Reactor Trip Signals / Engineered Safety Features Actuation Signals

Sections 12.2 / 12.3

HRTD
Human Resources
Training & Development

Objectives:

1. Given a list of reactor trips, explain the purpose (basis) of each.
2. Given a list of Reactor Protection System (RPS) interlocks, explain the purpose of each.
3. Given a list of control grade interlocks, explain the purpose of each.

Table 12.2-1
Summary of Reactor Trips

Trip	Coinc.	Setpoint	Interlocks	Purpose	Accident/Event
1. Source Range High Neutron Flux	1/2	10^5 cps	Manual block permitted by P-6; power to source range detectors is removed when manual block is initiated. Power to detectors cannot be turned on when power is above P-10.	Prevents an inadvertent power rise (excursion). A trip will occur unless the operator deliberately blocks the trip.	Reactivity addition accidents such as: a. Uncontrolled rod withdrawal from subcritical or low power condition, b. Inadvertent boron dilution, or c. Excessive heat removal caused by steamline break or feedwater addition accident
2. Intermediate Range High Neutron Flux	1/2	Current equiva-lent to 25% power level	Manual block permitted by P-10.	Prevents an inadvertent power rise (excursion). A trip will occur unless the operator deliberately blocks the trip.	Reactivity addition accidents such as: a. Uncontrolled rod withdrawal from subcritical or low power condition, b. Inadvertent boron dilution, or c. Excessive heat removal caused by steamline break or feedwater addition accident
3. Power Range High Neutron Flux - low setpoint	2/4	25%	Manual block permitted by P-10.	Prevents an inadvertent power rise (excursion). A trip will occur unless the operator deliberately blocks the trip.	Reactivity addition accidents such as: a. Uncontrolled rod withdrawal from subcritical or low power condition, b. Inadvertent boron dilution, or c. Excessive heat removal caused by steamline break or feedwater addition accident

Table 12.2-1 (cont'd)
Summary of Reactor Trips

Trip	Coinc.	Setpoint	Interlocks	Purpose	Accident/Event
4. Power Range High Flux - high setpoint	2/4	109%	No Interlocks	Limits maximum power level to prevent damage to fuel clad and to protect against centerline melting.	Inadvertent power excursions such as: a. Excessive load increase, b. Excessive heat removal, c. Boron dilution accident, d. Inadvertent rod withdrawal, or e. Rod ejection accident
5. High Positive Rate Neutron Flux	2/4	+5% change with a 2-sec time constant	No Interlocks	Limits power excursions. Prevents unacceptable power distribution.	Rod Ejection Accident
6. High Negative Rate Neutron Flux	2/4	-5% change with a 2-sec time constant	No Interlocks	Prevents unacceptable power distribution. Limits power overshoot from rod withdrawal in response to a dropped rod.	Dropped Rod
7. OTΔT	2/4	Variable (cal-culated)	No Interlocks	Prevents operation with DNBR <1.30.	Relatively slow transients such as: a. Uncontrolled rod withdrawal at power, b. Uncontrolled boron dilution, c. Excessive load increase, or d. Depressurization of the RCS

Table 12.2-1 (cont'd)
Summary of Reactor Trips

Trip	Coinc.	Setpoint	Interlocks	Purpose	Accident/Event
8. OPΔT	2/4	Variable (cal-culated)	No Interlocks	Prevents excessive power density (kw/ft).	Relatively slow transients such as: a. Uncontrolled rod withdrawal at power, b. Uncontrolled boron dilution, c. Excessive load increase, or d. Steamline break
9. Pressurizer Low Pressure	2/4	1865 psig (rate compen-sated)	Disabled below P-7 (10%)	Prevents operation with DNBR <1.30. Limits required range of OTΔT trip.	Depressurization of RCS due to: a. LOCA, b. Steamline break, or c. SG tube rupture
10. Pressurizer High Pressure	2/4	2385 psig	No Interlocks	Protects integrity of RCS pressure boundary.	Uncontrolled rod withdrawal at power, loss of electrical load, or turbine trip
11. Pressurizer High Water Level	2/3	92%	Disabled below P-7 (10%)	Prevents "solid-water" operations, prevents discharge of high energy water through relief and safety valves.	Uncontrolled rod withdrawal at power, loss of electrical load, or turbine trip
12. Low Reactor Coolant Flow	2/3 per loop	<90% of rated flow	<P-8 (39%): loss of flow in one loop, no direct trip. <P-7 (10%): loss of flow in two or more loops, no direct trip.	Ensures adequate loop flow to remove core heat. DNBR considerations.	Loss of coolant flow events such as: a. Partial loss of RCS flow, b. Complete loss of forced RCS flow, or c. Loss of off-site power to station auxiliaries.
13. Reactor Coolant Pump Bus Under-Voltage	1/2 on 2/2 buses	68.6% of nominal bus voltage	Disabled below P-7 (10%)	Redundant to low flow trip	Redundant to low flow trip

Table 12.2-1 (cont'd)
Summary of Reactor Trips

Trip	Coinc.	Setpoint	Interlocks	Purpose	Accident/Event
14. Reactor Coolant Pump Bus Under-Frequency	1/2 on 2/2 buses	57.7 Hz	Disabled below P-7 (10%); trips open the pump motor breakers when actuated to preserve pump coastdown time.	Redundant to low flow trip	Redundant to low flow trip
15. Reactor Coolant Pump Breaker	1/1 on 2/4 RCPs	Breaker open	Disabled below P-7 (10%)	Redundant to low flow trip	Redundant to low flow trip
16. Steam Generator Low-Low Level	2/3 on 1/4 SGs	11.5%	No Interlocks	Prevents loss of heat sink.	Loss of normal feedwater
17. Low Feedwater Flow	1/2 flow mis-match + 1/2 low level on 1/4 SGs	25.5% SG level AND 1.5×10^6 lbm/hr mismatch ($W_s > W_f$)	No Interlocks	Anticipates loss of heat sink.	Partial loss of normal feedwater
18. Turbine Trip	2/3 low pres-sure or 4/4 throttle valves closed	Westing-house: 45 psig auto-stop oil press. GE: 800 psig trip header press.	Disabled below P-7 (10%)	Removes heat source if steam load is lost to SGs.	Turbine trip, loss of load

Table 12.2-1 (cont'd)
Summary of Reactor Trips

Trip	Coinc.	Setpoint	Interlocks	Purpose	Accident/Event
19. SI Actuation	1/2 trains		No Interlocks		Any accident requiring a safety injection actuation signal
20. Manual	1/2 manual push-buttons		No Interlocks	Operator initiated backup to all trips	Any condition requiring a reactor trip
21. SSPS General Warning	2/2	General Warning		The SSPS has a self-check feature that will trip the reactor if both protection trains develop trouble.	

Table 12.2-2
Summary of Protection-Grade Interlocks

Number	Name	Setpoint	Coincidence	Functions
P-4	Reactor Trip Breaker Contact	Open if trip breaker is closed. Closed if trip breaker is open.	Trip breaker and its bypass breaker both open	1. Trips main turbine. 2. Isolates main feedwater with T_{avg} <564°F in 2/4 loops. 3. Input to SI block and reset logic. 4. If main feed regulating and bypass valves are closed by SI or SG high level, P-4 seals in the isolation.
P-6	Source Range Block Permissive	Intermediate range power > 10^{-10} amps.	1/2	Enables BLOCK/RESET switches to allow the operator to block SR high flux trip.
P-7	At-Power Permissive	Power < 10%	Power range power <10% (P-10 cleared) and turbine power (impulse pressure) <10% (P-13)	Automatically blocks the "at-power" trips: 1. Pressurizer low pressure, 2. Pressurizer high level, 3. All RCS low flow, and 4. Turbine tripped
P-8	3-Loop Flow Permissive	Power range power < 39%	3/4	Automatically blocks the single loop low flow reactor trip.
P-9 (Not on all plants)	Turbine Trip/Reactor Trip Permissive	Power range power < 50%	3/4	Blocks reactor trip on turbine trip below 50%.
P-10	Nuclear At-Power Block Permissive	Power range power > 10%	2/4	1. Opens contacts to SR high voltage power supply. 2. Enables BLOCK switches to allow the operator to block IR high flux trip and rod stop. 3. Enables BLOCK switches to allow the operator to block PR high flux - low setpoint trip. 4. Input to P-7.

Table 12.2-2 (cont'd)
Summary of Protection-Grade Interlocks

Number	Name	Setpoint	Coincidence	Functions
P-11	Low Pressurizer Pressure SI Block Permissive	Pressurizer pressure < 1915 psig	2/3	Enables BLOCK switches to allow the operator to block low pressurizer pressure ESF actuation. Removal of permissive provides open signal to accumulator isolation valves.
P-12	High Steam Flow SI Permissive	T_{avg} < 553°F	2/4	1. Enables BLOCK switches to allow the operator to block high steam flow ESF actuation. 2. Input to high steam flow ESF actuation logic. 3. Removes arming signal for steam dump operation. Operator may bypass the interlock on the three cooldown valves.
P-13	Turbine At-Power Permissive	Turbine power (impulse pressure) < 10%	2/2	Input to P-7
P-14	SG High Level Override	Steam generator narrow-range level > 69%	2/3 per SG on 1/4 SGs	1. Closes main feedwater regulating and bypass valves. 2. Trips all main feed pumps. 3. Trips main turbine. 4. Closes all main feedwater isolation valves.

Table 12.2-3
Summary of Control-Grade Interlocks

Number	Name	Setpoint	Coincidence	Interlocks	Functions
C-1	Intermediate Range High Flux Rod Stop	Intermediate range power > current equivalent to 20% power	1/2	Blocked when IR trip is blocked. Bypassed when IR trip is bypassed.	Stops control rod outward motion (manual & automatic).
C-2	Power Range High Flux Rod Stop	Power range power > 103%	1/4	Individual channel can be bypassed at local cabinet.	Stops control rod outward motion (manual & automatic).
C-3	OTΔT Rod Stop & Runback	Loop ΔT > (OTΔT reactor trip setpoint - 3%)	2/4	None	Stops control rod outward motion (manual & automatic) and initiates a turbine runback.
C-4	OPΔT Rod Stop & Runback	Loop ΔT > (OPΔT reactor trip setpoint - 3%)	2/4	None	Stops control rod outward motion (manual & automatic) and initiates a turbine runback.
C-5	Low Power Interlock	Turbine power (impulse pressure) < 15%	1/1 (one channel assigned)	None	Stops control rod outward motion in automatic only.
C-7	Loss of Load	Turbine power (impulse pressure) reduction > 10% step or 5%/min ramp	1/1 (one channel assigned)	Seals in. Must be reset.	Arms steam dumps in T_{avg} mode (loss-of-load controller).
C-8 (Plant with P-9 does not have)	Turbine Tripped	1. Throttle valves closed, or 2.aWestinghouse: auto-stop oil pressure <45 psig 2.bGE: trip header pressure < 800 psig	1. 4/4 2.a, b 2/3	Reactor trip (see function 2) disabled if P-7 satisfied.	1. Arms steam dumps in T_{avg} mode (turbine-trip controller). 2. Trips reactor.

Table 12.2-3 (cont'd)
Summary of Control-Grade Interlocks

Number	Name	Setpoint	Coincidence	Interlocks	Functions
C-9	Condenser Available Interlock	1. Condenser vacuum > 22 in. Hg, and 2. Condenser circulating water pump breaker closed	1. 2/2 2. 1/2	None	Ensures condenser is available for steam dump operation.
C-11	Control Bank D Withdrawal Interlock	Control bank D pulse-to-analog converter output >223 steps	1/1	None	Stops outward rod motion in automatic only.

Reactor Protection System:
Engineered Safety Features Actuation Signals

Section 12.3

Objectives

1. List the Engineered Safety Features (ESF) actuation signals and the accident(s) or conditions which will initiate each one.
2. List the systems or components that are actuated or realigned by each engineered safety features actuation signal.
3. Describe the effects of resetting a safety injection actuation signal and how the reset signal is removed.

TABLE 12.3-1
SUMMARY OF ENGINEERED SAFETY FEATURES ACTUATION SIGNALS

Signal	Coincidence	Setpoint	Interlocks	Accident/Condition
Safety Injection Actuation				
Low Pressurizer Pressure	2/3	1807 psig	Manual block; block enabled when pressurizer pressure < 1915 psig (P-11)	Loss-of-coolant accident (LOCA)
High Differential Pressure Between Steam lines	Any steam line 100 psi lower than at least two of the remaining three steam lines	100 psi Δ P	No Interlocks	Steam line break (SLB) upstream of the main steam line isolation valves (MSIVs)
High Steam Flow COINCIDENT WITH Low Steam Pressure OR Low-Low T_{avg}	1/2 flows on 2/4 steam lines 2/4 steam lines 2/4 RCS loops	Setpoint varies with turbine load (impulse pressure) 600 psig (Rate sensitive) 553°F	Manual block; block enabled when T_{avg} < 553°F (P-12)	SLB downstream of the MSIVs (common to all steam generators)
High Containment Pressure	2/3	3.5 psig	No Interlocks	High energy line break inside containment (LOCA or secondary pipe break)
Manual	1/2 actuation switches on main control board		No Interlocks	Operator backup to automatic actuation

Signal	Coincidence	Setpoint	Interlocks	Accident/Condition
Containment Spray Actuation				
High-High Containment Pressure	2/4	30 psig	No Interlocks	Large high energy line break inside containment (LOCA or secondary pipe break)
Manual	Simultaneous 2/2 actuation switches on main control board		No Interlocks	Operator backup to automatic actuation
Containment Isolation Phase A				
Any Safety Injection Actuation	Refer to Safety Injection Actuation portion of this table.			
Manual	1/2 actuation switches on main control board		No Interlocks	Operator backup to automatic actuation
Containment Isolation Phase B				
High-High Containment Pressure	2/4	30 psig	No Interlocks	Large high energy line break inside containment (LOCA or secondary pipe break)
Manual	Actuated with manual actuation of containment spray		No Interlocks	Operator backup to automatic actuation

TABLE 12.3-1 (cont'd)
SUMMARY OF ENGINEERED SAFETY FEATURES ACTUATION SIGNALS

Signal	Coincidence	Setpoint	Interlocks	Accident/Condition
Steam Line Isolation				
High-High containment pressure	2/4	30 psig	No Interlocks	Large high energy line break inside containment (LOCA or secondary pipe break)
High Steam Flow COINCIDENT WITH Low Steam Pressure OR Low-Low T_{avg}	1/2 flows on 2/4 steam lines 2/4 steam lines 2/4 RCS loops	Setpoint varies with turbine load (impulse pressure) 600 psig 553°F	No interlocks	SLB downstream of the MSIVs (common to all steam generators)
Feedwater Isolation				
Low T_{avg} COINCIDENT WITH Reactor Trip	2/4 RCS loops	564°F	P-4	Overcooling of reactor coolant following a reactor trip
High SG Water Level	2/3 levels on 1/4 SGs	69%	No Interlocks	SG overfill
Any Safety Injection Actuation	Refer to Safety Injection Actuation portion of this table.			
Auxiliary Feedwater Actuation				
Low-Low SG Water Level	2/3 levels on 1/4 SGs	11.5%	Can be defeated at RPS cabinets	Loss of heat sink
Trip of All Main Feed Pumps	2/2		Can be defeated using switches on main control board	Loss of heat sink
ESF Bus Undervoltage	1/2 taken twice on either ESF bus	2560 V with 1.1-sec delay	No Interlocks	Need for decay heat removal without offsite power
Any Safety Injection Actuation	Refer to Safety Injection Actuation portion of this table.			

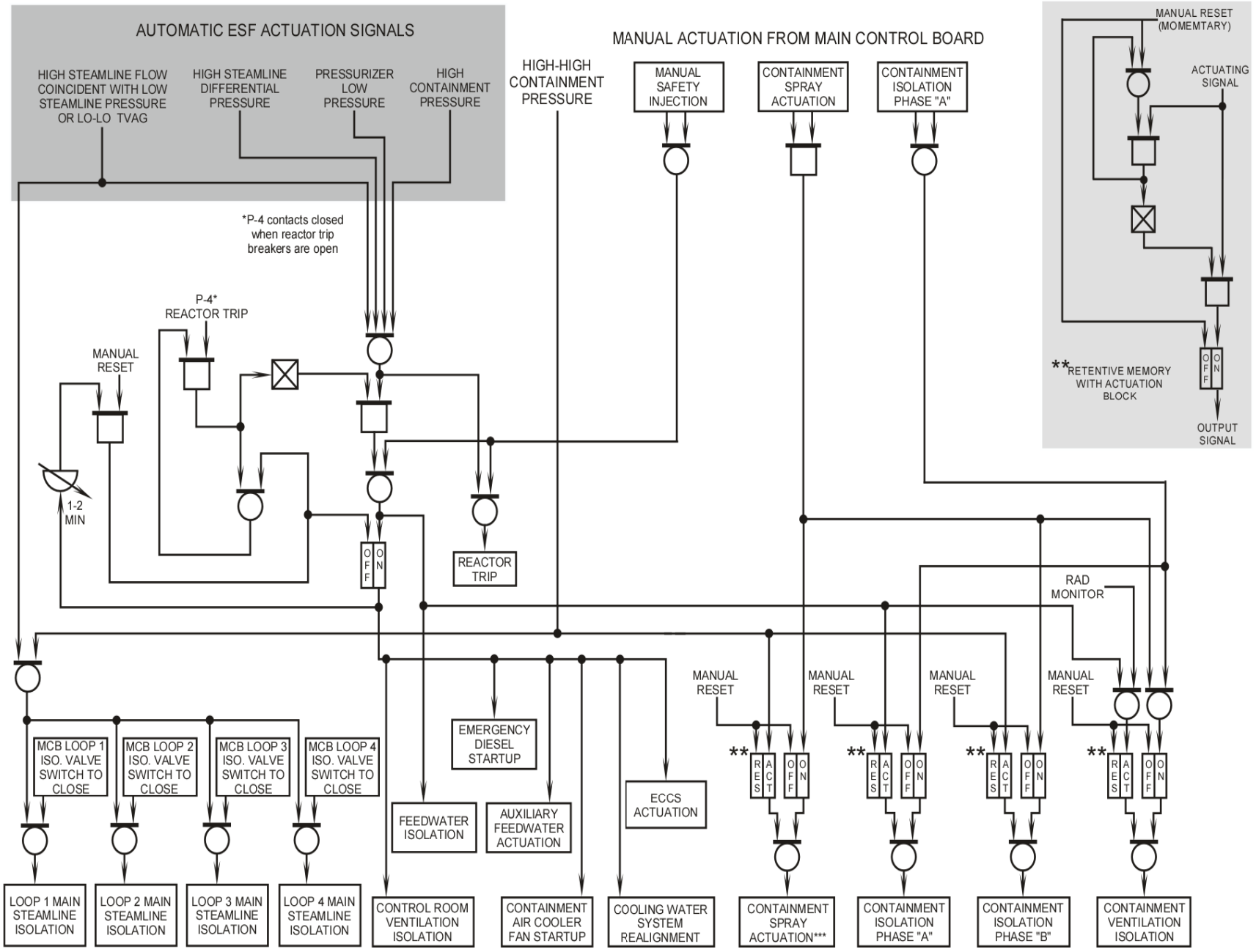


Figure 12.3-1 Engineered Safety Features Logic

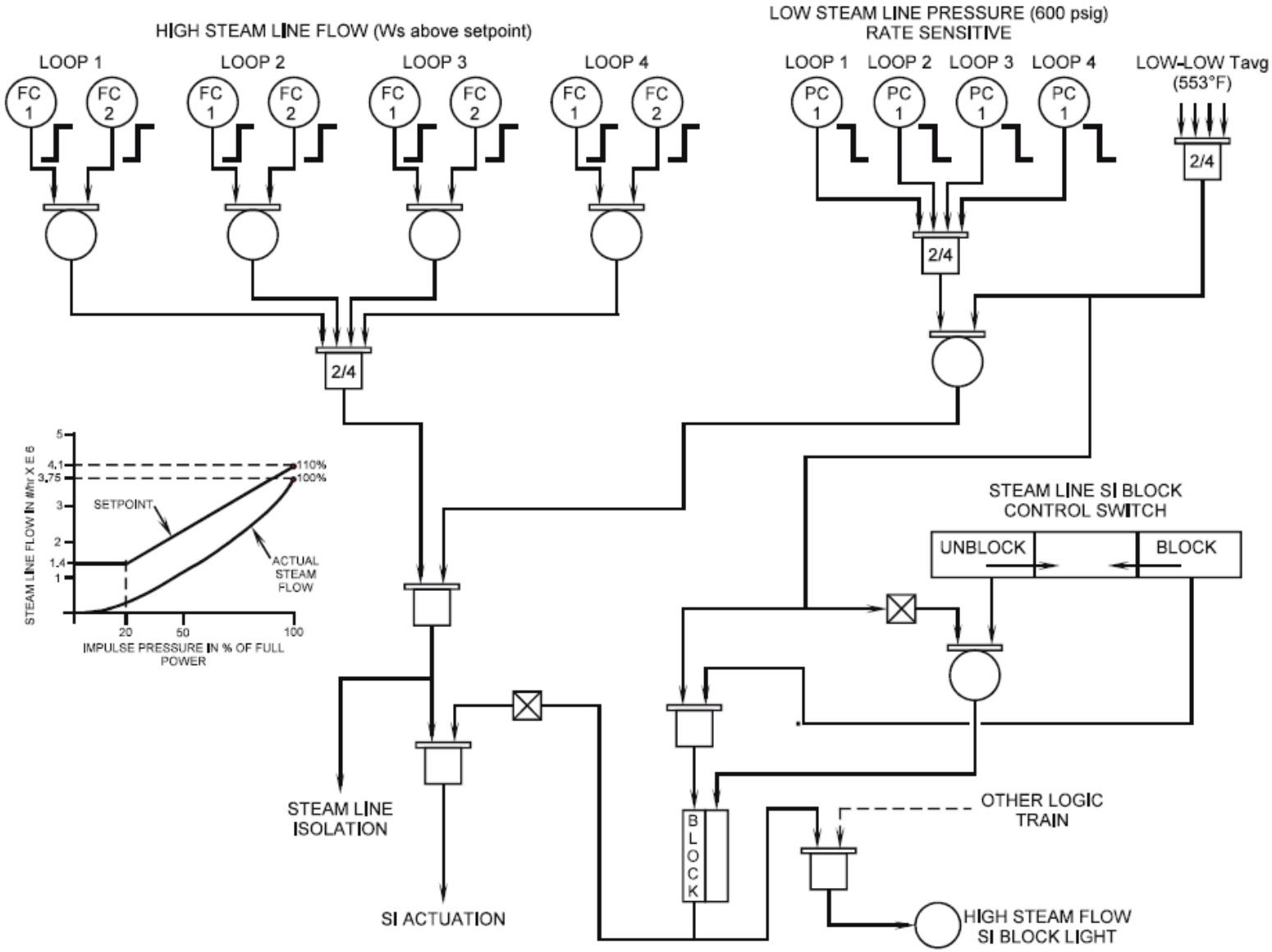
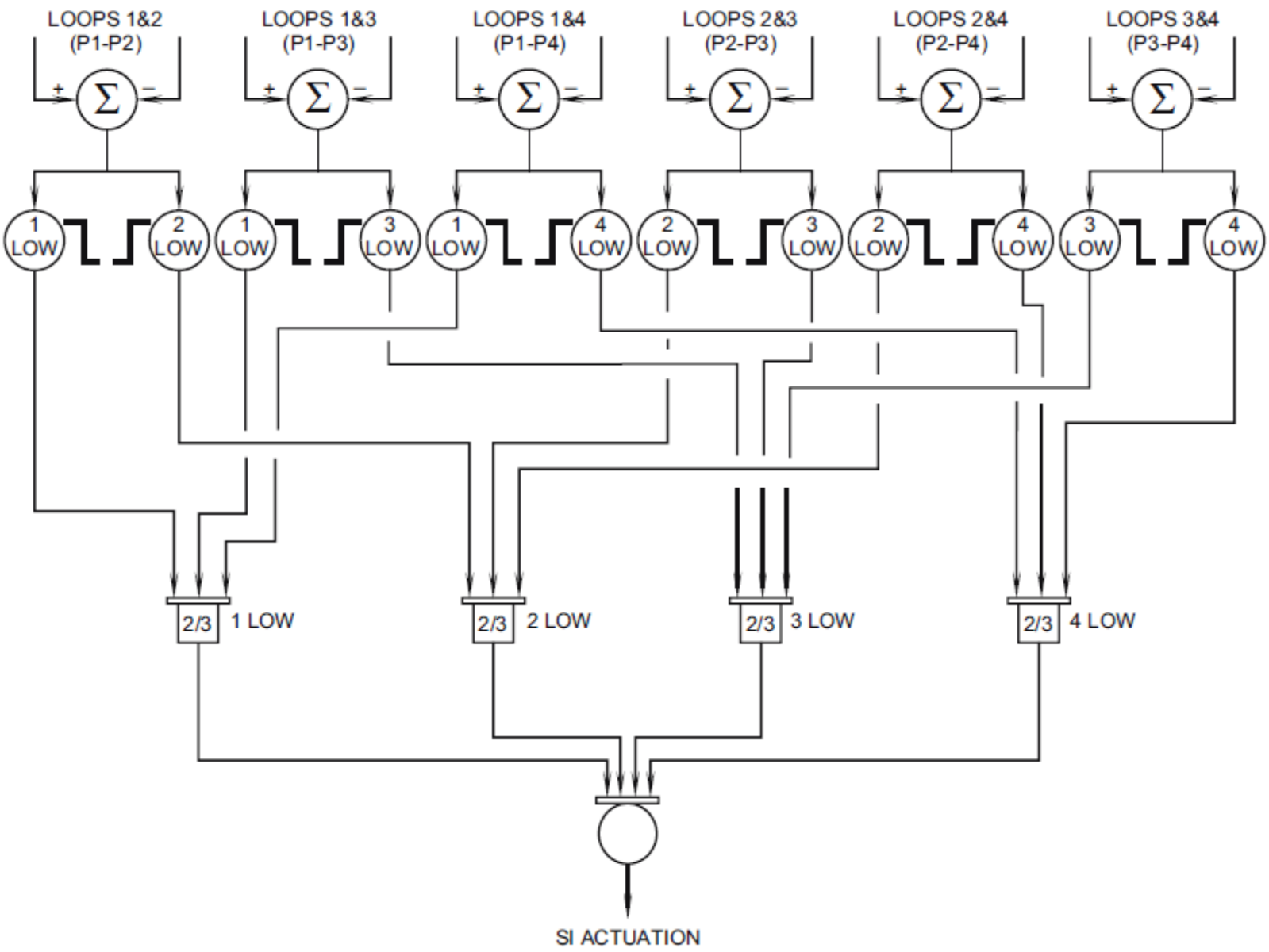


Figure 12.3-6 High Steam Line Flow ESF Actuation Logic


LOOPS 1&2
(P1-P2)
LOOPS 1&3
(P1-P3)
LOOPS 1&4
(P1-P4)
LOOPS 2&3
(P2-P3)
LOOPS 2&4
(P2-P4)
LOOPS 3&4
(P3-P4)
+
Σ
−
1 LOW
2 LOW
3 LOW
4 LOW
2/3
1 LOW
2 LOW
3 LOW
4 LOW
SI ACTUATION