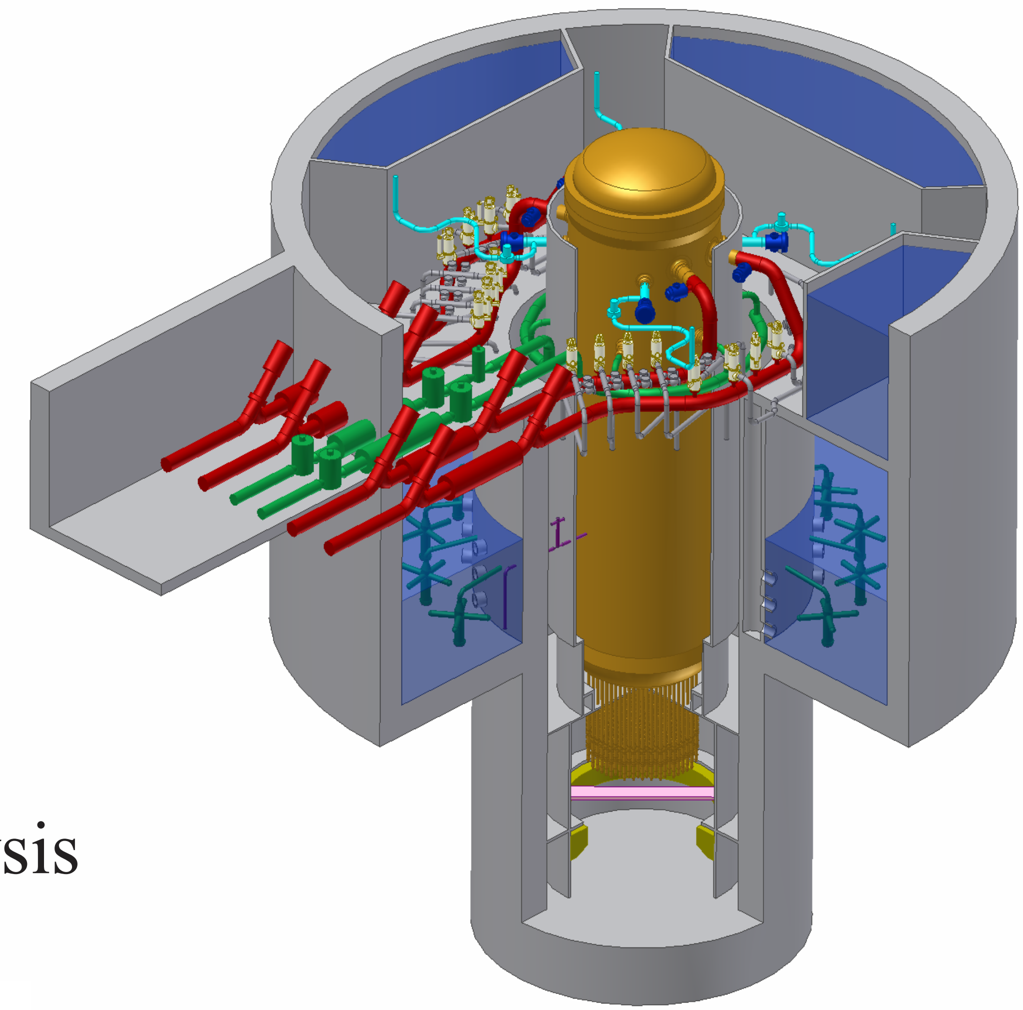

ESBWR Piping Analysis

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imagination at work

Agenda

- Define Piping Systems within Reactor & Refueling Building
- Review Piping Routing in Containment
- Review Selection Criteria for Pipes to be Analyzed
- Review Load Combination & Stress Criteria for Class 1 Piping Analysis
- Review Extent of Piping Analysis to be performed to support DCD
- Review Materials to be provided in DCD

Systems in Safety Related Buildings that Contain Primary Pressure Boundary Piping

Safety Related Systems

- B21 - Nuclear Boiler; Main Steam & Feedwater
- B32 - Isolation condenser
- C12 - Control Rod Drive
- C41 - Standby Liquid Control
- E50 - Gravity Driven Cooling

Non-Safety Related Systems

- G31 - Reactor Water Cleanup/Shutdown Cooling

Piping Comparison with ABWR

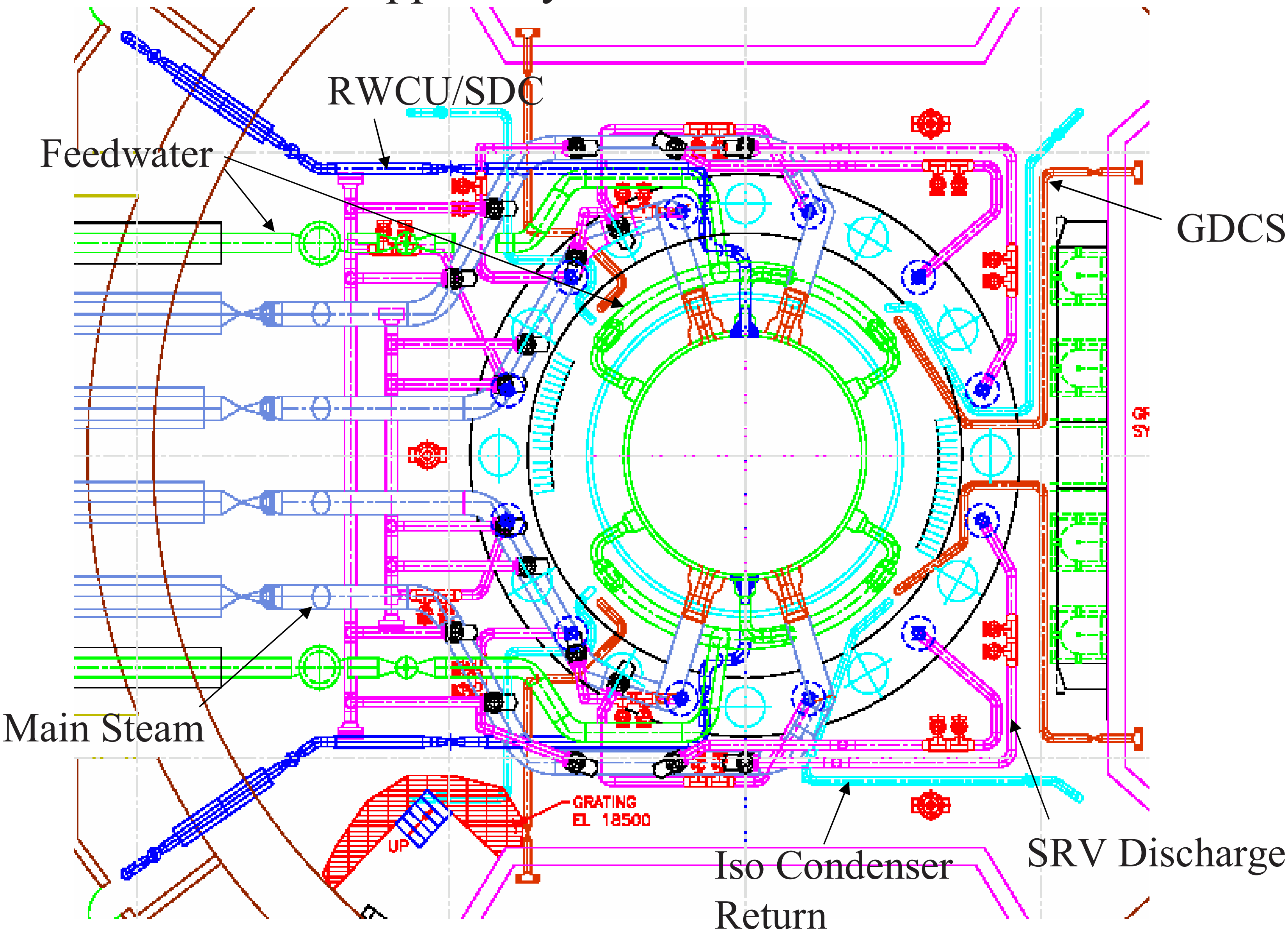
- Systems that are Equivalent
  - Main Steam & Feedwater
  - Control Rod Drive
- Comparable Systems that have changed
  - Standby Liquid Control
  - Reactor Water Cleanup/Shutdown Cooling
- New Systems
  - Isolation Condenser
  - Gravity Driven Cooling

Major Primary Pressure Boundary Piping inside Containment

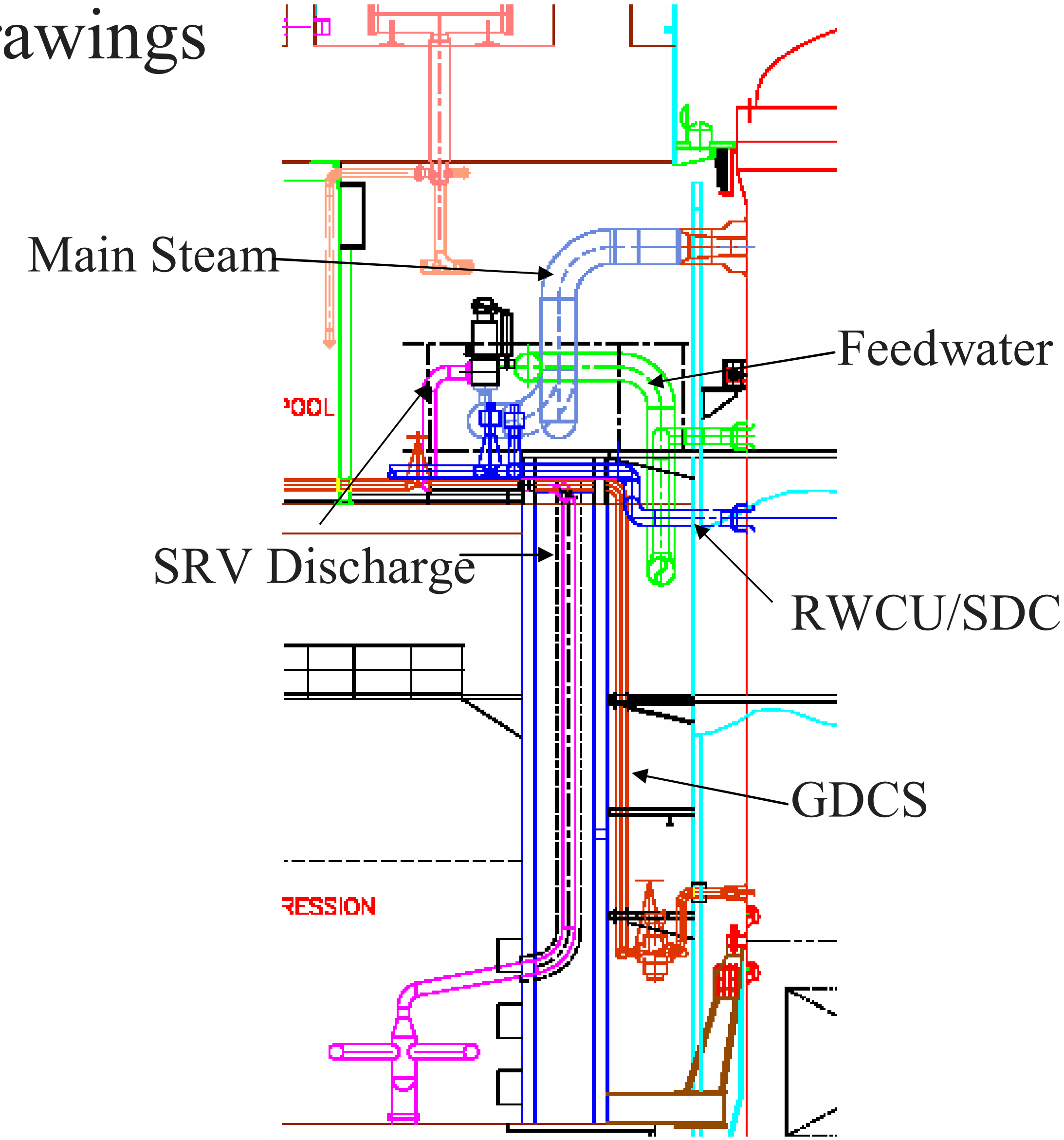
(greater than 3”)

- Main Steam
- Feedwater
- Isolation Condenser
- Reactor Water Cleanup/Shutdown Cooling
- Gravity Driven Cooling

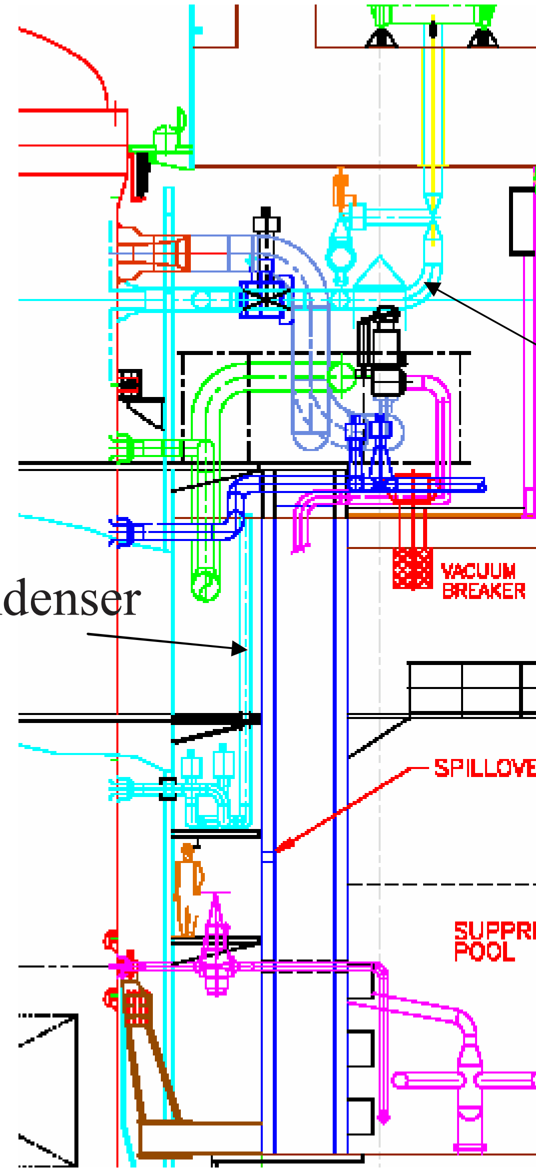
Piping Drawings
Upper Drywell Plan View



Piping Drawings
(Continued)



Piping Drawings
(Continued)



Piping Analysis Selection Criteria

1. High Energy Lines
2. High Thermal Expansion Differences between Anchor Locations
3. High Stressed Lines From Previous Experience
4. Large Pipe Size
5. Significant Thermal Transients (prior Experience)
6. ASME Class 1 (Inside Containment)

Selected Piping Analysis

Currently Being Performed to Support DCD

Inside Containment

- Main Steam Lines (28”) Including SRV Discharge Lines (10”)
- Feedwater (12” & 22”)
- Reactor Water Cleanup/Shutdown Cooling Line (12”)
- Isolation Condenser Line from RPV to Iso Condenser (14” & 18”)

Containment Piping not Selected for Analysis

- Small Lines (3” or less)
  - Drain Lines (Main Steam, RWCU/SDC)
  - RPV Water Level Instrument Lines
  - RPV Bottom Head Drain Lines
  - CRD Insert Lines
  - Standby Liquid Control
- Low Pressure Lines
  - Gravity Driven Lines – Max. Size 6”

    (Limited piping with High Pressure & smaller differential thermal expansion)
  - Fuel & Auxiliary Pool Cooling
- Other
  - Isolation Condenser Return Line

    (less severe than Iso Condenser steam line from RPV to Condenser)

Load Combinations and Acceptance Criteria
for Class 1 Piping Systems

Condition	Load Combination for all terms[(1) (2)]	Acceptance Criteria
Design	PD + WT	Eq 9 $\leq$ 1.5 S_m NB-3652
Service Level A & B	PP, TE, ΔT1, ΔT2 , TA-TB, RV_1, RV_2I, RV_2D, TSV, SSEI, SSED	Fatigue - NB-3653: Eq 12 & 13 $\leq$ 3.0 S_m U < 1.0
Service Level B	PP + WT + (TSV) PP + WT + (RV_1) PP + WT + (RV_2I)	Eq 9 $\leq$ 1.8 S_m, but not greater than 1.5 S_y Pressure not to exceed 1.1P_a (NB-3654)
Service Level C	PP + WT + $[(CHUGI)^2 + (RV_1)^2]^{1/2}$ PP + WT + $[(CHUGI)^2 + (RV_2I)^2]^{1/2}$	Eq 9 $\leq$2.25 S_m, but not greater than 1.8 S_y Pressure not to exceed 1.5 P_a (NB-3654)
Service Level D	PP + WT + $[(SSEI)^2 + (TSV)^2]^{1/2}$ PP + WT + $[(SSEI)^2 + (CHUGI)^2 + (RV_1)^2]^{1/2}$ PP + WT + $[(SSEI)^2 + (CHUGI)^2 + (RV_2I)^2]^{1/2}$ PP + WT + $[(SSEI)^2 + (CONDI)^2 + (RV_1)^2]^{1/2}$ PP + WT + $[(SSEI)^2 + (CONDI)^2 + (RV_2I)^2]^{1/2}$ PP + WT + $[(SSEI)^2 + (API)^2]^{1/2}$	Eq 9 $\leq$ 3.0 S_m but not greater than 2.0 S_y Pressure not to exceed 2.0 P_a (NB-3654)

Class 1 Piping Load Combinations Table - Notes and Legend

(1) RV_1 and TSV loads are used for MS Lines only

(2) RV_2 represents RV_2 ALL (all valves), RV_2SV (single Valve) and RV_2 AD (Automatic Depressurization operation)

Where: API = Annulus Pressurization Loads (Inertia Effect)

CHUGI = Chugging Load (Inertia Effect)

CONDI = Condensation Oscillation (Inertia Effect)

PD = Design Pressure

PP = Peak Pressure or the Operating Pressure Associated with that transient

RV_1 = SRV Opening Loads (Acoustic Wave)

RV_2D = SRV Basemat Acceleration Loads (Anchor Displacement Loads)

RV_2I = SRV Basemat Acceleration Loads (Inertia Effect)

SSED = Safe Shutdown Earthquake (Anchor Displacement Loads)

Extent of Piping Analysis

- Thermal Analysis (heatup and Transient)
- Criteria:
  - 0.80 x ASME Code limit for Eq. 12

Basis for Limited Pipe Analysis

- Experience from Lungmen Project
- Thermal Loads
- Seismic Loads are Site Specific COL Items
- Stresses from Dynamic Loads can be Modified by Adjusting Pipe Supports
- Thermal Stresses can not be changed after Pipe Routing is Fixed
- Dynamic Analysis Would take an Additional 6 months to Complete beyond Current DCD Schedule

Lungmen Project - Containment Piping Experience

Lungmen Line #	System	Eq 12 Max Stress Ratio (Thermal)	Eq 13 Max Stress Ratio (Dynamic)	Eq 14 Max Fatique
B21-2501A	Main Steam	0.70	0.46	0.079
B21-2502A	Main Steam	0.60	0.50	0.068
B21-2503A	Main Steam	0.54	0.50	0.076
B21-2504A	Main Steam	0.75	0.49	0.099
N22-2501	Feedwater	0.79	0.61	0.085
N22-2502	Feedwater	0.79	0.63	0.085
E11-2501	RHR	0.54	0.53	0.074
E11-2502	RHR	0.78	0.75	0.077
E22-2501	High Pressure Core Flooder	0.60	0.45	0.079

Lungmen Seismic Ground Acceleration = .4 g

Piping Related Documentation to be Provided in DCD

- Classification Summary (Table 3.2-1)
- System Schematic Diagrams
- Piping Line Designation Table
- Load Combinations and Acceptance Criteria for Safety-Related, ASME Code Class 1,2 and 3 Components, Component supports, and Class CS Structures (Table 3.9-2) - (Essentially the same as ABWR SAR)
- Class 1 Piping Load Combinations and Acceptance Criteria for ASME Class 1 Piping

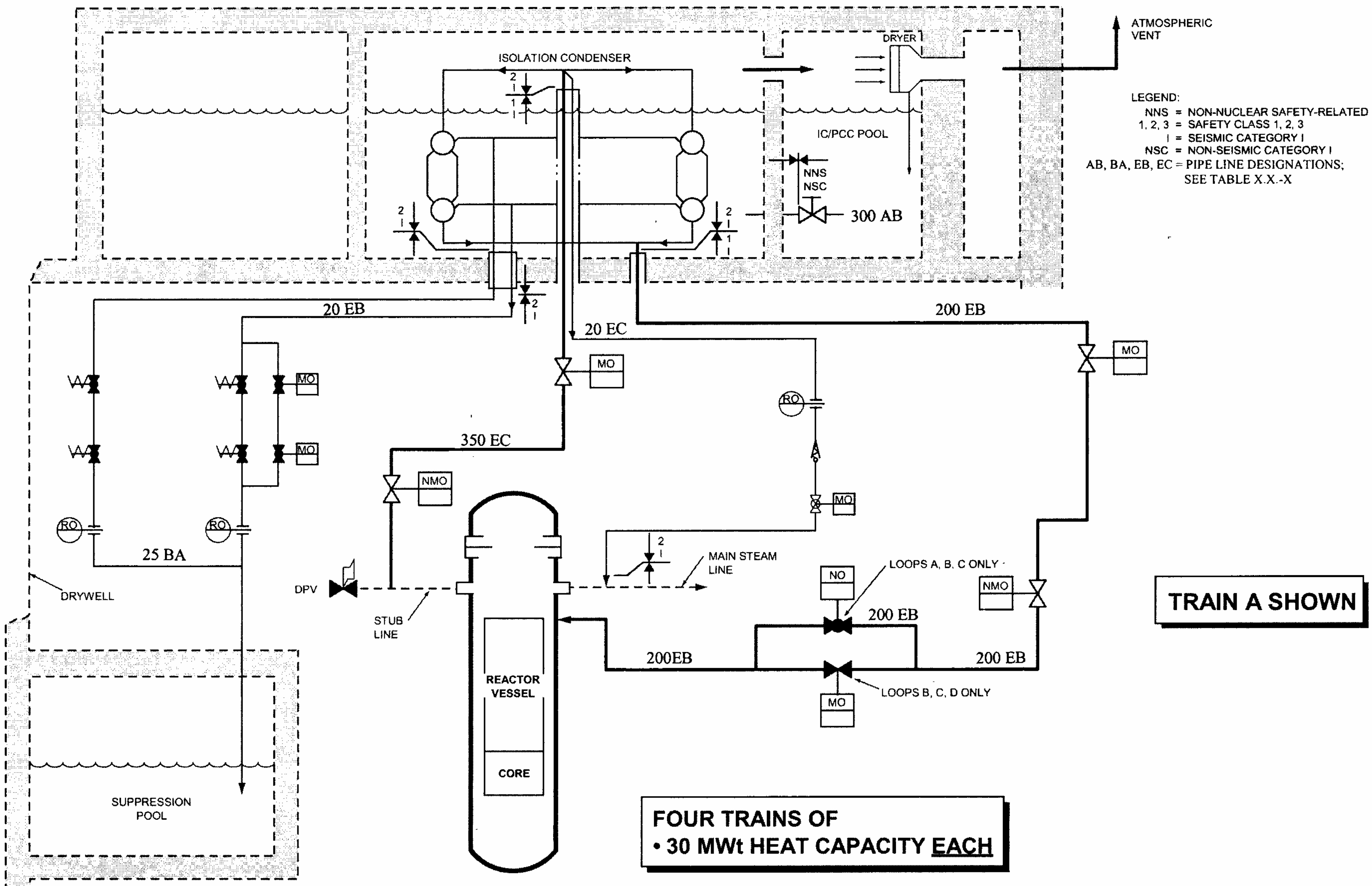
Example of Piping Classification Table

Table 3.2-1. Classification Summary

Principal Component[1]	Safety Desig.[2]	Location [3]	Quality Group[4]	QA Req. [5]	Seismic Category[6]
B NUCLEAR STEAM SUPPLY SYSTEMS					
B21 Nuclear Boiler System (NBS)					
1. Safety/relief discharge piping (including supports)	Q	CV	C	B	I
2. Piping and valves (including supports) for main steam (MSL) and feedwater (FW) lines up to and including the outermost containment isolation valves	Q	CV, RB	A	B	I
3. Piping (including supports) for MSL from outermost isolation valve to and including seismic interface restraint and FW from outermost isolation valve to the seismic interface restraint including the shutoff valve	Q	RB	B	B	I

Sample System Schematic Diagram

ESBWR Isolation Condenser System - Schematic Diagram



Sample Piping Line Designations

Table X.X-X - Piping Line Designations

Standard Line Designation	Service	Temperature Range	Primary Rating	Material
AA	Cond. Water/ Reactor Water	-30 to 260°C (-20 to 500°F)	150 LB	Carbon Steel
AB	Cond. Water/ Reactor Water	-30 to 260°C (-20 to 500°F)	150 LB	Stainless Steel
AC	Steam	to 260°C (to 500°F)	150 LB	Carbon Steel
AD	Service Water	-30 to 260°C (-20 to 500°F)	150 LB	Carbon Steel
AE	Radwaste	-30 to 260°C (-20 to 500°F)	150 LB	Carbon Steel
AF	Radwaste	-30 to 260°C (-20 to 500°F)	150 LB	Stainless Steel
AG*	Demineralized Water		150 LB	Aluminium
AH	Steam Condensate	to 260°C (to 500°F)	150 LB	Carbon Steel
AL	Fuel Oil	-30 to 260°C (-20 to 500°F)	150 LB	Carbon Steel
BA	Cond. Water/ Reactor Water	-30 to 260°C (-20 to 500°F)	300 LB	Carbon Steel
BB	Cond. Water/ Reactor Water	-30 to 260°C (-20 to 500°F)	300 LB	Stainless Steel
BC	Steam	to 260°C (to 500°F)	300 LB	Carbon Steel
BD	Service Water	-30 to 260°C (-20 to 500°F)	300 LB	Carbon Steel
BE	Steam Condensate	to 260°C (to 500°F)	300 LB	Carbon Steel
BF	Offgas	-30 to 260°C (-20 to 500°F)	300 LB	Carbon Steel
BG	Liquid Nitrogen	-196 to 65.5°C (-320 to 150°F)	300 LB	Stainless Steel

Table 3.9-2

Load Combinations and Acceptance Criteria for Safety-Related, ASME Code Class 1, 2 and 3 Components, Component Supports, and Class CS Structures

Plant Event		Service Loading Combination (1), (2), (3)	ASME Service Level (4)
1.	Normal Operation (NO)	N	A
2.	Plant/System Operating Transients (SOT)	(a) N + TSV	B
		(b) N + SRV(5)	B
3.	NO + SSE	N + SSE	B(12), (13)
4.	Infrequent Operating Transient (IOT), ATWS, DPV	(a) N(6) + SRV(5)	C (14)
		(b) N + DPV(7)	C(14)
5.	SBL	N + SRV(8) + SBL(9)	C(14)
6.	SBL or IBL + SSE	N + SBL (or IBL)(9) + SSE + SRV(8)	D(10), (14)
7.	LBL + SSE	N + LBL(9) + SSE	D(10), (14)
8.	NLF	N + SRV(5) + TSV(11)	D(14)

Table 3.9-2 Notes

Notes:

(1) See Legend on the following pages for definition of terms. Refer to Table 3.9-1 for plant events and cycles information.

The service loading combination also applies to Seismic Category I Instrumentation and electrical equipment (refer to Section 3.10).

(2) For vessels, loads induced by the attached piping are included as identified in their design specification.

For piping systems, water (steam) hammer loads are included as identified in their design specification.

(3) The method of combination of the loads is in accordance with NUREG-0484, Revision 1.

(4) The service levels are as defined in appropriate subsection of ASME Section III, Division 1.

(5) The most limiting load combination case among SRV(1), SRV(2) and SRV (ALL). For main steam and branch piping evaluation, additional loads associated with relief line clearing and blowdown into the suppression pool are included.

(6) The reactor coolant pressure boundary is evaluated using in the load combination the maximum pressure expected to occur during ATWS.

(7) This applies only to the Main Steam and Isolation Condenser systems. The loads from this event are combined with loads associated with the pressure and temperature concurrent with the event.

(8) The most limiting load combination case among SRV(1), SRV(2) and SRV (ADS). See Note (5) for main steam and branch piping.

(9) The piping systems that are qualified to the leak-before-break criteria of Subsection 3.6.3 are excluded from the pipe break events to be postulated for design against LOCA dynamic effects, viz., SBL, IBL and LBL.

(10) For active Class 2 and 3 pumps, the stresses are limited by criteria: $\sigma m \leq 1.2S$ (or $0.75\ S_y$), and (σm or σL) + $\sigma b \leq 1.8S$ (or $1.1\ S_y$), where the notations are as defined in the ASME Code, Section III, subsections NC or ND, respectively.

(11) This applies only to the main steam lines and components mounted on it. The low probability that the TSV and SRV loads can exist at the same time results in this combination being considered under service level D.

Table 3.9-2 Notes (continued)

(12) Applies only to fatigue evaluation of ASME Code Class 1 components and core support structures. See Dynamic Loading Event No. 12, Table 3.9-1, and Note 7 of Table 3.9-1 for number of cycles.

(13) For ASME Code 2 and 3 piping the following changes and additions to ASME Code Section III Subsection NC-3600 and ND-3600 are necessary and shall be evaluated to meet the following stress limits:

$$S_{SAM} = i\,\frac{M_c}{Z} \leq 3.0\ S_h \quad (\leq 2.0S_y) \qquad \text{Eq. (12a)}$$

Where: S_{SAM} is the nominal value of seismic anchor motion stress

M_c is the combined moment range equal to the greater of (1) the resultant range of thermal and thermal anchor movements plus one-half the range of the SSE anchor motion, or (2) the resultant range of moment due to the full range of the SSE anchor motions alone.

i and Z are defined in ASME Code Subsections NC/ND-3600

SSE inertia and seismic anchor motion loads shall not be included in the calculation of ASME Code Subsections NC/ND-3600 Equation (9), Service Levels A and B and Equations (10) and (11).

(14) All ASME Code Class 1, 2 and 3 Piping systems which are essential for safe shutdown under the postulated events are designed to meet the requirements of NUREG-1367 (Reference 3.9-7). Piping system dynamic moments can be calculated using an elastic response spectrum or time history analysis.

Summary

- Most Important & Limiting Piping Selected for Analysis
- Piping Selected for Analysis will Assure that Critical Piping will meet ASME Code
- Content of Material in DCD will Provide Complete & Convenient Information for NRC Review