52-001

October 8, 1992

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Standardization Project Directorate
Associate Directorate for Advanced Reactors
and License Renewal
Office of Nuclear Reactor Regulation

Dear Chet:

Subject: PROPOSED RESOLUTION OF ISLOCA ISSUE FOR ABWR

Enclosed is the subject document including modified P&IDs for the affected systems. Following NRC staff review and approval of the proposed ISLOCA resolution, GE will prepare a corresponding modification to Subsection 19B.2.15, High/Low Pressure Interface Design.

Sincerely,

Jack

Jack Fox
Advanced Reactor Programs

cc: George Thomas

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PROPOSED RESOLUTION OF ISLOCA ISSUES FOR ABWR.

Introduction

An intersystem loss of coolant accident (ISLOCA) is postulated to occur when a series of failures or inadvertent actions occur that allow the high pressure from one system to be applied to the low pressure design of another system, which could potentially rupture the pipe and loose coolant from the reactor system pressure boundary. This may also occur within the high and low pressure portions of a single system. Future ALWR designs like the ABWR are expected to reduce the possibility of a LOCA outside the containment by designing to the extent practicable all systems and subsystems connected to the RCS to an ultimate rupture strength (URS) at least equal to the full RCS pressure. The URS criteria was recommended by the Reference 1 and by recent discussions with the NRC Staff to determine low pressure piping's design pressure to contain ISLOCAs.

Evaluation Procedure

The pressure of each system piping boundary on all of the ABWR P&ID's was reviewed to identify where changes were needed to provide URS protection. Where low pressure piping interfaces with higher pressure piping connected to piping with reactor coolant at reactor pressure, pressure values were increased to 24.6 atg which is equivalent to 350 psig. (1 a. = 1 kg/sq cm; atg is gauge) The low pressure piping boundaries upgraded to URS pressures extend to the last closed valve connected to piping interfacing a low pressure sink, such as the suppression pool, condensate storage tank or other open configuration (identified tank). Each interfacing system's piping was reviewed for upgrading and in some with low pressure piping with normally open valves were changed to lock open valves to insure an open piping pathway from the last primary system closed valve to the tank or low pressure sink.

Typical systems for this upgrade include the:

1. Radwaste LCW and HCW receiving tank piping,
2. Fuel Pool Cooling System's RHR interface piping connected to the skimmer surge tanks,
3. Condensate Storage System's tank locked open supply valves,
4. Makeup Water Condensate and Makeup Water Purified Systems with locked open valves and pump bypass piping to the Condensate Storage Tank.

All test, vent and drain piping was upgraded where it interfaces with the piping upgraded to URS pressure. Similarly, all instrument and relief valve connecting piping was upgraded. P&IDs referencing ABWR SSAR Figures were marked with the new pressure boundary values identified with "clouds" and heavy piping lines to show the upgraded piping, equipment and instruments.

<u>Boundary Limits of URS</u>

The boundary limits of the URS design were established assuming slow rates of leakage between high and low pressure regions. This means only static pressurization needs to be considered and low pressure sinks do not pressurize This also means the piping between the valve adjacent to a low pressure sink and the low pressure sink does not pressurize; therefore, it can be assumed such a valve remains closed. The components considered to be low pressure sinks in this evaluation are:

(1) <u>Suppression Pool -</u> Provides a low pressure sink (just above atmospheric) for its interfacing systems and the first closed valve is at least 24.6 atg (350 psig) rated.

(2) <u>Condensate Storage Tank -</u> Vented to atmosphere and its locked open valves and stainless steel piping insure it is a low pressure sink for its interfacing systems. The first closed valve of each interfacing system with URS upgrade is at least 24.6 atg (350 psig) rating.

(3) SLC main tank - Vented to atmosphere with the first closed valve at least 24.6 atg (350 psig) rating.

(4) LCW Receiving Tank - Vented to atmosphere, and the first closed valve is at least 24.6 atg (350 psig) and one of the tank's dual valves is locked open.

(5) HCW Receiving Tank - Vented to atmosphere, and the first closed valve is at least 24.6 atg (350 psig) and one of the tank's dual valves is locked open.

Systems Evaluated

The following twelve systems, interfacing directly or indirectly with the RCS, were evaluated.

	SSAR Figure No.
Residual Heat Removal (RHR) System	5.4-10
High Pressure Core Flooder (HPCF) System	6.3-7
Reactor Core Isolation Cooling (RCIC) System	5.4-8
Control Rod Drive (CRD) System	4.6-8
Standby Liquid Control (SLC) System	9.3-1
Reactor Water Cleanup (CUW) System	5.4-12
Fuel Pool Cooling Cleanup (FPC) System	9.1-1
Nuclear Boiler (NB) System	5.1-3
Reactor Recirculation (RRS) System	5.4-4
Makeup Water (Condensate) (MUWC) System,	9.2-4
Makeup Water (Purified) (MUWP) System.	9.2-5
Radwaste System (LCW Receiving Tank, HCW Receiving Tank).	11.2-2

Piping Design Pressure for URS Compliance

The full URS condition is illustrated on Figure 1 at the full reactor pressure of 72.1 atg, 73.1 ata (1025 psig; 1040 psia) and the ultimate stress. The straight line from this point to the coordinates origin establishes

proportionality to the URS, which is valid since pressure and stress are proportional. Using an example of carbon steel with an ultimate stress of 4219 kg/cm^2 (60 kpsi) and an allowable stress of 1055 kg/cm^2 (15 kpsi), the ultimate based design pressure proportional to the allowable stress is 18 atg (256 psig). Thus for a pipe designed so that a 18 atg (256 psig) pressure produced the allowable 1055 kg/sq cm (15 kpsi) stress, then if an over pressurization of 72.1 atg (1025 psig) occurred in that pipe, its stress would rise to 4219 Kg/cm^2 (60 kpsi), the ultimate strength. Thus, 18 atg (256 psig) represents an ultimate based design stress that has no margin with respect to the URS.

In this case the ratio of allowable stress to ultimate stress is 15/60 = 0.25, which is the same as the ratio of design pressure to applied pressure, 256/1025 = 0.25. To use a design stress that has a reasonable margin with respect to the full URS, a ratio of 0.33 is utilized instead of 0.25. A ratio of 0.33 produces a design pressure of 24 atg (342 psig), which when nominally rounded up gives a 24.6 atg (350 psig) design pressure. For a pipe designed just for the 24.6 atg (350 psig) design pressure, an applied pressure of 98.5 atg (1401 psig) would be necessary to reach the full ultimate stress of 4219 kg/cm^2 (60 kpsi).

It is useful to incorporate a safety factor into the discussion as a measure of the design margin beyond a full URS condition. A safety factor definition is:

$$\text{S. F.} = \frac{\text{Load that would cause failure}}{\text{Service load imposed}}$$

$$\text{S. F.} = \frac{1401 \text{ psig}}{1025 \text{ psig}} = 1.367$$

And by proportionality

$$\text{S. F.} = \frac{350 \text{ psig}}{256 \text{ psig}} = 1.367$$

It is of interest to show how this relates to Service Level D of the ASME Code (Section III, NC-3611.2(c)(3)). For Service Level D, Pmax can be 2.0 times P. With Pmax = 72.1 atg (1025 psig), the design pressure, P, could be 36.1 atg (513 psig). For a design pressure of 36.1 atg (513 psig), the safety factor per the above is

$$S.F. = \frac{513 \text{ psig}}{256 \text{ psig}} = 2.00 \qquad \text{(Service Level D)}$$

The safety factor is 1.00 at the "ultimate based design pressure," see Figure 1, with a design pressure of 256. The selection of the 24.6 atg (350 psig) design pressure resulted in a safety factor of 1.367, which was considered a placement to the extent practical within the range between the ultimate based design pressure (S. F. = 1.00) and the Code service level D (S. F. = 2.00).

With the design pressure selected, a minimum pipe wall thickness can be calculated using the ASME Code equation NC-3641.1 (3). Results are shown for the range of pipe diameters in column F of Table 1.

$$t_m = \frac{(P)(D_o)}{2(S + Py)} + A$$

where
- P = Design Pressure
- S = Allowable Stress
- y = 0.4
- A = Corrosion Allowance
- Do = Outside pipe diameter

Next an actual pipe schedule wall thickness is selected as the next higher thickness from the calculated t_m (column G of Table 1). The increased wall thickness (t, in the equation below) from t_m permits a higher pressure (Pa) than the initial design pressure when limited to the same allowable stress. This is called the allowable working pressure (Pa, equation below), which is calculated by the ASME Code equation NC-3641.1 (5). The results are shown in columns I of Table 1.

$$P_a = \frac{2St}{D_o - 2yt}$$

The SSAR design documentation satisfies ISLOCA concerns by imposing the 24.6 atg design pressure, which as used in piping design, will result in pipes with margins as shown in columns G through J. However, if the COL applicant selects standard pipe or increased wall thickness for construction durability, even more ISLOCA protection will result. Table 1, columns K through N, shows the analysis for standard pipe, STD, and the next higher

pipe schedule for stainless. This information is provided to illustrate the extra safety factor that could occur from the selection of standard pipe or thicker walls for adequate construction durability.

The safety factor is calculated in columns J and N for carbon steel pipe (SA-333 Gr. 6) from P/256, where P is the permitted pressure (columns I or M) and the denominator 256 is:.

$$\frac{\text{(Reactor full pressure)(Allowable stress)}}{\text{(Ultimate stress)}} = \frac{(1025)(15)}{(60)} = 256 \text{ psig}$$

For stainless steel, between grades SA376 Type 316
SA312 Type 316 and
SA358 Type 316,

the properties of SA376 produce the lowest safety factor. The P denominator for stainless is:

$$\frac{(1025)(18.4)}{(75)} = 251$$

Columns I and M for stainless steel is P/251.

For the stainless steel pipe, the diameter Do, was adjusted by Do/0.9 to account for greater ductility and pipe swelling that occurs before rupture. The larger swelled diameter creates a higher stress on the wall due to the increased pressure area. The Do/0.9 value was provided from communication with Everit Rodabaugh, NRC consultant.

The corrosion allowance values in column C were selected from the Pressure Integrity of Nuclear Components specification listed on the ABWR Certification Program master parts list 298X301CP. item A11-3010.

Applicability of URS Non-piping Components

References 2 and 3 indicate the URS criteria also applies to associated flanges, connectors, packings, valve stem seals, pump seals, heat exchanger tubes and valve bonnets.

This is further illustrated in Attachment 1 which shows that the general membrane stresses for vessels, pumps and valves are equal or less than the allowable stress in all cases. Hence, the basic ratio developed for piping applies to vessels, pumps and valves.

Results

The results of this work are shown by the markups of the enclosed P&IDs, which are SSAR figures. The affected sheets are listed below.

System	SSAR Figure No.	Affected Sheet Nos.
Residual Heat Removal (RHR) System	5.4-10	1, 2, 3, 4
High Pressure Core Flooder (HPCF) System	6.3-7	1, 2
Reactor Core Isolation Cooling (RCIC) System	5.4-8	1, 3
Control Rod Drive (CRD) System	4.6-8	1, 3
Standby Liquid Control (SLC) System	9.3-1	1
Reactor Water Cleanup (CUW) System	5.4-12	2
Fuel Pool Cooling Cleanup (FPC) System	9.1-1	2
Nuclear Boiler (NB) System	5.1-3	1, 5
Reactor Recirculation (RRS) System	5.4-4	1

Makeup Water (Condensate) (MUWC) System	9.2-4	1
Makeup Water (Purified) (MUWP) System	9.2-5	1, 2
Radwaste System (LCW Receiving Tank, HCW Receiving Tank)	11.2-2	3, 7

In addition, the following two systems were identified as requiring an ISLOCA evaluation. However, these two systems are not in sufficient detail and this evaluation will be a requirement for the COI applicant.

Condensate, Feedwater and Condensate Air Extraction (C,FDW,AO) System
Sampling (SAM) System

The design pressure of the following two tanks was upgraded.

SLC test tank

RCIC turbine barometric condenser tank

Summary

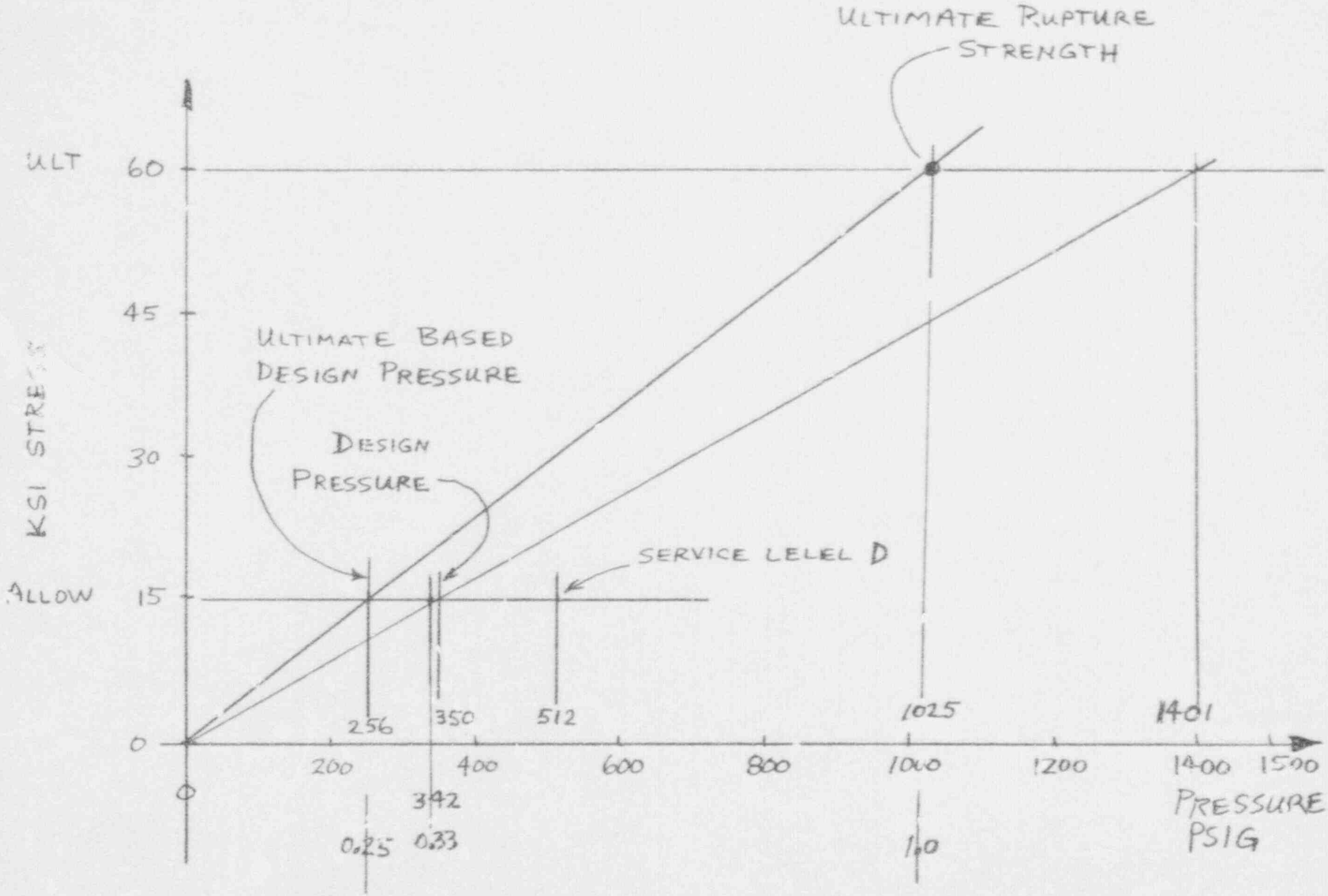
For ISLOCA considerations, a design pressure of 24.6 atg or (350 psig) provides an adequate margin with respect to the full reactor operating pressure of 72.1 atg (1025 psig) by applying the ultimate rupture strength (URS) methodology developed by this work. This design pressure was applied at the boundary symbols of the P&ID figures, and therefore, impose the requirement on the piping, valves, pumps, tanks, instrumentation and all other equipment shown between boundary symbols. Upgrading revisions were made to 14 systems.

References

1. Dino Scaletti, NRC to Patrick Marriott, GE, "Identification of New Issues for the General Electric Company Advanced Boiling Water Reactor Review," September 6, 1991

2. "American National Standard Forged Steel Fittings, Sockets - Welding and Threaded," ANSI B16.11-1973, Sections 6.2 and 9.2.3.

3. "BWR Owners Group Assessment of Emergency Core Cooling System Pressurization in Boiling Water Reactors," NEDC-31339, November 1986, Sections 3.2.2 and 3.2.3, on valve integrity and heat integrity, respectively.


ULTIMATE RUPTURE STRENGTH
ULT
60
45
ULTIMATE BASED DESIGN PRESSURE
KSI STRESS
30
DESIGN PRESSURE
SERVICE LELEL D
ALLOW
15
0
256
350
512
1025
1401
200
400
600
800
1000
1200
1400
1500
342
0.25
0.33
1.0
PRESSURE PSIG

	A	B	C	D	E	F	G	H	I	J	K	L	M	N
1	Pipe	Pipe	Corr.	Allow	Design	Calc.	Next	Pipe	Permited	Safety	STD	Pipe	Permited	Safety
2	Dia.,	Dia	Allw.	Stress	Press	Thk	Std Thk	Schl	Pressure	Factor	Thk	Schl	Pressure	Factor
3	metric	Do, in	A, in	S, psi	P, psi	tm, in	tm, in		P, psi		tm, in		P, psi	
4														
5				CARBON STEEL										
6														
7	500A	20	0.12	15000	350	0.3512	0.375	20	386.442	1.5081	0.375	20	386.442	1.5081
8	450A	18	0.12	15000	350	0.3281	0.375	...	429.872	1.6775	0.375	...	429.872	1.6775
9	400A	16	0.12	15000	350	0.3049	0.312	20	363.489	1.4185	0.375	30	484.3	1.89
10	300A	12	0.12	15000	350	0.2587	0.33	30	532.454	2.0779	0.375	...	648.525	2.5308
11	250[illegible]	10	0.12	15000	350	0.2356	0.25	20	394.099	1.5379	0.365	[illegible]0	749.694	2.9256
12	200A	8	0.12	15000	350	0.2125	0.25	20	493.921	1.9275	0.322	40	773.117	3.017
13	150A	6	0.12	15000	350	0.1894	0.28	40	817.439	3.19	0.28	0	817.439	3.19
14	100A	4	0.12	15000	350	0.1662	0.237	40	898.525	3.5064	0.237	0	898.525	3.5064
15	80A	3	0.12	15000	350	0.1547	0.216	40	985.222	3.8448	0.216	40	985.222	3.8448
16	50A	2	0.12	15000	350	0.1431	0.154	40	517.032	2.0177	0.154	40	517.032	2.0177
17														
18														
19				STAINLESS STEEL										
20											Next			
21											Std Thk			
22											tm, in			
23	500A	20	0.004	184[illegible]	350	0.2138	0.25	spcl	411.016	1.6375				
24	450A	18	0.004	18400	350	0.1928	0.25	spcl	457.138	1.8213				
25	400A	16	0.004	18400	350	0.1718	0.188	10S	384.06	1.5301				
26	300A	12	0.004	18400	350	0.1299	0.156	5S	423.381	1.6863	0.18	10S	490.944	1.956
27	250A	10	0.00[illegible]	18400	350	0.1089	0.134	5S	434.628	1.73[illegible]6	0.165	10S	539.486	2.1493
28	200A	8	0.00[illegible]	18400	350	0.0879	0.109	5S	432.847	1.7484	0.148	10S	603.988	2.4063
29	150A	6	0.004	18400	350	0.0669	0.109	5S	586.996	2.3386	0.134	10S	728.972	2.9043
30	100A	4	0.004	18400	350	0.046	0.083	5S	663.556	2.6436	0.12	10S	980.962	3.9082
31	80A	3	0.004	18400	350	0.0355	0.083	5S	889.016	3.5419	0.12	10S	1317.31	5.2483
32	50A	2	0.004	18400	350	0.025	0.065	5S	1032.84	4.1149	0.109	10S	1807.11	7.1996

Table 1

PG. 11

PIPING

NC-3640 PRESSURE DESIGN OF PIPING PRODUCTS

NC-3641 Straight Pipe

NC-3641.1 Straight Pipe Under Internal Pressure. The minimum thickness of pipe wall required for Design Pressures and for temperatures not exceeding those for the various materials listed in Tables I-7.0, including allowances for mechanical strength, shall not be less than that determined by Eq. (3) as follows:

$$t_m = \frac{PD_o}{2(S + Py)} + A \qquad (3)$$

where

t_m = minimum required wall thickness, in. If pipe is ordered by its nominal wall thickness, the

P = internal Design Pressure, psi

D_o = outside diameter of pipe, in. For design cal-

S = maximum allowable stress for the material at the Design Temperature, psi (Tables I-7.0)

A = an additional thickness to provide for material removed in threading, corrosion or erosion allowance, and material required for struc-

y = a coefficient having a value of 0.4, except that, for pipe with a D_o/t_m ratio less than 6, the value of y shall be taken as

$$y = \frac{d}{d + D_o} \qquad (6)$$

VESSELS

NC-3321 1989 SECTION III,

TABLE NC-3321-1
STRESS LIMITS FOR DESIGN AND SERVICE LOADINGS[1]

Service Limit	Stress Limits [Note (2)]
Design and Level A	$\sigma_m \leq 1.0\ S$ $(\sigma_m \text{ or } \sigma_L) + \sigma_b \leq 1.5\ S$

σ_m = general membrane stress, psi. This stress is equal to the average stress across the solid section under consideration. It excludes discontinuities and concentrations and is produced only by pressure and other mechanical loads

S = allowable stress value given in Tables I-7.0, psi. The allowable stress shall correspond to the highest metal temperature at the section under consideration during the loading under consideration.

PUMPS

NC-3416 NC-3000 — DESIGN NC-3423

TABLE NC-3416-1
STRESS AND PRESSURE LIMITS FOR DESIGN AND SERVICE LOADINGS

Service Limit	Stress Limits [Note (1)]	P_{max} [Note (2)]
Level A	$\sigma_m \leq S$ $(\sigma_m \text{ or } \sigma_L) + \sigma_b \leq 1.5S$	1.0

VALVES

NC-3530 1989 SECTION III, DIVISION 1 — NC NC-3531.4

TABLE NC-3521-1
LEVEL A, B, C, AND D SERVICE LIMITS

Service Limit	Stress Limits [Notes (1)-(4)]	P_{max} [Note (5)]
Level A	$\sigma_m \leq S$ $(\sigma_m \text{ or } \sigma_L) + \sigma_b \leq 1.5S$	1.0