 TORUS	· Owner CAUSE AND EFFECT MATRIX				Document No.	INS-LST-004
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INSTRUMENTATION AND CONTROLS · CAUSE AND EFFECT MATRIX						
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Notes

1. This matrix defines every automatic shutdown, trip, interlock and consequential action at the . Causes are rows and effects are columns. It is the programming and test reference for the safety PLC (CP-102B), the BPCS station controller (CP-102A) and the burner management system BMS-150 (CP-150). It is read with INS-RPT-001, Control Philosophy and Functional Narrative, whose section numbers appear in the Note column, and with INS-LST-003, Alarm and Trip Setpoint Schedule, which controls setpoint values.
2. Interlock numbers I-01 to I-16 are those shown on the P&IDs: safety PLC functions on PRO-DWG-111 and BPCS interlocks on PRO-DWG-113. Each table carries its interlock number in its title or in the cause description. SIF numbers and required safety integrity levels are set in SAF-SRS-001, Safety Requirements Specification.
3. Effect codes: X = trip, close or de-energize (output to its safe state); O = open, energize or activate; R = ramp to zero at the stated rate; S = stop, or place the controller in manual at 0 %; A = alarm only, at SCADA and the local interface; H = hold last value, inhibit movement; a dash means no action.
4. Safety PLC effects latch until reset. All safety resets are local: HS-200R for the station ESD, and the local station HS-10xR or HS-165R at each shutdown valve. No reset opens a valve by itself.
5. Shutdown valves close by spring when their solenoid is de-energized. SDV-106 has an electric spring-return actuator; the other SDVs are self-contained electro-hydraulic.
6. “Station ESD” in any table means every effect in the station ESD table. Delays are on-delays in the logic solver that owns the cause. Priorities follow INS-LST-003 (emergency, high, medium, low).

Table 1: Station ESD, Safety PLC Effects

Cause (I-01)	SDV-101	SDV-102	SDV-103	SDV-106	SDV-165	SDV-141	HS-150T burner trip	XY-214B beacon and horn, B-102	XS-WIL1 ESD to receiving operator
HS-201 ESD pushbutton, main gate	X	X	X	X	X	X	X	O	X
HS-202 ESD pushbutton, B-102	X	X	X	X	X	X	X	O	X
HS-203 ESD pushbutton, meter skid	X	X	X	X	X	X	X	O	X
HS-204 ESD pushbutton, heater	X	X	X	X	X	X	X	O	X
HS-215 receiving operator remote shutdown	X	X	X	X	X	X	X	O	X
GD-205 / GD-206 confirmed gas in B-101	X	X	X	X	X	X	X	O	X
GD-207 high-high at B-102 air intake	X	X	X	X	X	X	X	O	X
BE-213 fire at H-101	X	X	X	X	X	X	X	O	X
Loss of 24 VDC safety PLC power	X	X	X	X	X	X	X	-	X

Note 1: SDV-165 is on the H-101 fuel branch only, so the standby generator G-101 keeps its fuel after an ESD. SDV-106 and SDV-141 are included so that no liquid is sent to T-101 and no sample gas enters B-101 during an emergency.

Note 2: No automatic blowdown. Blowdown is manual, one section at a time, per SAF-RPT-005. Reopening order after reset: SDV-103, SDV-102, SDV-101, then SDV-106, SDV-165 and SDV-141, each after equalizing through its bypass (INS-RPT-001 Section 13).

Table 2: Station ESD Cause Details

Cause	Setpoint or vote	Delay	Priority	Reset	Note
HS-201 to HS-204	Normally closed latching pushbutton, open = ESD	0 s	Emergency	Pull out pushbutton, then HS-200R	RPT-001 Sec. 13
HS-215	Normally closed contact from receiving operator RTU via JB-W01	0 s	Emergency	Receiving operator restores, then HS-200R	Cable break trips (fail-safe)
GD-205 / GD-206 confirmed	One at 40 % LEL and the other at 20 % LEL or more	5 s	Emergency	Gas below 20 % LEL, then HS-200R	RPT-001 Sec. 15; SAF-RPT-003
GD-207 high-high	40 % LEL, single detector	5 s	Emergency	Gas below 20 % LEL, then HS-200R	RPT-001 Sec. 15
BE-213 fire	Fire output (20 mA), single detector	3 s	Emergency	Fire cleared, then HS-200R	Located so it cannot see the burner
Loss of 24 VDC	Inherent (de-energize to trip)	0 s	Emergency	Power restored, then HS-200R	All SDVs close

Table 3: Station ESD, BPCS Consequential Actions (I-16)

Cause	FCV-131	FCV-132	FIC-131	LIC-104 / LCV-104	HS-150P heater enable	TIC-135 / TIC-152	Run and verification sequences	XS-WIL3 SDV-103 closed	Note
Station ESD active (safety PLC status)	X (0 %)	X (0 %)	S	S (0 %)	X	S	Abort	O	Consequential alarms suppressed 10 min; RPT-001 Sec. 13

Table 4: OPSS Causes and Effects

Cause (I-02)	Setpoint or vote	Delay	SDV-102 (SY-102)	SDV-103 (SY-103)	XS-WIL2 trip to receiving operator	FCV-131	FCV-132	FIC-131	Note
PT-133A/B/C high-high, voting function PY-133	1,225 psig, 2oo3; a faulted channel votes to trip	0.5 s	X (full stroke 4 s maximum)	X	X	X (0 %)	X (0 %)	S	SIL 2; transmitters on separate input cards; reset HS-102R, then HS-103R
PT-133A/B/C pre-alarm	Median at 1,210 psig	2 s	-	-	-	A	A	A	High priority
PT-133 channel deviation	Any channel more than 25 psi from median	10 s	-	-	-	-	-	-	A, high priority
PT-133 one channel faulted	Below 3.6 mA or above 21.0 mA	2 s	-(vote becomes 1oo2)	-	-	-	-	-	A, high priority; repair within 72 h
PT-133 two channels faulted	As above	2 s	X	X	X	X (0 %)	X (0 %)	S	2oo3 satisfied by faults
HS-102C SDV-102 local close	Normally closed, open = close	0 s	X	-	X	X (0 %)	X (0 %)	S	Reset HS-102R
SDV-102 travel failure	ZSC-102 not made 5 s after trip	5 s	-	-	-	-	-	-	A, high priority
SDV-102 partial stroke test failure	ZSO-102 not cleared within the pulse window, or not re-made within 30 s	-	-(SY-102 re-energized)	-	-	-	-	-	A, high priority; quarterly test mandatory; overdue at 92 days (A, medium)

Note 1: The 49 CFR 192.201 limit for the assumed receiving trunkline is 1,290 psig (HOLD H-04). The trip sits 45 psi above the 1,180 psig maximum PIC-134 setting and 25 psi above the BPCS interlock at 1,200 psig. PRO-CAL-009 gives a process safety time of about 8.9 s from trip to limit and a peak of about 1,264 psig with the 4 s stroke; the SIF response is 5.5 s (1.5 s detection including the 0.5 s trip delay, plus the 4 s stroke), and the maximum allowable stroke is 7.4 s. The OPSS reset permissive is all three transmitters below 1,150 psig.

Note 2: The control valve and FIC-131 effects are BPCS consequential actions (I-16) driven by safety PLC status. They are not part of SIF-01. SDV-103 closure is a second isolation and is not credited.

Table 5: Process Trips and Interlocks

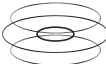
Cause	Setpoint	Delay	SDV-101	SDV-106	HS-104T LCV-104 force close	FCV-131 / FCV-132	FIC-131	LIC-104	Note
I-03 LSHH-105 V-101 level high-high (SIF-02)	26 in	2 s	X	-	-	X (0 %)	S	Stays in automatic to drain V-101	Reset HS-101R
I-04 LSLL-106 V-101 level low-low (SIF-03)	3 in	2 s	-	X	X	-	-	S (0 %)	SDV-106 is the credited element; RO-104 limits blow-by; reset HS-106R
I-05 LSHH-192 T-101 level high-high (SIF-04)	86.4 in (90 % of shell)	2 s	-	X	X	-	-	S (0 %)	Reset HS-106R
HS-101C SDV-101 local close	Normally closed	0 s	X	-	-	X (0 %)	S	-	Local
HS-103C SDV-103 local close	Normally closed	0 s	-(SDV-103 X)	-	-	X (0 %)	S	-	Local
I-12 LT-191 T-101 level high-high (BPCS)	76.8 in (80 % of shell)	60 s	-	-	-	-	-	S (0 %, latched)	Reset below 70 in; RPT-001 Sec. 9
I-12 LT-104 V-101 level low (BPCS)	6 in	30 s	-	-	-	-	-	H (0 % until 10 in)	RPT-001 Sec. 9
LCV-104 open, level not falling	ZT-104 above 50 % for 120 s	120 s	-	-	-	-	-	A	Possible gas blow-by, medium priority
I-11 PT-134 high-high (BPCS)	1,200 psig	3 s	-	-	-	X (0 %, latched)	S	-	Reset below 1,150 psig; not credited against control valve failure
LT-104 signal bad	Below 3.8 or above 20.5 mA	5 s	-	-	-	-	-	S (0 %)	Safety trips remain active

Note 1: The LCV-104 force-close input is an energize-to-close action on a fail-as-is actuator and is not credited in the LOPA.

Note 2: I-08, the PR-101 closure interlock, is mechanical: the closure cannot be released while the barrel is pressurized, and the locking sequence requires BDV-102 open and 0 psig on PI-102. It has no logic solver cause or effect. PT-102A alarms at 5 psig for information only.

Table 6: BMS-150 Causes and Effects

Cause (I-06)	Setpoint	Delay	XV-150A main valve 1	XV-150B main valve 2	XV-150C pilot valve	BY-153 igniter	SDV-165 (safety PLC via XS-150)	XA-150 trip alarm / XL-150 release	Note
BE-153A or BE-153B flame failure (SIF-05)	Loss of flame, 1oo2	4 s maximum response	X	X	X	X	X	O / X; TCV-152 to low fire	Re-purge before relight
BE-153A or BE-153B self-check fault	Detector fault	1 s	X	X	X	X	X	O / X	Treated as flame failure
LSL-154 low bath level (SIF-06)	At least 2 in above firetube (vendor)	5 s	X	X	X	X	X	O / X	Manual reset at CP-150
LSH-154B high bath level, coil leak	Vendor	5 s	X	X	X	X	X	O / X	BPCS emergency alarm to isolate the coil at HV-158A and HV-158B (HAZOP HZ-05)
TSHH-155 high-high bath temperature (SIF-07)	200 °F	0 s	X	X	X	X	X	O / X	Manual-reset switch

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Cause (I-06)	Setpoint	Delay	XV-150A main valve 1	XV-150B main valve 2	XV-150C pilot valve	BY-153 igniter	SDV-165 (safety PLC via XS-150)	XA-150 trip alarm / XL-150 release	Note
TT-156 heater gas outlet high-high (BPCS output TY-156 to BMS input TS-156)	140 °F; or TT-156 bad for 30 s	5 s	X	X	X	X	X	O / X	BPCS latch resets below 130 °F; BMS reset local
PSL-164A burner fuel pressure low	5 psig (HOLD H-15)	2 s	X	X	X	X	X	O / X	Manual reset
PSH-164B burner fuel pressure high	20 psig (HOLD H-15)	2 s	X	X	X	X	X	O / X	Manual reset
HS-150T safety PLC trip (station ESD)	De-energized	0 s	X	X	X	X	X (by I-01)	O / X	Station ESD table
Pilot or main trial for ignition failure	No flame in 10 s	10 s	X	X	X	X	X	O / X	Lockout, re-purge
ZSC-150A or ZSC-150B proof of closure not made	At start	-	X (start inhibited)	X	X	-	-	O / X	Start permissive
ZSL-152 TCV-152 not at low fire	At start	-	X (start inhibited)	X	X	-	-	- / X	Low-fire start
BMS internal fault or power loss	Watchdog	0 s	X	X	X	X	X	O / X	All outputs de-energize
HS-150P BPCS disable (heater mode OFF)	0 = disable	0 s	X	X	X	X	-(stays open)	- / X	Normal stop, no lockout

Note 1: SDV-165 closure on a burner trip is made by the safety PLC from the BMS trip relay XS-150, which is normally closed and opens on any trip or loss of BMS power. SDV-165 is reset locally at HS-165R after the BMS is reset.

Table 7: Gas Quality Shut-In

Cause (I-07)	Alarm	Shut-in limit	Delay (adjustable)	FIC-131	FCV-131 / FCV-132	SDV-103 (close request XY-103Q)	XS-WIL4 to receiving operator	Note
AT-141 heating value high	1,140 Btu/scf	Above 1,150 Btu/scf	15 min	R (10 MMSCFD/min)	X (0 %) at flow below 1 MMSCFD	X after flow below 1 MMSCFD for 60 s	O	HOLD H-13
AT-141 heating value low	980 Btu/scf	Below 970 Btu/scf	15 min	R	X	X	O	
AT-141 carbon dioxide high	1.8 mol %	Above 2.0 mol %	15 min	R	X	X	O	
AT-141 total inerts high	3.6 mol %	Above 4.0 mol %	15 min	R	X	X	O	Carbon dioxide plus nitrogen
AT-142 water vapor high	5.0 lb/MMscf	Above 7.0 lb/MMscf	15 min	R	X	X	O	
AT-143 hydrogen sulfide high	3.2 ppmv	Above 4.0 ppmv	15 min	R	X	X	O	0.25 gr/100 scf
AT-144 oxygen high	8 ppmv	Above 10 ppmv	15 min	R	X	X	O	
TT-173 delivery temperature low	42 °F	Below 40 °F	15 min	R	X	X	O	
TT-173 delivery temperature high	118 °F	Above 120 °F	15 min	R	X	X	O	
XS-WIL5 receiving operator permissive lost	Loss	Loss	10 min (HOLD H-14)	R	X	X	O	RPT-001 Sec. 18
Analyzer fault, chromatograph failure or PSL-141L carrier gas low	Fault	Timer not started	-	-	-	-	-	A; spot sample per agreement

Note 1: The shut-in is a BPCS function, not a safety instrumented function. The safety PLC closes SDV-103 on the hardwired request XY-103Q to XS-103Q, which can only move the valve toward its safe state.

Note 2: Restart requires all parameters in specification for 30 min, the receiving operator permissive present and a supervisor reset at SCADA. SDV-103 then reopens only if no ESD or OPSS trip is latched and PT-172 and PT-134 differ by less than 50 psi (RPT-001 Sec. 11).

Table 8: Fire and Gas Causes and Effects

Cause (I-09)	Setpoint or vote	Delay	Station ESD	SDV-141	XY-214A beacon, B-101	XY-214B beacon and horn, B-102	XY-214C B-102 HVAC off	XY-214D B-101 non-rated power off	Note
GD-205 or GD-206 high	20 % LEL, either detector	5 s	-	-	O	-	-	-	A, high priority
GD-205 / GD-206 high-high, unconfirmed	One at 40 % LEL, the other below 20 %	5 s	-	X	O	-	-	X	A, high priority
GD-205 / GD-206 high-high, confirmed	One at 40 % and the other at 20 % LEL or more	5 s	X	X	O	O	-	X	Emergency
GD-207 B-102 intake high	20 % LEL	5 s	-	-	-	O	X	-	A, high priority
GD-207 B-102 intake high-high	40 % LEL	5 s	X	X	-	O	X	-	Emergency
BE-213 heater area fire	Fire (20 mA)	3 s	X	X	-	O	-	-	Emergency
XS-212 B-102 smoke	Alarm contact	0 s	-	-	-	O	X	-	A, emergency; no ESD because B-102 holds no process gas
FSL-208 B-101 airflow low	Airflow low	5 min	-	-	-	-	-	X	A, high priority at 30 s
Gas detector fault	Below 3.0 mA	10 s	-	-	-	-	-	-	A, high priority; not a trip vote; portable monitor in place

Note 1: SDV-141 works with the restriction orifice RO-141A, which limits a sample tubing failure in B-101 to a release that the shelter ventilation can dilute (SAF-RPT-003).



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Table 9: BPCS Interlocks and Permissives

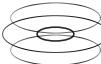
Cause	Condition	FCV-131	FCV-132	FIC-131	PIC-134	TCV-152	HS-150P heater enable	Note
I-10 duty valve position deviation (FCV-131 duty)	ZT-131 differs from demand by more than 5 % for 30 s	X (0 %, failed latch)	O (takes FY-131 output)	Bumpless transfer	Bumpless transfer	-	-	RPT-001 Sec. 5, high priority
I-10 duty valve fault or not in remote	XA-131 or HS-131R	X (0 %)	O	Transfer	Transfer	-	-	Same logic when FCV-132 is duty
I-10 no control valve available	Both failed or isolated	H	H	H	H	-	-	A, high priority
Flow computer input bad or link lost	Quality bad	-	-	S (manual hold)	Active	-	-	A, high priority
PT-134 input bad	Below 3.8 or above 20.5 mA	-	-	Setpoint frozen	S (output 100 %, override removed)	-	-	A, high priority
I-16 safety PLC status link lost	Modbus timeout 5 s	H	H	H (no upward ramp)	Active	-	-	A, high priority
I-14 heater bypass HV-158C open with heater ON	ZSO-158C made	-	-	-	-	S (low fire)	X	A, medium priority
I-14 heater mode OFF	Operator	-	-	-	-	S (0 %)	X	Normal
XL-150 not released	BMS not in run	-	-	-	-	S (low fire)	-	Cascade tracking
TT-151 bath high limit	190 °F	-	-	-	-	Low-select limit	-	Override, RPT-001 Sec. 7
TT-151 input bad	Quality bad	-	-	-	-	S (low fire)	-	A, high priority
I-14 TIC-135 setpoint	Characterizer on PT-134, 42.3 °F at 700 psig to 51.6 °F at 1,180 psig; rich-gas column on heating value alarm	-	-	-	-	Cascade setpoint	-	Source PRO-CAL-003
I-13 MOV-115 open command outside verification	Any	-	-	-	-	-	-	Command rejected, event logged
I-13 MOV command that would block in a run	Outside the Maintenance state	-	-	-	-	-	-	Command rejected; standby run outlet MOV stays open
I-13 meter run found blocked in	Both closed switches of one run made	-	-	-	-	-	-	A, high priority
I-13 series verification above 90 MMSCFD	Station flow above 90 MMSCFD	-	-	-	-	-	-	Start inhibited or aborted
I-13 verification abort	Conditions in RPT-001 Sec. 6	-	-	-	-	-	-	Restore step V8
I-15 V-101 bypass not closed	ZSO-103C made	-	-	Start inhibited	-	-	-	A, high priority
Both SCADA paths lost	5 min (INS-RPT-002)	H	H	Last setpoint held	Active	Active	-	Local alarm; optional communication-loss shut-in (HOLD H-01)

Table 10: Alarm-Only Station Causes

Cause	Condition	Priority	Operator response	Note
TSH-161B E-161 element over-temperature cutout	Tripped (E-161 de-energized by its own controller)	Medium	Reset at E-161; check PCV-161 outlet on TI-161C	TIC-161A set at 105 °F; RPT-001 Sec. 10
XA-161 E-161 common alarm	Low outlet temperature, heater fault or power off	Medium (60 s)	Check TI-161C and PT-164 before a burner trip on PSL-164A	RPT-001 Sec. 10
PT-164 fuel gas pressure high	35 psig	Medium (30 s)	Check PCV-162	PSV-161 set 250 psig protects the intermediate section
PSL-141L chromatograph carrier gas low	Pressure low	Medium (60 s)	Change carrier cylinder	Chromatograph stops on empty carrier
ZSO-103C V-101 bypass not closed	HV-103C not closed	High (5 s)	Confirm receiving operator approval or close	Also a startup permissive

Table 11: Open Items

Item	Responsible	Hold
BMS timings, fuel pressure switch settings and LSH-154B setting	Heater vendor	HOLD H-15

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Item		Responsible		Hold
Actuator stroke times, including the 5 s SDV-102 stroke		Valve and actuator vendors		HOLD H-15
Receiving trunkline segment length, which sets the OPSS process safety time		Receiving pipeline operator		HOLD H-04
Gas quality limits and shut-in delay		Owner and receiving pipeline operator		HOLD H-13
Receiving operator permissive and point list		Receiving pipeline operator		HOLD H-14