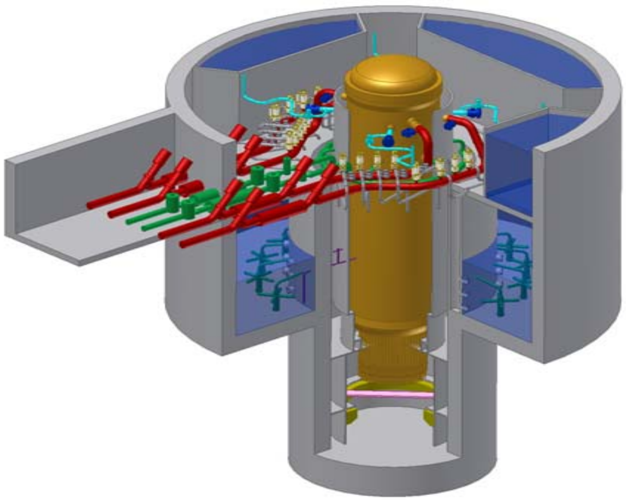


Presentation to
Nuclear Regulatory Commission

Summary
ESBWR Design Control Document, Tier 2
Chapter 6
Engineered Safety Features

September 27, 2005

imagination at work

Engineered Safety Features

Systems Provided to Mitigate the Consequences of Postulated Accidents

<u>Containment and Fission Product Removal Systems</u>

Containment System

Passive Containment Cooling System

<u>Emergency Core Cooling Systems</u>

Gravity-Driven Cooling System

Automatic Depressurization System

Isolation Condenser System

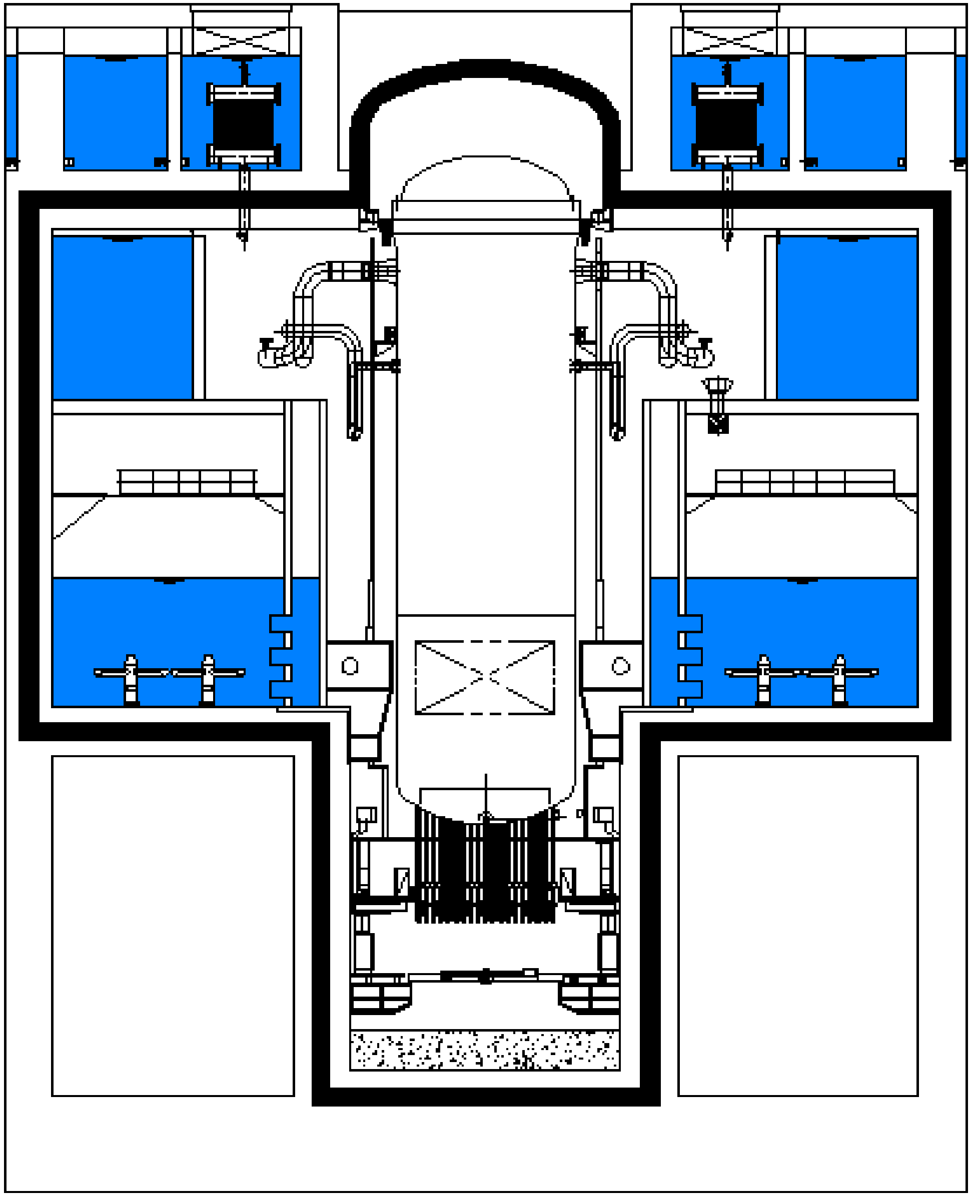
Standby Liquid Control System

<u>Control Room habitability Systems</u>

Sealed Emergency Operating Area

Emergency Breathing Air System

Containment



imagination at work

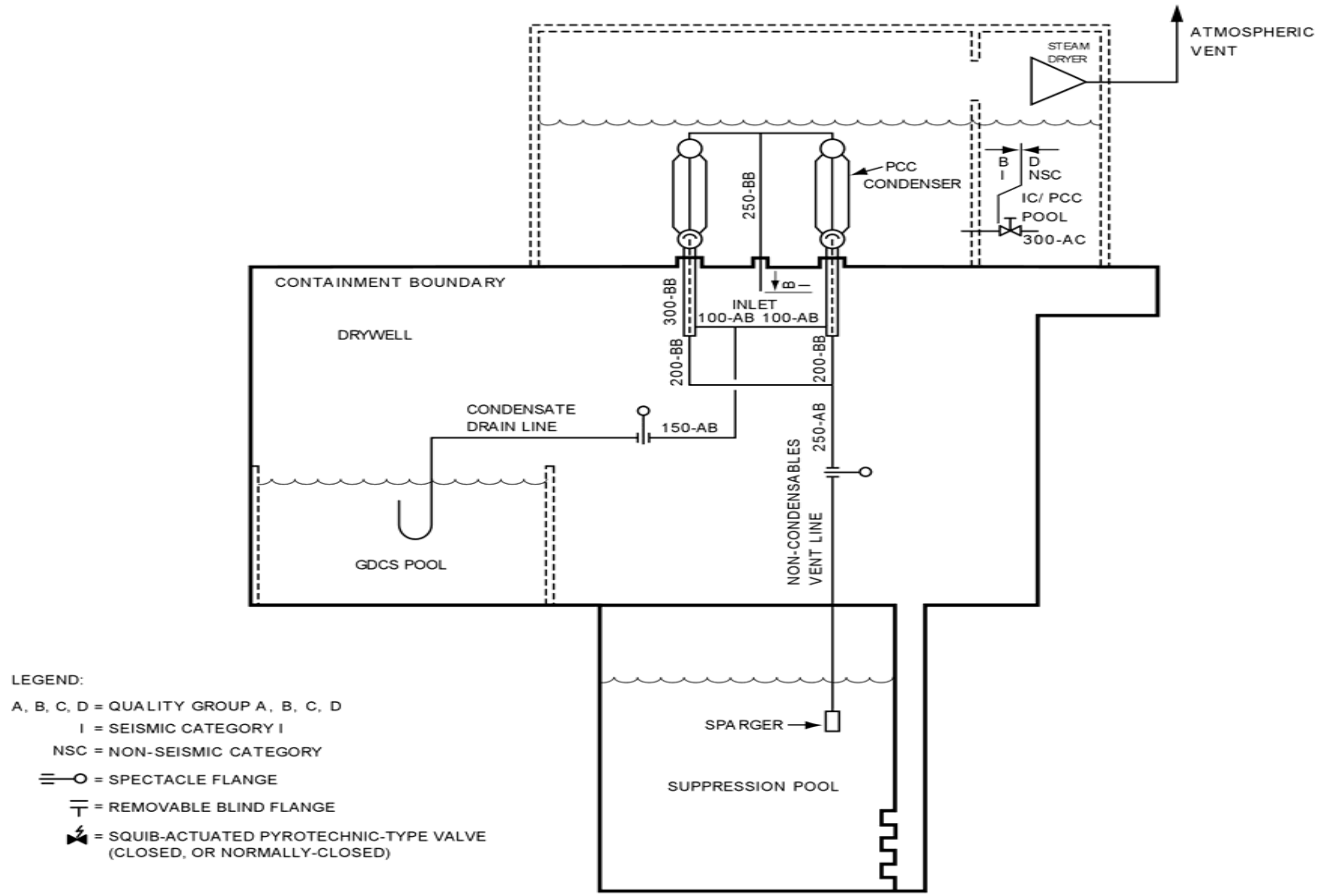
Safety Design Bases

- Maintain Functional Integrity during and following a LOCA
- Accommodate the Full Range of Loading Conditions for all Postulated Events
- Accommodate Pressure Differential between Drywell and Wetwell
- Limit fission Product Leakage Following Postulated DBA
- Withstand Fluid Jet Forces
- Withstand Hypothetical Missiles
- Direct High Energy Blowdown Fluids to the Suppression Pool and to PCCS

Containment Design Parameters

Design Conditions:	
Upper and Lower Drywell	
Design Pressure	310 kPa(g) [45 psig] / 414 kPa [60 psia]
Design Temperature	171°C (340°F)
Internal/External Differential Pressure	-20.7 kPa(d) [-3.0 psid]
Drywell to Wetwell Differential Pressure	241 kPa(d) [35 psid]/ -20.7 kPa(d) [-3.0 psid]
Inerting Gas	Nitrogen (with ≤ 3% Oxygen by Volume)
Wetwell	
Design Pressure	310 kPa(g) [45 psig] / 414 kPa [60 psia]
Design Temperature	121°C (250°F)
Inerting Gas	Nitrogen (with ≤ 3% Oxygen by Volume)
Horizontal Vent System	
Design Pressure	310 kPa(g) [45 psig] / 414 kPa [60 psia]
Design Temperature	171°C (340°F)
Containment Leak Rates	
Maximum Containment Leakage Excluding MSIV Leakage)	0.5% of Containment Volume per 24 hours Pressure 310 kPa(g) [45 psig]

imagination at work



LOOP A SHOWN

TYP LOOP B, C, D, E & F

Passive Containment Cooling System

imagination at work

PCCS System

REQUIREMENTS

- PASSIVE SYSTEM –NO ACTIVE COMPONENTS
- DESIGN PRESSURE AND TEMPERATURE THAT EQUAL OR EXCEED CONTAINMENT SEVERE ACCIDENT CAPABILITY

CLASSIFICATION

- SAFETY-RELATED, ASME SECT. III, CLASS 2 & SEISMIC I

PERFORMANCE

- CONDENSERS SIZED TO MAINTAIN THE CONTAINMENT WITHIN ITS PRESSURE LIMITS FOR DBA

Safety Related Functions

- Removes the Core Decay Heat Rejected to the Containment
  - Containment Cooling for a Minmum of 72 Hrs Post-LOCA
    - No Operator Action
    - Containment Pressure never Exceeds It's Design Pressure Limit of 310 kPa(g) (45 psig)
    - IC/PCCS Pool Inventory Doesn't Need to be Replenished

Major Equipment

CONDENSER

- QUANTITY = SIX (6)

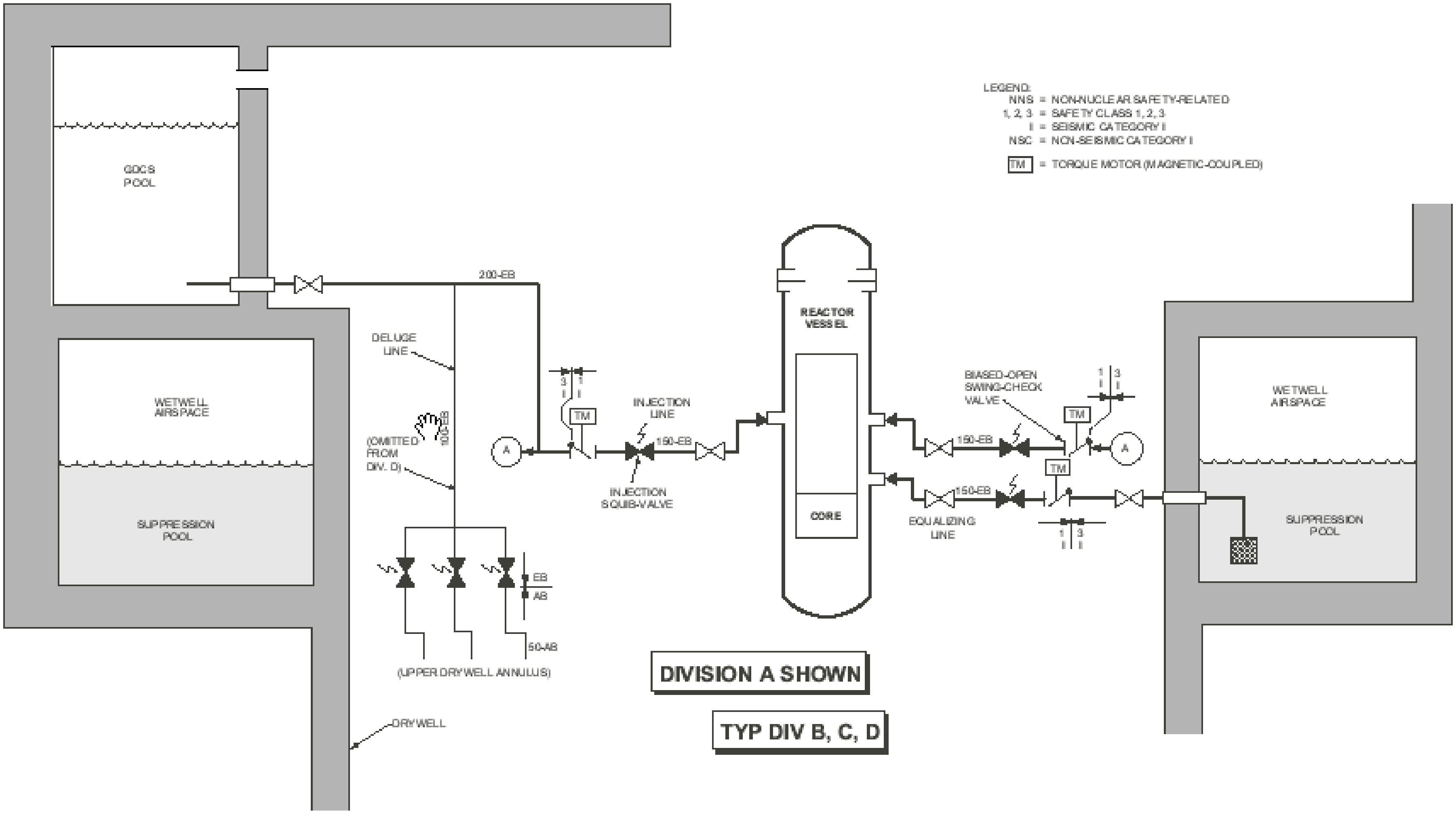
- EACH CONDENSER HEAT TRANSFER CAPACITY = 11MW WITH PURE SATURATED STEAM IN THE TUBES AT 308 KPA (ABSOLUTE) AND 134°C & POOL WATER TEMPERATURE AT ATMOSPHERIC PRESSURE AND 102°C.

- DESIGN PRESSURE AND TEMPERATURE = 758.5 KPA(G) (110 PSIG), 171°C (340°F)

- ASME CODE SECTION III, CLASS 2, SEISMIC CATEGORY I AND TEMA CLASS R

- MATERIAL - SS (NG) OR MATERIAL THAT IS NOT SUSCEPTIBLE TO IGSCC

- CONDENSER MODULE EASILY REMOVABLE IF REQUIRED FOR REPLACEMENT



Gravity-Driven Cooling System

GDCS Safety Related Functions

- Provide passive emergency core cooling after any event that threatens the reactor coolant inventory following RPV depressurization via ADS.
- Inject sufficient water into the depressurized RPV to keep the fuel covered following a LOCA.
- Flood lower drywell in event of a severe accident that results in high temperature in the lower drywell floor.
- The GDCS shall be "passive" from the standpoint that no external AC electrical power source or operator intervention is required.

GDCS System Details

- Four Independent Loops
- Three Gravity Driven Pools in Upper Containment
- System Actuated by Squib Valves (2 Valves in Parallel for Each Line)
- GDCS Pools are open to the Drywell
- Piping to RPV has Biased Open Check Valves to Prevent Outlet Water Flow from RPV

GDCS Piping

Three Separate Subsystems

GDCS (Short Term) Injection Lines from Pool to RPV to flood RPV after Depressurized

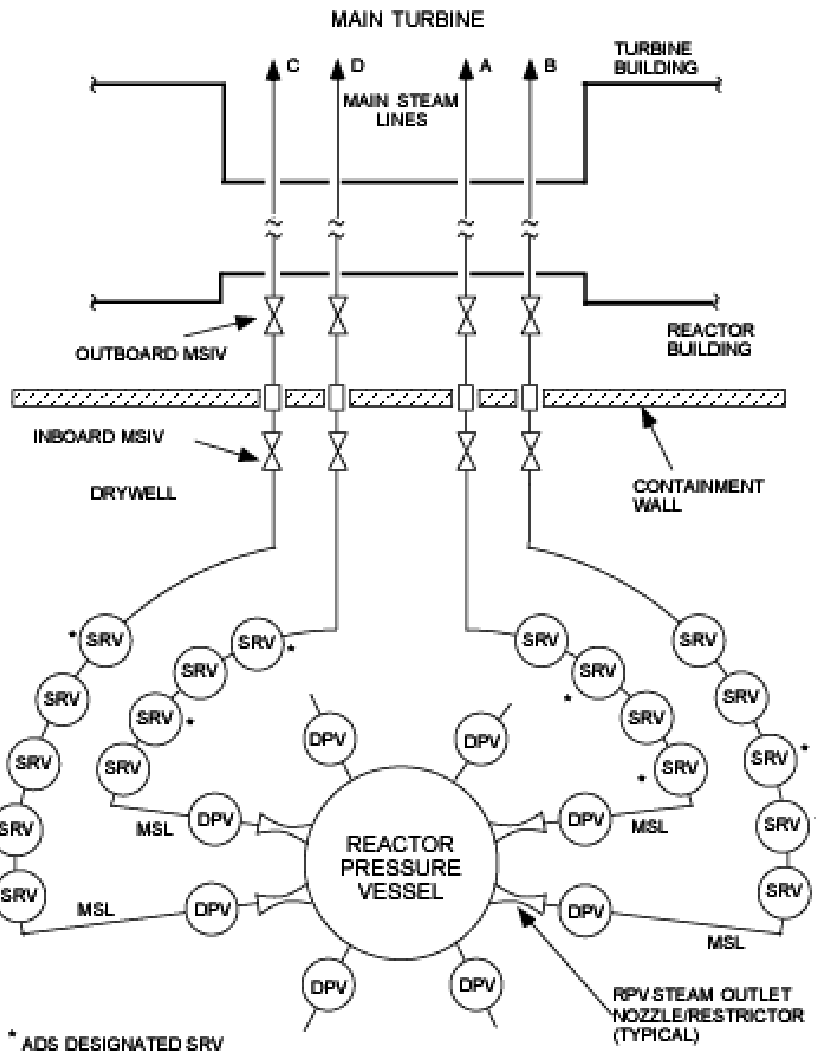
GDCS (Long Term) Equalizing Lines from Suppression Pool to RPV

GDCS Deluge Lines branch from Injection Piping to Flood Lower Drywell Volume

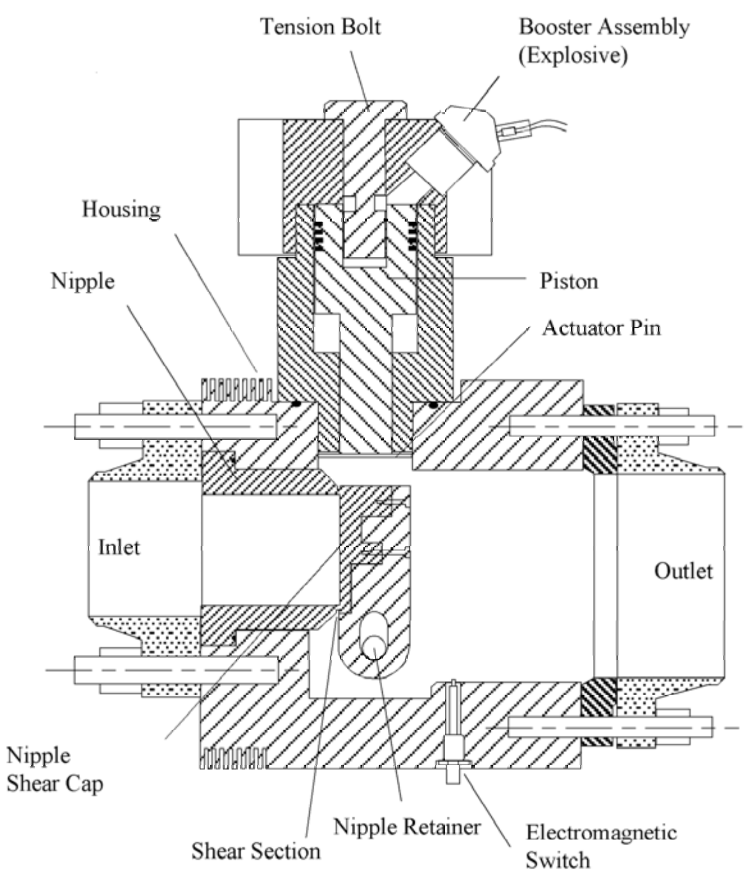
ADS Design Bases

- Quickly Depressurize RPV to Allow GDCS Injection Flow Replenish Core Coolant
- Maintain Reactor Depressurization for Continued GDCS Operation after an Accident
- Accomplish Safety-Related function Assuming a Single Failure of an Active component
- Employ valves that do not change Position due to an SSE
- Be Capable of Opening over the Full Range RPV Pressures and DW to RPV Differential Pressures

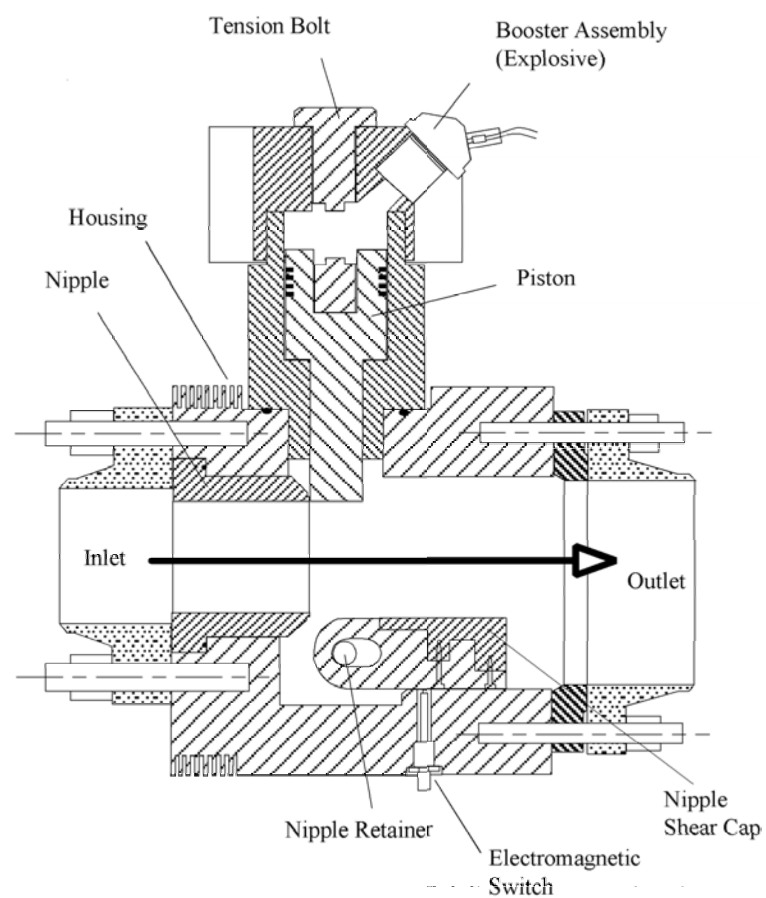
MSIV, SRV and DPV Arrangement



Depressurization Valve (DPV)

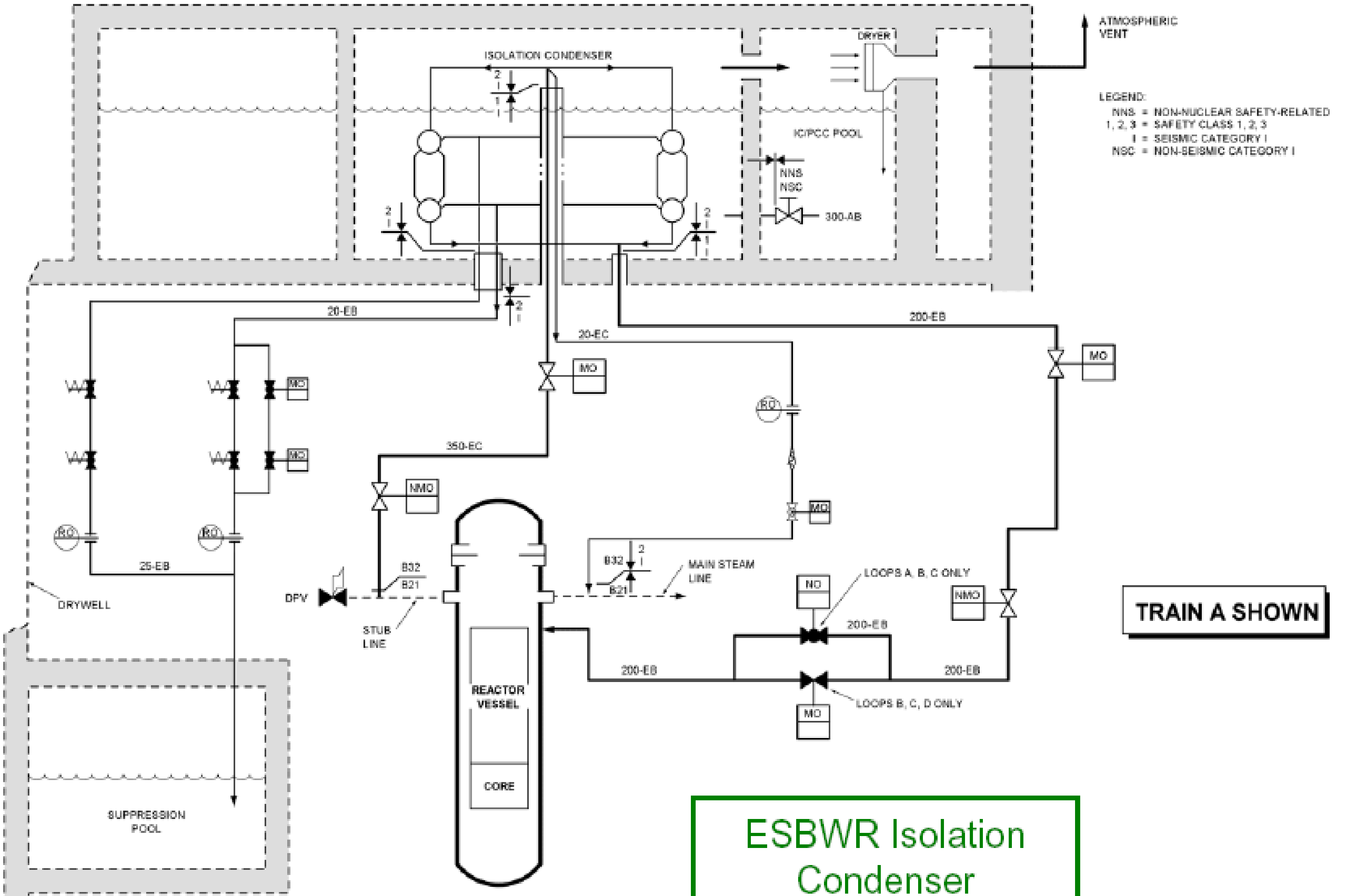


Unfired - Closed



Fired - Open

Depressurization Valve
Cross Section



ESBWR Isolation Condenser

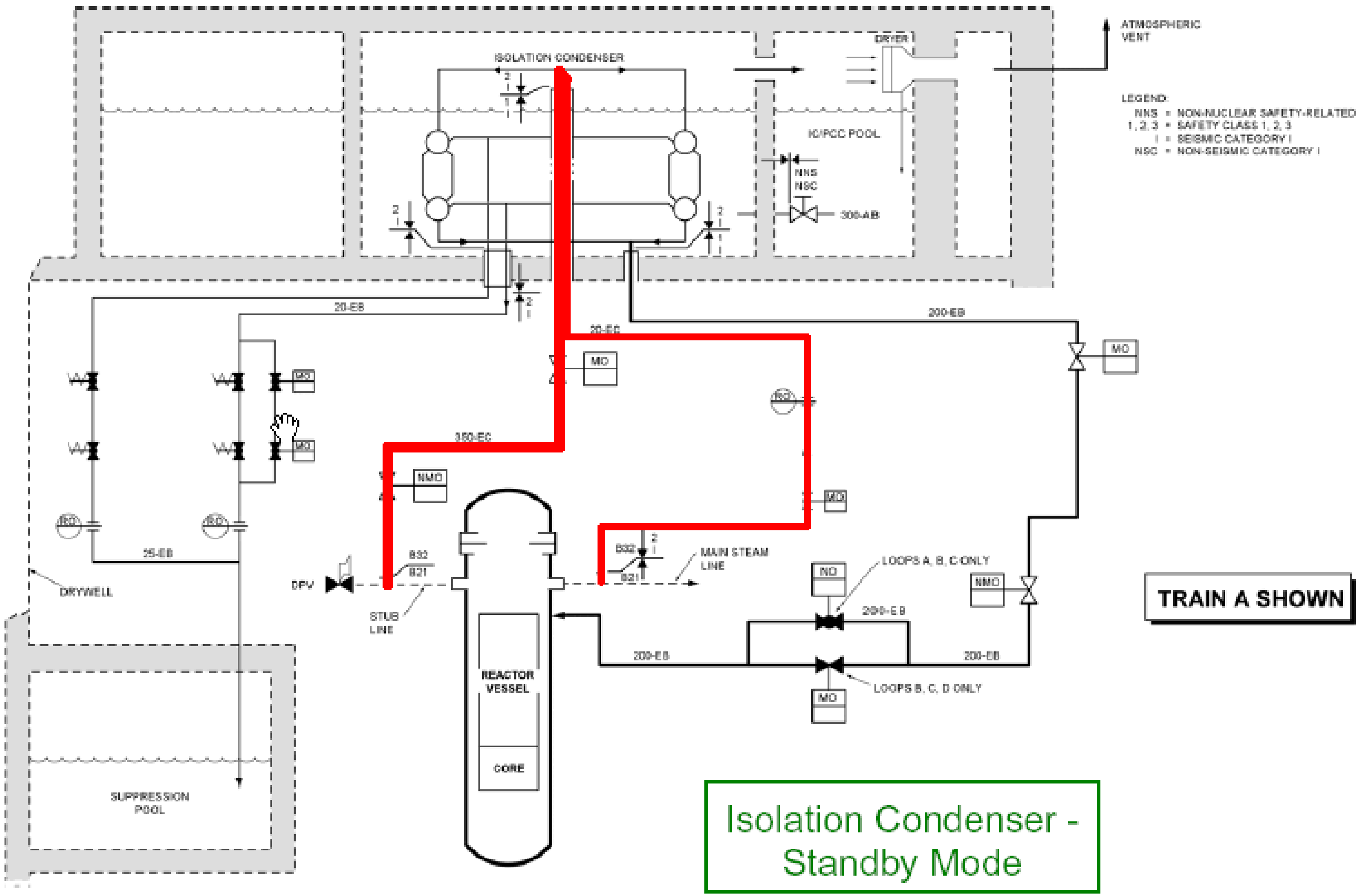
IC Safety Related Functions

- Automatically limit the reactor pressure and prevent SRV operation when the reactor becomes isolated following reactor scram during power operations
- Conserve sufficient reactor coolant volume to avoid automatic depressurization initiated by low reactor water level
- Remove reactor decay heat produced during and following transient events:
  - Sudden reactor isolation
  - Station Blackout (i.e., unavailability of all AC power for 72 hours)
  - Anticipated Transient Without Scram (ATWS)
- Maintain reactor coolant pressure boundary (RCPB) integrity

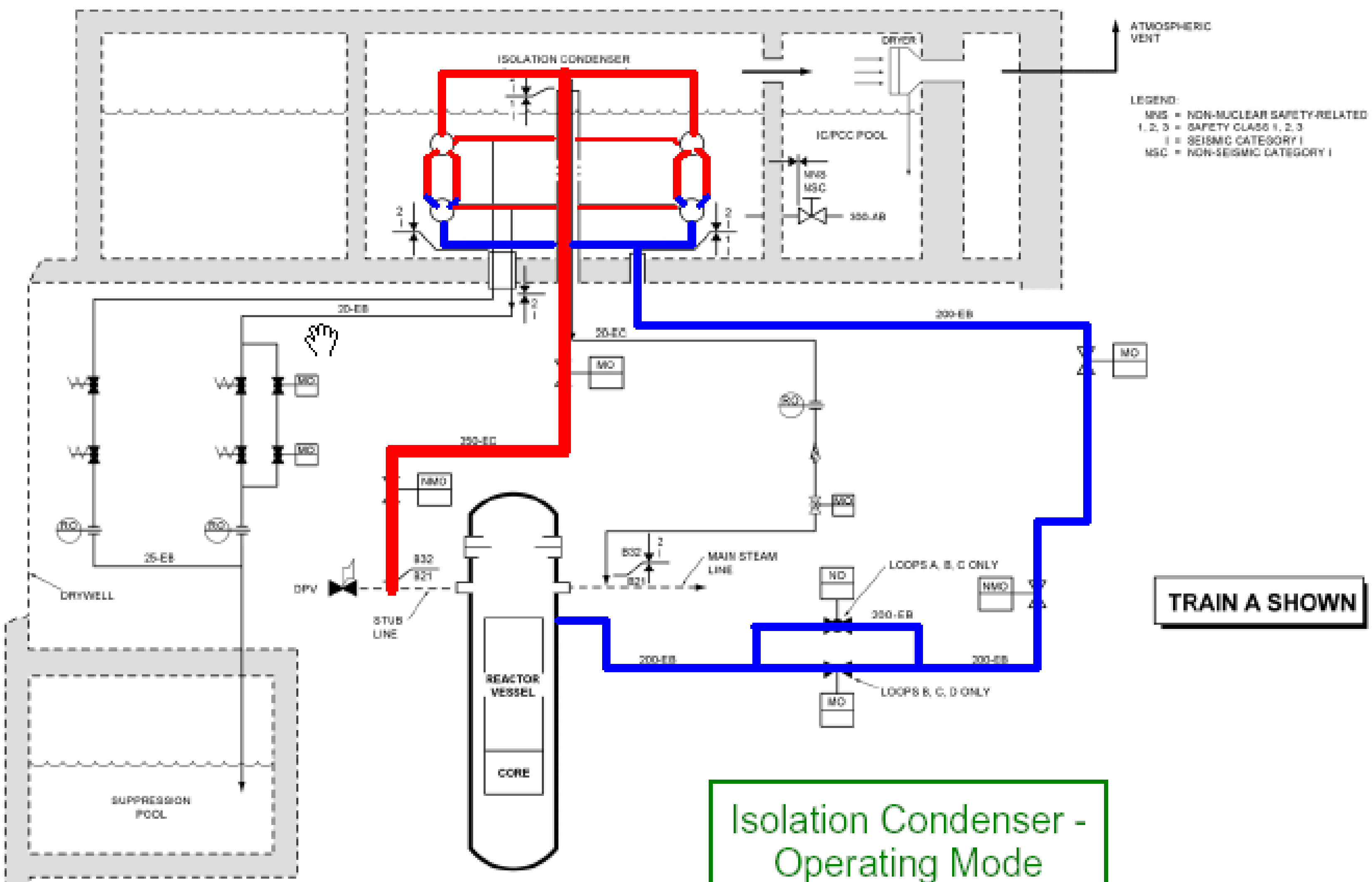
System Operation

Operating Modes:

- **Normal operation (standby)**
- **Plant Shutdown Operation**
- **Isolation Condenser Operation**



Isolation Condenser - Standby Mode

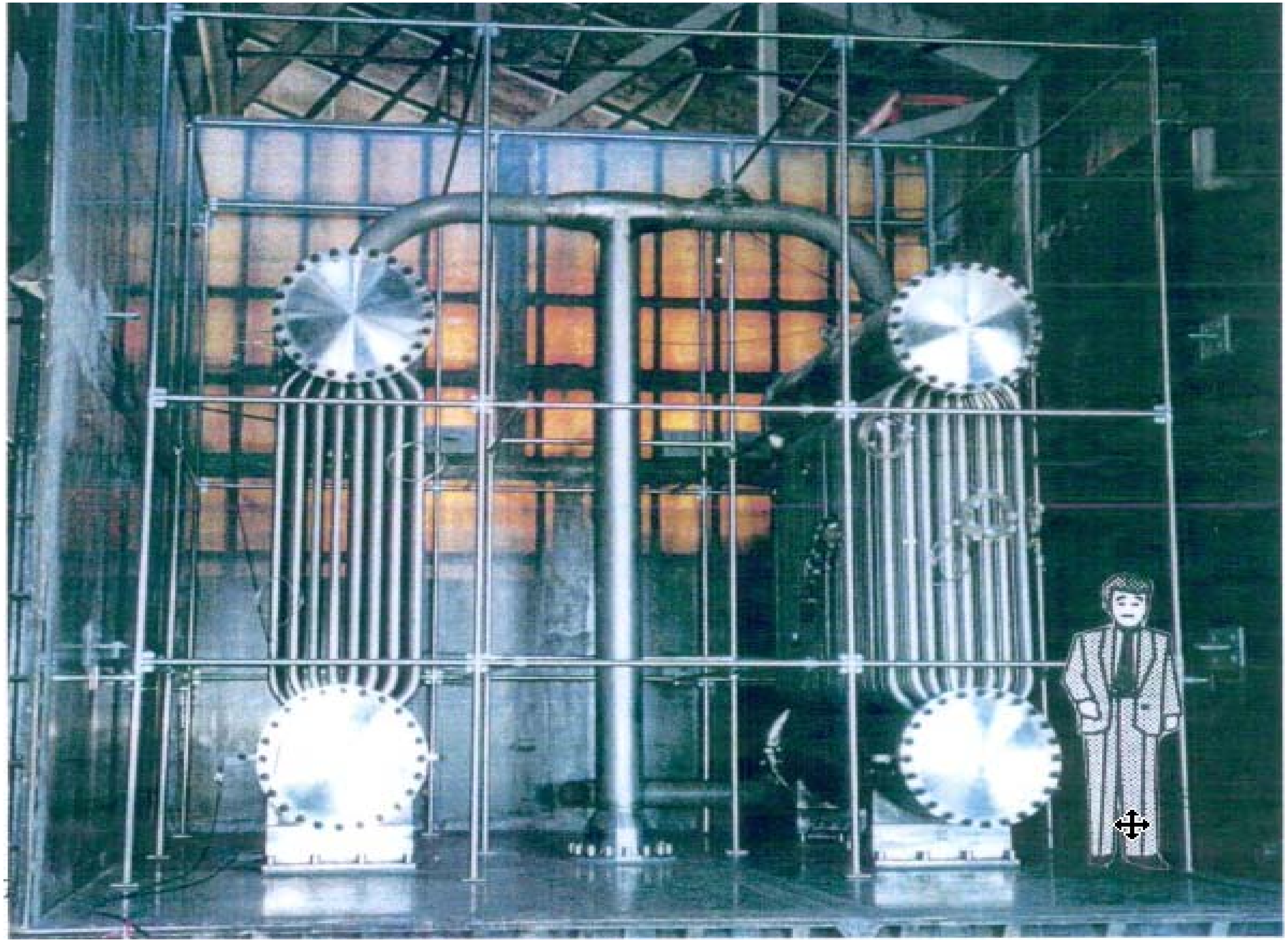


Isolation Condenser - Operating Mode

Isolation Condenser Unit:

- IC units total capacity: 135 MWt (all four units)
- 350 mm Inlet Steam Line
- 200 mm Condensate Return Line
- 20 mm diameter purge line connected to the steam inlet piping
- Vent line for both lower drum headers and both upper drum headers to remove any accumulated non-condensable gases

Full Scale Isolation Condenser Test Unit



IC Test Issues

<u>Noise During Initial Test</u>

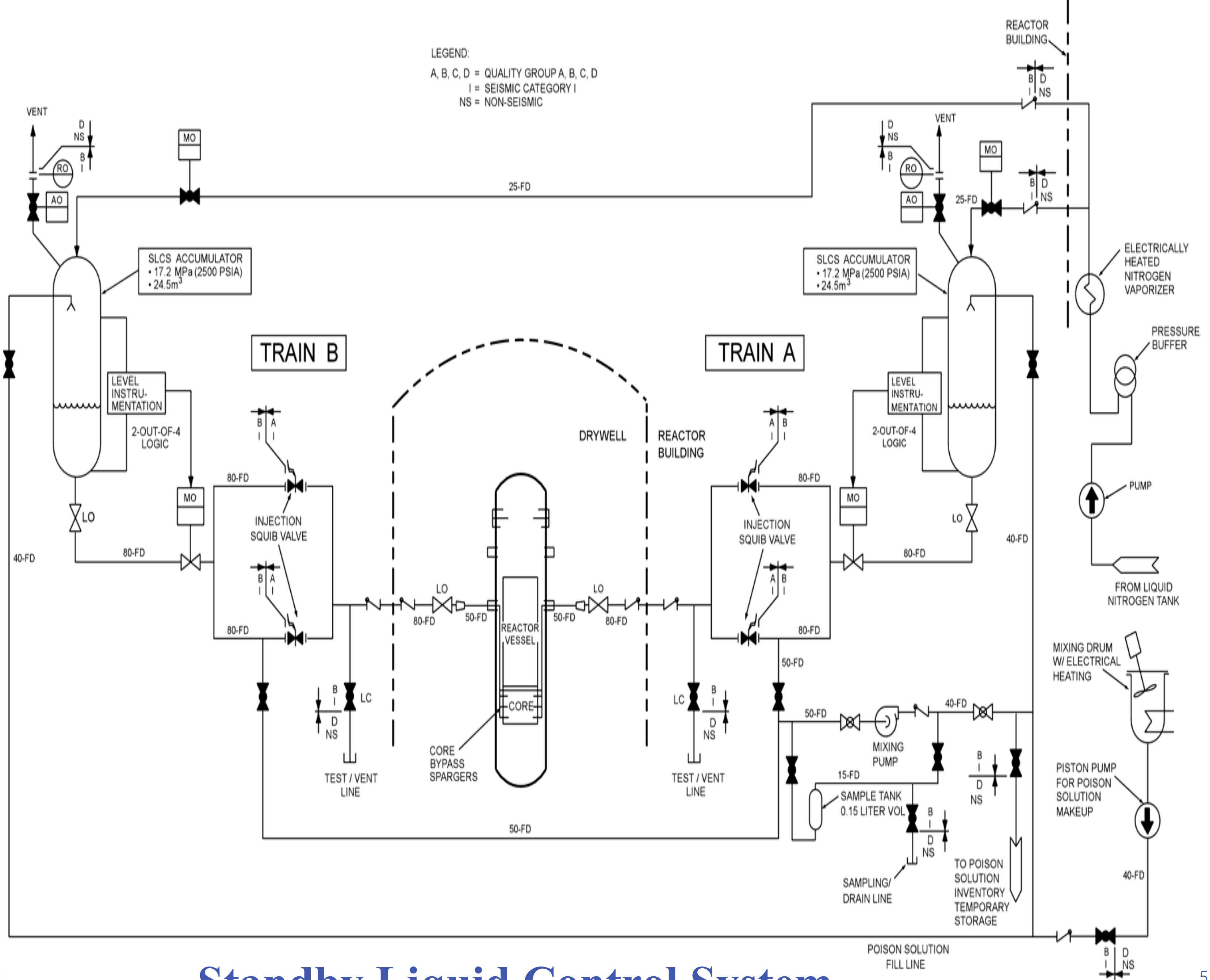
Cause: Water in Steam Inlet line & Fast Opening of Condensate Return Line Valve

Resolution: Design Steam Lines with Slope for Drainage and Controls to Open Valve Slower

<u>Header Flange Leakage</u>

Cause: Incorrect Design of O-Rings & Thermal Transient during Closure of Condensate Return Line Valve

Resolution: Redesign of O-Ring (Helicoflex self energizing O-ring) & Controls to Close Valve Slower



Standby Liquid Control System

imagination at work

Safety-Related Portions of the SLCS

- An accumulator tank for each SLCS train
- A piping system for nitrogen charging and sparging of the solution necessary to maintain nitrogen cover gas in the accumulator
- A pressure relief line and valve to prevent nitrogen pressure from exceeding the design pressure for each accumulator.
- A vent system to permit depressurization of each accumulator for access or after solution injection.
- An injection line to ensure manual or automatic injection, and post injection closure of the line for each SLCS train.
- Redundant level instrumentation for each accumulator to ensure adequate solution inventory and to close the injection after solution injection.
- A poison solution line used for initial charging and any necessary periodic makeup to each accumulator.

SLCS ATWS Mitigation Function Parameters

Parameter	Value
Initial reactor absolute pressure	8.61 MPa (1250 psia)
Approximate initial injection flow rate	18.4 l/s (292 gpm)
Approximate average injection velocity for the first 5.4 m3 of the injection	30.5 m/s (100 ft/s)
Approximate average velocity for the second 5.4 m3 of the injection	18.4 m/s (60 ft/s)
Total solution injection (per each train) at the initial reactor absolute pressure	5.4 m3 (1427 gal)
Equivalent natural boron concentration for the total solution injection volume	≥ 1600 ppm
Equivalent natural boron concentration at cold shutdown conditions	≥ 7.8 m3 (2061 gal) > 1100 ppm

MAJOR COMPONENTS

Accumulator

- Design Pressure 17.24 MPa
- Design Temperature 100°C
- Volume 24.5 m^3
- Height of the Vessel 5500 mm
- Inner Diameter 2450 mm
- Construction Seismic Category 1, Quality Group B ASME Section III, Class 2

  Carbon steel, Clad Stainless Steel

imagination at work

Major Components (Contd.)

Squib-Type Valves

- Nominal Diameter 50 mm
- Design Pressure 17.24 MPa
- Design Temperature 60°C
- Power 250 VDC, Class 1E
- Construction Seismic Category 1, Quality Group A, Forged Stainless Steel, ASME Section III, Class I
- Two Independent Igniting Circuits/ Coils for each valve

ESF Materials

- Selection Criteria:
- Materials Must Not Impair Operation
- Can withstand Environment Conditions
- Compatible with Water Conditions and Radiolytic Decomposition Products

Controls for Austentic Stainless Steel

- Limitations on Carbon Content Control (.02% limit for components exposed to reactor water that exceeds 200 degrees F)
- Controls to avoid Severe Sensitization
- Process Controls to Limit Exposure to Contaminants Including Controls on Contacting Equipment
- Limitations on Cold Work; Typically used in Solution heat Treated Condition
- Avoidance of Hot Cracking

Component Materials

- Containment – Components; Carbon Steel
  - Pool Liners; Stainless Steel
- PCCS - Stainless Steel
- ADS Valves - Stainless Steel
- GDCS Components - Stainless Steel
- ICS - Condenser; Inconel 600
  - Steam Piping; Carbon Steel
  - Condensate Piping; Stainless Steel
- SLC – Accumulator; Low Alloy Steel
  - Pipe; Stainless Steel