

 <p>Process Control Narrative</p>	Document # LZ-PCN-04-0006	Date Effective 23 January, 2018	Status Rev A.1
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Document Title Xenon Tower			

1. Change History and Approval Log (Process Control Narrative)

Rev	Date	Description of Changes	WBS Level Approval 1.4.6 1.4		PLC Group Acceptance
Draft 1	1/23/2018	Initial Draft (Uncontrolled)			
Draft 2	05/08/2019	Reformatted and edits			
Draft 3	7/16/2019	Completed Interlock table, Gas Gap procedure			
Rev A	7/16/2019	Initial Released Version	WHL 10/4/19		CED 10/4/19

2. Change History and Approval Log (Process Control Quality Assurance Narrative)

Rev	Date	Description of Changes	WBS Level Approval 1.4.6 1.4		PLC Group Acceptance
Rev A.0	7/16/19	Blank QA table			
Rev A.1	10/4/19	Rev A QA complete	WHL 10/4/19	CH 10/4/19	CED 10/4/19

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4. Acronyms

AI – Analog Input (PLC Signal Type)
AO – Analog Output (PLC Signal Type)
BD – Burst Disk Detection
COW - Cryogenics On Wheels (Liquid Nitrogen Storage Vessel)
DI – Discrete Input (PLC Signal Type)
DO – Discrete Output (PLC Signal Type)
ES or ESTOP – Emergency Stop (multi-I/O UDT)
EX – External Interlock
FS – Flow Switch
HP – High Pressure
HT – High Temperature
HMI – Human-Machine Interface
INTLK – Interlock
LD – Leak Detection
LF – Low Flow
LP – Low Pressure
LS – Level Switch
LUX – Large Underground Xenon
LZ – LUX Zeplin
mA – milliamp
MCD – Motor Control Digital
OL – Oil Level
OT - Oxygen Transducer (multi-I/O UDT)
PB - Push Button (multi-I/O UDT)
PBV – Pneumatic Bellows Valve
PCN – Process Control Narrative
PDV – Pneumatic Diaphragm Valve
PLC – Programmable Logic Controller
PS – Pressure Switch

PT – Pressure Transducer

PID – Proportional-Integral-Derivative

P&ID – Piping and Instrumentation Diagram

REL – Relay Output (PLC Signal Type)

RTD – Resistance Temperature Detector Input (PLC Signal Type)

s – Second

SF – Soft Start Fault

SRV - Safety Recovery Vessel

TBD – To Be Determined

TT – Temperature Transducer

UDT - Universal Data Type

VDC – Volts direct current

WBS – Work Breakdown Structure

5. Reference Documents

[LZ Master P&ID](#)

[LZ P&ID Valve and Instrument List](#)

[LZ Ignition-PLC Universal Data Types](#)

6. Instrument(s) (Input(s))

Tag Name	Common Name	Signal Type
4301TT	Temp: Weir Res: 1 (low)	RTD
4302TT	Temp: Weir Res: 2	RTD
4303TT	Temp: Weir Res: 3	RTD
4304TT	Temp: Weir Res: 4	RTD
4305TT	Temp: Weir Res: 5 (high)	RTD
4310TT	Temp: Hex Evap In	RTD
4311TT	Temp: Hex 1: (low)	RTD
4312TT	Temp: Hex 2	RTD
4313TT	Temp: Hex 3	RTD
4314TT	Temp: Hex 4	RTD
4315TT	Temp: Hex 5 (high)	RTD
4316TT	Temp: Evap Evap Out	RTD
4320TT	Temp: Hex Cond In	RTD
4321TT	Temp: Hex Cond Out	RTD
4325TT	Temp: Subcooler 1: (low)	RTD
4326TT	Temp: Subcooler 2	RTD
4327TT	Temp: Subcooler 3	RTD
4328TT	Temp: Subcooler 4: (high)	RTD
4329TT	Temp: Subcooler HEX LN2 side	RTD
4331TT	Temp: Subcooler Hex out	RTD
4340TT	Temp:TPC return A	RTD
4340TTR	Temp:TPC return B	RTD
4341TT	Temp: Skin return A	RTD
4341TTR	Temp: Skin return B	RTD
4600TT	LXe Tower Reservoir Condenser Thermosiphon, N2 Temperature Transducer A	RTD
4601TT	LXe Tower Reservoir Condenser Thermosiphon, N2 Temperature Transducer B	RTD
4605TT	LXe Tower Subcooler HEX Thermosyphon Xe Temperature Transducer A	RTD
4606TT	LXe Tower Subcooler HEX Thermosiphon Xe Temperature Transducer B	RTD
4610TT	LXe Tower Subcooler Vessel Condenser Thermosiphon N2 Temperature Transducer A	RTD
4611TT	LXe Tower Subcooler Vessel Condenser Thermosiphon N2 Temperature Transducer B	RTD

Tag Name	Common Name	Signal Type
4200PT	Pressure: Evaporator Out	AI
4201PT	Pressure: Weir Reservoir	AI
4202PT	Pressure: Subcooler	AI
4207PT	Pressure: Condenser In	AI
4208PT	dP: Reservoir Inlet	AI
4209PT	dp: Reservoir Outlet	AI
4210PT	dP: Condenser	AI
4211PT	dP: Subcooler	AI
4212PT	dP: Reservoir-Detector	AI
4213PT	dP: Subcooler-Detector	AI
4502PT	Helium source pressure	AI
4512PT	N2 source pressure	AI
4523PT	Gas gap vacuum pressure	AI
4530PT	Gas gap supply pressure	AI
4820PS	Reservoir BD telltale pressure switch (same part as 4819)	DI
4823PS	Subcooler BD telltale pressure switch (same part as 4822)	DI
4100LT	Reservoir standpipe liquid level	AI
4101LT	Reservoir liquid level	AI
4103LT	Reservoir standpipe liquid level	AI

7. Instrument(s) (Output(s))

Note on Manual Control Enable: An instrument's "MAN_XXXX" tag must be TRUE for the PLC to respond to Ignition commands targeting that instrument. For instruments that are governed by a control loop, the "MAN_XXXX" tag must be true for the PLC to allow Ignition to change loop modes or setpoints. Such instruments are indicated here by an asterisk "MAN_XXXX*", and appear in the control loop table in Section 9.2. If a non-control-loop instrument says "none" for Manual Control Enable, manual control is always allowed. If a control-loop instrument says "none" for Manual Control Enable, changing of loop modes and setpoints is always allowed.

Tag Name	Common Name	Signal Type	Manual Control Enable
4000PCV	Weir drain control valve	NO Valve: AO 4mA = 100% (fully open) 20mA = 0% (fully closed)	none
4001PCV	TPC return control valve		none
4002PCV	SKIN return control valve		none
4602HTR	LXe Tower Reservoir Condenser Thermosiphon Heater A	Heater: DO-P	none
4607HTR	LXe Tower Subcooler HEX Thermosiphon Xe Heater A1	Heater: DO-P	none
4612HTR	LXe Tower Subcooler Vessel Condenser Thermosiphon N2 Heater A	Heater: DO-P	none
4615HTR	LXe Tower Subcooler HEX Thermosiphon Xe Heater B1	Heater: DO-P	none
4700HTR	TPC Trimming Heater 1 (watts = TBD)	Heater: DO-P	none
4702HTR	Skin Trimming Heater 1 (watts = TBD)	Heater: DO-P	none
4704HTR	Subcooler Band Heater 1 (watts = TBD)	Heater: DO-P	none
4707HTR	Weir Res. Band Heater 1 (watts = TBD)	Heater: DO-P	none
4004PDV	Reservoir-detector connect	NC Valve: DO	MAN_TWR
4005PDV	Subcooler-detector connect	NC Valve: DO	MAN_TWR
4507PBV	Helium supply valve	NC Valve: DO	MAN_TWR
4517PBV	N2 supply valve	NC Valve: DO	MAN_TWR
4521PBV	Gas gap to vacuum shutoff	NC Valve: DO	MAN_TWR
4532PBV	Gas gap to subcooler	NC Valve: DO	MAN_TWR
4533PBV	Gas gap to subcooler condenser	NC Valve: DO	MAN_TWR
4534PBV	Gas gap to reservoir condenser	NC Valve: DO	MAN_TWR
4524VP	Vacuum pump to evacuate gas gap	Contact: DO	MAN_TWR

8. Referenced Set Point(s) / Internal Variables

Note: The following internal variables may be written to via Ignition. Variables that are part of pre-defined UDTs for the instruments above or the control loops and interlocks below are not included in this table.

Tag Name	Variable Description	Min/Typical Value/Max Allowed Value
MAN_TWR	LXeTower Manual control enable	F / F / T
GG_HE_FRAC	Setpoint to determine He fraction in gas gap	0/0.5/1.1
GG_PT4530_SET	Gas gap setpoint in 4530PT	0.8/1.0/1.1 bara
GG_PT4530_VAC	Vacuum setpoint in 4530PT	0.00/0.01/0.02 bara
GG_INIT_FILL	Command to begin gas gap procedure	bool command
GG_STOP_FILL	Command to stop gas gap procedure	bool command
GG_SEL	Selector for gas gap procedure target	INT, 1-3
GG_MAX_VACTIME	Maximum time allowed to evacuate gas gap	0 / 60 / 600 sec
GG_MAX_FILLTIME	Maximum time allowed to pressure in gas gap	0 / 60 / 600 sec
GG_HEPP_RETURN_1,2,3	Measure of the Helium partial pressure in the gas gap from the last gas gap fill procedure	REAL, read only
GG_PP_RETURN_1,2,3	Measure of the total pressure in the gas gap from the last gas gap fill procedure	REAL, read only
GG_INIT_EMPTY	Command to begin gas gap empty procedure	bool command

9. Process Control Narrative

9.1. Control System Interlocks

The Xenon Tower Interlocks are contained in the table below. Each interlock has a unique tag name via which it may be enabled (enforced) or disabled (not enforced) by a user with sufficient authority – authority levels are defined in the Ignition Slow Control Interface (and touchscreen HMI interface) and not included in this document. Each interlock also has a trigger condition, a set of actions, and a reset condition.

Interlock Actions may include a list of Prohibited Actions (actions to be prevented while the interlock is active, keyword ‘Prevent’) and/or a list of actions taken when the interlock is triggered (keyword ‘Initiate’ for procedures, or ‘Open’, ‘Close’, ‘Set’, etc.).

Unless otherwise indicated, any interlock that triggers actions will also **interrupt** and **abort** any procedure in progress (see procedure 9.10).

Reset conditions are typically either “Auto-reset” (the interlock is released when the interlock condition evaluates false) or “Manual-reset” (the interlock is released when the interlock condition evaluates false AND the corresponding interlock reset Profibus or MODBUS input reads true). Unless otherwise indicated, any debounce timers that apply to the interlock trigger condition apply to the interlock release condition as well. Some interlocks, indicated as “Auto-restart”, may trigger an automatic return to the pre-interlock state when the interlock clears – this will always be indicated explicitly in the table. Unless otherwise indicated, no action is taken on interlock reset except to release prohibitions on future actions. Also, any “Auto-restart” interlock should indicate a maximum number of restart tries before the auto-restart is disabled.

Interlock Tag Name	Control System Interlock	Control System Interlock Condition	Control System Interlock Action	Control System Interlock Reset
PT4201_INTLK	Reservoir pressure too high for detector	PT4201 > PT4201_INTLK_SET 0 / 2.5 / 2.8 bara	Close and Prevent Open: 4004PDV Hold 4000PCV at 0% (fully closed)	Auto-Reset after 10s debounce
PDV4005_INTLK	Maintain pressure differential between Subcooler and detector	PDV4005_OUT is FALSE	Close and Prevent Open: 4005PDV	Auto-Reset

PT4202_INTLK	Subcooler pressure too high for detector	PT4202 > PT4202_INTLK_SET 0 / 3.5 / 3.8 bara	Close and Prevent Open: 4005PDV Hold 4001PCV and 4002PCV at 0% (fully closed)	Auto-Reset after 10s debounce
PT4213_INTLK	Pressure differential between subcooler and detector too low	PT4213 < PT4213_INTLK_SET 0.0 / 0.55 / 0.8 bara	Hold 4001PCV and 4002PCV at 0% (fully closed) Close 1001PBV	Auto-Reset after 10s debounce
PCVSUM_INTLK	Minimum flow to TPC/Skin	PCV4001_OUT + PCV4002_OUT* < PCVSUM_INTLK_SET 0% / 50% / 200% *PCV4002_OUT evaluated before applying this interlock. Also PT4202_INTLK takes precedence	Set: 4002PCV = PCVSUM_INTLK_SET - PCV4001_OUT	Auto-Reset
PT4523_INTLK	Gas gap vacuum pump pressure high	PT4523 > PT4523_INTLK_SET && 4521PBV = CLOSED	Prevent Open: 4521PBV	Auto-Reset
PT4530_INTLK	Gas gap trunk pressure high	PT4530 > PT4530_INTLK_SET	Close and Prevent Open: 4532PBV, 4533PBV, 4534PBV	Auto-Reset
PBV4507_INTLK	Gas gap source Mutex	PBV4507_OUT = TRUE	Prevent Open: 4517PBV, 4521PBV	Auto-Reset
PBV4517_INTLK	Gas gap source Mutex	PBV4517_OUT = TRUE	Prevent Open: 4507PBV, 4521PBV	Auto-Reset
PBV4521_INTLK	Gas gap source Mutex	PBV4521_OUT = TRUE	Prevent Open: 4507PBV, 4517PBV	Auto-Reset
PBV4532_INTLK	Gas gap destination Mutex	PBV4532_OUT = TRUE	Prevent Open: 4533PBV, 4534PBV	Auto-Reset
PBV4533_INTLK	Gas gap destination Mutex	PBV4533_OUT = TRUE	Prevent Open: 4532PBV, 4534PBV	Auto-Reset

PBV4534_INTLK	Gas gap destination Mutex	PBV4534_OUT = TRUE	Prevent Open: 4532PBV, 4533PBV	Auto-Reset
TT4340_INTLK	High Temp	TT4340 > TT4340_INTLK_SET	Hold: HTR4700 at 0%	Auto-Reset after 10s debounce
TT4340R_INTLK	High Temp	TT4340R > TT4340R_INTLK_SET		
TT4341_INTLK	High Temp	TT4341 > TT4341_INTLK_SET	Hold: HTR4702 at 0%	
TT4341R_INTLK	High Temp	TT4341R > TT4341R_INTLK_SET		
TT4325_INTLK	High Temp	TT4325 > TT4325_INTLK_SET	Hold: HTR4704 at 0%	
TT4326_INTLK	High Temp	TT4326 > TT4326_INTLK_SET		
TT4301_INTLK	High Temp	TT4301 > TT4301_INTLK_SET	Hold: HTR4707 at 0%	Auto-Reset after 10s debounce
TT4302_INTLK	High Temp	TT4302 > TT4302_INTLK_SET		
TT4600_INTLK	High Temp	TT4600 > TT4600_INTLK_SET	Hold: HTR4602 at 0%	
TT4601_INTLK	High Temp	TT4601 > TT4601_INTLK_SET		
TT4605_INTLK	High Temp	TT4605 > TT4605_INTLK_SET	Hold: HTR4607 and HTR4615 at 0%	
TT4606_INTLK	High Temp	TT4606 > TT4606_INTLK_SET		
TT4610_INTLK	High Temp	TT4610 > TT4610_INTLK_SET	Hold: HTR4612 at 0%	
TT4611_INTLK	High Temp	TT4611 > TT4611_INTLK_SET		
SV8107_INTLK	Pump Protection	SV8107 = Open	Prevent Open: 4521PBV	

Note -- the next table of interlocks are not really interlocks, strictly speaking -- they cannot be enabled/disabled, and do not have tags in Ignition. Just trying to capture the logic on how the modes of intertwined loops in section 9.2 relate to each other.

Interlock Tag Name	Control System Interlock	Control System Interlock Condition	Control System Interlock Action	Control System Interlock Reset
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PT4201_PID_MODE_INTLK	PID Mutex	PT4201_PID_MODE == 3	Prevent: HTR4704_PID_MODE = TRUE	Auto-reset
PT4202_PID_MODE_INTLK	PID Mutex	PT4202_PID_MODE == 2	Prevent: HTR4707_PID_MODE = TRUE	Auto-reset
HTR4704_PID_MODE_INTLK	PID Mutex	HTR4704_PID_MODE = TRUE (Auto)	Prevent: PT4201_PID_MODE = 3	Auto-reset
HTR4707_PID_MODE_INTLK	PID Mutex	HTR4707_PID_MODE = TRUE (Auto)	Prevent: PT4202_PID_MODE = 2	Auto-reset

9.2. Control Loops

XeTower Control Loops are contained in the table below. Every control loop has associated internal variables for the loop mode (e.g. PID Enabled vs manual control), loop set point, and manual output, as well as parameters governing the loop feedback algorithm. Unless otherwise indicated, loop algorithm details (e.g. loop type and parameters) are to be determined by the FNAL Controls Group.

Tags exposed to Ignition for each loop type are described in the Ignition-PLD UDT document (see links in Section 5). This PCN includes loops of the following types:

- **Heater with redundant thermometer feedback (manual enable not required)**
- **Redundant Heater with redundant thermometer feedback (manual enable not required)**
- **Process variable with multiple (mutually exclusive) loops (manual enable not required)**

Manual Control: If a loop requires a manual enable, that means that changes to the Ignition-shared tags are not passed to the PLC logic tags unless the appropriate Manual Enable tag is TRUE. This includes setpoints, PID modes, etc.

Loop Name and tag list	Manipulated Variable / Tag Name	Output Min / Default / Max	Process (feedback) Variable / Tag Name	Setpoint Min / Default / Max
HTR4700_PID	HTR4700	0 / 0 / 100%	(0) TT4340 (1) TT4340R	160 / 170 / 325 K
HTR4702_PID	HTR4701	0 / 0 / 100%	(0) TT4341 (1) TT4341R	160 / 170 / 325 K
HTR4704_PID	HTR4704*	0 / 0 / 100%	(1) TT4325 (0) TT4326	160 / 170 / 325 K
HTR4707_PID	HTR4707*	0 / 0 / 100%	(1) TT4301 (0) TT4302	160 / 170 / 325 K
HTR4602_PID	HTR4602	0 / 0 / 100%	(0) TT4600 (1) TT4601	160 / 170 / 325 K
HTR4607_PID	(2) HTR4607 (1) HTR4615	0 / 0 / 100%	(1) TT4605 (0) TT4606	160 / 170 / 325 K
HTR4612_PID	HTR4612	0 / 0 / 100%	(0) TT4610 (1) TT4611	160 / 170 / 325 K
PT4202_PID	(1) 4001PCV (2) 4002PCV (3) 4704HTR	0 / 0 / 100% 0 / 0 / 100% 0 / 0 / 100%	PT4202	0 / 2.0 / 2.7 bara
PT4201_PID	(1) 4000PCV (2) 4707HTR	0 / 0 / 100% 0 / 0 / 100%	PT4201	0 / 2.0 / 2.7 bara
PT4211_PID	(-) 4704HTR (+) 4707HTR	0/0/100% 0/0/100%	PT4213	-0.3 / -0.1 / 0.3 bara

9.3. Set Gas Gap**9.3.1. Initiate Gas Gap Procedure**

Initiate gas gap fill procedure when GG_INIT_FILL is TRUE

9.3.2. Close all relevant valves

Close 4532PBV, 4533PBV, 4534PBV, 4521PBV, 4517PBV, 4507PBV

9.3.3. Evacuate gas gap trunk

Record state of 4524VP into a TEMPORARY variable.

Branch: If GG_PT4530_SET = 0, set TEMPORARY variable to true (4524VP ON)

If 4524VP is off, **engage** 4524VP.

Wait minimum of 10 seconds with pump on.

Open 4521PBV. Wait until PT4530 < GG_PT4530_VAC.

Timeout: If procedure elapsed time exceeds GG_MAX_VACTIME, Close 4521PBV and proceed to “End Procedure”

9.3.4. Evacuate selected gas gap

Open valve to the gas gap, as determined by GG_SEL.

Write 0 to GG_HEPP_RETURN_#, where # is the GG_SEL_Value.

GG_SEL Value	1	2	3
Gas Gap Valve	4532PBV	4533PBV	4534PBV

Wait a minimum of 5 seconds, then wait until PT4530 < GG_PT4530_VAC.

Timeout: If procedure elapsed time exceeds GG_MAX_VACTIME, Close the gas gap valve and 4521PBV and proceed to “End Procedure”

Branch: If GG_PT4530_SET = 0, proceed to “End Procedure”

9.3.5. Close valve to vacuum pump and to gas gap

Close 4521PBV

Close valve to selected gas gap as determined by GG_SEL

Branch: If GG_HE_FRAC = 1, proceed to “Fill antechamber with He”

9.3.6. Fill antechamber with appropriate N2 partial pressure

Open 4517PBV. Wait until PT4530 > (GG_PT4530_SET * (1-GG_HE_FRAC)).

Timeout: If step elapsed time exceeds GG_MAX_FILLTIME, Close the gas gap valve and close 4517PBV and proceed to “End Procedure”

9.3.7. Close valve to N2 bottle

Close 4517PBV. Write PT4530 to GG_PP_RETURN_#, where # is the GG_SEL_Value

Branch: If GG_HE_FRAC = 0, proceed to “Fill gas gap”

9.3.8. Fill antechamber with He to target total pressure

Open 4507PBV. Wait until PT4530 > GG_PT4530_SET.

Continuously write (PT4530 - GG_PP_RETURN_#) to GG_HEPP_RETURN_#, where # is the GG_SEL_Value

Timeout: If step elapsed time exceeds GG_MAX_FILLTIME, Close the gas gap valve and close 4507PBV and proceed to “End Procedure”

9.3.9. Close valve to He bottle

Close 4507PBV.

9.3.10. Fill gas gap

Open gas gap valve (same valve opened above in “Evacuate gas gap”).

Wait 15 seconds

Close gas gap valve

9.3.11. End Procedure

Write GG_HEPP_RETURN_# * (PT4530 / GG_PP_RETURN_#) to
GG_HEPP_RETURN_#

Write PT4530 to GG_PP_RETURN_# where # is the GG_SEL_Value

Reset 4524VP to initial state that was recorded to TEMPORARY variable in 9.3.3.

Set GG_INIT_FILL to FALSE to indicate procedure complete

9.4. Empty All

9.4.1. Initiate Gas Gap Procedure

Initiate gas gap fill procedure when GG_INIT_EMPTY is TRUE

9.4.2. Evacuate gas gap trunk

If 4524VP is off, **engage** 4524VP.

Wait minimum of 10 seconds with pump on.

Open 4521PBV. Wait until PT4530 < GG_PT4530_VAC.

Timeout: If procedure elapsed time exceeds GG_MAX_VACTIME, Close 4521PBV and proceed to “End Procedure”

9.4.3. Evacuate gas gaps

Open all valves to the gas gaps, 4532PBV, 4533PBV, 4534PBV.

Write 0 to GG_HEPP_RETURN_1, GG_HEPP_RETURN_2, GG_HEPP_RETURN_3.

GG_SEL Value	1	2	3
Gas Gap Valve	4532PBV	4533PBV	4534PBV

Wait a minimum of 5 seconds, then wait until PT4530 < GG_PT4530_VAC.

Timeout: If procedure elapsed time exceeds GG_MAX_VACTIME, Close the gas gap valves and 4521PBV and proceed to “End Procedure”

9.4.4. End procedure

Write PT4530 to GG_PP_RETURN_1, GG_PP_RETURN_2, GG_PP_RETURN_3

Set GG_INIT_EMPTY to FALSE to indicate procedure complete (with pump still pumping on gaps)

10. Process Control Quality Assurance Narrative**10.1. Instrument Checkout****10.1.1. Input Checkout**

Fill out this table with dates and initials as instruments are checked

Initials index:

- DK = Daniel Kodroff [dsk192@psu.edu]
- RC = Ricardo Cabrita [ricardo.cabrita@coimbra.lip.pt]
- HL = Hugh Lippincott
- GP = Guilherme Pereira
- JM = Jacob McLaughlin

Tag Name	PLC Connection check (correct instrument, live instrument)	Scaling check (PLC code)	Ignition check (correct tags, live readings)
4301TT	DK/DC 8/2	DK/RC 6/27	DK/RC 6/27
4302TT	DK/DC 8/2	DK/RC 6/27	DK/RC 6/27
4303TT	DK/DC 8/2	DK/RC 6/27	DK/RC 6/27
4304TT	DK/DC 8/2	DK/RC 6/27	DK/RC 6/27
4305TT	DK/DC 8/2	DK/RC 6/27	DK/RC 6/27
4310TT	DK/DC 8/2	DK/RC 6/27	DK/RC 6/27
4311TT	DK/DC 8/2	DK/RC 6/27	DK/RC 6/27
4312TT	DK/DC 8/2	DK/RC 6/27	DK/RC 6/27
4313TT	DK/DC 8/2	DK/RC 6/27	DK/RC 6/27
4314TT	DK/DC 8/2	DK/RC 6/27	DK/RC 6/27
4315TT	DK/DC 8/2	DK/RC 6/27	DK/RC 6/27
4316TT	DK/DC 8/2	DK/RC 6/27	DK/RC 6/27
4320TT	DK/DC 8/2	DK/RC 6/27	DK/RC 6/27
4321TT	DK/DC 8/2	DK/RC 6/27	DK/RC 6/27
4325TT	DK/DC 8/2	DK/RC 6/27	DK/RC 6/27
4326TT	DK/DC 8/2	DK/RC 6/27	DK/RC 6/27
4327TT	DK/DC 8/2	DK/RC 6/27	DK/RC 6/27
4328TT	DK/DC 8/2	DK/RC 6/27	DK/RC 6/27
4329TT	DK/DC 8/2	DK/RC 6/27	DK/RC 6/27
4331TT	DK/DC 8/2	DK/RC 6/27	DK/RC 6/27
4340TT	DK/DC 8/2	DK/RC 6/27	DK/RC 6/27
4340TTR	DK/DC 8/2	HL\GP 7/19	HL\GP 7/19
4341TT	DK/DC 8/2	DK/RC 6/27	DK/RC 6/27
4341TTR	DK/DC 8/2	HL\GP 7/19	HL\GP 7/19
4600TT	DK/DC 8/2	DK/RC 6/27	DK/RC 6/27
4601TT	DK/DC 8/2	DK/RC 6/27	DK/RC 6/27
4605TT	DK/DC 8/2	DK/DC 7/9	DK/DC 7/9

4606TT	DK/DC 8/2	DK/RC 6/27	DK/RC 6/27
4610TT	DK/DC 8/2	DK/RC 6/27	DK/RC 6/27
4611TT	DK/DC 8/2	DK/RC 6/27	DK/RC 6/27

Tag Name	PLC Connection check (correct instrument, live instrument)	Scaling check (PLC code)	Ignition check (correct tags, live readings)
4200PT	DK/RC 6/27	DK/RC 6/27	DK/RC 6/27
4201PT	DK/RC 7/3	DK/RC 7/3	DK/RC 7/3
4202PT	DK/RC 7/3	DK/RC 7/3	DK/RC 7/3
4207PT	DK/RC 7/3	DK/RC 7/3	DK/RC 7/3
4208PT	DK/RC 7/3	DK/RC 7/3	DK/RC 7/3
4209PT	DK/RC 7/3	DK/RC 7/3	DK/RC 7/3
4210PT	DK/RC 7/3	DK/RC 7/3	DK/RC 7/3
4211PT	DK/RC 7/3	DK/RC 7/3	DK/RC 7/3
4212PT	DK/DC 8/2	TJW 9/24	DK/DC 8/2
4213PT	DK/DC 8/2	TJW 9/24	DK/DC 8/2
4502PT	HL\GP 7/19	HL\GP 7/19	HL\GP 7/19
4512PT	HL\GP 7/19	HL\GP 7/19	HL\GP 7/19
4523PT	HL\GP 7/19	HL\GP 7/19	HL\GP 7/19
4530PT	HL\GP 7/19	HL\GP 7/19	HL\GP 7/19
4820PS	HL/IY/GP 8/22, TJW 9/26	HL/IY/GP 8/22, TJW 9/26	HL/IY/GP 8/22, TJW 9/26
4823PS	HL/IY/GP 8/22, TJW 9/26	HL/IY/GP 8/22, TJW 9/26	HL/IY/GP 8/22, TJW 9/26
4100LT	HL\GP 7/19		HL\GP 7/19
4101LT	HL\GP 7/19		HL\GP 7/19
4103LT	HL\GP 7/19		HL\GP 7/19

10.1.2. Output Checkout

Fill out this table with dates and initials as instruments are checked

Tag Name	PLC Connection check (correct instrument, live instrument)	Scaling/loop/action check (PLC code)	Ignition check (correct tags, manual control enable)
4000PCV	HL\GP 7/19	HL 7/19	HL\GP 7/19
4001PCV	HL\GP 7/19	HL 7/19	HL\GP 7/19
4002PCV	HL\GP 7/19	HL 7/19	HL\GP 7/19
4602HTR	DK/DC 7/23	DC 9/19	DK/DC 7/23
4607HTR	DK/DC 7/23	DC 9/19	DK/DC 7/23
4612HTR	DK/DC 7/23	DC 9/19	DK/DC 7/23
4615HTR	JM/GP 8/22	DC 9/19	JL/GP 8/22
4700HTR	DK/RC 7/2	DC 9/19	DK/RC 7/3
4702HTR	DK/DC 7/23	DC 9/19	DK/DC 7/23
4704HTR	DK/DC 7/23	DC 9/19	DK/DC 7/23
4707HTR	DK/DC 7/23	DC 9/19	DK/DC 7/23
4004PDV	TJW 9/24	TJW 9/24	TJW 9/24
4005PDV	TJW 9/24	TJW 9/24	TJW 9/24
4507PBV	HL\GP 7/19	HL\GP 7/19	HL\GP 7/19
4517PBV	HL\GP 7/19	HL\GP 7/19	HL\GP 7/19
4521PBV	HL\GP 7/19	HL\GP 7/19	HL\GP 7/19
4532PBV	HL\GP 7/19	HL\GP 7/19	HL\GP 7/19
4533PBV	HL\GP 7/19	HL\GP 7/19	HL\GP 7/19
4534PBV	HL\GP 7/19	HL\GP 7/19	HL\GP 7/19
4524VP	HL/JM 8/20/19	HL/JM 8/20/19	HL/JM 8/20/19

10.2. Interlock Checkout

Fill out this table with dates and initials as interlocks are checked

Interlock Tag Name	Interlock Condition Checked	Interlock Effect Checked	Ignition tags checked
PT4201_INTLK	JM 8/27/19	JM 8/27/19	JM 8/27/19
PDV4005_INTLK			
PT4202_INTLK	JM 8/27/19	JM 8/27/19	JM 8/27/19
PT4213_INTLK	DW 6/5/20		DW 6/5/20
PCVSUM_INTLK	JM 8-30-19	JM 8-30-19	JM 8-30-19
PT4523_INTLK	HL 8/21/19	HL 8/21/19	HL 8/21/19
PT4530_INTLK	HL 8/21/19	HL 8/21/19	HL 8/21/19
PBV4507_INTLK	HL 8/21/19	HL 8/21/19	HL 8/21/19
PBV4517_INTLK	HL 8/21/19	HL 8/21/19	HL 8/21/19
PBV4521_INTLK	HL 8/21/19	HL 8/21/19	HL 8/21/19
PBV4532_INTLK	HL 8/21/19	HL 8/21/19	HL 8/21/19
PBV4533_INTLK	HL 8/21/19	HL 8/21/19	HL 8/21/19
PBV4534_INTLK	HL 8/21/19	HL 8/21/19	HL 8/21/19
TT4340_INTLK	HL 8/22/19	HL 8/22/19	HL 8/22/19
TT4340R_INTLK	HL 8/22/19	HL 8/22/19	HL 8/22/19
TT4341_INTLK	HL 8/22/19	HL 8/22/19	HL 8/22/19
TT4341R_INTLK	HL 8/22/19	HL 8/22/19	HL 8/22/19
TT4325_INTLK	HL 8/22/19	HL 8/22/19	HL 8/22/19
TT4326_INTLK	HL 8/22/19	HL 8/22/19	HL 8/22/19
TT4301_INTLK	JM 8-30-19	JM 8-30-19	JM 8-30-19
TT4302_INTLK	HL 8/22/19	HL 8/22/19	HL 8/22/19
TT4600_INTLK	HL 8/22/19	HL 8/22/19	HL 8/22/19
TT4601_INTLK	HL 8/22/19	HL 8/22/19	HL 8/22/19
TT4605_INTLK	JM 8-30-19	JM 8-30-19	JM 8-30-19
TT4606_INTLK	JM 8-30-19	JM 8-30-19	JM 8-30-19
TT4610_INTLK	HL 8/22/19	HL 8/22/19	HL 8/22/19
TT4611_INTLK	HL 8/22/19	HL 8/22/19	HL 8/22/19
SV8107_INTLK			

10.3. Procedure Checkout

Fill out this table with dates and initials and procedures are checked

Procedure ID	Procedure normal operation checked	Procedure interrupts checked	Ignition tags associated with procedure checked
9.3 Set Gas Gap GG_INIT_FILL GG_SEL GG_HE_FRAC GG_PT4530_SET GG_PT4530_VAC GG_MAX_VACTIME GG_MAX_HETIME GG_MAX_N2TIME GG_HEPP_RETURN GG_HEFRAC_RETURN	HL 8/22/19	HL 8/22/19	HL 8/22/19

10.4. Notes from QA Process

Notes from 8/21/19 not already addressed in real time.

1. **RESOLVED** After Ian fixed the implementation of PT4530_INTLK, Hugh isn't sure if Guilherme has to add it to the display on ignition - the one where you see what interlocks involve a particular instrument. - **(Ignition solved)**
2. **RESOLVED** The gas gap procedure was checked without actually opening the valves, and without the stop button. It should be checked again with the stop button and in a real situation. -
3. **RESOLVED** While checking the gas gap with a real situation, there's an issue with the interlock on 4523PT - when you open the valve, the pressure rises as it's pumping out, so the interlock engages. This was fixed on 8/22/19, and Ian made the changes to the PLC. The interlock is now only operable if the valve is closed. -

Notes from 8/22/19-8/23/19

4. Many (all?) of these interlocks throw alarms, when they will go off as part of normal operation. We should look into that. - **Can be disabled through alarms page**
5. 4331TT doesn't appear on the ignition GUI -- **Ignition solved (8/27)**
6. Sensor 4326TT may be better as the primary sensor for HTR4704 - seems to actually respond to heat - Please also rename the "redundant sensor" as "secondary sensor" - PCN updated to reflect this - **Done in PLC, 8/23 -- -- Ignition solved (8/27)**

7. Typo in PCN - TT4301_INTLK written to hold 4704, but it should hold 4707 instead. I've edited the PCN, need to update the code - **Done in PLC, 8/23** - Ignition visualization just needs to be updated to show that this interlock applies to 4707 -- **Ignition solved (8/27)**.
8. Sensor 4302TT may be better as the primary sensor for HTR4707 - seems to actually respond to heat- Please also rename the "redundant sensor" as "secondary sensor" - PCN updated to reflect this - **Done in PLC, 8/23 -- Ignition solved (8/27)**.
9. TT4605 and TT4606_INTLK should also apply to HTR4615 - Done in PLC, 8/23, just need the visualization so they appear on the HTR4615 page -- **Ignition solved (8/27)**.
10. HTR4607 should probably feed back on 4606TT, which appears to be closer - Please also rename the "redundant sensor" as "secondary sensor" - PCN updated to reflect this - **Done in PLC, 8/23 -- Ignition solved (8/27)**.
11. I'd like to see the labels for 4340 and 4341TT on the front panel of the GUI -- **Ignition solved (8/27)**.
12. The controls for the PCVs appear to be broken - I can't tell if I'm in manual mode or not and whether I can set them. Also the display shows 0% which is supposed to be fully closed, but the hover over display shows the valves to be open (which I think is correct). ---- **Ignition solved (8/27)**
13. TT4301_INTLK should hold HTR4707, but only TT4302 is listed as an interlock -- -- **Ignition solved (8/27)**

Notes from Aug 30

14. PCVSUM_INTRLK does not set PCV4002 to a higher value when it triggers. **RESOLVED** - operator had misinterpreted the interlock, see discussion on #lzslowcontrol, Sept. 26.

Notes from Feb 12, 2020

15. Change 60s hold off on pumping out gas gap to 10 seconds, since we have feedback on the pressure and are using that as the interlock to open to the rest of the system. Also, for the "empty" procedure, please just leave the pump running and the relevant valves open. I have changed the procedure above to reflect this (the yellow highlights in procedure 9.3). Also, please add an abort fill button that closes all valves. Lastly, please add an "empty all" procedure that empties all the gas gaps (I added it as procedure 9.4 above). Also, did we ever add the fill fraction variables (the orange highlights in procedure 9.3)? **RESOLVED**

Notes from early May, 2020

16. Change GG_PP_RETURN_# to be the total partial pressure post fill, to be able to get the fraction that is helium. Add a first fault notification to gas gap filling so the operator sees if something finished in a bad state. **RESOLVED**

Notes from late May, 2020

17. Changed order of fill in Gas Gap so that, for a mixed fill, N2 fills first, then He. None of the shared variables changed, just SFC logic -- it is correctly reflected in the Set Gas Gap procedure above. Change was QA'd immediately after it was made, 5/27/20

RESOLVED

June 2020 notes

18. There was a mistake in the PCN for PT4201_INTLK and PT4202_INTLK - the valves they should point to were swapped. I updated this and highlighted in red. I also added a new interlock, PDV4005_INTLK, to keep PDV4005 closed always, since in normal operation, we never want to equalize the pressure between subcooler and detector without flooding the tower. This is highlighted in orange in the table.

RESOLVED

19. We need a new interlock on DPT4213 to close 4002PCV and 4001PCV if the differential pressure drops too low, to prevent flooding of the subcooler vessel and heat exchanger. I wrote it with an auto-reset, not sure if that is correct.

RESOLVED

20. Bug in PCN for the gas gap fill logic. Added a step to close all valves before starting a fill. Previously, if we had emptied on the procedure before, it left the valve open when you started filling the next gap.

RESOLVED

21. Can we check step 9.3.8 highlighted in yellow for the case where the helium fraction is equal to 100%. In that case, the display on ignition shows up as 0.

RESOLVED, QA'd for SC Condenser, but not other two gaps

22. Another swap in 4202PT_PID and 4201PT_PID, where they were pointing at the wrong vessels. Highlighted for now

RESOLVED (but not QA'd yet)

23. Added condition to PT4213_INTLK to also close 1001PBV to prevent pressure equalization from happening back through the circulation panel.

24. Added 4211_PID to try to maintain the level in the SC using the vessel heaters.

25. Change Set Gas Gap procedure to load the mixing chamber first, then open mixing chamber to gas gap

RESOLVED (but not QA'd yet)
