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BWR PRIMARY PIPING STRESSES FOR SYSTEM RELIABILITY ANALYSIS

W.F. ENGLISH
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U.S. ATOMIC ENERGY COMMISSION
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ATOMIC POWER EQUIPMENT DEPARTMENT

GENERAL ELECTRIC

SAN JOSE, CALIFORNIA

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ABSTRACT

The results of a detailed stress analysis of a typical BWR primary piping system are presented, for use in a determination of the system reliability during its design lifetime. Stresses resulting from normal and abnormal conditions are calculated, and analytical models are discussed. Results are tabulated for each piping component in the system.

SECTION I

INTRODUCTION

1.1 PURPOSE

The purpose of this report is to provide a tabulation of all components included in the primary piping system of a typical single-cycle boiling water reactor, and the design calculation model for determining the stresses in these components. This information will be used in the estimation of the reliability of the piping system, which is the objective of the Reliability Engineering Task of the Pipe Rupture Study.

1.2 PROCEDURE

A typical single-cycle BWR was chosen as the reference system. A flexibility analysis model using the MASS⁽⁷⁾ computer code was constructed from available drawings.

The thermal expansion stresses were calculated, disregarding the effects of pipe weight and pipe-supporting hangers. The temperature change encountered during normal operation which would yield the maximum stresses was imposed on each system. The longitudinal expansion due to internal pressure was considered by an additional temperature change which gives an equivalent axial strain. With these conditions, the MASS stress calculation No. 1052 yields a stress equal to S_E of the ASA B31.1 - 1955 piping code (see Appendix A).

Possible hanger and sway brace locations were chosen using the selection procedures outlined in Reference 1. Weight stresses were then calculated for the piping system, using a lumped mass model. Earthquake stresses were calculated using the same model but applying horizontal static forces equivalent to 0.43 g. The earthquake loading was assumed to be typical of that which might occur in the North Atlantic states of the U. S. Transient pressure and thermal stresses were calculated for various modes of plant operation, assuming both normal and accident conditions, at critical locations within the piping system.

1.3 SUMMARY OF RESULTS

The tabulation indicates there are approximately 800 components in the primary piping. A comparison of the nominal expansion stresses with the allowable stresses shows that most systems are extremely flexible. However, the shorter of the two primary core spray lines has stresses equal to the allowable stress. Primary stresses (pressure, weight, earthquake, and vibration) can be controlled by proper choice of pipe support and support location. By following procedures outlined in Reference 1 for choice and location of supports, it was found that no primary stresses exceeded the allowable stress.

SECTION II

STRESS CALCULATION MODEL OF PRIMARY PIPING

The stress calculation model of the primary piping of a single-cycle BWR, suitable for use with the MASS computer code, is based on a typical boiling water reactor plant. Layouts of most of the primary system were taken from drawings of a relatively standard BWR. However, for some systems where the appropriate drawings were not available, it was necessary to use for reference the drawings from another similar reactor.

2.1 COORDINATE SYSTEM

The coordinate system for locating MASS joints has its origin at the center of curvature of the hemisphere that describes the bottom head. The "x" axis is positive upwards along the centerline of the pressure vessel, the "y" axis is positive westward, and the "z" axis is positive southward. The orientation is shown in Figures 1 through 8.

2.2 SUB-MODELS

Because of the limited capacity of MASS, it was necessary to divide the primary piping model into sub-models. The sub-model number given in Table 1 refers to which of eight independent models the system is included. The sub-models are independent because the stresses of piping in one sub-model are not influenced by the stiffness and deflections of lines in another unless the deflections are extremely large and the pipes interact.

2.3 NUMBERING OF JOINTS

The numbering of the MASS joints is shown in Figures 1 through 9. Only the joints necessary to clarify the system are included in the illustrations. The range of joint numbers for each line is given in Table 1. No

joint number is used more than once in a particular sub-model, but some numbers are repeated in other sub-models. Therefore, when referring to a MASS joint number, it is necessary to state both the joint number and the sub-model number.

2.4 MODELING OF COMPONENTS

A component can be described as a part of the system that is represented by more than a single joint. The tubing input of MASS is used for modeling sections of straight pipe, elbows, bends, and valves. Equipment such as pumps, heat exchangers, and filters is assumed to be extremely stiff and is modeled by rigid connectors.

For the piping sections (straights, elbows, and bends), the nominal diameter and material were determined from the system piping and instrumentation diagram. The schedule number was taken as 80 if the line was designed for high pressure and temperature, or 40 if designed for low pressure and temperature. Exceptions were the recirculation lines and poison spray system, where the outside diameter and thickness were specified directly.

Valves were given the same outside radius as the piping in which they were included. To increase stiffness, the valve sections were given a thickness equal to half the outside radius. This results in a moment of inertia equal to 0.937 times that of a solid cylinder.

2.5 MODELING OF DISCONTINUITIES

For the MASS model, discontinuities can be established by a single joint. Tees and wyes are modeled as three sections of

FIGURE 1. MASS SUB-MODEL No. 1

FIGURE 2. MASS SUB-MODEL No. 2

FIGURE 3. MASS SUB-MODEL No. 3

FIGURE 4. MASS SUB-MODEL No. 4

FIGURE 5. MASS SUB-MODELS Nos. 5 AND 8

FIGURE 6. MASS SUB-MODEL No. 6

SCALE ≈ 80 in./in.

FIGURE 7, MASS SUB-MODEL No. 7

FIGURE 8. ARRANGEMENT OF RECIRCULATION LOOPS

FIGURE 9. RECIRCULATION LOOP NUMBERING

TABLE 1
RANGE OF MASS JOINT NUMBERS AND COMPONENT
TABULATION NUMBERS FOR EACH PIPING SYSTEM

<u>Sub-Model No.</u>	<u>Piping System</u>	<u>MASS Joint No.</u>	<u>Component Tabulation No.</u>
1	Primary Steam		
	North Side (Pressure Vessel to Isolation Valve)	501-521	1-20
	Relief Line	516, 522-532	21-31
	South Side (P. V. to I. V.)	601-621	101-120
	Relief Line	616, 622-632	121-131
	Vent Line (P. V. to D. W.)	551-565	51-65
	Branch to Primary Steam	563-519	63
	Drain Line (P. V. to D. W.)	651-661	151-160
2	Core Spray		
	Line 1 (P. V. to I. V.)	1-16	201-215
	Line 2 (P. V. to I. V.)	21-28	221-227
	Feed Water		
	South Side		
	Line 1 (P. V. to I. V.)	701-719	301-318
	Line 2 (P. V. to Line 1)	721, 725, 712	321-325
	North Side		
	Line 1 (P. V. to I. V.)	751-769	351-368
	Line 2 (P. V. to Line 1)	771-775, 762	371-375
3	Control Rod Drive		
	P. V. to C. R. D. System	1-17	401-416
	Insert (Thimble to D. W.)	21-36	421-435
	Withdraw (Thimble to D. W.)	41-57	441-456
	Poison Spray		
	(P. V. to I. V.)	61-69	461-468
4	Emergency Condenser Steam		
	North Side		
	Main Line P. V. to Branch Lines		
	P. V. to Branch Lines	161-177	501-516
	Branch a to condenser	177-186	517-525
	Branch b to condenser	177, 190-196	526-532
	South Side		
	Main Line		
	P. V. to Branch Lines	261-277	551-566
	Branch a to condenser	277-286	567-575
	Branch b to condenser	277, 290-296	576-582

TABLE 1 (Continued)

<u>Sub-Model No.</u>	<u>Piping System</u>	<u>MASS Joint No.</u>	<u>Component Tabulation No.</u>
5	Recirculation Loop No. 1		
	Main Line	2-15*	601-618
	Bypass	17-28	619-629
	Emergency Condenser Condensate		
	South Side (No. 1)		
	From Recirc. Loop 1	37, 52-76	652-676
	Branch a to condenser	76-81	677-681
	Branch b to condenser	76, 87-91	687-691
6	Recirculation Loop No. 2		
	Main Line	102-115*	1001-1018
	Bypass	117-128	1019-1029
	To Cleanup System	135, 322-311	1030-1041
	From Cleanup System	301-309, 136	1302-1310
	Cleanup		
	Heat Exchanger 1 to Drywell	642-646, 301	1297-1301
7	Recirculation Loop No. 3		
	Main Line	202-215*	701-716
	Bypass Line	217-228	717-727
	Recirculation Loop No. 4		
	Main Line	302-315*	801-816
	Bypass Line	317-328	817-827
8	Recirculation Loop No. 5		
	Main Line	402-415*	901-920
	Bypass Line	417-428	921-931
	Shutdown Cooling		
	From S. C. to R. L. No. 5	439, 511-521	932-942
	To S. C. from R. L. No. 5	437, 451, 501-509	943-951
	Emergency Condenser Condensate		
	North Side (No. 2)		
	From Recirc. Loop 5	451-476	952-976
	Branch a to condenser	476-481	976-981
	Branch b to condenser	476, 487-491	987-991

*See Figure 9

straight tubing intersecting at a point (Figure 10). Reducers are modeled as a point change in piping or tubing size (Figure 11).

Instrumentation lines of 1 inch nominal diameter or less were not included in the MASS model because of their negligible effect on the stress calculation for large lines.

2.6 BOUNDARY CONDITIONS

The restraints and operating conditions of the piping were chosen to give conservative results for the piping stresses.

2.6.1 Restraints

The connections of the piping to the pressure vessel nozzles are all taken as rigid—no angular deflection about any axis—with the linear deflection of the nozzle determined from thermal expansion of the vessel under operating conditions. The pipelines are also assumed to be rigidly attached to the drywell near their isolation valves, with the vertical linear deflections of the drywell determined from its thermal expansion under operating conditions. These linear deflections of the drywell and pressure vessel are relative to the floor elevation at $x = -441$ in. and the centerline of the pressure vessel at $y = z = 0$. The deflections were calculated using the coefficients of expansion given in Figure 12. The values for $\alpha \Delta T$ for the pressure vessel and the skirt are taken from Reference 1, using temperatures of 545°F and 350°F, respectively. The temperature of the drywell and concrete vessel support was taken as 150°F, and the skirt temperature was assumed to be the average of the pressure vessel and the drywell temperatures. The value for $(\alpha \Delta T)_3$ for the support is from Reference 2. The drywell coefficient of expansion is from Reference 3.

The restraints due to pipe-supporting hangers are not considered in the nominal expansion stress analysis. The pipe weight is taken as zero in this calculation. The expansion stress is actually the change in stress due to the temperature change in the pipeline.

2.6.2 Temperatures

In the calculation of thermal expansion stresses, an attempt was made to use the temperature encountered during normal operation that would give the maximum nominal stress. Table 2 lists the operating temperature, the operating pressure, and its equivalent ΔT given by

$$\Delta T = \frac{PR}{2 \alpha Et} \left[3 - \frac{E}{G} \right],$$

and the temperature put into the MASS stress calculation.

For sub-model 1, the input temperature should require no explanation.

For sub-model 2, the core spray line was given a temperature approximately equal to the ambient temperature of the drywell. This line contains stagnant water during normal operation of the reactor. Water is circulated through it only during periods when the reactor is shut down. Therefore, the maximum temperature of this line should never be greater than 140 to 150°F, except near the pressure vessel nozzle.

The feedwater line is assumed to have the temperature of the heated feedwater.

For sub-model 3, all control rod drive lines are assumed to be at reactor temperature. The 3-in. line from the pressure vessel to the control rod drive system is at reactor temperature and pressure during normal

REDUCERS ARE MODELED AS A POINT CHANGE IN PIPING OR TUBING SIZE (FIGURE 11)

FIGURE 10. MASS MODEL OF A PIPING TEE

REDUCERS ARE MODELED AS A POINT CHANGE IN PIPING OR TUBING SIZE

FIGURE 11. MASS MODEL OF A REDUCER

FIGURE 12. COEFFICIENTS OF EXPANSION

TABLE 2
MASS INPUT TEMPERATURE

Sub-Model No.	System	Operating Temperature	Operating Pressure	ΔT Pressure	MASS Temperature
1	Primary System and Relief	545	1000	10	555
	4 in. Vent	545	1000	7	552
	2 in. Vent	545	1000	6	551
	2 in. Drain	545	1000	6	551
2	Core Spray	140	1000	6	146
	Feedwater	315	1260	10	325
3	Control Rod Drive				
	All	-	-	-	551
	Poison Spray	-	-	-	551
4	Emergency Condenser Steam	545	1000	7	552
5, 6, 7, 8	Recirculation Loop Nos. 1-5	545	1015/ 1055	10	555
5 and 8	Emergency Condenser Condensate	150	1000	7	157
	Shutdown Cooling	140	1000	6	146
6	Cleanup				
	To Heat Exchanger No. 1 from Recirculation Loop No. 2	545	1000	6	551
	From Recirculation Pumps	140	1015	6	146
	From Heat Exchanger No. 1 to Recirculation Loop No. 2	436	1015	6	442

operation. The lines to and from the control rod drive thimble will see reactor temperature and pressure due to leakage through the drive during an extended scram.

The poison spray line was assumed to be at reactor temperature and pressure. This is a conservative assumption because the part of the line near the pressure vessel nozzle is the only section that would see reactor temperature and pressure during normal operation.

The temperature assumed for the emergency condenser steam lines and the recirculation loops should require no explanation.

The emergency condenser condensate lines see only water that has gone through

the emergency condensers. Even though this line contains stagnant water during normal operation, its temperature will not be greater than 150°F except near the tie-in to the recirculation lines. This is a local thermal discontinuity that should be investigated more thoroughly.

The previous discussion for the emergency condenser condensate also applies to the shutdown cooling lines inside the drywell.

The cleanup system has a variety of temperatures and pressures, but they are fairly straightforward and require little explanation. The temperature drops and increases through the heat exchangers were divided so that the ΔT 's for each pass through the exchangers were equal.

2.7 MASS FLEXIBILITY ANALYSIS

The MASS program achieves its results by first calculating the load-deflection relationships (the stiffness matrix) for each two-ended member in the structure, and then calculating the displacements at each joint which will result in the equilibrium of forces and moments at that joint. There are six displacements at each joint (three translational components and three rotational components). At each end of a structural member there are three forces and three moments which can be resolved into the following components:

1 axial force
2 transverse forces
1 torsional moment
2 bending moments

The stress calculation outlined in Appendix A considers only the bending and torsional moments. Stresses due to axial and transverse forces are generally negligible in piping systems.

In calculating the stiffness matrix for a structural member (piping component), the MASS program considers bending, shear, axial, and torsional deformations. The program also considers the increased bending flexibility of an elbow due to its cross section deforming to an oval shape.

SECTION III

TABULATION OF COMPONENTS AND DISCONTINUITIES

3.1 COMPONENTS

For the tabulation in Appendix B, components are defined as any discrete part of the piping.

3.1.1 Component Types

The components are of five types, as discussed below. A number that identifies the component type in the tabulation is also given.

- a. Straight—component type 1—includes all straight sections of pipe. The length of the straight is established by discontinuities in the piping or a transition from a straight to a bend.
- b. Elbow—component type 2—includes all curved sections that are to be welded into the line.
- c. Bend—component type 3—includes all curved sections that have a large

value for the ratio of radius of curvature to nominal diameter. These are assumed to be bend portions of a continuous pipe and are not actually a distinct component. It is tabulated separately for convenience in later reference to these sections of the piping.

- d. Valves—component type 4—includes all valves in the system that have been modeled, as discussed earlier.
- e. Equipment—component type 5—includes all pumps and heat exchangers.

3.1.2 Component Numbering

The range of component numbers for each sub-model and piping system is given in Table 1. This table and Figures 1 through 9 can be used to locate any component in the tabulation of Appendix B.

The numbering is not entirely systematic because of the complexity of the primary piping. It was attempted to number the components consecutively in each line, starting at the pressure vessel. However, some lines such as the emergency condenser condensate are not directly attached to the pressure vessel, and others are connected at more than one location (recirculation loops). Branch lines also complicate the component numbering. For cases in which the piping makes a complete loop, the numbering of components increases in the direction of normal flow. For lines in which only a section of the loop was included, the numbering increases in the direction going away from the pressure vessel. Branch line numbering was done as conveniently as possible.

3.1.3 Component Properties

For any further investigation of component flexibility, it is necessary to know the properties of the component. These are tabulated in Appendix B as they were put into the MASS flexibility model.

3.1.3.1 Geometry

- D - outside diameter of pipe
- D* - nominal diameter of pipe
- t - thickness of pipe
- ρ - radius of curvature of elbows and bends
- θ - included angle of elbows and bends
- l - length of straight pipe sections

$$A/A_{\max} = \frac{\text{cross-sectional flow area of pipe}}{\text{cross-sectional flow area of 26-in. recirculation line}}$$

3.1.3.2 Materials

The piping material is specified as carbon steel or stainless steel, from the piping and instrumentation diagrams. All carbon steel is assumed to be A-106C, and the stainless steel is Type 304 except for the

recirculation lines which are Type 316. All piping with nominal diameter greater than 12 in. is assumed to be fusion welded, and all smaller piping is taken as seamless, according to Reference 4.

3.2 DISCONTINUITIES

Discontinuities are defined as a part of the piping or an attachment to the piping which may cause a stress concentration.

3.2.1 Discontinuity Types

In the "Type" column of the tabulation in Appendix B, the discontinuities are denoted by the letter "D" and a discontinuity type number.

- a. Welds—discontinuity types 1 and 1a—are assumed to be one of two types in the primary piping according to Reference 4.
 - 1. Butt welds—denoted by D-1—are used in all piping greater than 2 in. nominal diameter.
 - 2. Socket welds—denoted by D-1a—are used for all piping equal to or less than 2 in. All valves in the primary system are assumed to be welded into the piping.
- b. Hangers—discontinuity type 2—are included as discontinuities because they exert a concentrated load on the piping. The exact hanger locations were not available for most of the piping. An approximation to their location was obtained by using the table on page 2 of Reference 1, and repeated on page 85 of Reference 3. This table gives the maximum allowable unsupported span for various pipe sizes. The hangers are

conveniently placed at MASS joint locations so that later work in which hanger influences will be investigated can be conducted without additional joints.

- c. Instrumentation—discontinuity types 3 and 3a—has been located approximately from information in the piping and instrumentation diagrams.

1. Instrumentation line taps—denoted by D-3—are connections of 1-in. lines or smaller which have not been included in the MASS flexibility analysis.
2. Flowmeters—denoted by D-3a—are also overlooked in the MASS analysis because of their geometry (see Figure 13).

- d. Branch line connections—discontinuity type 4—are points where two lines, both greater than 1 in., meet. Tees and wyes are included in this category for ease of tabulation. The tee can be thought of as being constructed from three straight components—two run components and one branch component—as shown in Figure 10. Wyes are treated in the same manner.

- e. Flanges—discontinuity type 5—are found only in the recirculation loops on decontamination nozzles.

- f. Reducers—discontinuity type 6—are tabulated as discontinuities because of the modeling discussed earlier (see Figure 11).

3.3 ALLOWABLE STRESSES

The allowable expansion stress for piping was calculated from

$$S_A = f (1.25 S_C + 0.25 S_H) ,$$

given in the ASA B31.1 piping code,⁽³⁾ where f is a function of the number of cycles and is equal to 1.0 for less than 7000 cycles. S_C and S_H are the cold and hot allowable stress for the piping material. For this tabulation, the values for S_C and S_H were taken from the ASME Boiler and Pressure Vessel Code, Section VIII, including the June 1965 addendum. S_H was based on the tabulated temperature, which includes the ΔT , to account for longitudinal expansion due to pressure as discussed previously. The same allowable stress was used for welded and seamless, because the welded pipe in the primary system is required to be fully radiographed.

The sum of the longitudinal stresses due to pressure, weight, and other sustained external loading is limited to an allowable stress of S_H .

FIGURE 13. FLOWMETER

3.4 NUMBER OF CYCLES

The number of significant thermal cycles which each system would see during the 40-year expected life of the reactor is based on an estimation of reactor operating procedures during its lifetime. It is important for future investigation, even though it does not affect S_A when less than 7000.

For the reactor primary steam lines and the vent pipe, the number of thermal cycles from ambient to operating temperature in 40 years is given as 360. This number includes 200 scrams and 160 normal startups and shutdowns.

The recirculation loops would go through a thermal cycle from ambient to operating during a scram or shutdown, so the number of cycles is taken as 360 for them also. The same number was used for the shutdown system at the tie-in to the recirculation loop.

The emergency condenser and cleanup systems were assumed to see the 360 cycles in reactor temperature and pressure, plus an additional 140 cycles. The additional 140 for the emergency condenser is a conservative number for the expected times

it will be used. The additional 140 for the cleanup is the number of times parts of the cleanup system may be bypassed for repair, changing of filters, etc.

Because there is a possibility that the drain line from the reactor may be tied into the cleanup line, it was assumed to see the 500 cycles of the cleanup system. The feedwater sees the effect of the 360 cycles in reactor temperature and pressure, plus an additional 80 cycles due to expected loss of heaters, giving a total of 440 cycles. The core spray and poison spray systems also see the cycling of the reactor plus an additional 10 cycles resulting from emergency conditions, giving a total of 370 cycles.

The 3-in. line from the pressure vessel to the control rod drive system sees the 360 cycles of the reactor. However, the lines from the control rod drive system to the control rod drive thimbles are maintained at a relatively low constant temperature, except during an extended scram. Then reactor water leaks through the drives into the line. Therefore, the number of cycles for the hydraulic lines is conservatively taken as the number of scrams expected, or 200.

SECTION IV

STRESS CALCULATIONS AND RESULTS

4.1 THERMAL EXPANSION STRESS

The tabulated stress S_E is the thermal expansion stress as calculated with the MASS model discussed in Section II and in Appendix A. The MASS calculation applied a stress intensification factor at elbows, as required

for the code calculation for S_E . It does not apply the factor to tees and socket welds, however, so separate calculations for these components were made as described below.

According to Reference 4, welding tees are used when the branch line is greater

than 2 in. or the branch line is greater than one-fourth of the diameter of the run. All branch lines or tees in the primary system are welding tees according to this criteria.

The stress intensification factor i for welding tees is calculated by Section 6 of the ASA B31.1 Code by

$$i = \frac{0.9}{\left(8.8 \frac{t}{D}\right)^{2/3}}$$

This factor was applied to the stress at the MASS joint connecting the branch and two run components. The stresses for each of the intersecting components were taken as the maximum of the stresses at their end joints with the stress intensification applied.

Socket welds were assumed for all piping of 2-in. diameter or less. The stress intensification factor for single-welded socket weld flanges is given by the ASA Code as 1.3. This was applied to the stresses at all socket welds.

Table 3 gives the number of different components and discontinuities in the primary piping.

TABLE 3
SUMMARY OF THE NUMBER OF
COMPONENTS AND DISCONTINUITIES

<u>Components</u>	
Straights	430
Elbows	180
Bends	80
Valves	80
<u>Discontinuities</u>	
Tees and Branches > 1 in.	76
Butt Welds	453
Socket Welds	73

The distribution of the ratio of expansion stresses to allowable stresses for all the straights, elbows, and bends is given in Figures 14 and 15. It should be noted that the only component that had a value of iS_E/S_A greater than 0.7 was the straight component number 226 in the core spray line. It had a value of 1.004, and should be investigated further. An additional allowable stress can be obtained by establishing that the longitudinal stresses are low compared to the hot allowable stress.

When observing these results, it should be remembered that this is only one part of the check of system stresses with the allowable stresses required by the piping code. Another separate comparison of the hoop stresses due to pressure with the allowable stresses is required. Some examples of this comparison are given in Table 4, and for the purposes of this summary it can be assumed that the remaining systems would have similar values.

A histogram of the cross-sectional flow areas of the individual components normalized by the cross-sectional flow area of the 26-in. recirculation lines is shown in Figures 16 and 17. This information should be useful in a statistical determination of the consequences of the complete severance of a pipe.

4.2 WEIGHT STRESS

The stresses in the primary piping which result from weight effects exert a small, although important, influence on the total stress in the piping system. The weights included in this analysis were those of the pipe, fluid, and insulation.

The piping is supported by a number of pipe hangers which have been judiciously located throughout the system in a manner intended to minimize the gravity-induced

FIGURE 14. DISTRIBUTION OF COMPONENT STRESSES

FIGURE 15. DISTRIBUTION OF COMPONENT STRESSES

FIGURE 16. DISTRIBUTION OF CROSS-SECTIONAL FLOW AREAS

FIGURE 17. DISTRIBUTION OF CROSS-SECTIONAL FLOW AREAS

TABLE 4
COMPARISON OF TYPICAL HOOP PRESSURE
STRESSES WITH THE ALLOWABLE STRESS

System	$S_p = \frac{Pr}{t}$	S_H^*	$\frac{S_p}{S_H}$
Primary Steam			
24 in. - A-106C	9,852	17,500	0.563
Core Spray			
6 in. - 304	7,667	16,000	0.479
Recirculation			
26 in. - 316	13,437	16,000	0.839

* S_H is the allowable stress at operating conditions.

stress in the piping for the number of hangers chosen. As stated previously, provision for pipe hangers was made while selecting joint locations for the flexibility analysis. The location chosen for the hangers followed the guidelines suggested in Reference 1. To reduce the stress resulting from weight loading, the hangers may be moved to more favorable locations, or additional hangers may be added. In fact, weight stress can be reduced to an almost negligible value by the addition of more and more hangers. This is obviously not economically feasible, nor is it necessary, since weight stresses are generally small when the guidelines given in Reference 1 are followed.

The weight stresses in a typical BWR were calculated using the MASS computer program and the same BWR piping model that was used in the thermal expansion stress analysis. It was determined that a conservative approximation of weight stress could be obtained by lumping distributed pipe weights (including the weight of fluid and insulation) into concentrated forces at the joints of the MASS computer model. This greatly simplifies the input for MASS because concentrated forces at joints can

be input as a boundary condition force acting in the vertical direction. On the other hand, the use of distributed weights in the MASS program, which is the more accurate procedure, requires considerable geometric manipulation to account for pipe orientations relative to both vertical and horizontal planes, and to account for pipe bends and elbows.

The closer the joints are spaced between supports, the more closely the concentrated force model approximates the distributed load case. It can be shown with a simple beam model that the conservatism in calculated stress associated with the concentrated force analogy approaches a factor of safety of 2 when a distributed load is replaced by a single concentrated load located midway between the supports.

To simplify the analysis further, it was assumed that at each hanger location there was zero vertical deflection as a result of pipe weight. For a given zero deflection at a hanger, the MASS computer program calculates the hanger load necessary to produce such restraint. This load can then be provided by either a constant or a variable support hanger. By selecting

a variable support hanger with as soft a spring as permitted by Reference 1, the change in hanger load can be minimized as the system goes from cold to hot. If the load change exceeds 25% when using a variable support hanger, it is recommended in Reference 1 that a constant support hanger be used.

A slight additional conservatism results from the use of a constant water density of 62.5 lb/ft^3 even though at operating pressure and temperature the density is generally less than this value. The weight of steam contained in the steam lines was neglected. All insulation was assumed to be Unibestos, which has a density of about 16 lb/ft^3 . Necessary insulation thicknesses were approximated using tables in Reference 1 which relate pipe size, temperature, and insulation thickness. Where possible, the weight of valves was obtained from APED or vendor drawings. In other instances, the valve weight was obtained from tables which are also included in Reference 1. These tables give valve weight as a function of valve type (gate, globe, etc.), size, and pressure rating. In every instance where it became necessary to use these tables, the heaviest valve listed for a given size and pressure rating was chosen to ensure conservatism.

The weight-induced stresses calculated using the techniques and assumptions just described are tabulated in the column entitled " S_w , Weight" in the table of stresses. In no case does the combination of longitudinal bending stress resulting from weight and longitudinal stress resulting from pressure exceed the allowable design stress for the material and temperature at the point under scrutiny. In some cases, where the combined longitudinal stress did slightly exceed the allowable, it was decided that rather than relocate existing hangers or add additional hangers to reduce the stress

and then perform another iteration of stress analysis, all the stresses in the affected portion of the sub-model would be scaled down so that the maximum combined stress would just equal the code allowable. The distribution of stresses should remain relatively unaffected and, therefore, have only a very small influence on the reliability study.

4.3 EARTHQUAKE STRESS

The stresses in the primary piping that result from earthquake forces are also calculated using the technique of concentrated loads at the joints of the MASS model. The forces are applied in two orthogonal directions (e.g., N-S then E-W), and the stresses are calculated for each loading direction. Generally, when using this method for determining earthquake stresses, the horizontal "g" loading must be established for the particular site location that has been chosen. Therefore, in order to determine reasonable earthquake design criteria for a typical BWR, a site location must be chosen for the plant and seismic information gathered which apply to that site. To keep this study relatively general, it was assumed that the site was located in the Middle Atlantic states at some point approximately equidistant from the regions of the large earthquakes of Charleston, S. C. (August 31, 1886) and Quebec, Canada (February 28, 1925). This was considered to be a typical plant location, even though the earthquakes described were accompanied by less intense ground shaking than that accompanying the several major California earthquakes.

The historic seismicity of that section of the United States is described in the U. S. Coast and Geodetic Survey publication, "Earthquake History of the United States: Part I."⁽⁵⁾ A plot of earthquake epicenters given in this publication is shown in Figure 18. A list of earthquakes for the Eastern U. S., covering the period from 1663

FIGURE 18. PLOT OF EARTHQUAKE EPICENTERS

to 1956, is given in Reference 5. The seismic probability map (Figure 19) shows the Middle Atlantic area as Zone 1, with the earthquake zones having the following classifications:

- Zone 0 - No damage
- Zone 1 - Minor damage
- Zone 2 - Moderate damage
- Zone 3 - Major damage

It is assumed that the site would not be located in the vicinity of a known earth fault. Therefore, the probability of fault displacements occurring in the vicinity of the reactor structure is assumed to be negligible.

The estimated maximum intensity of ground shaking to be anticipated at a site located in the Middle Atlantic states (Zone 1) should be based upon the largest close earthquake. A method suitable for obtaining an approximation of this intensity of shaking is to use the seismic probability map shown in Figure 19. For example, if, as explained in Reference 6, it is assumed that the spectrum intensity for California (El Centro) Zone 3 is $I_{0.2} = 2.7$, then the spectrum intensities corresponding to the other zones are:

- Zone 3 - $\frac{I_{0.2}}{2.70}$
- Zone 2 - 1.35
- Zone 1 - 0.67
- Zone 0 - 0.33

where $I_{0.2}$ is the spectrum intensity for 20% damping, a measure of the intensity of ground motion. Because of the importance of a reactor site and the limited seismic data available, it is common to assume an uncertainty or safety factor. For this case, a factor of 1.40 has been chosen which

yields a probable maximum intensity of $I_{0.2} = 0.67 \times 1.40 = 0.94$ expected at the site Zone 1 during the life of the plant.

The design of the BWR piping system to withstand earthquake forces should be based on a dynamic analysis of the piping using the acceleration response spectrum, S_a (Figure 20), or the velocity response spectrum, S_v (Figure 21), where S_a and S_v are related by the equation

$$S_a = \frac{2\pi}{T} S_v \quad T = \text{natural period of vibration.}$$

The spectra of Figures 20 and 21 correspond to a spectrum intensity $I_{0.2} = 0.94$ and can be obtained from Reference 7 as follows: Figures 7 and 8 of Reference 7 represent the Average Velocity and Average Acceleration Spectrum curves, respectively, for $I_{0.2} = 1.0$. These curves are multiplied by the design intensity factor for this plant, $I_{0.2} = 0.94$ to obtain the design spectra shown in Figures 20 and 21.

For structures (either buildings or equipment) whose failure might cause a nuclear incident, it will be assumed that the values of damping given in the following are appropriate for strong vibrations within the elastic limit:

	Percent Critical Damping
Concrete reactor structure	10.0
Reinforced concrete frame structures	5.0
Steel frame structures	2.5
Bolted and riveted assemblies	2.0
Welded assemblies	1.0
Vital piping systems	0.5

The natural periods of vibration of the buildings and equipment are also required for a complete dynamic analysis. However, in order to simplify calculations for this

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FIGURE 19. SEISMIC PROBABILITY MAP

FIGURE 20. EARTHQUAKE ACCELERATION RESPONSE SPECTRUM

FIGURE 21. EARTHQUAKE VELOCITY RESPONSE SPECTRUM

study, the maximum value of S_a given by the spectrum in Figure 20 for the applicable value of damping (0.5% for piping) will be chosen. Hence, the horizontal earthquake forces for a typical BWR piping system were determined using $S_a = 0.43$ g (see Figure 20).

Where long vertical runs of piping were present, it was necessary to add sway braces to prevent excessive lateral movement of the piping during earthquakes. The suggestions given in Reference 1 for acceptable pipe span for use in locating hangers were used as a guide for the proper placement of sway braces. The sway braces selected were taken from a standard pipe hanger and support catalog, and were chosen in accordance with the manufacturer's recommendations.

In some cases where the combined longitudinal stress slightly exceeded the allowable, it was decided that rather than add or relocate hangers and sway braces and then perform another iteration of stress analysis, all the stresses in the affected portion of the sub-model would be scaled down so that the maximum combined stress would just equal the code allowable. The distribution of stresses should remain relatively unaffected by the scaling and, therefore, have only a very small influence on the reliability study.

Many approximations have been made for the earthquake analysis, and undoubtedly some error is introduced with each approximation. As the techniques for calculating earthquake stresses are developed and refined, most of the approximations can be eliminated. Some areas of the analysis that require further refinement are:

- a. Use of distributed rather than concentrated forces;
- b. Consideration of a variable density of water with temperature;
- c. Method to determine the direction of the earthquake force vector that produces the maximum stress in the piping rather than using simple N- E-W force vectors;
- d. Improvement of information available on the basic seismology of the area;
- e. Determination of the force amplification from the ground to the attachments;
- f. Determination of relative anchor point movements and the effects therefrom;
- g. Consideration of large amplitude, variable damping;
- h. Accuracy of the basic flexibility analysis, particularly in the vicinity of tees, elbows, laterals, etc.;
- i. Determination of the effect of limit stops, where these may be present in a piping system; and
- j. Comparison of results of single-degree versus multi-degree spectra as exciting forces.

4.4 IMPACT STRESS

The stresses that result from impact loading on piping must be considered by the piping designer during layout and design of the piping system. For this study, an impact loading will be defined as a sudden application of forces or motions to a pipe or component during a time interval less than or equal to the lowest natural period of vibration of the pipe or component.

In most instances, hydraulic impact is either absent or insignificant; however, on other occasions it can become a major

cause of failure. The design procedures available to guard against an impact failure are idealized, and in many cases require experimental verification. Additional difficulty arises because the designer may not, in all instances, recognize the presence of a potentially hazardous design from the standpoint of impact loading. In other cases, where the seriousness of impact loading is recognized, both the design and operation of the system are coordinated to minimize or avoid any potential problem.

The primary area of concern in a BWR piping system is in the main steam line, where impact-type stresses can arise from two sources: (a) impact of a two-phase mixture with the quick-closing isolation valves in the steam line, and (b) the jet force reaction that results when safety and relief valves lift. In consideration of the first type of impact stress, an analysis⁽⁸⁾ was made of a steam line (24-in.) break outside the containment for a reactor pressure of 1000 psia. It was determined that a steam-water mixture slug could form in the steam line and slam into the isolation valves should a system malfunction cause a valve closure delay following the line break. Nozzle flow limiters installed in the steam lines and rapid isolation valve closure times tend to ensure continuous core coverage following a steam line break. The flow limiter considerably reduces blow-down, system decompression, and mixture level rise rates. Rapid isolation valve closure is expected to terminate blowdown before a swelling steam-water mixture enters the steam line and forms a mixture slug. For delayed valve closure in steam lines containing a nozzle flow limiter, the impact pressure rise has been calculated to be approximately 200 psi for a steam line break outside the containment. This is the most probable mode of impact loading anticipated during the steam line break accident.

The increase in primary membrane stress as a result of an impact pressure

rise of 200 psi is $\Delta \sigma_\theta = 1970$ psi and $\Delta \sigma_a = 985$ psi.

Stresses are also induced in the main steam line when, because of excessive pressure, the safety valves lift and discharge high-pressure steam. When steam is first discharged from the valves, a jet reaction force is applied to the valve and, in turn, is transmitted through the 6-in. relief line back into the 24-in. steam line. Stresses were calculated in the steam line using MASS by applying a force and moment (equivalent to the jet reaction force) to the steam line where it intersects with the relief line.

It was assumed that during a severe overpressure transient, all steam line safety valves⁽⁵⁾ could lift simultaneously. However, since the reaction forces of adjacent safety valves are in opposite directions, the most severe loading condition would occur if only four of the valves, oriented in the same direction, were to lift simultaneously. The stresses at the joints of the MASS model caused by this assumed transient are shown in the stress tabulation under the heading of impact stresses. Stresses are tabulated for the south side main steam line; similar stresses will also occur in the north side main steam line at the identical locations.

In addition to the stresses in the 24-in. steam line, there are also stresses induced in the 6-in. relief line which is cantilevered above the steam line. The maximum stress occurs at the intersection of the two pipes as a result of out-of-plane bending produced by the reaction force from the safety valve. The lowest natural frequency of the relief line must be determined in order to ensure that the jet force is applied over a sufficiently long period of time to permit the full bending stress to develop into the relief line. It was found from calculations that the period of vibration

was of the same magnitude as the time required for the jet of steam to travel from safety valve down the relief line to the vent tee (at which point the jet reaction force is

counterbalanced by diverting the steam flow equally in two opposite directions). The stresses calculated in the relief line for this condition were as follows:

$$\text{Primary membrane, } P_m : \sigma_1 = \frac{MC}{I} = 22,800 \text{ psi,}$$

$$\text{Primary bending, } P_b : \sigma_2 = \pm \frac{R_o - R_i}{2 R_m} \sigma_1 = \pm 1590 \text{ psi.}$$

Secondary membrane +

$$\text{Bending, } Q : \sigma_3 = C_2 \frac{MC}{I} = 90,300 \text{ psi,}$$

where

M = bending moment resulting from jet reaction force, in. -lb,

C = distance from neutral axis to outer fiber of pipe, in.,

I = moment of inertia of pipe, in.⁴,

R_o = outer radius of pipe, in.,

R_i = inner radius of pipe, in.,

R_m = mean radius of pipe, in.,

C₂ = stress intensification factor for tees loaded with an out-of-plane bending moment,

$$= \frac{0.9}{\left(\frac{t}{R_m}\right)^{2/3}} = 3.96 \text{ (2.0 is minimum)}$$

(per ASA B31.1), and

t = nominal pipe wall thickness, in.

These values of calculated stress exceed the code allowable stress, thereby indicating the need for a design modification. In actual practice, a design change would be instituted, and the stress level during plant

operation would be within the code allowable. In this particular case, the relief lines will have to be stiffened or braced to reduce the excessive stress.

4.5 TRANSIENT THERMAL STRESS

Transient thermal stresses were calculated in several BWR piping components to reflect the effect of the predicted transient temperature conditions described in References 9 and 10. It is not considered essential to calculate transient thermal stresses when using B31.1 as a design guideline. However, the design requirements of the new nuclear piping code (USAS B31.7) will require that transient stresses be calculated and will provide a method for checking the fatigue life based on the magnitude of the transient stress and the number of cycles. Therefore, the stresses were calculated for this report mainly to illustrate the method of calculation and to point out components and locations where transient stresses are significant. In each instance where the transient temperature distribution was determined, a simplified slab model was chosen to represent the pipe wall. One surface of the slab was assumed to be insulated (adiabatic) while the other surface, when in the presence of water, was assumed to respond directly to water temperature changes.⁽¹⁰⁾ Where one

surface was in the presence of steam (emergency condenser steam line), the surface heat transfer coefficient resulting from condensation of steam was calculated and applied in determining the resulting temperature distribution.⁽¹¹⁾

The peak stress that resulted in the pipe immediately after the occurrence of the transient was assumed to be a skin stress reflecting the entire temperature change of the fluid. For conservatism, in each case the temperature change of the fluid was assumed to occur in a step-wise fashion. The peak (skin) stress was calculated using the equation,

$$\sigma_{\theta} = \sigma_L = \frac{E \alpha \Delta T}{1 - \nu}$$

In addition to the initial step change in surface temperature, a temperature gradient will exist through the pipe at subsequent intervals of time, the gradient varying from a maximum at the initial time to zero at some later time when the pipe wall approaches a uniform steady-state temperature equal to the fluid temperature (for the model chosen). Since the transient temperature gradient is nonlinear, it can be broken into two parts: an equivalent linear gradient, and a temperature difference between the equivalent linear gradient and the actual temperature at the surface of the pipe.

For the model chosen, the temperature gradient through the pipe wall can be calculated for any desired time using the equations and charts given in Reference 12. An equivalent linear temperature gradient can be obtained from this nonlinear gradient by the following equations:

$$T_e(z) = T_{avg} + [\text{Grad } T(z)] Z,$$

where

T_e = equivalent linear temperature at Z, °F,

Grad T (z) = linear temperature gradient through thickness t, °F,

$$= \frac{\Delta T}{t} Z,$$

ΔT = temperature difference between the inner and outer surfaces, °F,

t = wall thickness, in.,

$$T_{avg} = \frac{1}{t} \int_{-t/2}^{t/2} T(z) dz,$$

T(z) = given nonlinear temperature distribution through t measured radially from the mid-thickness, °F, and

$$\begin{aligned} \int_{-t/2}^{t/2} [\text{Grad } T(z)] Z dz &= \\ &= \int_{-t/2}^{t/2} T(z) Z dz. \end{aligned}$$

The equivalent linear gradient can be determined as the difference between the values of T_e at $Z = -t/2$ and T_e at $Z = t/2$. On the surface of the pipe, thermal stresses are present because of the difference between T_e and T_{actual} at the surface.

Thermal stresses in the pipe wall resulting from the nonlinear temperature gradient at some time after initiation of the transient are expressed using the equivalent linear temperature gradient as follows:

$$\sigma_{\theta} = \sigma_L \frac{E \alpha (T_{e_{in}} - T_{e_{out}})}{2(1 - \nu)} \quad (\text{Secondary Stress})$$

$$\sigma_{\theta} = \sigma_L = \frac{E \alpha [(T_e - T_{actual})]_{\text{surface}}}{1 - \nu} \quad (\text{Peak Stress})$$

A summary of the transient thermal stresses that exist in several of the primary lines of the BWR piping system is given in Table 5. These stresses are categorized as the peak stress that occurs at time 0^+ , the secondary stress that results from the maximum equivalent linear temperature gradient at some later time, and the associated peak stress that occurs simultaneously with the secondary stress. The temperature transient that causes the stress and the number of the thermal cycles anticipated for each transient are also given in the table.

It was beyond the scope of this study to determine the axial variation in the transient radial temperature gradient. However, for conservatism, it can be assumed that the maximum transient thermal stress (those values tabulated in Table 5) occurs at each joint in a pipe which is either cold and suddenly heated, or hot and suddenly cooled. Discontinuities, stress concentrations, and other local effects were not considered.

4.6 VIBRATION STRESS

During reactor plant operation, vibration can be induced in piping in many ways; e. g., by any kind of reciprocating equipment, by rotating equipment because of mass unbalance, by operation of relief valves, safety valves or other similar devices, and by the fluid flow itself. Significant vibration problems are difficult to predict in the early stages of piping design because of the many complicated effects associated with pipe vibration; however, every effort should be made during the design phase to arrange and support the piping so as to minimize vibration. In addition, observation of the piping system during startup and the initial phases of operation to detect any undesirable vibration is also of primary importance.

A very good discussion of vibration in piping systems is contained in Chapter 9 of Reference 13, entitled "Vibration Prevention

and Control." Included in that chapter is a discussion of basic vibration theory, typical vibration problems in piping systems and trouble shooting procedures. This reference is of most value to the designer who is attempting to minimize vibration during the design and layout phase of piping design. Little, if any, aid in outlining methods or procedures for determining dynamic stresses in piping systems can be obtained from any of the piping or vessel design codes.

However, in considering vibration, it should be emphasized that in order to comply with USA B31.7, it will be the designer's responsibility to show, through design and observation, that vibration has been minimized to an acceptable value.

Therefore, a procedure must be established whereby the vibration of a piping system can be observed and measured under startup and initial operating conditions in order to ensure that vibration is within the acceptable limits dictated by the applicable design codes.

In determining an allowable stress for vibration, the designer must give consideration to all other simultaneous stresses that occur; then the margin between the sum of these stresses (summed according to B31.7) and the allowable stress intensity (per B31.7) is available for vibration.

The following procedure is suggested for calculating an allowable single amplitude vibration stress level. It is necessary to refer to the "hopper" diagram, Table I-702.5.5 of B31.7, for clarification of nomenclature.

- a. Calculate the stresses that result from all forms of loading at each point of interest in the piping system. The loading conditions may include pressure, mechanical load, thermal expansion, local thermal, impact, earthquake, and nondesign, both

TABLE 5
SUMMARY OF TRANSIENT THERMAL STRESSES

<u>System</u>	<u>Condition</u>	<u>Number of Design Cycles</u>	<u>Temperature Transient (°F)</u>	<u>Peak Stress at Time 0⁺(psi)</u>	<u>Maximum Secondary Stress at Time</u> (Not including stress concentrations)	<u>Maximum Peak Stress at Time</u>
<u>Sub-Model 1</u>						
Top Head Cooling Spray	Normal reactor shutdown	120	500 to 70	112,000	50,500 psi at 0.3 sec	26,000 psi at 0.3 sec
<u>Sub-Model 2</u>						
Core Spray Near Pressure Vessel	Accidental loss of core coolant by rupture of primary line	10	545 to 110	156,500	70,000 psi at 3 sec	46,000 psi at 3 sec
Feedwater Line Near Pressure Vessel	Normal reactor startup, cold feedwater enters hot recirculation line	120	545 to 100	116,000	52,000 psi at 5 sec	20,300 psi at 5 sec
<u>Sub-Model 3</u>						
Control Rod Drive Cooling Water Supply Line	With no cooling, housing heats to 150°F. Resumption of cooling lowers temperature to 50°F.	200	150 to 50	36,000	16,200 psi at 0.2 sec	9,620 psi at 0.2 sec
Control Rod Drive Hydraulic System Return Line	Cold return water enters hot line near pressure vessel	200	545 to 50	178,000	80,000 psi at 5 sec	30,000 psi at 5 sec
Poison Spray Line Near Pressure Vessel	Cold poison enters hot spray line near pressure vessel	10	545 to 100	160,000	72,000 psi at 5 sec	27,000 psi at 5 sec
<u>Sub-Model 4</u>						
Emergency Condenser Steam	Hot steam enters cold steam line	500	100 to 545	-	30,230 psi at 45 sec	6,750 psi at 45 sec
<u>Sub-Model 5</u>						
Emergency Condenser Condensate	Cold condensate enters hot recirculation line	500	545 to 100	160,000	72,000 psi at 5 sec	38,100 psi at 5 sec
<u>Sub-Model 6</u>						
Cleanup to Recirculation Tee	Cold cleanup water enters hot recirculation line	200	545 to 100	160,000	72,000 psi at 5 sec	38,100 psi at 5 sec
<u>Sub-Model 7</u>						
All Recirculation Loop Piping	Loop shutdown, cools to ambient, then restarted	100 (est.)	100 to 545	160,000	71,500 psi at 5 sec	37,800 psi at 5 sec
<u>Sub-Model 8</u>						
Shutdown Loop	Improper startup of shutdown loop	10	130 to 530	144,000	64,700 psi at 10 sec	33,500 psi at 10 sec

steady state and transient, and should include the effects of discontinuities and stress concentrations where these are called for in the "hopper" diagram.

- b. Combine all of these stresses in the manner prescribed by B31.7 and compare the combined stress (e. g., P_m , P_L , P_e , etc.) with the allowable stress intensity (S_m , $1.5S_m$ or $3S_m$), as shown in the "hopper" diagram.
- c. The minimum difference between the calculated combined stress and the allowable stress should be determined for each category where vibration must be considered. For example, calculate P_m , $P_L + P_b$, $P_L + P_b + P_e + Q$ and $P_L + P_b + P_e + Q + F$, and then determine the following quantities:
 1. $1.5S_m - P_L = A$
 2. $1.5S_m - [P_L \text{ (or } P_m) + P_b] = B$
 3. $3S_m - [P_L \text{ (or } P_m) + P_b + P_e + Q] = C$
 4. Single amplitude vibration stress (including discontinuities and stress concentrations) acting alone = D.

The additional stress produced by vibration should be limited to the minimum of A, B, C, or D. However, in no case should the stress resulting from vibration be permitted to exceed the endurance limit of the material (assumed to be equal to S_A at 10^6 cycles on Figures 1-702.5.7 (a) and 1-702.5.7 (b) in B31.7). Since vibration at only 1 cps amounts to a total of 1.26×10^9 cycles after 40 years, it is apparent that the significant design parameter when considering vibration is not $3S_m$ but rather the endurance limit of the material.

If there is a large margin of stress available to accommodate vibration (i. e., if the minimum of A, B, C, or D = the endurance limit), then the presence of excess vibration in the system is more readily detectable since a large vibratory stress will likely be accompanied by a large amplitude of vibration. However, as a design guide, it is suggested that the maximum single amplitude stress attributable to vibration be limited to the following values:

Maximum single amplitude stress from vibration alone

Carbon Steel	= 5,000 psi
Stainless Steel	= 10,000 psi

These values of stress give a safety margin of about 2.5 below the minimum fatigue stress of USA B31.7 for these materials. This should be ample to account for stress intensification at discontinuities (branches, tees, etc.).

Simplified relationships can be derived for sections of piping which may be treated as fixed-fixed, fixed-hinged, or cantilever beams,⁽¹⁴⁾ but these do not account for the complicated interaction of long runs of pipe containing pumps, valves, dampers, stops, etc.

It can be shown, using these simple piping models, that for a given allowable stress and maximum frequency of vibration (typically less than 150 for low-cycle fatigue damage considerations), the amplitude of vibration in the piping model (or system) should not exceed a calculated maximum value. This value of amplitude—which again depends upon the total stress that exists at the piping joint before the vibration stress is superimposed—may be 1/16 inch peak-to-peak⁽¹³⁾ for large pipe (over 12-in. diameter). However, it is recommended that the maximum permissible peak-to-peak amplitude of vibration for a

frequency of 150 cps (probably the maximum frequency of interest) be limited to the following values:

Maximum permissible p-p vibration amplitude

Carbon Steel $(S=5,000) = 0.033$ in. p-p

Stainless Steel $(S=10,000) = 0.066$ in. p-p

For frequencies, F , less than 150 cps, the maximum permissible amplitude can be increased by the ratio of $150/F$. A handy rule might be: "If you observe more than $1/32$ in. p-p for carbon steel or $1/16$ in. p-p for stainless steel pipe, take careful measurements, determine the dominant frequencies, and report results to the designer."

When the stress analysis indicates that the margin of stress available for vibration (i. e., A, B, C, or D) is considerably less than the maximum values recommended above, the designer should consider the economics

(and technical feasibility) of redesigning the piping system (including another iteration of stress analysis) to permit a higher vibratory stress versus the employment of sensitive instrumentation for the detection and measurement of the small vibration permitted by the stress limits. It would seem desirable to be able to perform all vibration "measurements" by visual observation of the piping system during startup and initial operation.

A sophisticated piping vibration analysis which would give calculated stresses at each pipe joint in the model for comparison with the allowable stress at those points (after other simultaneous stress has been considered) is beyond the scope of the pipe rupture study. Although possible to perform such an analysis, it is anticipated that in actual practice vibration will be acceptably accounted for by judicious design and by observation after initial plant startup.

SECTION V

APPLICATION TO CRACK INITIATION AND CRACK PROPAGATION STUDIES

Numerical results from this report will be utilized in calculating the probability of crack initiation and propagation through to leak in the primary system as a result of low cycle fatigue, taking into account the stress values at each component and the estimated uncertainty in those values. A description of the method by which this is accomplished is documented elsewhere.⁽¹⁵⁾ The purpose of this discussion is to show how the calculated stresses will be utilized in the crack initiation and crack propagation equations.

5.1 SOURCES OF CYCLIC STRESS

The stresses of primary importance in crack initiation and crack propagation studies are the thermal expansion stresses, S_E , which have been calculated, and the pressure stresses

S_p , which are readily calculated from nominal pipe dimensions. These stress cycles are associated with reactor startup and shutdown, for which the reactor design basis is 120 cycles in 40 years. Weight stresses and possible earthquake and impact stresses have also been calculated, but consideration of these stresses is appropriate to analysis of the later phases of possible piping failure, rather than the crack initiation and fatigue crack propagation phases. The transient thermal stresses, summarized in Table 5, should be considered for those particular lines and components in which they occur.

5.2 SIMPLIFIED INTERPRETATION OF PIPING STRESSES

Some simplifying assumptions regarding the orientation of the thermal expansion

stresses in straight and curved components are necessary to permit superposition of expansion stresses and pressure stresses. These simplifications will also permit a potential fatigue crack to be identified as either circumferentially or axially oriented, and thus avoid the complexities of a consideration of skew-oriented cracks. In the straight pipe section, S_E is the maximum difference of principal stresses resulting from bending and torsional moments in the pipe. These principal stresses may actually be oriented at an angle to the axis of the pipe as a result of the torsional component, but it will be assumed that S_E is due to bending only, and represents a uniaxial stress parallel to the axis of the pipe.

In the curved pipe section, S_E is an estimate, based on Piping Code rules, of the effective stress for fatigue crack initiation resulting from a combination of in-plane, out-of-plane, and torsional moments in the pipe. The actual stress distribution in the piping elbow is more complex than is implied by the method of calculation of S_E , but it will be assumed that S_E is the stress resulting from bending to oval shape of the elbow cross section. Then S_E is oriented in the transverse, or circumferential direction in the elbow.

The pressure stresses in all components are approximated by the simple equations:

$$\text{Circumferential stress} = S_p = \frac{Pr}{t},$$

$$\text{Axial stress} = \frac{1}{2} S_p,$$

where

P = pressure, psi,

r = mean pipe radius, and

t = pipe wall thickness.

The transient thermal stresses, which will be denoted S_T , are the values taken from Table 5, in the column marked "Peak Stress at Time 0+."

5.2.1 Crack Initiation

The general criterion for low-cycle fatigue crack initiation in piping materials is the experimental correlation that is observed between the cyclic shear strain range (or effective strain) and cycles to crack initiation. It is customary in design work to recognize, or assume, that an effective stress calculated by elastic theory is approximately in direct proportion to the actual value of effective strain, even though the limitations of elastic theory have been exceeded. The validity of this assumption has been the subject of investigations conducted under Task D-2 of the Pipe Rupture Study.⁽¹⁶⁾ The proportionality of calculated stress and actual strain will be assumed in the piping system reliability model. Figures 22 through 24 show the low-cycle fatigue data which are the basis for ASME code design rules,⁽¹⁷⁾ and will be used as the criterion for low-cycle fatigue crack initiation in the reliability model. An important consideration in the low-cycle fatigue crack initiation criterion is the effect of surface finish and/or initial defect size on cycles to crack initiation, with reference to smooth-bar laboratory test data. If the surface defect has a sharp edge, it can be treated as an initial crack, but if the defect has a finite tip radius, there will be a crack initiation or "incubation" period which can be predicted by the use of a stress concentration factor applied to the nominal effective stress in the region of the defect.

The effective stress amplitude S_a for fatigue crack initiation due to startup and shutdown cycles will be given by:

$$S_a = \frac{K}{2} \left(S_E + \frac{1}{2} S_p \right)$$

FIGURE 22. FATIGUE DATA-CARBON STEELS

FIGURE 23. FATIGUE DATA-STAINLESS STEELS

FIGURE 24. FATIGUE DATA-LOW-ALLOY STEELS

for straight pipe sections, or

$$S_a = \frac{K}{2} S_p$$

$$S_a = \frac{K}{2} (S_E + S_p),$$

for curved pipe sections.

For transient thermal cycles, $S_a = \frac{K}{2} S_T$, for all affected components. In these expressions, K is the defect stress concentration factor given by

$$K = 1 + 2 \sqrt{\frac{a_o}{r}},$$

a_o = defect depth,

r = effective tip radius of defect.

The distribution of a_o has been estimated. ⁽¹⁵⁾ A distribution for r will be similarly assigned, with care taken to ensure that a normal piping component surface finish is characterized by a reasonably small value of K . While this may seem to be a cumbersome way to represent the low-cycle fatigue behavior of piping components, it has the advantage of providing a consistent mathematical definition of the crack initiation and crack propagation phases, and permits the use of probability density functions defined by the Reliability Engineering Task for the pertinent variables.

5.2.2 Crack Propagation

Four categories of stress in a pipe wall have been identified in the analysis of fatigue crack propagation through the pipe wall, as follows:

- a. Primary membrane,
- b. Primary bending,
- c. Secondary membrane, and
- d. Secondary bending.

The terms, membrane and bending, refer to stresses that act normal to the plane of the crack and are uniformly distributed or linearly distributed, respectively, through the pipe wall thickness. The secondary stress categories are, by definition, those nominal stresses that are reduced in magnitude as the crack depth increases, as a result of increased local flexibility due to the presence of the crack. The primary stress categories are load-dependent and do not decrease with increasing crack depth.

The proper classification of stresses in a piping component into primary and secondary categories requires the stress analysis of the component with the equivalent crack flexibility included. This type of analysis is not yet feasible with the present state of development stress analysis techniques, but more important, there is evidence from preliminary calculations using the crack growth equation, that the primary versus secondary distinction will not be necessary in most cases. If the initial crack depth is small compared to the pipe wall thickness, then a very large proportion of the total number of cycles to grow through the wall is consumed while the crack is short and the primary versus secondary distinction is not significant. Furthermore, it is estimated that primary stresses predominate in most of the piping components. It will be expedient, conservative, and apparently quite accurate, then to omit the secondary stress categories from the crack growth equation, with the possible exception of special cases of local thermal stresses which can be considered separately.

The stresses to be used in the crack propagation equation may now be defined, using the following nomenclature:

σ_{pM} = primary membrane stress,

σ_{pB} = primary bending stress.

The stress values appropriate to startup and shutdown cycles will depend on S_E and S_p , and are determined as follows.

For the straight pipe section, use the larger of

$$\sigma_{pM} = S_E + \frac{1}{2} S_p \quad (\text{crack has a circumferential orientation}),$$

or

$$\sigma_{pM} = S_p \quad (\text{crack has an axial orientation}),$$

with

$$\sigma_{pB} = 0.$$

For the piping elbow, $\sigma_{pM} = S_p$ and $\sigma_{pB} = S_E$, and the crack is orientated in the axial (longitudinal) direction.

For transient thermal cycles, ...

$$\sigma_{pM} = 0$$

and

$$\sigma_{pB} = 0$$

for all affected components.

This thermal stress would be more accurately considered as a secondary rather than a primary stress, but as noted previously, the distinction will not be significant in the final results, and elimination of secondary stress categories will simplify the calculation procedure and provide a conservative result.

APPENDIX A

MASS TUBING STRESS CALCULATION NO. 1052

This stress calculation is given in Reference 18.

A.1 LONGITUDINAL BENDING

STRESS, S_B

a. Straight Tubes

$$S_B = \frac{Mr}{I}$$

$$M = \sqrt{M_i^2 + M_o^2}$$

M_i = in-plane bending moment,

M_o = out-of-plane bending moment.

b. Curved Tubes

$$S_B = \frac{Mr}{I} i$$

i = stress intensification factor,

$$i = \frac{0.9}{(h)^{2/3}}$$

$$h = \frac{t_p}{r^2}$$

A.2 AXIAL STRESS, S_A

Axial stress, S_A , is neglected by ASA Code and No. 1052 stress calculation.

A.3 TORSIONAL STRESS, S_T

$$S_T = \frac{M_T r}{2I}$$

M_T = torsional moment

A.4 PRESSURE STRESSES

a. Longitudinal Pressure Stress

$$S_{LP} = P \frac{A_i}{A_m}$$

P = pressure.

A_i = inside tube area,

A_m = cross-sectional area of metal.

b. Hoop Stress

$$S_H = P \frac{(D-t)}{2t}$$

A.5 COMBINED STRESSES

The effective stress printed out at each joint inputted to MASS is a combined stress based on the Maximum Shear Theory. This effective stress is the maximum of

$$S_{EFF} = 0.5 \left[S_L + S_H \pm \sqrt{4S_T^2 + (S_L - S_H)^2} \right]$$

or

$$\sqrt{4S_T^2 + (S_L - S_H)^2}$$

where

$$S_L = S_B + S_A + S_{LP}$$

A.6 COMPARISON OF STRESS CALCULATION 1052 WITH ASA CODE

With axial stress neglected by the stress calculation:

$$S_A = 0.$$

With no pressure inputted into the model:

$$S_{LP} = 0,$$

and

$$S_H = 0 .$$

Therefore, the stress printed out by MASS

stress calculation 1052 with no pressure inputted is

$$\sqrt{4S_T^2 + S_B^2} .$$

This is equivalent to the calculation for the expansion stress, S_E , given in the ASA code reference 1.

APPENDIX B

TABULATION OF COMPONENTS AND DISCONTINUITIES
IN A TYPICAL SINGLE-CYCLE BWR

Model Number 1 Main Steam (North Side) Component or Discontinuity	Component Number	Type	MASS Joint Number	Diameter D (Outside) in.	Thickness t, in.	Radius of Curvature, ρ , in.	ρ/D^*	Included Angle θ	Length of Straight Pipe, in.	Material	Operating Pressure, psi	Operating Temperature, °F	Number of Cycles/40 yr.	$S_A = f(1.25 S_c + 0.25 S_A)$, psi	S_E from MASS, psi	S_E/S_A	Stress Int. Factor, i	$(S_E/S_A)^i$	A/A_{max}	S_w , Weight Stress, psi	S_q , Earthquake Stress, psi
Pressure Vessel Nozzle Weld		D-1	501												3047	0.1167	1.0	0.1161		51	1260
Straight	1	1	501-502	24.0	1.218				11.0	A106C	1000	555	360	26,250	3047	0.1167		0.1161	0.8055	51	1106
Butt Weld		D-1	502												3595	0.1370	1.0	0.1370		86	1216
Elbow	2	2	502-503	24.0	1.218	24.0	1.0	90°		A106C	1000	555	360	26,250	6247	0.2380		0.2380	0.8055	108	3200
Butt Weld		D-1	503												6247	0.2380	1.0	0.2380		108	1325
Straight	3	1	503-504	24.0	1.218				224.0	A106C	1000	555	360	26,250	2570	0.0979		0.0979	0.8055	97	436
Flow Nozzle		D-3a	Between 503 & 504																		
Bend	4	3	504-505	24.0	1.218	144.0	6.0	15°		A106C	1000	555	360	26,250	709	0.0270		0.0270	0.8055	181	394
Straight	5	1	505-506	24.0	1.218				165.5	A106C	1000	555	360	26,250	3002	0.1144		0.1144	0.8055	181	788
Butt Weld		D-1	506												5561	0.2153	1.0	0.2153		207	1454
Elbow	6	2	506-507	24.0	1.218	36.0	1.5	90°		A106C	1000	555	360	26,250	5561	0.2153		0.2153	0.8055	207	1385
Butt Weld		D-1	507												4893	0.1864	1.0	0.1864		206	873
Straight	7	1	507-508	24.0	1.218				9.0	A106C	1000	555	360	26,250	3026	0.1153		0.1153	0.8055	144	735
6 in. Line to Safety Valve		D-4	508												2916	0.1111	1.54	0.1711		142	722
Straight	8	1	508-509	24.0	1.218				30.0	A106C	1000	555	360	26,250	2916	0.1111		0.1111	0.8055	142	722
6 in. Line to Safety Valve		D-4	509												2583	0.0984	1.54	0.1520		118	695
Bend	9	3	509-510	24.0	1.218	130.0	5.5	15°		A106C	1000	555	360	26,250	2585	0.0985		0.0985	0.8055	142	711
6 in. Line to Safety Valve		D-4	510												2218	0.0845	1.54	0.1300		142	711
Bend	10	3	510-511	24.0	1.218	130.0	5.5	16°		A106C	1000	555	360	26,250	2218	0.0845		0.0845	0.8055	319	798
6 in. Line to Safety Valve		D-4	511												1758	0.0670	1.54	0.1030		319	798
Bend	11	3	511-512	24.0	1.218	130.0	5.4	14°		A106C	1000	555	360	26,250	1758	0.0670		0.0766	0.8055	319	795
6 in. Line to Safety Valve		D-4	512												1305	0.0497	1.54	0.0766		108	795
Straight	12	1	512-513	24.0	1.218				42.0	A106C	1000	555	360	26,250	1305	0.0497		0.0766	0.8055	108	788
6 in. Line to Safety Valve		D-4	513												826	0.0315	1.54	0.0485		91	788
Straight	13	1	513-514	24.0	1.218				30.0	A106C	1000	555	360	26,250	826	0.0315		0.0315	0.8055	166	781
6 in. Line to Safety Valve		D-4													823	0.0314	1.54	0.0484			
Straight	14	1	514-515	24.0	1.218				30.0	A106C	1000	555	360	26,250	1128	0.0430		0.0662	0.8055	166	781
6 in. Line to Safety Valve		D-4	515												1128	0.0430	1.54	0.0662		191	775
Straight	15	1	515-516	24.0	1.218				30.0	A106C	1000	555	360	26,250	1571	0.0598		0.0662	0.8055	191	845
6 in. Line to Safety Valve		D-4	516												1571	0.0598	1.54	0.0921		166	812
Straight	16	1	516-517	24.0	1.218				12.0	A106C	1000	555	360	26,250	1745	0.0665		0.0665	0.8055	164	883
Butt Weld		D-1	517												3045	0.1160	1.0	0.1160		224	1510
Elbow	17	2	517-518	24.0	1.218	36.0	1.5	90°		A106C	1000	555	360	26,250	3617	0.1378		0.1378	0.8055	224	1392
Butt Weld		D-1	518												3524	0.1342	1.0	0.1342		150	969
Straight	18	1	518-519	24.0	1.218				204.0	A106C	1000	555	360	26,250	1947	0.0742		0.1340	0.8055	87	1302
Branch from Vent Line		D-4	519												2285	0.0870	1.54	0.1340		64	3084
Elbow	19	2	519-520	24.0	1.218	24.0	1.0	90°		A106C	1000	555	360	26,250	2644	0.1001		0.1340	0.8055	186	2269

Model Number 1 Main Steam (North Side), Steam Relief Line Component or Discontinuity	Component Number	Type	MASS Joint Number	Diameter D (Outside), in.	Thickness t, in.	Radius of Curvature, ρ, in.	ρ/D*	Included Angle θ	Length of Straight Pipe, in.	Material	Operating Pressure, psi	Operating Temperature, °F	Number of Cycles/40 yr.	$S_A = f(1.25 S_c + 0.25 S_A)$, psi	S_E from MASS, psi	S_E/S_A	Stress In. Factor, i	$(S_E/S_A)_i$	A/A _{max}	S_w , Weight Stress, psi	S_q , Earthquake Stress, psi
Butt Weld		D-1	520												2032	0.0774	1.0	0.0774		186	1616
Isolation Valve	20	4	520-521	24.0	6.0				57.0	A106C	1000	555	360	26,250	1383	0.0127		0.0127	0.2495	137	777
6 in. Branch of Tee 516	21	1	516-522	6.624	0.432				18.0	A106C	1000	555	360	26,250	943	0.0359	1.0	0.0359	0.0575	99	1443
Butt Weld		D-1	522												943	0.0359	1.0	0.0359		97	842
Valve	22	4	522-523	6.624	1.6				27.0	A106C	1000	555	360	26,250	463	0.0176		0.0176	0.0203	45	388
Butt Weld		D-1	523												1005	0.0383	1.0	0.0383		40	348
Straight	23	1	523-524	6.624	0.432				9.0	A106C	1000	555	360	26,250	1026	0.0391		0.0391	0.0575	106	595
Butt Weld		D-1	524												1389	0.0529	1.0	0.0529		110	615
Elbow	24	2	524-525	6.624	0.432	12	2.0	90°		A106C	1000	555	360	26,250	1389	0.0529		0.0529	0.0575	144	800
Butt Weld		D-1	525												1268	0.0483	1.0	0.0483		103	368
Straight	25	1	525-526	6.624	0.432				36.0	A106C	1000	555	360	26,250	992	0.0378		0.0378	0.0575	656	652
Bend	26	3	526-527	6.624	0.432	32	5.3	60°		A106C	1000	555	360	26,250	814	0.0310		0.0310	0.0575	89	552
Straight	27	1	527-528	6.624	0.432				73.2	A106C	1000	555	360	26,250	660	0.0251		0.0251	0.0575	249	870
Bend	28	3	528-529	6.624	0.432	31	5.3	90°		A106C	1000	555	360	26,250	478	0.0182		0.0182	0.0575	174	934
Straight	29	1	529-530	6.624	0.432				25.7	A106C	1000	555	360	26,250	328	0.0125		0.0125	0.0575	818	1090
Bend	30	3	530-531	6.624	0.432	12	2.0	90°		A106C	1000	555	360	26,250	345	0.0131		0.0131	0.0575	134	2427
Straight	31	1	531-532	6.624	0.432				173.7	A106C	1000	555	360	26,250	636	0.0242		0.0242	0.0575	161	2663
Model 1 - Steam Vent Line																					
Pressure Vessel		D-1	551												265	0.0101	1.0	0.0101		6	390
Nozzle Weld																					
Straight	51	1	551-552	4.5	0.337				30.0	A106C	1000	551	360	26,250	265	0.0101		0.0101	0.0254	5	270
4 × 2 Reducer		D-6	552												1498	0.0571	1.0	0.0571		32	1579
Elbow	52	2	552-553	2.376	0.218	6	3.0	90°		A106C	1000	551	360	26,250	1498	0.0571		0.0571	0.0065	207	1629
Socket Weld		D-1a	553												1423	0.0542	1.3	0.0705		207	1629
Straight	53	1	553-554	2.376	0.218				161.9	A106C	1000	551	360	26,250	1423	0.0542		0.0542	0.0065	419	1265
Socket Weld		D-1a	554												340	0.0130	1.3	0.0169		419	1265
Elbow	54	2	554-555	2.376	0.218	6	3.0	90°		A106C	1000	551	360	26,250	395	0.0150		0.0150	0.0065	82	1274
Socket Weld		D-1a	555												395	0.0150	1.3	0.0195		82	1274
Straight	55	1	555-556	2.376	0.218				142.0	A106C	1000	551	360	26,250	395	0.0150		0.0150	0.0065	71	1576
Flange		D-5	556												157	0.0060	1.0	0.0060		71	1576
Straight	56	1	556-557	2.376	0.218				64.0	A106C	1000	551	360	26,250	157	0.0060		0.0060	0.0065	66	2476
Socket Weld		D-1a	557												150	0.0019	1.3	0.0025		66	2476
Elbow	57	2	557-558	2.376	0.218	6	3.0	90°		A106C	1000	551	360	26,250	103	0.0039		0.0039	0.0065	146	2765
Socket Weld		D-1a	558												103	0.0039	1.3	0.0051		146	2765
Straight	58	1	558-559	2.376	0.218				56.4	A106C	1000	551	360	26,250	693	0.0264		0.0264	0.0065	141	4177
Socket Weld		D-1a	559												693	0.0264	1.3	0.0343		141	4177

Model Number 1 Steam Vent Line Component or Discontinuity	Component Number	Type	MASS Joint Number	Diameter D (Outside), in.	Thickness t, in.	Radius of Curvature, ρ , in.	ρ/D^*	Included Angle θ	Length of Straight Pipe, in.	Material	Operating Pressure, psi	Operating Temperature, °F	Number of Cycles/40 yr.	$S_A = f(1.25 S_c + 0.25 S_A)$, psi	S_E from MASS, psi	$(S_E/S_A)^i$	Stress Int. Factor, i	$(S_E/S_A)^i$	A/A _{max}	S_w , Weight Stress, psi	S_q , Earthquake Stress, psi	S_I , Impact
Elbow	59	2	559-560	2.376	0.218	6	3	90°		A106C	1000	551	360	26,250	745	0.0284		0.0284	0.0065	33	4872	
Socket Weld		D-1a	560												745	0.0284	1.3	0.0369		33	4872	
Straight	60	1	560-561	2.376	0.218				314.0	A106C	1000	551	360	26,250	745	0.0284		0.0284	0.0065	7	7293	
Straight	61	1	561-562	2.376	0.218				160.0	A106C	1000	551	360	26,250	180	0.0069		0.0069	0.0065	7	7293	
Run of Tee 563	62	1	562-563	2.376	0.218				24.0	A106C	1000	551	360	26,250	545	0.0208		0.0216	0.0065	7	4178	
2 x 2 Tee		D-4	563												545	0.0208		0.0216		27	1841	
Branch to Main Steam	63	1	563-519	2.376	0.218				59.2	A106C	1000	551	360	26,250	545	0.0870		0.0216	0.0065	65	2566	
Run of Tee 563	64	1	563-564	2.376	0.218				54.0	A106C	1000	551	360	26,250	0	0		0	0.0065	0	1841	
Weld		D-1a	564												0	0	1.3	0		0	0	
Valve	65	4	564-565	2.376	0.6				6.0	A106C	1000	551	360	26,250	0	0		0	0.0024	0	0	
Model 1 - Main Steam (South Side)																						
Pressure Vessel		D-1	601												3046	0.1160	1.0	0.1160		41	1171	4861
Nozzle Weld																						
Straight	101	1	601-602	24.0	1.218				11.0	A106C	1000	555	360	26,250	3046	0.1160		0.1160	0.8055	40	1046	2033
Butt Weld		D-1	602												3603	0.1373	1.0	0.1373		80	1174	3912
Elbow	102	2	602-603	24.0	1.218	24	2.0	90°		A106C	1000	555	360	26,250	6242	0.2378		0.2378	0.8055	119	3001	1138*
Butt Weld		D-1	603												6242	0.2378	1.0	0.2378		55	1242	4687
Straight	103	1	603-604	24.0	1.218				224.0	A106C	1000	555	360	26,250	2568	0.0978		0.0978	0.8055	107	487	632
Flow Nozzle (Between 603 and 604)		D-3a																				
Bend	104	3	604-605	24.0	1.218	144.0	6.0	15°		A106C	1000	555	360	26,250	710	0.0270		0.0270	0.8055	195	487	1045
Straight	105	1	605-606	24.0	1.218				165.5	A106C	1000	555	360	26,250	3001	0.1143		0.1143	0.8055	110	803	1182
Butt Weld		D-1	606												5565	0.2120	1.0	0.2120		198	1464	3317
Elbow	106	2	606-607	24.0	1.218	36	1.5	90°		A106C	1000	555	360	26,250	5647	0.2151		0.2151	0.8055	206	1032	3305
Butt Weld		D-1	607												4890	0.1863	1.0	0.1863		144	742	2655
Straight	107	1	607-608	24.0	1.218				9.0	A106C	1000	555	360	26,250	3028	0.1154		0.1710	0.8055	142	726	2744
6 in. Line to Safety Valve		D-4	608												2918	0.1112	1.54	0.1710		142	726	3092
Straight	108	1	608-609	24.0	1.218				30.0	A106C	1000	555	360	26,250	2918	0.1112		0.1710	0.8055	120	695	3459
6 in. Line to Safety Valve		D-4	609												2586	0.0985	1.54	0.1517		120	695	4140
Bend	109	3	609-610	24.0	1.218	129	5.5	15°		A106C	1000	555	360	26,250	2586	0.0985		0.1517	0.8055	133	729	4176
6 in. Line to Safety Valves		D-4	610												2224	0.0847	1.54	0.1304		133	729	4176
Bend	110	3	610-611	24.0	1.218	129	5.5	16°		A106C	1000	555	360	26,250	2224	0.0847		0.1304	0.8055	297	856	4270
6 in. Line to Safety Valve		D-4	611												1766	0.0673	1.54	0.1036		297	856	5134
Bend	111	3	611-612	24.0	1.218	130	5.5	14°		A106C	1000	555	360	26,250	1766	0.0673		0.8055	0.8055	120	674	5255
6 in. Line to Safety Valve		D-4	612												1314	0.0501	1.54	0.0785		120	674	5255
Straight	112	1	612-613	24.0	1.218				42.0	A106C	1000	555	360	26,250	1314	0.0501		0.0785	0.8055	37	528	2253
6 in. Line to Safety Valve		D-4	613												834	0.0318	1.54	0.0490		37	528	3086
Straight	113	1	613-614	24.0	1.218				30.0	A106C	1000	555	360	26,250	834	0.0318		0.0490	0.8055	37	516	1201

Model Number 1 Main Steam (South Side) *Steam Relief Line (South Side) Component or Discontinuity	Component Number	Type	MASS Joint Number	Diameter D (Outside), in.	Thickness t, in.	Radius of Curvature, ρ , in.	ρ/D^*	Included Angle θ	Length of Straight Pipe, in.	Material	Operating Pressure, psi	Operating Temperature, °F	Number of Cycles/40 yr.	$S_A = f(1.25 S_c + 0.25 S_A)$, psi	S_E from MASS, psi	S_E/S_A	Stress Int. Factor, i	$(S_E/S_A)_i$	A/A_{max}	S_w , Weight Stress, psi	S_q , Earthquake Stress, psi	S_I , Impact
6 in. Line to Safety Valve Straight	114	D-4 1	614 614-615	24.0	1.218				30.0	A106C	1000	555	360	26,250	825	0.0314	1.54	0.0480		77	516	1201
6 in. Line to Safety Valve Straight	115	D-4 1	615 615-616	24.0	1.218				30.0	A106C	1000	555	360	26,250	1124	0.0428	1.54	0.0480	0.8055	77	512	1858
6 in. Line to Relief Valve Straight	116	D-4 1	616 616-617	24.0	1.218				30.0	A106C	1000	555	360	26,250	1124	0.0428	1.54	0.0659	0.8055	72	512	1152
Butt Weld Elbow	117	D-1 2	617 617-618	24.0	1.218	35.9	1.5	90°		A106C	1000	555	360	26,250	1564	0.0596	1.54	0.0659	0.8055	72	524	3050
Butt Weld Straight	118	D-1 1	618 618-619	24.0	1.218				12.0	A106C	1000	555	360	26,250	1564	0.0596	1.54	0.0918	0.8055	34	515	3056
Butt Weld Elbow	119	D-1 2	619 619-620	24.0	1.218	24.0	1.0	90°		A106C	1000	555	360	26,250	1743	0.0664	1.0	0.0918	0.8055	33	493	947
Butt Weld Isolation Valve	120	D-1 4	620 620-621	24.0	1.218				204.0	A106C	1000	555	360	26,250	3034	0.1156	1.0	0.1156	0.8055	35	572	1205
*Straight	121	D-1 1	621 616-622	6.624	0.432					A106C	1000	555	360	26,250	3603	0.1373	1.0	0.1373	0.8055	64	1784	14720
Butt Weld Valve	122	D-1 4	622 622-623	6.624	1.6					A106C	1000	555	360	26,250	3514	0.1339	1.0	0.1339	0.8055	87	997	7928
Butt Weld Straight	123	D-1 1	623 623-624	6.624	0.432					A106C	1000	555	360	26,250	1942	0.0739	1.0	0.0739	0.8055	57	1206	7277
Butt Weld Elbow	124	D-1 2	624 624-625	6.624	0.432	12.0	2.0	90°		A106C	1000	555	360	26,250	2309	0.0880	1.0	0.0880	0.8055	46	2849	17690
Butt Weld Straight	125	D-1 1	625 625-626	6.624	0.432					A106C	1000	555	360	26,250	2670	0.1017	1.0	0.1017	0.8055	74	1508	8942
Bend	126	3	626-627	6.624	0.432	32.0	5.3	60°		A106C	1000	555	360	26,250	2050	0.0781	1.0	0.0781	0.8055	197	440	2742
Straight	127	1	627-628	6.624	0.432				57.0	A106C	1000	555	360	26,250	338	0.0129		0.0129	0.2495	144	733	4245
Bend	128	3	628-629	6.624	0.432	31.1	5.2	90°		A106C	1000	555	360	26,250	803	0.0306	1.0	0.0306	0.0575	211	3817	255
Straight	129	1	629-630	6.624	0.432				18.0	A106C	1000	555	360	26,250	803	0.0306	1.0	0.0306	0.0575	211	3629	118
Bend	130	3	630-631	6.624	0.432	12.0	2.0	90°		A106C	1000	555	360	26,250	432	0.0165	1.0	0.0165	0.0575	97	1698	118
Straight	131	1	631-632	6.624	0.432				27.0	A106C	1000	555	360	26,250	937	0.0357	1.0	0.0357	0.0575	208	3682	256
									9.0	A106C	1000	555	360	26,250	982	0.0374	1.0	0.0374	0.0575	208	3752	256
										A106C	1000	555	360	26,250	1301	0.0495	1.0	0.0495	0.0575	282	3867	348
										A106C	1000	555	360	26,250	1301	0.0495	1.0	0.0495	0.0575	297	4558	259
										A106C	1000	555	360	26,250	1202	0.0458	1.0	0.0458	0.0575	253	3498	192
									36.0	A106C	1000	555	360	26,250	1015	0.0387		0.0387	0.0575	1276	2617	29
										A106C	1000	555	360	26,250	946	0.0360		0.0360	0.0575	524	1847	28
									73.2	A106C	1000	555	360	26,250	823	0.0314		0.0314	0.0575	189	1567	26
										A106C	1000	555	360	26,250	489	0.0186		0.0186	0.0575	87	880	27
									64.7	A106C	1000	555	360	26,250	286	0.0109		0.0109	0.0575	1111	1544	27
										A106C	1000	555	360	26,250	342	0.0130		0.0130	0.0575	1506	397	41
									173.7	A106C	1000	555	360	26,250	897	0.0342		0.0342	0.0575	0	0	0

*Note: Safety valves are oriented such that alternate valves discharge in opposite directions so as to counterbalance the reaction forces. The impact stresses shown above assumed that four valves discharging in the same direction functioned properly while the four counterbalancing valves did not function. This is the worst case and would occur with low probability. Operation of one valve occurs with probability ~ 1 and results in stresses $\sim 1/4$ the values shown above.

Model Number 1 Reactor Drain Pipe	Component Number	Type	MASS Joint Number	Diameter D (Outside), in.	Thickness t, in.	Radius of Curvature, ρ , in.	ρ/D^*	Included Angle θ	Length of Straight Pipe, in.	Material	Operating Pressure, psi	Operating Temperature, °F	Number of Cycles/40 yr.	$S_A = f(1.25 S_c + 0.25 S_A)$, psi	S_E from MASS, psi	S_E/S_A	Stress i. Int. Factor	$(S_E/S_A)^i$	A/A _{max}	S_w Weight Stress, psi	S_q Earthquake Stress, psi
Pressure Vessel Nozzle Weld		D-1a	651							Seam- less 304					9219	0.3532	1.3	0.4592		81	2046
Straight	151	1	651-652	2.374	0.218				16.0	304	1000	551	500	26,100	9794	0.3752		0.3752	0.0065	77	1696
Weld		D-1a	652												16940	0.6490	1.3	0.8437		134	1836
Elbow	152	2	652-653	2.374	0.218	2.0	1.0	90°		304	1000	551	500	26,100	16940	0.6490		0.6490	0.0065	44	2695
Weld		D-1a	653												16940	0.6490	1.3	0.8224		25	1594
Straight	153	1	653-654	2.374	0.218				95.0	304	1000	551	500	26,100	9545	0.3657		0.3657	0.0065	70	1753
Weld		D-1a	654												9801	0.3755	1.3	0.4882		121	3033
Elbow	154	2	654-655	2.374	0.218	2.0	1.0	90°		304	1000	551	500	26,100	10230	0.3920		0.3920	0.0065	52	3000
Weld		D-1a	655												10230	0.3920	1.3	0.5096		30	1734
Straight	155	1	655-656	2.374	0.218				120.3	304	1000	551	500	26,100	5913	0.2266		0.2266	0.0065	5	2493
Weld		D-1a	656												2759	0.1057	1.3	0.1374		8	4313
Elbow	156	2	656-657	2.374	0.218	2.0	1.0	45°		304	1000	551	500	26,100	2833	0.1085		0.1085	0.0065	6	4220
Weld		D-1a	657												2833	0.1085	1.3	0.1411		4	2439
Straight	157	1	657-658	2.374	0.218				15.3	304	1000	551	500	26,100	2976	0.1140		0.1140	0.0065	79	1642
Weld		D-1a	658												5150	0.1973	1.3	0.2565		137	2450
Elbow	158	2	658-659	2.374	0.218	2.0	1.0	45°		304	1000	551	500	26,100	5229	0.2003		0.2003	0.0065	34	2889
Weld		D-1a	659												5224	0.2002	1.3	0.2603		20	1678
Straight	159	1	659-660	2.374	0.218				196.0	304	1000	551	500	26,100	4032	0.1545		0.1545	0.0065	22	2104
Weld		D-1a	660												4032	0.1545	1.3	0.2009		13	1244
Valve	160	4	660-661	2.374	0.218				4.0	304	1000	551	500	26,100	2469	0.0946		0.0946	0.0024	13	1443
Model Number 2 Core Spray (Line 1)																					
Pressure Vessel Nozzle Weld		D-1	1												478	0.0174	1.0	0.0174		2306	3826
Straight	201	1	1-2	6.624	0.432				30.9	304	1000	146	370	27,400	478	0.0174		0.0174	0.0575	350	3139
Weld		D-1	2												613	0.0224	1.0	0.0224		621	4678
Elbow	202	2	2-3	6.624	0.432	8	1.3	90°		304	1000	146	370	27,400	741	0.0270		0.0270	0.0575	196	4687
Weld		D-1	3												741	0.0270	1.0	0.0270		128	4687
Straight	203	1	3-4	6.624	0.432				81.0	304	1000	146	370	27,400	638	0.0233		0.0233	0.0575	85	1436
Weld		D-1	4												638	0.0233	1.0	0.0233		85	1436

Model Number 2 Core Spray (Line 1) (Continued)	Component Number	Type	MASS Joint Number	Diameter D (Outside), in.	Thickness t, in.	Radius of Curvature, ρ, in.	ρ/D*	Included Angle θ	Length of Straight Pipe, in.	Material	Operating Pressure, psi	Operating Temperature, °F	Number of Cycles/40 yr.	$S_A = f(1.25 S_c + 0.25 S_A)$, psi	S_E from MASS, psi	S_E/S_A	Stress Int. Factor, i	$(S_E/S_A)_i$	A/A _{max}	S _w , Weight Stress, psi	S _q , Earthquake Stress, psi
Elbow	204	2	4-5	6.624	0.432	40	6.6	90°		Seamless 304	1000	146	370	27,400	698	0.0255		0.0255	0.0575	572	2028
Weld		D-1	5												698	0.0255	1.0	0.0255		572	2028
Straight	205	1	5-6	6.624	0.432				8.0	304	1000	146	370	27,400	698	0.0255		0.0255	0.0575	591	2085
Bend	206	3	6-7	6.624	0.432	40	6.6	45°		304	1000	146	370	27,400	695	0.0254		0.0254	0.0575	591	2097
Straight	207	1	7-8	6.624	0.432				59.1	304	1000	146	370	27,400	659	0.0241		0.0241	0.0575	472	2097
Hanger Location		D-2	8												609	0.0222	1.0	0.0222		933	1728
Bend	208	3	8-9	6.624	0.432	40	6.6	45°		304	1000	146	370	27,400	609	0.0222		0.0222	0.0575	100	1728
Straight	209	1	9-10	6.624	0.432				138.0	304	1000	146	370	27,400	576	0.0210		0.0210	0.0575	476	1409
Bend	210	3	10-11	6.624	0.432	40	6.6	45°		304	1000	146	370	27,400	513	0.0187		0.0187	0.0575	476	1347
Hanger Location		D-2	11												497	0.0181	1.0	0.0181		418	1347
Straight	211	1	11-12	6.624	0.432				145.0	304	1000	146	370	27,400	552	0.0201		0.0201	0.0575	454	1598
Bend	212	3	12-13	6.624	0.432	40	6.6	45°		304	1000	146	370	27,400	600	0.0219		0.0219	0.0575	454	1598
Hanger Location		D-2	13												600	0.0219	1.0	0.0219		371	1056
Straight	213	1	13-14	6.624	0.432				120.6	304	1000	146	370	27,400	885	0.0323		0.0323	0.0575	542	2038
Bend	214	3	14-15	6.624	0.432	41	6.8	66°		304	1000	146	370	27,400	1061	0.0387		0.0387	0.0575	542	3078
Weld		D-1	15												1061	0.0387	1.0	0.0387		570	3078
Isolation Valve	215	4	15-16	6.624	0.432				30.0	304	1000	146	370	27,400	531	0.0194		0.0194	0.0575	1153	1489
Model Number 2 Core Spray - Line 2										Seam- less											
Pressure Vessel Nozzle Weld		D-1	21	6.624	0.432				30.9	304	1000	146	370	27,400	17240	0.6292	1.0	0.0692		3654	892
Straight	221	1	21-22	6.624	0.432				30.9	304	1000	146	370	27,400	17240	0.6292		0.0692	0.0575	77	677
Weld		D-1	22												388	0.0142	1.0	0.0142		110	757
Elbow	222	2	22-23	6.624	0.432	8	1.3	90°		304	1000	146	370	27,400	5344	0.1950		0.1950	0.0575	1356	890
Weld		D-1	23												5344	0.1950	1.0	0.1950		762	593
Straight	223	1	23-24	6.624	0.432				51.0	304	1000	146	370	27,400	6443	0.2351		0.2351	0.0575	381	726
Weld		D-1	24												6443	0.2351	1.0	0.2351		381	726
Valve	224	4	24-25	6.624	0.432				30.0	304	1000	146	370	27,400	11990	0.4376		0.4376	0.0575	157	759
Weld		D-1	25												11990	0.4376	1.0	0.4376		157	759
Bend	225	3	25-26	6.624	0.432	40	6.6	90°		304	1000	146	370	27,400	11990	0.4376		0.4376	0.0575	173	244
Straight	226	1	26-27	6.624	0.432				43.8	304	1000	146	370	27,400	27450	1.0020		1.0020	0.0575	298	286
Weld		D-1	27												27450	1.0020	1.0	1.0020		138	650
Isolation Valve	227	4	27-28	6.624	0.432				30.0	304	1000	146	370	27,400	20390	0.7442		0.7442	0.0575	878	1033

Model Number 2 Feed Water (South Side) Component or Discontinuity	Component Number	Type	MASS Joint Number	Diameter D (Outside), in.	Thickness t, in.	Radius of Curvature, ρ , in.	ρ/D^*	Included Angle θ	Length of Straight Pipe, in.	Material	Operating Pressure, psi	Operating Temperature, °F	Number of Cycles/40 yr.	$S_A = f(1.25 S_c + 0.25 S_A)$, psi	S_E Expansion	S_E/S_A	Stress Int. Factor, i	$(S_E/S_A)^i$	A/A _{max}	S_w , Weight Stress, psi	S_q , Earthquake Stress, psi
Pressure Vessel Nozzle Weld		D-1	701												892	0.0340	1.0	0.0340		1478	2548
Straight	301	1	701-702	10.75	0.593				18.8	A106C	1260	325	440	26,250	892	0.0340		0.0340	0.1585	564	2489
Weld		D-1	702												984	0.0375	1.0	0.0375		976	2876
Elbow	302	2	702-703	10.75	0.593	15	1.5	90°		A106C	1260	325	440	26,250	1270	0.0484		0.0484	0.1585	463	3800
Weld		D-1	703												1270	0.0484	1.0	0.0484		256	3800
Straight	303	1	703-704	10.75	0.593				130.9	A106C	1260	325	440	26,250	704	0.0268		0.0268	0.1585	290	2048
Bend	304	3	704-705	10.75	0.593	15	1.5	45°		A106C	1260	325	440	26,250	514	0.0196		0.0196	0.1585	526	3981
Straight	305	1	705-706	10.75	0.593				210.6	A106C	1260	325	440	26,250	471	0.0179		0.0179	0.1585	624	2192
Bend	306	3	706-707	10.75	0.593	15	1.5	45°		A106C	1260	325	440	26,250	875	0.0333		0.0333	0.1585	232	988
Bend	307	3	707-708	10.75	0.593	15	1.5	60°		A106C	1260	325	440	26,250	851	0.0324		0.0324	0.1585	644	603
Hanger		D-2	708												807	0.0307	1.0	0.0307		1346	1136
Straight	308	1	708-709	10.75	0.593				168.7	A106C	1260	325	440	26,250	1184	0.0451		0.0451	0.1585	1123	1191
Bend	309	3	709-710	10.75	0.593	15	1.5	45°		A106C	1260	325	440	26,250	2160	0.0823		0.0823	0.1585	1947	2180
Straight	310	1	710-711	10.75	0.593				51.9	A106C	1260	325	440	26,250	1642	0.0626		0.0626	0.1585	1046	1191
10 × 18 Reducer		D-6	711												1642	0.0626	1.0	0.0626		634	907
18-in. Run of Tee 712	311	1	711-712	18.0	0.937				24.0	A106C	1260	325	440	26,250	411	0.0157		0.1605	0.4505	173	225
Pressure Vessel Nozzle Weld		D-1	721												1983	0.0755	1.0	0.0755		1594	1335
Straight	321	1	721-722	10.75	0.593				18.8	A106C	1260	325	440	26,250	1983	0.0755		0.0755	0.1585	316	1565
Weld		D-1	722												2382	0.0907	1.0	0.0907		575	2559
Elbow	322	2	722-723	10.75	0.593	15	1.5	90°		A106C	1260	325	440	26,250	2382	0.0907		0.0907	0.1585	992	2565
Weld		D-1	723												1745	0.0665	1.0	0.0665		545	2565
Straight	323	1	723-724	10.75	0.593				165.0	A106C	1260	325	440	26,250	1281	0.0488		0.0488	0.1585	870	1699
Bend	324	3	724-725	10.75	0.593	15	1.5	49°		A106C	1260	325	440	26,250	2371	0.0903		0.0903	0.1585	1628	3236
10-in. Branch of Tee 712	325	1	725-712	10.75	0.593				170.4	A106C	1260	325	440	26,250	2790	0.1063		0.1605	0.1585	1510	1745
10 × 18 Tee 12		D-4	712												2790	0.1063	1.51	0.1605		273	304
18-in. Run of Tee 712	312	1	712-713	18.0	0.937				139.4	A106C	1260	325	440	26,250	675	0.0257		0.1605	0.4505	1153	571
Hanger		D-2	713												1053	0.0401	1.0	0.0401		2070	973
Bend	313	3	713-714	18.0	0.937	27	1.5	90°		A106C	1260	325	440	26,250	1444	0.0550		0.0550	0.4505	433	2331
Straight	314	1	714-715	18.0	0.937				42.1	A106C	1260	325	440	26,250	849	0.0323		0.0323	0.4505	259	1296
Weld		D-1	715												849	0.0323	1.0	0.0323	0.4505	219	909
Valve	315	4	715-716	18.0	4.5				48.7	A106C	1260	325	440	26,250	325	0.0128		0.0128	0.4505	83	345
Weld		D-1	716												882	0.0336	1.0	0.0336		69	571
Straight	316	1	716-717	18.0	0.937				47.0	A106C	1260	325	440	26,250	915	0.0349		0.0349	0.4505	182	1507
Weld		D-1	717												1632	0.0622	1.0	0.0622		164	2743
Elbow	317	2	717-718	18.0	0.937	27	1.5	90°		A106C	1260	325	440	26,250	2005	0.0764		0.0764	0.4505	234	2446
Weld		D-1	718												2005	0.0764	1.0	0.0764		296	2446
Isolation Valve	318	4	718-719	18.0	4.5				31.0	A106C	1260	325	440	26,250	485	0.0185		0.0185	0.4505	294	1093

Model Number 2 Feed Water (North Side) Component or Discontinuity	Component Number	Type	MASS Joint Number	Diameter D (Outside), in.	Thickness t, in.	Radius of Curvature, ρ , in.	ρ/D^*	Included Angle θ	Length of Straight Pipe, in.	Material	Operating Pressure, psi	Operating Temperature, °F	Number of Cycles/40 yr.	$S_A = f(1.25 S_c + 0.25 S_A)$, psi	S_E from MASS, psi	S_E/S_A	Stress Int. Factor, i	$(S_E/S_A)^i$	A/A_{max}	S_w Weight Stress, psi	S_q Earthquake Stress, psi
Pressure Vessel Nozzle Weld		D-1	751												892	0.0340	1.0	0.0340		2633	3634
Straight	351	1	751-752	10.75	0.593				18.8	A106C	1260	325	440	26,250	892	0.0340		0.0340	0.1585	994	3602
Weld		D-1	752												985	0.0375	1.0	0.0375		1780	4549
Elbow	352	2	752-753	10.75	0.593	15	1.5	90°		A106C	1260	325	440	26,250	1270	0.0484		0.0484	0.1585	665	5513
Weld		D-1	753												1270	0.0484	1.0	0.0484		363	5513
Straight	353	1	753-754	10.75	0.593				130.9	A106C	1260	325	440	26,250	704	0.0268		0.0268	0.1585	362	3046
Bend	354	3	754-755	10.75	0.593				210.6	A106C	1260	325	440	26,250	514	0.0196		0.0196	0.1585	663	5878
Straight	355	1	755-756	10.75	0.593				210.6	A106C	1260	325	440	26,250	471	0.0179		0.0179	0.1585	873	3237
Bend	356	3	756-757	10.75	0.593	15	1.5	45°		A106C	1260	325	440	26,250	876	0.0334		0.0334	0.1585	239	790
Bend	357	3	757-758	10.75	0.593	15	1.5	60°		A106C	1260	325	440	26,250	852	0.0325		0.0325	0.1585	682	707
Hanger		D-2	758												808	0.0308	1.0	0.0308		1397	1650
Straight	358	1	758-759	10.75	0.593				168.7	A106C	1260	325	440	26,250	1183	0.0451		0.0451	0.1585	1923	1472
Bend	359	3	759-760	10.75	0.593	15	1.5	45°		A106C	1260	325	440	26,250	2160	0.0823		0.0823	0.1585	1823	2694
Straight	360	1	760-761	10.75	0.593				51.9	A106C	1260	325	440	26,250	1642	0.0626		0.0626	0.1585	1038	1442
10 - 18 Reducer		D-6	761												1642	0.0626	1.0	0.0626		611	909
18-in. Run of Tee 762	361	1	761-762	18.0	0.937				24.0	A106C	1260	325	440	26,250	411	0.0157		0.1605	0.4505	166	242
Pressure Vessel Nozzle Weld		D-1	771												1983	0.0755	1.0	0.0755		1598	1408
Straight	371	1	771-772	10.75	0.593				18.8	A106C	1260	325	440	26,250	1983	0.0755		0.0755	0.1585	312	1680
Weld		D-1	772												2381	0.0907	1.0	0.0907		569	2865
Elbow	372	2	772-773	10.75	0.593	15	1.5	90°		A106C	1260	325	440	26,250	2381	0.0907		0.0907	0.1585	1003	2800
Weld		D-1	773												1745	0.0665	1.0	0.0665		551	2800
Straight	373	1	773-774	10.75	0.593				165.8	A106C	1260	325	440	26,250	1281	0.0488		0.0488	0.1585	873	1766
Bend	374	3	774-775	10.75	0.593	15	1.5	49°		A106C	1260	325	440	26,250	2370	0.0903		0.0903	0.1585	1634	3620
10-in. Branch of Tee 762	375	1	775-762	10.75	0.593				170.4	A106C	1260	325	440	26,250	2789	0.1062		0.1605	0.1585	1517	1953
10 - 18 Tee 762		D-4	762												2789	0.1062	1.51	0.1605		866	1031
18-in. Run of Tee 762	362	1	762-763	18.0	0.937				139.4	A106C	1260	325	440	26,250	675	0.0257		0.1605	0.4505	1147	333
Hanger		D-2	763												1053	0.0401	1.51	0.0401		2060	673
Bend	363	3	763-764	18.0	0.937	27	1.5	90°		A106C	1260	325	440	26,250	1444	0.0550		0.0550	0.4505	425	2442
Straight	364	1	764-765	18.0	0.937				42.1	A106C	1260	325	440	26,250	849	0.0323		0.0323	0.4505	216	1373
Weld		D-1	765												849	0.0323	1.51	0.0323		82	958
Valve	365	4	765-766	18.0	4.5				48.5	A106C	1260	325	440	26,250	335	0.0128		0.0128	0.1403	69	364
Weld		D-1	766												882	0.0336	1.51	0.0336		182	651
Straight	366	1	766-767	18.0	0.937				47.0	A106C	1260	325	440	26,250	915	0.0349		0.0349	0.4505	166	1621
Weld		D-1	767												1633	0.0622	1.51	0.0622		243	2928
Elbow	367	2	767-768	18.0	0.937	27	1.5	90°		A106C	1260	325	440	26,250	2005	0.0764		0.0764	0.4505	291	2501
Weld		D-1	768												2005	0.0764	1.51	0.0764		65	2501
Isolation Valve	368	4	768-769	18.0	4.5				31.0	A106C	1260	325	440	26,250	485	0.0184		0.0184	0.1403	300	1114

Model Number 3 Control Rod Drive (From C. R. D. to P. V.)	Component Number	Type	MASS Joint Number	Diameter D (Outside), in.	Thickness t, in.	Radius of Curvature, ρ , in.	ρ/D^*	Included Angle θ	Length of Straight Pipe, in.	Material	Operating Pressure, psi	Operating Temperature, °F	Number of Cycles/40 yr.	$S_A = f(1.25 S_C + 0.25 S_A)$, psi	S_E from MASS, psi	S_E/S_A	Stress Int. Factor, i	$(S_E/S_A)^i$	A/A_{max}	S_w , Weight Stress, psi	S_q , Earthquake Stress, psi
Pressure Vessel Nozzle Weld		D-1	1							Seam- less					1675	0.0642	1.0	0.0642		3520	5570
Straight	401	1	1-2	3.5	0.3				42.8	304	1000	551	360	26,100	1675	0.0642		0.0642	0.0146	3520	4480
Weld		D-1	2												1821	0.0698	1.0	0.0698		314	4600
Elbow	402	2	2-3	3.5	0.3	5	1.6	90°		304	1000	551	360	26,100	1841	0.0706		0.0706	0.0146	788	5320
Weld		D-1	3												1753	0.0672	1.0	0.0672		788	5320
Straight	403	1	3-4	3.5	0.3				153.0	304	1000	551	360	26,100	1387	0.0531		0.0531	0.0146	613	5320
Weld		D-1	4												784	0.0300	1.0	0.0300		696	4890
Elbow	404	2	4-5	3.5	0.3	5	1.6	90°		304	1000	551	360	26,100	859	0.0329		0.0329	0.0146	696	4890
Weld		D-1	5												859	0.0329	1.0	0.0329		671	4030
Straight	405	1	5-6	3.5	0.3				44.0	304	1000	551	360	26,100	722	0.0277		0.0277	0.0146	523	4220
Hanger and Weld		D-1, 2	6												882	0.0338	1.0	0.0338		258	4380
Elbow	406	2	6-7	3.5	0.3	5	1.6	90°		304	1000	551	360	26,100	882	0.0338		0.0338	0.0146	258	4940
Weld		D-1	7												767	0.0294	1.0	0.0294		208	4940
Straight	407	1	7-8	3.5	0.3				37.0	304	1000	551	360	26,100	714	0.0274		0.0274	0.0146	389	3840
Hanger		D-2	8												714	0.0274	1.0	0.0274		389	1410
Bend	408	3	8-9	3.5	0.3	40	13.3	45°		304	1000	551	360	26,100	805	0.0308		0.0308	0.0146	844	1410
Hanger		D-2	9												805	0.0308	1.0	0.0308		844	889
Straight	409	1	9-10	3.5	0.3				145.0	304	1000	551	360	26,100	1260	0.0483		0.0483	0.0146	844	1100
Hanger		D-2	10												1260	0.0483	1.0	0.0483		532	1100
Bend	410	3	10-11	3.5	0.3	40	13.3	45°		304	1000	551	360	26,100	1291	0.0495		0.0495	0.0146	561	1560
Hanger		D-2	11												1250	0.0479	1.0	0.0479		561	1560
Straight	411	1	11-12	3.5	0.3					304	1000	551	360	26,100	1250	0.0479		0.0479	0.0146	570	1560
Hanger		D-2	12												667	0.0256	1.0	0.0256		570	1110
Bend	412	3	12-13	3.5	0.3	40	13.3	45°		304	1000	551	360	26,100	667	0.0256		0.0256	0.0146	570	1110
Hanger		D-2	13												486	0.0186	1.0	0.0186		430	960
Straight	413	1	13-14	3.5	0.3				104.2	304	1000	551	360	26,100	989	0.0379		0.0379	0.0146	430	3420
Bend	414	3	14-15	3.5	0.3	5	1.3	90°		304	1000	551	360	26,100	1278	0.0490		0.0490	0.0146	140	4400
Hanger		D-2	15												1278	0.0490	1.0	0.0490		96	4400
Straight	415	1	15-16	3.5	0.3				192.4	304	1000	551	360	26,100	1018	0.0390		0.0390	0.0146	80	3970
Connection to Isolation Valve		D-1	16												973	0.0373	1.0	0.0373		66	3970
Isolation Valve	416	4	16-17	3.5	0.3				12.0	304	1000	551	360	26,100	579	0.0222		0.0222	0.0050	460	2680

Model Number 3 Control Rod Drive (Insert) Component or Discontinuity	Component Number	Type	MASS Joint Number	Diameter D (Outside), in.	Thickness t, in.	Radius of Curvature, ρ , in.	ρ/D^*	Included Angle θ	Length of Straight Pipe, in.	Material	Operating Pressure, psi	Operating Temperature, °F	Number of Cycles/40 yr.	$S_A = f(1.25 S_c + 0.25 S_A)$, psi	S_E from MASS, psi	S_E/S_A	Stress Int. Factor, i	$(S_E/S_A)^i$	A/A_{max}	S_w Weight Stress, psi	S_q Earthquake Stress, psi
Weld to CRD Thimble		D-1a	21							Seamless					6857	0.2627	1.3	0.3415		1867	3689
Straight	421	1	21-22	1.050	0.154				28.0	304	1000	551	200	26,100	6857	0.2627		0.2627	0.001	1898	3689
Bend	422	3	22-23	1.050	0.154	5	0.66	90°		304	1000	551	200	26,100	3351	0.1284		0.1284	0.001	1936	1507
Socket Weld Reducer Coupling		D-1a, 6	23												2902	0.1112	1.3	0.1446		1936	2223
Bend	423	3	23-24	1.316	0.179	5	5	60°		304	1000	551	200	26,100	1615	0.0619		0.0619	0.0016	1026	1338
Straight	424	1	24-25	1.316	0.179				5.6	304	1000	551	200	26,100	1649	0.0632		0.0632	0.0016	974	1339
Bend	425	3	25-26	1.316	0.179	5	5	60°		304	1000	551	200	26,100	1771	0.0679		0.0679	0.0016	836	1344
Straight	426	1	26-27	1.316	0.179				43.7	304	1000	551	200	26,100	2475	0.0948		0.0948	0.0016	1770	1167
Bend	427	3	27-28	1.316	0.179	5	5	90°		304	1000	551	200	26,100	2475	0.0948		0.0948	0.0016	1770	915
Hanger		D-2	28												2234	0.0856	1.0	0.0856		1120	770
Straight (Riser)	428	1	28-29	1.316	0.179				88.0	304	1000	551	200	26,100	3620	0.1387		0.1387	0.0016	1120	770
Hanger		D-2	29												3620	0.1387	1.0	0.1387		764	451
Bend	429	3	29-30	1.316	0.179	5	5	90°		304	1000	551	200	26,100	3861	0.1479		0.1479	0.0016	1421	516
Straight	430	1	30-31	1.316	0.179				52.5	304	1000	551	200	26,100	3861	0.1479		0.1479	0.0016	1421	516
Bend	431	3	31-32	1.316	0.179	10	10	30°		304	1000	551	200	26,100	2933	0.1124		0.1124	0.0016	1687	1036
Hanger		D-2	32												2833	0.1085	1.0	0.1085		1687	1032
Straight	432	1	32-33	1.316	0.179				18.5	304	1000	551	200	26,100	2833	0.1085		0.1085	0.0016	1687	1032
Hanger		D-2	33												2586	0.0991	1.0	0.0991		4319	841
Bend	433	3	33-34	1.316	0.179	10	10	24°		304	1000	551	200	26,100	2586	0.0991		0.0991	0.0016	4319	1455
Straight	434	1	34-35	1.316	0.179				188.6	304	1000	551	200	26,100	2514	0.0963		0.0963	0.0016	2532	1455
Socket Weld 1 in. x 1 in.		D-1a	35												993	0.0380	1.3	0.0494		1171	762
Straight	435	1	35-36	1.316	0.179				81.1	304	1000	551	200	26,100	2433	0.0932		0.0932	0.0016	3346	965
Hanger and Weld		D-1a, 2	36												2433	0.0932	1.3	0.1213		3925	2040

Model Number 3 Control Rod Drive Withdraw	Component Number	Type	MASS Joint Number	Diameter D (Outside), in.	Thickness t, in.	Radius of Curvature, ρ , in.	ρ/D^*	Included Angle θ	Length of Straight Pipe, in.	Material	Operating Pressure, psi	Operating Temperature, °F	Number of Cycles/40 yr.	$S_A = f(1.25 S_c + 0.25 S_A)$, psi	S_E from MASS, psi	S_E/S_A	Stress Int. Factor, i	$(S_E/S_A)^i$	A/A_{max}	S_w Weight Stress, psi	S_q Earthquake Stress, psi
Weld at CRD Thimble		D-1a	41							Seamless					2371	0.0908	1.3	0.1180		2798	6033
Straight	441	1	41-42	1.05	0.154				46.0	304	1000	551	200	26,100	2371	0.0908		0.0908	0.001	3520	6033
Bend	442	3	42-43	1.05	0.154	5	5	90°		304	1000	551	200	26,100	1052	0.0403		0.0403	0.001	3526	2105
Straight	443	1	43-44	1.05	0.154				49.0	304	1000	551	200	26,100	1346	0.0516		0.0516	0.001	3041	2535
Bend	444	3	44-45	1.05	0.154	5	5	60°		304	1000	551	200	26,100	1349	0.0517		0.0517	0.001	3041	677
Socket Weld		D-1a	45												1319	0.0505	1.3	0.0657		2910	656
Straight	445	1	45-46	1.05	0.154				35.7	304	1000	551	200	26,100	1319	0.0505		0.0505	0.001	2910	1536
Bend	446	3	46-47	1.05	0.154	5	5	60°		304	1000	551	200	26,100	1303	0.0499		0.0499	0.001	1116	1536
Straight	447	1	47-48	1.05	0.154				20.8	304	1000	551	200	26,100	1538	0.0589		0.0589	0.001	1434	1226
Bend	448	3	48-49	1.05	0.154	5	5	90°		304	1000	551	200	26,100	1538	0.0589		0.0589	0.001	1434	867
Hanger (Riser)		D-2	49												1424	0.0546	1.0	0.0546		1199	968
Straight (in Riser)	449	1	49-50	1.05	0.154				100.0	304	1000	551	200	26,100	2205	0.0845		0.0845	0.001	1237	968
Hanger (Riser)		D-2	50												2204	0.0844	1.0	0.0844		1237	621
Bend	450	3	50-51	1.05	0.154	5	5	90°		304	1000	551	200	26,100	2323	0.0890		0.0890	0.001	1237	720
Straight	451	1	51-52	1.05	0.154				136.2	304	1000	551	200	26,100	2323	0.0890		0.0890	0.001	1145	721
Bend	452	3	52-53	1.05	0.154	10	10	30°		304	1000	551	200	26,100	1131	0.0433		0.0433	0.001	1145	1163
Straight	453	1	53-54	1.05	0.154				124.8	304	1000	551	200	26,100	1066	0.0408		0.0408	0.001	784	1043
Hanger		D-2	54												655	0.0255	1.0	0.0255		378	934
Bend	454	3	54-55	1.05	0.154	10	10	24°		304	1000	551	200	26,100	698	0.0267		0.0267	0.001	1192	934
Straight	455	1	55-56	1.05	0.154				12.0	304	1000	551	200	26,100	834	0.0320		0.0320	0.001	1192	553
Socket Weld Reducer 1 in. x 3/4 in.		D-1a, 6	56												834	0.0320	1.3	0.0416		885	1072
Straight	456	1	56-57	1.05	0.154				81.2	304	1000	551	200	26,100	1637	0.0627		0.0627	0.001	885	1951
Hanger and Weld		D-1a, 2	57												1637	0.0627	1.3	0.0815		547	1951
Model Number 3 Poison Spray Weld to Pressure Vessel Nozzle		D-1a	61							Seamless					2314	0.0887	1.3	0.1153		529	5912
Straight	461	1	61-62	2.0	0.5				7.32	304	1000	551	370	26,100	2314	0.0887		0.0887	0.0017	529	5912
2 in. x 1-1/2 in. Tee		D-4	62												1842	0.0706	1.0	0.0706		65	4326
Straight	462	1	62-63	2.0	0.5				7.32	304	1000	551	370	26,100	1842	0.0706		0.0706	0.0017	607	4326
2 in. x 1-1/2 in. Reducer		D-6	63												2596	0.0995	1.0	0.0995		1085	5096
Straight	463	1	63-64	1.9	0.2				5.21	304	1000	551	370	26,100	2596	0.0995		0.0995	0.0039	1936	5096
Hanger		D-2	64												2273	0.0871	1.0	0.0871		1936	3501
Bend	464	3	64-65	1.9	0.2	6	4	105°		304	1000	551	370	26,100	2273	0.0871		0.0871	0.0039	1936	3501
Straight	465	1	65-66	1.9	0.2				490.0	304	1000	551	370	26,100	4491	0.1721		0.1721	0.0039	260	375
Bend	466	3	66-67	1.9	0.2	6	4	90°		304	1000	551	370	26,100	4491	0.1721		0.1721	0.0039	944	245
Straight	467	1	67-68	1.9	0.2				111.5	304	1000	551	370	26,100	12710	0.4870		0.4870	0.0039	944	649
Attachment to Valve and Hanger		D-1a, 2	68												12710	0.4870	1.3	0.6331		184	2751
Isolation Valve	468	4	68-69	1.9	0.5				9.0	304	1000	551	370	26,100	8998	0.3448		0.3448	0.0039	2642	2995

Model Number 4 Emergency Condenser Steam (North Side) Component or Discontinuity	Component Number	Type	MASS Joint Number	Diameter D (Outside), in.	Thickness t, in.	Radius of Curvature, ρ, in.	ρ/D*	Included Angle θ	Length of Straight Pipe, in.	Material	Operating Pressure, psi	Operating Temperature, °F	Number of Cycles/40 yr.	$S_A = f(1.25 S_c + 0.25 S_A)$, psi	S_E from MASS, psi	S_E/S_A	Stress Int. Factor, i	$(S_E/S_A)_i$	A/A _{max}	S_w , Weight Stress, psi	S_q , Earthquake Stress, psi
Pressure Vessel		D-1	161												6974	0.2672	1.0	0.2672		2217	2512
Nozzle Weld										Seamless											
Straight	501	1	161-162	10.75	0.593				3.0	304	1000	552	500	26,100	7033	0.2695		0.2695	0.1585	2166	2604
Weld		D-1	162												7033	0.2695	1.0	0.2695		3291	4060
Elbow	502	2	162-163	10.75	0.593	18	1.8	90°		304	1000	552	500	26,100	11320	0.4337		0.4337	0.1585	1973	4715
Weld		D-1	163												11320	0.4337	1.0	0.4337		1973	4715
Straight	503	1	163-164	10.75	0.593				43.5	304	1000	552	500	26,100	7161	0.2744		0.2744	0.1585	1707	2949
Bend	504	3	164-165	10.75	0.593	48	4.8	70°		304	1000	552	500	26,100	6390	0.2448		0.2448	0.1585	2882	2662
Hanger		D-2	165												4325	0.1657	1.0	0.1657		2882	1434
Straight	505	1	165-166	10.75	0.593				111.9	304	1000	552	500	26,100	5085	0.1948		0.1948	0.1585	910	1904
Weld		D-1	166												7270	0.2785	1.0	0.2785		1195	3073
Elbow	506	2	166-167	10.75	0.593	18	1.8	90°		304	1000	552	500	26,100	8131	0.3115		0.3115	0.1585	1172	3760
Weld		D-1	167												8131	0.3115	1.0	0.3115		1172	3760
Straight	507	1	167-168	10.75	0.593				156.0	304	1000	552	500	26,100	5321	0.2039		0.2039	0.1585	2731	2469
Pipe to Valve Attachment		D-1	168												4770	0.1828	1.0	0.1828		2731	2469
Valve	508	4	168-169	10.75	0.593				36.0	304	1000	552	500	26,100	2389	0.0915		0.0915		1111	1933
Valve to Valve Connection		D-1	169												2389	0.0915	1.0	0.0915		1078	1242
Valve	509	4	169-170	10.75	0.593				36.0	304	1000	552	500	26,100	2907	0.1114		0.1114		1078	1306
Pipe to Valve Attachment		D-1	170												7147	0.2738	1.0	0.2738		1651	3210
Straight	510	1	170-171	10.75	0.593				117.0	304	1000	552	500	26,100	11780	0.4513		0.4513	0.1585	4635	2835
Reducer (10 × 16) Hanger		D-2, 6	171												11780	0.4513	1.0	0.4513		4635	2835
Bend	511	3	171-172	16.0	0.843	60	3.75	90°		Welded	1000	552	500	26,100	4025	0.1542		0.1542	0.3549	1461	1303
Straight	512	1	172-173	16.0	0.843				266.0	304	1000	552	500	26,100	3685	0.1412		0.1412	0.3549	436	1398
Bend	513	3	173-174	16.0	0.843	60	3.75	90°		304	1000	552	500	26,100	1786	0.0684		0.0684	0.3549	436	1886
Hanger		D-2	174												1786	0.0684	1.0	0.0684		190	1886
Straight	514	1	174-175	16.0	0.843				6.0	304	1000	552	500	26,100	1809	0.0693		0.0693	0.3549	183	1886
Bend	515	3	175-176	16.0	0.843	60	3.75	90°		304	1000	552	500	26,100	1809	0.0693		0.0693	0.3549	218	1827
16-in. Run of Tee 177	516	1	176-177	16.0	0.843				73.0	304	1000	552	500	26,100	1259	0.0482		0.1917	0.3549	218	1382
Tee (16 × 12)		D-4	177												3335	0.1278	1.5	0.1917		45	1382
16-in. Run of Tee 177	517	1	177-178	16.0	0.843				10.0	304	1000	552	500	26,100	3480	0.1333		0.1917	0.2242	45	577
Reducer (16 × 12) Weld		D-1, 6	178												6307	0.2416	1.0	0.2416		121	1826
Elbow	518	2	178-179	12.75	0.687	18	1.5	90°		304	1000	552	500	26,100	6307	0.2416		0.2416	0.2242	121	1826

Model Number 4 Emergency Condenser Steam (North Side) (Continued) Component or Discontinuity	Component Number	Type	MASS Joint Number	Diameter D (Outside), in.	Thickness t, in.	Radius of Curvature, ρ, in.	ρ/D*	Included Angle θ	Length of Straight Pipe, in.	Material	Operating Pressure, psi	Operating Temperature, °F	Number of Cycles/40 yr.	$S_A = f(1.25 S_c + 0.25 S_A)$, psi	S_E from MASS, psi	S_E/S_A	Stress Int. Factor, i	$(S_E/S_A)^i$	A/A _{max}	S_w , Weight Stress, psi	S_q , Earthquake Stress, psi
Weld		D-1	179							Welded					5239	0.2007	1.0	0.2007		72	1588
Straight	519	1	179-180	12.75	0.687				66.3	304	1000	552	500	26,100	3264	0.1251		0.1251	0.2242	90	1096
Bend	520	3	180-181	12.75	0.687	60	5.0	90°		304	1000	552	500	26,100	2037	0.0780		0.0780	0.2242	316	1079
Straight	521	1	181-182	12.75	0.687				9.4	304	1000	552	500	26,100	2144	0.0821		0.0821	0.2242	377	1022
Hanger		D-2	182												2144	0.0821	1.0	0.0821		377	1022
Bend	522	3	182-183	12.75	0.687	60	5.0	90°		304	1000	552	500	26,100	3234	0.1239		0.1239	0.2242	173	1022
Straight	523	1	183-184	12.75	0.687				57.6	304	1000	552	500	26,100	3234	0.1239		0.1239	0.2242	332	1384
Weld		D-1	184												4301	0.1648	1.0	0.1648		443	1789
Elbow	524	2	184-185	12.75	0.687	18	1.5	90°		304	1000	552	500	26,100	4507	0.1727		0.1727	0.2242	443	2756
Weld		D-1	185												4507	0.1727	1.0	0.1727		376	2756
Straight	525	1	185-186	12.75	0.687				14.5	304	1000	552	500	26,100	2733	0.1047		0.1047	0.2242	222	1622
Emergency Condenser Attachment		D-1	186												3936	0.1508	1.0	0.1508		169	1622
12-in. Branch of Tee 177	526	1	177-190	12.75	0.687				84.3	304	1000	552	500	26,100	3936	0.1508		0.1917	0.2242	334	4076
Bend	527	3	190-191	12.75	0.687	60	5.0	90°		304	1000	552	500	26,100	2676	0.1025		0.1025	0.2242	1291	3458
Hanger		D-2	191												2676	0.1025	1.0	0.1025		1291	3458
Straight	528	1	191-192	12.75	0.687				51.4	304	1000	552	500	26,100	2883	0.1105		0.1105	0.2242	1291	3458
Weld		D-1	192												5048	0.1934	1.0	0.1934		704	5323
Elbow	529	2	192-193	12.75	0.687	18	1.5	90°		304	1000	552	500	26,100	5048	0.1934		0.1934	0.2242	704	5322
Weld		D-1	193												3812	0.1461	1.0	0.1461		179	3153
Straight	530	1	193-194	12.75	0.687				40.4	304	1000	552	500	26,100	3615	0.1385		0.1385	0.2242	530	1791
Weld		D-1	194												5044	0.1933	1.0	0.1933		961	2150
Elbow	531	2	194-195	12.75	0.687	18	1.5	90°		304	1000	552	500	26,100	6089	0.2333		0.2333	0.2242	961	4373
Weld		D-1	195												6089	0.2333	1.0	0.2333		624	4373
Straight	532	1	195-196	12.75	0.687				14.5	304	1000	552	500	26,100	3395	0.1301		0.1301	0.2242	742	2398
Condenser Attachment		D-1	196												2972	0.1139	1.0	0.1139		742	2398

Model Number 4 Emergency Condenser Steam (South Side) Component or Discontinuity	Component Number	Type	MASS Joint Number	Diameter D (Outside), in.	Thickness t, in.	Radius of Curvature, ρ , in.	ρ/D^*	Included Angle θ	Length of Straight Pipe, in.	Material	Operating Pressure, psi	Operating Temperature, °F	Number of Cycles/40 yr.	$S_A = f(1.25 S_c + 0.25 S_A)$, psi	S_E from MASS, psi	S_E/S_A	Stress Int. Factor, i	$(S_E/S_A)_i$	A/A _{max}	S_w , Weight Stress, psi	S_q , Earthquake Stress, psi
Pressure Vessel Nozzle Weld		D-1	261							Seam- less					8063	0.3089	1.0	0.3089		2088	2365
Straight	551	1	261-262	10.75	0.593				3.0	304	1000	552	500	26,100	8116	0.3110		0.3110	0.1585	2039	2456
Weld		D-1	262												8796	0.3370	1.0	0.3370		3144	3977
Elbow	552	2	262-263	10.75	0.593	18	1.8	90°		304	1000	552	500	26,100	12220	0.4682		0.4682	0.1585	1722	4606
Weld		D-1	263												12220	0.4682	1.0	0.4682		1605	4606
Straight	553	1	263-264	10.75	0.593				39.0	304	1000	552	500	26,100	7878	0.3018		0.3018	0.1585	1549	2595
Bend	554	3	264-265	10.75	0.593	48	4.8	70°		304	1000	552	500	26,100	6651	0.2548		0.2548	0.1585	1549	2595
Hanger		D-2	265												4249	0.1628	1.0	0.1628		2721	1415
Straight	555	1	265-266	10.75	0.593				111.9	304	1000	552	500	26,100	4565	0.1749		0.1749	0.1585	848	1892
Weld		D-1	266												6412	0.2457	1.0	0.2457		1116	3059
Elbow	556	2	266-267	10.75	0.593	18	1.8	90°		304	1000	552	500	26,100	7235	0.2776		0.2776	0.1585	1110	3580
Weld		D-1	267												7235	0.2776	1.0	0.2776		982	3580
Straight	557	1	267-268	10.75	0.593				156.0	304	1000	552	500	26,100	4765	0.1826		0.1826	0.1585	2575	2365
Valve Attachment		D-1	268												4590	0.1759	1.0	0.1759		1047	2365
Valve	558	4	268-269	10.75	0.593				36.0	304	1000	552	500	26,100	2322	0.0890		0.0890	0.1585	1017	1198
Valve to Valve Connection		D-1	269												2322	0.0890	1.0	0.0890		1017	1198
Valve	559	4	269-270	10.75	0.593				36.0	304	1000	552	500	26,100	2835	0.1086		0.1086	0.1585	632	1270
Valve Attachment		D-1	270												6968	0.2670	1.0	0.2670		1553	3123
Straight	560	1	270-271	10.75	0.593				117.0	304	1000	552	500	26,100	11460	0.4391		0.4391	0.1585	4347	3123
Hanger and 10-in. × 16 in. Reducer		D-2, 6	271							Welded					11460	0.4391	1.0	0.4391		1370	2878
Bend	561	3	271-272	16.0	0.843	60	3.75	90°		304	1000	552	500	26,100	3923	0.1503	1.0	0.1503	0.3549	277	1303
Straight	562	1	272-273	16.0	0.843				296.0	304	1000	552	500	26,100	3619	0.1387		0.1387	0.3549	277	1477
Bend	563	3	273-274	16.0	0.843	60	3.75	90°		304	1000	552	500	26,100	1641	0.0629		0.0629	0.3549	190	1917
Hanger		D-2	274												1641	0.0629	1.0	0.0629		190	1917
Straight	564	1	274-275	16.0	0.843				6.0	304	1000	552	500	26,100	1656	0.0634		0.0634	0.3549	177	1917
Bend	564	3	275-276	16.0	0.843	60	3.75	90°		304	1000	552	500	26,100	1656	0.0634		0.0634	0.3549	200	1860
16-in. Run of Tee 277	566	1	276-277	16.0	0.843				73.0	304	1000	552	500	26,100	1089	0.0417		0.1892	0.3549	48	1300
12-in. × 16-in. Tee		D-4	277												3290	0.1261	1.5	0.1892		43	1300
16-in. Run of Tee 277	567	1	277-278	16.0	0.843				10.0	304	1000	552	500	26,100	3401	0.1303		0.1892	0.2242	35	562

Model Number 4 Emergency Condenser Steam (South Side) (Continued)	Component Number	Type	MASS Joint Number	Diameter D (Outside), in.	Thickness t , in.	Radius of Curvature, ρ , in.	ρ/D^*	Included Angle θ	Length of Straight Pipe, in.	Material	Operating Pressure, psi	Operating Temperature, °F	Number of Cycles/40 yr.	$S_A = f(1.25 S_C + 0.25 S_A)$, psi	S_E from MASS, psi	S_E/S_A	Stress Int. Factor, i	$(S_E/S_A)_i$	A/A_{max}	S_w Weight Stress, psi	S_q Earthquake Stress, psi
12-in. x 16-in. Reducer (Weld)		D-6	278							Welded					6232	0.2388	1.5	0.2388		111	1374
Elbow	568	2	278-279	12.75	0.687	18	1.5	90°		304	1000	552	500	26,100	6232	0.2388		0.2388	0.2242	97	1874
Weld		D-1	279												5090	0.1950	1.5	0.1950		63	1507
Straight	569	1	279-280	12.75	0.687				66.3	304	1000	552	500	26,100	3148	0.1206		0.1206	0.2242	92	1071
Bend	570	3	280-281	12.75	0.687	60	5.0	90°		304	1000	552	500	26,100	1954	0.0749		0.0749	0.2242	342	1071
Straight	571	1	281-282	12.75	0.687				9.38	304	1000	552	500	26,100	2061	0.0790		0.0790	0.2242	420	1115
Hanger		D-2	282												2061	0.0790	1.5	0.0790		420	1115
Bend	572	3	282-283	12.75	0.687	60	5.0	90°		304	1000	552	500	26,100	3241	0.1242		0.1242	0.2242	208	1115
Straight	573	1	283-284	12.75	0.687				38.4	304	1000	552	500	26,100	3241	0.1242		0.1242	0.2242	215	625
Weld		D-1	284												4679	0.1793	1.5	0.1793		310	903
Elbow	574	2	284-285	12.75	0.687	18	1.5	90°		304	1000	552	500	26,100	4715	0.1807		0.1807	0.2242	285	1574
Weld		D-1	285												4717	0.1807	1.0	0.1807		285	1574
Straight	575	1	285-286	12.75	0.687				14.5	Welded A312,304	1000	552	500	26,100	2776	0.1064		0.1064	0.2242	182	957
Attachment to Condenser		D-1	286												3674	0.1408	1.0	0.1408		163	957
12-in. Branch of Tee 277	576	1	277-290	12.75	0.687				84.3	A312,304	1000	552	500	26,100	3674	0.1408		0.1892	0.2242	222	1969
Bend	577	3	290-291	12.75	0.687	60	5.0	90°		A312,304	1000	552	500	26,100	2557	0.0980		0.0980	0.2242	566	1897
Hanger		D-2	291												2557	0.0980	1.0	0.0980		566	1897
Straight	578	1	291-292	12.75	0.687				9.38	A312,304	1000	552	500	26,100	2555	0.0979		0.0979	0.2242	492	1897
Bend	579	3	292-293	12.75	0.687	60	5.0	90°		A312,304	1000	552	500	26,100	3320	0.1272		0.1272	0.2242	492	1884
Straight	580	1	293-294	12.75	0.687				17.6	A312,304	1000	552	500	26,100	3541	0.1357		0.1357	0.2242	294	647
Weld		D-1	294												4981	0.1908	1.0	0.1908		488	1081
Elbow	581	2	294-295	12.75	0.687	18	1.5	90°		A312,304	1000	552	500	26,100	5824	0.2231		0.2231	0.2242	488	2065
Weld		D-1	295												5824	0.2231	1.0	0.2231		447	2065
Straight	582	1	295-296	12.75	0.687				14.5	A312,304	1000	552	500	26,100	3309	0.1268		0.1268	0.2242	346	1157
Attachment to Condenser		D-1	296												2917	0.1118	1.0	0.1118		346	1157

Model Number 5 Recirculation Loop No. 1 (Main Line) Component or Discontinuity	Component Number	Type	MASS Joint Number	Diameter D (Outside), in.	Thickness t, in.	Radius of Curvature, ρ, in.	ρ/D*	Included Angle θ	Length of Straight Pipe, in.	Material	Operating Pressure, psi	Operating Temperature, °F	Number of Cycles/40 yr.	$S_A = f(1.25 S_c + 0.25 S_A)$, psi	S_E from MASS, psi	S_E/S_A	Stress Int. Factor, i	$(S_E/S_A)^i$	A/A _{max}	S_w , Weight Stress, psi	S_q , Earthquake Stress, psi
Pressure Vessel		D-1	2												821	0.315	1.0	0.0315		200	1285
Nozzle Weld										Welded					1533	0.0587		0.0587		745	1285
Bend	601	3	2-3	25.99	0.982	39	1.5	90°		316	1015	555	360	27,400	1533	0.0587	1.0	0.0587	1.0	189	533
Weld		D-1	3																		
Straight (Run of Tee 37)	602	1	3-37	25.99	1.875				19.5	316	1015	555	360	27,400	419	0.0161		0.0587	0.8569	200	172
Straight (Run of Tee 37)	603	1	37-38	25.99	1.875				209.5	316	1015	555	360	27,400	505	0.0193		0.0236	0.8569	252	693
Weld		D-1	38												749	0.0287	1.0	0.0287		140	1192
Straight	604	1	38-35	25.99	0.982				23.0	316	1015	555	360	27,400	749	0.0287		0.0287	1.0	241	1192
Hanger		D-2	35												735	0.0282	1.0	0.0282		220	1145
Straight	604	1	35-4	25.99	0.982				103.0	316	1015	555	360	27,400	735	0.0282		0.0282	1.0	220	1145
Valve Attachment		D-1	4												676	0.0259	1.0	0.0259		128	951
Valve	606	4	4-5	25.99	6.5				60.0	316	1015	555	360	27,400	194	0.0074		0.0074	0.2923	37	274
Valve Attachment		D-1	5												1476	0.0566	1.0	0.0566		23	725
Elbow	607	2	5-6	25.99	0.982	38.9	1.5	90°		316	1015	555	360	27,400	1476	0.0566		0.0566	1.0	167	894
Weld		D-1	6												355	0.0136	1.0	0.0136		132	894
Straight	608	1	6-7	25.99	0.982				10.6	316	1015	555	360	27,400	232	0.0089		0.0089	1.0	58	529
Thermocouple		D-3	Bet. 6&7																		
1 in. Pres. Sensing Line		D-3	Bet. 6&7																		
Blanked-Off Decontamination Nozzle		D-5	Bet. 6&7																		
Weld		D-1													365	0.0140	1.0	0.0140		12	1280
Elbow	609	2	7-8	25.99	0.982	25.9	1.0	90°		316	1015	555	360	27,400	1341	0.0514		0.0514	1.0	15	1402
Pump Attachment		D-1	8												1341	0.0541	1.0	0.0514		478	1402
Pump	610	5	8-10												1232	0.0472	1.0	0.0472			
Pump Attachment		D-1	10																	172	643
Sector of Elbow	611	2	10-17	25.99	0.982	40	1.5	48°		316	1055	555	360	27,400	2190	0.0839		0.0839	1.0	211	643
Thermocouple		D-3	Bet. 10&17																		
1 in. Pres. Sensing Line		D-3	Bet. 10&17																		
Bypass Connection		D-4	17												2190	0.0839	1.875	0.1573		213	674
Sector of Elbow	612	2	17-11	25.99	0.982	42	1.6	26°		316	1055	555	360	27,400	1657	0.0635		0.0635	1.0	191	674
Valve Attachment		D-1	11												1657	0.0635	1.875	0.0635		32	506
Valve	613	4	11-12	25.99	0.982				75.0	316	1055	555	360	27,400	273	0.0105		0.0105		25	155
Valve Attachment		D-1	12												909	0.0348	1.875	0.0348		86	539
Straight	614	1	12-28	25.99	0.982				7.5	316	1055	555	360	27,400	909	0.0348		0.0348	1.0	85	540

Model Number 5 Recirculation Loop No. 1 (Main Line) (Continued)	Component Number	Type	MASS Joint Number	Diameter D (Outside), in.	Thickness t, in.	Radius of Curvature, ρ , in.	ρ/D^*	Included Angle θ	Length of Straight Pipe, in.	Material	Operating Pressure, psi	Operating Temperature, °F	Number of Cycles/40 yr.	$S_A = f(1.25 S_c + 0.25 S_A)$, psi	S_E from MASS, psi	S_E/S_A	Stress Int. Factor, i	$(S_E/S_A)^i$	A/A_{Max}	S_w , Weight Stress, psi	S_q , Earthquake Stress, psi
Bypass Connection		D-4	28							Seam- less 316					905	0.0347	1.875	0.0651		86	542
Straight	615	1	28-36	25.99	0.982				50.5	316	1055	555	360	27,400	905	0.0347		0.0347	1.0	86	542
Flow Meter		D-3a	Bet. 28&36																		
Hanger		D-2	36												878	0.0336	1.875	0.0336	1.0	86	532
Straight	616	1	36-40	25.99	0.982				113.2	316	1055	555	360	27,400	878	0.0336		0.0336	1.0	156	525
Straight	616	1	40-39	25.99	0.982				19.5	316	1055	555	360	26,100	817	0.0313		0.0313	1.0	169	525
Straight	616	1	39-13	25.99	0.982				19.5	316	1055	555	360	26,100	807	0.0309		0.0309	1.0	169	538
Weld		D-1	13												1829	0.0701	1.875	0.0701		185	673
Elbow	617	2	13-14	25.99	0.982	40	1.5	76°		316	1055	555	360	26,100	1829	0.0701		0.0701	1.0	389	673
Weld		D-1	14												918	0.0352	1.875	0.0352		186	659
Straight	618	1	14-15	25.99	0.982				31.4	316	1055	555	360	26,100	924	0.0354		0.0354	1.0	85	659
Pres. Vessel Nozzle Weld		D-1	15												924	0.0354	1.875	0.0354		89	441
Model Number 5 Recirculation Loop 1 - Bypass Line																					
Straight	619	1	17-18	2.374	0.218				5.0	316	1055	555	360	26,100	132	0.0051		0.0051	0.0065	1402	2462
Weld		D-1a	18												152	0.0058	1.3	0.0076		847	3197
Elbow	620	2	18-19	2.374	0.218	3.0	1.5	88°		316	1055	555	360	26,100	162	0.0063		0.0063	0.0065	850	3208
Weld		D-1a	19												165	0.0063	1.3	0.0082		922	3208
Straight	621	1	19-20	2.374	0.218				26.7	316	1055	555	360	26,100	134	0.0051		0.0051	0.0065	716	2470
Weld		D-1a	20												93	0.0036	1.3	0.0047		500	1602
Straight	622	1	20-21	2.374	0.218				2.5	316	1055	555	360	26,100	93	0.0036		0.0036	0.0065	500	1602
Branch to Decontamination Nozzle		D-4	21												83	0.0032	1.04	0.0042		482	1482
Straight	623	1	21-22	2.374	0.218				33.6	316	1055	555	360	26,100	83	0.0032		0.0032	0.0065	482	1482
Weld		D-1a	22												71	0.0027	1.3	0.0035		470	754
Elbow	624	2	22-23	2.374	0.218	3.0	1.5	90°		316	1055	555	360	26,100	83	0.0032		0.0032	0.0065	470	754
Weld		D-1a	23												83	0.0032	1.3	0.0042		513	689
Straight	625	1	23-24	2.374	0.218				6.0	316	1055	555	360	26,100	63	0.0024		0.0013	0.0065	391	764
Valve Attachment		D-1a	24												58	0.0022	1.3	0.0029		325	764
Valve	626	4	24-25	2.374	0.6				7.5	316	1055	555	360	26,100	34	0.0013		0.0024	0.0024	192	516
Valve Attachment		D-1a	25												52	0.0020	1.3	0.0026		148	872
Straight	627	1	25-26	2.374	0.218				85.4	316	1055	555	360	26,100	81	0.0031		0.0031	0.0065	251	1058
Weld		D-1a	26												106	0.0041	1.3	0.0053		953	1272
Elbow	628	2	26-27	2.374	0.218	3.0	1.5	90°		316	1055	555	360	26,100	106	0.0041		0.0041	0.0065	1257	1397
Weld		D-1a	27												83	0.0032	1.3	0.0042		431	1397
Straight	629	1	27-28	2.374	0.218				20.0	316	1055	555	360	26,100	115	0.0044		0.0044	0.0065	4413	1889

Model Number 5 Emergency Condenser Condensate (South Side) Component or Discontinuity	Component Number	Type	MASS Joint Number	Diameter D (Outside), in.	Thickness t, in.	Radius of Curvature, ρ , in.	ρ/D^*	Included Angle θ	Length of Straight Pipe, in.	Material	Operating Pressure, psi	Operating Temperature, °F	Number Cycles/40 yr.	$S_A = f(1.25 S_c + 0.25 S_A)$, psi	S_E from MASS, psi	S_E/S_A	Stress Int. Factor, i	$(S_E/S_A)_i$	A/A _{max.}	S_w , Weight Stress, psi	S_q , Earthquake Stress, psi
10 in. x 26 in. Tee in Recirculation Line 1		D-4	37							Seam- less					4159	0.1518	1.22	0.1852		4835	3329
Straight	652	1	37-52	10.75	0.593				51.3	304	1000	157	500	27,400	4159	0.1518		0.1852	0.1585	2070	3329
Valve Attachment		D-1	52												3389	0.1237	1.0	0.1237		1377	1397
Valve	653	4	52-53	10.75	2.5				26.0	304	1000	157	500	27,400	1379	0.0503		0.0503	0.0582	810	930
Valve Attachment		D-1	53												3115	0.1137	1.0	0.1137		1992	1070
Straight	654	1	53-54	10.75	0.593				75.0	304	1000	157	500	27,400	3115	0.1137		0.1137	0.1585	588	1319
Weld		D-1	54												4748	0.1733	1.0	0.1733		1058	2413
Elbow	655	2	54-55	10.75	0.593	15	1.5	90°		304	1000	157	500	27,400	4748	0.1733		0.1733	0.1585	436	3020
Weld		D-1	55												3939	0.1438	1.0	0.4380		434	3020
Straight	656	1	55-56	10.75	0.593				85.7	304	1000	157	500	27,400	2627	0.0958		0.0958	0.1585	447	1654
Weld		D-1	56												3442	0.1256	1.0	0.1256		476	2209
Elbow	657	2	56-57	10.75	0.593	15	1.5	90°		304	1000	157	500	27,400	4451	0.1624		0.1624	0.1585	553	2209
Weld		D-1	57												4451	0.1624	1.0	0.1624		380	1547
Straight	658	1	57-58	10.75	0.593				71.5	304	1000	157	500	27,400	2529	0.0923		0.0923	0.1585	1280	868
Weld		D-1	58												2466	0.0900	1.0	0.0900		2309	594
Elbow	659	2	58-59	10.75	0.593	15	1.5	90°		304	1000	157	500	27,400	2466	0.0900		0.0900	0.1585	1744	661
Weld		D-1	59												1546	0.0571	1.0	0.0571		1747	661
Straight	660	1	59-60	10.75	0.593				10.9	304	1000	157	500	27,400	928	0.0339		0.0339	0.1585	1793	362
Weld and Hanger		D-1&2	60												826	0.0301	1.0	0.0301		1984	554
Elbow	661	2	60-61	10.75	0.593	15	1.5	90°		304	1000	157	500	27,400	1060	0.0387		0.0387	0.1585	3724	761
Weld		D-1	61												1060	0.0387	1.0	0.0387		2037	761
Straight	662	1	61-62	10.75	0.593				243.0	304	1000	157	500	27,400	3179	0.1160		0.1160	0.1585	1135	2729
Valve Connection		D-1	62												3179	0.1160	1.0	0.1160		804	2729
Valve	663	4	62-63	10.75	2.5				33.0	304	1000	157	500	27,400	401	0.0146		0.0146	0.0582	120	2449
Valve Connection		D-1	63												760	0.0277	1.0	0.0277		295	4268
Straight	664	1	63-64	10.75	0.593				28.0	304	1000	157	500	27,400	760	0.0277		0.0277	0.1585	39	4268
Bend	665	3	64-65	10.75	0.593	47.6	4.8	46°		304	1000	157	500	27,400	633	0.0231		0.0231	0.1585	147	3505

Model Number 5 Emergency Condenser Condensate (South Side) (Continued) Component or Discontinuity	Component Number	Type	MASS Joint Number	Diameter D (Outside), in.	Thickness t, in.	Radius of Curvature, ρ , in.	ρ/D^*	Included Angle θ	Length of Straight Pipe, in.	Material	Operating Pressure, psi	Operating Temperature, °F	Number of Cycles/40 yr.	$S_A = f(1.25 S_c + 0.25 S_A)$, psi	S_E from MASS, psi	S_E/S_A	Stress Int. Factor, i	$(S_E/S_A)_i$	A/A_{max}	S_w Weight Stress, psi	S_q Earthquake Stress, psi
Straight	666	1	65-66	10.75	0.593				174.4	Seam- less 304	1000	157	500	27,400	806	0.0294		0.0294	0.1585	281	3864
Bend	667	3	66-67	10.75	0.593	48.2	4.8	90°		304	1000	157	500	27,400	806	0.0294		0.0294	0.1585	1489	3864
Hanger		D-2	67												258	0.0094	1.0	0.0094		1489	1655
Straight	668	1	67-68	10.75	0.593				18.0	304	1000	157	500	27,400	258	0.0094		0.0094	0.1585	693	1672
Bend	669	3	68-69	10.75	0.593	49.0	4.5	90°		304	1000	157	500	27,400	1019	0.0372		0.0372	0.1585	391	2094
Straight	670	1	69-70	10.75	0.593				252.2	304	1000	157	500	27,400	1328	0.0485		0.0485	0.1585	583	2094
Bend	671	3	70-71	10.75	0.593	48.0	4.8	90°		304	1000	157	500	27,400	1415	0.0516		0.0516	0.1585	1287	1642
Hanger		D-2	71												1415	0.0516	1.0	0.0516		1287	1015
Straight	672	1	71-72	10.75	0.593				24.0	304	1000	157	500	27,400	1549	0.0565		0.0565	0.1585	698	1264
Bend	673	3	72-73	10.75	0.593	48.0	4.8	90°		304	1000	157	500	27,400	1711	0.0624		0.0674	0.1585	588	2210
Straight	674	1	73-74	10.75	0.593				84.0	304	1000	157	500	27,400	1812	0.0625		0.0625	0.1585	569	2210
Bend	675	3	74-75	10.75	0.593	48	4.8	90°		304	1000	157	500	27,400	2078	0.0758		0.0758	0.1585	831	2153
Hanger		D-2	75												2051	0.0749	1.0	0.0749		831	1635
Branch of Tee 76	676	1	75-76	10.75	0.593				78.0	304	1000	157	500	27,400	2163	0.0789		0.1231		273	2762
8 in. x 10 in. Tee		D-4	76												2318	0.0846	1.455	0.1231		1140	4979
Run of Tee 76	677	1	76-77	8.624	0.5				75.6	304	1000	157	500	27,400	2318	0.0846		0.1231	0.1007	421	4979
Bend	678	3	77-78	8.624	0.5	48	6.0	90°		304	1000	157	500	27,400	1220	0.0445		0.0445	0.1007	659	2490
Straight	679	1	78-79	8.624	0.5				52.8	304	1000	157	500	27,400	1888	0.0689		0.0689	0.1007	176	3832
Weld		D-1	79												2867	0.1046	1.0	0.1046		264	5753
Elbow	680	2	79-80	8.624	0.5	15	1.9	60°		304	1000	157	500	27,400	2961	0.1081		0.1081	0.1007	963	7310
Weld		D-1	80												2759	0.1007	1.0	0.1007		667	7310
Straight	681	1	80-81	8.624	0.5				10.8	304	1000	157	500	27,400	2060	0.0752		0.0752	0.1007	1452	4949
Condenser Attachment		D-1	81												1863	0.0680	1.0			1452	4949
Run of Tee 76	687	1	76-87	8.624	0.5				68.4	304	1000	157	500	27,400	1896	0.0692		0.1231	0.1007	771	2674
Bend	688	3	87-88	8.624	0.5	48	6.0	90°		304	1000	157	500	27,400	1896	0.0692		0.0692	0.1007	292	2541
Straight	689	1	88-89	8.624	0.5				52.8	304	1000	157	500	27,400	2001	0.0730		0.0730	0.1007	617	2847
Weld		D-1	89												3041	0.1110	1.0	0.1110		251	4304
Elbow	690	2	89-90	8.624	0.5	15	1.9	60°		304	1000	157	500	27,400	3115	0.1137		0.1137	0.1007	378	4743
Weld		D-1	90												2900	0.1058	1.0	0.1058		1097	4743
Straight	691	1	90-91	8.624	0.5				10.8	304	1000	157	500	27,400	2396	0.0874		0.0874	0.1007	761	4038
Condenser Attachment		D-1	91												2391	0.0873	1.0	0.0873		1505	4038

Model Number 6 Recirculation Loop No. 2 (Main Line) Component or Discontinuity	Component Number	Type	MASS Joint Number	Diameter D (Outside), in.	Thickness t, in.	Radius of Curvature, ρ, in.	ρ/D*	Included Angle θ	Length of Straight Pipe, in.	Material	Operating Pressure, psi	Operating Temperature, °F	Number of Cycles/40 yr.	$S_A = f(1.25 S_c + 0.25 S_A)$, psi	S_E from MASS, psi	S_E/S_A	Stress Int. Factor, i	$(S_E/S_A)^i$	A/A _{max} .	S_w , Weight Stress, psi	S_q , Earthquake Stress, psi
Pres. Vessel Nozzle Weld		D-1	102												659	0.0252	1.0	0.0252		95	858
Elbow	1001	2	102-103	25.99	0.982	39.0	1.5	90°		Welded 316	1015	555	360	26,100	1625	0.0623		0.0623	1.0	95	676
Weld		D-1	103												1625	0.0623	1.0	0.0623		33	819
Straight	1002	1	103-137	25.99	0.982				19.5	316	1015	555	360	26,100	708	0.0271		0.0271	1.0	28	475
Straight	1002	1	137-138	25.99	0.982				19.5	316	1015	555	360	26,100	702	0.0269		0.0289	1.0	31	418
Hanger		D-2	138												697	0.0267	1.0	0.0267		36	381
Run of Tee 135	1003	1	138-135	25.99	0.982				213.0	316	1015	555	360	26,100	697	0.0267		0.0490	1.0	36	792
Run of Tee 135	1004	1	135-104	25.99	0.982				103.0	316	1015	555	360	26,100	616	0.0236		0.0490	1.0	86	790
End of Valve - Weld		D-1	104												592	0.0227	1.0	0.0227		48	720
Valve	1005	4	104-105	25.99	6.5				60.0	316	1015	555	360	26,100	170	0.0065		0.0065	0.2923	14	207
End of Valve - Weld		D-1	105												1332	0.0510	1.0	0.0510		9	131
Elbow	1006	2	105-106	25.99	0.982	39.0	1.5	90°		316	1015	555	360	26,100	1332	0.0510		0.0510	1.0	48	511
Weld		D-1	106												316	0.0131	1.0	0.0121		173	723
Straight	1007	1	106-107	25.99	0.982				18.6	316	1015	555	360	26,100	193	0.0074		0.0074	1.0	76	436
Thermocouple		D-3	Bet. 106&107																		
Blanked-Off																					
Decontamination Nozzle		D-5	Bet. 106&107																		
1 in. Pres. Sensing Line		D-3	Bet. 106&107																		
Weld		D-1	107												295	0.0113	1.0	0.0113		45	546
Elbow	1008	2	107-108	25.99	0.982	26.0	1.0	90°		316	1015	555	360	26,100	1216	0.0466		0.0466	1.0	132	1229
Pump Connection		D-1	108												1216	0.0466	1.0	0.0466		182	1243
Pump	1009	5	108-110																		
Pump Connection		D-1	110												1176	0.0451	1.0	0.0451		102	720
Sector of Elbow	1010	2	110-117	25.99	0.982	40.1	1.5	48°		316	1015	555	360	26,100	2063	0.0790		0.0790	1.0	102	627
Thermocouple		D-3	Bet. 110&117																		
1 in. Pres Sensing Line		D-3	Bet. 110&117																		
Bypass Line Connection		D-4	117												2063	0.0790	1.875	0.1480		201	735
Sector of Elbow	1011	2	117-111	25.99	0.982	42.5	1.6	25.7		316	1015	555	360	26,100	1562	0.0598		0.0598	1.0	200	739

Model Number 6 Recirculation Loop No. 2 (Main Line) (Continued)	Component Number	Type	MASS Joint Number	Diameter D (Outside), in.	Thickness t, in.	Radius of Curvature, ρ , in.	ρ/D^*	Included Angle θ	Length of Straight Pipe, in.	Material	Operating Pressure, psi	Operating Temperature, °F	Number of Cycles/40 yr.	$S_A = f(1.25 S_c + 0.25 S_A)$, psi	S_E from MASS, psi	S_E/S_A	Stress Int. Factor, i	$(S_E/S_A)^i$	A/A_{max}	S_w , Weight Stress, psi	S_q , Earthquake Stress, psi
End of Valve	1012	D-1	111	25.99	6.5				75.0	Welded 316	1015	555	360	26,100	1562	0.0598	1.0	0.0598		201	552
Valve		4	111-112	25.99	6.5										258	0.0099		0.0099	0.2923	28	155
End of Valve		D-1	112												873	0.0334	1.0	0.0334		38	449
Straight	1013	1	112-113	25.99	0.982				7.5	316	1015	555	360	26,100	873	0.0334		0.0334	1.0	133	595
Bypass Connection		D-4	128												871	0.0334	1.874	0.0630		138	600
Run of Tee 136	1014	1	128-136	25.99	0.982					316	1015	555	360	26,100	871	0.0334		0.0620	1.0	144	602
Flow Meter		D-3a	Bet. 128 & 136																		
Run of Tee 136	1015	1	136-140	25.99	0.982				113.2	316	1015	555	360	26,100	863	0.0331		0.0620	1.0	150	598
Hanger		D-2	140												826	0.0316	1.0	0.0316		80	476
Straight	1016	1	140-139	25.99	0.982				19.5	316	1015	555	360	26,100	826	0.0316		0.0316	1.0	80	476
Straight	1016	1	139-113	25.99	0.982				19.5	316	1015	555	360	26,100	820	0.0314		0.0314	1.0	69	491
Weld		D-1	113												1871	0.0717	1.0	0.0717		61	523
Elbow	1017	2	113-114	25.99	0.982	39.0	1.5	76		316	1055	555	360	26,100	1871	0.0717		0.0717	1.0	101	725
Weld		D-1	114												837	0.0321	1.0	0.0321		108	651
Straight	1018	1	114-115	25.99	0.982				31.4	316	1055	555	360	26,100	842	0.0323		0.0323	1.0	53	454
Pres.Vessel Nozzle Weld		D-1	115												842	0.0323	1.0	0.0323		67	477
Model Number 6 Recirculation Loop No. 2 Bypass Line										Seam- less 316											
Straight	1019	1	117-118	2.374	0.218				5.0		1055	555	360	26,100	138	0.0053		0.0053	0.0065	1465	1806
Weld		D-1a	118												156	0.0068	1.3	0.0058		877	2520
Elbow	1020	2	118-119	2.374	0.218	3.0	1.5	875		316	1055	555	360	26,100	170	0.0065		0.0065	0.0065	881	3291
Weld		D-1a	119												170	0.0065	1.3	0.0084		952	3150
Straight	1021	1	119-120	2.374	0.218				26.7	316	1055	555	360	26,100	137	0.0052		0.0052	0.0065	738	2418
Blanked-Off Decontamination Nozzle		D-4	120												90	0.0034	1.04	0.0035		511	1891
Straight	1022	1	120-121	2.374	0.218				2.5	316	1055	555	360	26,100	90	0.0034		0.0034	0.0065	511	1891
Weld		D-1a	121												81	0.0031	1.3	0.0040		493	1732
Straight		D-1a	122												54	0.0021	1.3	0.0027		452	562
Elbow	1024	2	122-123	2.374	0.218	3.0	1.5	90°		316	1055	555	360	26,100					0.0065	482	741
Weld		D-1a	123														1.3			527	628
Straight	1025	1	123-124	2.374	0.218				6.0	316	1055	555	360	26,100					0.0065	402	619
End of Valve		D-1a	124														1.3			335	701
Valve	1026	4	124-125	2.374	0.6				7.5	316	1055	555	360	26,100					0.0024	198	415
End of Valve		D-1a	125														1.3			154	700
Straight	1027	1	125	2.374	0.218				85.4	316	1055	555	360	26,100					0.0065	260	825
Weld		D-1a	126														1.3			973	981
Elbow	1028	2	126-127	2.374	0.218	3.0	1.5	90°		316	1055	555	360	26,100					0.0065	1284	1186
Weld		D-1a	127														1.3			439	1290
Straight	1029	1	127-128	2.374	0.218				20.0	316	1055	555	260	26,100					0.0065	333	1132

Model Number 6 Cleanup System Ref. 706 E 206 148 F 444 237 E 798 237 E 794	Component Number	Type	MASS Joint Number	Diameter D (Outside), in.	Thickness t, in.	Radius of Curvature, ρ, in.	ρ/D*	Included Angle θ	Length of Straight Pipe, in.	Material	Operating pressure, psi	Operating Temperature, °F	Number of Cycles/40 yr.	$S_A = f(1.25 S_c + 0.25 S_A)$, psi	S_E from MASS, psi	S_E/S_A	Stress Int. Factor, i	$(S_E/S_A)^i$	A/A _{max} .	S_w Weight Stress, psi	S_q Earthquake Stress, psi
6 in. × 26 in. Tee in Recirc. Loop 2		D-4	135							Seam- less 304					4911	0.1881	1.875	0.3528		74	4222
Branch of Tee 135 to C.U.	1030	1	135-322	6.624	0.432				42.5	304	1000	551	500	26,100	4911	0.1881		0.3528	0.0575	4688	3462
Weld		D-1	322												4837	0.1853	1.0	0.1853		787	3480
Elbow	1031	2	322-321	6.624	0.432	9.0	3.0	90°		304	1000	551	500	26,100	7281	0.2790		0.2790	0.0575	1283	5716
Weld		D-1	321												7281	0.2790	1.0	0.2790		196	4659
Straight	1032	1	321-320	6.624	0.432				216.0	304	1000	551	500	26,100	4436	0.1700		0.1700	0.0575	119	3227
Weld		D-1	320												3005	0.1151	1.0	0.1151		116	4977
Elbow	1033	2	320-319	6.624	0.432	9.0	3.0	90°		304	1000	551	500	26,100	3416	0.1309		0.1309	0.0575	190	4467
End of Valve - Weld		D-1	319												3416	0.1309	1.0	0.1309		711	3500
Valve	1034	4	319-318	6.624	1.6				24.0	304	1000	551	500	26,100	1052	0.0403		0.0403	0.0203	200	1210
End of Valve - Weld		D-1	318												3671	0.1407	1.0	0.1407		327	3733
Elbow	1035	2	318-317	6.624	0.432	9.0	3.0	45°		304	1000	551	500	26,100	3914	0.1500		0.1500	0.0575	1165	3508
Weld		D-1	317																	1045	3066
Straight	1036	1	317-316	6.624	0.432				33.4	304	1000	551	500	26,100						636	1976
Weld		D-1	316																	260	2109
Elbow	1037	2	316-315	6.624	0.432	9.0	3.0	45°		304	1000	551	500	26,100						426	1812
Weld		D-1	315																	338	1771
Straight	1038	1	315-314	6.624	0.432				36.0	304	1000	551	500	26,100						205	1078
End of Valve - Weld		D-1	314																	205	276
Valve	1039	4	314-313	6.624	1.6				24.0	304	1000	551	500	26,100					0.0203	95	128
End of Valve - Weld		D-1	313																	95	37
Straight	1040	1	313-312	6.624	0.432				12.0	304	1000	551	500	26,100					0.0575	205	26
Weld		D-1	312																	205	43
Elbow	1041	2	312-311	6.624	0.432	9.0	3.0	45°		304	1000	551	500	26,100						336	2.5
Weld Near Drywell Penetra. Hanger and Weld		D-1	311												3122	0.1196	1.0	0.1196			
	1302	2	301-302	6.624	0.432	9.0	1.5	90°		304	1015	442	500	26,300	2307	0.0877		0.0877	0.0575	0	0
		D-1	302												1388	0.0528	1.0	0.0528		495	588
Valve	1303	4	302-303	6.624	1.6				24.0	304	1015	442	500	26,300	615	0.0234		0.0234	0.0203	157	186
		D-1	303												1310	0.0498	1.0	0.0498		234	565
	1304	1	303-304	6.624	0.432				6.0	304	1015	442	500	26,300	1319	0.0529		0.0529	0.0575	507	1226
		D-1	304												1349	0.0513	1.0	0.0513		431	1442
	1305	2	304-305	6.624	0.432	9.0	1.5	90°		304	1015	442	500	26,300	1973	0.0750		0.0750	0.0575	660	2348
		D-1	305												1973	0.0750	1.0	0.0750		507	2605
	1306	1	305-306	6.624	0.432				291.6	304	1015	442	500	26,300	2643	0.1005		0.1005	0.0575	309	3469
		D-1	306												2642	0.1005	1.0	0.1005		321	1746
Valve	1307	4	306-307	6.624	1.6				24.0	304	1015	442	500	26,300	1362	0.0518		0.0518	0.0203	148	1749
		D-1	307												1362	0.0518	1.0	0.0518		148	2093
	1308	1	307-308	6.624	0.432				5.0	304	1015	442	500	26,300	3017	0.1147		0.1147	0.0575	322	2092
		D-1	308												4933	0.1876	1.0	0.1876		322	2210
	1309	2	308-309	6.624	0.432	9.0	1.5	90°		304	1015	442	500	26,300	4990	0.1897		0.1897	0.0575	529	3560
		D-1	309												4990	0.1897	1.0	0.1897		1677	3859
Branch of Tee 136 From C. U.	1310	1	309-136	6.624	0.432				47.5	304	1015	442	500	26,300	3073	0.1168		0.1168	0.0575	1049	2370
6 in. × 26 in. Tee in Recirc. Loop No. 2		D-2	136												863	0.0331	1.875	0.0620		7241	2074

Model Number 7 Recirculation Loop No. 3 (Main Line)	Component Number	Type	MASS Joint Number	Diameter D (Outside), in.	Thickness t	Radius of Curvature, ρ , in.	ρ/D^*	Included Angle θ	Length of Straight Pipe, in.	Material	Operating Pressure, psi	Operating Temperature, °F	Number of Cycles/40 yr.	$S_A = f(1.25 S_c + 0.25 S_A)$, psi	S_E from MASS, psi	S_E/S_A	Stress Int. Factor, i	$(S_E/S_A)^i$	A/A _{max.}	S_w , Weight Stress, psi	S_q , Earthquake Stress, psi
Pres. Vessel Nozzle Weld		D-1	202												689	0.0264	1.0	0.0264		145	846
Elbow	701	2	202-203	25.99	0.982	39.0	1.5	90		Welded 316	1015	555	360	26,100	1621	0.0621	1.0	0.0621	1.0	56	617
Weld		D-1	203												1621	0.0621	1.0	0.0621		25	828
Straight	702	1	203-237	25.99	0.982				19.5	316	1015	555	360	26,100	706	0.0270	1.0	0.0270	1.0	23	363
Straight	702		237-238	25.99	0.982				19.5	316	1015	555	360	26,100	699	0.0268	1.0	0.0268		22	367
Straight	702		238-235	25.99	0.982				213.0	316	1015	555	360	26,100	692	0.0265	1.0	0.0265	1.0	15	361
Hanger		D-2	235												628	0.0241	1.0	0.0241		15	452
Straight	703	1	235-204	25.99	0.982				103.0	316	1015	555	360	26,100	628	0.0241	1.0	0.0241	1.0	19	452
Valve Attachment		D-1	204												605	0.0232	1.0	0.0232		5	548
Valve	704	4	204-205	25.99	6.5				60.0	316	1015	555	360	26,100	174	0.0067	1.0	0.0067	0.2923	6	158
Valve Attachment		D-1	205												1364	0.0523	1.0	0.0523		50	100
Elbow	705	2	205-206	25.99	0.982	39	1.5	90°		316	1015	555	360	26,100	1364	0.0523	1.0	0.0523	1.0	165	419
Weld		D-1	206												339	0.0130	1.0	0.0130		72	653
Straight	706	1	206-207	25.99	0.982				18.6	316	1015	555	360	26,100	192	0.0074	1.0	0.0074	1.0	53	353
Thermocouple		D-3	Bet. 206&207																		
1 in. Pres. Sensing Line		D-3	Bet. 206&207																		
Blanked-Off Decontamina- tion Nozzle		D-5	Bet. 206&207																		
Weld		D-1	207												263	0.0101	1.0	0.0101		161	473
Elbow	707	2	207-208	25.99	0.982	25	1.0	90°		316	1015	555	360	26,100	1192	0.0457	1.0	0.0457	1.0	111	1057
Pump Attachment		D-1	208												1198	0.0458	1.0	0.0458		111	935
Pump	708	5	208-210																		
Pump Attachment		D-1	210												1195	0.0458	1.0	0.0458		32	766
Sector of Elbow	709	2	210-217			40.1	1.6	47.9		316	1015	555	360	26,100	2091	0.0801	1.0	0.0801	1.0	63	583
Thermocouple		D-3	Bet. 210&217																		
1 in. Pres. Sensing Line		D-3	Bet. 210&217																		
Bypass Connection		D-4	217												2091	0.0801	1.875	0.1502		65	587
Sector of Elbow	710	2	217-211	25.99	0.982	42.4	1.6	25.7		316	1015	555	360	26,100	1579	0.0605	1.0	0.0605	1.0	34	527

Model Number 7 Recirculation Loop No. 3 (Main Line) (Continued)	Component Number	Type	MASS Joint Number	Diameter D (Outside), in.	Thickness t, in.	Radius of Curvature, ρ , in.	ρ/D^*	Included Angle θ	Length of Straight Pipe, in.	Material	Operating Pressure, psi	Operating Temperature, °F	Number of Cycles/40 yr.	$S_A = f(1.25 S_c + 0.25 S_A)$, psi	S_E from MASS, psi	S_E/S_A	Stress Int. Factor, i	$(S_E/S_A)^i$	A/A_{max}	S_w Weight Stress, psi	S_q Earthquake Stress, psi
Valve Attachment	711	D-1	211	25.99	6.5				75.0	Welded 316	1015	555	360	26,100	1579	0.0605	1.0	0.0605	0.2923	4	422
Valve		4	211-212												261	0.0100		0.0100		4	146
Valve Attachment	712	D-1	212	25.99	0.982				7.5	316	1015	555	360	26,100	880	0.0337	1.0	0.0337	1.0	13	508
Straight		1	212-228												880	0.0337		0.0337		12	505
Bypass Connection	713	D-4	228	25.99	0.982				50.5	316	1015	555	360	26,100	878	0.0336	1.875	0.0630	1.0	19	506
Straight		1	228-236												878	0.0336		0.0336		15	462
Flow Meter		D-3a	Bet. 228&236																		
Hanger		D-2	236												860	0.0330	1.0	0.0330		15	462
Straight	714	1	236-240	25.99	0.982				113.2	316	1015	555	360	26,100	859	0.0330		0.0330	1.0	8	424
Straight	714	1	240-239	25.99	0.982				19.2	316	1015	555	360	26,100	823	0.0315		0.0315	1.0	8	435
Straight	714	1	239-213	25.99	0.982				19.2	316	1015	555	360	26,100	817	0.0313		0.0313	1.0	7	465
Weld		D-1	213												1864	0.0714	1.0	0.0714		6	622
Elbow	715	2	213-214	25.99	0.982	38.9	1.5	76°		316	1055	555	360	26,100	1864	0.0714		0.0714	1.0	7	593
Weld		D-1	214												825	0.0316	1.0	0.0316		16	597
Straight	716	1	214-215	25.99	0.982				31.4	316	1055	555	360	26,100	816	0.0313		0.0313	1.0	7	399
Pres. Vessel Nozzle Weld		D-1	215												816	0.0313	1.0	0.0313		101	413
Model 7 - Recirc Loop No. 3 - Bypass Line										Seam- less 316											
Straight	717	1	217-218	2.374	0.218				5.0		1055	555	360	26,100	138	0.0053	1.3	0.0053	0.0065	1661	2047
Weld		D-1a	218												159	0.0061		0.0079		1000	2340
Elbow	718	2	218-219	2.374	0.218	3.0	1.5	87.9		316	1055	555	360	26,100	171	0.0066	1.3	0.0066	0.0065	1007	3073
Weld		D-1a	219												171	0.0066		0.0086		1087	2784
Straight	719	1	219-220	2.374	0.218				26.7	316	1055	555	360	26,100	139	0.0053		0.0053	0.0065	837	2127
Blanked-Off/Decontamina- tion Nozzle		D-4	220												90	0.0034	1.04	0.0035		549	1966
Straight	720	1	220-221	2.374	0.218				2.5	316	1055	555	360	26,100	90	0.0034		0.0034	0.0065	549	1966
Weld		D-1a	221												80	0.0031	1.3	0.0040		533	1788
Straight	721	1	221-222	2.374	0.218				33.6	316	1055	555	360	26,100	80	0.0031		0.0031	0.0065	533	1788
Weld		D-1a	222												77	0.0030	1.3	0.0039		472	498
Elbow	722	2	222-223	2.374	0.218	3.0	1.5	90°		316	1055	555	360	26,100	89	0.0034		0.0034	0.0065	488	654
Weld		D-1a	223												89	0.0034	1.3	0.0044		565	528
Straight	723	1	223-224	2.374	0.218				6.0	316	1055	555	360	26,100	68	0.0026		0.0026	0.0065	431	525
Valve Attachment		D-1a	224												62	0.0024	1.3	0.0031		368	637
Valve	724	4	224-225	2.374	0.60				7.5	316	1055	555	360	26,100	37	0.0014		0.0014	0.0024	218	377
Valve Attachment		D-1a	225												56	0.0021	1.3	0.0027		178	468
Straight	725	1	225-226	2.374	0.218				85.3	316	1055	555	360	26,100	79	0.0030		0.0030	0.0065	301	792
Weld		D-1a	226												103	0.0039	1.3	0.0051		975	803
Elbow	726	2	226-227	2.374	0.218	3.0	1.5	90°		316	1055	555	360	26,100	103	0.0039		0.0039	0.0065	1286	979
Weld		D-1a	227												80	0.0031	1.3	0.0040		437	1095
Straight	727	1	227-228	2.374	0.218				20.0	316	1055	555	360	26,100	113	0.0043		0.0043	0.0065	4532	1390

Model Number 7 Recirculation Loop No. 4 (Main Line) Component or Discontinuity	Component Number	Type	MASS Joint Number	Diameter D (Outside), in.	Thickness t, in.	Radius of Curvature, ρ , in.	ρ/D^*	Included Angle θ	Length of Straight Pipe, in.	Material	Operating Pressure, psi	Operating Temperature, °F	Number of Cycles/40 yr.	$S_A = f(1.25 S_c + 0.25 S_A)$, psi	S_E from MASS, psi	S_E/S_A	Stress Int. Factor, i	$(S_E/S_A)^i$	A/A _{max}	S_w , Weight Stress, psi	S_q , Earthquake Stress, psi
Pressure Vessel Nozzle Weld		D-1	302												694	0.0266	1.0	0.0266		134	836
Elbow	801	2	302-303	25.99	0.982	39.0	1.5	90°		Welded 316	1015	555	360	26,100	1637	0.0627		0.0627	1.0	52	735
Weld		D-1	303												1637	0.0627	1.0	0.0627		23	484
Straight	802	1	303-337	25.99	0.982				19.5	316	1015	555	360	26,100	713	0.0273		0.0273	1.0	22	433
Straight	802	1	337-338	25.99	0.982				19.5	316	1015	555	360	26,100	705	0.0270		0.0270	1.0	22	433
Straight	802	1	338-335	25.99	0.982				213.0	316	1015	555	360	26,100	698	0.0267		0.0267	1.0	20	415
Hanger		D-2	335												629	0.0241	1.0	0.0241		15	499
Straight	803	1	335-304	25.99	0.982				103.0	316	1015	555	360	26,100	629	0.0241		0.0241	1.0	15	499
Valve Attachment		D-1	304												603	0.0231	1.0	0.0231		19	596
Valve	804	4	304-305	25.99	6.5				60.0	316	1015	555	360	26,100	170	0.0065		0.0065	0.2923	5	171
Valve Attachment		D-1	305												1354	0.0519	1.0	0.0519		6	121
Elbow	805	2	305-306	25.99	0.982	39.0	1.5	90°		316	1015	555	360	26,100	1354	0.0519		0.0519	1.0	51	494
Weld		D-1	306												1328	0.0126	1.0	0.0126		166	685
Straight	806	1	306-307	25.99	0.982				18.6	316	1015	555	360	26,100	187	0.0072		0.0072	1.0	72	338
1 in. Pressure Sensing Line		D-3	Between 306 & 307																		
Thermocouple		D-3	Between 306 & 307																		
Blanked-Off Decon- tamination Nozzle		D-5	Between 306 & 307																		
Weld		D-1	307												272	0.0104	1.0	0.0104		54	442
Elbow	807	2	307-308	25.99	0.982	26.0	1.1	90°		316	1015	555	360	26,100	1199	0.0459		0.0459	1.0	162	936
Pump Attachment		D-1	308												1199	0.0459	1.0	0.0459		112	935
Pump	808	5	308-310																		
Pump Attachment		D-1	310												1202	0.0461	1.0	0.0461		31	822
Sector of Elbow	809	2	310-317	25.99	0.982	40.0	1.5	47.9°			1055	555	360	26,100	2096	0.0803		0.0803	1.0	63	598
Thermocouple		D-3	Between 310 & 317																		
1 in. Pressure Sensing Line		D-3																			
Bypass Connection		D-5	317												2096	0.0803	1.875	0.1506		65	596
Sector of Elbow	810	2	317-311	25.99	0.982	42.5	1.6	25.7		316	1055	555	360	26,100	1584	0.0607		0.0607	1.0	35	524

Model Number 7 Recirculation Loop No. 4 (Main Line) (Continued) Component or Discontinuity	Component Number	Type	MASS Joint Number	Diameter D (Outside), in.	Thickness t, in.	Radius of Curvature, ρ , in.	ρ/D^*	Included Angle θ	Length of Straight Pipe, in.	Material	Operating Pressure, psi	Operating Temperature, °F	Number of Cycles/40 yr.	$S_A = f(1.25 S_C + 0.25 S_A)$, psi	S_E from MASS, psi	S_E/S_A	Stress Int. Factor, i	$(\dot{S}_E/S_A)_i$	A/A _{max}	S_W , Weight Stress, psi	S_q , Earthquake Stress, psi
Valve Attachment	811	D-1	311	25.99	6.5				75.0	Welded 316	1055	555	360	26,100	1584	0.0607	1.0	0.0607	0.2923	5	107
Valve		4	311-312												1261	0.0100				4	135
Valve Attachment	812	D-1	312	25.99	0.982				7.5	316	1055	555	360	26,100	1881	0.0338	1.0	0.0338	1.0	13	467
Straight		1	312-328												881	0.0338				12	463
Bypass Connection	813	D-4	328	25.99	0.982				50.5	316	1055	555	360	26,100	1878	0.0336	1.875	0.0630	1.0	19	463
Straight		1	328-336												878	0.0336				15	440
Flow Meter	814	D-3a	Between 328-336	25.99	0.982				113.2	316	1055	555	360	26,100	859	0.0329	1.0	0.0329	1.0	15	440
Hanger		D-2	336												859	0.0329				15	440
Straight	814	1	336-340	25.99	0.982				19.5	316	1055	555	360	26,100	859	0.0329		0.0329	1.0	7	412
Straight	814	1	340-339						19.5	316	1055	555	360	26,100	820	0.0314				7	412
Straight	814	1	339-313						19.5	316	1055	555	360	26,100	813	0.0311				7	395
Weld	815	D-1	313	25.99	0.982	39.0	1.5	76°		316	1055	555	360	26,100	1855	0.0711	1.0	0.0711	1.0	6	388
Elbow		2	313-314												1855	0.0711				8	500
Weld	816	D-1	314	25.99	0.982				31.4	316	1055	555	360	26,100	821	0.0315	1.0	0.0315	1.0	16	488
Straight		1	314-315												814	0.0312				7	336
Pressure Vessel Nozzle Weld		D-1	315												814	0.0312	1.0	0.0312		101	348
Model Number 7 Recirculation Loop No. 4 (Bypass Line)																					
Straight	817	1	317-318	23.74	0.218				5.0	Seam- less 316	1055	555	360	26,100	139	0.0053		0.0053	0.0065	1385	1784
Weld	818	D-1a	318	23.74	0.218	3.0	1.5	87.6°		316	1055	555	360	26,100	159	0.0061	1.3	0.0079	0.0065	853	2352
Elbow		2	318-319												172	0.0066				856	2295
Weld	819	D-1a	319	23.74	0.218				26.7	316	1055	555	360	26,100	172	0.0066	1.3	0.0086	0.0065	930	2567
Straight		1	319-320												139	0.0053				722	1195
Blanked-Off Decon- tamination Nozzle	820	D-4	320	23.74	0.218				2.5	316	1055	555	360	26,100	90	0.0034	1.04	0.0035	0.0065	499	1816
Straight		1	320-321												90	0.0034				499	1816
Weld	821	D-1a	321	23.74	0.218				33.6	316	1055	555	360	26,100	80	0.0031	1.3	0.0040	0.0065	480	1638
Straight		1	321-322												80	0.0031				480	482

Model Number 7 Recirculation Loop No. 4 (Bypass Line) (Continued)	Component Number	Type	MASS Joint Number	Diameter D (Outside), in.	Thickness t, in.	Radius of Curvature, ρ , in.	ρ/D^*	Included Angle θ	Length of Straight Pipe, in.	Material	Operating Pressure, psi	Operating Temperature, °F	Number of Cycles/40 yr.	$S_A = f(1.25 S_c + 0.25 S_A)$, psi	S_E from MASS, psi	S_E/S_A	Stress Int. Factor, i	$(S_E/S_A)^i$	A/A_{max}	S_w , Weight Stress, psi	S_q , Earthquake Stress, psi
Weld		D-1a	322							Seam- less 316					77	0.0030	1.3	0.0039		440	632
Elbow	822	2	322-323	23.74	0.218	3.0	1.5	90°			1055	555	360	26,100	88	0.0034		0.0034	0.0065	472	640
Weld		D-1a	323												88	0.0034	1.3	0.0042		514	637
Straight	823	1	323-324	23.74	0.218				6.0	316	1055	555	360	26,100	68	0.0026		0.0026	0.0065	392	434
Valve Attachment		D-1a	324												62	0.0024	1.3	0.0031		324	434
Valve	824	4	324-325	23.74	0.60				7.5	316	1055	555	360	26,100	37	0.0014		0.0014	0.0020	192	510
Valve Attachment		D-1a	325												56	0.0021	1.3	0.0027		147	863
Straight	825	1	325-326	23.74	0.218				85.4	316	1055	555	360	26,100	79	0.0030		0.0030	0.0059	249	961
Weld		D-1a	326												103	0.0039	1.3	0.0051		960	1147
Elbow	826	2	326-327	23.74	0.218	3.0	1.5	90°		316	1055	555	360	26,100	103	0.0039		0.0039	0.0059	1267	1308
Weld		D-1a	327												80	0.0031	1.3	0.0040		436	1110
Straight	827	1	327-328	23.74	0.218				20.0	316	1055	555	360	26,100	114	0.0044		0.0044	0.0059	4433	1703
Bypass Connection																					
Model Number 8 Recirculation Loop No. 5 (Main Line)																					
Pressure Vessel Nozzle Weld		D-1	402												2940	0.1126	1.0	0.1126		192	2243
Elbow	901	2	402-403	25.99	0.982	39.0	1.5	90°		Welded 316	1015	555	360	26,100	2940	0.1126		0.1126	1.0	577	620
Weld		D-1	403												2090	0.0801	1.0	0.0801		146	231
26 in. Run of Tee 437	902	1	403-437	25.99	1.875				19.5	316	1015	555	360	26,100	977	0.0374		0.0456	0.8569	179	354
26 in. Run of Tee 437	903	1	437-438	25.99	1.875				19.5	316	1015	555	360	26,100	691	0.0265		0.0456	0.8569	369	375
Weld		D-1	438												1126	0.0431	1.0	0.0431		347	400
Straight	904	1	438-435	25.99	0.982				213.0	316	1015	555	360	26,100	1126	0.0431		0.0431	1.0	596	689
Hanger		D-2	435												581	0.0223	1.0	0.0223		225	694
Straight	905	1	435-404	25.99	0.982				103.0	316	1015	555	360	26,100	581	0.0223		0.0223	1.0	56	694
Valve Attachment		D-1	404												561	0.0215	1.0	0.0215		16	703
Valve	906	4	404-405	25.99	6.5				60.0	316	1015	555	360	26,100	189	0.0072		0.0072	0.2923	22	202
Valve Attachment		D-1	405												1327	0.0508	1.0	0.0508		169	157
Elbow	907	2	405-406	25.99	0.982	39.0	1.5	90°		316	1015	555	360	26,100	1327	0.0508		0.0508	1.0	162	833
Weld		D-1	406												730	0.0280	1.0	0.0280		108	558
Straight	908	1	406-407	25.99	0.982				18.5	316	1015	555	360	26,100	532	0.0200		0.0200	1.0	122	441
Thermocouple		D-3	Between 406 & 407																		

Model Number 8 Recirculation Loop No. 5 (Main Line) (Continued)	Component Number	Type	MASS Joint Number	Diameter D (Outside), in.	Thickness t, in.	Radius of Curvature, ρ , in.	ρ/D^*	Included Angle θ	Length of Straight Pipe, in.	Material	Operating Pressure, psi	Operating Temperature, °F	Number of Cycles/40 yr.	$S_A = f(1.25 S_C + 0.25 S_A)$, psi	S_E from MASS, psi	S_E/S_A	Stress Int. Factor, i	$(S_E/S_A)^i$	A/A _{max}	S_w , Weight Stress, psi	S_q , Earthquake Stress, psi
1 in. Pressure Tap		D-3	Between 406 & 407																		
Blanked-Off Decontamination Nozzle		D-5	Between 406 & 407																		
Weld		D-1	407												668	0.0256	1.0	0.0256		262	1089
Elbow	909	2	407-408	25.99	0.982	26.0	1.0	90°		Welded 316	1015	555	360	26,100	1472	0.0564		0.0564	1.0	200	1327
Pump Attachment		D-1	408												1472	0.0564	1.0	0.0564		200	1327
Pump	910	5	408-410																		
Pump Attachment		D-1	410												655	0.0251	1.0	0.0251		118	852
Sector of Elbow	911	2	410-417	25.99	0.982	40.0	1.5	48°		316	1015	555	360	26,100	1296	0.0497		0.0491	1.0	116	646
Thermocouple		D-3	Between 410 & 417																		
1 in. Pressure Tap		D-3	Between 410 & 417																		
Bypass Connection		D-4	417												1296	0.0497	1.875	0.0932		112	648
Sector of Elbow	912	2	417-411	25.99	0.982	42.5	1.6	26°		316	1015	555	360	26,100	1064	0.0408		0.0408	1.0	185	527
Valve Attachment		D-1	411												1064	0.0408	1.0	0.0408		25	385
Valve	913	4	411-412	25.99	6.5				75.0	316	1015	555	360	26,100	229	0.0038		0.0088	0.2923	31	144
Valve Attachment		D-1	412												798	0.0306	1.0	0.0306		107	500
Straight	914	1	412-428	25.99	0.982				7.5	316	1015	555	360	26,100	818	0.0314		0.0314	1.0	116	499
Bypass Connection		D-4	428												819	0.0314	1.875	0.0589		123	501
Straight	915	1	428-436	25.99	0.982				50.5	316	1015	555	360	26,100	966	0.0370		0.0370	1.0	200	483
Flow Meter		D-3a	Between 428 & 436																		
Hanger		D-2	436												966	0.0370	1.0	0.0370		200	483
Straight	916	1	436-440	25.99	0.982				113.2	316	1015	555	360	26,100	1328	0.0509		0.0509	1.0	200	500
Weld		D-1	440												1328	0.0509	1.0	0.0509		396	291
26 in. Run of Tee	917	1	440-439	25.99	1.875				19.5	316	1055	555	360	26,100	810	0.0310		0.0378	0.8569	230	308
26 in. Run of Tee	918	1	439-413	25.99	1.875				19.5	316	1055	555	360	26,100	759	0.0291		0.0355	0.8569	250	394
Weld		D-1	413												2983	0.1143	1.0	0.1143		82	239
Elbow	919	2	413-414	25.99	0.982	39.0	1.5	76°		316	1055	555	360	26,100	2983	0.1143		0.1143	1.0	298	909
Weld		D-1	414												1639	0.0628	1.0	0.0628		189	900
Straight	920	1	414-415	25.99	0.982				31.4	316	1055	555	360	26,100	1523	0.0584		0.0584	1.0	83	408
Pressure Vessel Nozzle Weld		D-1	415												1523	0.0584	1.0	0.0584		117	863

Model Number 8 Recirculation Loop No. 5 (Bypass Line) Component or Discontinuity	Component Number	Type	MASS Joint Number	Diameter D (Outside), in.	Thickness t, in.	Radius of Curvature, ρ , in.	ρ/D^*	Included Angle θ	Length of Straight Pipe, in.	Material	Operating Pressure, psi	Operating Temperature, °F	Number of Cycles/40 yr.	$S_A = f(1.25 S_C + 0.25 S_A)$, psi	S_E from MASS, psi	S_E/S_A	Stress Int. Factor, i	$(S_E/S_A)^i$	A/A _{max}	S_w , Weight Stress, psi	S_q , Earthquake Stress, psi
Straight Weld Elbow Weld Straight Blanked-Off Decontam- ination Nozzle Straight Weld Straight Weld Elbow Weld Straight Valve Connection Valve Valve Connection Straight Weld Elbow Weld Straight	921	1	417-418	2.374	0.218				5.0	Seamless 316	1055	555	360	26,100	118	0.0045		0.0045	0.0065	1469	1923
		D-1a	418												135	0.0052	1.3	0.0068		886	2337
	922	2	418-419	2.374	0.218	3.0	1.5	88°		316	1055	555	360	26,100	151	0.0058		0.0058	0.0065	890	3007
		D-1a	419												151	0.0058	1.3	0.0075		963	3166
	923	1	419-420	2.374	0.218				26.7	316	1055	555	360	26,100	120	0.0046		0.0046	0.0065	747	2450
		D-4	420												76	0.0029	1.04	0.0030		510	1620
	924	1	420-421	2.374	0.218				2.5	316	1055	555	360	26,100	76	0.0029		0.0029	0.0065	510	1620
		D-1a	421												68	0.0026	1.3	0.0034		491	1449
	925	1	421-422	2.374	0.218				33.6	316	1055	555	360	26,100	68	0.0026		0.0026	0.0065	491	1449
		D-1a	422												67	0.0026	1.3	0.0034		449	576
	926	2	422-423	2.374	0.218	3.0	1.5	90°		316	1055	555	360	26,100	78	0.0030		0.0030	0.0065	479	759
		D-1a	423												78	0.0030	1.3	0.0039		522	733
	927	1	423-424	2.374	0.218				6.0	316	1055	555	360	26,100	60	0.0023		0.0023	0.0065	398	727
		D-1a	424												54	0.0021	1.3	0.0027		330	818
	928	4	424-425	2.374	0.60				7.5	316	1055	555	360	26,100	32	0.0012		0.0012	0.0024	195	484
		D-1a	425												47	0.0018	1.3	0.0023		151	551
	929	1	425-426	2.374	0.218				85.3	316	1055	555	360	26,100	83	0.0032		0.0032	0.0065	255	932
		D-1a	426												108	0.0041	1.3	0.0053		975	1110
	930	2	426-427	2.374	0.218	3.0	1.5	90°		316	1055	555	360	26,100	108	0.0041		0.0041	0.0065	1286	1329
		D-1a	427												84	0.0032	1.3	0.0042		425	1479
	931	1	427-428	2.374	0.218				20.0	316	1055	555	360	26,100	99	0.0038		0.0038	0.0065	4498	1910
Model Number 8 from Shutdown Cooling 14 in. × 24 in. Tee in Recirculation Loop No. 5		D-4	439												2937	0.1125	1.22	0.1373		2692	4532
Straight	932	1	439-511	14.0	0.75				32.7	Welded 304	1000	146	360	26,100	2937	0.1125		0.1373	0.2707	1383	4257
Weld		D-1	511												4351	0.1667	1.0	0.1667		1611	4902
Elbow	933	2	511-512	14.0	0.75	21.0	1.5	90°		304	1000	146	360	26,100	4351	0.1667		0.1667	0.2707	644	4292
Weld		D-1	512												2127	0.0815	1.0	0.0815		563	4299
Straight	934	1	512-513	14.0	0.75				6.0	304	1000	146	360	26,100	2075	0.0745		0.0795	0.2707	527	4299
Weld		D-1	513												2080	0.0797	1.0	0.0797		537	7460

Model Number 8 from Shutdown Cooling Component or Discontinuity	Component Number	Type	MASS Joint Number	Diameter D (Outside), in.	Thickness t, in.	Radius of Curvature, ρ, in.	ρ/D*	Included Angle θ	Length of Straight Pipe, in.	Material	Operating Pressure, psi	Operating Temperature, °F	Number of Cycles/40 yr.	$S_A = f(1.25 S_c + 0.25 S_A)$, psi	S_E from MASS, psi	S_E/S_A	Stress Int. Factor, i	$(S_E/S_A)^i$	A/A _{max}	S_w , Weight Stress, psi	S_q , Earthquake Stress, psi
Elbow	935	2	513-514	14.0	0.75	21.0	1.5	90°		Welded 304	1000	146	360	26,100	4433	0.1698		0.1698	0.2707	1746	6342
Weld		D-1	514												4433	0.1698	1.0	0.1698		980	3560
Straight	936	1	514-515	14.0	0.75				101.3	304	1000	146	360	26,100	2509	0.0961		0.0961	0.2707	616	1634
Valve Connection		D-1	515												631	0.0242	1.0	0.0242		240	635
Valve	937	4	515-516	14.0	3.5				42.0	304	1000	146	360	26,100	252	0.0097		0.0097	0.0849	196	492
Valve Connection		D-1	516												649	0.0249	1.0	0.0249		505	1265
Straight	938	1	516-517	14.0	0.75				69.0	304	1000	146	360	26,100	1897	0.0727		0.0729	0.2707	750	1835
Weld		D-1	517												3330	0.1276	1.0	0.1276		1336	3261
Elbow	939	2	517-518	14.0	0.75	21.0	1.5	90°		304	1000	146	360	26,100	3330	0.1276		0.1276	0.2707	554	1943
Weld		D-1	518												2247	0.0861	1.0	0.0861		512	1745
Straight	940	1	518-519	14.0	0.75				6.0	304	1000	146	360	26,100	2242	0.0859		0.0859	0.2707	494	1717
Weld		D-1	519												2252	0.0863	1.0	0.0863		498	1836
Elbow	941	2	519-520	14.0	0.75	21.0	1.5	90°		304	1000	146	360	26,100	4666	0.1788		0.1788	0.2707	905	2182
Weld		D-1	520												4666	0.1788	1.0	0.1788		807	1224
Straight	942	1	520-521	14.0	0.75				58.9	304	1000	146	360	26,100	3482	0.1334		0.1334	0.2707	2809	101
Drywell Penetration		D-2	521												3482	0.1334		0.1334		2809	0
Model Number 8 to Shutdown Cooling																					
14 in. × 26 in. Tee in Recirculation Line No. 5		D-4	437												9262	0.3549	1.22	0.4330		4430	3247
Branch of Tee 437	943	1	437-451	14.0	0.75				30.0	Welded 304	1000	146	360	26,100	9262	0.3549		0.4330	0.2707	2848	1866
Run of Tee 451		D-4	451												7576	0.3903	1.49	0.5815		1411	2024
10 in. × 14 in. Tee to E. C. C. No. 2	944	1	451-501	14.0	0.75				26.0	304	1000	146	360	26,100	7576	0.3903		0.5815	0.2707	798	1241
Run of Tee 451		D-1	501												5830	0.2234	1.0	0.2234		310	482
Valve Connection																					
Valve	945	4	501-502	14.0	0.35				42.0	304	1000	146	360	26,100	2676	0.1025		0.1025	0.0849	413	230
Valve Connection		D-1	502												6882	0.2637	1.0	0.2637		1062	592
Straight	946	1	502-503	14.0	0.75				8.0	304	1000	146	360	26,100	7555	0.2995		0.2995	0.2707	1046	609
Weld		D-1	503												11690	0.4479	1.0	0.4479		1451	979
Elbow	947	2	503-504	14.0	0.75	21.0	1.5	90°		304	1000	146	360	26,100	11690	0.4479		0.4479	0.2707	1579	821
Weld		D-1	504												9195	0.3523	1.0	0.3523		1579	492

Model Number 8 to Shutdown Cooling (Continued)	Component Number	Type	MASS Joint Number	Diameter D (Outside), in.	Thickness t, in.	Radius of Curvature, ρ, in.	ρ/D*	Included Angle θ	Length of Straight Pipe, in.	Material	Operating Pressure, psi	Operating Temperature, °F	Number of Cycles/40 yr.	$S_A = f(1.25 S_c + 0.25 S_A)$, psi	S_E from MASS, psi	S_E/S_A	Stress Int. Factor, i	$(S_E/S_A)^i$	A/A _{max}	S_w , Weight Stress, psi	S_q , Earthquake Stress, psi
Straight	948	1	504-505	14.0	0.75				39.5	Welded 304	1000	146	360	26,100	7001	0.2682		0.2682	0.2707	894	382
Weld		D-1	505												8241	0.3157	1.0	0.3157		767	606
Elbow	949	2	505-506	14.0	0.75	21.0	1.5	90°		304	1000	146	360	26,100	8241	0.3157		0.3157	0.2707	1351	406
Weld		D-1	506												7941	0.3043	1.0	0.3043		597	406
Elbow	950	2	506-507	14.0	0.75	21.0	1.5	90°		304	1000	146	360	26,100	11240	0.4307		0.4307	0.2707	327	480
Weld		D-1	507												11240	0.4307	1.0	0.4307		470	269
Straight	951	1	507-508	14.0	0.75				92.3	304	1000	146	360	26,100	6500	0.2490		0.2490	0.2707	2797	0
Drywell Penetration		D-2	508												3436	0.1316	1.0	0.1316		2797	0
Model Number 8 Emergency Condenser Condensate																					
10 in. Branch of Tee 451	952	1	451-452	10.75	0.593				54.2	Seamless 304	1000	157	500	26,100	4622	0.1771		0.2639	0.1585	7419	3496
Valve Connection		D-1	452												3844	0.1473	1.0	0.1473		3048	867
Valve	953	4	452-453	10.75	2.5				36.0	304	1000	157	500	26,100	1564	0.0599		0.0599	0.0582	1240	353
Valve Connection		D-1	453												3399	0.1302	1.0	0.1302		542	178
Straight	954	1	453-454	10.75	0.593				51.4	304	1000	157	500	26,100	3399	0.1302		0.1302	0.1585	1332	437
Weld		D-1	454												5118	0.1961	1.0	0.1961		572	1435
Elbow	955	2	454-455	10.75	0.593	15.0	1.5	90°		304	1000	157	500	26,100	5118	0.1961		0.1961	0.1585	969	2624
Weld		D-1	455												3519	0.1348	1.0	0.1348		473	2785
Straight	956	1	455-456	10.75	0.593				83.9	304	1000	157	500	26,100	2448	0.0938		0.0938	0.1585	414	1526
Weld		D-1	456												3467	0.1328	1.0	0.1328		521	624
Elbow	957	2	456-457	10.75	0.593	15.0	1.5	90°		304	1000	157	500	26,100	4633	0.1775		0.1775	0.1585	747	1124
Weld		D-1	457												4633	0.1775	1.0	0.1775		657	582
Straight	958	1	457-458	10.75	0.593				83.8	304	1000	157	500	26,100	2532	0.0970		0.0970	0.1585	570	467
Weld		D-1	458												1863	0.0714	1.0	0.0714		1855	740
Elbow	959	2	458-459	10.75	0.593	15.2	1.5	90°		304	1000	157	500	26,100	1863	0.0714		0.0714	0.1585	3269	561
Weld		D-1	459												897	0.0344	1.0	0.0344		2296	533
Straight	960	1	459-460	10.75	0.593				10.6	304	1000	157	500	26,100	997	0.0382		0.0382	0.1585	2296	304
Hanger and Weld		D-1&2	460												1434	0.0549	1.0	0.0549		2328	430
Elbow	961	2	460-461	10.75	0.593	15.0	1.5	90°		304	1000	157	500	26,100	1829	0.0701		0.0701	0.1585	2401	645

Model Number 8 Emergency Condenser Condensate (Continued)	Component Number	Type	MASS Joint Number	Diameter D (Outside), in.	Thickness t, in.	Radius of Curvature, ρ, in.	ρ/D*	Included Angle θ	Length of Straight Pipe, in.	Material	Operating Pressure, psi	Operating Temperature, °F	Number of Cycles/40 yr.	$S_A = f(1.25 S_C + 0.25 S_A)$, psi	S_E from MASS, psi	S_E/S_A	Stress Int. Factor, i	$(S_E/S_A)^i$	A/A _{max}	S_w Weight Stress, psi	S_q Earthquake ¹ Stress, psi
Weld		D-1	461							Seam- less 304					1829	0.0701	1.0	0.0701		4324	1036
Straight	962	1	461-462	10.75	0.593				243.1		1000	157	500	26,100	5216	0.1998		0.1998	0.1585	2369	614
Valve Connection		D-1	462												5216	0.1998	1.0	0.1998		1289	2748
Valve	963	4	462-463	10.75	0.593				33.0	304	1000	157	500	26,100	413	0.0158		0.0158	0.1585	598	2324
Valve Connection		D-1	463												791	0.0303	1.0	0.0303		152	1755
Straight	964	1	463-464	10.75	0.593				28.0	304	1000	157	500	26,100	791	0.0303		0.0303	0.1585	373	4313
Bend	965	3	464-465	10.75	0.593	47.6	4.8	46°		304	1000	157	500	26,100	663	0.0254		0.0254	0.1585	27	3539
Straight	966	1	465-466	10.75	0.593				174.0	304	1000	157	500	26,100	803	0.0308		0.0308	0.1585	147	3812
Bend	967	3	466-467	10.75	0.593	48.3	4.8	90°		304	1000	157	500	26,100	803	0.0308		0.0308	0.1585	263	1235
Hanger		D-2	467												244	0.0093	1.0	0.0093		1438	1674
Straight	968	1	467-468	10.75	0.593				19.3	304	1000	157	500	26,100	361	0.0138		0.0138	0.1585	815	1723
Bend	969	3	468-469	10.75	0.593	48.3	4.8	90°		304	1000	157	500	26,100	1009	0.0387		0.0387	0.1585	400	2107
Straight	970	1	469-470	10.75	0.593				252.2	304	1000	157	500	26,100	1336	0.0512		0.0512	0.1585	400	1555
Bend	971	3	470-471	10.75	0.593	48.0	4.8	90°		304	1000	157	500	26,100	1429	0.0548		0.0548	0.1585	560	1063
Hanger		D-2	471												1429	0.0548	1.0	0.0548		1385	1317
Straight	972	1	471-472	10.75	0.593				24.0	304	1000	157	500	26,100	1564	0.0599		0.0599	0.1585	789	1317
Bend	973	3	472-473	10.75	0.593	48.0	4.8	90°		304	1000	157	500	26,100	1724	0.0661		0.0661	0.1585	594	2251
Straight	974	1	473-474	10.75	0.593				84.0	304	1000	157	500	26,100	1803	0.0691		0.0691	0.1585	594	2156
Bend	975	3	474-475	10.75	0.593	48.0	4.8	90°		304	1000	157	500	26,100	2062	0.0790		0.0790	0.1585	771	1818
Hanger		D-2	475												2031	0.0778	1.0	0.0778		771	1818
10 in. Branch of Tee 476	976	1	475-476	10.75	0.593				78.0	304	1000	157	500	26,100	2140	0.0782		0.1193	0.1585	252	2847
8 in. × 10 in. Tee		D-4	476												2208	0.0846	1.41	0.1193		535	4653
8 in. Run of Tee 476	977	1	476-477	8.624	0.50				56.4	304	1000	157	500	26,100	2208	0.0846		0.1193	0.1007	317	2635
Bend	978	3	477-478	8.624	0.50	48.0	6.0	90°		304	1000	157	500	26,100	1121	0.0430		0.0403	0.1007	333	931
Straight	979	1	478-479	8.624	0.50				52.8	304	1000	157	500	26,100	1896	0.0726		0.0706	0.1007	83	3389
Weld		D-1	479												2884	0.1105	1.41	0.1105		125	5121
Elbow	980	2	479-480	8.624	0.50	15.0	1.9	60°		304	1000	157	500	26,100	2976	0.1140		0.1140	0.1007	515	6545
Weld		D-1	480												2766	0.1060	1.41	0.1060		353	4300
Straight	981	1	480-481	8.624	0.50				10.8	304	1000	157	500	26,100	2019	0.0774		0.0774	0.1007	859	4455
Condenser Attachment		D-1	481												1822	0.0698	1.41	0.0698		859	4455
8 in. Run of Tee 476	987	1	476-487	8.624	0.50				87.6	304	1000	157	500	26,100	1822	0.0698		0.1193	0.1007	114	2906
Bend	988	3	487-488	8.624	0.50	48.0	6.0	90°		304	1000	157	500	26,100	1755	0.0672		0.0672	0.1007	254	2221
Straight	989	1	488-489	8.624	0.50				52.8	304	1000	157	500	26,100	1954	0.0748		0.0748	0.1007	304	910
Weld		D-1	489												2960	0.1134	1.41	0.1134		123	2526
Elbow	990	2	489-490	8.624	0.50				52.8	304	1000	157	500	26,100	2960	0.1134		0.1134	0.1007	183	3835
Weld		D-1	490												2794	0.1070	1.41	0.1070		687	4364
Straight	991	1	490-491	8.624	0.50				10.8	304	1000	157	500	26,100	2327	0.0890		0.0890	0.1007	468	3425
Condenser Attachment		D-1	491												2937	0.1125	1.41	0.1125		1059	3624

REFERENCES

1. "Pipe Hanger Design and Engineering," Grinnell Corporation, 1964.
2. American Institute of Steel Construction - Manual.
3. American Standard Code for Pressure Piping, ASA B31.1 - 1955.
4. General Electric Design Specification for Piping and Valve 22A1045.
5. "Earthquake History of the United States," Part I, U. S. Coast and Geodetic Survey, Eastern Resume of Earthquake History.
6. Housner, G. W., "Behavior of Structures During Earthquakes," Proc. ASCE, J. Eng. Mech. Div., pp. 109-129.
7. Beitch, L., "MASS - Digital Computer Program for Static and Dynamic Analysis of General Structures," April 27, 1964, TIS No. R64FPD93 (General Electric Company proprietary information).
8. Moody, F. J., NUSA-167 "Impact Pressure from High Speed Fluid Slugs," July 30, 1965 (Internal GE Memo).
9. G. E. Drawing 885D941, "Nozzle Thermal Cycles," September 1965.
10. Desai, M. P., "Reactor Vessel Nozzle and Auxiliary System Temperature Cycles, Design Guide," GE Memo DA-10, October 25, 1966.
11. LeFort, P. N., "Stress Analysis of the Tarapur Isolation Condenser at the 8-inch Inlet Nozzle," GE Memo SAR-6, October 17, 1966.
12. Schneider, P. J., "Temperature Response Charts," John Wiley & Sons, Inc., New York, 1963.
13. "Design of Piping Systems," M. W. Kellogg Co., John Wiley & Sons, Inc., New York, 1956.
14. Internal APED Memo, "Pipe Vibration Stress," J. E. Corr to S. W. Tagart, March 29, 1967.
15. Wilson, S. A., "Reliability Engineering, Sixth Quarterly Progress Report, Pipe Rupture Study," GEAP-5279.
16. Krempl, E., "Low-Cycle Fatigue Strength Reduction in Notched Flat Plates," GEAP-5410, January 1967.
17. "Criteria of Section III of the ASME Boiler and Pressure Vessel Code for Nuclear Vessels," 1964.
18. Goldfarb, A. O., and Beitch, L., "FAST II - Digital Computer Program for the Analysis of Space Structures," December 17, 1962, TIS No. R62FPD391.

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