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**LOFT EMERGENCY CORE
COOLANT FACILITY PIPING REVIEW**

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The following changes have been made to LTR 113-30:

1. On Page ii - Sentence added at end of Summary.
2. Pages 3 and 4 added.
3. Page 6a added - Modified sketch for ISO #1
4. Appendix B added.
5. Page 20 - New hangers 1 through 5 deleted, Supports 6 and 9 changed from snubbers to special U-Bolt restraints.

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IDAHO NATIONAL ENGINEERING LABORATORY
LOFT TECHNICAL REPORT
LOFT PROGRAM

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<u>SUMMARY</u>		

Using the Applied Mechanics Branch Piping Design Standard (LTR 10-21) as the analytical criterion, a review was made of all lines under two inches in diameter contained in the LOFT emergency core coolant facility not analyzed elsewhere, to determine adequacy of deadweight, seismic and thermal support. Some lines from other systems were also analyzed because of interconnection with the ECC System. ASME Code requirements are satisfied through application of the design standard. Results indicated that some additional supports, as noted herein, will be necessary before the system can be considered adequately supported. In some instances existing restraints failed thermal analysis but since offset values were generated for an operating temperature of 200°F, and the actual temperature will not exceed 150°F within the piping analyzed, no changes need be made to these restraints. During the review it was discovered that lines attached to Line 1"-PC-57-VA needed additional supports. Lines associated with ISO #1 have been reanalyzed by more vigorous methods to simplify the supports for valves in this part of the ECC piping system.

RECOMMENDATIONS

1. Install the hangers as noted herein.
2. A stress analysis should be performed on lines associated with Line 1"-PC-57-VA.
3. One hanger, as noted on isometric sketch number 3, needs to be secured.

The purpose of this review was to examine all remaining lines of the LOFT emergency core coolant facility piping outside of containment and with a diameter of less than two inches, not analyzed by ITT Grinnell Corporation. Because of a discrepancy on the Grinnell analysis, lines 3"-ECCV-10-A, 2"-ECCV-10-A and 2"-ECCV-11-A were included in this review. In addition, some lines from other systems which connected to the ECC piping were also examined, as listed on the isometric sketches in this report. An on-site "walk-through" was made first to verify existing restraint and valve locations. Very short stub lines were eliminated by inspection. All remaining lines, together with the lines analyzed by Grinnell and lines being currently analyzed by R. M. Fors of the Applied Mechanics Branch constitute a complete analysis of the ECC facility piping as now listed in LOFT Specification P-1, Line Designation Tables.

Since all lines to be examined had a normal operating temperature of 150° F or less, the Applied Mechanics Branch Piping Design Standard (LTR 10-21 by J. W. Muffett) was employed to determine adequate support configuration. This standard provides for satisfaction of the ASME Code requirements for Class 1 and Class 2 Nuclear Piping through comparison of the system under consideration to systems which do meet the stress allowables of the code. This comparison is achieved by observation of rules used to locate deadweight and seismic supports and rules used to determine which supports must be non-rigid in order to assure sufficient flexibility for thermal expansion and anchor movements.

The examination of the piping proceeded as follows: Isometric sketches of the piping were made and consecutive sections called half spans were examined in accordance with the rules outlined in the Standard. Tables A-1 and A-2 show the span lengths and span loads for piping of various diameters. Valves contained in Table A-2 were calculated for the .35g seismic event at the LOFT site. Once deadweight and seismic supports were located, these supports were checked for stresses imposed by anchor movement and pipe thermal expansion using the rules outlined in the Standard in conjunction with Tables A-3 and A-4. In cases where the operating temperature was less than 100° F, anchor movements were ignored. Since the required offsets for thermal growth were given for a temperature of 200° F, instances where the actual offset was not sufficient were noted, but in most cases were considered adequate, if the actual offset was close to the required offset. Work sheets were used to document the employed procedure and are available upon request from the Applied Mechanics branch.

After analysis for deadweight, seismic and thermal loadings was completed, another on-site "walk-through" was made to verify the validity of new support configuration. In areas where wall penetrations had been previously ignored, or where nearby anchor points or hangers gave adequate support, installations indicated by the Standard were removed. During this "walk-through" it was found that some lines attached to line 1"-PC-57-VA (see sketch No. 5) were not adequately supported. An analysis of these lines should be made.

The results of this review form the remainder of this report and consist of Table I, Index of Examined Lines, the piping sketches indicating additional hanger locations; Table II, which lists the hangers, their directions and their imposed loads; and an Appendix which contains a copy of the Tables and rules provided by the Applied Mechanics Branch Piping Design Standard. The imposed loads were determined by consideration of all seismic loadings between adjacent hangers plus all deadweight loadings for all hangers acting in the vertical direction. Table I also suggests types of hangers to be used. For the most part, U-bolts are recommended because at many locations a two-directional restraint is indicated. In areas where a U-bolt is indicated for a one-directional restraint, loadings in the other direction were checked and, unless noted, may be considered to be the same as the listed value. When bolting the U-bolt to the pipe, use two nuts on each leg to prevent deformation of the pipe or the support plate during assembly.

The following symbols are used on the isometrics:

- — Anchor Point or New Hanger Location
- — Hanger No. (Additional Installation)
- — Existing Restraints

The reanalysis of the piping shown on ISO #1 was performed analytically using the SAPP, SAPSP10, and INEL-PIPE II computer programs. The piping model and configuration for revised supports for this system as shown on this sketch designates ISO #1 modified. The basis for this analysis is given in the following paragraph:

The piping system was assumed to be subject to the following loading conditions:

1. Operating temperature 200°F
2. Operating pressure 600 psig
3. Relief valve operation-loads as determined by the Thermal Analysis Branch
4. Seismic loading-Safe Shutdown Earthquake static equivalent - 2 cases
 - (a) 1.13 g horizontal component (x)
.75 g vertical component (z)
 - (b) 1.13 g horizontal component (y)
.75 g horizontal component (z)
5. Valve data

CV valves - 35 pounds at assumed mass center of valve and operator
5 inches above pipe center line

Relief valves - 24 pounds at assumed mass center on vertical axis

2.

The following tapes were created:

SAP UNIT 10 DATA - L.RMFECVVA T9G056
 SAPSP10 UNIT 10 DATA - L.RMFECVVA.SNGLE T9G039
 OUTPUT DATA - (SAPP-SAPSP10-INELPIPE II)
 L.RMFECVVI U9A998

Results of the run show that all stresses satisfy allowable stress limits for Class II or III piping. Microfiche copies of the SAPSP10 and INEL-PIPE II programs as well as output is included as appendices to this report. Maximum loads at supports are given in the following table.

<u>Support No.</u> <u>(Boundary Element)</u>	<u>Load lb^(a)</u>
1 (Reaction at Wall)	25,-31
2 (Reaction at Wall)	137,-105
3	131,-110
4	-15,-177

<u>Support No. (Boundary Element)</u>	<u>Load lb^(a)</u>
5	51,-38
6 (b)	41,-99
7	62,-416
8	78,-35
9	172,-12
10	6,-127
11	50,-497
12	129,-77
13	256,-79
14	6,-41

2.

(a) A positive load is a load due to a pipe displacement in the positive coordinated direction. Support numbers in this table and the associated loads refer to the boundary element number designation of the pipe restraints in the referenced analysis and correspond to the designation shown on the isometric sketch by the small numbers such as "B.E.1". These numbers are distinct from the hanger numbers in Table II.

(b) Support pairs 6, 7; 8, 9; 10, 11, 12, & 13 simulate U bolts at the restraint locations. These U bolts must be installed so as to permit axial movement of the pipe due to thermal expansion.

One run was also made to determine whether axial restraint at the valve locations was permissible. This run gave an overstress condition at one elbow location. It was therefore concluded that some freedom of axial movement was required. The tapes associated with this run are:

SAP UNIT 10 DATA L.RMFECCVA T93577
 SAPSP10 UNIT 10 DATA L.RMFECCVA.SNGL A93586
 OUTPUT L.RMFECCV2
 3-2-77 U9I422

TABLE I
INDEX OF EXAMINED LINES

<u>Line No.</u>	<u>Isometric No.</u>
1"-ECC-134-A	7
1"-ECCD-17-VB	4
1/2"-ECCD-21-VD	13
1/2"-ECCD-22-VF	8
1"-ECCD-25-VF	2
1"-ECCD-27-VF	2
1"-ECCD-29-VB	3
1"-ECCD-31-VG	9
1"-ECCD-32-VG	14
1"-ECCD-53-VB	3
1"-ECCD-54-VB	3
1"-ECCD-55-VB	12
1"-ECCD-57-VB	11
1"-ECCD-58-VB	2
1"-ECCD-59-VB	2
1"-ECCD-60-VB	2
1"-ECCD-65-VB	2
1"-ECCD-114-VF	2
1"-ECCD-115-VF	2
1"-ECCV-6-A	1
1"-ECCV-7-A	1
3"-ECCV-10-A	1
2"-ECCV-10-A	1
2"-ECCV-11-A	1
1"-ECCV-21-VB	1
1"-ECCV-22-VB	1
1"-ECCV-23-VB	1
1"-ECCV-24-VB	1
1/2"-ECCV-116-VB	10
1/2"-ECCV-117-VF	10
1/2"-ECCV-118-VB	10
1/2"-ECCV-119-VF	10
1/2"-ECCV-121-VF	3
1"-ECCV-123-VF	3
1/2"-ECCV-123-VF	3
3/4"-C-271-E	4
1"-PC-54-VD	5
1/2"-PC-55-VA	5
3/4"-PC-56-VA	5
1"-PC-57-VA	5
1/2"-PRD-249-E	3

9

90 inches

Note:
 Restraint pairs A&B
 fail thermal analysis
 in X. Considered
 negligible for
 operating temperature
 $\leq 100^\circ\text{F}$.

ECC - FACILITY

ISO # 1

Valves snubbed
 at C.G. in all
 three directions

- 1"-ECCV-22-VB
- 1"-ECCV-6-A
- 1"-ECCV-21-VB
- 2"-ECCV-10-A
- 1"-ECCV-7-A
- 1"-ECCV-23-VB
- 1"-ECCV-24-VB
- 2"-ECCV-11-A
- 3"-ECCV-10-A

20 inches

1"-ECCD-60-VB
 1"-ECCD-114-VF
 1"-ECCD-58-VB
 1"-ECCD-25-VF
 1"-ECCD-115-VF
 1"-ECCD-59-VB
 1"-ECCD-27-VF
 1"-ECCD-65-VB

ECC-FACILITY - ISO #2

1/2"-PRD-249-E

ECC-FACILITY - ISO #3

6

1"-ECCD-17-VB
3/4"-C-271-F

ECC-FACILITY - ISO #4

$\frac{1}{2}$ " - PC - 55 - VA
 $\frac{3}{4}$ " - PC - 56 - VA
 1" - PC - 57 - VA (Partial)

Note: Branch lines
 from 1" - PC - 57 - VA
 not analyzed.
 Supports are
 needed.

20 inches

ECC - FACILITY - ISO # 5

LIN# 113-30 KEY.

10

1"-PC-54-V0

No installations required.

ECC-FACILITY - ISO #6

1" - ECC - 134-A

Note: Installation incomplete.
Hangers may be required
in all 3 directions just
above inlet valve.

10 inches

ECC - FACILITY - ISO # 7

1"-ECCD-22-VF

No hangers required.

ECC-FACILITY - ISO # 8

LTR# 113-30
REV. 1

10 inches

1"-ECCD-31-V6

No hangers required

ECC-FACILITY - ISO # 9

10 inches

No hangers required

$\frac{1}{2}$ " - ECCV-116-VB
 $\frac{1}{2}$ " - ECCV-117-VF
 $\frac{1}{2}$ " - ECCV-118-VB
 $\frac{1}{2}$ " - ECCV-119-VF

ECC-FACILITY - ISO # 10

No hangers required.

Existing restraint fails thermal
check in x-direction. Considered
adequate for operating temperature
of 150°F.

1"-ECCD-57-VB

ECC-FACILITY - ISO # 11

LIK# 113-30
REV. 1

17

1"-ECCD-55-V8

No hangers required.

Existing restraint fails thermal
check in x-direction. Considered
adequate for operating temperature
of 150°F.

ECC-FACILITY - ISO #12

$\frac{1}{2}$ "-ECCD-21-VD

10 inches

ECC-FACILITY - ISO # 13

LTR# 113-30
REV. 1

19

1"-ECCD-32-VF

ECC-FACILITY-ISO #14

LTR# 113-30
REV. 1

TABLE II

LOFT EMERGENCY CORE COOLANT FACILITY PIPING - RECOMMENDED INSTALLATIONS

<u>Hanger Number</u>	<u>Isometric Number</u>	<u>Global Direction</u>	<u>Load (Lbs)</u>	<u>Type and Location</u>
1				
2				
3				
4				
5				
6	1	Y	250	Existing U-Bolt Modified to Prevent Axial Movement of Pipe within U-Bolt
	1	Z	250	" " " " " "
7	1	Y	250	" " " " " "
	1	Z	250	" " " " " "
8	1	Y	250	" " " " " "
	1	Z	250	" " " " " "
9	1	Y	250	" " " " " "
	1	Z	250	" " " " " "
10	2	Z	100	Rod Hanger Just South of Elbow
11	2	Y	150	U-Bolt Just East of Elbow
12	2	X	200	U-Bolt Just East of Elbow
13	2	Y	200	U-Bolt 18 Inches South of Elbow
14	2	Z	200	U-Bolt 18 Inches South of Elbow

20

5.

T A B L E II (continued)

<u>Hanger Number</u>	<u>Isometric Number</u>	<u>Global Direction</u>	<u>Load (Lbs)</u>	<u>Type and Location</u>
15	2	Z	100	U-Bolt 5 Inches North of Elbow
16	3	Z	100	U-Bolt Just Below Elbow
17	3	X	100	U-Bolt Just Below Elbow
18	3	Z	100	U-Bolt In Place of Existing Rod Hanger
19	3	Y	100	U-Bolt 18 Inches South of Elbow
20	3	X	100	U-Bolt Just East of Elbow
21	5	Z	100	U-Bolt to Replace Existing Strap Hanger
22	5	Z	100	*Bar Hanger Four Inches North of Valve 5333
23	5	Z	**250	U-Bolt Just Below RV-232
24	13	Z	100	U-Bolt Just South of Elbow
25	13	Y	100	U-Bolt Just South of Elbow
26	13	Z	100	U-Bolt Two Inches Above Opening
27	13	X	100	U-Bolt Two Inches Above Opening
28	14	X	100	U-Bolt Just Above Elbow
29	14	Z	100	U-Bolt Just Above Elbow
30	14	Z	100	U-Bolt Just North of Elbow
31	14	X	100	U-Bolt Five Feet Above Elbow
32	14	Z	100	U-Bolt Five Feet Above Elbow
33	14	Y	100	Bar Hanger Just South of Elbow

* Provides X-Direction Support For V-5333-LC

** May be Greater Dependent Upon Performance of Analysis
Indicated in Recommendation No. 2

A P P E N D I X A

RULES AND TABLES PROVIDED FROM
APPLIED MECHANICS BRANCH
PIPING DESIGN STANDARD

(Ltr 10-21)

A.1. Rules for Locating Weight Supports

1. A half-span of plain pipe must have a vertical support at one end.
2. A half-span which includes an elbow must have a vertical support at both ends.
3. The length of a half-span which includes a concentrated weight of less than 10% of the normal span load (Table B-1) should not exceed 40% of the normal span length. It must have a vertical support on one side.
4. A half-span which includes a concentrated weight of from 10% to 40% of the normal span load must have a vertical support on both sides.
5. The length of a half-span which includes a concentrated weight of more than 40% but less than 250% of the normal span load should not exceed 10% of the normal span length and should have a vertical support on both sides. This length does not include the actual length of the concentrated weight.
6. A concentrated weight which exceeds 250% of the normal span load should be supported directly rather than by the piping to which it is attached.
7. The length of a half-span with one free end should not exceed 50% of the normal span length.
8. A half-span with a concentrated weight should not have a free end.
9. Supports not required by these rules should not be used.

TABLE A-1
RECOMMENDED SPANS FOR DEAD WEIGHT SUPPORTS.

NOM. DIAM.	SCH	WATER-FILLED		GAS-FILLED		ROD DIAM.
		SPAN*	LOAD (LB)	SPAN*	LOAD (LB)	
1/2	40	5'-5"	12	6'-10"	10	3/8
	80	6'-6"	12	6'-10"	12	
	160	6'-6"	14	6'-7"	14	
3/4	40	7'-7"	16	8'-4"	16	3/8
	80	7'-11"	20	8'-4"	18	
	160	7'-10"	22	8'-1"	22	
1	40	9'-0"	26	9'-10"	24	3/8
	80	9'-2"	32	9'-10"	30	
	160	9'-2"	33	9'-6"	38	
1-1/4	40	10'-5"	42	11'-7"	38	3/8
	80	10'-9"	50	11'-6"	46	
	160	10'-10"	58	11'-5"	56	
1-1/2	40	11'-4"	52	12'-10"	48	3/8
	80	11'-9"	64	12'-10"	58	
	160	11'-10"	80	12'-6"	76	
2	40	12'-9"	82	14'-9"	72	3/8
	80	13'-2"	102	14'-9"	94	
	160	13'-6"	136	14'-4"	128	
2-1/2	40	14'-6"	138	16'-9"	120	1/2
	80	15'-0"	168	16'-7"	152	
	160	15'-1"	202	16'-2"	190	
3	40	15'-6"	210	18'-1"	180	1/2
	80	16'-2"	248	18'-1"	232	
	160	16'-7"	326	17'-10"	306	
3-1/2	40	16'-7"	272	19'-9"	232	5/8
	80	17'-5"	340	19'-9"	302	
	XXS	17'-11"	520	18'-11"	496	
4	40	17'-7"	346	21'-2"	290	5/8
	80	18'-7"	436	21'-3"	384	
	160	19'-2"	584	20'-6"	542	

*The actual span should not exceed the recommended value by more than 1 foot.

A.2. Rules for locating Seismic Supports

1. A horizontal half-span must have a horizontal, lateral restraint at one end.
2. A vertical half-span must have two orthogonal, horizontal restraints at one end.
3. A half-span which includes a bend and lies in a vertical plane must be supported at both ends--a horizontal, lateral support at the horizontal end and two orthogonal, lateral supports on the vertical end, (see rule 14).
4. A straight, horizontal section of pipe which is less than $4/10$ of the normal span in length requires no horizontal restraints. It is treated as a concentrated weight in its axial direction.
5. A horizontal section of pipe whose length exceeds $4/10$ of the normal span must be restrained along its axis.
6. A half-span which contains a concentrated weight of less than 10% of the normal seismic-span weight should not exceed 40% of the normal-span length. It should be supported on one side with horizontal restraints.
7. A half-span which includes a concentrated weight of from 10% to 40% of the normal seismic-span weight must be supported on both ends with horizontal restraints.
8. The length of a half-span which includes a concentrated weight of more than 40% but less than 250% of the normal seismic-span weight should not exceed 10% of the normal span (exclusive of the actual length of the concentrated weight). This half-span should be supported on both ends by horizontal supports.
9. A concentrated weight which exceeds 250% of the normal seismic-span weight should be supported directly, rather than by the piping to which it is attached. Horizontal support is required at the center of gravity.

A.2. Rules for locating Seismic Supports (continued)

10. In general, motor operators for valves should be restrained in three orthogonal directions. For vertically mounted operators, only horizontal, lateral support is required.
11. A half-span with a concentrated weight should not have a free end; horizontal, lateral support should be provided.
12. Supports not required by these rules should not be used.
13. If the distance between adjacent rigid hangers exceeds the normal seismic support span, vertical supports should be added between these rigid hangers.
14. As an alternative to rule 3, a half-span which includes an elbow may end at the elbow and be supported at a tangent point.

TABLE A-2

LOFT FACILITY PIPING

Recommended Spans for Seismic Restraints

<u>Nom. Dia. (in.)</u>	<u>Sch.</u>	<u>Span (ft)</u>	<u>Load (lb)</u>
1/2	160	11	8
3/4	160	12	12
1	160	14	20
1-1/4	160	16	26
1-1/2	160	17	44
2	160	19	70
2-1/2	160	21	86
3	160	23	175
3-1/2	XS	24	170
4	160	26	330

3. Procedure for Thermal Support System Design

All equipment nozzles and header connections should be checked for movement in three (orthogonal) directions. The movement in each direction should be checked with Table D-1 to determine the minimum acceptable offset. The offset is the total length of pipe which is perpendicular to the component of nozzle movement and lies between the nozzle and the first restraint which acts in the direction of that component. If that minimum is not met, an expansion loop must be added or a restraint changed to non-rigid (spring or snubber). The thermal expansion worksheet serves as documentation for this process.

After all nozzle movements have been accomodated, thermal expansion of the pipe must be examined. The following procedure is recommended and is to be documented on the thermal expansion worksheet.

1. Identify all adjacent pairs of parallel rigid restraints.
2. Find the total length of pipe between the restraints of each pair with the pipe axis parallel to the direction of restraint .
3. Use Table D-2 to determine the minimum acceptable offset for this length of pipe.
4. Find the total length of pipe between restraints with pipe axis perpendicular to the direction of restraint.
5. Provide expansion loops if necessary or change supports to non-rigid types so that the value from 3 does not exceed the the value from 4.

TABLE A-3

RECOMMENDED OFFSET NEAR NOZZLES
WITH EXPANSION MOVEMENTS*

		DEFLECTION (IN)									
		1/4	1/2	3/4	1	1 1/4	1 1/2	1 3/4	2	2 1/4	2 1/2
NOMINAL DIAMETER	1/2	3'-11"	5'-6"	6'-9"	7'-9"	8'-9"	9'-6"	10'-3"	11'-0"	11'-8"	12'-4"
	3/4	4'-4"	6'-2"	7'-6"	8'-9"	9'-9"	10'-8"	11'-6"	12'-4"	13'-0"	13'-9"
	1	4'-10"	6'-11"	8'-5"	9'-9"	10'-11"	11'-11"	12'-11"	13'-9"	14'-7"	15'-5"
	1 1/4	5'-6"	7'-9"	9'-6"	10'-11"	12'-3"	13'-5"	14'-6"	15'-6"	16'-5"	17'-4"
	1 1/2	5'-10"	8'-3"	10'-2"	11'-9"	13'-1"	14'-4"	15'-6"	16'-6"	17'-6"	18'-6"
	2	6'-6"	9'-3"	11'-4"	13'-1"	14'-7"	16'-0"	17'-4"	18'-6"	19'-7"	20'-6"
	2 1/2	7'-2"	10'-2"	12'-6"	14'-4"	16'-1"	17'-8"	19'-0"	20'-4"	21'-7"	22'-9"
	3	7'-11"	11'-3"	13'-9"	15'-10"	17'-9"	19'-5"	21'-0"	22'-5"	23'-10"	25'-1"
	3 1/2	8'-6"	12'-0"	14'-9"	17'-0"	19'-0"	20'-9"	22'-6"	24'-0"	25'-6"	26'-10"
	4	9'-0"	12'-9"	15'-7"	18'-0"	20'-2"	22'-0"	23'-10"	25'-6"	27'-0"	28'-5"

*THIS IS THE MINIMUM LENGTH OF PIPE WHICH SHOULD BE INSTALLED PERPENDICULAR TO THE DIRECTION OF NOZZLE MOVEMENT BETWEEN THE NOZZLE AND THE FIRST RESTRAINT WHICH ACTS IN THAT DIRECTION. MOVEMENTS IN THREE ORTHOGONAL DIRECTIONS SHOULD BE CONSIDERED.

TABLE A-4

RECOMMENDED OFFSET FOR ACCOMODATION OF THERMAL EXPANSION

		EXPANDING LENGTH (ft)									
		5	10	15	20	25	30	35	40	45	50
N O M I N A L D I A M E T E R	1/2	1'-7"	2'-3"	2'-9"	3'-2"	3'-7"	3'-11"	4'-3"	4'-6"	4'-10"	5'-1"
	3/4	1'-9"	2'-6"	3'-1"	3'-7"	4'-0"	4'-5"	4'-9"	5'-1"	5'-5"	5'-8"
	1	2'-0"	2'-10"	3'-5"	4'-0"	4'-6"	4'-11"	5'-4"	5'-8"	6'-0"	6'-4"
	1-1/4	2'-3"	3'-2"	3'-10"	4'-6"	5'-0"	5'-5"	5'-11"	6'-4"	6'-8"	7'-1"
	1-1/2	2'-5"	3'-5"	4'-2"	4'-10"	5'-5"	5'-11"	6'-4"	6'-10"	7'-3"	7'-7"
	2	2'-8"	3'-10"	4'-8"	5'-5"	6'-0"	6'-7"	7'-1"	7'-7"	8'-1"	8'-6"
	2-1/2	3'-0"	4'-2"	5'-2"	5'-11"	6'-7"	7'-3"	7'-10"	8'-4"	8'-10"	9'-4"
	3	3'-3"	4'-7"	5'-3"	6'-6"	7'-4"	8'-0"	8'-8"	9'-3"	9'-10"	10'-4"
S I Z E	3-1/2	3'-6"	4'-11"	6'-0"	7'-0"	7'-10"	8'-7"	9'-3"	9'-10"	10'-6"	11'-0"
	4	3'-8"	5'-3"	6'-5"	7'-5"	8'-3"	9'-1"	9'-10"	10'-6"	11'-1"	11'-8"

Procedure for Thermal Support System Design

All equipment nozzles and header connections should be checked for movement in three (orthogonal) directions. The movement in each direction should be checked with Table D-1 to determine the minimum acceptable offset. The offset is the total length of pipe which is perpendicular to the component of nozzle movement and lies between the nozzle and the first restraint which acts in the direction of that component. If that minimum is not met, an expansion loop must be added or a restraint changed to non-rigid (spring or snubber). The thermal expansion worksheet serves as documentation for this process.

After all nozzle movements have been accommodated, thermal expansion of the pipe must be examined. The following procedure is recommended and is to be documented on the thermal expansion worksheet.

1. Identify all adjacent pairs of parallel rigid restraints.
2. Find the total length of pipe between the restraints of each pair with the pipe axis parallel to the direction of restraint.
3. Use Table D-2 to determine the minimum acceptable offset for this length of pipe.
4. Find the total length of pipe between restraints with pipe axis perpendicular to the direction of restraint.
5. Provide expansion loops if necessary or change supports to non-rigid types so that the value from 3 does not exceed the value from 4.

APPENDIX B

RELIEF VALVE OPERATIONS

HYDRAULIC FORCE CALCULATIONS

R.H. Derry
2/22/77

LTR# 113-30 REV. 1

LIQUID H_2O (10% overpressure)

$$GPM = 64$$

$$P = 750 \text{ psig}$$

$$P_b = -2 \text{ psig}$$

$$K_{sg} \cong 1.0$$

$$A = \frac{GPM}{16.3 K_{sg} \sqrt{P - P_b}}$$

$$= \frac{64}{16.3 (1.0) \sqrt{750 - (-2)}}$$

$$= 0.1432 \text{ in}^2$$

$$= 0.0009944 \text{ ft}^2 \quad \text{orifice area}$$

GASEOUS N₂

$$P_0 = 750 \text{ psi}$$

$$A = .0009944 \text{ ft}^2$$

$$\rho_0 = 3.766 \frac{\text{lbm}}{\text{ft}^3}$$

$$W = \dot{m}$$

$$T_0 = 520 \text{ }^\circ\text{R}$$

Assuming isentropic flow -- choked flow ($A^* = A$)

Fliegner's Formula (Assuming Air)

$$\frac{W}{A^*} \frac{\sqrt{T_0}}{P_0} = 0.532$$

$$\frac{W}{A^*} = 0.532 \frac{(750)(144)}{\sqrt{520}}$$

$$\frac{W}{A^*} = 2520 \frac{\text{lbm}}{\text{sec ft}^2}$$

$$W = 2520 (.0009944)$$

$$W = 2.506 \frac{\text{lbm}}{\text{sec}}$$

$$\frac{\rho^*}{\rho_0} = 0.6339$$

$$\rho^* = 0.6339 (3.766) = 2.387 \frac{\text{lbm}}{\text{ft}^3}$$

$$Q^* = \frac{W}{\rho^*} = \frac{2.506}{2.387} = 1.05 \frac{\text{ft}^3}{\text{sec}}$$

$$ROC(x-mom.) = \Sigma F_x$$

$$(\dot{m} V_{out})_x - (\dot{m} V_{in})_x + \frac{\partial}{\partial t} (MV)_x = F_x$$

$$F_x = -\left(2.506 \frac{\text{lbm}}{\text{sec}}\right)\left(464 \frac{\text{ft}}{\text{sec}}\right) = -1163 \frac{\text{lbm ft}}{\text{sec}^2}$$

$$F_x = \frac{-1163 \frac{\text{lbm ft}}{\text{sec}^2}}{32.2 \frac{\text{lbm ft}}{\text{lbf sec}^2}}$$

$$F_x = -36 \text{ lbf}$$

$$ROC(y-mom.) = \Sigma F_y$$

$$(\dot{m} V_{out})_y - (\dot{m} V_{in})_y + \frac{\partial}{\partial t} (MV)_y = F_y$$

$$F_y = -\left(2.506 \frac{\text{lbm}}{\text{sec}}\right)\left(464 \frac{\text{ft}}{\text{sec}}\right) = -1163$$

$$F_y = -36 \text{ lbf}$$

$$\frac{A}{A^*} = \frac{.02330}{.0009944} = 23.43$$

$$M_x \approx 4.9$$

$$M_y \approx 0.416$$

$$\frac{P_y}{P_x} \approx 27.8$$

$$\frac{V_x}{V_y} \approx 4.95$$

$$\frac{T_y}{T_x} \approx 5.6$$

$$\frac{\rho_y}{\rho_x} \approx 4.95$$

$$T_x = 0.1723 (520) = 89.6 \text{ } ^\circ\text{F}$$

$$T_y = 5.6 (89.6) = 502 \text{ } ^\circ\text{F}$$

$$C_y = \sqrt{k R T_y} = \sqrt{1.4 (1774) (502)} = 1116 \text{ ft/sec}$$

$$V_y = M_y C_y = 0.416 (1116)$$

$$V_y = 464 \text{ ft/sec.}$$