STONE & WEBSTER ENGINEERING CORPORATION

CALCULATION TITLE PAGE

CLIENT & PROJECT	PAGE 1 OF 498
TEXAS UTILITIES GENERATING CO. / CPSES UNITS 1 AND 2	Including 10 ATTACHMENTS

CALCULATION TITLE (INDICATIVE OF THE OBJECTIVE):

FATIGUE CYCLE DETERMINATION FOR PIPE SUPPORTS

☒ NUCLEAR SAFETY RELATED

☐ NON - NUCLEAR SAFETY RELATED

CALCULATION IDENTIFICATION NUMBER

J.O. OR W.O. NO.	DIVISION & GROUP	CURRENT CALC. NO.	OPTIONAL TASK CODE	OPTIONAL WORK PACKAGE NO.
15454	NP(C)	GEN X 103		

PREPARER(S)/DATE(S)	REVIEWER(S)/DATE(S)	INDEPENDENT REVIEWER(S)/DATE(S)	REV. NO. OR NEW CALC. NO.	SUPERSEDES * CALC. NO. OR REV. NO.	CONFIRMATION * REQUIRED (X) YES	NO
Shil Lee 9/12/86 J. Liaw 9/13/86 M. H. Ye 9/13/86	J. Liaw 9/13/86 Shil Lee 9/13/86 J. Liaw 9/13/86	Chuenjai Lin 9/15/86	REV. 0		✓ SEE PAGES 11, 15 ATT # 6, 8	
Yaw-jing Wu 9-16-86						

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Page 3 - 16A	J. Liaw	M. H. Yu
Attachment #1 page 13, 171 thru 201	M. H. Yu	J. Liaw
Attachmen # 10	M. H. Yu	J. Liaw

OBJECTIVE: TO DETERMINE FATIGUE CYCLES FOR CPSES PIPE SUPPORTS TO COMPLY WITH THE ASME SECTION III NF-3130 CODE REQUIREMENTS (DESIGN RULES FOR LINEAR TYPE SUPPORTS). THE RULES FOR DESIGNING LINEAR TYPE SUPPORTS GIVEN IN NF-3132.3 ARE ESSENTIALLY THE SAME AS THOSE GIVEN IN NF-3230 FOR LINEAR ELASTIC ANALYSIS, EXCEPT THAT THE MAXIMUM RANGE OF STRESS, NAMELY THE DIFFERENCE BETWEEN THE MINIMUM AND MAXIMUM VALUE OF THE STRESS THROUGHOUT EACH CYCLE AND THE FREQUENCY WITH WHICH THE SUPPORT WILL BE SUBJECTED TO THIS RANGE OF STRESS, SHALL BE TAKEN INTO CONSIDERATION WHEN SO STIPULATED BY THE DESIGN SPECIFICATION (NA-3250). THE THEORY OF FAILURE USED IN THE RULES FOR THE DESIGN OF LINEAR TYPE SUPPORTS IS THE MAXIMUM STRESS THEORY. IN THE MAXIMUM STRESS THEORY, THE CONTROLLING STRESS IS THE MAXIMUM PRINCIPAL STRESS. SUPPORT MEMBERS AND THEIR CONNECTIONS SUBJECT TO A NUMBER OF CYCLES (>20,000) OF FATIGUE LOADING RESULTING IN DAMAGE AS DEFINED IN NF-3331.2, SHALL BE PROPORTIONED TO SATISFY THE STRESS RANGE LIMITATIONS

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ASSUMPTIONS

1.) THE MAX. 30 CYCLES PER OCCURRENCE ARE USED FOR FLUID TRANSIENT CALCULATIONS OTHER THAN CHEMICAL AND VOLUME CONTROL AND MAIN STEAM SYSTEMS. THE 30 CYCLES PER OCCURRENCE WERE OBTAINED BY SWEEPING THE SINGLE DEGREE OF FREEDOM SYSTEM AT THE MAJOR FLUID TRANSIENT FREQUENCIES FOUND IN THE FORCING FUNCTIONS.

2.) THE 720 CYCLES FOR SEISMIC EVENT ARE ASSUMED. THIS IS BASED ON FSAR 3.7B.3.2 6 EARTHQUAKES AND 120 CYCLES PER EARTHQUAKE.

3.) SINGLE DEGREE OF FREEDOM MODEL IS USED TO PREDICT THE POSSIBLE HIGHEST FLUID TRANSIENT RESPONSE CYCLES (REF 5)

4.) UNIT 2 ASSESSMENT ON THERMAL CYCLES (REF 4) IS APPLICABLE FOR UNIT 1 PROBLEMS.

5.) DYNAMIC STRESS CYCLES OBTAINED FROM FLUID TRANSIENT CALCULATIONS FOR UNIT 1 PROBLEMS IS APPLICABLE TO UNIT 2 PROBLEMS OF SAME SYSTEM.

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<u>ANALYSIS</u> : THE TOTAL SERVICE CYCLES OF A PIPE SUPPORT OVER 40 YEARS OF PLANT LIFE IS OBTAINED BY COMBINING THE TOTAL EQUIVALENT CYCLES RESULTING FROM THE FLUID TRANSIENT EVENT AND THE EQUIVALENT SEISMIC TO THE THERMAL CYCLES. TO OBTAIN THE FLUID TRANSIENT EQUIVALENT STRESS CYCLES FROM ANY GIVEN TIME HISTORY MOTION. THE TIME HISTORY IS APPLIED TO SEVERAL SINGLE DEGREE OF FREEDOM SYSTEMS (SDOF), AS BASIC EXCITATION. THE RELATIVE-DISPLACEMENT RESPONSE OF EACH SDOF IS ANALYZED TO YIELD EQUIVALENT STRESS CYCLES. THE COUNTING IS BASED ON CALCULATING HALF OF EACH ALTERNATING PEAK TO PEAK RESPONSE I.E. $U_1/2$, $U_2/2$, $U_3/2$ ... etc; AND THEN NORMALIZING EACH OF THESE VALUES TO THE MAXIMUM SUCH RESPONSE USING AN EXPONENT FORMULA. THE EXPONENT FORMULA TO CALCULATE THE EQUIVALENT CYCLES N_{EQ} IS AS FOLLOWS

$$N_{EQ} = \sum_{a=1}^{n} \left(\frac{U_a/2}{U_{max}/2} \right)^P \qquad (1)$$

WHERE n REPRESENTS THE TOTAL ALTERNATING CYCLES IN THE RESPONSE, U_{MAX} IS THE MAXIMUM OF ANY PEAK TO PEAK RESPONSE AND P IS THE EXPONENT

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ANALYSIS (CONTINUED):

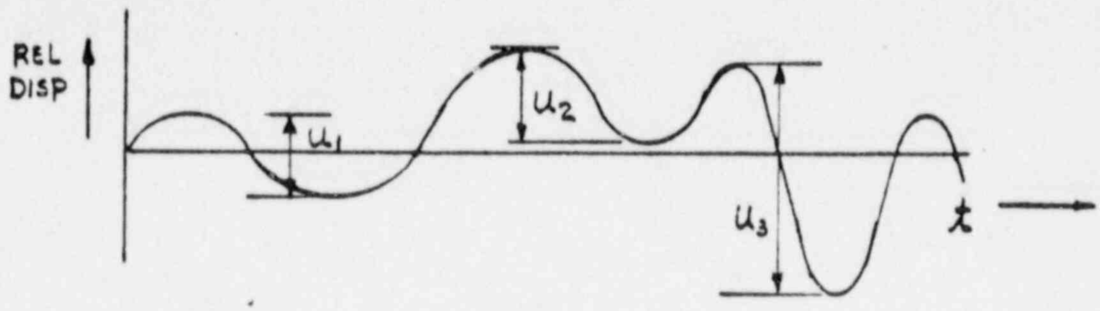

FIGURE 1

ONE OF THE IMPORTANT PARAMETER IN EQUATION (1) IS P. THIS VALUE DEPENDS ON THE PORTION OF THE S-N FATIGUE CURVE WHERE S_i, $i = 1 \ldots n$ LOCATE. A SIMPLE AND CONSERVATIVE METHOD IS TO USE THE SLOPE OF S-N CURVE AT THE HIGHEST STRESS LEVEL RATHER THAN USING THAT OF THE CORD BECAUSE OF THE CONCAVITY OF THE CURVE. THE RESULTS OF A STUDY OF THREE TYPES OF MATERIALS (1) CARBON, LOW ALLOY, AND HIGH TENSILE STEELS, (2) AUSTENITIC STEELS, NICKEL-CHROMIUM-IRON ALLOY, NICKEL-IRON-CHROMIUM ALLOY, AND NICKEL-COPPER ALLOY. AND (3) HIGH STRENGTH STEEL BOLTING, INDICATE A CONSERVATIVE VALUE OF $P=2$ CAN BE USED. THE VALUE OF $P=2$ CORRESPONDS TO A STRESS LEVEL OF ABOUT 550 KSI AND SHOULD ENVELOP THE MAXIMUM STRESS IN AN ENGINEERED COMPONENT. THE EQUIVALENT THERMAL CYCLES IS DETERMINED FROM THE ASME NC-3611 PROCEDURE. IF THE RANGE OF TEMPERATURE CHANGE VARIES, EQUIVALENT FULL TEMPERATURE CYCLES MAY BE COMPUTED AS FOLLOWS:

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ANALYSIS (CONTINUED):

$$N = N_E + r_1^5 N_1 + r_2^5 N_2 + \cdots + r_n^5 N_n$$

WHERE N_E = NUMBER OF CYCLES AT FULL TEMPERATURE CHANGE ΔT_E, FOR WHICH EXPANSION STRESS, S_E HAS BEEN CALCULATED

$N_1, N_2 \ldots\ldots N_n$ = NUMBER OF CYCLE AT LESSER TEMPERATURE CHANGES, $\Delta T_1, \Delta T_2, \ldots\ldots \Delta T_n$

$r_1, r_2 \ldots, r_n = (\Delta T_1)/(\Delta T_E), (\Delta T_2)/(\Delta T_E), \ldots, (\Delta T_n)/(\Delta T_E)$ = THE RATIO OF ANY LESSER TEMPERATURE CYCLES FOR WHICH THE EXPANSION STRESS S_E HAS BEEN CALCULATED.

THE OPERATING CONDITIONS AND THE ASSOCIATED NUMBER OF OCCURRENCES ARE OBTAINED FROM PRDP & SID DOCUMENTS.

THE PLANT HAS 200 START UP / SHOT DOWN CYCLES.

ANALYSIS (CONTINED)

THE DETAIL METHOD of CALCULATING EQUIVALENT DYNAMIC CYCLES FROM ATT # 5 ILLUSTRATED BELOW :

$$N = N_S + \sum_i \left(\frac{R_{Ti}}{R}\right)^{p} (N_{Ti} - N_S)$$

WHERE

N = COMBINED DYNAMIC CYCLES

N_S = SEISMIC CYCLES

$p = 2.0$, R_{Ti} = ith FLUID TRANSIENT LOAD

R = MAX. COMBINED FLUID TRANSIENT & SEISMIC LOAD

N_{Ti} = ith FLUID TRANSIENT CYCLES,

USED TO COMBINE DYNAMIC CYCLES (FLUID TRANSIENT AND SEISMIC CYCLES)

SINCE THEMAL AND DYNAMIC LOADS ARE ADDED DIRECTLY TO BE CONSIDERED AS A TOTAL LOAD FOR SUPPORT DESIGN, THE ABOVE MENTIONED DYNAMIC CYCLE COMBINATION AND ANALYSIS is CONSIDERED VERY CONSERVATIVE.

REFERENCES

1. ASME BOILER AND PRESSURE VESSEL CODE, SECTION III, DIVISION 1, NUCLEAR POWER PLANT COMPONENTS, 1974 EDITION, SUBSECTION C AND D, F INCLUDING WINTER 1974 ADDENDA

2. PROJECT PROCEDURE CPPP-10, REV. 1 DATED 4-1-86, PROCEDURE FOR REVIEW OF PLANT OPERATING MODE CONDITIONS.

3. FSAR - FINAL SAFETY ANALYSIS REPORT FOR CPSES, REV. 2-27-78, INCLUDING UPDATE AND ALL AMENDMENTS AS OF 8-7-86.

4. S&W CALCULATION 15616-NP(C)-GENX-025 REV. 1 TITLE "EQUIVALENT NUMBER OF THERMAL STRESS CYCLES AND STRESS RANGE REDUCTION FACTOR FOR PIPING REGIONS, PER PROBLEM, OF THE CHEMICAL AND VOLUME CONTROL SYSTEM (CS) OF CPSES UNIT 2 AND COMMON PIPING" DATED 9-15-86

*5. 15454-NP(C)-GENX-109 REV. 0 "VERIFICATION OF FLUID TRANSIENT CYCLES CALCULATION PROGRAM".

6. SYSTEM IDENTIFICATION DOCUMENTS - CPSES UNIT 1

SYSTEM	REV.	DATED
6.1 SID-AF	2	6-16-86
6.2 SID-BR	2	6-9-86
6.3 SID-CA	2	6-10-86
6.4 SID-CC	2	6-13-86
6.5 SID-CH	2	6-11-86
6.6 SID-CI	2	6-12-86

* SEE ATT# 8 (CONFIRMATION REQUIRED)

REFERENCE (CONTINUED)

6. SYSTEM IDENTIFICATION DOCUMENTS - CPSES UNIT 1

	SYSTEM	REV.	DATED
6.7	SID-CO	NOT REVIEWED	
6.8	SID-CS	3	8-4-86
6.9	SID-CT	2	6-5-86
6.10	SID-DD	2	6-12-86
6.11	SID-DO	2	6-11-86
6.12	SID-FW	2	6-11-86
6.13	SID-GH	NOT REVIEWED	
6.14	SID-HA	NOT REVIEWED	
6.15	SID-MS	3	7-23-86
6.16	SID-PS *	0	7-10-86
6.17	SID-RC	2	6-12-86
6.18	SID-RH	4	6-11-86
6.19	SID-RM *	0	8-29-86
6.20	SID-SB	NOT REVIEWED	
6.21	SID-SF	2	6-6-86
6.22	SID-SI	3	6-12-86
6.23	SID-SW	2	6-12-86
6.24	SID-VA	2	6-12-86
	SID-VA(H)	2	6-6-86
6.25	SID-VD	2	6-9-86
6.26	SID-WP	2	6-9-86

* FOR UNIT 2 ONLY

REFERENCE (CONTINUED)

6. SYSTEM IDENTIFICATION DOCUMENTS - CPSES UNIT 1

SYSTEM	REV.	DATED
6.27 SID-FP	1	6/10/86

7. S&W FLUID TRANSIENT CALCULATIONS

7.1 15454-NP(B) - F01 REV. 1 DATED 6/14/86
PUMP START (WATER SLUG IMPACT) (TRAIN A & B)

7.2 15454-NP(B) - F03 REV. 0 DATED 2/5/86
PUMP START (WATER SLUG IMPACT) (TRAIN A & B)

7.3 15454-NP(B) - F02 REV. 1 DATED 6/24/86
PUMP TRIP (CHECK VALVE SLAM)

7.4 15454-NP(B) - F04 REV. 0 DATED 10/29/85
RELIEF VALVE DISCHARGE 8708A, B

7.5 15454-NP(B) - F06 REV. 1 DATED 1-10-86
PUMP TRIP AND PUMP START (TRAIN A & B)

7.6 15454-NP(B) - F19 REV. 0 DATED 2-3-86
PUMP TRIP AND PUMP START (TRAIN A & B)

7.7 15454-NP(B) - F23 REV. 0 DATED 7-22-86
PUMP START WITH AIR COLUMN

7.8 15454-NP(B) - F05 REV. 0 DATED 12-19-85
RELIEF VALVE DISCHARGE 8117

7.9 15454-NP(B) - F07 REV. 0 DATED 12-10-85
RELIEF VALVE DISCHARGE 8118

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REFERENCE (CONTINUED)

7. S & W FLUID TRANSIENT CALCULATIONS (CONTINUED)

7.10 15454 - NP(B) - F08 REV. 1 DATED 1-25-86
RELIEF VALVE DISCHARGE 8120

7.11 15454 - NP(B) - F09 REV. 0 DATED 12-10-85
RELIEF VALVE DISCHARGE 8119

7.12 15454 - NP(B) - F15 REV. 0 DATED 1-10-86
RELIEF VALVE DISCHARGE 8121

7.13 15454 - NP(B) - F16 REV. 0 DATED 1-10-86
RELIEF VALVE DISCHARGE 8123

7.14 15454 - NP(B) - F17 REV. 0 DATED 12-10-85
RELIEF VALVE DISCHARGE 8510A, B

7.15 15454 - NP(B) - F10 REV. 1 DATED 6-23-86
MAIN STEAM TURBINE TRIP

7.16 15454 - NP(B) - F18 REV. 0 DATED 2-12-86
FEEDPUMP TURBINE TRIP

7.17 15454 - NP(B) - F11 REV. 0 DATED 1-23-86
AUX FEEDPUMP TURBINE TRIP

7.18 15454 - NP(B) - F12 REV. 1 DATED 8-6-86
S/RV DISCHARGE

7.19 15454 - NP(B) - F20 REV. - DATED 6-13-86 **
PIPE BREAK (VALVE SLAM)

** PRELIMINARY RESULTS BASED ON IOM (CONFIRMATION REQUIRED)

REFERENCE (CONTINUED)

7. S & W FLUID TRANSIENT CALCULATIONS (CONTINUED)

7.20 15454 - NP(B) - F24 REV. 0 DATED 7-7-86
3/4" × 1" THERMAL AND AIR RELIEF VALVE OPENING

7.21 15454 - NP(B) - F13 REV. 0 DATED 3-14-86
PUMP TRIP (CHECK VALVE SLAM)

7.22 15454 - NP(B) - F21 REV. - DATED 6-23-86 **
PUMP TRIP (CHECK VALVE SLAM)

7.23 15454 - NP(B) - F14 REV. 0 DATED 5-1-86
PRESSURIZER S/RV DISCHARGE

7.24 15454 - NP(B) - F22 REV. 0 DATED 7-10-86
RELIEF VALVE DISCHARGE 8634

7.25 + 15454 - NP(B) - F25 REV. 0 DATED 7-22-86
OPENING AND CLOSING OF ISOLATION AND CONTROL VALVES

7.26 + 15454 - NP(B) - F26 REV. 0 DATED 7-23-86
CLOSURE OF THE SCREEN WASH PUMP SUCTION CHECK VALVES.

7.27 + 15454 - NP(B) - F27 REV. 0 DATED 7-29-86
CLOSING OF ISOLATION VALVE IN CC SYSTEM

*8. 15454-NP(C)-GENX-108 REV. 0 "VERIFICATION OF FFT PROGRAM".

** PRELIMINARY RESULTS BASED ON 10M (CONFIRMATION REQUIRED)

+ FLUID TRANSIENT LOADS ARE INSIGNIFICANT.

* SEE ATT # 6 (CONFIRMATION REQUIRED)

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REV. 0

CONCLUSION

THE SUPPORT ENGINEERING APPLYS THE THERMAL AND DYNAMIC LOADS TO SUPPORTS SIMULTANEOUSLY FOR CAPACITY CHECK IN LOAD CONDITION 3, THEREFORE THE FATIGUE CYCLES DETERMINATION CAN BE CONSERVATIVELY BASED ON ENVELOPED CYCLES OF THE THERMAL, FLUID TRANSIENT AND SEISMIC CYCLES AS SHOWN ON SUMMARY SECTION. THE THERMAL CYCLES FOR ALL SYSTEMS EXCEPT CHEMICAL & VOLUME CONTROL ARE UNDER 7000. THE DETAIL THERMAL CYCLE ANALYSIS FOR CHEMICAL & VOLUME CONTROL IS SHOWN IN CALCULATION 15454-NP(C)-GENX-025 REV. 1 (REF. 4) AND THE CYCLES WERE PROVED TO BE UNDER 20000. THE FLUID TRANSIENT CYCLES FOR ALL SYSTEMS EXCEPT STRESS PROBLEMS NO 23A, B, C & D IN MAIN STEAM SYSTEM ARE UNDER 16000. THE DETAIL FLUID TRANSIENT CYCLES ANALYSIS FOR STRESS PROBLEMS 23A, 23B, 23C & 23D IS SHOWN IN ATTACHMENT #10 AND THE CYCLES WERE PROVED TO BE UNDER 20,000. OVERALL ALL THE SYSTEMS OF SUPPORT FATIGUE CYCLES ARE UNDER 20,000. AND THEREFORE, NO HIGH CYCLE FATIGUE EVALUATION AS SPECIFIED IN NF 3132.3 IS REQUIRED FOR BOTH UNIT 1 & UNIT 2 SUPPORTS.

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SUMMARY OF FATIGUE CYCLE DETERMINATION (CONTINUED)

SYSTEM DESIGNATION	SYSTEM DESCRIPTION	ESTIMATED THERMAL CYCLE	ESTIMATED FLUID TRANSIENT CYCLE	ESTIMATED SEISMIC CYCLE	ENVELOPED MAXIMUM ESTIMATED FATIGUE CYCLE	ASME NF-3000 ALLOWABLE CYCLE	REMARK
DO	DIESEL GENERATOR FUEL OIL	7000	N/A	720	7000	20000 ↓	CYCLES SHOWN ON SID ARE NOT THER. CYCLES
FW	STEAM GENERATOR FEED WATER	7000	6000	720	7000		
GH	WASTE PROCESSING - GAS	7000	N/A	720	7000		
HA	HYDROGEN ANALYZING	7000	N/A	720	7000		
MS	MAIN STEAM	7000	EQUIV. DYN. cycles < 20000		<20000		FOR F.T. DETAIL SEE ATT. 10
PS	PROCESS SAMPLING	7000	N/A	720	7000		
RC	REACTOR COOLANT	7000	1200	720	7000		

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SUMMARY OF FATIGUE CYCLE DETERMINATION

SYSTEM DESIGNATION	SYSTEM DESCRIPTION	ESTIMATED THERMAL CYCLE	ESTIMATED FLUID TRANSIENT CYCLE	ESTIMATED SEISMIC CYCLE	ENVELOPED MAXIMUM ESTIMATED FATIGUE CYCLE	ASME NF-3000 ALLOWABLE CYCLE	REMARK
AF	AUXILIARY FEEDWATER	7000	3000	720	7000	20000	
BR	BORON RECYCLE	7000	1200	720	7000		
CA	SERVICE AIR	7000	N/A	720	7000		
CC	COMPONENT COOLING WATER	7000	N/A	720	7000		
CH	CHILLED WATER	7000	N/A	720	7000		
CI	INSTRUMENT AIR	7000	N/A	720	7000		
CO	CONDENSATE	7000	N/A	720	7000		
CS	CHEMICAL AND VOLUME CONTROL	12962	1200	720	12962		FOR DET. ON THER. SEE ATT #2
CT	CONTAINMENT SPRAY	7000	30	720	7000		
DD	DEMINERALIZED AND REACTOR MAKE UP WATER	7000	N/A	720	7000		

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SUMMARY OF FATIGUE CYCLE DETERMINATION (CONTINUED)

SYSTEM DESIGNATION	SYSTEM DESCRIPTION	ESTIMATED THERMAL CYCLE	ESTIMATED FLUID TRANSIENT CYCLE	ESTIMATED SEISMIC CYCLE	ENVELOPED MAXIMUM ESTIMATED FATIGUE CYCLE	ASME NF-3000 ALLOWABLE CYCLE	REMARK
RH	RESIDUAL HEAT REMOVAL	7000	6000	720	7000	20000.	
RM	RADIATION MONITORING	7000	N/A	720	7000		
SB	STEAM GENERATOR BLOWDOWN & CLEAN UP	7000	N/A	720	7000		
SF	SPENT FUEL POOL COOLING & CLEAN-UP	7000	N/A	720	7000		
SI	SAFETY INJECTION	7000	30	720	7000		
SW	SERVICE WATER	7000	6000	720	7000		
VA	HYDROGEN PURGE	7000	N/A	720	7000		
VD	VENT AND DRAIN	7000	N/A	720	7000		
WP	WASTE PROCESS LIQUID	7000	N/A	720	7000		
FP	FIRE PROTECTION	7000	N/A	720	7000		

NOTE N/A = NOT APPLICABLE (NO FLUID TRANSIENT)

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FLUID TRANSIENT CYCLES DETERMINATION

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Attachment #1

Introduction of Computer Program PREFFT and FTRANS1

Water Hammer or Steam Hammer computer code generates force-time histories and these data are stored in magnetic tapes. PREFFT (The program name is HAMMER) computer code reads these data from the magnetic tape and rewrite on disk in a format which FTRANS1 computer code is able to read, i.e., PREFFT is a preprocessor for FTRANS1. FTRANS1 converts source hydraulic forces into piping vibrations, i.e., from the time domain to frequency domain using a fast fourier transform method.

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System: Main Steam

Calculation No.: F10

Fluid Transient Data Set Name: MS.F1010.CUR32

FFT Job No.: 3286   Job Date: 8/29/86

Major Forcing Function Frequency

0.73, 1.22, 2.2, 3.4, 4.6, 5.6, 6.6, 7.1, 8.5
10.5, 11.0, 15.1, 19.0, 19.5, 22.9

System: Main Steam

Calculation No.: F18

Fluid Transient Data Set Name: MS.F1813.CUR17

FFT Job No.: 3291   Job Date: 8/29/86

Major Forcing Function Frequency

0.488, 1.22, 2.2, 2.93, 4.2, 6.1, 7.6, 8.8, 9.8
10.3, 11.2, 12.9, 20.0, 23.7, 45.9, 56.4

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System: Main Steam

Calculation No.: F11

Fluid Transient Data Set Name: MS.F117.CUR54

FFT Job No.: 3977   Job Date: 09/08/86

Major Forcing Function Frequency

0.977, 3.42, 5.37, 7.32, 7.81, 9.77, 11.7, 13.7
16.6, 18.1, 20.0, 22.0, 24.4, 25.4, 26.4, 29.3
31.7, 32.7, 34.7, 36.1, 37.1, 39.1, 41.5, 43.0, 43.9
44.9, 47.9, 49.3, 51.8, 55.2, 56.6, 58.1

System: Main Steam

Calculation No.: F11

Fluid Transient Data Set Name: MS.F117.CUR10

FFT Job No.: 6408   Job Date: 09/09/86

Major Forcing Function Frequency

0.977, 2.93, 5.37, 7.32 9.28, 10.7, 11.7, 13.7
15.6, 18.1, 19.5, 21.0, 22.9, 24.4, 25.9, 27.8
29.8

A 5010.65

CALCULATION IDENTIFICATION NUMBER				
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System: Main Steam

Calculation No.: F11

Fluid Transient Data Set Name: MS.F118.CUR27

FFT Job No.: 3346 Job Date: 8/29/86

Major Forcing Function Frequency

0.977, 2.93, 5.4, 6.8, 7.8, 9.8, 12.2, 14.1,

→ 16.6, 18.6, 27.3, 40.5, 42.0, 44.4, 45.9, 4[illegible].9

54.2, 67.9, 86.9

System: Main Steam

Calculation No.: F11

Fluid Transient Data Set Name: MS.F118.CUR39

FFT Job No.: 3357 Job Date: 8/29/86

Major Forcing Function Frequency

0.977, 3.4, 5.9, 7.8, 10.3, 15.1, 21.0, 22.5

25.9, 27.8, 29.8, 31.7, 33.2, 35.2

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System: Main Steam

Calculation No.: F11

Fluid Transient Data Set Name: MS. F119. CUR14

FFT Job No.: 3361 Job Date: 8/29/86

Major Forcing Function Frequency

0.977, 3.4, 4.4, 5.9, 7.8, 10.3, 11.2, 12.7

17.6, 22.9, 24.4, 26.4, 28.3, 29.8

System: Main Steam

Calculation No.: F11

Fluid Transient Data Set Name: MS. F119. CUR25

FFT Job No.: 3366 Job Date: 8/29/86

Major Forcing Function Frequency

1.95, 3.42, 4.4, 5.9, 6.8, 8.8, 11.2, 13.2

15.6, 17.6, 20.0, 22.5, 37.6, 45.6, 47.9

STONE & WEBSTER ENGINEERING CORPORATION

CALCULATION SHEET

Attachment #1

A 5010.65

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System: Main Steam

Calculation No.: F12

Fluid Transient Data Set Name: MS.F121.CUR02

FFT Job No.: 708 Job Date: 9/12/86

Major Forcing Function Frequency

4.88, 9.77, 29.3, 53.7, 83, 122.1

System: Main Steam

Calculation No.: F12

Fluid Transient Data Set Name: MS.F121.CUR04

FFT Job No.: 740 Job Date: 9/12/86

Major Forcing Function Frequency

4.88, 9.77, 29.3, 48.8, 68.4, 190.

STONE & WEBSTER ENGINEERING CORPORATION

CALCULATION SHEET

Attachment #1

5010.65

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System: Chemical and Volume Control

Calculation No.: PX-F05

Fluid Transient Data Set Name: CS.F0510.CUR05

FFT Job No.: 2648 Job Date: 8/29/86

Major Forcing Function Frequency

11.9, 33.6, 47, 84.8

System: Chemical and Volume Control

Calculation No.: PX-F07

Fluid Transient Data Set Name: CS.F075.CUR03

FFT Job No.: 2651 Job Date: 8/29/86

Major Forcing Function Frequency

19.5, 45.9, 53.7, 58.6, 77.1

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System: Chemical and Volume Control

Calculation No.: F07

Fluid Transient Data Set Name: CS.F075.CUR43

FFT Job No.: 2652 Job Date: 8/29/86

Major Forcing Function Frequency

7.81, 13.7, 26.4, 35.2, 43.0, 54.7, 64.5

System: Chemical and Volume Control

Calculation No.: F08

Fluid Transient Data Set Name: CS.F0816.CUR04

FFT Job No.: 2659 Job Date: 8/29/86

Major Forcing Function Frequency

4.88, 8.54, 12.9, 14.4, 19.0, 20.3, 24.7

27.3, 38.6, 53.6, 59.6,

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System: Chemical and Volume Control

Calculation No.: F09

Fluid Transient Data Set Name: CS.F093.CUR22

FFT Job No.: 2660 Job Date: 8/29/86

Major Forcing Function Frequency

17.4, 28.2, 36.9, 45.6, 56.4, 65.1

System: Chemical and Volume Control

Calculation No.: PX-F09

Fluid Transient Data Set Name: CS.F093.CUR64

FFT Job No.: 2662 Job Date: 8/29/86

Major Forcing Function Frequency

2.17, 6.51, 15.2, 23.9, 36.9, 43.4, 56.4, 69.4

System: Chemical and Volume Control

Calculation No.: F15

Fluid Transient Data Set Name: CS.F1513.CUR99

FFT Job No.: 2666 Job Date: 8/29/86

Major Forcing Function Frequency

6.51, 13.0, 18.4, 28.2, 40.1, 43.4, 56.4
81.4

System: Chemical and Volume Control

Calculation No.: F16

Fluid Transient Data Set Name: CS.F1614 CUR118

FFT Job No.: 2669 Job Date: 8/29/86

Major Forcing Function Frequency

0.488, 3.91, 8.79, 10.3, 14.6, 17.1, 19.5, 21.5
24.9, 27.3, 30.3, 32.2, 36.1, 40.0, 42.5,
43.9, 44.9, 47.4, 48.3,

CALCULATION IDENTIFICATION NUMBER				PAGE 12
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System: Chemical and Volume Control

Calculation No.: F17

Fluid Transient Data Set Name: CS.F178.CUR19

FFT Job No.: 2670 Job Date: 8/29/86

Major Forcing Function Frequency

0.543, 5.43, 6.51, 13.0, 14.6, 19.5, 26.6

32.6, 36.3, 39.1, 46.1, 52.6, 58.6, 65.1

System: N/A

Calculation No.:

Fluid Transient Data Set Name:

FFT Job No.: Job Date:

Major Forcing Function Frequency

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	SYSTEM	PI	TAPE #	FILE#	CURVE #	TRANSIENT DURATION	NO. OF TIME STEPS	TIME STEP	DATA SET NAME	JOB #	TRANSIENT OCCURRENCES	EQUIVALENT CYCLES	STRESS PROBLEM #
1	CONTAINMENT SPRAY	F01	006380	01	05 95	1.0	501	0.002	CPPP.CT.F011.CUR#	5561/5566	1	30*	024 027 029K 029M 029D 029S 029U 029W 029Y 030
	(CT)			04	06 328	3.0	1501	0.002	CPPP.CT.F014.CUR#	5571/5576	1	30*	032 035A 035B 035C 035D 036
				07	35 213	2.0	1001	0.002	CPPP.CT.F017.CUR#	5581/5582	1	30*	
				10	09	3.0	1501	0.002	CPPP.CT.F0110.CUR#	5592	1	30*	
				09	09 75	3.0	1501	0.002	CPPP.CT.F019.CUR#	5596/5601	1	30*	
		F03	005892	07	06 102	1.0	501	0.002	CPPP.CT.F037.CUR#	5618/5622	1	30*	028 029L 029N 029P 029T 029V 029X 029Z 031 033
				01	10 112	3.0	1501	0.002	CPPP.CT.F031.CUR#	5627/5628	1	30*	037B 037W 037X 037Y 037Z
				02	06 102	3.0	1501	0.002	CPPP.CT.F032.CUR#	5630/5634	1	30*	
				06	10 248	3.0	1501	0.002	CPPP.CT.F036.CUR#	5638/5641	1	30*	
				03	06 293	3.0	1501	0.002	CPPP.CT.F033.CUR#	5649/5653	1	30*	
2	SAFETY INJECTION	F02	013207	08	09 82	1.5	501	0.003	CPPP.SI.F028.CUR#	6667/6674	1	30*	019A 019B 019C 024 069 [illegible]
	(SI)			09	14 76	1.5	501	0.003	CPPP.SI.F029.CUR#	659/ 667	1	30*	
3	STATION SERVICE WATER	F06	010924	08	09 76	3.0	1001	0.003	CPPP.SW.F068.CUR#	5688/5692	200	6000*	067W 06[illegible] 067Y 067Z 068S 068T 068U 068V 164
	(SW)	F19	008458	05	06 31	3.0	1001	0.003	CPPP.SW.F195.CUR#	8718/8727	200	6000*	067S 067T 067U 067V 068A 068W 068X 068Y 068Z
		F23	012750	01	02 05	10.00453	2002	0.005	CPPP.SW.F231.CUR#	8040/8057	200	6000*	067S 067T 067U 067V 067W 067X 067Y 067Z 068A 068B
				02	02 05	10.00453	2002	0.005	CPPP.SW.F232.CUR#	8067/8078	200	6000*	068T 068U 068V 068W 068X 068Y 068Z 164
4	RESIDUAL HEAT REMOVAL	F04	004282	03	06	0.5	501	0.001	CPPP.RH.F043.CUR#	5669	200	6000*	042B
	(RH)			04	06	0.5	501	0.001	CPPP.RH.F044.CUR#	5672	200	6000*	
5	CHEMICAL AND VOLUME CONTROL	F05	011349	10	05	1.0	1251	0.0008	CPPP.CS.F0510.CUR#	5678	40	600	042A 042B
		F07	004282	05	03 43	1.0	501	0.002	CPPP.CS.F075.CUR#	5706/5709	40	600/1000	051B 092A N016 N019 N071
	(CS)	F08	011349	16	04	2.5	2501	0.001	CPPP.CS.F0816.CUR#	5719	40	1200*	N016 N071 N019 052V 092A 092B 093B
		F09	005294	03	22 64	0.45	501	0.0009	CPPP.CS.F093.CUR#	5729/5735	40	600/600	052V 092A N016 N019 N068 N071
		F15	011349	13	99	0.81	901	0.0009	CPPP.CS.F1513.CUR#	5798	40	1200*	042B 045Q 045R 045S 045T 045U
		F16	011349	14	118	1.25	626	0.002	CPPP.CS.F1614.CUR#	5803	40	1200*	042B 045T 051A 052V 052W 092A N016 N019 N071
		F17	011349	08	19	1.08	1201	0.0009	CPPP.CS.F178.CUR#	5811	40	1200	051A 051B 051C
6	MAIN STEAM (MS)	F10	008813	10	32	2.99984	1501	0.002	CPPP.MS.F1010.CUR#	5968	790	15800**	001 002 003 004 023A, 023B, 023C, 023D
		F18	008813	13	17	2.99984	1501	0.002	CPPP.MS.F1813.CUR#	5819	790	15800	NA
		F11	008813	07	10 54	1.79955	1801	0.001	CPPP.MS.F117.CUR#	5741/6699	80	1606	080A 080B 080C 080D
				08	27 39	1.79955	1801	0.001	CPPP.MS.F118.CUR#	5750/5755	80	1600	
				09	14 25	1.79955	1801	0.001	CPPP.MS.F119.CUR#	5762/5764	80	1600	
		F12	[illegible]	[illegible]	[illegible]	[illegible]	301	[illegible]	CPPP.MS.F121.CUR#	[illegible]	790	15800**	023A, 023B, 023C, 023D
											990	15800??	
7	FEEDWATER (FW)	F20	013471	15	32	2.0	1001	0.002	CPPP.FW.F2015.CUR#	5830	1	30*	005 006 007 008 009A 009B 009C 009D 010B 010C
				17	44 52	2.0	1001	0.002	CPPP.FW.F2017.CUR#	5833/5836	1	30*	012D 012E 152 153 154 155 169 170 171 172
				18	16 01	2.0	1001	0.002	CPPP.FW.F2018.CUR#	5838/5840	1	30*	
				14	13 46	2.0	1001	0.002	CPPP.FW.F2014.CUR#	5844/5846	1	30*	
				21	24 35	0.6	601	0.001	CPPP.FW.F2021.CUR#	5853/5856	1	30*	
				22	11	0.6	601	0.001	CPPP.FW.F2022.CUR#	5857	1	30*	
				23	07 13	0.6	601	0.001	CPPP.FW.F2023.CUR#	5861/5865	1	30*	
				24	27	0.6	601	0.001	CPPP.FW.F2024.CUR#	5868	1	30*	
		F13	006423	03	94	6.00001	3001	0.002	CPPP.FW.F133.CUR#	5781	200	6000*	005 006 007 008 009A 009B 009C 009D 010B 010C
			006423	01	105	5.00001	2501	0.002	CPPP.FW.F131.CUR#	5788	200	6000*	012D 012E 152 153 154 155 169 170 171 172
8	AUXILIARY FEEDWATER	F21	011397	11	16 59	1.5	501	0.003	CPPP.AF.F2111.CUR#	5875/5879	100	3000*	10A 10B 10C 11A 11B 11C 12A 12B 12D 12E
	(AF)			12	151 302	1.5	501	0.003	CPPP.AF.F2112.CUR#	5883/5886	100	3000*	151 152 153 154 155
9	REACTOR COOLANT (RC)	F14	011240	01	06	0.71025	1501	0.0005	CPPP.RC.F1401.CUR#	5971	40	1200*	1-042B
10	BORON RECYCLE (BR)	F22	011000	01	83	0.5	501	0.001	CPPP.BR.F221.CUR#	5891	40	1200*	1-089 1-091 1-092B 1-093B 1-094 1-N008 1-N053
				02	106	0.5	501	0.001	CPPP.BR.F222.CUR#	5895	40	1200*	1-N070 1-N078 1-N098 2-N007 2-N00[illegible]
				03	110	0.5	501	0.001	CPPP.BR.F223.CUR#	5900	40	1200*	

* 30 CYCLES PER OCCURRENCES ARE USED.

** FOR DETAIL CYCLE CALCULATION, SEE ATTACHMENT #10

CHEMICAL & VOLUME CONTROL THERMAL CYCLES

SUMMARY OF RESULTS

PROBLEM NO. (1)	SID	PRDP REV.	PRDP DATE	STRESS RANGE RED. FACTOR f	CALCULATED ON PAGES	EQUIVALENT CYCLES
1-N085	CS	2	7-1-86	1	16	≤7000
1-N086	↓	0	5-14-86	1	16	≤7000
1-N087		1	7-8-86	1	17	≤7000
1-N088		2	7-3-86	1	17-18	≤7000
1-N095		0	5-19-86	0.9	19-20	9289
1-N098		0	6-2-86	1	21-24	≤7000
1-N112		0	5-12-86	0.9	25	7585
1-N117		0	6-10-86	1	25-27	≤7000
1-N118	CS,WP	0	6-10-86	1	27	≤7000
1-N123	CS	0	6-5-86	1	28	≤7000
(2-039)		—	—	—	—	—
2-040		1	7-10-86	1	29	≤7000
(2-041A)	↓	—	—	—	—	—
(2-041L)	CS,RC	—	—	—	—	—
2-042A	CS	0	6-9-86	1	31-35	≤7000
2-042B	CS,RH,RC	0	7-21-86	1	36-37	≤7000
(2-043B)	CS	—	—	—	—	—
(2-043D)	RC,CS	—	—	—	—	—
(2-043Y)	CS	—	—	—	—	—
(2-044)	CS,RC	—	—	—	—	—
(2-045C)	CS	—	—	—	—	—
(2-045D)	↓	—	—	—	—	—
(2-045E)		—	—	—	—	—
2-045Q		1	7-15-86	1	29-30	≤7000
2-045R		1	7-11-86	1	29-30	≤7000
2-045S		1	7-15-86	1	29-30	≤7000
2-045T		0	5-19-86	1	38	≤7000
(2-045V)		—	—	—	—	—
(2-045W)		—	—	—	—	—
(2-045X)		—	—	—	—	—
(2-045Y)	↓	—	—	—	—	—
2-046A	CS,RH	0	6-18-86	1	39-43	≤7000
2-046B	CS	1	7-18-86	0.9	44-45	12439
2-047A	↓		(2)	0.9	49-54	10815
2-047B	CS,SI	1	5-1-86	1	55	≤7000

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SUMMARY OF RESULTS, CONT'D

PROBLEM NO.	SID	PRDP REV.	PRDP DATE	STRESS RANGE RED. FACTOR f	CALCULATED ON PAGES	EQUIVALENT CYCLES
2-051 A	CS,SI	0	5-22-86	1	56-58	≤7000
2-051 B	CS	0	7-18-86	1	59-60	≤7000
2-051 C	↓	1	7-10-86	1	45-46	≤7000
2-051 D		0	5-30-86	1	61	≤7000
2-052 B		0	6-2-86	1	62	≤7000
2-052 C		0	6-6-86	0.9	63-64	≤7000
2-052 U		0	6-2-86	1	65	≤7000
2-052 V		1	7-14-86	1	46	≤7000
2-052 W		1	7-14-86	1	46	≤7000
2-052 Z	↓	1	7-24-86	1	46-47	≤7000
2-071 A	RH,CS,SI	0	5-9-86	1	55	≤7000
2-092 A	BR,CS	0	7-11-86	1	66	≤7000
2-150 F	CS	0	4-18-86	0.9	47	7585
2-150 G	↓	0	4-18-86	0.9	47	7585
2-150 H		0	4-24-86	0.9	48	7585
2-150 I		0	4-23-86	0.9	48	7585
2-150 J		0	4-23-86	0.9	48	7585
2-N001	↓	1	7-18-86	1	47-48	≤7000
2-N002	CS,DD	0	6-26-86	0.9	67-72	8461
2-N007	BR,CS	0	8-6-86	1	73-74	≤7000
2-N010	CS,WP	1	7-22-86	0.9	75	7585
2-N030	CS	0	6-4-86	1	76-77	≤7000

FOOTNOTES:

(1) PROBLEM NUMBERS IN PARENTHESES ARE WITHIN WESTINGHOUSE SCOPE. NO PRDP EXISTS.

NC-3600 PIPING DESIGN

NC-3610 GENERAL REQUIREMENTS

NC-3611 Acceptability

The requirements for acceptability of a piping system are given in the following subparagraphs.

NC-3611.1 Allowable Stress Values. Allowable stress values to be used for the design of piping systems are given in Tables I-7.0 for acceptable materials at various temperatures.

NC-3611.2 Limits of Calculated Stresses Due to Sustained Loads and Thermal Expansion

(a) Internal Pressure Stress. The calculated stress due to internal pressure shall not exceed the allowable stress values except as permitted in NC-3612.3.

(b) External Pressure Stress. Piping subject to external pressure shall be considered safe when the wall thickness and means of stiffening meet the requirements of NC-3641.2.

(c) Allowable Stress Range for Expansion Stresses. The expansion stress, S_E, (NC-3672.9) shall not exceed the allowable stress range, S_A, given by the following formula:

$$S_A = f\,(1.25\ S_c + 0.25\ S_h)$$

where

S_c = basic material allowable stress at minimum (cold) temperature, psi

S_h = basic material allowable stress at maximum (hot) temperature, psi

f = stress range reduction factor for cyclic conditions for total number, N, of full temperature cycles over total number of years during which system is expected to be in operation, from Table NC-3611.2(c)-1

(1) In determining the basic material allowable stresses, S_c and S_h, joint efficiencies need not be applied.

TABLE NC-3611.2(c)-1
STRESS RANGE REDUCTION FACTORS

Number of Equivalent Full Temperature Cycles N	f
7,000 and less	1.0
7,000 to 14,000	0.9
14,000 to 22,000	0.8
22,000 to 45,000	0.7
45,000 to 100,000	0.6
100,000 and over	0.5

(2) Stress reduction factors apply essentially to noncorrosive service and to corrosion resistant materials, where employed to minimize the reduction in cyclic life caused by corrosive action.

(3) If the range of temperature change varies, equivalent full temperature cycles may be computed as follows:

$$N = N_E + r_1^5 N_1 + r_2^5 N_2 + \ldots r_n^5 N_n$$

where

N_E = number of cycles at full temperature change, ΔT_E, for which expansion stress, S_E, has been calculated

$N_1, N_2 \ldots N_n$ = number of cycles at lesser temperature changes, $\Delta T_1, \Delta T_2 \ldots \Delta T_n$

$r_1, r_2, \ldots, r_n$ = $(\Delta T_1)/(\Delta T_E)$, $(\Delta T_2)/(\Delta T_E)$, …, $(\Delta T_n)/(\Delta T_E)$ = the ratio of any lesser temperature cycles for which the expansion stress, S_E, has been calculated. S75

(d) Additive Stresses. The sum of the longitudinal stresses due to pressure, weight and other sustained loads shall not exceed the allowable stress in the hot condition, S_h. Where the sum of these stresses is less than S_h, the difference between S_h and this sum may be added to the term $0.25S_h$ in Formula (1) for determining the allowable stress range, S_A.

NC-3611.3 Limits of Calculated Stresses

(a) Normal Operating Conditions. The sum of stresses due to design pressure, weight, and other sustained loads shall not exceed S_h and the requirements of Equation 8, NC-3652.1 shall be met. In addition, either the stress range due to thermal expansion as calculated by Equation 10, NC-3652.3 shall not exceed S_A, or the sum of stresses due to design pressure, weight, other sustained loads and the stress range due to thermal expansion shall not exceed the sum of S_A and S_h as required by Equation 11, NC-3652.3.

(b) During Upset Conditions. The sum of the stresses produced by maximum pressure, live and dead loads and those produced by occasional loads such as wind or earthquake defined in the Design Specifications as normal or upset, may be as much as 1.2 times the allowable stress values given in Tables I-7.0. Under upset conditions, the requirements of all equations of NC-3651 shall be met.

(c) During Emergency Conditions. The sum of the stresses produced by internal pressure, live and dead loads and those produced by occasional loads defined in the Design Specifications or emergency conditions