 = \text{Proportional Gain for Override control} \cong 0.0005$
$K4 = \text{Override control setpoint} \cong 70$

The resulting output of the AYC is the setpoint for the total inlet hydrolysis water (TC53126), which is heated by steam directly injected into a ring heater. This steam becomes some of the hydrolysis water; it must be accounted for in the calculation of total water (FYC53123). See Section 4.3.2 for details.

The engineering range of AYC53129 is typically 30 to 70 Angstroms. AYC53129 shall not use SP-PV tracking.

4.3.7 Recycle Butanol

Reference P&IDs: L2CC-030-25-PI-5526, L2CC-030-25-PI-5532, L2CC-030-25-PI-5533, L2CC-030-25-PI-9060-02, L2CC-006-25-PI-9067, LCCC-074.9-PI-144

Recycle butanol is introduced into the system to remove C6+ Alcohol from the slurry stream. C2 and C4 alcohols are removed in the butanol stripper. Recycle butanol flow controller (FC53215) receives its setpoint from a ratio (FFC53215) of recycle butanol flow rate (FC53215) to slurry from the hydrolysis reactor (FC53201). FFC53215 shall not use SP-PV tracking.

The M-value of the stripped alkoxide and the use of TAP significantly affect how many units of alumina are produced per unit of water reacted per unit of stripped alkoxide. As more alumina slurry is produced, more extraction butanol is required. Lower M values and TAP production both result in more alumina production. To compensate for this, feedback ratio controller (FFC53201) adjusts the SP of FFC53215 according to the ratio of recycle butanol flow to slurry feed to the Butanol Stripper. The PV equation follows:

$$\mathrm{FC\widehat{53201}} = \text{4-hour rolling average of FC53201.PV} \qquad \text{(sampled at 10-second intervals)}$$

$$\mathrm{FC\widehat{53215}} = \text{4-hour rolling average of FC53215.PV} \qquad \text{(sampled at 10-second intervals)}$$

$$\mathrm{FFC53201.PV} = \mathrm{FC\widehat{53215}} / \mathrm{FC\widehat{53201}} \qquad \text{(in LB/LB)}$$

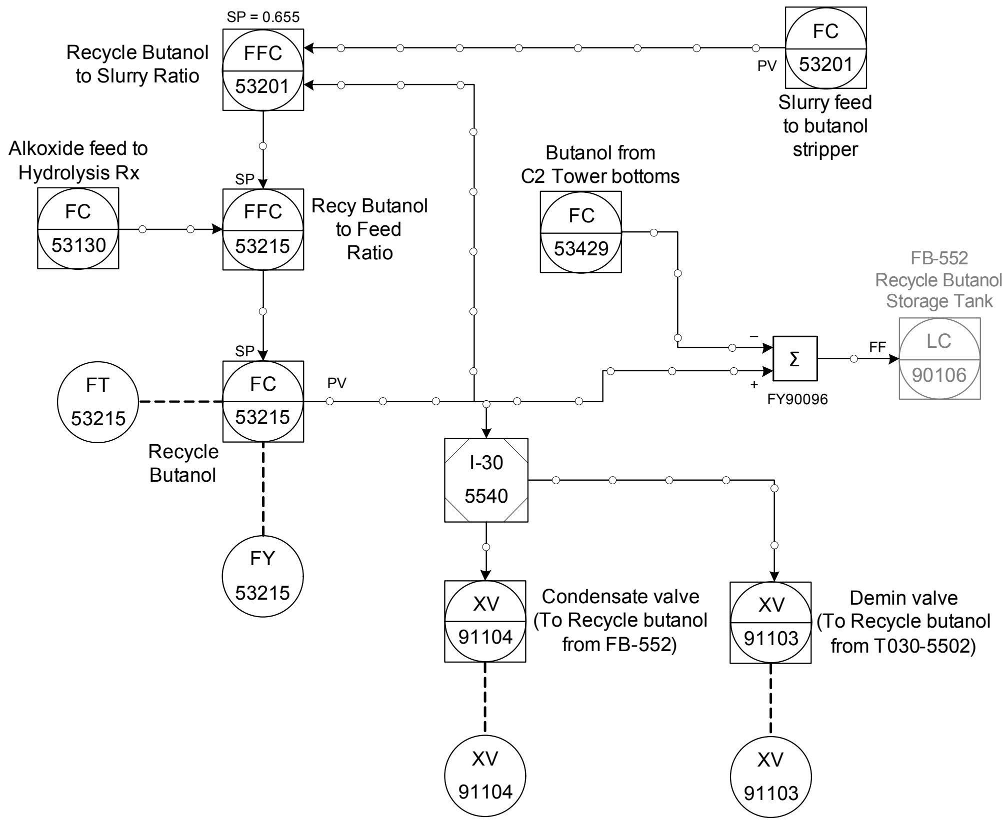
FFC53201 uses a normal PID algorithm with very low gain and long integral time for its tuning. The SP for FFC53201 shall be changed only by the engineer. Initial value for SP is 0.655, based on HMB data. FFC53201 shall not use SP-PV tracking.

The recycle butanol flow measurement, along with the C2 tower bottoms flow, is used as a feedforward signal for the existing recycle butanol level controller (LC90106), pure butanol to FB-552. LC90106 must be modified to function within the control strategy described here. For details, see Appendix II.

Device XV91104 allows operators to open up an automated condensate valve XV-91104, which puts metered (via a rotameter) condensate to the suction of the S-5500 recycle butanol pumps. This is done occasionally since too low a water content in recycle butanol can cause problems in the extraction section. When recycle butanol flow falls below a pre-determined value, a DCS interlock closes automated valve XV-91104 so that the recycle butanol does not become too diluted with water. Only Manual operator interaction from the DCS can open the valve.

When operating in TAP production mode, the operator selects FC53201 to ratio with butanol. When operating in normal production, he selects FC53130 to ratio with butanol. The setpoint of FFC53215 needs to change based on the position of HS53215.

If T030-5502 is functioning as recycle butanol tank, XV91103 can be used to open XV-91103 and put metered demin water into the suction of -5500 recycle butanol pumps.


SP = 0.655
Recycle Butanol to Slurry Ratio
FFC 53201
FC 53201
PV
Slurry feed to butanol stripper
Alkoxide feed to Hydrolysis Rx
FC 53130
SP
FFC 53215
Recy Butanol to Feed Ratio
Butanol from C2 Tower bottoms
FC 53429
FB-552 Recycle Butanol Storage Tank
LC 90106
FF
Σ
FY90096
SP
FT 53215
FC 53215
PV
Recycle Butanol
I-30 5540
FY 53215
XV 91104
Condensate valve (To Recycle butanol from FB-552)
XV 91103
Demin valve (To Recycle butanol from T030-5502)
XV 91104
XV 91103

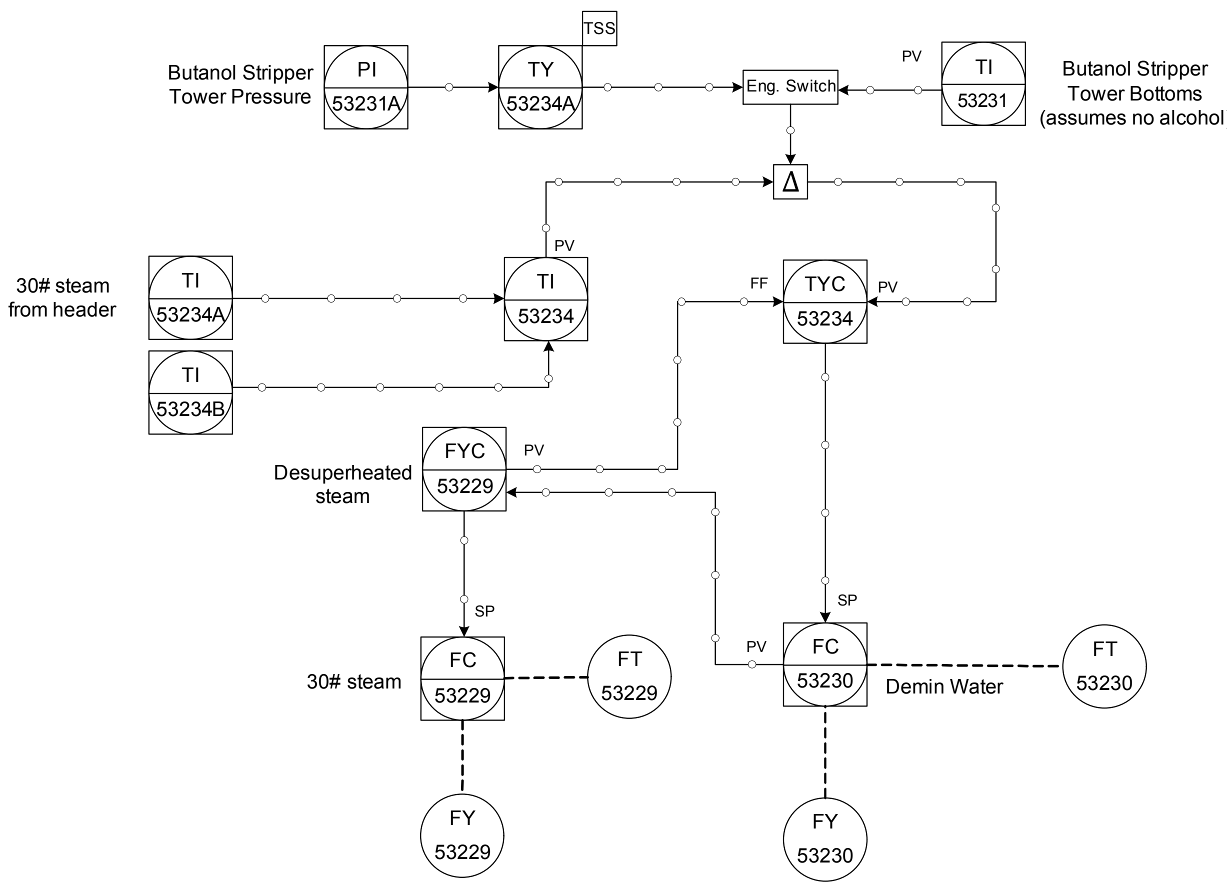
4.3.8 Butanol Stripper Desuperheater

Reference P&IDs: L2CC-030-25-PI-5534

Steam desuperheater Z030-5502 provides desuperheated steam to the Butanol Stripper. The operator sets the amount of desuperheat via the delta temperature controller (TYC53234). TYC53234 ensures that steam with the proper amount of superheat (typically 5°F) enters the butanol stripper. Higher levels of superheat will remove water from the slurry and increase tray fouling. The operator also sets the desuperheated steam flow rate (FYC53229), which provides the remote setpoint to steam controller (FC53229). Based on the temperature of the incoming desuperheated steam vs. the Butanol Stripper bottoms temperature (TI53231), the steam desuperheater controller adjusts the demin water flow controller setpoint (FC53230). The bottoms temperature is considered to be at the saturated steam temperature. A check of this is done inside the TY53234A loop by calculating the saturation temperature for steam at the stripper pressure (PI53231A). The result should be comparable to the TI53231 indication. An Engineering Switch is set to select which of the two shall be used in the delta calculation.

Increasing demin water flow will cause FYC53229 to reduce the amount of steam flow in order to maintain the net steam flow rate set by the operator. This controller does not use feedback, but calculates the output to the steam FC53229 via difference between the FYC53229 setpoint and FC53230 PV.

TYC53234 receives a feed forward signal from the desuperheated flow rate controller measurement.



4.3.9 Dehydrator BTU Control

Reference P&IDs: L2CC-030-25-PI-5540

Tray 3 of the Dehydrator is temperature-controlled (TC53304) via a standard BTU Controller (QYC53310) for reboiler X030-5503. Tray 5 can also be selected instead of Tray 3, if desired. The temperature profile of the column indicates the separation of the components within the tower. If the temperature is too low, the internal vapor traffic must be increased. TC53304 adjusts the setpoint of QYC53310, which in turn sends the hot oil flow controller (FC53310) a remote setpoint. Tower temperature control points must be verified before startup.

The flow controller FC53310 provides the valve position of FV-53310 to the optimizing controller (ZC81124) for the hot oil heater. Refer to L2CC-030-70-EN-8000 for more details.

The density (ρ) equation is used to compensate the flow measurement (FI53310) due to temperature changes in the hot oil.

$$\rho = 62.4 * (1.0484 - 0.0004214 * \mathrm{TI53310A})$$

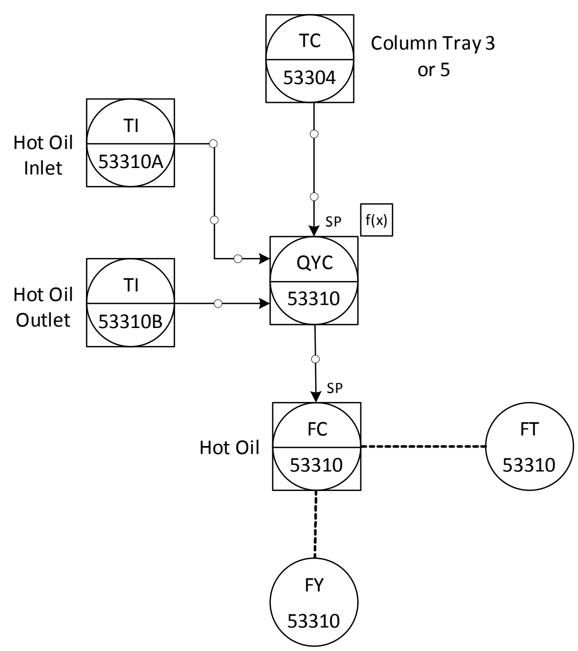
The heat duty controller performs the following calculation using the hot oil inlet and outlet temperatures.

$$Cp = 0.0004675 * \left(\frac{\mathrm{TI53310A} + \mathrm{TI53310B}}{2}\right) + 0.3477$$

$$\mathrm{QC53310.PV}\ (Heat\ duty\ meas) = \mathrm{FC53310.PV} * Cp * (\mathrm{TI53310A.PV} - \mathrm{TI53310B.PV})/1000$$

$$\mathrm{FC53310.SP}\ (Control\ Output) = 1000 * \mathrm{QC53310.SP}/Cp/(\mathrm{TI53310A.PV} - \mathrm{TI53310B.PV})$$

The QC is expressed in MM BTU/hr. The FC is expressed in M lb/hr.



4.3.10 Dehydrator Feed ramp control

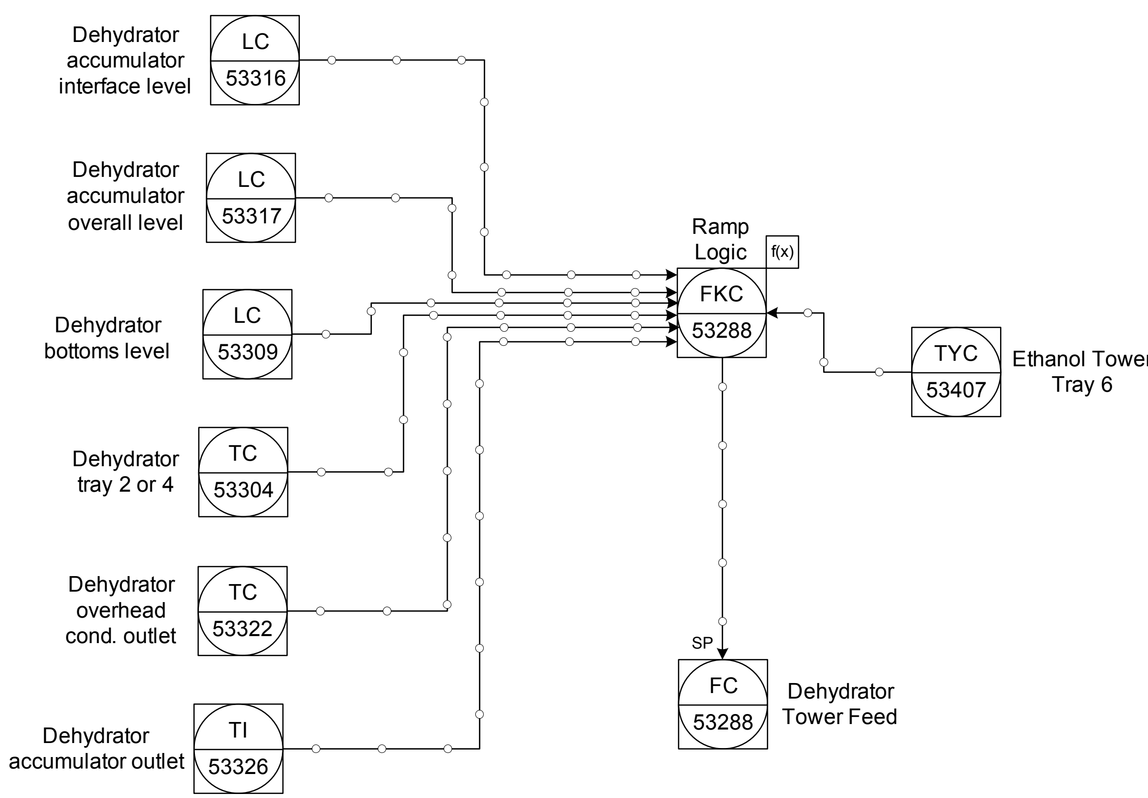
Reference P&IDs: L2CC-030-25-PI-5539

The dehydrator tower feed has a ramp controller. The operator specifies the final setpoint in lbs/hr and the ramp rate in lbs/hr/min. When activated, the controller changes the setpoint according to the specified ramp rate. The logic observes various level and temperature deviation constraints. If any of these are active, it suspends the ramp. Only high deviations are considered on Ramp Up, while only low deviations are considered on Ramp Down. Ramping continues once the constraint no longer exists.

The following constraints are considered in the ramping logic:

a. LC53316 – Dehydrator accumulator interface level deviation
b. LC53317 – Dehydrator accumulator overall level deviation
c. LC53309 – Dehydrator bottoms level deviation
d. TC53304 – Dehydrator tray 2 or 4 temperature deviation (TC53304 allows selection of either tray temperature)
e. TC53322 – Dehydrator overhead condenser outlet temperature > 160°F
f. TI53326 – Dehydrator accumulator outlet temperature > 129°F
g. TYC53407 – Ethanol tower tray 6 temperature deviation

Once the controller reaches the final setpoint, the ramp controller releases the feed flow controller to its normal mode (Auto for operator, or Cascade to the wet crude alcohol storage tank level controller). The controller will display the current setpoint, the ramp rate, and the final setpoint. The ramp rate in lbs/hr-min and the ending setpoint in lbs/hr are entered by the operators and have minimum and maximum limits.



4.3.11 T030-5503 Crude Alcohol Inventory Controller

Reference P&IDs: L2CC-030-25-PI-5539, L2CC-030-25-PI-5540, L2CC-030-25-PI-5541, L2CC-030-25-PI-5548, L2CC-030-25-PI-9061-01

The inventory in crude alcohol storage tank T030-5503 is managed via LC91162. It provides a setpoint for the dehydrator tower feed controller (FC53288) whenever ramp controller (FKC53288) is not in use. The same constraints that suspend the ramp (see Section 4.3.9) affect LC91162 in a similar fashion. Any constraint that has exceeded its limit will serve to curtail the control action of LC91162, i.e. its output holds. Once all constraints are cleared, control action resumes.

4.3.12 Dehydrator Tower Accumulator Interface Level Controller

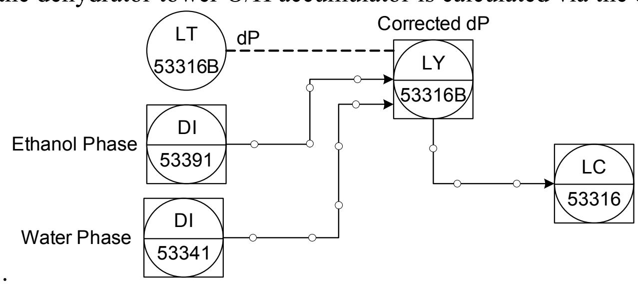
Reference P&IDs: L2CC-030-25-PI-5541, L2CC-030-25-PI-5543, L2CC-030-25-PI-5553

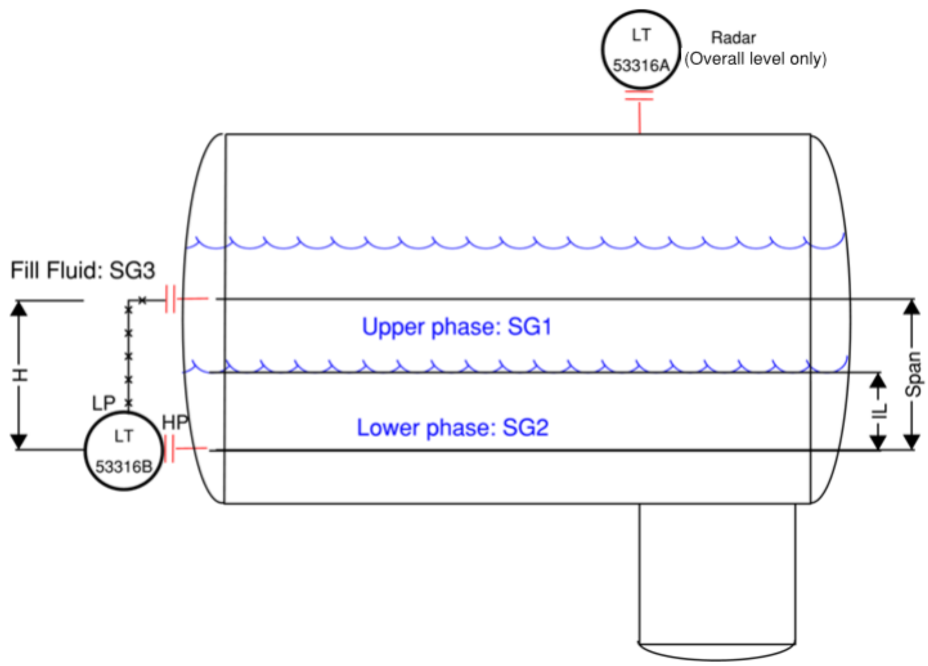
The dehydrator tower accumulator level (LC53316) is controlled by adjusting the net flow (FYC53341) of water leaving the accumulator. Unfortunately, this flow is not measured directly. Flow meter FI53341 measures the flow that contains both the flow from the accumulator (the desired measured variable) and flow from the ammonia absorber (FI53468). FYC53341 computes the difference (Δ) between FI53341 and FI53468 and uses the result as its measured variable.

4.3.13 Dehydrator Tower O/H Accumulator D-5509 Level Interface Measurement

Reference P&IDs: L2CC-030-25-PI-5541, L2CC-030-25-PI-5543, L2CC-030-25-PI-5548

The level interface for the dehydrator tower O/H accumulator is calculated via the density-compensated dP transmitter LT-53316B.





$$dP = HP - LP$$
$$LP = H * SG3$$
$$HP = SG2 * IL + SG1 * (H - IL)$$
$$dP = SG2 * IL + SG1 * (H - IL) - H * SG3$$
$$H = 28 \text{ ft}$$

$$SG1 = DI53391$$
$$SG2 = DI53341$$
$$SG3 = 0.93$$

$$IL = \frac{dP + H * (SG3 - SG1)}{(SG2 - SG1)}$$

$$LY53316B(\text{in } \%) = 100 * \frac{IL}{H}$$

4.3.14 Butanol Tower BTU Control

Reference P&IDs: L2CC-030-25-PI-5544

Tray 4 of the Butanol Tower is temperature-controlled (TC53351) via a standard BTU Controller (QYC53358) for reboiler X030-5508. Tray 2 can also be selected. The temperature profile of the column indicates the separation of the components within the tower. If the temperature is too low, the internal vapor traffic must be increased. TC53351 adjusts the setpoint of QYC53358, which in turn sends the hot oil flow controller (FC53358) a remote setpoint. Tower temperature control points must be verified before startup.

The flow controller FC53358 provides the valve position of FV-53358 to the optimizing controller (ZC81124) for the hot oil heater. Refer to L2CC-030-70-EN-8000 for more details.

The density (ρ) equation is used to compensate the flow measurement (FI53358) due to temperature changes in the hot oil.

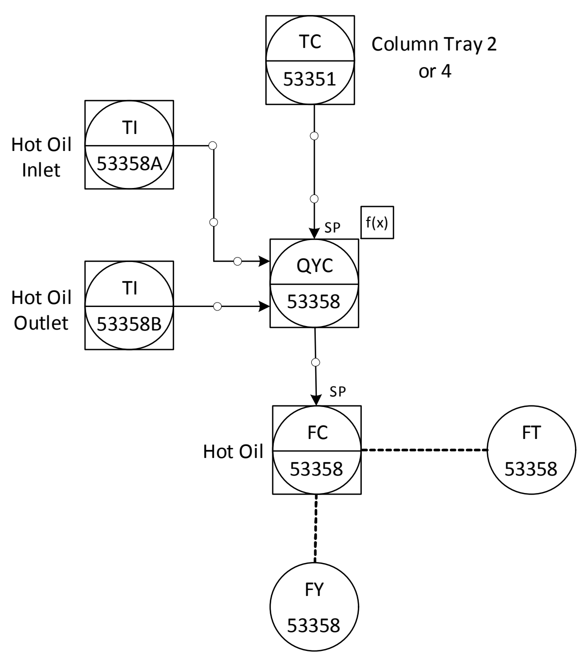
$$\rho = 62.4 * (1.0484 - 0.0004214 * \mathrm{TI53358A})$$

The heat duty controller performs the following calculation using the hot oil inlet and outlet temperatures.

$$Cp = 0.0004675 * \left(\frac{\mathrm{TI53358A} + \mathrm{TI53358B}}{2}\right) + 0.3477$$

$$\mathrm{QC53358.PV}\ (Heat\ duty\ meas) = \mathrm{FC53358.PV} * Cp * (\mathrm{TI53358A.PV} - \mathrm{TI53358B.PV})/1000$$

$$\mathrm{FC53358.SP}\ (Control\ Output) = (1000 * \mathrm{QC53358.SP})/(Cp * (\mathrm{TI53358A.PV} - \mathrm{TI53358B.PV}))$$



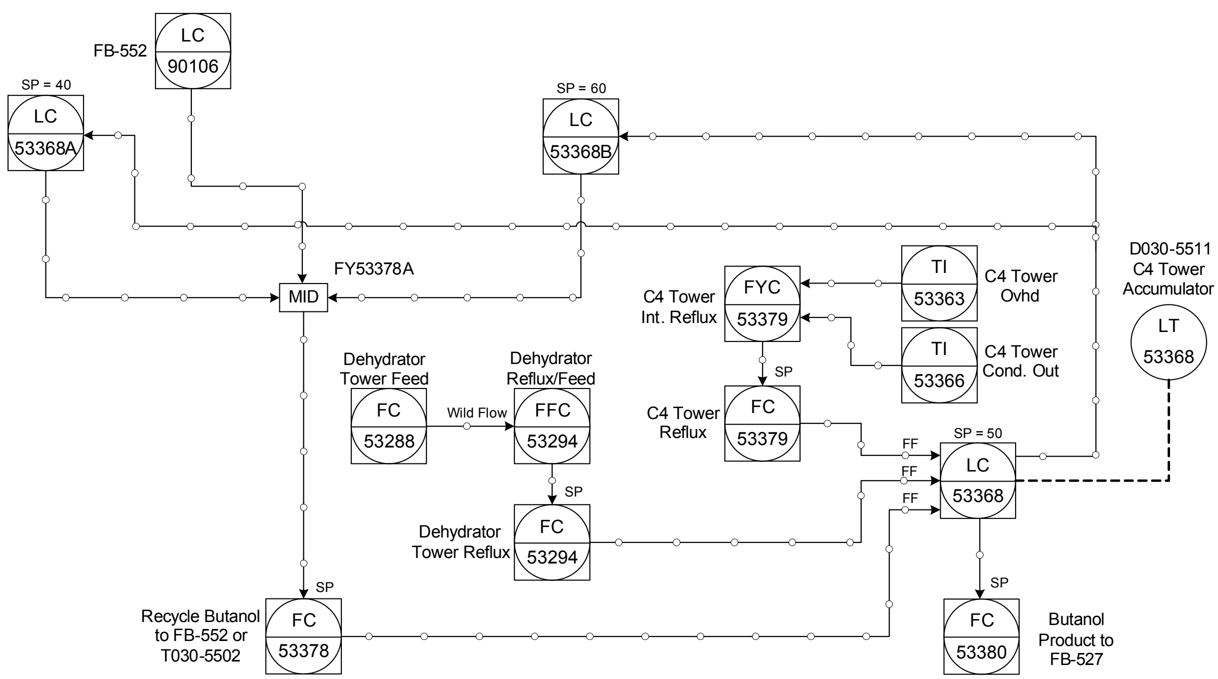
4.3.15 Butanol Tower O/H Accumulator Level Control

Reference P&IDs: L2CC-030-25-PI-5539, L2CC-030-25-PI-5540, L2CC-030-25-PI-5545, L2CC-030-25-PI-5547, LCCC-074.9-PI-144-D

The Butanol Tower O/H Accumulator collects high purity butanol product from the tower overhead. Liquid butanol is used as reflux for both the butanol tower (FC53379) and the dehydrator tower (FC53294). Butanol product also supplies recycle butanol material to main tank FB-552 or swing tank T030-5502. LC90106 controls the FB-552 level by adjusting the butanol product flow (FC53378) to the tank. Alternatively, LC91200 controls the T030-5502 level the same way, depending on the selection that is made for the swing tank operation (by the DCS Engineer, see section 4.5.1 for details).. Liquid level in the accumulator (LC53368) is controlled by setting the remaining product flow to the butanol product tank FB-527 via FC53380. As long as the accumulator level is not too low and not too high, LC90106/LC91200 has control of FC53378 to maintain FB-552/T030-5502 level. If the accumulator level goes high, an override controller (LC53368B) increases the flow to FB-552/T030-5502. If the accumulator level goes low, an override controller (LC53368A) decreases the flow to FB-552/T030-5502. Once the system reaches equilibrium, the flow to FB-552/T030-5502 resumes its normal control action.

LC53368 includes feedforward action based on the sum of the other butanol product flows: (FC53379 + FC53294 + FC53378).

Note: LC90106 is an existing control loop. It must be modified to function within the control strategy described here. For details on the required changes, see Appendix II of this document.



4.3.16 Butanol Tower Reflux

Reference P&IDs: L2CC-030-25-PI-5545, L2CC-030-25-PI-5547

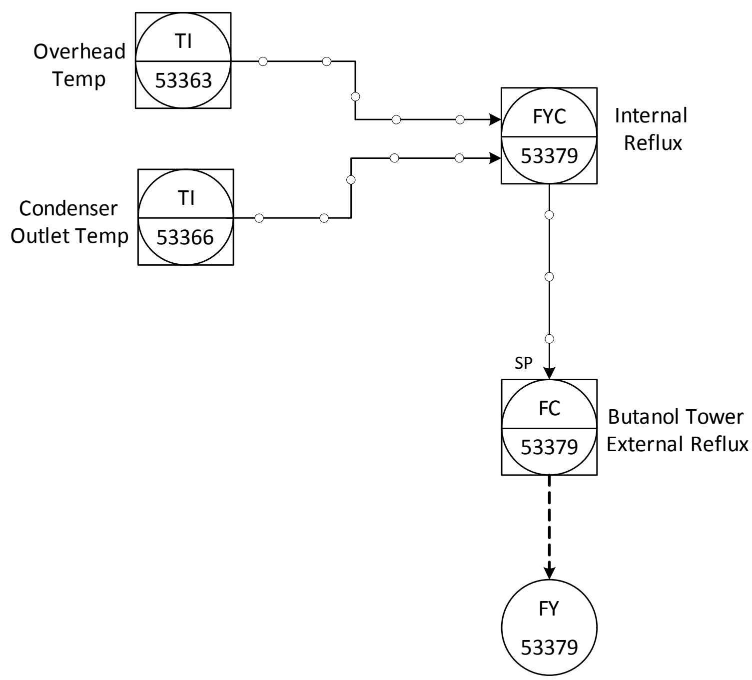
Internal reflux is defined as the liquid down flow inside the column. The application here attempts to calculate the internal reflux at the entry point of the external reflux to stabilize tower operation below. The external reflux flow controller (FC53379) receives its setpoint from the internal reflux controller (FYC53379).

Internal reflux flow FYC53379 is calculated using the differential between the overhead temperature TI53363 and accumulator temperature TC53366 along with external reflux flow FC53379 and the ratio of the liquid heat capacity and heat of vaporization.

$$\mathrm{FYC53379.PV}\ (Int.Reflux\ meas.) = \mathrm{FC53379.PV} * \left(1 + \frac{\mathrm{Cp}}{\lambda}(\mathrm{TI53363.PV} - \mathrm{TC53366.PV})\right)$$

$$\mathrm{FC53379.SP}\ (Control\ Output) = \mathrm{FYC53379.SP} / \left(1 + \frac{\mathrm{Cp}}{\lambda}(\mathrm{TI53363.PV} - \mathrm{TC53366.PV})\right)$$

Where Cp is heat capacity and λ is heat of vaporization for the reflux material. The quotient of these two is estimated at 0.0022, which uses a Cp value of 0.65 and a λ of 295.

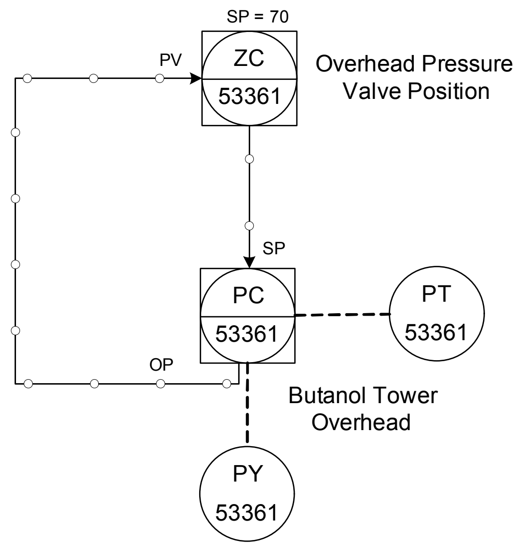


4.3.17 Butanol Tower O/H Pressure

Reference P&IDs: L2CC-030-25-PI-5545

The Butanol tower pressure (PC53361) is controlled by throttling the release of the overhead vapor stream. Since this column runs at a vacuum, separation efficiency improves significantly with lower pressure. To minimize the pressure while maintaining effective pressure control, a valve position controller (ZC53361) gradually adjusts the PC53361 setpoint to the point where the pressure control valve averages at the position target, typically 70%.

ZC53361 uses the output (valve position) of the PC53361 loop as its PV. Tuning is generally low gain with a long reset time so that the pressure setpoint does not shift noticeably in the short term. The setpoint for ZC53361 shall be clamped between 50 and 80 to avoid sub-optimal settings.



4.3.18 Ethanol Tower Reboiler

Reference P&IDs: L2CC-030-25-PI-5548

The Ethanol tower separates feed into three components:

- Overhead vapor – mostly ethanol, some water, ammonia, and other components
- Sidedraw – Mostly ethanol with about 12% water and contains trace amounts of O/H vapor and bottoms components
- Bottoms – Mostly Butanol, some water and as little as possible ethanol

The separation of these components is based on their relative boiling points. At lower pressures the boiling points for these components all shift downward, so the same composition can be achieved at lower temperature. Ethanol and water form an azeotrope, so there is a limit to how much water can be removed from the Ethanol, which also affects the boiling point of the mixture.

Reboiler steam is controlled to meet tower below tray 6 (bottom portion of the stripping section) target temperature (TI53407) while not exceeding a tower pressure drop limit (PDYC53392), which indicates the tower is getting close to flooding conditions. TI53407 and PI53399 are employed in a pressure-compensated temperature (PCT) calculation to infer the composition of ethanol in the butanol product at the tower bottoms. The PCT result is displayed and controlled by TYC53407, which uses feedforward based on the tower feed, FC53391. TYC53407 and PDYC53392 are reverse acting, and provide a remote setpoint to FC53413 via a low selector. The PCT equation follows:

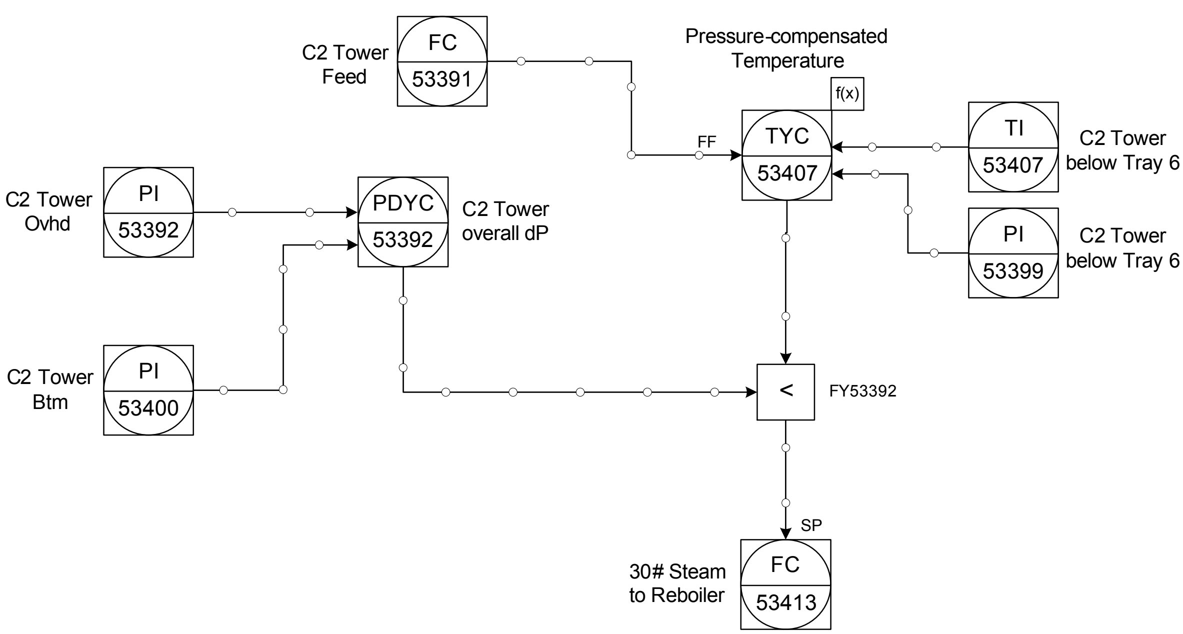
$$\mathrm{TYC53407} = \mathrm{TI53407} - \mathrm{K}_f * (\mathrm{PI53399} - \mathrm{P}_{ref})$$

where:

K_f = K factor relating temperature to pressure at constant composition, initially set to 1.0

P_{ref} = Reference Pressure, initially set to 7.2

The constants 1.0 and 7.2 are used in Ziegler 1. These constants can be adjusted after startup.



4.3.19 Ethanol Tower Sidedraw and Reflux

Reference P&IDs: L2CC-030-25-PI-5548, L2CC-030-25-PI-5549, L2CC-030-25-PI-5551

Internal reflux is defined as the liquid down flow inside the column. Internal reflux ratio is the percentage of the internal reflux below the sidedraw takeoff point, which continues down the column and not taken as sidedraw product draw. Control of internal reflux ratio attempts to stabilize tower operation below the sidedraw. The sidedraw flow controller (FC53430) receives its setpoint from the internal reflux ratio controller (FFYC53430). External reflux flow controller (FC53432) receives its setpoint from the ethanol tower accumulator level controller (LC53420).

Internal reflux flow is calculated using the differential between the overhead temperature TI53414 and condenser outlet temperature TI53418 along with external reflux flow FC53432 and the ratio of the liquid heat capacity and heat of vaporization. This is reduced by the amount of sidedraw flow (FC53430) and divided by the calculated internal reflux flow to yield the portion that travels down the column. The equations for measurement and control follow:

$$\mathrm{Int.Reflux} = \mathrm{FC53432.PV} * \left(1 + \frac{\mathrm{Cp}}{\lambda}(\mathrm{TI53414.PV} - \mathrm{TI53418.PV})\right)$$

$$\mathrm{FFYC53430.PV\ (Int.Reflux\ Ratio\ meas)} = 100 * (1 - \mathrm{FC53430.PV/Int.Reflux})$$

$$\mathrm{FC53430.SP\ (Control\ Output)} = \mathrm{Int.Reflux} * (1 - \mathrm{FFYC53430.SP}/100)$$

Where Cp is heat capacity and λ is heat of vaporization for the reflux material. The quotient of these two is currently estimated at 0.0018, based on HMB data..

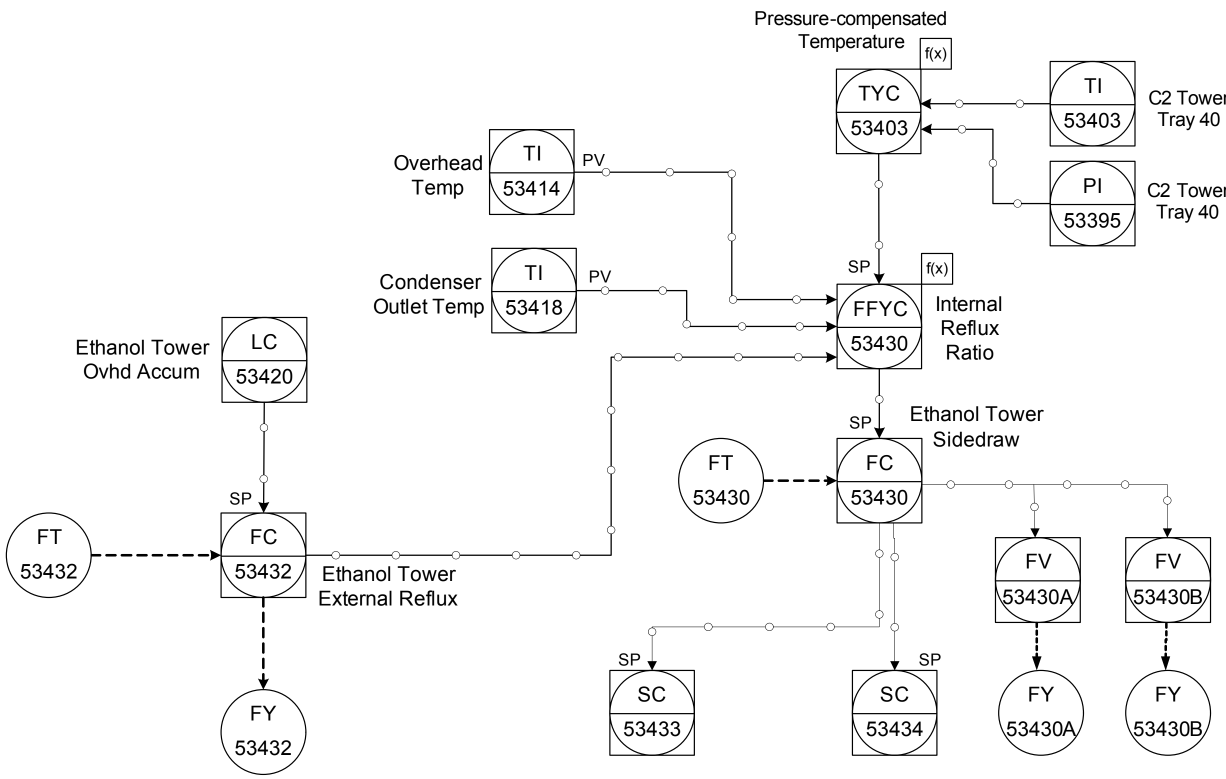
The Internal Reflux Ratio (FFYC53430) setpoint is adjusted to maintain ethanol product quality. The temperature (TI53403) and pressure (PI53395) at tray 40 are employed in a pressure-compensated temperature (PCT) calculation to infer the composition of butanol in the ethanol product at the tower sidedraw. The PCT result is displayed and controlled by TYC53403 sends a setpoint to internal reflux ratio controller FFYC53430. TYC53403 is direct acting. The PCT equation follows:

$$\mathrm{TYC53403} = \mathrm{TI53403} - \mathrm{K}_f * (\mathrm{PI53395} - \mathrm{P}_{ref})$$

where:
K_f = K factor relating temperature to pressure at constant composition, initially set to 1.0
P_{ref} = Reference Pressure, initially set to 7.2

The constants 1.0 and 7.2 are used in Ziegler 1. These constants can be adjusted if needed after startup.

(Ethanol Tower Sidedraw and Reflux, continued)



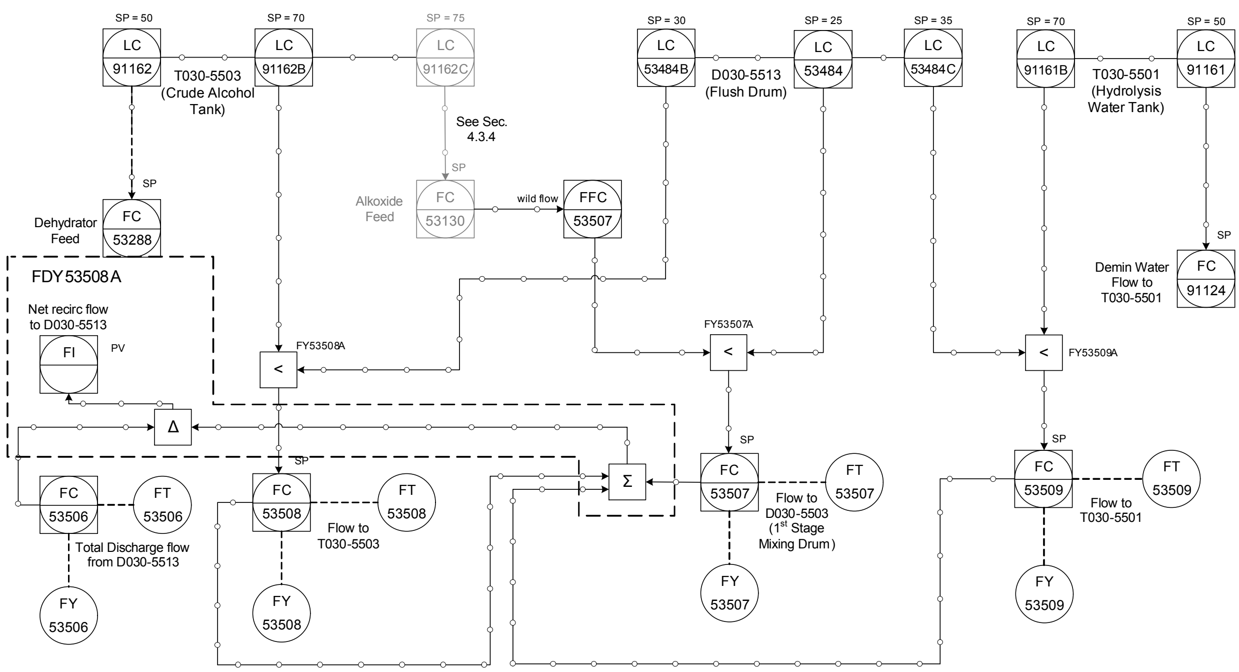
Ethanol tower sidedraw flow controller (FC53430) controls the flow rate by adjusting both the speed controller (SC53433 / SC53434, 6:1 turn down) and modulating the variable stroke actuator (FY53430A/B, 7:1 turndown) of pumps P030-5517A/B. From 0% to 60% output of FC53430, FY53430A/B will vary from 0%-70%. From 60% to 100% output of FC53430, SC53433/SC53434 will vary from a minimum speed of 6 Hz to a maximum speed of 60 Hz. The stroke will be limited to 70% of maximum to ensure mechanical reliability of the pumps.

4.3.20 Flush/Collection Drum Out Flow

Reference P&IDs: L2CC-030-25-PI-5526, L2CC-030-25-PI-5555, L2CC-030-25-PI-5558, L2CC-030-25-PI-9060-01, L2CC-030-25-PI-9061-01

The Flush/Collection Drum inventory is maintained by a series of level controllers with phased setpoints. Each is cascaded to a different flow slave. LC53484 is the primary inventory controller, cascading to FC53507, the flow that returns to the 1st Stage Mixing Drum. FC53507 is limited by a ratio controller (FFC53507) that follows the main alkoxide feed (FC53130) as its wild flow. The secondary inventory controller is LC53484B that cascades to FC53508, the flow to the Crude Alcohol Tank (T-5503). This flow is limited by a high-level override controller (LC91162B) that monitors level in T-5503. A tertiary inventory controller, LC53484C, cascades to FC53509, the flow to the Hydrolysis Water Tank (T-5501). FC53509 is limited by a high-level override controller (LC91161B) that monitors level in T-5501.
Each of the three level controllers, LC53484, LC53484B, and LC53484C, has a progressively higher setpoint. Thus, as the Flush Drum level increases, if the primary controller is limited and cannot maintain its setpoint, the secondary flow will begin to open its flow controller. If the secondary controller still is unable to maintain its higher setpoint, the tertiary controller will begin to open its flow controller.

There is a local panel in the field, LCP-55100, located near D030-5513 to allow for manual control of the level in the drum by selecting a flow destination.. Refer to Section 3.3.4 for a description of the local panel.



4.3.21 Tank Interface Levels (T030-5501/02/03)

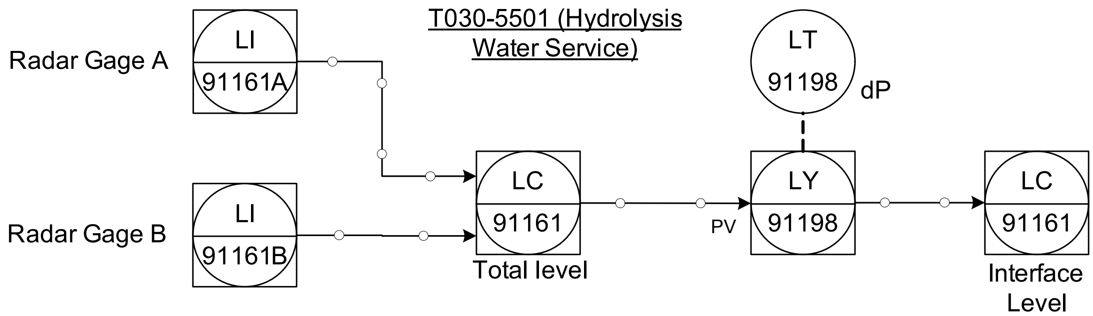
Reference P&IDs: L2CC-030-25-PI-9060-01, L2CC-030-25-PI-9061-01, and L2CC-030-25-PI-9062-01

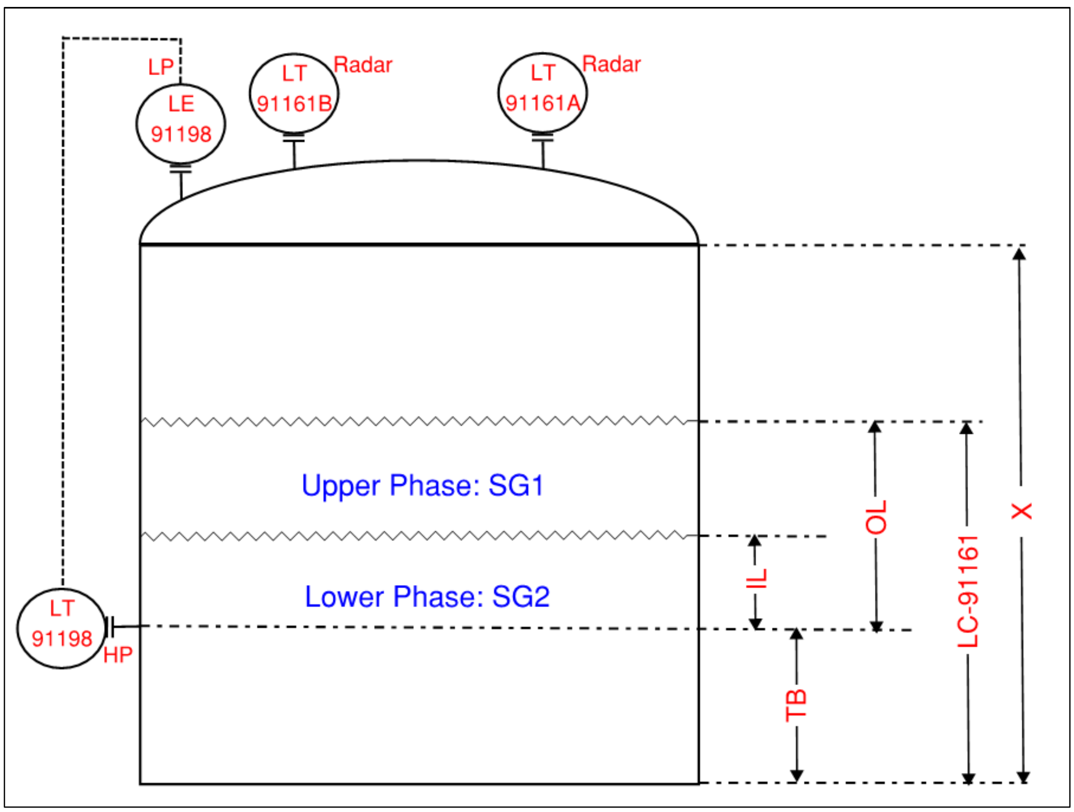
The following describes the calculations involved in determining the water/alcohol interface for tanks T030-5501, 5502, and 5503. T030-5501 normally functions in hydrolysis water service, T030-5502 in recycle butanol service, and T030-5503 in wet crude alcohol service.

For tank T030-5502, the top interface level (LY91206) only functions if T030-5501 is out of service and T030-5502 is serving as T030-5501. Likewise, the bottom interface level (LY91207) only fucntions if T030-5503 is out of service and T030-5502 is serving as T030-5503. Refer to section 3.3.4 for a discussion on the tanks and their various services.

The following table summarizes the functions of the interface level indication tags under the different services:

T-5502 Service (Selected in I-30-9016)	LY91198 (T-5501 Interface level)	LY91206 (T-5502 Top Interface level)	LY91207 (T-5502 Bottom Interface Level)	LY91199 (T-5503 Interface Level)
Hydrolysis Water	OOS	In Service	OOS	In Service
Wet Crude Alcohol	In Service	OOS	In Service	OOS
Recycle Butanol	In Service	OOS	OOS	In Service





Note: The above graphics and the following equations are for T030-5501 interface level when it is in hydrolysis water service. The dP LT on this tank uses two separate sensors connected by an electrical connection (ERS system).

$\mathrm{OL} = \mathrm{X} * \mathrm{LC91161.PV}/100 - \mathrm{TB}$

LT-91198 $= \mathrm{dP} = \mathrm{HP} - \mathrm{LP}$

$\mathrm{dP} = \mathrm{IL} * \mathrm{SG2} + (\mathrm{OL} - \mathrm{IL}) * \mathrm{SG1} = \mathrm{OL} * \mathrm{SG1} + \mathrm{IL} * (\mathrm{SG2} - \mathrm{SG1})$

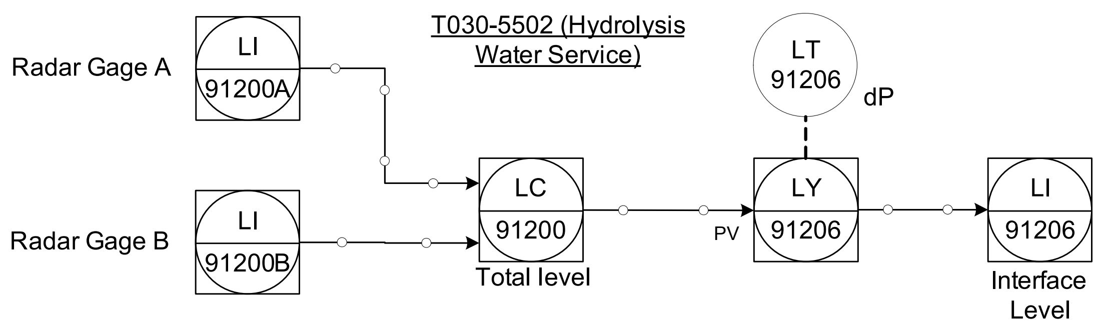
$\mathrm{dP} = \mathrm{OL} * \mathrm{SG1} + \mathrm{IL} * (\mathrm{SG2} - \mathrm{SG1})$

$\mathrm{IL} = (\mathrm{dP} - \mathrm{OL} * \mathrm{SG1})/(\mathrm{SG2} - \mathrm{SG1})$

$$\mathrm{LY91198}\ (\%) = 100 * \frac{(\mathrm{IL} + \mathrm{TB})}{\mathrm{X}}$$

where:

$\mathrm{X}\ (\mathrm{ft}) = \text{full tank height} = 40.0$
$\mathrm{TB}\ (\mathrm{ft}) = 18.0$
$\mathrm{SG1}\ (\mathrm{lb/ft^3}) = \text{alcohol layer} = 0.79$
$\mathrm{SG2}\ (\mathrm{lb/ft^3}) = \text{water layer} = 0.98$
$\mathrm{OL}\ (\mathrm{ft}) = \text{height of Overall Level measured by Radar gage}$
$\mathrm{IL}\ (\mathrm{ft}) = \text{height of Interface Level}$
$\mathrm{HP}\ (\text{ft of } \mathrm{H_2O}) = \text{Pressure at lower tap of dP cell}$
$\mathrm{LP}\ (\text{ft of } \mathrm{H_2O}) = \text{Pressure at upper tap of dP cell}$



Note: The following equations are for T030-5502 interface level when it is in hydrolysis water service. This tank is equipped with two standard, capillary dP cells, one on the high end (LT-91206, for Hydrolysis Water Service) and one towards the bottom (LT-91207, for Wet Crude Alcohol Service).

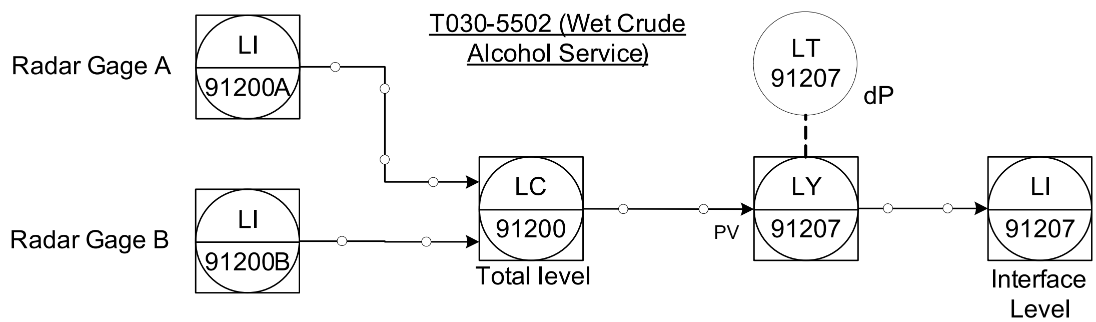
$\mathrm{OL} = \mathrm{X} * \mathrm{LC91200.PV}/100 - \mathrm{TB}$
$\text{LT-91206} = \mathrm{dP} = \mathrm{HP} - \mathrm{LP}$
$\mathrm{HP} = \mathrm{IL} * \mathrm{SG2} + (\mathrm{OL} - \mathrm{IL}) * \mathrm{SG1}$
$\mathrm{LP} = \mathrm{H} * \mathrm{SG3}$
$\mathrm{dP} = \mathrm{IL} * \mathrm{SG2} + (\mathrm{OL} - \mathrm{IL}) * \mathrm{SG1} - \mathrm{H} * \mathrm{SG3} = \mathrm{OL} * \mathrm{SG1} + \mathrm{IL} * (\mathrm{SG2} - \mathrm{SG1}) - \mathrm{H} * \mathrm{SG3}$
$\mathrm{dP} = \mathrm{OL} * \mathrm{SG1} + \mathrm{IL} * (\mathrm{SG2} - \mathrm{SG1}) - \mathrm{H} * \mathrm{SG3}$
$\mathrm{IL} = (\mathrm{H} * \mathrm{SG3} + \mathrm{dP} - \mathrm{OL} * \mathrm{SG1})/(\mathrm{SG2} - \mathrm{SG1})$

$$\mathrm{LY91206}\ (\%) = 100 * \frac{(\mathrm{IL} + \mathrm{TB})}{\mathrm{X}}$$

where:

$\mathrm{X}\ (\mathrm{ft}) = \text{full tank height} = 30.0$
$\mathrm{H}\ (\mathrm{ft}) = 20.17$
$\mathrm{TB}\ (\mathrm{ft}) = 17.0$

$SG1\ (lb/ft^3) = \text{alcohol layer} = 0.79$
$SG2\ (lb/ft^3) = \text{water layer} = 0.98$
$SG3\ (lb/ft^3) = \text{fill fluid} = 0.93$
$OL\ (ft) = \text{Overall Level measured by Radar gage}$
$IL\ (ft) = \text{Interface Level}$
$HP\ (\text{ft of } H_2O) = \text{Pressure at lower tap of dP cell}$
$LP\ (\text{ft of } H_2O) = \text{Pressure at upper tap of dP cell}$



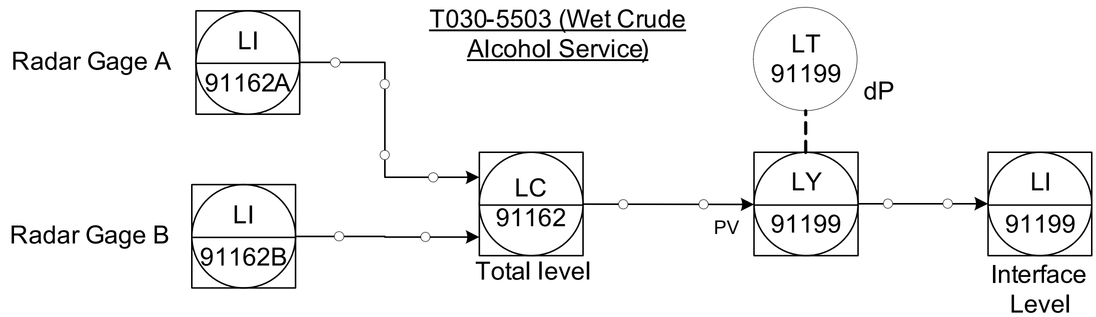
Note: the following equations are for T030-5502 interface level when it is in wet crude alcohol service.

$OL = X * LC91200.PV/100 - TB$
$LT\text{-}91207 = dP = HP - LP$
$HP = IL * SG2 + (OL - IL) * SG1$
$LP = H * SG3$
$dP = IL * SG2 + (OL - IL) * SG1 - H * SG3 = OL * SG1 + IL * (SG2 - SG1) - H * SG3$
$dP = OL * SG1 + IL * (SG2 - SG1) - H * SG3$
$IL = (H * SG3 + dP - OL * SG1)/(SG2 - SG1)$

$$LY91207\ (\%) = 100 * \frac{(IL + TB)}{X}$$

where:

$X\ (ft) = \text{full tank height} = 30.0$
$H\ (ft) = 20.17$
$TB\ (ft) = 17.0$
$SG1\ (lb/ft^3) = \text{alcohol layer} = 0.79$
$SG2\ (lb/ft^3) = \text{water layer} = 0.98$
$SG3\ (lb/ft^3) = \text{fill fluid} = 0.93$
$OL\ (ft) = \text{Overall Level measured by Radar gage}$
$IL\ (ft) = \text{Interface Level}$
$HP\ (\text{ft of } H_2O) = \text{Pressure at lower tap of dP cell}$
$LP\ (\text{ft of } H_2O) = \text{Pressure at upper tap of dP cell}$



Note: the following equations are for T030-5503 interface level when it is in wet crude alcohol service. This tank uses the same set-up as T-5501 other than the interface level transmitter being a capillary dP cell as well.

$$\mathrm{OL} = \mathrm{X} * \mathrm{LC91162.PV}/100 - \mathrm{TB}$$
$$\text{LT-91199} = \mathrm{dP} = \mathrm{HP} - \mathrm{LP}$$
$$\mathrm{HP} = \mathrm{IL} * \mathrm{SG2} + (\mathrm{OL} - \mathrm{IL}) * \mathrm{SG1}$$
$$\mathrm{LP} = \mathrm{H} * \mathrm{SG3}$$
$$\mathrm{dP} = \mathrm{IL} * \mathrm{SG2} + (\mathrm{OL} - \mathrm{IL}) * \mathrm{SG1} - \mathrm{H} * \mathrm{SG3} = \mathrm{OL} * \mathrm{SG1} + \mathrm{IL} * (\mathrm{SG2} - \mathrm{SG1}) - \mathrm{H} * \mathrm{SG3}$$
$$\mathrm{dP} = \mathrm{OL} * \mathrm{SG1} + \mathrm{IL} * (\mathrm{SG2} - \mathrm{SG1}) - \mathrm{H} * \mathrm{SG3}$$
$$\mathrm{IL} = (\mathrm{H} * \mathrm{SG3} + \mathrm{dP} - \mathrm{OL} * \mathrm{SG1})/(\mathrm{SG2} - \mathrm{SG1})$$

$$\mathrm{LY91199}\ (\%) = 100 * \frac{(\mathrm{IL} + \mathrm{TB})}{\mathrm{X}}$$

where:

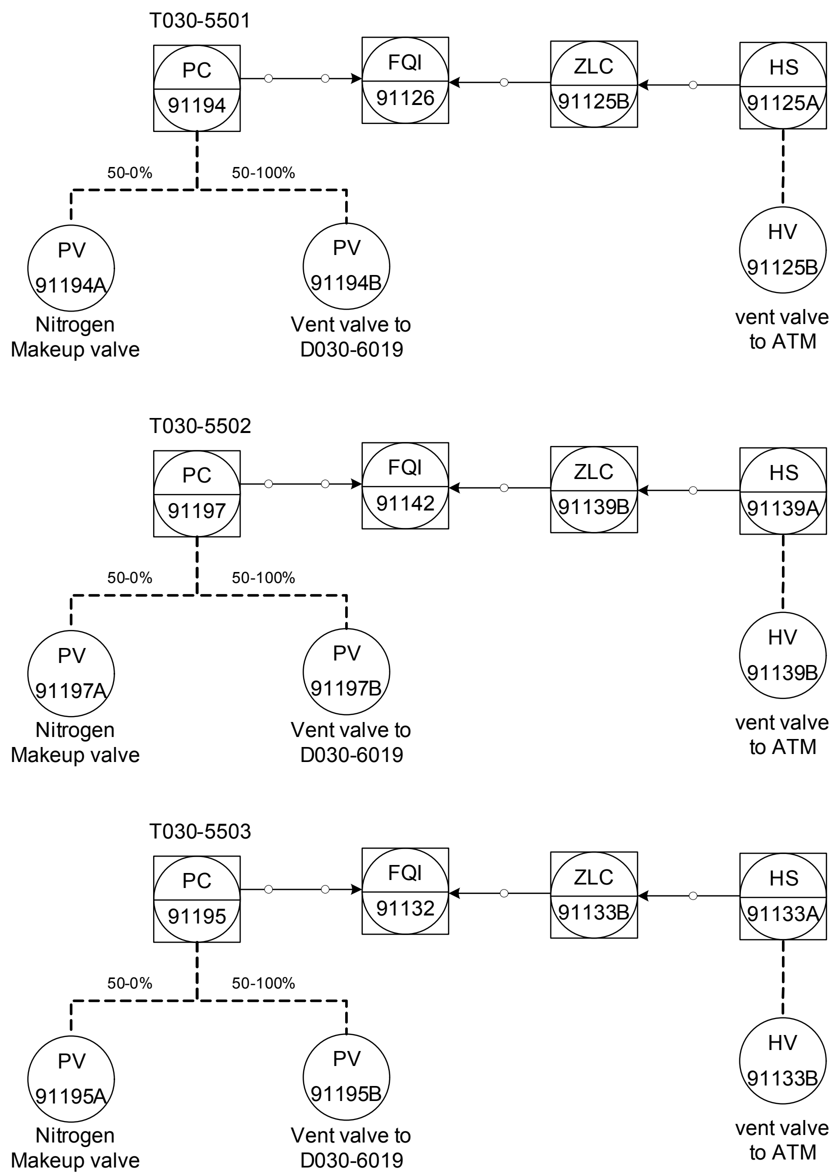
$\mathrm{X}\ (\mathrm{ft}) = \text{full tank height} = 30.0$
$\mathrm{H}\ (\mathrm{ft}) = 20.17$
$\mathrm{TB}\ (\mathrm{ft}) = 17.0$
$\mathrm{SG1}\ (\mathrm{lb/ft^3}) = \text{alcohol layer} = 0.79$
$\mathrm{SG2}\ (\mathrm{lb/ft^3}) = \text{water layer} = 0.98$
$\mathrm{SG3}\ (\mathrm{lb/ft^3}) = \text{fill fluid} = 0.93$
$\mathrm{OL}\ (\mathrm{ft}) = \text{Overall Level measured by Radar gage}$
$\mathrm{IL}\ (\mathrm{ft}) = \text{Interface Level}$
$\mathrm{HP}\ (\text{ft of } H_2O) = \text{Pressure at lower tap of dP cell}$
$\mathrm{LP}\ (\text{ft of } H_2O) = \text{Pressure at upper tap of dP cell}$

4.3.22 Tank Emissions Counters (T030-5501/02/03)

Reference P&IDs: L2CC-030-25-PI-9060-01, L2CC-030-25-PI-9061-01, L2CC-030-25-PI-9062-01

Tanks T030-5501, T030-5502, and T030-5503 use a split range tank blanketing system. The nitrogen makeup and vent combine to maintain an inert atmosphere inside the tanks. The vent is normally routed to the cold side flare through a knockout drum (D030-6022). However, in the event of high-high pressure in the knockout drum, interlocks I-30-9018, I-30-9019, I-30-9020 (refer to section 5.21, 5.22, 5.23) route the tank vents to atmosphere to a permitted point source. A restriction orifice is needed in the outlet line to ensure a flow rate that is within the air permit limits.

On T030-5501/02/03, when XV-91125B/33B/34B is not closed, the emissions counter (FQI91126/42/32) totalizes the flow rate based on the valve position of vent valve PV-91194B/97B/95B.



4.4 Simple loops

Controller Action – Direct: Increasing signal input corresponds to increasing output (4 - 20mA, 0 - 100%, etc.).
Reverse: Increasing signal input corresponds to decreasing output (20 – 4mA, 100 – 0%, etc.).

Valve Action – Direct: Valve is Fail Close (FC).
Reverse: Valve is Fail Open (FO).

Controller / Loop Tag	PV Tag(s)	End Device Tag	P&ID	Controller Type	Controller Action	Valve Action	Notes
TC53525	TT-53525	TV-53525A TV-53525B	L2CC-030-25-PI-5512-03	PID	Reverse	Direct (FC)	Split-range output where: A is 10% - 0%, B is 10% - 100%.
PC53529	PT-53529	PV-53529A PV-53529B	L2CC-030-25-PI-5512-03	PID	Direct	A: Reverse (FO) B: Direct (FC)	Split-range output where: A is 50% - 0%, B is 50% - 100%.
LC53536 FC53540	LT-53536A LT-53536B FT-53540	FV-53540	L2CC-030-25-PI-5512-03	PID	L - Reverse F - Reverse	Direct (FC)	Cascade Loop
FC53541	FT-53541	FV-53541	L2CC-030-25-PI-5512-03	PID	Reverse	Reverse (FO)	Simple Loop (Recirculation)
LC53110	LT-53110	LV-53110	L2CC-030-25-PI-5520	PID	Direct	Reverse (FO)	Simple Loop
FC53127 TC53126	FT-53127 TT-53126	FV-53127	L2CC-030-25-PI-5525	PID	F - Reverse T - Reverse	Direct (FC)	Cascade loop
PC53138	PT-53138	PV-53138A PV-53138B	L2CC-030-25-PI-5527	PID	Direct	A - Direct (FC) B - Reverse (FO)	Split-range output where: A is 47% - 0%, B is 52% - 100%.
LC53136 FC53163	LT-53136A/B FT-53163	FV-53163	L2CC-030-25-PI-5527 L2CC-030-25-PI-5528	PID	L – Direct F – Reverse	Direct (FC)	Cascade Loop

Controller / Loop Tag	PV Tag(s)	End Device Tag	P&ID	Controller Type	Controller Action	Valve Action	Notes
LC53199 FC53228	LT-53199A LT-53199B FT-53228	FV-53228	L2CC-030-25-PI-5529 L2CC-030-25-PI-5532 L2CC-030-25-PI-5533	PID	L – Direct F – Reverse	Reverse (FO)	Cascade loop
PC53174	PT-53174	PV-53174A PV-53174B	L2CC-030-25-PI-5530	PID	Direct	A - Direct (FC) B - Reverse (FO)	Split-range output where: A is 47% - 0%, B is 52% - 100%.
LC53175 FC53221	LT-53175A LT-53175B FT-53221	FV-53221	L2CC-030-25-PI-5530 L2CC-030-25-PI-5533	PID	L - Direct F - Reverse	Direct (FC)	Cascade loop
LC53176	LT-53176A LT-53176A	LV-53176	L2CC-030-25-PI-5530	PID	L - Direct	Direct (FC)	Simple Loop
LC53200 FC53201	LT-53200A LT-53200B FT-53201	FV-53201	L2CC-030-25-PI-5532	PID	L - Direct F – Reverse	Direct (FC)	Cascade loop
PC53198	PT-53198	PV-53198A PV-53198B	L2CC-030-25-PI-5532	PID	Direct	A - Direct (FC) B - Reverse (FO)	Split-range output where: A is 47% - 0%, B is 52% - 100%.
TC53220	TT-53220	TV-53220	L2CC-030-25-PI-5533	PID	Reverse	Direct (FC)	Simple Loop
FC53222	FT-53222	FV-53222	L2CC-030-25-PI-5533	PID	Reverse	Reverse (FO)	Simple Loop
FC53223	FT-53223	FV-53223	L2CC-030-25-PI-5533	PID	Reverse	Reverse (FO)	Simple Loop
FC53229	FT-53229	FV-53229	L2CC-030-25-PI-5534	PID	Reverse	Direct (FC)	Simple Loop
FC53230	FT-53230	FV-53230	L2CC-030-25-PI-5534	PID	Reverse	Direct (FC)	Simple Loop

Controller / Loop Tag	PV Tag(s)	End Device Tag	P&ID	Controller Type	Controller Action	Valve Action	Notes
LC53237 FC53259	LT-53237A LT-53237B FT-53259	SC53251 SC53252	L2CC-030-25-PI-5534 L2CC-030-25-PI-5536	PID	L - Direct F - Reverse S – Reverse	N/A	Cascade loop - FC53259 provides the same setpoint to both SCs. When pump P030-5504A or B stops, speed control loop for that pump is put in manual mode with zero output. LC53237 will continue to control the other pump.
TC53270	TT-53270	TV-53270	L2CC-030-25-PI-5537	PID	Direct	Reverse (FO)	Simple Loop
LC53284	LT-53284	LV-53284	L2CC-030-25-PI-5538	PID	Direct	Direct (FC)	Simple Loop
TC53287	TT-53287	TV-53287A/B	L2CC-030-25-PI-5539	PID	Reverse	Direct (FC)	Split Range: TC: 0% - 30%, A: 0% - 100% TC: 30% - 100%, B: 0% - 100%
LC91162 FC53288	LT-91162A LT-91162B FT-53288	FV-53288	L2CC-030-25-PI-5539 L2CC-030-25-PI-9061-01	PID	L - Direct F - Reverse	Direct (FC)	Cascade loop
QYC53310 FC53310	TT-53310A TT-53310B TT-53304A TT-53304B FT-53310	FV-53310	L2CC-030-25-PI-5540	PID	T - Reverse F - Reverse	Direct	Cascade loop - Refer to BTU standard controller
LC53309 FC53331	LT-53309A LT-53309B FT-53331	FV-53331	L2CC-030-25-PI-5540 L2CC-030-25-PI-5542	PID	L-Direct F - Reverse	Direct (FC)	Cascade loop
LC53316 FC53341	LT-53316A LT-53316B FT-53341	FV-53341	L2CC-030-25-PI-5541 L2CC-030-25-PI-5543	PID	L-Direct F - Reverse	Direct (FC)	Cascade loop - Interface level
FC53340	FT-53340	FV-53340	L2CC-030-25-PI-5541 L2CC-030-25-PI-5543	PID	Reverse	Reverse (FO)	Simple Loop

Controller / Loop Tag	PV Tag(s)	End Device Tag	P&ID	Controller Type	Controller Action	Valve Action	Notes
LC53317 FC53391	LT-53316A LT-53317 FT-53391	FV-53391	L2CC-030-25-PI-5541 L2CC-030-25-PI-5548	PID	L-Direct F - Reverse	Direct (FC)	Cascade loop - Overall level
FC53332	FT-53332	FV-53332	L2CC-030-25-PI-5542	PID	Reverse	Reverse (FO)	Simple Loop
QYC53358 FC53358	TT-53358A TT-53358B TT-53351A TT-53351B FT-53358	FV-53358	L2CC-030-25-PI-5544	PID	T - Reverse F - Reverse	Direct	Cascade loop - Refer to BTU standard controller
LC53357 FC53377	LT-53357A LT-53357B FT-53377	FV-53377	L2CC-030-25-PI-5544 L2CC-030-25-PI-5546	PID	L-Direct F - Reverse	Direct (FC)	Cascade loop
FC53376	FT-53376	FV-53376	L2CC-030-25-PI-5546	PID	Reverse	Reverse (FO)	Simple Loop
LC53368 FC53380	LT-53368 FT-53380	FV-53380	L2CC-030-25-PI-5545 L2CC-030-25-PI-5547	PID	L - See notes F - Reverse	Direct (FC)	Cascade loop - See Complex loops for level control
FC53379	FT-53379	FV-53379	L2CC-030-25-PI-5547	PID	Reverse	Direct (FC)	Simple Loop
TC53390	TT-53390	TV-53390	L2CC-030-25-PI-5547	PID	Direct	Reverse (FO)	Simple Loop
FY53378A FC53378	FT-53378	FV-53378	L2CC-030-25-PI-5547	PID	L - Direct F - Reverse	Direct	Cascade loop – See Complex loops for details
FC53381	FT-53381	FV-53381	L2CC-030-25-PI-5547	PID	Reverse	Reverse (FO)	Simple Loop
FC53413	FT-53413	FV-53413	L2CC-030-25-PI-5548	PID	Reverse	Direct	Simple loop - FC53413 receives setpoint from FY53392. Refer to complex loop section
LC53412 FC53429	LT-53412A LT-53412B FT-53429	FV-53429	L2CC-030-25-PI-5548 L2CC-030-25-PI-5550	PID	L-Direct F - Reverse	Reverse (FO)	Cascade loop

Controller / Loop Tag	PV Tag(s)	End Device Tag	P&ID	Controller Type	Controller Action	Valve Action	Notes
FC53428	FT-53428	FV-53428	L2CC-030-25-PI-5550	PID	Reverse	Reverse (FO)	Simple Loop
FC53430	FT-53430	SC53433 SC53433	L2CC-030-25-PI-5551	PID	F - Reverse S - Reverse	N/A	Simple loop - FC53430 receives setpoint from FFYC53430. Refer to complex loop section
FC53431	FT-53431	FV-53431	L2CC-030-25-PI-5551	PID	Reverse	Direct (FC)	Simple loop - Refer to complex loop section
FC53432	FT-53432	FV-53432	L2CC-030-25-PI-5551	PID	Reverse	Direct (FC)	Simple loop - Refer to complex loop section
FC53433	FT-53433	FV-53433	L2CC-030-25-PI-5551	PID	Reverse	Reverse (FO)	Simple Loop
FC53453	FT-53453	FV-53453	L2CC-030-25-PI-5553	PID	Reverse	Reverse (FO)	Simple loop
LC53458	LT-53458A LT-53458B	LV-53458	L2CC-030-25-PI-5553	PID	Direct	Reverse (FO)	Simple Loop
PC53479	PT-53479	PV-53479A PV-53479B	L2CC-030-25-PI-5555	PID	Direct	A - Direct (FC) B - Reverse (FO)	Split-range output where: A is 47% - 0%, B is 52% - 100%.
PC53551 FC53510 FC53511	PT-53551A PT-53551B FT-53510 FT-53511	FV-53510 FV-53511	L2CC-030-25-PI-5557	PID	P – Direct F – Reverse	Fail Last	Split Range: PC: 0% - 56%, FV-53511: 0% - 100% PC: 44% - 100%, FV-53510: 0% - 100% Refer to I-30-5547
FC53506	FT-53506	FV-53506	L2CC-030-25-PI-5558	PID	Reverse	Direct (FC)	Simple loop
FC53508	FT-53508	FV-53508	L2CC-030-25-PI-5558	PID	Reverse	Direct (FC)	Simple loop - See complex loops

Controller / Loop Tag	PV Tag(s)	End Device Tag	P&ID	Controller Type	Controller Action	Valve Action	Notes
FC53509	FT-53509	FV-53509	L2CC-030-25-PI-5558	PID	Reverse	Direct (FC)	Simple loop - See complex loops
FC53507	FT-53507	FV-53507	L2CC-030-25-PI-5558	PID	Reverse	Direct (FC)	Simple loop - See complex loops
FC91125	FT-91125	FV-91125	L2CC-030-25-PI-9060-01 L2CC-030-25-PI-9060-01	PID	Reverse	Reverse (FO)	Simple loop
LC91161 FC91124	LT-91161A LT-91161B FT-91124	FV-91124	L2CC-030-25-PI-9060-01	PID	L - Reverse F - Reverse	Direct (FC)	Cascade loop
PC91194	PT-91194A PT-91194B PT-91194C	PV-91194A PV-91194B	L2CC-030-25-PI-9060-01	PID	Direct	A - Direct (FC) B - Reverse (FO)	Split-range output where: A is 47% - 0%, B is 52% - 100%.
PC91195	PT-91195A PT-91195B PT-91195C	PV-91195A PV-91195B	L2CC-030-25-PI-9061-01	PID	Direct	A - Direct (FC) B - Reverse (FO)	Split-range output where: A is 47% - 0%, B is 52% - 100%.
FC91134	FT-91134	FV-91134	L2CC-030-25-PI-9061-02	PID	Reverse	Reverse (FO)	Simple loop
FC91135	FT-91135	SC91135	L2CC-030-25-PI-9061-02	PID	F - Reverse S - Reverse	N/A	Simple loop
FC91185	FT-91185	FV-91185	L2CC-030-25-PI-9062-01	PID	Reverse	Reverse (FO)	Simple loop
FC91190	FT-91190	FV-91190	L2CC-030-25-PI-9065	PID	Reverse	Reverse (FO)	Simple loop

4.5 Sequential Control Strategies

4.5.1 Tank Selection

Reference P&IDs: L2CC-030-25-PI-9060-01, L2CC-030-25-PI-9061-01, L2CC-030-25-PI-9062-01
Tank T030-5502 is a swing tank. If hydrolysis water tank (T030-5501), Crude alcohol tank (T030-5503), or Recycle Butanol tank (FB-552) is taken out of service, the swing tank can operate for any one of these tanks. Selecting and switching the controls between the various tanks will be a manual operation and require a DCS engineer to make the changes. This is to prevent accidentally lining up valves incorrectly.

4.5.2Ram and Flush Sequence

Reference P&ID s: L2CC-030-25-PI-5525, L2CC-030-25-PI-5526, L2CC-030-25-PI-5527, L2CC-030-25-PI-5530, L2CC-030-25-PI-5532, L2CC-030-25-PI-5533, L2CC-030-25-PI-9060-01

Valves HV-53134 and HV-53135 are injection nozzles equipped with ram valves designed to push through any coating that builds up on the inside of the nozzle. Normally, only one of the ram valves is in service at a time while the other is manually isolated and used as a spare. Build up could cause loss of feed and false level readings.

1, Bypass interlock I-30-5511, and disable FF control for LC91162.
2. The sequence, once activated by HS53139, will store the mode and the setpoint of the following controllers:
   a. FYC53123 – Hydrolysis water feed to hydrolysis reactor flow controller
   b. FC53130 – Stripped alkoxide feed to the hydrolysis reactor
   c. LC53136 – Hydrolysis reactor overall level
   d. LC53147 – Hydrolysis reactor interface level
   e. LC53175 – 1st stage separator overall level
   f. LC53176 – 1st stage separator interface level
   g. LC53199 – 2nd stage separator overall level
   h. LC53200 – 2nd stage separator interface level
   i. FC53215 – Recycle butanol
   j. LC91161 – Hydrolysis water storage tank T030-5501 overall level
   k. LC91162 – Crude alcohol tank T030-5503 overall level
   l. FC53229 – Steam flow control to Butanol Stripper
3. Set all the controllers from step 2 to manual and hold last position.
4. Disable alarms from the controllers from step 2.
5. Actuate the injection valve in service to ram and return, and then wait a few seconds.
6. When the timer completes, the rams return to the open position.
7. Once the stripped alkoxide (FC53130) flow settles to its stored setpoint, all the controllers from step 2 return to original mode (auto or manual) with their stored setpoints.
8. Enable alarms, interlock I-30-5511, and FF on LC91162.

This function is expected to operate once a shift for 10 – 15 minutes. If FC53130 does not return to its setpoint, the operator can repeat the sequence. The sequence will save the original modes and setpoints of the controllers until FC53130 reaches its setpoint.

5.0 PROCESS INTERLOCKS

5.1 I-30-5511: Alkoxide Low-Low Flow Isolation

Reference P&IDs: L2CC-030-25-PI-5526
Existing Interlock: I-01
Interlock identifies and protects against backflow of Hydrolysis Reactor contents into the alkoxide feed line which would react and form solids which could plug the pipe. Interlock is bypassed specifically during the ram and flush sequence.

When alkoxide flow FC53130 goes into low-low flow condition for 15 seconds:

A. FC53130 is placed in manual mode with a zero output, via one-shot command.
B. Close alkoxide shutoff valve EBV-53132, via one-shot command.

Reset: Operator can open FV-53130 and EBV-53132 and has 3 minutes to re-stablish flow above low-low setpoint. Otherwise, the trip initiates again.

5.2 I-30-5512: Hydrolysis Reactor (R030-5501) High-High Interface Level

Reference P&IDs: L2CC-030-25-PI-5527, L2CC-030-25-PI-5528
Existing Interlock: I-03
Interlock protects the crude alcohol storage tank (T030-5503) from ingress of slurry by closing the alcohol outlet valve. Interlock does not cut feed.

When Hydrolysis Reactor level 1oo2 LI53147A/B goes into high-high condition for 10 seconds:

A. Wet Crude Alcohol to Crude storage tank T030-5503 flow FC53163 will be put to manual mode with valve closed.

Reset: Once high-high level alarm has cleared, interlock is reset and controller returns to previous setpoint in AUTO mode.

5.3 I-30-5513: Ram and Flush Sequence

Moved to Section 4.5.2

5.4 I-30-5515: Butanol Stripper (W030-5504) High-High Pressure

Reference P&IDs: L2CC-030-25-PI-5532, L2CC-030-25-PI-5534
Existing Interlock: I-06
Interlock protects butanol stripper from over pressure by cutting feed flow and steam flow. When the feed flow is cut, the alkoxide feed may need to be reduced (action by operator) otherwise slurry may backup and cause an upset.

When high-high pressure is detected via PI53239 or PI53235:

A. Cut feed to the stripper by setting FC53201 to manual with the valve closed.
B. Cut steam flow to the stripper by setting FC53229 to manual with the valve closed.

Reset: When the pressure drops below high, the interlock releases FC53201and FC53229 in manual mode and returns functionality to the operator.

5.5 I-30-5516: Ethanol Tower (W030-5502) High-High Pressure

Reference P&IDs: L2CC-030-25-PI-5548, L2CC-030-25-PI-5549
Existing Interlock: I-07
Interlock protects ethanol tower from over pressure by cutting feed flow and steam heater flow.

When interlock activates on:

- 2oo3 of Ethanol Tower W030-5502 High-High Pressure PI53394, PI53392, PI53400
  OR
- 2oo2 Loss of Ethanol Tower Ovhd Condenser Fin Fans A/B XL53419A, and XL53419B

The following occurs:

A. Cut feed to ethanol tower by setting FC53391 to manual with the valve closed.
B. Cut 30# steam flow to ethanol tower by setting FC53413 to manual with the valve closed.

Reset:

- When at least 2oo3 pressures drop below their respective high set point
  AND
- When at least one fin fan is running on X030-5504 (XL53419A/B)

The interlock releases FC53391and FC53413 in manual mode and returns functionality to the operator.

5.6 I-30-5517: Dehydrator Tower (W030-5501) High-High Pressure

Reference P&IDs: L2CC-030-25-PI-5539, L2CC-030-25-PI-5540, L2CC-030-25-PI-5541
Existing Interlock: I-08
Interlock protects dehydrator tower from over pressure by cutting feed flow and hot oil flow.

Interlock activates on 2oo4 between Dehydrator Tower High-High Pressure PI53296, PI53300, XL53323A, and XL53323B:

A. Cut feed to the tower by setting FC53288 to manual with the valve closed.
B. Cut hot oil flow to the tower by setting FC53310 to manual with the valve closed.

Reset: On any three of the following: Pressure PI53296 and PI53300 drops below their respective high-high trip threshold and fin fans running (XL53323A/ XL53323B), The interlock releases FC53288and FC53310 in manual mode and returns functionality to the operator.

5.7 I-30-5518: Butanol Tower (W030-5503) High-High Pressure

Reference P&IDs: L2CC-030-25-PI-5542, L2CC-030-25-PI-5544, L2CC-030-25-PI-5545
Existing Interlock: I-09
Interlock protects Butanol tower from over pressure by cutting feed flow and hot oil flow.

Interlock activates on 2oo4 between PI53343, PI53346, XL53367A, and XL53367B:

A. Cut feed to the tower by setting FC53331 to manual with the valve closed.
B. Cut hot oil flow to the tower by setting FC53358 to manual with the valve closed.

Reset: On any three of the following: Pressure PI53343 and PI53346 drops 2 psi below their respective high-high trip threshold and fin fans running (XL53367A / XL53367B), The interlock releases FC53331and FC53358 in manual mode and returns functionality to the operator.
.

5.8 I-30-5519: P030-5514 and P030-5520 Spare Pump

Reference P&IDs: L2CC-030-25-PI-5553, L2CC-030-25-PI-5556
Existing Interlock: N/A

The ammonia absorber tower bottoms pump (P030-5520) and refrigerated vent pump (P030-5514) share a common spare pump (P030-5526). The hand switch (HS53469) selects if P030-5526 is sparing for P030-5514 or for P030-5520. Selection is disabled if P030-5526 is already running.

P030-5520 runs continuously and the level of W030-5505 is controlled via LC53458. There is no Auto-Start for pumps in this service due to the critical nature. The operator will need to confirm alignment and start the bypass pump if deemed necessary.

P030-5514 control is ON/OFF. When LI53488A/B/C reaches High level threshold, the pump is started. When LI53488A/B/C reaches low level threshold, the pump is stopped. On failure (stops running or fails to start) of the main pump P030-5514 via run status (XL53489), spare pump P030-5526 (if selected) will become the main pump and start/stop as needed.

If the spare pump (5030-5226) is running as main pump and stops running or fails to start via run status (XL53461), then the associated pump P030-5514 will start. This will be only attempted by the system 3 times, and is only valid for the vent knockout process (P030-5514), and not the tower bottoms service.

The interlock does not act when a main pump is turned off normally, only when it fails while in service (run status).

Reset: Interlock resents when either of the pumps in the aligned pair comes into service and is verified via run status. This also resets the number of failed attempts tracked.

5.9 I-30-5520: S-5500 Flush/Collection Drum (D030-5513) Low-Low Pressure

Reference P&IDs: L2CC-030-25-PI-5555, L2CC-030-25-PI-5558
Existing Interlock: N/A
Interlock protects the drum from low pressure and possible air ingress by closing all of the valves that allow pump out.

Interlock activates on low-low pressure via PI53481, if level (LI53484A/B) is not above high alarm setpoint:

A. Set Alcohol / Water to First Stage Mixer (D030-5503) FC53507 to manual with the valve closed.
B. Set Alcohol / Water to Crude Alcohol Storage Tank (T030-5503) FC53508 to manual with the valve closed.
C. Set Alcohol / Water to Hydrolysis Water Storage Tank (T030-5501) FC53509 to manual with the valve closed.

Reset: When pressure (PI53481) is above low alarm setpoint, the interlock releases FC53507, FC53508, and FC53509 in manual mode and returns functionality to the operator.

5.10 I-30-5521: Hot Demin Water Pumps (P030-5522A/B) Low-Low Level

Reference P&IDs: L2CC-030-25- PI-5512-03
Existing Interlock: N/A
Interlock protects hot demin water pumps on low-low liquid level in D030-5521.

Interlock activates on 1oo2 low-low LI53536A/B:

A. Stop pump P030-5522A via HS53538
B. Stop pump P030-5522B via HS53539

Reset: When level (LI53536A/B) is above low alarm setpoint, P030-5522A/B functionality will be returned to the operator.

5.11 I-30-5522: Hot Demin Water Drum (D030-5521) High-High Level

Reference P&IDs: L2CC-030-25- PI-5512-03
Existing Interlock: N/A
Interlock closes the demin water feed valve to the hot demin water drum at high-high liquid level.

Interlock activates on 1oo2 high-high LI53536A/B:

A. Close demin water feed valve XV-53537
B. Place FC-53540 in manual mode with an output of 0% via one-shot command.

Reset: When level (LI53536A/B) is below high alarm setpoint, XV-53537 functionality will be returned to the operator.

5.12 I-30-5523: Condensate Collection Drum (D030-5520) Low-Low Level

Reference P&IDs: L2CC-030-25- PI-5520
Existing Interlock: N/A
Interlock protects condensate pumps on low-low liquid level in D030-5520.

Interlock activates on low-low LC53110:

A. Stop pump P030-5525A via HS53115
B. Stop pump P030-5525B via HS53116
C. Open 30# steam valve XV-53104

Reset: When level (LC53110) is above low alarm setpoint, XV-53104 will be closed and functionality will be returned to the operator for P030-5525A/B and XV-53104.

5.13 I-30-5524: Condensate Collection Drum (D030-5520) High-High Level

Reference P&IDs: L2CC-030-25- PI-5520
Existing Interlock: N/A
Interlock opens the condensate drain valve at high-high liquid level.

Interlock activates on high-high LC53110:

A. Opens the condensate drain XV-53103

Reset: When level (LC53110) is below high alarm setpoint, XV-53103 is closed and functionality will be returned to the operator.

5.14 I-30-5525: Surface Drainage Sump Pump

Reference P&IDs: L2CC-030-25-PI-5554
Existing Interlock: I-N/A
Interlock protects the surface drainage sump pump from low-low level.

Interlock activates on low-low level LI53473:

A. Stop surface drainage sump pump P030-5527 via HS53472.

Reset: When level (LI53473) is above low alarm setpoint, functionality will be returned to the operator for P030-5527.

5.15 I-30-5526: High-High Fan Vibration

Reference P&IDs: L2CC-030-25-PI-5520
Existing Interlock: I-04
Interlock protects fan motors from high-high vibration.

When VI53117A goes into high-high condition for 5 seconds:

A. S-5500 Condensate Collection Drum O/H Condenser MX030-5522B (Fan B) is stopped via HS53117A.

Reset: Once a fan stops, return functionality to operator.

5.16 I-30-5527: High-High Fan Vibration

Reference P&IDs: L2CC-030-25-PI-5520
Existing Interlock: I-04
Interlock protects fan motors from high-high vibration.

When VI53117B goes into high-high condition for 5 seconds:

A. S-5500 Condensate Collection Drum O/H Condenser MX030-5522A (Fan A) is stopped via HS53117B.

Reset: Once a fan stops, return functionality to operator.

5.17 I-30-5528: High-High Fan Vibration

Reference P&IDs: L2CC-030-25-PI-5528
Existing Interlock: I-04
Interlock protects fan motors from high-high vibration.

When VI53161A goes into high-high condition for 5 seconds:

A. Wet Crude Alcohol Product Cooler MX030-5516A (Fan A) is stopped via HS53161A.

Reset: Once a fan stops, return functionality to operator.

5.18 I-30-5529: High-High Fan Vibration

Reference P&IDs: L2CC-030-25-PI-5528
Existing Interlock: I-04
Interlock protects fan motors from high-high vibration.

When VI53161B goes into high-high condition for 5 seconds:

A. Wet Crude Alcohol Product Cooler MX030-5516B (Fan B) is stopped via HS53161B.

Reset: Once a fan stops, return functionality to operator.

5.19 I-30-5530: High-High Fan Vibration

Reference P&IDs: L2CC-030-25-PI-5535
Existing Interlock: I-04

Interlock protects fan motors from high-high vibration.

When VI53247A goes into high-high condition for 5 seconds:

A. Butanol Stripper O/H Condenser MX030-5515A (Fan A) is stopped via HS53247A.

Reset: Once a fan stops, return functionality to operator.

5.20 I-30-5531: High-High Fan Vibration

Reference P&IDs: L2CC-030-25-PI-5535
Existing Interlock: I-04
Interlock protects fan motors from high-high vibration.

When VI53247B goes into high-high condition for 5 seconds:

A. Butanol Stripper O/H Condenser MX030-5515B (Fan B) is stopped via HS53247B.

Reset: Once a fan stops, return functionality to operator.

5.21 I-30-5532: High-High Fan Vibration

Reference P&IDs: L2CC-030-25-PI-5541
Existing Interlock: I-04
Interlock protects fan motors from high-high vibration.

When VI53323A goes into high-high condition for 5 seconds:

A. Dehydrator Tower O/H Condenser MX030-5502B (Fan B) is stopped via HS53323A.

Reset: Once a fan stops, return functionality to operator.

5.22 I-30-5533: High-High Fan Vibration

Reference P&IDs: L2CC-030-25-PI-5541
Existing Interlock: I-04
Interlock protects fan motors from high-high vibration.

When VI53323B goes into high-high condition for 5 seconds:

A. Dehydrator Tower O/H Condenser MX030-5502A (Fan A) is stopped via HS53323B.

Reset: Once a fan stops, return functionality to operator.

5.23 I-30-5534: High-High Fan Vibration

Reference P&IDs: L2CC-030-25-PI-5545
Existing Interlock: I-04
Interlock protects fan motors from high-high vibration.

When VI53367A goes into high-high condition for 5 seconds:

A. Butanol Tower O/H Condenser MX030-5507B (Fan B) is stopped via HS53367A.

Reset: Once a fan stops, return functionality to operator.

5.24 I-30-5535: High-High Fan Vibration

Reference P&IDs: L2CC-030-25-PI-5545
Existing Interlock: I-04
Interlock protects fan motors from high-high vibration.

When VI53367B goes into high-high condition for 5 seconds:

A. Butanol Tower O/H Condenser MX030-5507A (Fan A) is stopped via HS53367B.

Reset: Once a fan stops, return functionality to operator.

5.25 I-30-5536: High-High Fan Vibration

Reference P&IDs: L2CC-030-25-PI-5549
Existing Interlock: I-04
Interlock protects fan motors from high-high vibration.

When VI53419A goes into high-high condition for 5 seconds:

A. Ethanol Tower O/H Condenser MX030-5504B (Fan B) is stopped via HS53419A.

Reset: Once a fan stops, return functionality to operator.

5.26 I-30-5537: High-High Fan Vibration

Reference P&IDs: L2CC-030-25-PI-5549
Existing Interlock: I-04
Interlock protects fan motors from high-high vibration.

When VI53419B goes into high-high condition for 5 seconds:

A. Ethanol Tower O/H Condenser MX030-5504A (Fan A) is stopped via HS53419B.

Reset: Once a fan stops, return functionality to operator.

5.27 I-30-5538: High-High Fan Vibration

Reference P&IDs: L2CC-030-25-PI-5552
Existing Interlock: I-04
Interlock protects fan motors from high-high vibration.

When VI53451A goes into high-high condition for 5 seconds:

A. Ethanol Tower Bottoms Cooler MX030-5506A (Fan A) is stopped via HS53451A.

Reset: Once a fan stops, return functionality to operator.

5.28 I-30-5539: High-High Fan Vibration

Reference P&IDs: L2CC-030-25-PI-5552
Existing Interlock: I-04
Interlock protects fan motors from high-high vibration.

When VI53451B goes into high-high condition for 5 seconds:

A. Ethanol Tower Bottoms Cooler MX030-5506B (Fan B) is stopped via HS53451B.

Reset: Once a fan stops, return functionality to operator.

5.29 I-30-5540: Low Recycle Butanol Flow

Reference P&IDs: L2CC-030-25-PI-5533, L2CC-030-25-PI-9060-02, L2CC-006-25-PI-9067
Existing Interlock: N/A
Interlock prevents section 5500 from process upset by preventing too much demin water/condensate from being injected into recycle butanol tank if recycle butanol feed to hydrolysis is stopped.

Interlock activates when FC53215 falls below 17,500 lbs/hr:

A. Close condensate valve XV-91104 (condensate injected into Recycle Butanol Feed from FB-552).
B. Close demin valve XV-91103 (demin injected into Recycle Butanol Feed from T030-5502) (out of service unless T030-5502 is in use for recycle butanol service).

Reset: When FC53215 is above 17,500 lbs/hr, valve XV-91104 returns to previous position (XV-91103 if in recycle butanol service).

5.30 I-30-5541: Butanol Stripper Bottoms Pump

Reference P&IDs: L2CC-030-25-PI-5534, L2CC-030-25-PI-5536
Existing Interlock: N/A
Interlock prevent damage to pumps P030-5504A/B due to loss of level in W030-5504

On 1oo2 Low-Low level via LI53237A/B:

A. Stop P030-5504A via HS-53252
B. Stop P030-5504B via HS-53251

Reset: When level (LI53237A/B) is above low alarm setpoint, functionality will be returned to the operator for P030-5504A/B

5.31 I-30-5542: Butanol Tower High-High Level

Reference P&IDs: L2CC-030-25-PI-5542, L2CC-030-25-PI-5544
Existing Interlock: N/A
Interlock prevents overfill of W030-5503

On 1oo2 High-High-level via LI53357A/B:

A. Stop feed to tower via FV-53331, putting FC53331 in manual and closed.

Reset: When level (LI53357A/B) is below high alarm setpoint, functionality will be returned to the operator for FC53331.

5.32 I-30-5543: Loss of Nitrogen Sweep

Reference P&IDs: L2CC-030-25-PI-5556
Existing Interlock: N/A
Interlock prevents potential oxygen back flow into Flush/Collection Drum D030-5513 or S-5500 Surface Drainage Drum D030-5522.

On Low-Low Pressure via PI53487:

A. Open 30# steam valve XV-53480.

Reset: When pressure (PI53487) is above low alarm setpoint, valve XV-53480 closes.

5.33 I-30-5544: Refrigerated Vent Knockout Drum

Reference P&IDs: L2CC-030-25-PI-5556
Existing Interlock: N/A
Interlock prevents overflow of Refrigerated Vent Knockout Drum D030-5512.

On 2oo3 High-High level via LI53488A/B/C:

A. Stop flow to D030-5512 by closing XV-53479 (through HS-53479)

Reset: When level (LI53488A/B/C) is below high alarm setpoint, XV-53479 remains closed and functionality will be returned to the operator.

5.34 I-30-5545: Low-Low level P030-5516A/B Pump Protection

Reference P&IDs: L2CC-030-25-PI-5555
Existing Interlock: N/A
Interlock prevents damage to pumps P030-5516A/B due to low-low level in Flush/Collection drum.

On low-low level in D030-5513 via 1oo2 LI53484A/B:

A. Stop P030-5516A via HS-53477
B. Stop P030-5516B via HS-53478

Reset: When level (LI53484A/B) is above low alarm setpoint, P030-5516A/B functionality will be returned to the operator.

5.35 I-30-5546: P030-5512A/B Autostart

Reference P&IDs: L2CC-030-25-PI-5545, L2CC-030-25-PI-5547
Existing Interlock: N/A
Interlock will auto start a spare pump in an attempt to reduce high level in accumulator.

For high-high level, Autostart will only occur if no pump is running. Main pump will start first, and spare will only start if main pump fails to start. Main pump is selectable by operator.

When P030-5512A is not running due to command mismatch via XL-53381 or high-high level in D030-5511 via LI53368:

A. Start pump P030-5512B via HS-53382

When P030-5512B is not running due to command mismatch via XL-53382 or high-high level in D030-5511 via LI53368:

B. Start pump P030-5512A via HS-53381

Reset: N/A

5.36 I-30-5547: Eductor Control

Reference P&IDs: L2CC-030-25-PI-5557
Existing Interlock: N/A
Interlock will allow K030-5502A to operate when Process load is sufficient to justify 2 eductors in operation.

When PC53551 output exceeds 50%:

A. Open XV-53501

When PC53551 output is below 45%:

A. Close XV-53501

Reset: N/A

5.37 I-30-5548: High-High Level in D030-5513

Reference P&IDs: L2CC-030-25-PI-5555
Existing Interlock: N/A

Interlock prevents liquid from going out the stack in an overflow liquid relief case in D030-5513.

On High-High level in D030-5513 via 1oo2 LI53484A/B:

A. Close PV-53479B by placing the controller in manual mode
B. Close XV-53481

Reset: When level (LI53484A/B) is below high alarm setpoint, the controller returns to the previous mode and XV-53481 opens and functionality will be returned to the operator.

5.38 I-30-5550: P030-5527 Bearing Flush

Reference P&IDs: L2CC-030-25-PI-5554
Existing Interlock: N/A
Interlock flushes the bearings for P030-5527.

Permissive to start pump P030-5527: Demin water valve open indication via ZSO-53473

When P030-5527 is not running based on XL53472:

A. Close demin water valve XV-53473.

Reset: N/A (One-shot).

5.39 I-30-9011: Hydrolysis Water Storage Tank (T030-5501) High-High Level

Reference P&IDs: L2CC-030-25-PI-5520, L2CC-030-25-PI-5539, L2CC-030-25-PI-5558, L2CC-030-25-PI-9060-01
Existing Interlock: I-13
Interlock protects the tank from over filling by closing off the main feed valves. Not all flows have automatic valves to shut off.

When High-High 1oo2 LI91161A/B:

A. Stop feed from Flush/Collections drum by setting FC53509 to manual with the valve closed.
B. Stop feed from demin water by setting FC91124 to manual with the valve closed.
C. Set Condensate to Hydrolysis Water Storage Tank (T030-5501) LC53110 to manual with valve closed.
D. Reduce crude alcohol flow rate to dehydrator tower to minimum value over 10 minutes via dehydrator tower Feed Ramper (FKC53288)

Reset: When level (LI91161A/B) is below high-high trip point threshold, functionality will be returned to the operator with previous setpoints.

5.40 I-30-9012: Hydrolysis Water Storage Tank (T030-5501) Low-Low Pressure

Reference P&IDs: L2CC-030-25-PI-5526, L2CC-030-25-PI-9060-01, L2CC-030-25-PI-9060-02, L2CC-030-25-PI-9061-02
Existing Interlock: N/A
Interlock protects the tank from air ingress from vacuum safety valve by shutting off the pump-out pumps. Alkoxide feed will also need to be reduced to give the operator more time to react.

Interlock activates on 2oo3 from PI91194A/B/C:

A. Stop hydrolysis water to hydrolysis reactor pumps P030-5502A/B via HS91129 / 91130.
B. Stop alkoxide feed to hydrolysis reactor by closing EBV-53132.
C. Stop alcohol / water draw pump P030-5518 via HS91135.
D. Set alcohol / water draw controller FC91135 to manual with 0%.

Reset: When pressure (PI91194A/B/C) is above low alarm setpoint, functionality for items listed above will be returned to the operator with previous setpoint for FC91135.

5.41 I-30-9013: Crude Alcohol Storage Tank (T030-5503) and Section 550 Recycle Butanol Storage Tank (FB-552) High-High Level

Reference P&IDs: L2CC-030-25-PI-5526, L2CC-030-25-PI-5528, L2CC-030-25-PI-5547, L2CC-030-25-PI-5552, L2CC-030-25-PI-5558, L2CC-030-25-PI-9061-01, LCCC-074.9-PI-144-D
Existing Interlock: I-15
Interlock protects the tanks from over filling by closing off the main feed valves. Not all flows have automatic valves to shut off. Interlock I-16 (High-high level Interlock on FB-552) has additional functionality, refer to Sasol's document "Cold Side Control Strategies and Interlocks" for detail.

When high-high level in T030-5503 from 1oo2 LI91162A/B occurs:

A. Open XV-53444 in order to divert through cooler to FB-552 (via XV-53446)
    a. Once confirmed open, Stop Recycle Crude alcohol from butanol tower reflux pumps by closing XV-53385 and closing XV-53445
B. Open XV-53446 in order to divert to FB-552.
    a. Once confirmed open, Stop Recycle Crude alcohol from ethanol tower bottoms cooler to T030-5503 by closing XV-53447
C. Stop Flush/Collections drum feed by setting FC53508 to manual with the valve closed.
D. Stop Wet Crude alcohol feed from hydrolysis reactor by setting FC53163 to manual with the valve closed.
E. Reduce alkoxide flow rate to Hydrolysis Reactor to minimum value over 10 minutes via Feed Ramper (FKC53130)

Reset: When level (LI91162A/B) is below high-high trip point threshold, functionality for items listed above will be returned to the operator with previous setpoints for control.

When high-high level in FB-552 (above 85%) from LC90106 occurs:

A. Open XV-53447 in order to divert to T030-5503
    a. Once confirmed open, Close ethanol tower bottoms cooler to FB-552 valve XV-53446
B. Open XV-53444 in order to prevent bypassing cooler X030-5506 and XV-53446
    a. Once confirmed open, Close ethanol tower bottoms cooler bypass valve XV-53445

Reset: When level (LC90106) is below high-high trip point threshold, functionality for items listed above will be returned to the operator.

When LI91162A or B and LC90106 are high-high at the same time:

A. Close XV-53444, XV-53385, XV-53445, XV-53446, XV-53447
B. Stop Flush/Collections drum feed by setting FC53508 to manual with the valve closed.
C. Stop Wet Crude alcohol feed from hydrolysis reactor by setting FC53163 to manual with the valve closed.
D. Reduce alkoxide flow rate to Hydrolysis Reactor to minimum value over 10 minutes via Feed Ramper (FKC53130)

Reset: When level (LI91162A/B/ LC90106) is below high-high trip point threshold, functionality for items listed above will be returned to the operator with previous setpoints for control.

5.42 I-30-9014: Crude Alcohol Storage Tank (T030-5503) Low-Low Pressure

Reference P&IDs: L2CC-030-25-PI-9061-01, L2CC-030-25-PI-9061-02
Existing Interlock: N/A
Interlock protects the tank from air ingress from vacuum safety valve by shutting off the pump-out pumps.

Interlock activates on 2oo3 low-low pressure from PI91195A/B/C:
A. Stop dehydrator tower charge pumps P030-5506A/B.

Reset: When pressure is above low-low alarm setpoint for 2oo3 PI91195A/B/C, functionality will be returned to the operator.

5.43 I-30-9015: Alcohol / Water Draw Pump (P030-5518) Low-Low Flow

Reference P&IDs: L2CC-030-25-PI-9061-02
Existing Interlock: I-N/A
Interlock protects the pump from damage that can be caused by a plugged or blocked discharge.

Interlock activates on low-low flow from FC91135 after 10 seconds:
A. Stop alcohol / water draw pump P030-5518.
B. Set alcohol / water controller FC91135 to manual with 0% output.

Reset: Once pump is stopped, functionality for items listed above will be returned to the operator with previous setpoints for control FC91135.

5.44 I-30-9016: Swing Tank Storage Tank (T030-5502) High-High Level

Interlock protects the tank from over filling. This tank is a swing tank so the interlock will need to configured for the service that it will be used for, at the time it is needed. The DCS configuration and graphics must be modified when this tank is put into service.

Hydrolysis Water Configuration:
Reference P&IDs: L2CC-030-25-PI-5520, L2CC-030-25-PI-5526, L2CC-030-25-PI-5558, L2CC-030-25-PI-9062-01
Existing Interlock: I-13
Interlock protects the tank from over filling by closing off the main feed valves. Not all flows have automatic valves to shut off.

When High-High 1oo2 LI91200A/B:
A. Stop feed from Flush/Collections drum by setting FC53509 to manual with the valve closed.
B. Stop feed from demin water by setting FC91124 to manual with the valve closed.
C. Set Condensate to Hydrolysis Water Storage Tank (T030-5501) LC53110 to manual with valve closed.

D. Reduce crude alcohol flow rate to dehydrator tower to minimum value over 10 minutes via dehydrator tower Feed Ramper (FKC53288)

Reset: When level (LI91200A /B) is below high-high trip point threshold, functionality will be returned to the operator with previous setpoints.

Crude Alcohol Configuration:
Reference P&IDs: L2CC-030-25-PI-5526, L2CC-030-25-PI-5528, L2CC-030-25-PI-5547, L2CC-030-25-PI-5552, L2CC-030-25-PI-5558, L2CC-030-25-PI-9062-01, LCCC-074.9-PI-144-D
Existing Interlock: I-15
Interlock protects the tanks from over filling by closing off the main feed valves. Not all flows have automatic valves to shut off. Interlock I-16 (High-high level Interlock on FB-552) has additional functionality, refer to Sasol's document "Cold Side Control Strategies and Interlocks" for detail.

When high-high level in T030-5503 from 1oo2 LI91200A/B occurs:

A. Open XV-53444 in order to divert through cooler to FB-552 (via XV-53446)
    a. Once confirmed open, Stop Recycle Crude alcohol from butanol tower reflux pumps by closing XV-53385 and closing XV-53445
B. Open XV-53446 in order to divert to FB-552.
    a. Once confirmed open, Stop Recycle Crude alcohol from ethanol tower bottoms cooler to T030-5503 by closing XV-53447
C. Stop Flush/Collections drum feed by setting FC53508 to manual with the valve closed.
D. Stop Wet Crude alcohol feed from hydrolysis reactor by setting FC53163 to manual with the valve closed.
E. Reduce alkoxide flow rate to Hydrolysis Reactor to minimum value over 10 minutes via Feed Ramper (FKC53130)

Reset: When level (LI91200A/B) is below high-high trip point threshold, functionality for items listed above will be returned to the operator with previous setpoints for control.

When high-high level in FB-552 (above 85%) from LC90106 occurs:

A. Open XV-53447 in order to divert to T030-5503
    a. Once confirmed open, Close ethanol tower bottoms cooler to FB-552 valve XV-53446
B. Open XV-53444 in order to prevent bypassing cooler X030-5506 and XV-53446
    a. Once confirmed open, Close ethanol tower bottoms cooler bypass valve XV-53445

Reset: When level (LC90106) is below high-high trip point threshold, functionality for items listed above will be returned to the operator.

When LI91200A or B and LC90106 are high-high at the same time:

A. Close XV-53444, XV-53385, XV-53445, XV-53446, XV-53447
B. Stop Flush/Collections drum feed by setting FC53508 to manual with the valve closed.
C. Stop Wet Crude alcohol feed from hydrolysis reactor by setting FC53163 to manual with the valve closed.
D. Reduce alkoxide flow rate to Hydrolysis Reactor to minimum value over 10 minutes via Feed Ramper (FKC53130)

Reset: When level (LI91200A/B/ LC90106) is below high-high trip point threshold, functionality for items listed above will be returned to the operator with previous setpoints for control.

Recycle Butanol Configuration:
Reference P&IDs: L2CC-030-25-PI-5552, L2CC-030-25-PI-9062-01
Existing Interlock: I-N/A

When High-High Level on 1oo2 LI91200A/B on T030-5502:

A. Close XV-53446, flow from cooler to FB-552 / T030-5502.
B. Close XV-53445, flow bypassing cooler to FB-552 / T030-5502
C. Open XV-53447, flow from cooler to T030-5503
D. Open XV-53444, flow to cooler.

Reset: When level (LI91200A/B) is below high-high trip point threshold, functionality for items listed above will be returned to the operator.

5.45 I-30-9017: Swing Tank Storage Tank (T030-5502) Low-Low Pressure

Interlock protects the tank from air ingress from vacuum safety valve by shutting off the pump-out pumps. This tank is a swing tank so the interlock will need to configured for the service that it will be used for, at the time it is needed. The DCS configuration and graphics must be modified when this tank is put into service.

Hydrolysis Water Configuration:
Reference P&IDs: L2CC-030-25-PI-5526, L2CC-030-25-PI-9060-01, L2CC-030-25-PI-9060-02, L2CC-030-25-PI-9061-02, L2CC-030-25-PI-9062-01
Existing Interlock: I-N/A

When Low-Low Pressure on 2oo3 PI91197A/B/C:

A. Stop hydrolysis water to hydrolysis reactor pumps P030-5502A/B via HS91129 / 91130.
B. Stop alkoxide feed to hydrolysis reactor by closing EBV-53132.
C. Stop alcohol / water draw pump P030-5518 via HS91135.
D. Set alcohol / water draw controller FC91135 to manual with 0%.

Reset: When pressure (PI91197A /B/C) is above low alarm setpoint, functionality for items listed above will be returned to the operator with previous setpoint for FC91135.

Crude Alcohol Configuration:
Reference P&IDs: L2CC-030-25-PI-9061-01, L2CC-030-25-PI-9062-01
Existing Interlock: I-N/A

When Low-Low Pressure on 2oo3 PI91197A/B/C:

A. Stop dehydrator tower charge pumps P030-5506A/B.

Reset: When pressure is above low alarm setpoint for 2oo3 PI91197A/B/C, functionality will be returned to the operator.

Recycle Butanol Configuration:
Reference P&IDs: L2CC-030-25-PI-9060-02, L2CC-030-25-PI-9062-01
Existing Interlock: I-N/A

When Low-Low Pressure on 2oo3 PT-91197A/B/C:

A. Stop Butanol swing tank P030-5521 via HS-91140.
B. Stop Hydrolysis Water Feed P030-5502B (when in Recycle Butanol feed service) via HS-91130

Reset: When pressure is above low alarm setpoint for 2oo3 PI91197A/B/C, functionality will be returned to the operator.

5.46 I-30-9018: Flare Knockout Drum Backflow to T030-5501 Protection

Reference P&IDs: L2CC-030-25-PI-6058, L2CC-030-25-PI-9060-01
Existing Interlock: I-N/A
Interlock protects Hydrolysis water storage tank (T030-5501) against backflow from the Vent Knockout drum (D030-6019) due to high pressure at D030-6019.

When PDY-91194 (2oo3 differential voting between T030-5501 [PI91194A/B/C] and D030-6019 [PI61628A/B/C]) detects the pressure at D030-6019 approaching the pressure of T030-5501:

A. Close XV-91125A vent from T030-5501 Hydrolysis Water storage tank via HS-91125A.

Reset: When differential PDY91194 is above low alarm setpoint, XV-91125A will open and functionality will be returned to the operator.

5.47 I-30-9019: Flare Knockout Drum Backflow to T030-5502 Protection

Reference P&IDs: L2CC-030-25-PI-6058, L2CC-030-25-PI-9062-01
Existing Interlock: I-N/A
Interlock protects Swing tank (T030-5502) against backflow from the Vent Knockout drum (D030-6019) due to high pressure at D030-6019.

When PDY91197 (2oo3 differential voting between T030-5502 [PI91197A/B/C] and D030-6019 [PI61628A/B/C]) detects the pressure at D030-6019 approaching the pressure of T030-5502:

A. Close XV-91139A vent from T030-5502 Swing tank via HS-91139A.

Reset: When differential PDY91197 is above low alarm setpoint, XV-91139A will open and functionality will be returned to the operator.

5.48 I-30-9020: Flare Knockout Drum Backflow to T030-5503 Protection

Reference P&IDs: L2CC-030-25-PI-6058, L2CC-030-25-PI-9061-01
Existing Interlock: I-N/A
Interlock protects Crude Alcohol storage tank (T030-5503) against backflow from the Vent Knockout drum (D030-6019) due to high pressure at D030-6019.

When PDY91195 (2oo3 differential voting between T030-5503 [PI91195A/B/C] and D030-6019 [PI61628A/B/C]) detects the pressure at D030-6019 approaching the pressure of T030-5503:

A. Close XV-91133A vent from T030-5503 Crude Alcohol storage tank via HS-91133A.

Reset: When differential PDY91195 is above low alarm setpoint, XV-91133A will open and functionality will be returned to the operator.

5.49 Additional requirements

The DCS will be required to take action due to trips executed by the SIS. (e.g. placing a controller in manual with output of 0%) The SIS/DCS interface for communicating commands related to these actions will generally be via Modbus TCP/IP. Descriptions for DCS actions due to trips executed in the SIS are located in the “Safety Interlock

Cause and Effects Diagrams" for each respective area and as well as shown on the P&ID. Reference the following drawings:

- L2CC-030-70-EN-1002
- L2CC-030-70-EN-2002
- L2CC-030-70-EN-3002
- L2CC-030-70-EN-4002
- L2CC-030-70-EN-4202
- L2CC-030-70-EN-5502
- L2CC-030-70-EN-6002
- L2CC-030-70-EN-6502
- L2CC-030-70-EN-8002
- L2CC-030-70-EN-8102
- L2CC-030-70-EN-8502
- L2CC-038-70-EN-5602
- L2CC-038-70-EN-5702

APPENDIX

I. Existing Ziegler DeltaV Links Required for Expansion Project

ABB Tag	P&ID	Direction	Delta V Tag	New P&ID	Notes
LC90106	LCCC-074.9-PI-144	New to Existing	FC53215	L2CC-030-25-PI-5533	Refer to section 4.3.7 and Appendix 2.a
LC90106	LCCC-074.9-PI-144	Existing to New	FC53378	L2CC-030-25-PI-5547	Refer to section 4.3.15 and Appendix 2.a
FY-90096	LCCC-074.9-PI-144	New to Existing	FC53429	L2CC-030-25-PI-5550	Refer to Appendix 2.a
LC90106	N/A	Existing to New	I-30-9013	L2CC-030-25-PI-5552	Refer to section 5.41
WI90544-1	LCCC-074.9-PI-131	New to Existing	FC53380	L2CC-030-25-PI-5547	Refer to L2CC-030-70-EN-9000
LC90366	LCCC-074.9-PI-123-D	New to Existing	FC53130	L2CC-030-25-PI-5526	Refer to L2CC-030-70-EN-9000

II. Existing Ziegler DeltaV Configuration Modification Required for Expansion Project

FB-552 Interface to S-550 and S-5500

Reference P&IDs: L2CC-030-25-PI-5533, L2CC-030-25-PI-5545, L2CC-030-25-PI-5547, L2CC-030-25-PI-5550, L2CC-006-25-PI-9067, LCCC-074.55-PI-105-D, LCCC-074.55-PI-118-D, LCCC-074.9-PI-144-D

Tank FB-552 receives recycle butanol from Sections 550 and 5500 and supplies recycle butanol to Sections 550 and 5500. If Section 550 (or Section 5500) consumes more recycle butanol from FB-552, Section 550 (or Section 5500) will produce more recycle butanol into FB-552 after some time.

The level controller on FB-552 (LC90106) adjusts the aggregate of both recycle butanol flows (FC55005 and FC53378) that enter FB-552 from their respective Butanol Tower accumulators. It does this via its output (LC90106.OP), which in turn sets the setpoints of the two flow controllers according to an allocation scheme. Each of the flow controllers can be overridden by its respective accumulator level controllers, LC55005A/B or LC53368A/B. See section 4.3.14 for a more detailed description of that.

LC90106 uses feed forward based on the sum of the recycle butanol flows supplied to S-550 (FC55555) and S-5500 (FC53215), less the butanol flows produced by the ethanol tower bottoms in S-550 (FC55010) and S-5500 (FC53429).

$$\mathrm{LC90106.FF} = \mathrm{FC53215.PV} + \mathrm{FC55555.PV} - \mathrm{FC55010.PV} - \mathrm{FC53429.PV}$$

The allocation scheme is based upon the distribution of the recycle butanol being supplied to the individual sections (S-550 and S-5500). The entering flows from the two sections are allocated according to the proportion of the flows going out to those respective sections. The equations are as follows:

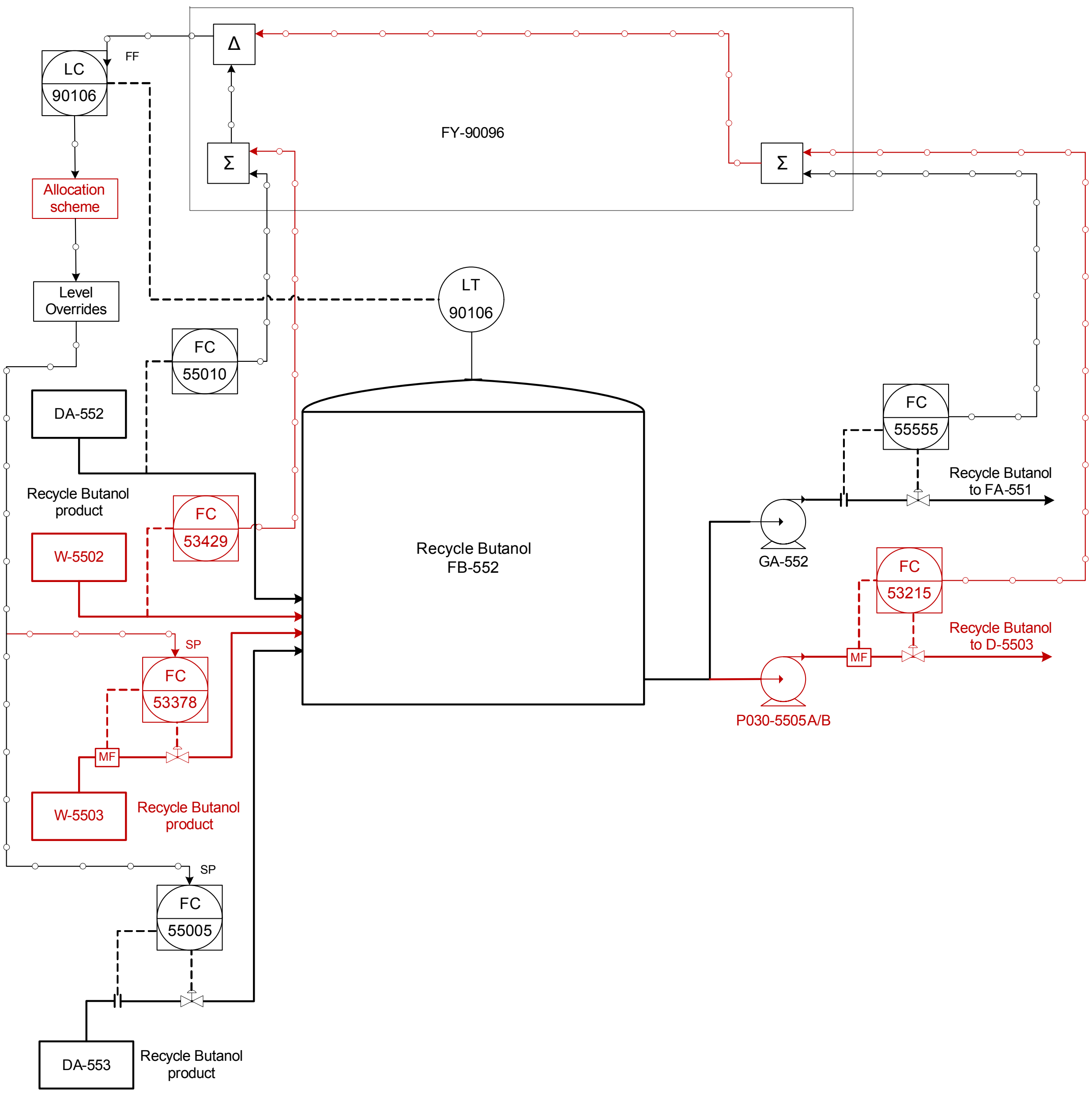
For Section S-550:

$$\mathrm{FC55005.SP} = \mathrm{LC90106.OP} * \left(\frac{\mathrm{FC55555.PV}}{\mathrm{FC55555.PV} + \mathrm{FC53215.PV}}\right)$$

For Section S-5500:

$$\mathrm{FC53378.SP} = \mathrm{LC90106.OP} * \left(\frac{\mathrm{FC53215.PV}}{\mathrm{FC55555.PV} + \mathrm{FC53215.PV}}\right)$$

The diagram on the following page provides a schematic of the control strategy. Red denotes the equipment and controls added by the Ziegler 2 project.


FY-90096
Δ
Σ
Σ
LC
90106
FF
Allocation scheme
Level Overrides
LT
90106
FC
55010
DA-552
Recycle Butanol product
FC
53429
W-5502
Recycle Butanol
FB-552
SP
FC
53378
MF
W-5503
Recycle Butanol product
SP
FC
55005
DA-553
Recycle Butanol product
FC
55555
Recycle Butanol to FA-551
GA-552
FC
53215
Recycle Butanol to D-5503
MF
P030-5505A/B