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ATOMICS INTERNATIONAL
A Division of North American Aviation Inc.

NAA-SR-MEMO COVER SHEET

REPORT TITLE Sodium Component Test Installation Feasibility Study
Report. Primary Sodium Piping Design without Bellows

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NAA-SR-MEMO 12018

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1. Introduction

The primary sodium heat transfer system presently includes five bellows type expansion joints with gimbal hardware. These expansion joints are installed in the sodium lines to the primary sodium pump. Three are in the suction, two are in the discharge line. The application of these joints was necessary to assure that pipe stresses due to thermal expansion of piping and equipment are within the Code allowable ranges and to assure that force and moment reactions on the equipment do not exceed limits allowed by the manufacturer.

The feasibility study included preparation of a layout showing revised piping configurations with modifications which accomplish the elimination of the bellows from the primary sodium system. An analysis of the piping flexibility demonstrated compliance with Code requirements concerning allowable pipe stresses and facilitated appraisal of the effects of the reactions on adjacent equipment. A review of the presented piping arrangement by C. F. Braun & Co., consultant on SCTI feasibility studies is part of the project.

The purpose of the alternate design studies was to establish the feasibility of relocating the primary pump so as to eliminate the separate sodium level controls in the primary pump barrel and the primary sodium expansion tank. This objective can be accomplished by raising the pump to the same elevation as the expansion tank. This report discusses two possible locations, one inside the tank, the other adjacent to the tank; lists the modifications required to pump and expansion tank, and outlines the necessity of additions and revisions to the piping arrangement. The installation of additional expansion tank capacity may be necessary to resolve the sodium level control problems by elimination of all operational limitations.

The studies reported in this Technical Data Record demonstrated the feasibility of eliminating the bellows from the primary sodium system and the feasibility of relocating the primary pump to eliminate separate sodium level controls. The pipe loop configurations shown in Appendix "A" do not neces-

sarily represent an optimum and preference over the bellows has not been established. A preferred arrangement of the primary pump and expansion tank has not been selected and piping layouts suitable to the new pump location have not been studied. Due to the numerous variables, extensive reliability and economic studies are required to arrive at a combination of the suggested modifications which result in the most desirable and recommended arrangement of the primary system.

2. Results of the Study

Appendix "A" of this report shows an isometric layout of the pump suction and discharge lines, and of the cold by-pass line in the primary sodium system. The configurations shown on this layout are based on the results of the feasibility study and represent one solution of the problem. Due to the great variety of the possible combinations of configurations, and to the additional design work required to maintain the necessary clearances, this layout must be considered as preliminary. However, the presented solution offers sufficient evidence of the feasibility of the bellows-free primary system. These configurations incorporate the following modifications to the existing system:

- a) All bellows type expansion joints have been removed.
- b) One pipe loop has been added to the pump suction line.
- c) One pipe loop has been added to the pump discharge line in a vertical plane. This loop creates a new high point in the system which requires an additional vent line (item f).
- d) The cold by-pass line has been rerouted to originate in the vicinity of the sodium preheater instead of the pump.
- e) An anchor has been added to the pump discharge line at the sodium preheater inlet.
- f) A vent connection has been provided at the high point defined in item c). A vent line, with an orifice and block valve, ties into the inert gas space of the expansion tank.

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The feasibility analysis of the preliminary piping configurations is summarized in Appendices "B" and "C". Appendix "B" covers pump suction line 503-10-P from the Primary Sodium Expansion Tank to the Primary Sodium Pump. Appendix "C" shows a four-anchor configuration between the Sodium Heater, the Intermediate Heat Exchanger, the Primary Sodium Pump, and the Sodium Preheater. This configuration consists of the sodium outlet line 501-10-P, pump discharge line 504-10-P, and cold by-pass line 511-10-P. The flexibility calculations were performed by means of the PSA-2 Pipe Stress Analysis Code as applied to the IBM Fortran IV program.

The highest calculated pipe stresses due to thermal expansion in the 10-inch size Schedule 40S Type 304 welded stainless steel piping are tabulated as follows:

<u>Pipe Line No.</u>	<u>Design Temp.</u>	<u>Code Allowable Stress Range</u>	<u>Maximum Pipe Stress</u>
501-10-P	1300	24,525 psi	16,950 psi
503-10-P	1000	25,600 psi	8,965 psi
504-10-P	1000	25,600 psi	9,334 psi
511-10-P	1000	25,600 psi	12,232 psi

Sodium outline 501-10-P was included in the configuration for the accuracy of the calculated stress levels but did not require any modification.

Forces and moments were obtained from the flexibility analysis computer to establish the reactions on the equipment. These values were reviewed to establish the feasibility of the configurations. A complete stress analysis was not performed on any equipment to obtain actual stress values. The general review of the effects of these reactions on the equipment is summarized as follows:

- a) The reactions on the sodium outlet of the sodium heater are not changed by the modifications and thus did not require any investigation.
- b) The forces and moments on the primary sodium inlet nozzle of the

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intermediate heat exchanger resulting from the thermal expansion of the four-anchor configuration do not exceed the 4000 lb and 40,000 ft lb. values, respectively, allowed by the manufacturer.

- c) Tentative calculation of stresses at the outlet nozzle of the primary sodium expansion tank resulted in a combined stress level of 20,075 psi due to internal pressure and thermal expansion of the pipe line 503-10-P. Thermal stress calculation was based on a flat head, but the actual stresses in the existing semielliptical head are lower. For this type of nozzle loads, the ASME Boiler and Pressure Vessel Code, Section III, Nuclear Vessel, has provisions which permit stress values for the above combined stresses three times the allowable stresses listed in Section VIII of the ASME Code. The allowable stress for Type 304 stainless steel at 1000°F design temperature is 8800 psi; three times of this value amounts to 26,400 psi.
- d) Flexibility analysis of the primary sodium pump suction and discharge lines showed that reactions on the pump nozzles did not exceed the following values in any of the main directions:

	<u>10" suction nozzle</u>	<u>8" discharge nozzle</u>
Forces	600 lbs	560 lbs
Bending moments	3200 ft lbs	3300 ft lbs
Torsional moments	6600 ft lbs	5000 ft lbs

These values are reasonably in proportion with loadings on similar type sodium pumps which have had complete stress analysis and their adequacy has been verified by actual operations.

- e) The reactions at the inlet nozzle of the sodium preheater are taken up by a new pipe anchor. This anchor is not necessary for the present sodium return line with two expansion joints. A brief review of the sodium preheater design indicated that the installation of the new pipe anchor requires modification of the refractory support for the preheater headers to allow free expansion of the preheater tubing.

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The above results of the flexibility analysis indicated that the pipe stresses caused by thermal expansion of pipe lines shown in Appendices "B" and "C" are considerably lower than the allowable values. However, the effects of the reaction forces and moments on the equipment nozzles will require additional investigation. In the course of the final design, competent and accurate stress analysis must be performed on the equipment, particularly on the primary sodium pump to verify their capability to withstand those reactions. The final stress analysis will facilitate an accurate evaluation of the piping configuration shown in Appendix "A" and may induce further modifications to improve the economy of the suggested layout.

Investigations were made of changes in sodium storage capacity, pumping power, and other process requirements due to these modifications. The discussed changes will add approximately 450 gallons of sodium to the system and the present storage volume is sufficient to accommodate this addition. Change in pumping power requirements due to the 2.1 psi increase in the pressure drop is negligible. The available NPSH for the pump amounts to 23.7 psi and 12.5 psi minimum is required for the new configuration.

3. Review by Consultant

C. F. Braun & Co.'s report on the investigation of the primary piping of the SCTI installation is attached as Appendix "D" to this Technical Data Record. The analysis of the consultant shows close agreement with Atomics International's results and concludes that the configurations are about as flexible as they can be made. Reactions on the pump nozzles do not exceed limiting forces and moments used for oil refinery and chemical plant pumps. A comparison with the overconservative NEMA Code SM20, applicable to large steam turbines and centrifugal compressors, indicated excessive moments on the pump nozzles. A sophisticated moment stop near the pump on one or both lines may be used to lower these moments.

4. Pump Relocation Study

The present location of the free-surface type primary sodium pump requires

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maintaining two free surfaces in the primary sodium system. One in the pump barrel, the second is in the expansion tank and is approximately 25 ft higher. Two separate sodium level control systems are required to maintain these separate free surface levels. This arrangement entails the danger of flooding the pump barrel if a failure occurs in the level control system. In order to achieve nearly identical sodium level in the pump and the expansion tank, the pump must be raised to a higher elevation. It can either be installed in the tank, or installed adjacent to the tank.

Installation of the pump in the expansion tank requires the following modifications and additions to the pump and tank:

- a) Lengthening the pump barrel and shaft by 1-1/2 to 2 feet to provide sufficient gas space above the maximum sodium level.
- b) Changing of the carbon steel mounting flange on the pump to stainless to meet the tank rating of 100 psig pressure at 1000°F temperature.
- c) Cutting openings in the pump barrel to provide continuous common free sodium surface in pump and tank.
- d) Revising air cooling system around the upper pump bearing.
- e) Addition of mounting ring to the tank with thermal radiation barrier.
- f) Installation of pump discharge line in the tank with penetration through the bottom head.
- g) Installation of baffle system into the tank, including pump suction bell.

Installation of the pump in the expansion tank eliminates the pump suction line but requires an extension of the pump discharge line between the penetration through the tank and the junction to the present discharge line. The configuration of the new discharge line to provide sufficient flexibility and the additional loops to the present lines to replace the bellows requires more investigation.

Relocation of the pump adjacent to the expansion tanks requires extensive additions to the present structural framing to support the pump. In addition

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to the new pump suction and discharge lines, an overflow and a vent line must be provided from the pump barrel to the expansion tank. These lines require new connections on the pump and tank. Again, flexibility of the new pipe lines and of the existing ones without bellows requires more analytical and design effort.

Both arrangements of the pump and tank assembly discussed above accomplish the common free surface and single level control, although in the separate installation there would be some lag of the pump level behind the tank. This lag could be kept to a minimum by adequately sizing the overflow line. However, in both cases, the volume available for the thermal expansion of the sodium in the system is limited by the 2 ft sodium level range in the pump barrel. The present arrangement allows 4 ft variation of the level in the expansion tank and even with this limitation of the expansion volume, draining of sodium in the storage tank is necessary when the hot leg sodium temperature is changed by approximately 500°F. This limitation may be eliminated by installation of more sodium expansion space, in addition to the major modifications listed for both alternate locations.

The present studies did not develop a completely satisfactory solution of the sodium level control problem, did not establish the degree of need for common sodium level in the pump and the expansion tank, and did not evaluate the advantages and disadvantages of the various modifications. Consequently, additional studies are required to establish the most desirable solution and to reach a conclusion whether such a modification should be recommended.

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5. References

- a) U.S. AEC Canoga Park Area Office letter CP-66-8063 dated February 21, 1966 to AI - Redesign of SCTI Piping.
- b) AI-NAA-SR-TDR No. 11941 - Sodium Component Test Facility Feasibility Study Report - Secondary Sodium Piping Design Without Bellows.
- c) American Standard Code for Pressure Piping ASA B31.1.
- d) ASME Boiler and Pressure Vessel Code
Section III Nuclear Vessels
Section VIII Unfired Pressure Vessels
- e) AI-64-Memo-142, Pipe Stress Analysis Code PSA 2 by B. H. Boonstra.

6. Appendices

- A. Isometric Layout of the Primary Sodium Pump Suction and Discharge and Cold By-pass Piping Without Bellows Type Expansion Joints.
- B. Stress Analysis Summary Sheet - Line 503-10-P.
- C. Stress Analysis Summary Sheet - Lines 501-10-P, 504-10-P, and 511-10-P.
- D. C. F. Braun & Co. SCTI Primary Piping Feasibility Study.

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APPENDIX "A"

SCT1 - ISOMETRIC LAYOUT
OF THE PRIMARY SODIUM
PUMP SUCTION & DISCH.
AND COLD BY-PASS
PIPING WITHOUT
BELLOWS TYPE EXPASION
JOINTS.

ATOMICS INTERNATIONAL
SCTI PRIMARY SODIUM PIPING
FEASIBILITY STUDY
PROJECT 2956-P

C F BRAUN & CO

Alhambra California

June 10, 1966

LEW

Atomics International PIPING STRESS ANALYSIS
SCTI PRIMARY SODIUM PIPING
Canoga Park, California FEASIBILITY STUDY

Project 2956-P

June 10, 1966

Here is the report of our investigation of a portion of the primary piping of your SCTI installation.

SCOPE We met with you on Friday, June 3. J Carey, C C Conners, G Landler, C Dipol, and W Hughes attended for AI. O L Lewis, L C Reynolds, and L E Wright were present for Braun. The scope of work defined for Braun was to check the AI feasibility studies that had been made of a piping configuration to allow the removal of the existing expansion joints in this system.

Two pipelines were studied. The suction to the primary sodium pump and the discharge from the primary sodium pump including the bypass.

PROBLEMS ANALYZED Since this is a feasibility study we have made a thermal expansion analysis only, assuming balanced supports. Deadload is not a consideration. Problem 5 covers the pump suction line, and Problem 6 covers the pump discharge and bypass.

REFERENCE MATERIAL These problems have been analyzed using the input data from your Stress Runs 504-10-P and 503-10-P, and the layout isometric drawing you supplied.

DISCUSSION Our computer analysis shows close agreement with your own analysis. Stresses in the suction line are in the lower-third of the stress range, and at the pump the stress is 12 percent of the allowable. Stresses in the discharge are generally in the lower-half of the stress range, and at the pump the stress is 11 percent of the allowable.

Our rules for limiting forces and moments on refinery and chemical plant pumps limit the stress at the pump nozzle to 25 percent of the allowable and any force to 100 times the nozzle size in inches. This would allow 1000 pounds in any direction at the suction nozzle and 800 pounds in any direction on the discharge nozzle. The limiting stress at either nozzle would be 6500 psi. Your sodium pump may or may not be as rugged as refinery pumping equipment.

At the other extreme of limiting forces and moments on equipment is the NEMA Code SM20 which is used to determine the allowable reactions applied to large steam turbines and centrifugal compressors. Using the conservative NEMA standard, the results show that the forces meet the requirements, but that the moments do not - particularly the moments about the Z-axis since they are additive.

The practical limit to reactions on the pump lies somewhere between these two rules.

LEW

Atomics International PIPING STRESS ANALYSIS
SCTI PRIMARY SODIUM PIPING
Canoga Park, California FEASIBILITY STUDY

Project 2956-P

June 10, 1966

CONCLUSIONS The piping configuration is about as flexible as it can be made. If the moments are considered excessive, the only reasonable method to lower them appears to be the addition of a sophisticated moment stop near the pump on one or both lines.

FF 10-2-61

PIPELINE DATA CHECK

D. F. T. 2154-120
 PIPE FLEXIBILITY DATA
 INPUT PROGRAM 45.1012
 THERMAL EXPANSION ONLY
 ANALYST JWG
 R. U. NO. 0036
 DATE 06-08-66

DESIGN CLASSIFICATION 1

MATERIAL CLASS 41
 MATERIAL ST. 155,000 PSI
 DESIGN TEMPERATURE 100°F
 DESIGN PRESSURE 100 PSI

ELASTIC MODULUS 29,000,000 PSI
 ELASTIC COEFFICIENT 22.0 x 10⁻⁶ IN/IN/°F
 EXPANSION COEFFICIENT 6.5 x 10⁻⁶ IN/IN/°F
 ALLOWABLE STRESS 15,000 PSI

P. INT. NO.	Y=0.00	Y=0.00	Y=0.00	Y=0.00	Y=0.00	Y=0.00	Y=0.00	Y=0.00	Y=0.00	Y=0.00
01	+	1.0000	+	1.0000	+	1.0000	+	1.0000	+	1.0000
02	+	1.0000	+	1.0000	+	1.0000	+	1.0000	+	1.0000
03	+	1.0000	+	1.0000	+	1.0000	+	1.0000	+	1.0000
04	+	1.0000	+	1.0000	+	1.0000	+	1.0000	+	1.0000
05	+	1.0000	+	1.0000	+	1.0000	+	1.0000	+	1.0000
06	+	1.0000	+	1.0000	+	1.0000	+	1.0000	+	1.0000
07	+	1.0000	+	1.0000	+	1.0000	+	1.0000	+	1.0000

NOTES: 2 = ELL (OR HEN) 5 = UNKINF TEE 9 = STICKLE FLG 11 = HIGLE SEC 13 = 45-DEG ELL
 3 = WFLJIN, TEE 6 = MITER HLND 10 = LAP/JINT FLG 12 = RESTRAINT 15 = W V FLANGF
 4 = PRINF TEE 7 = SLIP-OUT FLG 14 = S R L' 304

PE31-R-01

STRESS REPORT

PROJECT 2986-173

PIPING FLEXIBILITY

DATE 06-08-66

LINE 503

TYPE OF ANALYSIS = 1

PROBLEM 5

THERMAL EXPANSION

FULL RANGE TERMINAL REACTIONS							HOT TERMINAL REACTIONS (NO COLD SPRING)						
FORCES, LBS			MOMENTS, FT-LBS				FORCES, LBS			MOMENTS, FT-LBS			
PT NO	FX	FY	FZ	MX	MY	MZ	PT NO	FX	FY	FZ	MX	MY	MZ
1	602	482	*243	3220	*1282	6695	1	483	387	*195	2583	*1028	5371
7	*602	*482	243	*4732	*1069	*15101	7	*483	*387	195	*3796	*857	*12113

CALCULATED STRESSES			ALLOWABLE STRESSES, PSI			ELASTIC MODULUS		STRESS	
FOR RANGE, PSI			RANGE		COLD	HOT	MILLION PSI		INTENSIFICATION
PT NO	S1	S2	S3	S4	SC	SH	EC	EH	FACTOR
1	3025			26812	18750	13500	28.30	22.70	1.00
2	5826	2440		26812	18750	13500	28.30	22.70	2.61
3	3706	5207		26812	18750	13500	28.30	22.70	2.61
4	9288	8835		26812	18750	13500	28.30	22.70	2.61
5	7250	6335		26812	18750	13500	28.30	22.70	2.61
6	1695	2939		26812	18750	13500	28.30	22.70	2.61
7	6363			26812	18750	13500	28.30	22.70	1.00

MAXIMUM STRESS IS 9288 PSI AT X = 26.202, Y = -3.712, Z = -0.250

FINAL MOVEMENTS OF POINTS							RESTRAINT INDICES					
DEFLECTIONS, INCHES			ROTATIONS, RADIANS				0 = FIXED			1 = FREE		
PT NO	DX	DY	DZ	RX	RY	RZ	X	Y	Z	TX	TY	TZ
1	0.000	-0.540	0.000	0.0000	0.0000	0.0000	0	0	0	0	0	0
7	0.000	-0.574	0.000	0.0000	0.0000	0.0000						

NET INITIAL FREE MOVEMENTS OF BRANCHES								COLD SPRING MULTIPLIERS		
BRANCH		DEFLECTIONS, INCHES			ROTATIONS, RADIANS			FOR RANGE REACTIONS		
FROM	TO	DX	DY	DZ	RX	RY	RZ	XCS	HUT	COLD
1	7	1.234	2.627	*0.947	0.0000	0.0000	0.0000	0	0.602	0.000
								25	0.668	*0.250
								50	0.535	*0.500
								75	0.401	*0.750
								100	0.267	*1.000

CUSTOMER ATOMICS INTERNATIONAL
 LOCATION CANOGA PARK, CALIF
 UNIT

STRESS SKETCH

PROJECT 2956-100 PROBLEM 5
 LINE NUMBER 503-10-P
 DATE 6-7-66 BY JWG

ANCHOR MOVEMENTS:

POINT	Δx	Δy	Δz	ϕx	ϕy	ϕz
1	0	-540	0	0	0	0
7	0	-574	0	0	0	0

CHECK LIST
(SEE ALSO PIPING ENGINEERING 5.3201)

1	DESIGN TEMPERATURES & PRESSURES	✓
2	PIPE SIZES AND WALL THICKNESSES	✓
3	PIPE BEND RADIUS IF NOT L R ELLS	✓
4	MATERIAL SPECIFICATIONS & GRADES	✓
5	COLUMN AND VESSEL TEMPERATURES	*
6	HEAT EXCHGR SHELL TEMPERATURES	*
7	HEAT EXCHGR FIXED END LOCATED	*
8	TYPES OF PIPE SUPPORTS SHOWN	*
9	PIPE SUPPORTS LOCATED	*
10	VALVES, REDUCERS ETC. LOCATED	*
11	LENGTHS OF VALVES ETC. GIVEN	*
12	TYPES OF FLANGES NOTED	*
13	TYPES OF BRANCH CONNS NOTED	*
14	BRANCH REINF. PAD THICKNESSES	*
15	INSULATION DATA GIVEN	*
16	STEAM TRACING TEMPERATURE NOTED	*
17	EQUIPMENT NUMBERS NOTED	✓
18	NORTH ARROW SHOWN	✓
19	TITLE BLOCK COMPLETED	✓
20	PIPING AREAS INDICATED	*

*NOT APPLICABLE

PIPE WALL THICKNESS OR SCHEDULE

SIZE 10"

THK SCH 40

SECTION	1-7			
TEMPERATURE	1000			
PRESSURE				
FLUID	Na			
MATERIAL	304SS			
CODE SECTION				

REFERENCE DRAWINGS

SPECIAL INSTRUCTIONS

ANALYST GASCOYNE DATE 6-8-66

ANALYSIS MADE BY

EXPANSION ☒ DEADLOAD ☐ SEISMIC ☐ WIND ☐

ANALYST'S COMMENTS

MAXIMUM STRESS PSI ALLOWABLE STRESS PSI RE/ DATE BY ROOM NO

CUSTOMER ATOMICS INTERNATIONAL
LOCATION CANOGA PARK, CALIF
UNIT

STRESS SKETCH

PROJECT 2956-100 PROBLEM 6
LINE NUMBER 504-10-P, 511-10-P
DATE 6-7-66 BY JWG

NOTES

ALL BENDS ARE L R ELBOWS (R = 15")

ALL BRANCH CONNS ARE WELD TEES

ANCHOR MOVEMENTS

POINT	Δx	Δy	Δz	ϕx	ϕy	ϕz
1	-1.16	-1.460	.153	0	0	0
10	0	0	0	0	0	0
26	0	2.820	.375	0	0	0
41	0	1.000	0	0	0	0

CHECK LIST
(SEE ALSO PIPING ENGINEERING 5.3201)

1	DESIGN TEMPERATURES & PRESSURES	✓
2	PIPE SIZES AND WALL THICKNESSES	✓
3	PIPE BEND RADII IF NOT L R ELLS	✓
4	MATERIAL SPECIFICATIONS & GRADES	✓
5	COLUMN AND VESSEL TEMPERATURES	*
6	HEAT EXCHGR SHELL TEMPERATURES	*
7	HEAT EXCHGR FIXED END LOCATED	*
8	TYPES OF PIPE SUPPORTS SHOWN	*
9	PIPE SUPPORTS LOCATED	*
10	VALVES REDUCERS ETC. LOCATED	✓
11	LENGTHS OF VALVES ETC. GIVEN	✓
12	TYPES OF FLANGES NOTED	*
13	TYPES OF BRANCH CONNS NOTED	✓
14	BRANCH REINF. PAD THICKNESSES	*
15	INSULATION DATA GIVEN	*
16	STEAM TRACING TEMPERATURE NOTED	*
17	EQUIPMENT NUMBERS NOTED	✓
18	NORTH ARROW SHOWN	✓
19	TITLE BLOCK COMPLETED	✓
20	PIPING AREAS INDICATED	*

* NOT APPLICABLE

PIPE WALL THICKNESS OR SCHEDULE

SIZE	10"	8"	12"	20"
THICK/SCH	40	40	40	30

SECTION	1-18	18-41
TEMPERATURE	1000F	1300F
PRESSURE		
FLUID	Na	Na
MATERIAL	304SS	304SS
CODE SECTION		

REFERENCE DRAWINGS

SPECIAL INSTRUCTIONS

ANALYST GASCOYNE RUN DATE 6-8-66

ANALYSIS MADE FOR

EXPANSION ☒ DEADLOAD ☐ SEISMIC ☐ WIND ☐

ANALYST'S COMMENTS

MAXIMUM STRESS PSI ALLOWABLE STRESS PSI

REV DATE BY ROOM NO

PI 10-11

PIPELINE DATA CHECK

PROJECT 2256-110	PIPELINE FLEXIBILITY ANALYSIS	ANALYST JRG
LINE NO 204	EXP 1 PHASE 10-11	ROOM NO 0036
INCH 14	INCH 14 EXP 1 1/2 ONLY	DATE 06-09-66

DESIGN CONDITION	1	2
MATERIAL CLASS	AY	AY
MATERIAL TYPE	STAINLESS STEEL	STAINLESS STEEL
DESIGN TEMPERATURE	+ 100 DEGREE F	+ 100 DEGREE F
DESIGN PRESSURE	+ 0 PSI	+ 0 PSI
PLASTIC MODULUS, COLD	28.3 MILLION PSI	28.3 MILLION PSI
PLASTIC MODULUS, HOT	27.7 MILLION PSI	27.7 MILLION PSI
EXPANSION COEFFICIENT	+ 11.48 IN/IN PER 100 FT	+ 11.48 IN/IN PER 100 FT
ALLOWABLE STRESS, SA	24913 PSI	24913 PSI

POINT NO	X=COORD	Y=COORD	Z=COORD	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
01	+ 0.0000	+ 0.0000	+ 0.0000																				
02	+ 0.0000	+ 0.0000	+ 0.0000																				
03	+ 0.0000	+ 0.0000	+ 0.0000																				
04	+ 0.0000	+ 0.0000	+ 0.0000																				
05	+ 6.5000	+ 0.0000	+ 0.0000																				
06	+ 6.5000	+ 14.4167	+ 0.0000																				
07	+ 6.5000	+ 14.4167	+ 0.0000																				
08	+ 6.5000	+ 5.5833	+ 0.0000																				
09	+ 19.7500	+ 5.5833	+ 0.0000																				
10	+ 21.5933	+ 5.5833	+ 0.0000																				
11	+ 19.7500	+ 5.5833	+ 0.0000																				
12	+ 8.0000	+ 5.5833	+ 0.0000																				
13	+ 8.0000	+ 5.5833	+ 0.0000																				
14	+ 8.0000	+ 11.7500	+ 0.0000																				
15	+ 4.3333	+ 11.7500	+ 0.0000																				
16	+ 4.3333	+ 11.7500	+ 0.0000																				
17	+ 4.3333	+ 12.6876	+ 0.0000																				
18	+ 4.3333	+ 12.6876	+ 0.0000																				
19	+ 4.3333	+ 12.6876	+ 0.0000																				
20	+ 4.3333	+ 12.6876	+ 0.0000																				

CODES	2 = ELL OR HEND	3 = UNREIN TEE	4 = SOCKET FLG	11 = RIGID SECT	14 = 45-DEG ELL
	3 = WELDING TEE	6 = MITER HEND	9 = TANGENT FLG	12 = RESTRAINT	15 = W N FLANGE
	4 = REIN TEE	7 = SLIP ON FLG	10 = SCREW FLG	13 = S R ELBOW	

PE10-R=1

PIPELINE DATA CHECK

PROJECT	2956-100	PIPING FLEXIBILITY ANALYSIS	ANALYST	JWG
LINE NO	504	INPUT PROGRAM PE10-12	ROOM NO	0036
PROBLEM	5	THERMAL EXPANSION ONLY	DATE	06-08-66

POINT NO	X-COORD	Y-COORD	Z-COORD	CODE	DD	THK	RAD	K	DES COND
21	+ 4.3333	+ 19.6876	+ 3.7916		8.625	0.322		1.00	2
22	+ 4.3333	+ 19.6876	+ 5.4166	3	20.000	0.500		1.00	2
23	+ 5.9583	+ 19.6876	+ 5.4166		20.000	0.500		1.00	2
24	+ 9.5833	+ 19.6876	+ 5.4166		12.750	0.406		1.00	2
25	+ 11.7500	+ 19.6876	+ 5.4166	3	10.750	0.365		1.00	2
26	+ 11.7500	+ 19.6876	+ 1.0833		10.750	0.365		1.00	2
27	+ 2.7083	+ 19.6876	+ 5.4166		20.000	0.500		1.00	2
28	+ 1.4166	+ 19.6876	+ 5.4166		12.750	0.406		1.00	2
29	+ 2.2501	+ 19.6876	+ 5.4166	2	10.750	0.365	1.250	8.13	2
30	+ 2.2501	+ 19.6876	+ 4.1666	11	10.750	0.365		1.00	2
31	+ 2.2501	+ 19.6876	+ 1.9999		10.750	0.365		1.00	2
32	+ 2.2501	+ 19.6876	+ 7.5834	2	10.750	0.365	1.250	8.13	2
33	+ 7.2501	+ 19.6876	+ 7.5834	2	10.750	0.365	1.250	8.13	2
34	+ 7.2501	+ 19.6876	+ 7.4166	12	10.750	0.365		1.00	2
35	+ 7.2501	+ 19.6876	+ 23.4166	2	10.750	0.365	1.250	8.13	2
36	+ 10.2501	+ 19.6876	+ 23.4166	2	10.750	0.365	1.250	8.13	2
37	+ 10.2501	+ 19.6876	+ 7.4166	2	10.750	0.365	1.250	8.13	2
38	+ 25.5209	+ 19.6876	+ 7.4166	2	10.750	0.365	1.250	8.13	2
39	+ 25.5209	+ 19.6876	+ 8.6666	11	10.750	0.365		1.00	2
40	+ 25.5209	+ 19.6876	+ 10.8333		10.750	0.365		1.00	2
41	+ 25.5209	+ 19.6876	+ 18.2500		10.750	0.365		1.00	2

CODES	2 = ELL OR BEND	5 = UNREINF TEE	8 = SOCKWLD FLG	11 = RIGID SECT	14 = 45-DEG ELL
	3 = WELDING TEE	6 = MITER BEND	9 = LAPJOINT FLG	12 = RESTRAINT	15 = W N FLANGE
	4 = REINF TEE	7 = SLIP-ON FLG	10 = SCREWED FLG	13 = S R ELBOW	

FILE NO 1

STRESS REPORT

PROJECT 2954-111

EX. 111-111-111
TYPE OF ANALYSIS
THERMAL ANALYSIS

DATE 06-08-66

PT	THERMAL REACTION (1) COLLECTOR						THERMAL REACTION (2) COLLECTOR					
	FX	FY	FZ	MX	MY	MZ	FX	FY	FZ	MX	MY	MZ
1	5522	5098	425	3704	2120	313						
17	2113	1111	1114	5534	2111	2111						
18	2113	1111	1114	5534	2111	2111						
24	2113	1111	1114	5534	2111	2111						
31	2113	1111	1114	5534	2111	2111						

PT	STRESS			ALLOWABLE STRESS			PLASTIC MODULI			STRESS		
	FX	FY	FZ	RANGE	CELU	MAX	FX	FY	FZ	CELU	MAX	CELU
1	271			24112	14750	14750	24.3			2.61		
2	3115			24112	14750	14750	24.3			2.61		
3	3524			24112	14750	14750	24.3			2.61		
4	4031			24112	14750	14750	24.3			2.61		
5	627			24112	14750	14750	24.3			2.61		
6	6464			24112	14750	14750	24.3			2.61		
7	9018			24112	14750	14750	24.3			2.61		
8	9111			24112	14750	14750	24.3			2.61		
9	1303			24112	14750	14750	24.3			2.61		
10	5048			24112	14750	14750	24.3			2.61		
11	1639			24112	14750	14750	24.3			2.61		
12	9814			24112	14750	14750	24.3			2.61		
13	17596			24112	14750	14750	24.3			2.61		
14	7234			24112	14750	14750	24.3			2.61		
15	7217			24112	14750	14750	24.3			2.61		
16	12102			24112	14750	14750	24.3			2.61		
17	11307			24112	14750	14750	24.3			2.61		
18	5068			24112	14750	14750	24.3			2.61		
19	17301			24112	14750	14750	24.3			2.61		
20	8353			24112	14750	14750	24.3			2.61		
21	5107			24112	14750	14750	24.3			2.61		
22	1057			24112	14750	14750	24.3			2.61		
23	1444			24112	14750	14750	24.3			2.61		
24	4582			24112	14750	14750	24.3			2.61		
25	14500			24112	14750	14750	24.3			2.61		
26	3774			24112	14750	14750	24.3			2.61		

PE11-R-01

PROJECT 2956-100

LINE 504

PROBLEM 6

PIPING FLEXIBILITY

TYPE OF ANALYSIS = 1

THERMAL EXPANSION

STRESS REPORT

DATE 06-08-66

PT NO	CALCULATED STRESSES FOR RANGE, PSI			ALLOWABLE STRESSES, PSI			ELASTIC MODULUS MILLION PSI		STRESS INTENSIFICATION FACTOR
	S1	S2	S3	RANGE S4	COLD SC	HOT SH	EC	EH	
27	763	2362		24112	18750	2700	28.30	20.70	1.00
28	2037	3208		24112	18750	2700	28.30	20.70	1.00
29	5849	3271		24112	18750	2700	28.30	20.70	2.61
30									
31	704			24112	18750	2700	28.30	20.70	1.00
32	8346	10526		24112	18750	2700	28.30	20.70	2.61
33	13039	13252		24112	18750	2700	28.30	20.70	2.61
34	558	558		24112	18750	2700	28.30	20.70	1.00
35	17027	16914		24112	18750	2700	28.30	20.70	2.61
36	16406	14006		24112	18750	2700	28.30	20.70	2.61
37	375	2994		24112	18750	2700	28.30	20.70	2.61
38	16228	15955		24112	18750	2700	28.30	20.70	2.61
39									
40	5377			24112	18750	2700	28.30	20.70	1.00
41	2665			24112	18750	2700	28.30	20.70	1.00

MAXIMUM STRESS IS 17027 PSI AT X = -7.704, Y = 19.688, Z = 22.962

FINAL MOVEMENTS OF POINTS

RESTRAINT INDICES

PT NO	DEFLECTIONS, INCHES			ROTATIONS, RADIAN			0 = FIXED 1 = FREE					
	DX	DY	DZ	RX	RY	RZ	X	Y	Z	TX	TY	TZ
1	-0.116	-0.460	0.153	0.0000	0.0000	0.0000	0	0	0	0	0	0
9	0.210	0.007	-0.001	-0.0005	0.0001	0.0007						
10	0.000	0.000	0.000	0.0000	0.0000	0.0000	0	0	0	0	0	0
18	-0.746	2.516	-0.852	-0.0025	-0.0026	0.0062	1	1	1	1	1	1
22	-1.189	2.686	0.769	-0.0004	-0.0039	0.0020						
26	0.000	2.820	0.375	0.0000	0.0000	0.0000	0	0	0	0	0	0
34	-0.707	1.922	0.671	0.0028	0.0082	0.0031	1	1	1	1	1	1
41	0.000	1.000	0.000	0.0000	0.0000	0.0000	0	0	0	0	0	0

C F BRAUN & CO

PAGE 3

STRESS REPORT

DATE 06-08-66

PF11-H*01

PRO IFFT 354-111

IVE 7.4

PR 101EM 6

P-155 FLEXIBILITY

TYPE OF ANALYSIS = 1

THESE ARE EXHAUSTIVE

NET INITIAL FORCE MOVEMENTS OF BRANCHES

BRANCH		DEFLECTION VALUES			INITIAL JOINT RADIALS		
FROM	TO	Y	Z	Y	YR	ZR	YZ
1	= 4	-2.113	-1.131	-0.224	1.2200	0.000	1.200
10	= 9	0.210	0.265	0.000	0.100	2.200	1.000
9	= 18	2.265	2.265	2.517	0.000	1.200	1.000
3K AT 10		0.000	0.000	0.000	0.000	0.000	0.000
18	= 22	0.000	0.000	1.521	0.000	0.000	0.000
26	= 22	-1.154	2.265	1.509	0.000	0.000	1.000
22	= 34	-1.415	2.265	2.311	0.000	0.000	0.000
3K AT 34		0.000	0.000	0.000	0.000	0.000	0.000
34	= 41	-2.813	-1.071	1.696	0.000	0.000	0.000

CALCULATING MULTIPLIERS

FOR ANALYSIS

YLR FLR CLR

NET CALCULATED

DESIGN MULTIPLIER > 1

APPENDIX "B"

STRESS ANALYSIS
SUMMARY SHEET
LINE 503-10-P

[illegible]

SECTION

6 300 THRU 355
7 355 " 360

POINT	CALC. FOR $\Delta x, \Delta y \neq \Delta z$	
300	Δx	0
	Δy	- .54"
	Δz	0
360	Δx	0
	Δy	- .574"
	Δz	0
	Δx	
	Δy	
	Δz

POINT 300

POINT 360

CONVENTION FOR POSITIVE
FORCES & MOMENTS

MAXIMUM STRESS = 3765
@ POINT 330

'IFE' HANGERS	PCINT							Sc=	A.S. KARWOWSKI & PREPARED BY: W.J. HUGHES	ATOMICS INTERNATIONAL A DIVISION OF NORTH AMERICAN AVIATION, INC.	PAGE NO. OF
	LOAD							Sh=	J.F. HAGELSTON CHECKED BY:		REPORT NO.
	MOVEMENT							SA=1.25Sc+.25Sh SA=	DATE: 5-19-66 PRIMARY Na LINE 503		MODEL NO. SCT1