# Anticipated Transient Without Scram (ATWS)

GE BWR/4 Technology Course
R-504B – 4.2

# Objectives

1. Define the term “anticipated transient without scram” (ATWS).
2. Recognize the potential consequences of an ATWS event and the expected plant response for the worst case ATWS event with no operator actions.
3. Recognize the regulatory requirements for BWRs contained in 10CFR50.62, to reduce the risk from an ATWS event.
4. Identify potential causes of an ATWS event in BWR design and the indications of each.
5. Recognize the strategies used in the EOPs to limit core power during an ATWS event and ultimately to shut down the reactor.

# Anticipated Operational Occurrence

## 10 CFR 50 Appendix A

Those conditions of normal operation which are expected to occur one or more times during the life of the plant

# AOO EXAMPLES

**RPV PRESSURE DECREASE EVENTS**
- Loss of Feedwater Heating
- Increase in Steam Flow
- Safety lifting

**RPV PRESSURE INCREASE EVENTS**
- EHC Malfunction
- Generator Load Reject
- Turbine Trip/Loss of Vacuum
- MSIV Closure

**DECREASE IN REACTOR COOLANT SYSTEM FLOWRATE**
- Recirculation Pump Trip(s)
- Recirculation Flow Control Failure

**REACTOR COOLANT INVENTORY INCREASE**
- HPCI Initiation
- FWLC failure

**REACTOR COOLANT INVENTORY DECREASE**
- FWLC Failure
- SRV Opening
- Loss of Feed

**REACTIVITY EXCURSIONS**
- Control Rod Withdrawal Error
- Recirculation Flow Control Failure
- Control Rod Drop
- Fuel bundle placed in wrong spot

# ATWS

10 CFR 50.62:

Anticipated Transient Without Scram means an anticipated operational occurrence followed by failure of the reactor trip portion of the protective system (RPS)

# History – Ongoing Debate

1969 Advisory Committee on Reactor Safeguards (ACRS)

- Separation of control and protection systems
- Common mode failure preventing shutdown.

1971 ACRS approved implementation of ATWS-RPT at Newbolt Island (Hope Creek) and other BWR/4s

1974 Vendors submitted analyses on ATWS in response to WASH -1270

1978 NUREG 0460 ATWS (USI A-9)

– PRA to estimate benefit of modifications

# Browns Ferry 06/28/1980

- Deliberate scram from 30% power entering an outage
- 76 of 185 control rods failed to fully insert
- Cause was high level in SDV
- All rods on one side of the core
- SDV partially drained & scram attempted for a second & third time
- 15 minutes to insert all rods
- Cause: accumulated drainage to SDV

# Salem February 1983

- On 2/23/83 and **again** on 2/25/83
- Lost control of steam generator level
- Reactor did not automatically trip
- Operators took actions within 30 seconds of exceeding setpoint and manually tripped Rx
- Cause was binding of trip breaker undervoltage trip mechanism due to lack of lubrication.

# History

- 1983 NUREG-1000, “Generic Implications of ATWS Events at the Salem Nuclear Power Plant”
- 1983: GL 83-28:
  - Post-Trip Review
  - Equipment Classification and Vendor Interface
  - Post-Maintenance Testing
  - Reactor Trip System Reliability Improvements

# Risk = Probability x Consequences

- Probability uncertainty:
  - Initiating Event frequency (around 4/Rx-year)
  - RPS reliability (especially common mode failures)
  - Human Error Probability (HEP) range of values
- Consequences are severe:
  - Transient with failure to trip may cause or follow core isolation (MSIV closure)
  - High power levels (especially if recirc pumps continue to run) add heat directly to suppression pool causing containment failure and large early release

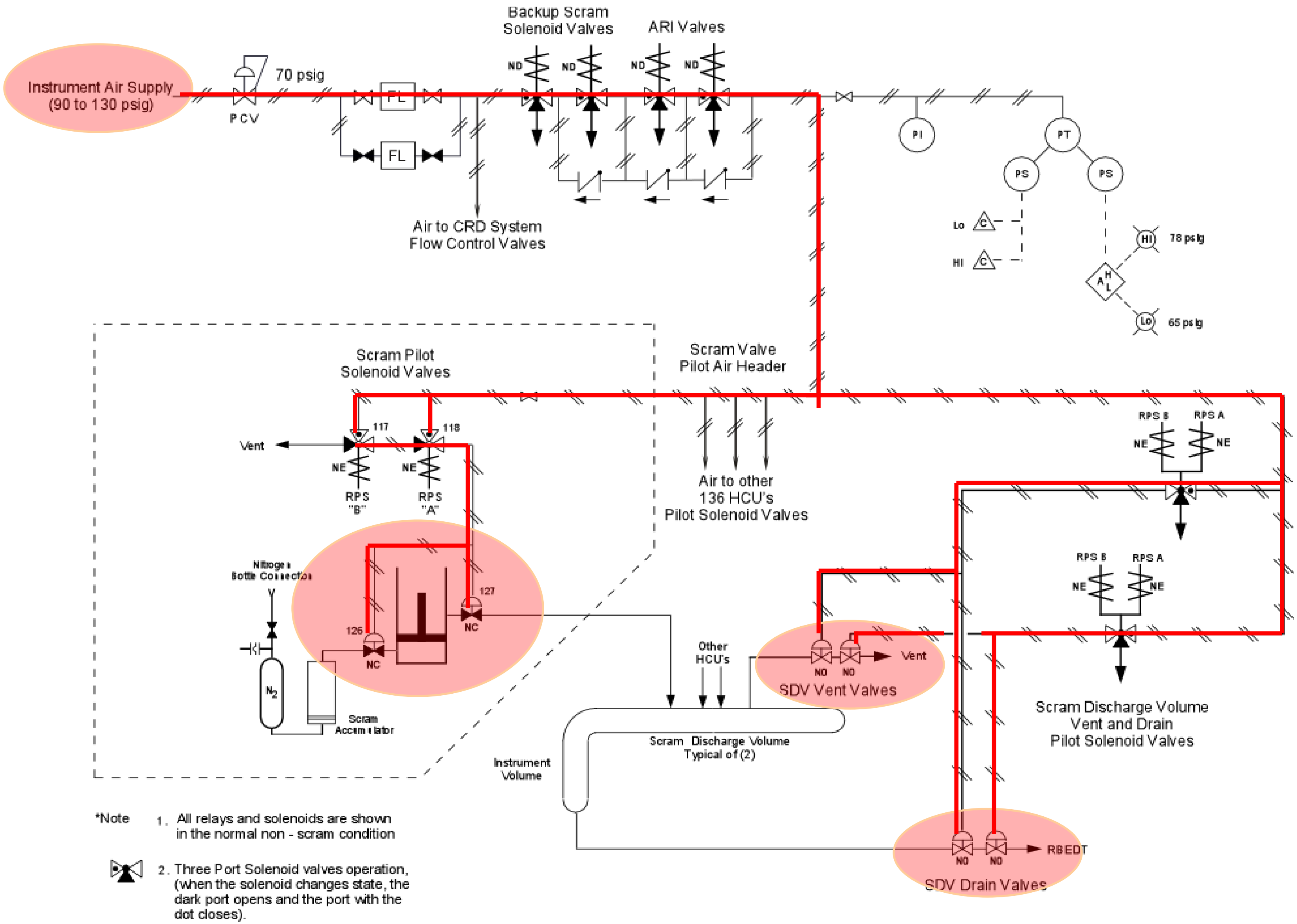
**RPS already meets GDCs**

# ATWS Rule

- 1984 ATWS Rule 10CFR50.62
  - Alternate Rod Injection (ARI) diverse from RPS from sensor output to final actuation device. Must have redundant scram air header exhaust valves.
  - SLC minimum injection rate of 86 gpm and boron concentration of 13%. Must include automatic actuation for plants constructed after 1984
  - ATWS-RPT

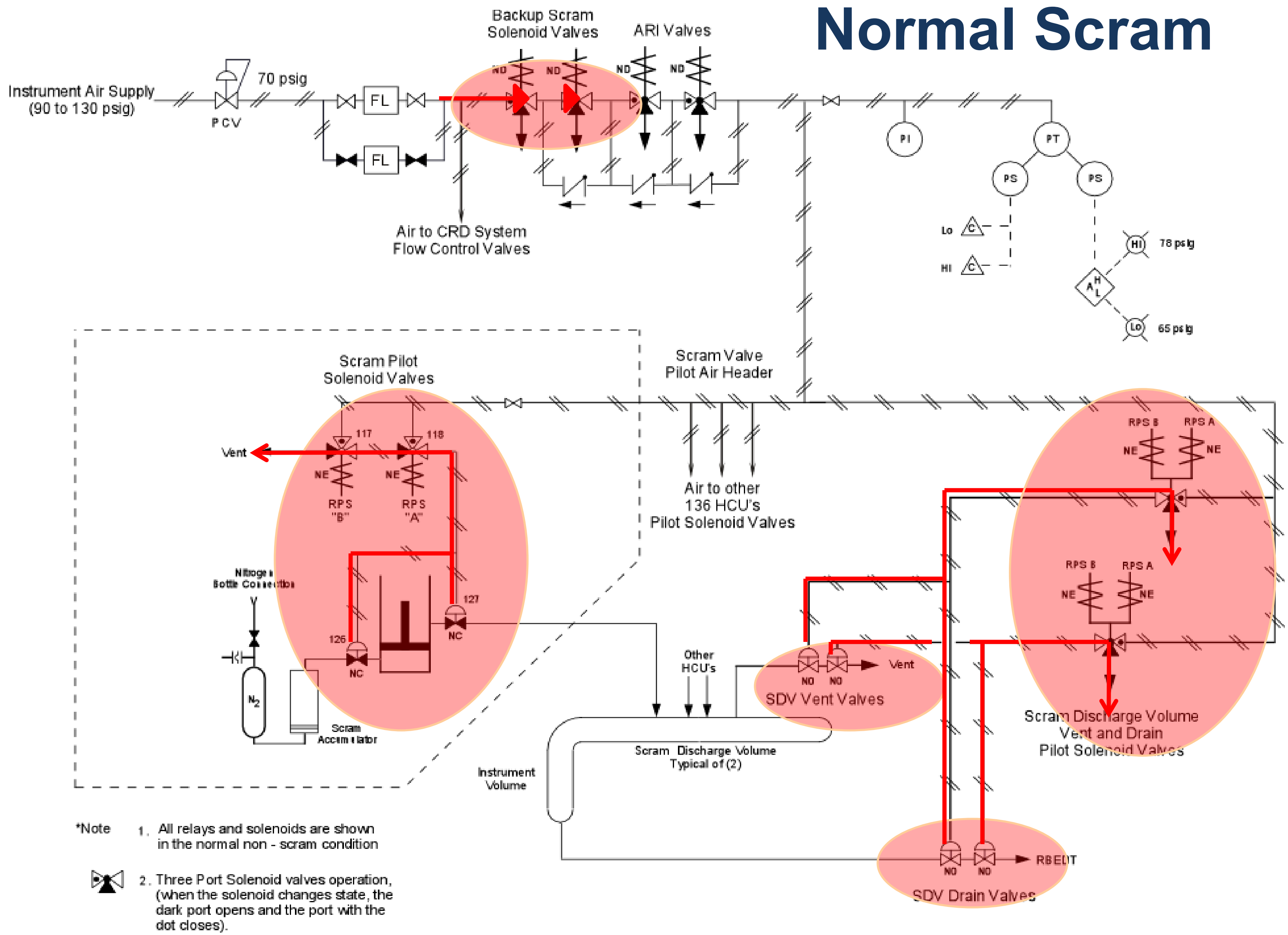
# Potential Causes & Indications of ATWS

- Failure of RPS relays to open
- Failure of scram air header to vent to atmosphere
- Stuck control rods (Mechanically bound or Hydraulically locked)
- Hydraulic lock from SDV filled
  - SDV Not Drained Alarm
  - Multiple partial insertion of rods



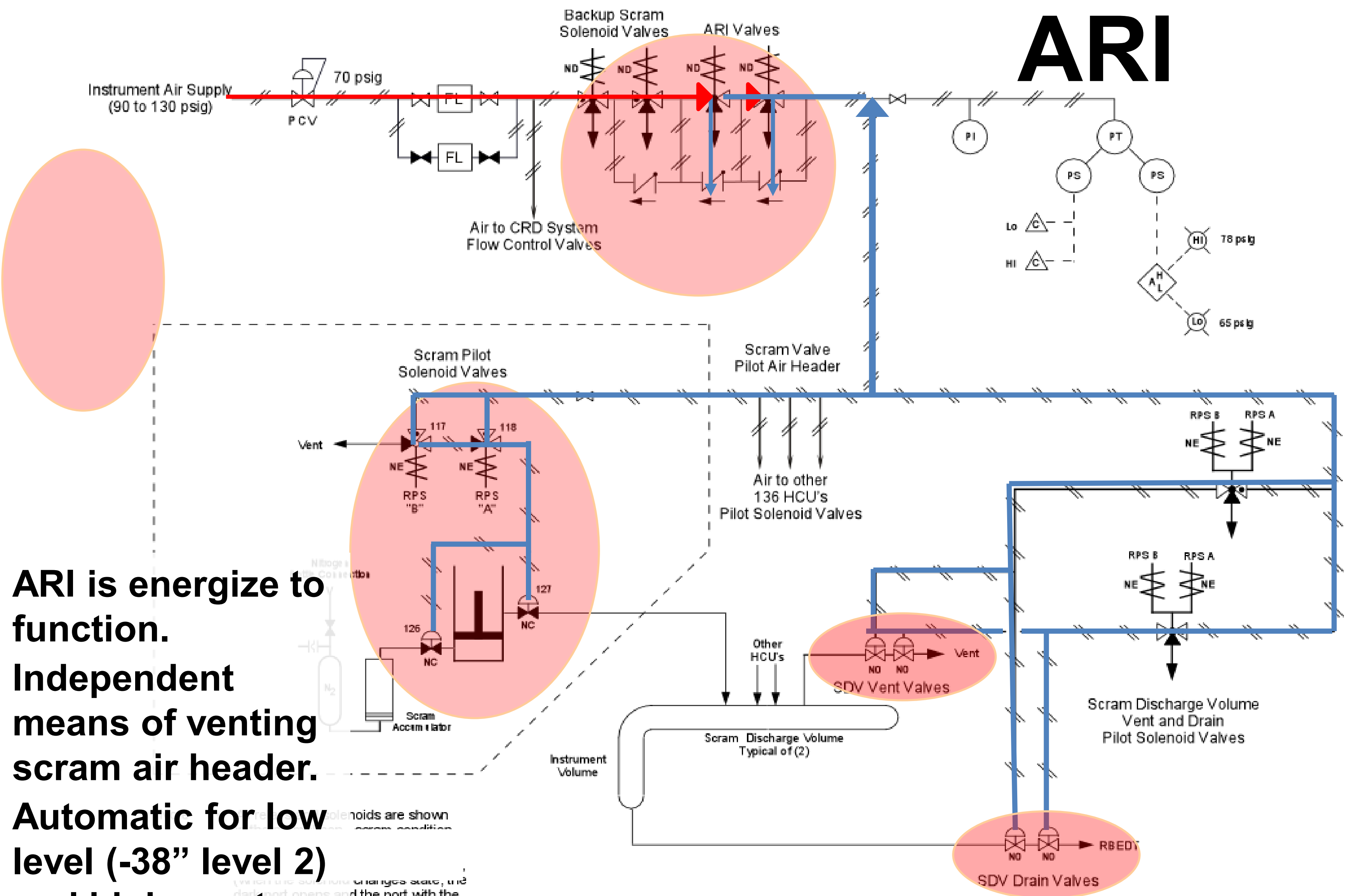

Scram air header pressure is normally pressurized to keep scram valves closed and SDV valves open.

# Normal Scram

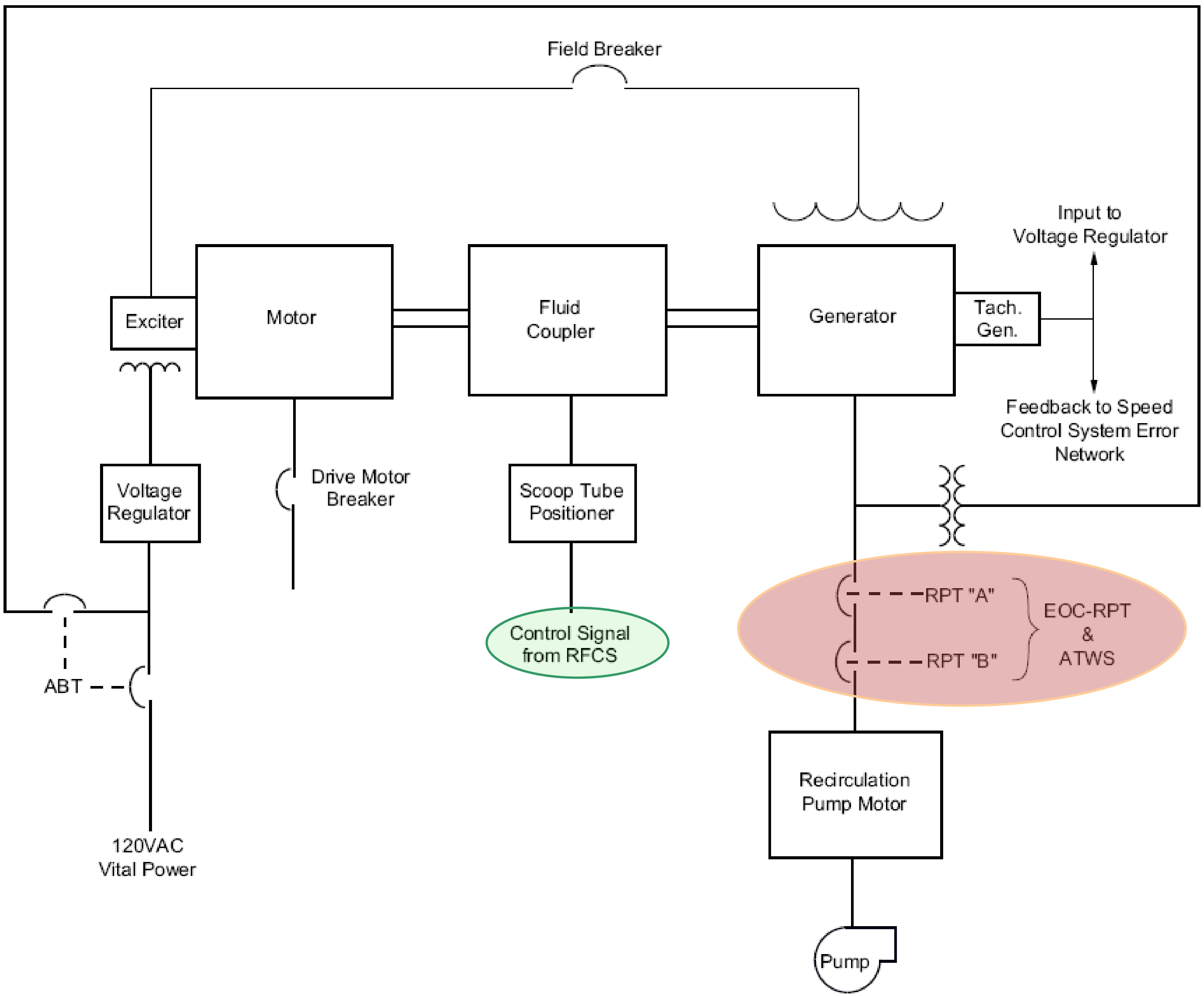



**RPS signal isolates air and bleeds off scram valves and SDV valves**

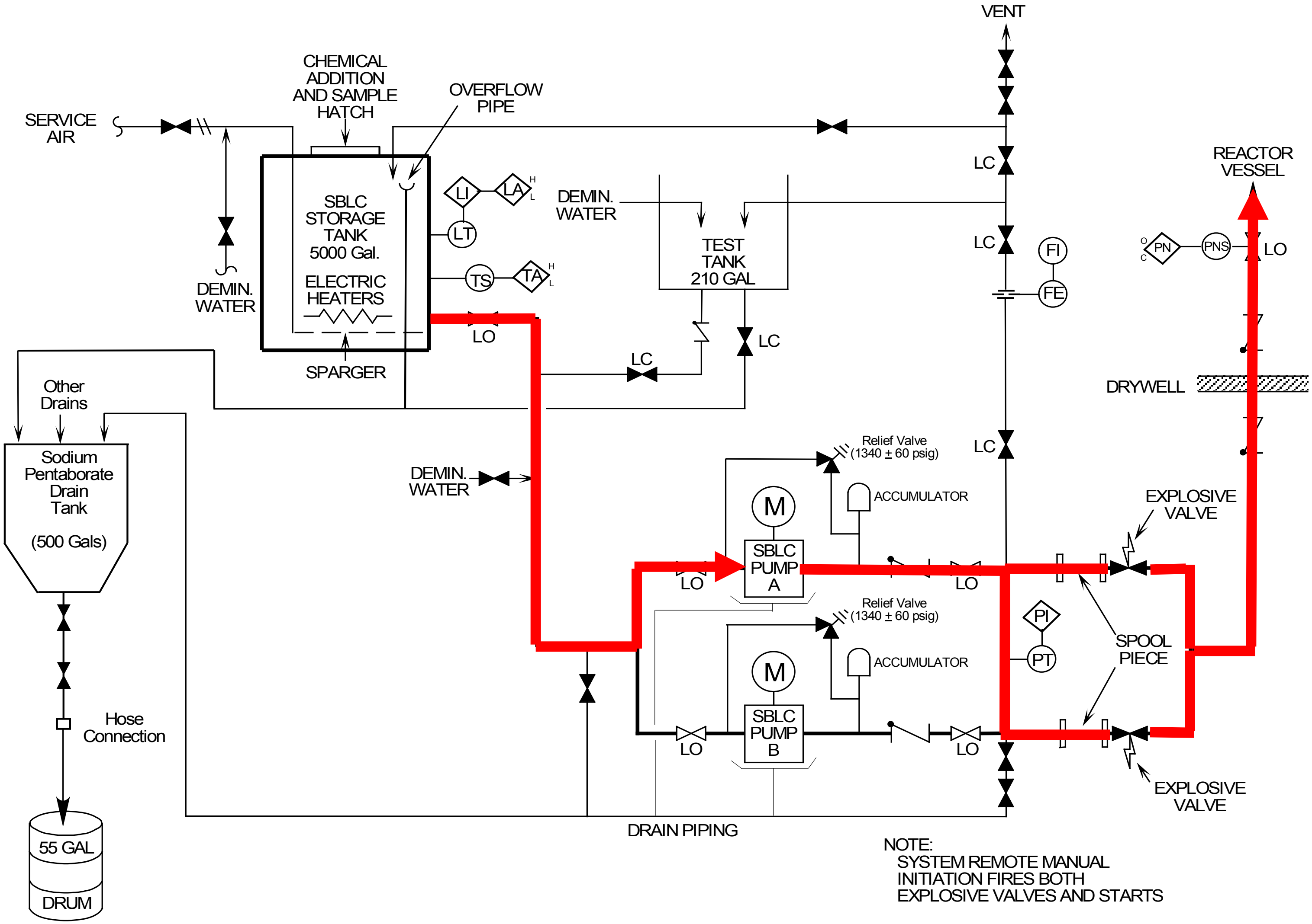
# ARI




- ARI is energize to function.
- Independent means of venting scram air header.
- Automatic for low level (-38” level 2) and high reactor pressure.
- Manual pushbuttons.


Field Breaker
Input to
Voltage Regulator
Exciter
Motor
Fluid
Coupler
Generator
Tach.
Gen.
Feedback to Speed
Control System Error
Network
Voltage
Regulator
Drive Motor
Breaker
Scoop Tube
Positioner
Control Signal
from RFCS
RPT "A"
RPT "B"
EOC-RPT
&
ATWS
ABT
120VAC
Vital Power
Recirculation
Pump Motor
Pump

# ATWS RPT




# Rule: 86 gpm @ 13%, Auto
# Actual: 41.2 gpm @ 85%, Manual

# Standard Review Plan

**An ATWS event cannot be classified as either an AOO or a design-basis accident**.

- Beyond design basis: Requires failure of single failure proof RPS
- The probability of an AOO, in coincidence with multiple failures or a common mode failure, is much lower than the probability of any of the other events that are evaluated under SRP Chapter 15.

**AOOs with failure to scram that could lead to unacceptable conditions including**:

- closure of main steamline isolation valves, or
- turbine trip with bypass available

***if unmitigated unstable power oscillations are allowed to grow*.**

# Worst Case

High Pressure or Low Level AOOs?

- Power spike from pressure increase
- Lower level actually helps to lower power
- High pressure adds heat directly to containment,
- Potential for both fuel failure and loss of containment

# Worst Case

MSIV closure or Turbine Trip w/o Bypass Valves

- MSIV closure slower than CVs
- TT has larger steam volume and delayed pressure wave
- Assuming recirc pumps continue to run:
  - MSIV closure: Power spike up to 527%
  - TT w/o BPV: power spike “Only” 392%

# Worst Case

Remember that MSIV closure can be caused by many things:

- Manual
- High Steam Flow or radiation
- High area temperatures
- Low MS Header Pressure
- Level 1
- Low Vacuum
- Loss of power to NSSSS (including LOOP)

# Worst Case

An ATWS does have the possibility of leading to a core damage situation and containment failure if the operator does not follow the Emergency Operating Procedures and initiate corrective actions like SLC initiation or lowering of RPV level.

Core damage + loss of containment ➔ 10CFR100

## How important is a recirculation pump trip during an ATWS?

If the recirculation pumps continue to run during an ATWS, power level will remain high and a severe pressure (and hence power) excursion will occur.

**This will make fuel and containment failure more probable and/or will cause it to occur sooner.**

# Scram Signals for MSIV Closure

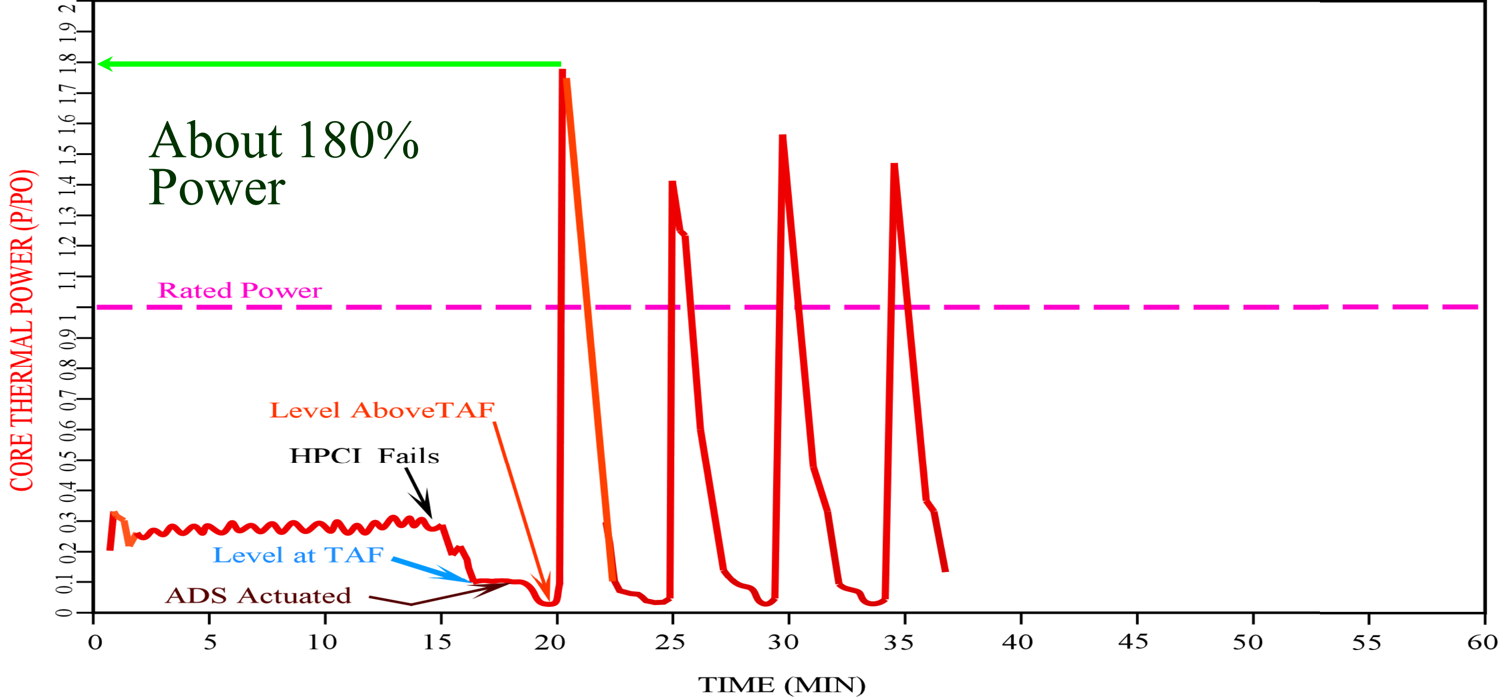
| Scram Signal | Signal Bypass | Probable Cause | Reason for Scram |
|---|---|---|---|
| APRM High-High Fixed Flux Trip (118%) (6 APRM's) | Mode switch not in **RUN** Joystick in **BYPASS*** | Power transient | Protect fuel cladding against excessive power (MCPR Safety Limit) |
| High Reactor Pressure (1043 psig) (4 pressure switches) | NONE | Pressure control transient | Protect reactor coolant boundary integrity (RPV Pressure Safety Limit) |
| MSIV Closure (<10% closed) (8 limit switches) | Mode switch not in **RUN**. | MSIV closure signal | Protect fuel cladding against positive reactivity insertion following void collapse (MCPR Safety Limit) |

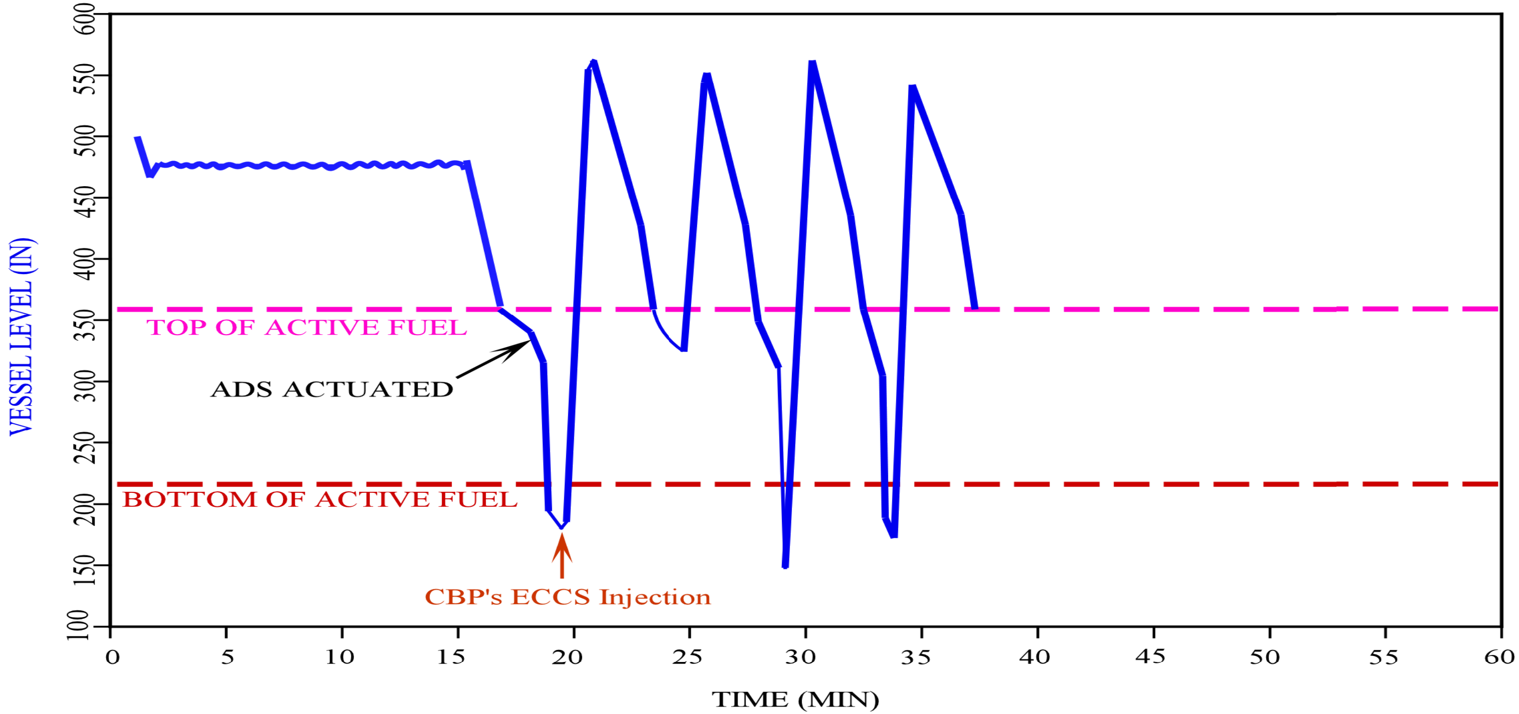
- Will also receive ARI signal on high pressure @ 1120#

| EVENT | TIME (MIN) | COMMENT |
|---|---|---|
| MSIV closure initiated | 0 | No scram |
| ATWS-RPT | 0.1 | At reactor 1135 psia pressure |
| HPCI and RCIC Start | 1.0 | At reactor vessel level of 476.5 inches. |
| HPCI suction shift | 8.3 | High suppression pool level |
| HPCI fails | 14.8 | Suppression pool temperature 190 $^{o}$F |
| CS and RHR systems start, ADS timer initiated. | 16.0 | Reactor vessel level 413.5 inches |
| TAF uncovered | 16.7 | Vessel level 360 inches |
| ADS actuation | 18.0 | Two minutes after timer actuation |
| BAF uncovered | 19.0 | Vessel level 216 inches |
| RHR, CS, and Condensate booster pumps start injecting | 19.6 | CBPs at 418 psia; CS at 357 psia; RHR at 346 psia |
| First core recovery | 19.9 | |
| Water introduction by RHR, CS and CBPs stop as vessel pressure increases | 20.4 | |
| Vessel pressure at relief valve setpoint | 20.7 | Vessel pressure 1120 psia |
| First core power peak | 20.7 | Thermal power = 178% |
| Drywell coolers fail on over temperature | 22.4 | Drywell temperature 200 $^{o}$F |
| Second core uncovery | 23.1 | |

**In this analysis the recirculation pumps trip**

| EVENT | TIME (MIN) | COMMENT |
|---|---|---|
| RHR, CS and CBPs start injecting | 24.4 | |
| Second core recovery | 24.7 | |
| Injection by RHR, CS and CBPs stops | 25.2 | |
| Vessel pressure at relief valve setpoint | 25.4 | |
| RCIC turbine trip on high exhaust pressure | 26.0 | |
| Second power peak | 27.7 | Thermal power = 140 % |
| Third core uncovery | 28.6 | |
| RHR, CS and CBPs start injecting | 29.0 | |
| Third core uncovery | 29.4 | |
| Injection by RHR, CS and CBPs stop | 29.8 | |
| Third power peak | 30.0 | Thermal power = 156 % |
| Relief valves lift | 30.1 | |
| Fourth core uncovery | 32.1 | |
| RHR, CS and CBPs start injecting | 33.6 | |
| DRYWELL FAILS | 36.8 | Pressure at 132 psia |


About 180%
Power
Rated Power
Level AboveTAF
HPCI Fails
Level at TAF
ADS Actuated
CORE THERMAL POWER (P/PO)
TIME (MIN)


TOP OF ACTIVE FUEL
ADS ACTUATED
BOTTOM OF ACTIVE FUEL
CBP's ECCS Injection
VESSEL LEVEL (IN)
TIME (MIN)

# SRP Acceptance Criteria

A. ATWS-RPT.

B. Alternate rod injection system (ARI) with independent scram air header exhaust valve.

C. A standby liquid control system (SLCS), 86 gpm of 13%  sodium pentaborate decahydrate solution of Boron-10, (automatic initiation for new plants)

# SRP Acceptance Criteria

D. Each plant EOPs must implement the ATWS/Stability Mitigation Actions:

   i. Following a failure to scram, the reactor vessel water level must be lowered to a level below the feedwater spargers that will allow vessel steam to preheat the cold feedwater

   ii. If unstable power oscillations are detected following a failure to scram, boron injection through the SLCS must be initiated manually

# ATWS mitigation strategies

- Insert manual scram and ARI
- Trip recirculation pumps
- SLC Injection
- Manual insert rods (by any and all means)
- Lower reactor water level

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