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LOFT DRAG-DISC TURBINE TANSDUCER SHROUD
AND COVER WELD ANALYSIS AND EVALUTION

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INTERNAL TECHNICAL REPORT

Title: LOFT DRAG-DISC TURBINE TRANSDUCER SHROUD
AND COVER WELD ANALYSIS AND EVALUATION

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SUMMARY

The stress analysis and evaluation of the drag-disc turbine transducer (DTT) shroud and cover welds used in the Loss-Of-Fluid Test (LOFT) facility is presented in tabular form. The LOFT DTTs investigated are either currently in use or are planned for use in future experiments, both nonnuclear and nuclear. The purpose of the analysis was to determine structural adequacy.

DTT shroud and cover weld locations, numbers, types, and areas were obtained from Aerojet Nuclear Company (ANC) Drawings, Nos. 207726, Rev. A; 204600, Revs. D, E, L, and M; 204645, Rev. K; and 206875, Rev. B. Some locations and areas are based on information in ANC Quality Discrepancy Reports (QDRs) and analysis as referenced in the tables.

Hydraulic loads were determined for both nuclear and nonnuclear conditions using axial and cross flow areas and a drag coefficient of 2.5. However, to allow for the sudden load application during blowdown on the DTTs in the blowdown loop, an additional dynamic load factor of 2.0 was applied.

Thermal loads applied to the shroud and cover welds due to restraint of differential thermal expansion between the shrouds and DTT body, and the covers and DTT body were determined by using an average temperature difference between the shroud and covers and the DTT body.

The requirements of the ASME Boiler and Pressure Vessel Code, Section III of the ASME Boiler and Pressure Vessel Code of 1974, for Class I components were used to evaluate the subject welds. In those cases where stress levels exceeded the code allowable, a simplified elastic/plastic procedure was used to obtain the fatigue life of the weld. This procedure was justified since the thermal conditions and the resulting stresses met the appropriate criteria.

The results of this analysis may be found in Tables XXV - XXVII summarizing the status of LOFT DTTs. The meters currently installed and/or planned for use in Experiment L1-5 are deemed structurally adequate, provided a modular unit is installed at the PC-1 location. Use of modular meters in the plenum and downcomer is recommended with Core II for future loss-of-coolant experiments (LOCEs). For nuclear experiments following L2-1, it is recommended that modular DTT units be used in all piping locations.

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6.0 CONCLUSIONS AND RECOMMENDATIONS

Those meters currently installed and/or planned for use in Experiment L1-5 are deemed structurally adequate as presently fabricated, with the exception of the PC-1 location. Analysis, using a modular unit at PC-1 is included in a separate report^[9].

Those meters currently installed in the plenum locations and on the downcomer instrumentation stalk (1ST-1, 2ST-1, 1UP-1, 3UP-1, 5UP-1, and dummy units above core locations 7 and 9) are adequate for nuclear experiments to be run with Core 1 in place, assuming Core 1 will experience no more than four nuclear LOCEs. Use of the modular meters in the plenum and downcomer locations mentioned above is recommended with fabrication and installation of Core 2 for future nuclear LOCEs. In addition, use of a modular unit at the PC-1 location for all nuclear experiments is recommended, subject to the results of the analysis of that design^[9].

For Experiment L2-1, the meters planned for use in the piping locations (PC-2, PC-3, BL-1, and BL-2) should not be utilized without modifications to welds 4, 5, and 8. The fatigue life of each of these welds is marginal, and increasing length and/or weld size is recommended if modular units are not available for use.

However, for nuclear experiments following L2-1, it is recommended that the modular DTT unit be used in all piping locations. In the event that modular units are not available for the piping locations for subsequent nuclear LOCEs, weld modifications to welds 4, 5, and 8 are necessary in order to increase fatigue lives to reasonable values. Analysis of proposed weld changes and evaluation is recommended if the non-modular DTTs are to be used for nuclear experiments.

It is also recommended that weld 1, on the dummy DTT units be modified if the units are to be installed in Core 2. Length and/or weld

LOFT DRAG-DISC TURBINE TRANSDUCER SHROUD AND COVER WELD ANALYSIS AND EVALUATION

1.0 INTRODUCTION

The purpose of the stress analysis and evaluation of the drag-disc turbine transducer (DTT) shroud and cover welds used at the Loss-Of-Fluid Test (LOFT) facility was to determine whether those meters currently installed, and/or planned for use in Experiment L1-5 are structurally adequate as presently fabricated for nonnuclear Test L1-5, and subsequent nuclear experimentation. The analysis dealt with prediction of stress levels in the subject welds arising from reaction of thermal and hydraulic loads for nonnuclear and nuclear (L2-4) conditions. The predicted stresses were compared to ASME Section III^[1], Class I component stress allowables for evaluation of the welds, and are summarized in Tables XIII - XXVII.

2.0. GEOMETRY FOR APPLICABLE DRAG-DISC TURBINE TRANSDUCERS

2.1 Weld Identification and Geometry

The information in Tables I - VII summarizes the DTT shroud and cover weld locations, numbers, types, and areas for the DTT drawings referenced below. These drawings are applicable to the meters currently in use and/or for meters which are planned for later use.

ANC 207726 Rev. A^[2]

ANC 204600 Revs. D, E, L, and M^[3]

ANC 204645 Rev. K^[4]

ANC 206875 Rev. B^[5]

2.2 Hydraulic Flow Areas For Shrouds And Covers

Table VIII summarizes the axial and cross flow areas of the shrouds and covers subject to hydraulic loads. The values were taken from previous analyses and/or calculated from drawing dimensions as indicated.

3.0 THERMAL/HYDRAULIC PREDICTED LOADS FOR EXPERIMENTS L1-5 AND L2-4

3.1 Hydraulic Loads

Tables IX and X summarize the hydraulic loads on the shrouds and covers for both axial and cross flow for nonnuclear and nuclear conditions respectively. The loads were determined using

$$P = C_d \times A \times \rho \times V^2 / 2 \times g_c$$

where

C_d = drag coefficient (2.5)

A = flow areas

ρ = density

V = velocity

g_c = gravitation constant.

The dynamic pressure terms ($\rho V^2 / 2g_c$) were supplied by Thermal/Hydraulic Branch personnel^[6,7,8] (see Appendix B). An additional dynamic load factor of 2.0 was applied for the DTTs in the blowdown loop to account for the sudden load application during loss-of-coolant experiments (LOCEs).

3.2 Thermal Loads

Tables XI and XII summarize the equivalent loads applied to the shroud and cover welds due to the restraint of differential thermal expansion between the shroud and DTT body, and the covers and DTT body. These loads were determined by using an average temperature difference between the shroud and covers and the DTT body, as supplied by Thermal/Hydraulic Branch personnel^[6,8] (Appendix B). The average temperature difference gives rise to an equivalent thermal expansion load determined by

$$P_{eq} = K \times \delta L$$

and

$$\delta L = L \times \alpha \times \Delta T$$

where

P_{eq} = equivalent load

K = shroud or cover stiffness

δL = change in length due to temperature difference

L = shroud or cover length interfacing body

α = coefficient of thermal expansion

ΔT = average temperature difference.

Previous analyses (Appendix A) outline the procedures for obtaining these equivalent loads, and were used with the referenced thermal data on the following tables to generate the summarized thermal loads. Note that for the plenum locations (1ST-1, 2ST-1, 1UP-1, 3UP-1, 5UP-1, and dummy meters above "C" fuel assemblies), the nonnuclear thermal loads were the same as the nuclear thermal loads. Due to lack of thermal data (ΔT s) for the nonnuclear case, the ΔT s for the nuclear case were utilized and are conservative.

4.0 STRESS ANALYSIS OF LOFT DRAG-DISC TURBINE TRANSDUCER SHROUD AND COVER WELDS

Tables XIII - XXIV summarize the stresses in the referenced DTT shroud and cover welds for meters currently installed and/or planned for the subject locations. The stresses arise from application of the hydraulic and thermal loads summarized in Section 3.0 to the welds with geometry summarized in Section 2.0. The loads were assumed to be evenly distributed along the welds, and a stress concentration factor of 4.0 was applied to stresses in intermittent welds.

Evaluation of the welds was done in accordance with ASME Boiler and Pressure Vessel Code, Section III, Subsection NB-3200^[1]. Simplified elastic-plastic analysis was used to establish fatigue life for the subject welds. Supporting analysis and evaluation is included in Appendix A.

5.0 RESULTS

The primary stresses resulting from hydraulic loads were combined with secondary stresses resulting from the equivalent thermal loads to yield a stress intensity. This stress intensity was compared to an allowable (three times design) intensity. In this case the allowable was 45,750 psi for the stainless steel and weld materials. Although many of the calculated stress intensity values exceeded the allowable, the criteria for simplified elastic-plastic analysis was met, and allowed determination of fatigue life for these cases.

Note that in some instances, a comparison of load and geometric data allowed evaluation of the welds on some DTTs without calculating stresses since those meters had less severe loading conditions and like or larger welds than other meters which were analyzed in detail. In particular, for the 1ST-1 and 2ST-1 locations, results for the meters in the 3UP-1 and 5UP-1 locations were utilized. Also, for the PC-3 location for LI-5 conditions, results for both types of DTTs are based on using ANC Drawing 204600, Rev. M.

A summary of this analysis may be found in Tables XXV - XXVII, evaluating the status of LOFT DTTs. It should be noted that the minimum fatigue life in the accompanying tables is based upon the worst temperature difference between shroud and body. Although this condition may occur only once during each LOCE, several slugs of hot and cold water will pass the DTTs during the experiment. These slugs will give rise to smaller stresses, adversely affecting the fatigue life of the subject welds. For this reason, the recommendations for use of modular units and weld modifications to non-modular units should be adhered to. (See Section 6.0.)

size should be increased in order to increase the fatigue life, followed by review of the design change by Applied Mechanics Branch personnel.

TABLE I

LOFT DTT SHROUD AND COVER WELDS IDENTIFICATION AND GEOMETRY (207726, Rev. A)^[2]

Weld Location	Number	Type	Length (in.)	Area (in. ²)	Notes
Front to rear shroud	1	square groove	0.911	0.046	
Shroud to body (right)	20	fillet	2.055	0.116	
Shroud to body (left)	2	fillet	3.280	0.186	
End plate to front cover	3	square groove	1.206	0.024	
Front cover to body	4	square groove	1.375	0.028	
End plate to body	5	square groove	0.756	0.023	
Torsion bar cover to body	8	square groove	0.278	0.006	
Shaft cover to body	7, 21	square groove and fillet	2.080	0.069	combined length and area
End cover to shaft cover	6	square groove	0.928	0.019	

TABLE II

LOFT DTT SHROUD AND COVER WELDS IDENTIFICATION AND GEOMETRY (204600, Rev. D AND E)^[3]

Weld Location	Number	Type	Length (in.)	Area ₂ (in. ²)	Notes
Front to rear shroud	2	square groove	3.796	0.190	
Shroud to body (right)	1	bevel groove	2.06 ^[a]	0.063 ^[a]	
Shroud to body (left)	1	bevel groove	2.0 ^[a]	0.067 ^[a]	
End plate to front cover	3	square groove	1.206	0.039	
Front cover to body	4	square groove	0.720 ^[a]	0.022 ^[a]	
End plate to body	7	square groove	0.663	0.021	
Torsion bar cover to body	6	square groove and fillet	1.48	0.053	2 welds included
Shaft cover to body	5	square groove	1.50 ^[a]	0.032 ^[a]	
End cover to shaft cover	8	square groove	0.72	0.023	

[a] Amended to requirements stated in Appendix B, Gott-4-76, for 1ST-1, 2ST-1, 3UP-1 and 5UP-1 locations.

TABLE III

LOFT DTT SHROUD AND COVER WELDS IDENTIFICATION AND GEOMETRY (204600, REV. L)^[3]

Weld Location	Number	Type	Length (in.)	Area ₂ (in. ²)	Notes
Front to rear shroud	2	square groove	1.27 ^[a]	0.064 ^[a]	
Shroud to body (right)	1, 10	fillets	1.68 ^[a]	0.101 ^[a]	
Shroud to body (left)	1	fillets	1.98 ^[a]	0.119 ^[a]	
End plate to front cover	3	square groove	1.206 ^[b]	0.039	
Front cover to body	4	square groove	1.0 ^[a]	0.032 ^[a]	
End plate to body	7	square groove	0.663 ^[b]	0.021 ^[b]	
Torsion bar cover to body	6	square groove and fillet	1.48 ^[b]	0.053 ^[b]	2 welds included
Shaft cover to body	5	square groove	0.96 ^[a]	0.031 ^[a]	
End cover to shaft cover	8	square groove	0.72 ^[a]	0.023 ^[a]	

[a] Amended as per EG&G Quality Discrepancy Report TF-104 (December 15, 1976) for meter in spare "C" assembly (S/N 13).

[b] Weld geometry supplied by LOFT Experimental Measurements Branch.

TABLE IV

LOFT DTT SHROUD AND COVER WELDS IDENTIFICATION AND GEOMETRY (204600, REV. L)^[3]

Weld Location	Number	Type	Length (in.)	Area ₂ (in. ²)	Notes
Front to rear shroud	2	square groove	1.16 ^[a]	0.058 ^[a]	
Shroud to body (right)	1, 10	fillets	1.80 ^[a]	0.108 ^[a]	
Shroud to body (left)	1	fillet	1.80 ^[a]	0.108 ^[a]	
End plate to front cover	3	square groove	0.525 ^[a]	0.017 ^[a]	
Front cover to body	4	square groove	1.11 ^[a]	0.036 ^[a]	
End plate to body	7	square groove	0.663 ^[b]	0.021 ^[b]	
Torsion bar cover to body	6	square groove and fillet	1.48 ^[b]	0.053 ^[b]	2 welds included
Shaft cover to body	5	square groove	1.20 ^[a]	0.038 ^[a]	
End cover to shaft cover	8	square groove	0.72 ^[b]	0.023 ^[b]	

[a] Amended as per Quality Discrepancy Report QDR TF-106 (December 20, 1976) for meter in 1UP-1 location (S/N 14).

[b] Weld geometry supplied by LOFT Experimental Measurements Branch.

TABLE V

LOFT DTT SHROUD AND COVER WELDS IDENTIFICATION AND GEOMETRY (204600, REV. M)^[3]

Weld Location	Number	Type	Length (in.)	Area ₂ (in. ²)	Notes
Front to rear shroud	2	square groove	0.911	0.046	
Shroud to body (right)	1, 10	fillets	1.50 ^[a]	0.090 ^[a]	combined length and area
Shroud to body (left)	1	fillet	1.75 ^[a]	0.106 ^[a]	
End plate to front cover	3	square groove	1.206	0.030	
Front cover to body	4	square groove	2.50	0.063	
End plate to body	7	square groove	0.756 ^[a]	0.019 ^[a]	
Torsion bar cover to body	6	square groove	0.640	0.013 ^[a]	
Shaft cover to body	5, 9	square groove and fillet	2.074 ^[a]	0.073 ^[a]	combined length and area
End cover to shaft cover	8	square groove	0.720	0.018	

[a] Weld geometry supplied by LOFT Experimental Measurements Branch.

TABLE VI

LOFT DTT SHROUD AND COVER WELDS IDENTIFICATION AND GEOMETRY (204645, REV. K)^[4]

Weld Location	Number	Type	Length (in.)	Area ₂ (in. ²)	Notes
Front to rear shroud	2	square groove	0.911	0.046	
Shroud to body (right)	1	fillet	3.280	0.197	
Shroud to body (left)	1	fillet	3.280	0.197	
End plate to front cover	3	square groove	1.206	0.030	
Front cover to body	4	square groove	2.50	0.063	
End plate to body	7 ^[a]	square groove	0.756	0.019	
Torsion bar cover to body	6	square groove	0.640	0.019	
Shaft cover to body	5, 9	square groove and fillet	2.560 ^[b]	0.098	combined length and area
End cover to shaft cover	8	square groove	0.720	0.018	

[a] Weld number not shown on drawing.

[b] Weld geometry supplied by LOFT Experimental Measurements Branch.

TABLE VII

LOFT DTT SHROUD AND COVER WELDS IDENTIFICATION AND GEOMETRY (206875, REV. B)^[5]

Weld Location	Number	Type	Length (in.)	Area ₂ (in. ²)	Notes
Front to rear shroud	2	square groove	0.911	0.027	
Shroud to body (right)	1	fillet	1.64	0.070	
Shroud to body (left)	1	fillet	1.64	0.070	
End plate to front cover	4	square groove	see note	see note	weld length and area combined with W4 below
Front cover to body	3	square groove	2.50	0.075	
End plate to body	4	square groove	1.26	0.038	
Torsion bar cover to body	none	--	--	--	no cover on dummy DTT
Shaft cover to body	5	fillet	2.464	0.052	
End cover to shaft cover	none	--	--	--	no cover on dummy DTT

TABLE VIII

LOFT DTT SHROUD AND COVER AREAS FOR HYDRAULIC LOAD CALCULATIONS

Component	Axial Flow		Cross Flow	
	Area (in. ²)	Notes	Area (in. ²)	Notes
Shroud (plenum type) ^[3,5]	0.717	Appendix B	7.70	calculated
Shroud (piping type) ^[2,4]	0.717	Appendix B	7.10	calculated
Front cover	0.963	calculated	0.469	calculated
End plate	0	does not see axial flow	0.755	calculated
Torsion bar cover	0.108	calculated	0	does not see cross flow
Shaft cover	0	axial flow load from shaft cover end	0.875	calculated
Shaft cover end	0.102	calculated	0	does not see cross flow

TABLE IX

LOFT DTT SHROUD AND COVER HYDRAULIC LOADS (NONNUCLEAR)^[a]

Location and Drawing	$\frac{\rho V^2}{2g_c}$ (psi)	Axial Loads (lb)				Cross Flow Loads (lb)			
		Shroud	Front Cover	Torsion Bar Cover	Shaft Cover End	Shroud	Front Cover	Shaft Cover	End Plate
PC-2 204645 Rev. p ^[4]	axial ^[7] 6.47	11.6	15.6	1.75	1.65	0	0	0	0
PC-3 204600 Rev. M ^[3]	cross 0 axial ^[7] 6.47	11.6	15.6	1.75	1.65	26.9	1.64	3.06	2.64
PC-3 204645 Rev. K ^[4]	cross 1.40 axial ^[7] 6.47	11.6	15.6	1.75	1.65	24.8	1.64	3.06	2.64
BL-1 207726 Rev. A ^{[b][2]}	cross 1.40 axial ^[7]	31.0	41.6	4.66	4.40	71.6	4.34	8.14	7.02
BL-2 207726 Rev. A ^{[b][2]}	8.63 cross 1.86								
1ST-1 204600 Rev. D ^{[c][3]}	axial ^[7]	2.91	3.90	0.44	0.41	0	0	0	0
2ST-1 204600 Rev. D ^{[c][3]}	1.62 cross 0								
1UP-1 204600 Rev. L ^{[d][3]}	axial ^[6]	43.1	57.9	6.49	6.13	0	0	0	0
3UP-1, 5UP-1 204600	24.05								
Rev. D ^{[c][3]}	cross 0								
Dummys 206875 Rev. B ^[5]	0								

[a] Drag coefficient = $C_d = 2.5$.

[b] Dynamic load factor of 2 applied.

[c] Welds per Appendix B, Gott-4-76.

[d] Welds per EG&G Quality Discrepancy Reports, QDRs TF-104 and -106, (December 1976).

TABLE X

LOFT DTT SHROUD AND COVER HYDRAULIC LOADS (NUCLEAR)^[a]

Location and Drawing	$\frac{\rho v^2}{2g_c}$ (psi)	Axial Loads (lb)				Cross Flow Loads (lb)			
		Shroud	Front Cover	Torsion Bar Cover	Shaft Cover End	Shroud	Front Cover	Shaft Cover	End Plate
PC-1 207726 Rev. A ^[2]	axial ^[7]	11.6	15.6	1.75	1.65	26.9	1.64	3.06	2.64
PC-3 207726 Rev. A ^[2]	6.47								
	cross								
	1.40								
PC-2 207726 Rev. A ^[2]	axial ^[7]	11.6	15.6	1.75	1.65	0	0	0	0
	6.47								
	cross								
	0								
BL-1 207726 Rev. A ^{[b][2]}	axial ^[7]	31.0	41.6	4.66	4.40	71.6	4.36	8.14	7.02
BL-2 207726 Rev. A ^{[b][2]}	8.63								
	cross								
	1.86								
1ST-1 204600 Rev. D ^[3]	axial ^[7]	2.91	3.90	0.44	0.41	0	0	0	0
1ST-1 207726 Rev. A ^[2]	1.62								
2ST-1 204600 Rev. D ^[3]	cross								
2ST-1 207726 Rev. A ^[2]	0								
1UP-1 204600 Rev. L ^{[c][3]}	axial ^[6]	43.1	57.9	6.49	6.13	0	0	0	0
1UP-1 207726 Rev. A ^[2]	24.05								
3UP-1, 5UP-1 204600	cross								
Rev. D ^[3] , 207726 Rev. A ^[2]	0								
Dummys 206875 Rev. B ^[4]	axial ^[6]	43.1	57.9	6.49	6.13	0	0	0	0
	24.05								
	cross								
	0								

[a] Drag coefficient = $C_d = 2.5$.

[b] Dynamic load factor of 2 applied.

[c] Welds per EG&G Quality Discrepancy Reports, QDRs TF-104 and -106, (December 1976).

TABLE XI

LOFT DTT SHROUD AND COVER EQUIVALENT LOADS DUE TO RESTRAINT OF DIFFERENTIAL THERMAL EXPANSION (NONNUCLEAR, L1-5)^[f]

Location & Drawing	Avg. ^[g] ΔT	Shroud/ Shroud (lb)	Shroud/Body Both Sides (lb)		Front Cover/ Body (lb)		End Plate/ Body (lb)		Torsion Bar Cover/Body (lb)		Shaft Cover/ Body (lb)	
			Axial	Trans. ^[a] Horiz.	Trans. ^[a] Vert.	Trans. ^[a] Horiz.	Axial	Trans. ^[a] Horiz.	Trans. ^[a] Vert.	Trans. ^[a] Horiz.	Axial	Trans. ^[a] Horiz.
PC-2 204645 Rev. D ^{[b][4]} PC-3 204600 Rev. M ^{[g][3]} PC-3 204645 Rev. K ^[4]	75 ^[e]	3940	1970	6.7	805	5.9	541	687	189	403	1290	5.1
BL-1 207726 Rev. A ^[2] BL-2 207726 Rev. A ^[2]	75 ^[e]	3940	1970	6.7	805	5.9	541	687	189	403	1290	5.1
1ST-1 204600 Rev. D ^{[g][3]} 2ST-1 204600 Rev. D ^{[g][3]}	121 ^{[c][8]}	6360	3180	10.9	1300	9.6	874	1110	305	650	2090	8.2
1UP-1 204600 Rev. L ^{[c][3]}	130 ^{[d][8]}	6830	3420	11.7	1400	10.3	937	1190	328	698	2240	8.8
3UP-1 204600 Rev. D 5UP-1 204600 Rev. D	130 ^{[d][8]}	6830	3420	11.7	1400	10.3	937	1190	328	698	2240	8.8
Dummy 206875 Rev. B	130 ^{[d][8]}	6830	3420	11.7	1400	10.3	937	1190	328	698	2240	8.8

[a] lb/in. weld length.

[b] Welds per 207726 Rev. A.

[c] Weld per EG&G Quality Discrepancy Reports, QDRs TF-104 and -106.

[d] These are for nuclear conditions and are conservative for L1-5.

[e] See Appendix B, KAH-1-76.

[f] Force in Table XI is the ratio of the ΔT in Table XI to the ΔT in Appendix A, (JSM-1-77) multiplied by the force in Appendix A (JSM-1-77).

[g] Welds per Appendix B, Gott-4-76.

TABLE XII

LOFT DTT SHROUD AND COVER EQUIVALENT LOADS DUE TO RESTRAINT OF DIFFERENTIAL THERMAL EXPANSION (NUCLEAR, L2-4)^[b]

Location & Drawing	Avg. ^[8] ΔT	Shroud/ Shroud (lb)	Shroud/Body Both Sides (lb)		Front Cover/ Body (lb)		End Plate/ Body (lb)		Torsion Bar Cover/Body (lb)		Shaft Cover/ Body (lb)	
			Axial	Trans. ^[a] Horiz.	Trans. Vert.	Trans. ^[a] Horiz.	Axial	Trans. Horiz.	Trans. Vert.	Trans. Horiz.	Axial	Trans. ^[a] Horiz.
PC-1 207726 Rev. A ^[2]	220	11650	5820	19.8	2370	17.5	1600	2030	560	1180	3820	15.2
PC-2 207726 Rev. A ^[2]	133	6990	3490	11.9	1420	10.5	960	1220	335	710	2290	9.1
PC-3 207726 Rev. A ^[2]												
BL-1 207726 Rev. A ^[2]	129	6780	3390	11.5	1380	10.2	930	1180	325	690	2220	8.8
BL-2 207726 Rev. A ^[2]												
1ST-1 207726 Rev. A ^[2]	121	6360	3180	10.9	1300	9.6	874	1110	305	650	2090	8.2
2ST-1 207726 Rev. A ^[2]												
1UP-1 207726 Rev. A ^[2]	130	6830	3420	11.7	1400	10.3	937	1190	328	698	2240	8.8
3UP-1 207726 Rev. A ^[2]												
5UP-1 207726 Rev. A ^[2]												
Dummy 206875 Rev. B ^[5]	130	6830	3420	11.7	1400	10.3	937	1190	328	698	2240	8.8

[a] lb/in. weld length.

[b] Force in Table XII is the ratio of the ΔT in Table XII to the ΔT in Appendix A (JSM-1-77) multiplied by the force in Appendix A (JSM-1-77).

TABLE XIII

LOFT DTT SHROUD AND COVER WELDS STRESS ANALYSIS FOR LOAD CONDITION L1-5^{[a][4]} AT PC-2

Weld Location	Weld No.	Primary Stresses ^[e] (psi)		Secondary Stresses (psi)		S_n ^[b] (psi)	K_e ^[c]	S_a ^[d] (psi)	Allowed No. Cycles
		Type ^[f] & Direction	Magnitude	Type ^[f] & Direction	Magnitude				
Front/rear shroud	1	σ_x /--	1,008/0	σ_x /--	85,650/0	86,660	3.33	132,560	520
Shroud/body (right)	20	τ_{yx} /--	400/0	τ_{yx}/τ_{yz}	16,980/120	34,160	1.0	15,700	$>10^6$
Shroud/body (left)	2	τ_{yx} /--	63/0	τ_{yx}/τ_{yz}	10,590/120	21,310	1.0	9,790	$>10^6$
End plate/front cover	3	--/--	0/0	--/--	0/0	0	1.0	0	$>10^6$
Front cover/body	4	σ_x/τ_{xy}	2,230/0	τ_{xy}/τ_{xz}	28,750/290	57,500	1.84	58,660	20,000
End plate/body	5	--/--	0/0	τ_{yx}/τ_{yz}	23,520/29,870	76,040	3.19	111,390	850
Torsion bar cover/body	8	σ_x /--	1,168/0	τ_{xy}/τ_{xz}	31,500/67,170	148,380	3.33	226,970	125
Shaft cover/body	7, 21	τ_{yx} /--	96/0	τ_{yx}/τ_{yz}	18,700/100	37,400	1.0	17,180	$>10^6$
End cover/shaft cover	6	σ_x /--	87/0	--/--	0/0	87	1.0	40	$>10^6$

[a] Welded per 207726 Rev. A.

[b] S_n = calculated stress intensity (primary plus secondary).[c] K_e = fatigue life reduction factor.[d] S_a = alternating stress intensity (modified by K_e and modulus of elasticity).

[e] Stress concentration factor of 4 applied to noncontinuous welds.

[f] x = parallel to shroud axis; y = parallel to front cover axis; z = parallel to torsion bar axis.

TABLE XIV

LOFT DTT SHROUD AND COVER WELDS STRESS ANALYSIS FOR LOAD CONDITION L1-5^[3] AT PC-3

Weld Location	Weld No.	Primary Stresses ^[a] (psi)		Secondary Stresses (psi)		S_n ^[b] (psi)	K_e ^[c]	S_a ^[d] (psi)	Allowed No. Cycles
		Type ^[e] & Direction	Magnitude	Type ^[e] & Direction	Magnitude				
Front/rear shroud	2	$\sigma_x/--$	1,008/0	$\sigma_x/--$	85,650/0	86,660	3.33	132,560	520
Shroud/body (right)	1, 10	τ_{yx}/τ_{yz}	256/596	τ_{yx}/τ_{yz}	21,890/112	44,320	1.0	20,360	$>10^6$
Shroud/body (left)	1	τ_{yx}/τ_{yz}	220/508	τ_{yx}/τ_{yz}	18,580/111	37,680	1.0	17,310	$>10^6$
End plate/front cover	3	$\sigma_y/--$	88/0	$--/--$	0/0	88	1.0	40	$>10^6$
Front cover/body	4	σ_x/τ_{xz}	248/26	τ_{xy}/τ_{xz}	12,780/234	25,560	1.0	11,740	$>10^6$
End plate/body	7	$\sigma_y/--$	556/0	τ_{yx}/τ_{yz}	28,470/36,160	92,040	3.33	140,790	420
Torsion bar cover/body	6	$\sigma_x/--$	540/0	τ_{xy}/τ_{xz}	14,538/31,000	68,480	2.64	83,050	2,500
Shaft cover/body	5	τ_{yx}/τ_{yz}	200/372	τ_{yx}/τ_{yz}	39,090/278	78,580	3.33	120,200	700
End cover/shaft cover	8	$\sigma_x/--$	92/0	$--/--$	0/0	92	1.0	42	$>10^6$

[a] Stress concentration factor of 4 applied to noncontinuous welds.

[b] S_n = calculated stress intensity (primary plus secondary).[c] K_e = fatigue life reduction factor.[d] S_a = alternating stress intensity (modified by K_e and modulus of elasticity).

[e] x = parallel to shroud axis; y = parallel to front cover axis; z = parallel to torsion bar axis.

TABLE XV

LOFT DTT SHROUD AND COVER WELDS STRESS ANALYSIS FOR LOAD CONDITION L1-5^[2] AT BL-1 AND BL-2

Weld Location	Weld No.	Primary Stresses ^[a] (psi)		Secondary Stresses (psi)		S_n ^[b] (psi)	K_e ^[c]	S_a ^[d] (psi)	Allowed No. Cycles
		Type ^[e] & Direction	Magnitude	Type ^[e] & Direction	Magnitude				
Front/rear shroud	1	$\sigma_x/--$	2,700/0	$\sigma_x/--$	85,650/0	88,350	3.33	135,150	500
Shroud/body (right)	20	τ_{yx}/τ_{yz}	536/1,236	τ_{yx}/τ_{yz}	16,890/119	35,140	1.0	16,140	$>10^6$
Shroud/body (left)	2	τ_{yx}/τ_{yz}	83/192	τ_{yx}/τ_{yz}	10,590/119	21,360	1.0	9,810	$>10^6$
End plate/front cover	3	$\sigma_y/--$	293/0	$--/--$	0/0	293	1.0	134	$>10^6$
Front cover/body	4	σ_x/τ_{xz}	5,940/624	τ_{xy}/τ_{xz}	28,750/290	57,830	1.87	49,570	20,000
End plate/body	5	$\sigma_y/--$	1,220/0	τ_{yx}/τ_{yz}	23,520/29,870	76,040	3.19	111,310	850
Torsion bar cover/body	8	$\sigma_x/--$	3,108/0	τ_{xy}/τ_{xz}	31,500/67,170	148,420	3.33	226,990	125
Shaft cover/body	7, 21	τ_{yx}/τ_{yz}	256/472	τ_{yx}/τ_{yz}	18,700/154	39,940	1.0	18,350	$>10^6$
End cover/shaft cover	6	$\sigma_x/--$	232/0	$--/--$	0/0	232	1.0	107	$>10^6$

[a] Stress concentration factor of 4 applied to noncontinuous welds.

[b] S_n = calculated stress intensity (primary plus secondary).[c] K_e = fatigue life reduction factor.[d] S_a = alternating stress intensity (modified by K_e and modulus of elasticity).

[e] x = parallel to shroud axis; y = parallel to front cover axis; z = parallel to torsion bar axis.

TABLE XVI

LOFT DTT SHROUD AND COVER WELDS STRESS ANALYSIS FOR LOAD CONDITION L1-5 AND L2-4^{[a][3]} AT 1UP-1

Weld Location	Weld No.	Primary Stresses ^[b] (psi)		Secondary Stresses (psi)		S_n ^[c] (psi)	K_e ^[d]	S_a ^[e] (psi)	Allowed No. Cycles
		Type ^[f] & Direction	Magnitude	Type ^[f] & Direction	Magnitude				
Front/rear shroud	2	σ_x /--	2,972/0	σ_x /--	117,760/0	120,730	3.33	184,690	200
Shroud/body (right)	1, 10	τ_{yx} /--	798/0	τ_{yx}/τ_{yz}	31,670/195	64,940	2.38	71,040	4,500
Shroud/body (left)	1	τ_{yx} /--	798/0	τ_{yx}/τ_{yz}	31,670/195	64,940	2.38	71,040	4,500
End plate/front cover	3	--/--	0/0	--/--	0/0	0	1.0	0	$>10^6$
Front cover/body	4	σ_x /--	6,433/0	τ_{xy}/τ_{xz}	38,890/318	78,040	3.33	119,380	750
End plate/body	7	--/--	0/0	τ_{yx}/τ_{yz}	44,620/56,670	144,260	3.33	220,700	130
Torsion bar cover/body	6	σ_x /--	490/0	τ_{xy}/τ_{xz}	6,190/13,170	29,100	1.0	13,370	$>10^6$
Shaft cover/body	5	τ_{yx} /--	645/0	τ_{yx}/τ_{yz}	58,950/278	119,200	3.33	182,340	210
End cover/shaft cover	8	σ_x /--	267/0	--/--	0/0	267	1.0	123	$>10^6$

[a] Welds per EG&G Quality Discrepancy Report, QDR TF-106 (December 20, 1976).

[b] Stress concentration factor of 4 applied to noncontinuous welds.

[c] S_n = calculated stress integrity (primary plus secondary).[d] K_e = fatigue life reduction factor.[e] S_a = alternating stress intensity (modified by K_e and modulus of elasticity).

[f] x = parallel to shroud axis; y = parallel to front cover axis; z = parallel to torsion bar axis.

TABLE XVII

LOFT DTT SHROUD AND COVER WELDS STRESS ANALYSIS FOR LOAD CONDITION L1-5 AND L2-4^{[a][3]} AT 1UP-1 (SPARE)

Weld Location	Weld No.	Primary Stresses ^[b] (psi)		Secondary Stresses (psi)		S_n ^[c] (psi)	K_e ^[d]	S_a ^[e] (psi)	Allowed No. Cycles
		Type ^[f] & Direction	Magnitude	Type ^[f] & Direction	Magnitude				
Front/rear shroud	2	σ_x /--	2,690/0	σ_x /--	10,670/0	109,400	3.33	167,300	250
Shroud/body (right)	1, 10	τ_{yx} /--	853/0	τ_{yx}/τ_{yz}	33,860/209	69,430	2.71	86,340	2,000
Shroud/body (left)	1	τ_{yx} /--	724/0	τ_{yx}/τ_{yz}	28,740/177	58,930	1.95	52,660	16,000
End plate/front cover	3	--/--	0/0	--/--	0/0	0	1.0	0	$>10^6$
Front cover/body	4	σ_x /--	7,237/0	τ_{xy}/τ_{xz}	43,750/358	87,720	3.33	134,200	500
End plate/body	7	--/--	0/0	τ_{yx}/τ_{yz}	44,620/56,670	144,260	3.33	220,700	130
Torsion bar cover/body	6	σ_x /--	490/0	τ_{xy}/τ_{xz}	6,190/13,170	29,100	1.0	13,370	$>10^6$
Shaft cover/body	5	τ_{yx} /--	645/0	τ_{yx}/τ_{yz}	58,950/278	119,200	3.33	182,340	210
End cover/shaft cover	8	σ_x /--	267/0	--/--	0/0	267	1.0	123	$>10^6$

[a] Welds per EG&G Quality Discrepancy Report, QDR TF-104 (December 15, 1976).

[b] Stress concentration factor of 4 applied to noncontinuous welds.

[c] S_n = calculated stress integrity (primary plus secondary).[d] K_e = fatigue life reduction factor.[e] S_a = alternating stress intensity (modified by K_e and modulus of elasticity).

[f] x = parallel to shroud axis; y = parallel to front cover axis; z = parallel to torsion bar axis.

TABLE XVIII

LOFT DTT SHROUD AND COVER WELDS STRESS ANALYSIS FOR LOAD CONDITION L1-5 AND L2-4^{[f],[3]} AT 3UP-1 AND 5UP-1

Weld Location	Weld No.	Primary Stresses ^[a] (psi)		Secondary Stresses (psi)		S_n ^[b] (psi)	K_e ^[c]	S_a ^[d] (psi)	Allowed No. Cycles
		Type ^[e] & Direction	Magnitude	Type ^[e] & Direction	Magnitude				
Front/rear shroud	2	σ_x /--	227/0	σ_x /--	35,950/0	40,177	1.0	18,460	>10 ⁶
Shroud/body (right)	1	τ_{yx} /--	1,368/0	τ_{yx}/τ_{yz}	54,290/383	111,320	3.33	170,280	250
Shroud/body (left)	1	τ_{yx} /--	1,287/0	τ_{yx}/τ_{yz}	51,044/349	104,660	3.33	160,090	300
End plate/front cover	3	--/--	0/0	--/--	0/0	0	1.0	0	>10 ⁶
Front cover/body	4	σ_x /--	10,530/0	τ_{xy}/τ_{xz}	63,640/310	127,720	3.33	195,370	170
End plate/body	7	--/--	0/0	τ_{yx}/τ_{yz}	44,620/56,670	144,260	3.33	220,670	130
Torsion bar cover/body	6	σ_x /--	490/0	τ_{xy}/τ_{xz}	6,190/13,170	29,100	1.0	13,370	>10 ⁶
Shaft cover/body	5	τ_{yx} /--	766/0	τ_{yx}/τ_{yz}	70,000/413	141,540	3.33	216,500	135
End cover/shaft cover	8	σ_x /--	267/0	--/--	0/0	267	1.0	123	>10 ⁶

[a] Stress concentration factor of 4 applied to noncontinuous welds.

[b] S_n = calculated stress integrity (primary plus secondary).[c] K_e = fatigue life reduction factor.[d] S_a = alternating stress intensity (modified by K_e and modulus of elasticity).

[e] x = parallel to shroud axis; y = parallel to front cover axis; z = parallel to torsion bar axis.

[f] Welds per Appendix B, Gott-4-76.

TABLE XIX

LQFT DTT SHROUD AND COVER WELDS STRESS ANALYSIS FOR LOAD CONDITION L1-5 AND L2-4^[5] AT DUMMY LOCATIONS

Weld Location	Weld No.	Primary Stresses ^[a] (psi)		Secondary Stresses (psi)		S_n ^[b] (psi)	K_e ^[c]	S_a ^[d] (psi)	Allowed No. Cycles
		Type ^[e] & Direction	Magnitude	Type ^[e] & Direction	Magnitude				
Front/rear shroud	2	σ_x /--	6,385/0	σ_x /--	252,960/0	259,340	3.33	396,700	30
Shroud/body (right)	1	τ_{yx} /--	308/0	τ_{yx}/τ_{yz}	48,860/550	98,340	3.33	150,430	370
Shroud/body (left)	1	τ_{yx} /--	308/0	τ_{yx}/τ_{yz}	48,860/550	98,340	3.33	150,430	370
End plate/front cover	4	--/--	0/0	--/--	0/0	0	1.0	0	>10 ⁶
Front cover/body	3	σ_x /--	772/0	τ_{xy}/τ_{xz}	18,670/195	37,350	1.0	17,160	>10 ⁶
End plate/body	4	--/--	0/0	τ_{yx}/τ_{yz}	24,660/31,320	79,720	3.33	121,950	700
Torsion bar cover/body	None								N.A.
Shaft cover/body	5	τ_{yx} /--	472/0	τ_{yx}/τ_{yz}	43,080/417	86,160	3.33	131,800	600
End cover/shaft cover	None								N.A.

[a] Stress concentration factor of 4 applied to noncontinuous welds.

[b] S_n = calculated stress integrity (primary plus secondary).[c] K_e = fatigue life reduction factor.[d] S_a = alternating stress intensity (modified by K_e and modulus of elasticity).

[e] x = parallel to shroud axis; y = parallel to front cover axis; z = parallel to torsion bar axis.

TABLE XX

LOFT DTT SHROUD AND COVER WELDS STRESS ANALYSIS FOR LOAD CONDITION L2-4^[2] AT PC-1

Weld Location	Weld No.	Primary Stresses ^[a] (psi)		Secondary Stresses (psi)		S_n ^[b] (psi)	K_e ^[c]	S_a ^[d] (psi)	Allowed No. Cycles
		Type ^[e] & Direction	Magnitude	Type ^[e] & Direction	Magnitude				
Front/rear shroud	1	$\sigma_x/--$	1,010/0	$\sigma_x/--$	253,260/0	254,270	3.33	388,990	30
Shroud/body (right)	20	τ_{yx}/τ_{yz}	200/464	τ_{yx}/τ_{yz}	50,170/350	100,760	3.33	154,130	320
Shroud/body (left)	2	τ_{yx}/τ_{yz}	30/72	τ_{yx}/τ_{yz}	31,290/350	62,640	2.21	63,590	7,000
End plate/front cover	3	$\sigma_y/--$	110/0	$--/--$	0/0	110	1.0	51	$>10^6$
Front cover/body	4	σ_x/τ_{xz}	2,230/234	τ_{xy}/τ_{xz}	84,640/860	169,300	3.33	259,000	80
End plate/body	5	$\sigma_y/--$	460/0	τ_{yx}/τ_{yz}	69,570/88,260	224,760	3.33	343,800	35
Torsion bar cover/body	8	$\sigma_x/--$	1,170/0	τ_{xy}/τ_{xz}	93,330/196,670	435,380	3.33	666,000	<10
Shaft cover/body	7, 21	τ_{yx}/τ_{yz}	95/180	τ_{yx}/τ_{yz}	55,360/458	110,920	3.33	169,700	260
End cover/shaft cover	6	$\sigma_x/--$	87/0	$--/--$	0/0	87	1.0	40	$>10^6$

[a] Stress concentration factor of 4 applied to noncontinuous welds.

[b] S_n = calculated stress intensity (primary plus secondary).[c] K_e = fatigue life reduction factor.[d] S_a = alternating stress intensity (modified by K_e and modulus of elasticity).

[e] x = parallel to shroud axis; y = parallel to front cover axis; z = parallel to torsion bar axis.

TABLE XXI

LOFT DTT SHROUD AND COVER WELDS STRESS ANALYSIS FOR LOAD CONDITION L2-4^[2] AT PC-2 AND PC-3

Weld Location	Weld No.	Primary Stresses ^[a] (psi)		Secondary Stresses (psi)		S_n ^[b] (psi)	K_e ^[c]	S_a ^[d] (psi)	Allowed No. Cycles
		Type ^[e] & Direction	Magnitude	Type ^[e] & Direction	Magnitude				
Front/rear shroud	1	σ_x /--	1,010/0	σ_x /--	153,100/0	154,100	3.33	238,300	100
Shroud/body (right)	20	τ_{yx}/τ_{yz}	200/464	τ_{yx}/τ_{yz}	30,330/210	61,080	2.10	58,960	10,000
Shroud/body (left)	2	τ_{yx}/τ_{yz}	30/72	τ_{yx}/τ_{yz}	18,920/210	37,900	1.0	17,400	$>10^6$
End plate/front cover	3	σ_y /--	110/0	--/--	0/0	110	1.0	51	$>10^6$
Front cover/body	4	σ_x/τ_{xz}	2,230/234	τ_{xy}/τ_{xz}	51,170/520	102,380	3.33	156,600	320
End plate/body	5	σ_y /--	460/0	τ_{yx}/τ_{yz}	42,060/53,360	135,880	3.33	207,850	140
Torsion bar cover/body	8	σ_x /--	1,170/0	τ_{xy}/τ_{xz}	56,420/118,900	236,220	3.33	402,640	27
Shaft cover/body	7, 21	τ_{yx}/τ_{yz}	95/180	τ_{yx}/τ_{yz}	33,470/277	67,140	2.54	78,730	3,200
End cover/shaft cover	6	σ_x /--	87/0	--/--	0/0	87	1.0	40	$>10^6$

[a] Stress concentration factor of 4 applied to noncontinuous welds.

[b] S_n = calculated stress intensity (primary plus secondary).[c] K_e = fatigue life reduction factor.[d] S_a = alternating stress intensity (modified by K_e and modulus of elasticity).

[e] x = parallel to shroud axis; y = parallel to front cover axis; z = parallel to torsion bar axis.

TABLE XXII

LOFT DTT SHROUD AND COVER WELDS STRESS ANALYSIS FOR LOAD CONDITION L2-4^[2] AT BL-1 AND BL-2

Weld Location	Weld No.	Primary Stresses ^[a] (psi)		Secondary Stresses (psi)		S_n ^[b] (psi)	K_e ^[c]	S_a ^[d] (psi)	Allowed No. Cycles
		Type ^[e] & Direction	Magnitude	Type ^[e] & Direction	Magnitude				
Front/rear shroud	1	$\sigma_x/--$	2,700/0	$\sigma_x/--$	148,500/0	151,200	3.33	231,300	105
Shroud/body (right)	20	τ_{yx}/τ_{yz}	534/1,240	τ_{yx}/τ_{yz}	29,420/205	59,980	2.02	55,700	13,000
Shroud/body (left)	2	τ_{yx}/τ_{yz}	80/192	τ_{yx}/τ_{yz}	18,350/205	36,860	1.0	10,930	$>10^6$
End plate/front cover	3	$\sigma_y/--$	294/0	$--/--$	0/0	294	1.0	135	$>10^6$
Front cover/body	4	σ_x/τ_{xz}	5,960/625	τ_{xy}/τ_{xz}	49,630/504	99,460	3.33	152,000	290
End plate/body	5	$\sigma_y/--$	1,230/0	τ_{yx}/τ_{yz}	40,790/51,750	131,800	3.33	202,000	160
Torsion bar cover/body	8	$\sigma_x/--$	3,130/0	τ_{xy}/τ_{xz}	54,730/115,320	255,400	3.33	391,000	30
Shaft cover/body	7, 21	τ_{yx}/τ_{yz}	254/480	τ_{yx}/τ_{yz}	32,460/269	65,440	2.42	72,700	4,000
End cover/shaft cover	6	$\sigma_x/--$	233/0	$--/--$	0/0	233	1.0	107	$>10^6$

[a] Stress concentration factor of 4 applied to noncontinuous welds.

[b] S_n = calculated stress intensity (primary plus secondary).[c] K_e = fatigue life reduction factor.[d] S_a = alternating stress intensity (modified by K_e and modulus of elasticity).

[e] x = parallel to shroud axis; y = parallel to front cover axis; z = parallel to torsion bar axis.

TABLE XXIII

LOFT DTT SHROUD AND COVER WELDS STRESS ANALYSIS FOR LOAD CONDITION L2-4^[2] AT 1ST-1 AND 2ST-1

Weld Location	Weld No.	Primary Stresses ^[a] (psi)		Secondary Stresses (psi)		S_n ^[b] (psi)	K_e ^[c]	S_a ^[d] (psi)	Allowed No. Cycles
		Type ^[e] & Direction	Magnitude	Type ^[e] & Direction	Magnitude				
Front/rear shroud	1	σ_x /--	3,750/0	σ_x /--	139,290/0	143,000	3.33	219,000	120
Shroud/body (right)	20	τ_{yx} /--	740/0	τ_{yx}/τ_{yz}	27,590/193	56,600	1.78	46,300	32,000
Shroud/body (left)	2	τ_{yx} /--	110/0	τ_{yx}/τ_{yz}	17,210/193	34,660	1.0	15,920	$>10^6$
End plate/front cover	3	--/--	0/0	--/--	0/0	0	1.0	0	$>10^6$
Front cover/body	4	σ_x /--	8,290/0	τ_{xy}/τ_{xz}	46,550/470	93,480	3.33	143,000	400
End plate/body	5	--/--	0/0	τ_{yx}/τ_{yz}	38,260/48,540	123,600	3.33	189,000	200
Torsion bar cover/body	8	σ_x /--	4,350/0	τ_{xy}/τ_{xz}	51,330/108,170	239,500	3.33	366,000	35
Shaft cover/body	7, 21	τ_{yx} /--	350/0	τ_{yx}/τ_{yz}	30,450/250	61,600	2.14	61,000	9,000
End cover/shaft cover	6	σ_x /--	320/0	--/--	0/0	320	1.0	147	$>10^6$

[a] Stress concentration factor of 4 applied to noncontinuous welds.

[b] S_n = calculated stress intensity (primary plus secondary).[c] K_e = fatigue life reduction factor.[d] S_a = alternating stress intensity (modified by K_e and modulus of elasticity).

[e] x = parallel to shroud axis; y = parallel to front cover axis; z = parallel to torsion bar axis.

TABLE XXIV

LOFT DTT SHROUD AND COVER WELDS STRESS ANALYSIS FOR LOAD CONDITION L2-4^[2] AT 1-, 3-, 5UP-1 AND DUMMY LOCATIONS

Weld Location	Weld No.	Primary Stresses ^[a] (psi)		Secondary Stresses (psi)		S_n ^[b] (psi)	K_e ^[c]	S_a ^[d] (psi)	Allowed No. Cycles
		Type ^[e] & Direction	Magnitude	Type ^[e] & Direction	Magnitude				
Front/rear shroud	1	σ_x /--	3,750/0	σ_x /--	148,500/0	152,250	3.33	233,000	100
Shroud/body (right)	20	τ_{yx} /--	740/0	τ_{yx}/τ_{yz}	29,420/205	60,320	2.05	56,700	13,000
Shroud/body (left)	2	τ_{yx} /--	110/0	τ_{yx}/τ_{yz}	18,350/205	36,920	1.0	16,560	$>10^6$
End plate/front cover	3	--/--	0/0	--/--	0/0	0	1.0	0	$>10^6$
Front cover/body	4	σ_x /--	8,290/0	τ_{xy}/τ_{xz}	49,630/504	99,600	3.33	152,000	340
End plate/body	5	--/--	0/0	τ_{yx}/τ_{yz}	40,790/51,750	131,800	3.33	202,000	150
Torsion bar cover/body	8	σ_x /--	4,350/0	τ_{xy}/τ_{xz}	54,730/115,320	255,400	3.33	391,000	30
Shaft cover/body	7, 21	τ_{yx} /--	350/0	τ_{yx}/τ_{yz}	32,460/269	65,620	2.43	73,300	4,000
End cover/shaft cover	6	σ_x /--	320/0	--/--	0/0	320	1.0	147	$>10^6$

[a] Stress concentration factor of 4 applied to noncontinuous welds.

[b] S_n = calculated stress intensity (primary plus secondary).[c] K_e = fatigue life reduction factor.[d] S_a = alternating stress intensity (modified by K_e and modulus of elasticity).

[e] x = parallel to shroud axis; y = parallel to front cover axis; z = parallel to torsion bar axis.

TABLE XXV
LOFT DTT STATUS SUMMARY (TEST L1-5)

<u>Location</u>	<u>Type/ Configuration</u>	<u>Drawing Number</u>	<u>Revision</u>	<u>Thermal/ Hydraulic Report Number</u>	<u>Applied Mechanics Report Number</u>	<u>Minimum Fatigue Life (Cycles)</u>	<u>Status</u>
PC-1	modular/rake	208191	--	LTR 141-74	LTR 141-77	480,000	useable for L1-5
PC-2	pipng	204645	p ^[2]	LTR 141-74	LTR 141-80	125	useable for L1-5
PC-3	plenum/rake or pipng	204600 204645	M K	LTR 141-74	LTR 141-80	420	useable for L1-5
BL-1	plenum/rake	207726	A	LTR 141-74	LTR 141-80	125	useable for L1-5
BL-2	plenum/rake	207726	A	LTR 141-74	LTR 141-80	125	useable for L1-5
1ST-1	plenum	204600	D ^[b]	LTR 141-74 LTR 141-67	LTR 141-80	130	useable for L1-5
2ST-1	plenum	204600	D ^[b]	LTR 141-74 LTR 141-67	LTR 141-80	130	useable for L1-5
1UP-1	plenum	204600	L ^[a]	LTR 141-64 LTR 141-67	LTR 141-80	130	useable for L1-5
3UP-1	plenum	204600	E ^[b]	LTR 141-64 LTR 141-67	LTR 141-80	130	useable for L1-5
5UP-1	plenum	204600	D ^[b]	LTR 141-64 LTR 141-67	LTR 141-80	130	useable for L1-5
Dummy	dummy	206875	B	LTR 141-64 LTR 141-67	LTR 141-80	370	useable for L1-5

[a] Welds per EG&G Quality Discrepancy Reports, QDRs TF-104 and -105 (December 1976).

[b] Welds per Appendix B, Gott-4-76.

TABLE XXVI
LOFT DTT STATUS SUMMARY (TEST L2-1)

Location	Type/ Configuration	Drawing Number	Revision	Thermal/ Hydraulic Report Number	Applied Mechanics Report Number	Minimum Fatigue Life (Cycles)	Status
PC-1	plenum/pipe	207726 ^[2]	A	LTR 141-74 LTR 141-67	LTR 141-80	< 10	use not recommended
PC-2	plenum/pipe	207726 ^[2]	A	LTR 141-74 LTR 141-67	LTR 141-80	27	weld modification recommended prior to use in L2-1
PC-3	plenum/pipe	207726 ^[2]	A	LTR 141-74 LTR 141-67	LTR 141-80	27	weld modification recommended prior to use in L2-1
BL-1	plenum/rake	207726 ^[2]	A	LTR 141-74 LTR 141-67	LTR 141-80	30	weld modification recommended prior to use in L2-1
BL-2	plenum/rake	207726 ^[2]	A	LTR 141-74 LTR 141-67	LTR 141-80	30	weld modification recommended prior to use in L2-1
1ST-1	plenum	204600 ^[3]	D ^[b]	LTR 141-74 LTR 141-67	LTR 141-80	130	useable for L2-1
2ST-1	plenum	204600 ^[3]	D ^[b]	LTR 141-74 LTR 141-67	LTR 141-80	130	useable for L2-1
1UP-1	plenum	204600 ^[3]	L ^[a]	LTR 141-64 LTR 141-67	LTR 141-80	130	useable for L2-1
3UP-1	plenum	204600 ^[3]	E ^[b]	LTR 141-64 LTR 141-67	LTR 141-80	130	useable for L2-1
5UP-1	plenum	204600 ^[3]	D ^[b]	LTR 141-64 LTR 141-67	LTR 141-80	130	useable for L2-1
Dummy	dummy	206875 ^[5]	B	LTR 141-64 LTR 141-67	LTR 141-80	370	useable for L2-1

[a] Welds per EG&G Quality Discrepancy Reports, QDRs TF-104 and -106 (December 1976).

[b] Welds per Appendix B, Gott-4-76.

TABLE XXVII

LOFT DTT STATUS SUMMARY TEST, NUCLEAR; L2-4 CONDITIONS

Location	Type/ Configuration	Drawing Number	Revision	Thermal/ Hydraulic Report Number	Applied Mechanics Report Number	Minimum Fatigue Life (Cycles)	Status
PC-1	plenum/pipe	207726 ^[2]	A	LTR 141-74 LTR 141-67	LTR 141-80	< 10	use not recommended
PC-2	plenum/pipe	207726 ^[2]	A	LTR 141-74 LTR 141-67	LTR 141-80	27	weld modifications and reanalysis recommended prior to use
PC-3	plenum/pipe or plenum/rake	207726 ^[2]	A	LTR 141-74 LTR 141-67	LTR 141-80	27	weld modifications and reanalysis recommended prior to use
BL-1	plenum/rake	207726 ^[2]	A	LTR 141-74 LTR 141-67	LTR 141-80	30	weld modifications and reanalysis recommended prior to use
BL-2	plenum/rake	207726 ^[2]	A	LTR 141-74 LTR 141-67	LTR 141-80	30	weld modifications and reanalysis recommended prior to use
1ST-1	plenum	207726 ^[2]	A	LTR 141-74 LTR 141-67	LTR 141-80	35	weld modifications and reanalysis recommended prior to use
2ST-1	plenum	207726 ^[2]	A	LTR 141-74 LTR 141-67	LTR 141-80	35	weld modifications and reanalysis recommended prior to use
1UP-1	plenum	207726 ^[2]	A	LTR 141-64 LTR 141-67	LTR 141-80	30	weld modifications and reanalysis recommended prior to use
3UP-1	plenum	207726 ^[2]	A	LTR 141-64 LTR 141-67	LTR 141-80	30	weld modifications and reanalysis recommended prior to use
5UP-1	plenum	207726 ^[2]	A	LTR 141-64 LTR 141-67	LTR 141-80	30	weld modifications and reanalysis recommended prior to use
Dummy	dummy	206875 ^[5]	B	LTR 141-64 LTR 141-67	LTR 141-80	370	weld modification recommended prior to use in Core 2

LTR 141-80

7.0 REFERENCES

1. ASME Boiler and Pressure Vessel Code, Section III, Subsection NB-3200 (1974).
2. Aerojet Nuclear Company, Drawing No. 207726 Rev. A, "Drag-Disc Turbine Assembly".
3. Aerojet Nuclear Company, Drawing No. 204600 Revs. D, E, L, and M "Assembly".
4. Aerojet Nuclear Company, Drawing No. 204645 Rev. K, "LOFT Piping Drag-Disc Turbine Flowmeter Assembly".
5. Aerojet Nuclear Company, Drawing No. 206875 Rev. B, "LOFT Dummy Drag-Disc Turbine Flowmeters".
6. T. L. Kinnaman, Evaluation of Thermal and Hydraulic Loadings on the LOFT DTTs, LTR 141-64 (April 1977).
7. T. L. Kinnaman, Re-evaluation of Hydraulic Loads on the LOFT DTTs, LTR 141-74, (RE-A-77-115) (December 6, 1977).
8. G. Kyllingstad, Fluid Loads on LOFT DTT Shrouds Located in Reactor Vessel Downcomer and DTT Thermal Loads During Nuclear LOCE, LTR 141-67 (to be issued).
9. W. R. Mosby, Stress Analysis of the LOFT Modular DTT Flowmeter for LOCE Transients (L1-5 and L2-4), (Supplement No. 1), LTR 141-77, Sup. 1, (RE-A-77-118, Sup. 1), (December 2, 1977).

APPENDIX A

SUPPORTING STRESS ANALYSIS

INTEROFFICE CORRESPONDENCE

date January 19, 1977
 to M. W. Schulz
 from J. S. Martinell *J. S. Martinell*
 subject EVALUATION OF LOFT PLENUM TYPE DTT SHROUD AND COVER WELDS - JSM-1-77

- Ref:
- (a) Document Change Notice, DCN-L-2544, October 7, 1976
 - (b) "LOFT Dummy Drag Disk Turbine Flowmeters", ANC Drawing 206875, December 24, 1976
 - (c) "LOFT Drag-Disk, Turbine Flow Meter Assembly", ANC Drawing 204600, Rev. K, January 14, 1972
 - (d) ASME Boiler and Pressure Vessel Code, Section III, 1974

This letter documents the stress analysis and preliminary evaluation of the welds attaching the shrouds and cover pieces to the LOFT plenum type DTT's as defined in Reference (a). The geometry and material types for the components included in this analysis were taken from References (b) and (c). Hydraulic and thermally induced loads associated with LOCE conditions were considered.

Thermal stresses induced by restraint of free end displacement of the DTT body by the shrouds and cover pieces were calculated for a "worst case" temperature difference of 530°F (body at 600°F and shrouds and cover pieces at 70°F). This approximation gives rise to secondary stresses which exceed the requirements of Subsection NB-3222.3 of Reference (d) as summarized in the Table below and documented in the accompanying Attachment. In addition, combination of thermal stresses with those induced by hydraulic loads yields stress levels which exceed the requirements of Subsection NB-3222.2 of Reference (d).

<u>Weld No.</u>	<u>Expansion Stress Intensity</u> (Pe)	<u>Allowable</u> (3 S _m)
W-1	192,000	41,700
W-2	899,000	41,700
W-3	75,900	41,700
W-4	257,000	41,700
W-5	119,000	41,700

M. W. Schulz
January 19, 1977
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Since the welds do not meet Code requirements on secondary and combined primary plus secondary stresses resulting from the assumed load conditions, fatigue analyses to determine the allowable number of cycles for each weld was deemed inappropriate at this time. It is recommended that a more detailed thermal/hydraulic analysis of the subject DTT's be considered to determine the following:

- (1) a more representative temperature distribution in the DTT body and shrouds and cover pieces for use in calculating thermal stresses in the subject welds,
- (2) the number of thermal cycles which occur at the DTT locations during LOCE's for use in evaluating the welds from a fatigue standpoint.

Revised weld evaluation will depend upon the results of the recommended detailed thermal/hydraulic analysis.

er

Attachment
As stated

SHROUD

WELDS

W-1

Attachment
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LTR 141-80

DRAWINGS

206875

204600

RADIAL GROWTH OF SHROUD

Change in L due to temperature difference
in body and shroud is δL

$$\delta L = L \alpha \Delta T$$

$$L = 0.7 \text{ in}$$

$$\alpha = 9.82 \times 10^{-6} \text{ in/in-°F}$$

$$\Delta T = 600 - 70 = 530 \text{ °F}$$

$$\delta L = (0.7)(9.82 \times 10^{-6})(530) = 3.64 \times 10^{-3} \text{ in (increase in width of gap)}$$

LTR 141-80

From Roarke, p221, for circular rings, Case 2,

$$\delta L = D_{wn} = \frac{-WR^3}{Et^3/12(1-\nu^2)} \left(\frac{\Theta}{\pi} \left\{ (\pi - \Theta)(2c^2 + k_1) + 2sc(2 + k_2) \right\} - sc(2 + k_2) - \frac{s^2}{\pi} (2 + c^2 k_5) \right)$$

$$W = 16 \text{ lb/in}$$

$$R = 0.725 \text{ in}$$

$$\Theta = 28.87^\circ \approx 30^\circ = \pi/6 \text{ rad.}$$

$$\left. \begin{array}{l} k_1 = 1 \\ k_2 = 1 \\ k_5 = 1 \end{array} \right\} \text{neglecting hoop \& shear stresses}$$

$$S = \sin(\Theta) = 0.48$$

$$C = \cos(\Theta) = 0.88$$

$$E = 28.3 \times 10^6 \text{ psi}$$

$$t = 0.05 \text{ in}$$

$$\nu = 0.3$$

LTR 141-80

$$\frac{R^3}{Et^3/12(1-\nu^2)} = \frac{(0.725)^3(12)(1-.09)}{(28.3 \times 10^6)(0.05)^3} = 1.176 \times 10^{-3}$$

$$\left(\frac{\frac{1}{16}}{\left(\frac{1}{16} \right) \left(\frac{1}{16} \right)} \right) = \left(\frac{\frac{1}{16}}{\frac{1}{16}} \right)$$

$$\frac{\theta}{\pi} = \frac{\pi/6}{\pi} = \frac{1}{6}$$

$$\pi - \theta = \pi - \pi/6 = \frac{5\pi}{6}$$

$$2c^2 + k_1 = (2)(.88)^2 + 1 = 2.549$$

$$25c(2+k_2) = (2)(.48)(.88)(3) = 2.534$$

$$\frac{\theta}{\pi} \left\{ (\pi - \theta)(2c^2 + k_1) + 25c(2+k_2) \right\} = \frac{1}{6} \left(\frac{5\pi}{6} (2.549) + 2.534 \right) = 1.535$$

$$5c(2+k_2) = (.48)(.88)(3) = 1.267$$

$$\frac{s^2}{\pi} (2 + c^2 k_r) = \frac{(.48)^2}{\pi} (2 + (.88)^2(1)) = 0.203$$

$$\delta L = D_{wu} = -W \left(1.176 \times 10^{-3} \right) \left(1.535 - 1.267 - 0.203 \right)$$

$$\delta L = D_{wu} = -W \left(7.644 \times 10^{-5} \right)$$

$$W = -D_{wu} / (7.644 \times 10^{-5}) = \frac{-3.64 \times 10^{-3}}{7.644 \times 10^{-5}} = \underline{\underline{-47.62 \text{ lbf/in}}}$$

From drawing change notice DCN-L-2544,
weld at shroud-body interface is $\frac{1}{16}$ " fillet,
 $\frac{1}{4}$ " long on $\frac{1}{2}$ " intervals. Thus there is
a $\frac{1}{16}$ " fillet, $\frac{1}{2}$ " long per inch of interface.
The effective area per inch is,

$$A_e = (L_T) \left(\frac{1}{2} \right)$$

$$L_T = \frac{\sqrt{2}}{2} \left(\frac{1}{16} \right) = 0.04419$$

$$A_e = 0.0221 \text{ in}^2/\text{in}$$

The stress on the effective area is

$$\sigma_{A_e} = \left(\frac{47.62}{.0221} \right) \frac{\text{lbF/in}}{\text{in}^2/\text{in}} = \underline{\underline{2,155. \text{ lbF/in}^2}}$$

AXIAL GROWTH OF FLOW METER BODY

$$\delta L = L \alpha \Delta T$$

$$L = 3.28 \text{ in}$$

$$\alpha = 9.82 \times 10^{-6} \text{ in/in-}^{\circ}\text{F}$$

$$\Delta T = 600 - 70 = 530^{\circ}\text{F}$$

$$\delta L = (3.28)(9.82 \times 10^{-6})(530) = 0.017 \text{ in}$$

$$\delta L = \frac{PL}{AE} \Rightarrow P = \frac{AE \delta L}{L}$$

$$A = \frac{5}{6} \pi (.75^2 - .70^2) = 0.190 \text{ in}^2$$

$$E = 28.3 \times 10^6 \text{ psi}$$

$$L = 3.28 \text{ in}$$

$$\frac{AE}{L} = \frac{(0.190)(28.3 \times 10^6)}{3.28} = 1.639 \times 10^6 \text{ lb/in}$$

$$P = (1.639 \times 10^6)(0.017) = 2.786 \times 10^4 \text{ lb}$$

$$P = 27,860 \text{ lb}$$

Weld required to carry this load is $\frac{1}{16}$ " fillet, $\frac{1}{4}$ " long in $\frac{1}{2}$ " intervals on both sides of shroud; thus total effective area is,

$$A_e = (L_t) \left(\frac{1}{2} \right) (3.28) (2) = 3.28 L_t$$

$$L_t = \frac{\sqrt{2}}{2} \left(\frac{1}{16} \right) = .0442 \text{ in}$$

$$A_e = (3.28) (.0442) = 0.145 \text{ in}^2$$

Stress in the weld is then,

$$\sigma = \frac{P}{A} = \frac{27,860}{.145} = 192,200. \text{ lbf/in}^2$$

Use this value in weld evaluation, (ASME SECTION III, NB-3200) τ .

$$P = 27,860. \quad (\text{from W-1 calc's})$$

$$A_w = L_w t_w$$

$$L_w = (.25) \pi (1.5) \left(\frac{5}{16}\right) = 0.982 \text{ in}$$

$$t_w = \frac{1}{32}''$$

$$A_w = .982/32 = 0.031 \text{ in}^2$$

$$\sigma = \frac{27,860}{.031} = 899,000 \text{ lb/in}^2$$

This stress is the limiting case since it is the largest and will give rise to the lowest number of cycles.

Separation of this weld does not create a structural problem.

DRAWINGS: 206875

204600

RADIAL GROWTH OF COVER

$$\delta L = L \alpha \Delta T$$

$$L = 0.80 \text{ in}$$

$$\alpha = 9.82 \times 10^{-6} \text{ in/in-}^\circ\text{F}$$

$$\Delta T = 600 - 70 = 530^\circ\text{F}$$

$$\delta L = (0.8)(9.82 \times 10^{-6})(530) = 4.16 \times 10^{-3} \text{ in}$$

Roarke, p 221, Case 2;

$$\delta L = D w_u = \frac{-WR^3}{Et^3/12(1-\nu^2)} \left\{ \frac{\theta}{\pi} \left[(\pi - \theta)(2c^2 + k_1) + 2sc(2 + k_2) \right] - sc(2 + k_2) - \frac{s^2}{\pi} (2 + c^2 k_5) \right\}$$

$$W = 1 \text{ lb/in}$$

$$R = 0.384 \text{ in}$$

$$\theta = 90^\circ = \pi/2 \text{ rad.}$$

$$\left. \begin{array}{l} k_1 = 1 \\ k_2 = 1 \\ k_5 = 1 \end{array} \right\} \text{ neglecting hoop \& shear stress}$$

$$s = \sin \theta = 1.0$$

$$c = \cos \theta = 0.0$$

$$E = 28.3 \times 10^6 \text{ psi}$$

$$t = 0.032 \text{ in}$$

$$\nu = 0.3$$

$$\frac{R^3}{Et^3/12(1-\nu^2)} = \frac{(.384)^3(12)(.91)}{(28.3 \times 10^6)(.032^3)} = 6.668 \times 10^{-4} \text{ in}^2/\text{lb}$$

$$\frac{\theta}{\pi} = \frac{1}{2}$$

$$\pi - \theta = \pi/2$$

$$2c^2 + k_1 = 1$$

$$2sc(2+k_2) = 0$$

$$5c(2+k_2) = 0$$

$$\frac{s^2}{\pi}(2+c^2k_5) = \frac{2}{\pi}$$

$$\delta L = -W(6.668 \times 10^{-4}) \left(\left(\frac{1}{2} \right) \left(\frac{\pi}{2} \right) - \frac{2}{\pi} \right) = -W(9.921 \times 10^{-5})$$

$$W = -\delta L / (9.921 \times 10^{-5})$$

$$W = -\frac{4.16 \times 10^{-3}}{9.921 \times 10^{-5}} = -41.93 \text{ lbf/in}$$

WELD STRESS

Weld is .03" square groove weld on both sides of cover. Total area is,

$$A_T = (2)(L_w)(t_w)$$

$$L_w = \text{weld length} = 1.25 \text{ in}$$

$$t_w = \text{weld thickness} = 0.03 \text{ in}$$

$$A_T = (2)(1.25)(.03) = .075 \text{ in}^2$$

The total force is,

$$W_T = W \times 1.25 = 42 \times 1.25 = 53 \text{ lbf}$$

Weld stress (shear) is

$$\tau = \frac{W_T}{A_T} = \frac{53}{.075} = 707.16 \text{ lbf/in}^2$$

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AXIAL GROWTH OF COVER

$$\Delta L = L \alpha \Delta T$$

$$L = 1.25 \text{ in}$$

$$\alpha = 9.82 \times 10^{-6} \text{ in/in} \cdot ^\circ\text{F}$$

$$\Delta T = 600 - 70 = 530^\circ\text{F}$$

$$\Delta L = (1.25)(9.82 \times 10^{-6})(530) = 6.51 \times 10^{-3} \text{ in}$$

$$\delta L = \frac{PL}{AE} \Rightarrow P = \frac{AE}{L} \delta L$$

$$A = \frac{\pi}{2} (.4^2 - .368^2) = 0.0386 \text{ in}^2$$

$$E = 28.3 \times 10^6 \text{ psi}$$

$$L = 1.25 \text{ in}$$

$$P = \frac{(0.0386)(28.3 \times 10^6)(6.51 \times 10^{-3})}{1.25} = 5,690 \text{ lbf.}$$

Stress

$$\sigma = \frac{P}{A_t} = \frac{5,690}{.075} = 75,870 \text{ psi}$$

Use this stress to evaluate weld.

DRAWINGS: 206875

LTR 141-80

204600

$$\delta L = L \alpha \Delta T$$

$$= (0.8)(9.82 \times 10^{-6})(530) = 4.164 \times 10^{-3} \text{ in}$$

$$\delta L = \frac{PL}{AE} \Rightarrow P = \frac{AE}{L} \delta L$$

$$P = \frac{(1.03)(.032)(28.3 \times 10^6)(4.164 \times 10^{-3})}{(0.8)} = 4855 \text{ lbf}$$

Weld stress

$$\sigma = \frac{P}{A_w}, \quad A_w = (.03)(1.03 - .4) = 0.0189 \text{ in}^2$$

$$\sigma = \frac{4855}{.0189} = 256,878 \text{ psi}$$

Evaluate with NB-3200 criteria

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DRAWINGS: 206875

204600

RADIAL GROWTH OF COVER

$$\delta L = \alpha L \Delta T$$

$$L = 0.624 \text{ in}$$

$$\alpha = 9.82 \times 10^{-6} \text{ in/in} \cdot ^\circ\text{F}$$

$$\Delta T = 600 - 70 = 530^\circ\text{F}$$

$$d = .203$$

$$\delta L = (624)(9.82 \times 10^{-6})(530) = 3.25 \times 10^{-3} \text{ in}$$

Roark, p. 221, Case 2;

$$W = 16/\text{in}$$

$$R = .296 \text{ in}$$

$$\theta = 90^\circ = \pi/2$$

$$K_1 = K_2 = K_3 = 1$$

$$S = 1.0$$

$$C = 0.0$$

$$E = 28.3 \times 10^6 \text{ psi}$$

$$t = .032$$

$$\nu = 0.3$$

$$\frac{R^3}{Et^3/12(1-\nu^2)} = \frac{(.296)^3(12)(.91)}{(28.3 \times 10^6)(.032^3)} = 3.054 \times 10^{-4} \text{ in}^2/12$$

$$\frac{\theta}{\pi} = \frac{1}{2}$$

$$\pi - \theta = \pi/2$$

$$2c^2 + k_1 = 1$$

$$2r < (2 + k_2) = 0$$

$$r < (2 + k_2) = 0$$

$$\frac{r^2}{\pi} (2 + c^2 k_r) = \frac{2}{\pi}$$

$$\delta L = -W (3.054 \times 10^{-4}) \left(\left(\frac{1}{2} \right) \left(\frac{\pi}{2} \right) - \frac{2}{\pi} \right) = -W (4.544 \times 10^{-5})$$

$$W = \frac{-\delta L}{(4.544 \times 10^{-5})} = \frac{3.25 \times 10^{-3}}{4.544 \times 10^{-5}} = 72 \text{ lb.f./in}$$

Stress: $\frac{1}{32}$ " fillet, $\frac{1}{4}$ " long on $\frac{1}{2}$ " intervals

$$A_e = \frac{\sqrt{2}}{2} \left(\frac{1}{32} \right) \left(\frac{1}{2} \right) = 0.011 \text{ in}^2/\text{in}$$

$$\sigma = \frac{72}{.011} = 6545. \text{ lb.f./in}^2$$

AXIAL GROWTH OF COVER

$$\delta L = L \alpha \Delta T, \quad L = 2.464 \text{ in}$$

$$\delta L = (2.464)(9.82 \times 10^{-6})(530) = 0.013 \text{ in}$$

$$\delta L = \frac{PL}{AE} \Rightarrow P = \left(\frac{AE}{L} \right) \delta L$$

$$A = 2(.203)(.032) + \frac{\pi}{2} (.312^2 - .280^2) = .043 \text{ in}^2$$

$$P = \frac{(.043)(28.3 \times 10^6)}{2.464} (.013) = 6,420 \text{ lbf}$$

Stress: A_T = total weld area,

$$A_T = (2)(2.464)(.011) = 0.054 \text{ in}^2$$

$$\sigma = \frac{6420}{.054} = 118,890.$$

Evaluate the weld using this stress.

Next

WELD EVALUATION

Allowable stress intensity for 304 SS, S.A. 240 is used after comparison of chemical and strength data with 304 SS, S.A. 167.

$$S_m @ 600^\circ = 13,900 \text{ psi}$$

$$\text{Allowable} = 3 S_m = 41,700 \text{ psi}$$

$$\underline{W-1} : P_e = 192,000. > 3 S_m$$

$$\underline{W-2} : P_e = 899,000. > 3 S_m$$

$$\underline{W-3} : P_e = 75,900. > 3 S_m$$

$$\underline{W-4} : P_e = 257,000. > 3 S_m$$

$$\underline{W-5} : P_e = 119,000. > 3 S_m$$

None of the welds meet code requirements.

Recommend revised thermal analysis to reduce ΔT between body and shrouds and covers.

cc: R. C. Guenzler *Lab* G. B. Shull
J. R. Karvinen M. W. Schulz
L. P. Leach R. D. Wesley
C. A. Moore *com/lab* K. B. Wilson
R. G. Rahl *RR* J. S. Martinell - 2
H. A. Rau

INTEROFFICE CORRESPONDENCE

LTR 141-80

date February 10, 1977

to R. L. Crumley

from J. S. Martinell *J. S. Martinell*

subject EVALUATION OF LOFT PIPING TYPE DTT SHROUD AND COVER WELDS -
JSM-2-77

Ref:

- (a) "LOFT Piping Drag-Disk, Turbine Flow Meter Assembly",
ANC Drawing 204645, Rev. L, May 22, 1972
- (b) Personal Communication, C. E. Winsel to J. S. Martinell,
Jan 26, 1977
- (c) ASME Boiler and Pressure Vessel Code, Section III,
Subsection NB-3200, 1974
- (d) R. C. Gottula ltr to L. Y. Ybarrondo, Gott-4-76,
LOFT Drag Disk Turbine Meter Shroud Welds, June 9, 1976
- (e) Personal Communication, K. A. Hedquist to J. S.
Martinell, Feb 9, 1977
- (f) Personal Communication, K. B. Wilson to J. S. Marti-
nell, Feb 9, 1977

This letter documents the stress analysis and evaluation of the welds attaching the shrouds and cover pieces to the LOFT piping type DTT's as defined in References (a) and (b). Hydraulic and thermally induced loads associated with LOCE conditions were considered, and evaluation was performed according to the criteria of Reference (c). Data for estimating hydraulic loads was taken from Reference (d). Thermally induced loads were calculated assuming restraint of free end displacement of the shrouds and cover pieces by the DTT body. Temperature histories for the PC-1 and BL-1 locations were taken from Reference (e) and are based on experimental data from previous tests at LOFT.

Analysis of the subject welds on the piping DTT's at the PC-1 and BL-1 locations is sufficient for evaluation of these welds as well as for those on the piping DTT's at the PC-2, PC-3, BL-2, and CS-1 locations since the DTT's at the latter locations experience hydraulic and thermal conditions near or less severe than the conditions at the BL-1 location. Results of the attached analysis for the subject welds on the DTT at the PC-1 location indicate that stresses resulting from combined thermal and hydraulic loads do not meet the $3S_m$ requirements of Reference (c) due to a temperature difference of 240°F between the shrouds and DTT body. Weld stresses for the BL-1 location meet the $3S_m$ requirements with the exception of weld number W-2, which is not critical since failure of this weld would not cause shroud separation from the DTT body. Even though the weld stresses at the

PC-1 location do not meet the $3S_m$ code requirements, it is felt that the DTT at this location can be safely utilized for L1-4 without design modifications. Basis for this decision is drawn from the following:

- (1) The $3S_m$ requirements of Reference (c), which are not met, are controversial, with some members of the ASME Code committee believing that the type of thermal stresses we are considering should be exempted from the $3S_m$ limit. The rules were this way at one time but were changed as a result of an inconsistency between piping and vessel requirements. This inconsistency was resolved on the conservative side as might be expected.
- (2) Quench testing of a piping DTT with identical welds indicates no visual damage to welds after 30 thermal cycles as documented per Reference (f).
- (3) Fatigue analysis using the procedures of Reference (c) with relaxed requirements on the thermally induced stress, indicates the most highly loaded weld (ie, W-2) can withstand 600 thermal cycles.

The subject welds on the DTT's at the PC-2, PC-3, BL-1, BL-2, and CS-1 locations are deemed adequate for conditions expected during L1-4. However, it is recommended that the shroud and cover designs be reviewed and/or modified in order to reduce thermal stresses, and a more refined stress analysis be performed for evaluation of the designs prior to nuclear LOCE's.

It should be emphasized that this analysis applies only to the subject welds on the piping type DTT's, and does not apply for the plenum type meters in the fuel assemblies or those in the downcomer. The results are dependent on the thermal data of Reference (e) as mentioned previously and subject to the limits of that analysis.

er

Attachment
As stated

THERMAL STRESS
CALCULATIONS

Ref. J.S. Martinell Ltr to M.W. Schulz,
Evaluation of LØFT Plenum Type
DTT Shroud and Cover Welds -
JSM-1-77

REVISED WELD ANALYSIS (THERMAL)

PC-1 LOCATION

$$\Delta T = 240^\circ F$$

W-1 - full length, .085 fillet, revised area is,

$$A = \left(\frac{\sqrt{2}}{2} \right) (.085) (3.28 + 3.28 - .5) = 0.364 \text{ in}^2$$

Revised stress due to axial growth is,

$$\rightarrow \sigma = (192,200) \left(\frac{240}{530} \right) \left(\frac{.145}{.364} \right) = 34,670. \text{ psi (shear)}$$

$$S_m = \frac{S_m|_{600} + S_m|_{70}}{2} = \frac{16,600 + 13,900}{2} = 15,300 \text{ psi}$$

$$3S_m = 45,900. \text{ psi}$$

$$\rightarrow S = 2\sigma = 69,300. > 45,900. = 3S_m$$

Revised radial stress

$$\rightarrow \sigma = (3155) \left(\frac{240}{342} \right) \left(\frac{.145}{.364} \right) = 602.$$

(negligible compared to above)

W-2 - full penetration square groove weld
loaded in tension, .12"/.50"

$$\Delta T = 240^{\circ}F$$

Revised load due to axial growth is

$$\rightarrow P = 27,860 \left(\frac{240}{530} \right) = 12,615.$$

$$\sigma = \frac{P}{A_w}$$

$$A_w = L_w \times t$$

$$t = \text{strand thickness} = .05"$$

$$L_w = \left(\frac{.12}{.50} \right) \pi (1.5) \left(\frac{5}{6} \right) = 0.942"$$

$$A_w = (.05)(.942) = .047 \text{ in}^2$$

Revised stress is,

$$\rightarrow \sigma = 12,615 / .047 = 268,400 \text{ psi}$$

$$S = 268,000 > 45,900 = 3 S_m$$

Reanalyze for differential expansion in axial direction (of front cover) only

$$P = A E \alpha \Delta T$$

$$A = \frac{\pi}{2} (.4^2 - .368^2) = .0386$$

$$E = 28.3 \times 10^6 \text{ psi}$$

$$\alpha = 9.82 \times 10^{-6} \text{ in/in-}^\circ\text{F}$$

$$\Delta T = 240^\circ\text{F}$$

$$\rightarrow P = (.0386)(28.3)(9.82)(240) = 2575 \text{ lbf}$$

$$\sigma = \frac{P}{A_w}$$

$$A_w = L_w \times t_b$$

$$L_w = (2)(1.25) = 2.5 \text{ in}$$

$$t_b = .032 \text{ in}$$

$$\rightarrow \sigma = 2575 / (2.5)(.032) = 32,180 \text{ lbf/in}^2$$

$$\rightarrow S = 2\sigma = 64,360$$

Revised radial stress

$$\rightarrow \sigma = 707 \left(\frac{240}{530} \right) \left(\frac{.075}{.080} \right) = 300$$

(negligible compared to axial)

Reanalyze for differential expansion in axial direction only.

$$\rightarrow \delta = \alpha L \Delta T = (9.82 \times 10^{-6})(2.464)(240) = .0058''$$

Include effects of holes on axial stiffness of shroud.

$$K_{eq} = \frac{1}{\sum (\frac{1}{K_i})} = \frac{1}{\left\{ \frac{2}{K_1} + \frac{2}{K_2} + \frac{8}{K_3} \right\}}$$

$$K_1 = \frac{A_1 E_1}{L_1}, \quad A_1 = (.244 + .244 + \frac{\pi}{2}(.312))(.032) = .066 \text{ in}^2$$

$$E_1 = 28.3 \times 10^6 \text{ psi}$$

$$L_1 = .168''$$

$$K_1 = \frac{(.066)(28.3 \times 10^6)}{.168} = 1.112 \times 10^7$$

$$K_2 = \frac{A_2 E_1}{L_2}, \quad A_2 = \left(\frac{.066}{.032} - .25 \right) (.032) = .058 \text{ in}^2$$

$$L_2 = .125 \text{ in}^2$$

$$K_2 = \frac{(.058)(28.3 \times 10^6)}{.125} = 1.313 \times 10^7$$

$$K_3 = \frac{A_3 E_1}{L_3}, \quad L_3 = .125$$

$$K_3 = \frac{(.066)(28.3 \times 10^6)}{.125} = 1.494 \times 10^7$$

$$K_{eg} = \frac{1}{\frac{2}{1.112 \times 10^7} + \frac{9}{1.313 \times 10^7} + \frac{8}{1.494 \times 10^7}} = 7.14 \times 10^5 \text{ lb/in}$$

$$\rightarrow P = K_{eg} \delta = (7.14 \times 10^5)(.0058) = 4,141 \text{ lb}$$

Assume load is equally distributed along the weld.

$$\sigma = \frac{P}{A_w}$$

$$A_w = A_{ws} + A_{wg}$$

$$A_{ws} = (.219)(6)(.032) = .042 \text{ in}^2$$

$$A_{wg} = (.38 \times 2)(.075) \frac{\sqrt{2}}{2} = .040 \text{ in}^2$$

$$A_w = .082 \text{ in}^2$$

$$\rightarrow \sigma = \frac{4,141}{.082} = 50,500 \text{ psi}$$

$$\rightarrow S = 2\sigma = 101,000.$$

Revised radial stress,

$$\rightarrow \sigma = (3,273) \left(\frac{240}{530} \right) \left(\frac{.054}{.080} \right) = 1000.$$

(negligible compared to axial)

Worst case is due to differential expansion parallel to drag-dire stem

$$\rightarrow \delta = \alpha L \Delta T = (9.82 \times 10^{-6})(.3)(240) = .0007''$$

$$K_{eq} = \frac{1}{\sum \left(\frac{1}{K_i} \right)} = \frac{1}{\left\{ \frac{2}{K_1} + \frac{1}{K_2} \right\}}$$

$$K_1 = \frac{A_1 E_1}{L_1}, \quad A_1 = (.44)(.032) = .014 \text{ in}^2$$

$$E_1 = 28.3 \times 10^6 \text{ psi}$$

$$L_1 = .0875$$

$$K_1 = \frac{(.014)(28.3 \times 10^6)}{.0875} = 4.528 \times 10^6$$

$$K_2 = \frac{A_2 E_1}{L_2}, \quad A_2 = (.44 - .25)(.032) = 6.08 \times 10^{-3}$$

$$L_2 = .125$$

$$K_2 = \frac{(6.08 \times 10^{-3})(28.3 \times 10^6)}{.125} = 1.377 \times 10^6$$

$$K_{eq} = \frac{1}{\frac{2}{4.528 \times 10^6} + \frac{1}{1.377 \times 10^6}} = 8.562 \times 10^5$$

$$\rightarrow P = (8.562 \times 10^5)(.0007) = 605.16 \text{ f}$$

$$\sigma = P/A_w, \quad A_w = (.4)(.16)(.032) = .0192 \text{ in}^2$$

$$\rightarrow \sigma = 605 / .0192 = 31,530 \text{ psi}$$

$$\rightarrow S = 2 \sigma = 63,100.$$

Worst case is due to diff. expansion along axis of body & shroud.

$$\rightarrow \delta = \alpha L \Delta T = (9.82 \times 10^{-6}) / (.63) (240) = .00148''$$

$$P = K_g \delta$$

$$K_{eq} = \frac{1}{\sum_i \left(\frac{1}{k_i} \right)} = \frac{1}{\left(\frac{1}{k_1} + \frac{1}{k_2} \right)}$$

$$k_1 = \frac{A_1 E_1}{L_1}, \quad A_1 = (.8)(.032) = 0.026 \text{ in}^2$$

$$E_1 = 28.3 \times 10^6 \text{ psi}$$

$$L_1 = .63 - .25 = .38''$$

$$k_1 = \frac{(.026)(28.3 \times 10^6)}{.38} = 1.936 \times 10^6$$

$$k_2 = \frac{A_2 E_1}{L_2}, \quad A_2 = (.8 - .25)(.032) = 0.0176 \text{ in}^2$$

$$L_2 = .25''$$

$$k_2 = \frac{(.0176)(28.3 \times 10^6)}{.25} = 1.992 \times 10^6$$

$$K_{eq} = \frac{1}{\left(\frac{1}{1.936 \times 10^6} \right) + \left(\frac{1}{1.992 \times 10^6} \right)} = 9.818 \times 10^5 \text{ lb/in}$$

$$\rightarrow P = (9.818 \times 10^5)(.00148) = 1458 \text{ lbf}$$

$$\sigma = P/A_w, \quad A_w = \left(\frac{.12}{.20} \right) (2) (.63) (.032) = .024 \text{ in}^2$$

$$\rightarrow \sigma = \frac{1458}{.024} = 60,740 \text{ lbf/in}^2$$

$$S = 2\sigma = 121,500 \quad 68$$

REVISED WELD ANALYSIS (THERMAL)2 BL-1 location,

$$\Delta T = 75^\circ F$$

$$S_m = \frac{S_m|_{600} + S_m|_{70}}{2} = 15,300 \text{ psi}$$

$$3S_m = 45,900 \text{ psi}$$

W-1, 10

Revised load due to reduced ΔT is,

$$\rightarrow P = (27,860) \left(\frac{75}{53.0} \right) = 3,942 \text{ lbf}$$

Weld is not the same on both sides of shroud, thus welds on the side with smaller area are more highly loaded.

$$\Sigma \text{ Forces } \left\{ \sigma_1 A_1 + \sigma_2 A_2 = P \right.$$

$$\Sigma \text{ Moments about } \bar{x} \left\{ \sigma_1 A_1 L_1 = \sigma_2 A_2 L_2, \quad L_1 = L_2 \Rightarrow \sigma_1 A_1 = \sigma_2 A_2 \right.$$

$$2\sigma_1 A_1 = P \Rightarrow \sigma_1 = \frac{P}{2A_1}$$

$$\sigma_2 = \sigma_1 \left(\frac{A_1}{A_2} \right)$$

PC-2

W-1, 10

10/

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$$A_1 = (1.5) \left(\frac{\sqrt{2}}{2} \right) (.085) = .0902$$

$$A_2 = (1.75) \left(\frac{\sqrt{2}}{2} \right) (.085) = .105$$

$$\rightarrow \sigma_1 = \frac{3,942}{(2)(.0902)} = 21,853. \text{ psi}$$

$$\rightarrow \sigma_2 = 21,853 \left(\frac{.0902}{.105} \right) = 18,773. \text{ psi}$$

$$+ \dots S = 2\sigma = 43,700.$$

Radial stress negligible compared to these values

Remaining welds (2-9) are identical to those on meter in PC-1 location. Stress can be found by ratio of ΔT 's between two locations,

$$\rightarrow W-2 \quad \sigma = 268,400 \left(\frac{75}{240} \right) = 83,875. \text{ psi}$$

W-3 NO THERMAL STRESS

$$\rightarrow W-4 \quad \sigma = 32,180 \left(\frac{75}{240} \right) = 10,100. \text{ psi}$$

$$\rightarrow W-5,9 \quad \sigma = 50,500 \left(\frac{75}{240} \right) = 15,780. \text{ psi}$$

$$\rightarrow W-6 \quad \sigma = 31,530 \left(\frac{75}{240} \right) = 9,850. \text{ psi}$$

$$\rightarrow W-7 \quad \sigma = 60,740 \left(\frac{75}{240} \right) = 18,980. \text{ psi}$$

W-8 NO THERMAL STRESS

Combine with hydraulic loads and compare with 35m on stress intensity.

HYDRAULIC STRESS
CALCULATIONS

Ref: R.C. Gottula Ltr to L.J. Ybarrondo,
LOFT Drag Disk Turbine Meter
Shroud Welds - Gott-4-76

ρV^2

CALCULATIONS

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HYDRAULIC LOAD SUMMARY

(PIPING METERS)

Discussion with Norm Pace (1/31/77)
indicator steady-state flow conditions
should be conservative. From letter G.11-4-76,

PC-1 - $\rho V^2 = \frac{(47)(48.5)^2}{(144)(64.4)} = 11.922 \text{ lb/in}^2$
(can be crossflow)

PC-2 - $\rho V^2 = \frac{(47)(48.5)^2}{(144)(64.4)} = 11.922 \text{ lb/in}^2$
(axial flow only)

PC-3 - $\rho V^2 = \frac{(47)(48.5)^2}{(144)(64.4)} = 11.922 \text{ lb/in}^2$
(can be crossflow)

BL-1 - blowdown conditions assumed,

+
BL-2 $\rho V^2 = \frac{(47.6)(86.4)^2}{(144)(64.4)} = 38.317 \text{ lb/in}^2$
37.436

(axial flow with load factor of 2)

CS-1 - steady state conditions assumed

$$\rho V^2 = \frac{(47)(62.25^2)}{(144)(64.4)} = 19.639 \text{ lb/in}^2$$

(axial flow only)

$C_D = 2.5$ (worst case)

$A = \text{area (in}^2\text{)}$

$$F = C_D \times A \times \rho V^2 \times L.F.$$

L.F. = load factor (dynamic)

FLOW AREAS

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1. AXIAL FLOW

COMPONENT	FLOW AREA
SHROUD	0.7174 in^2 (COTT-4-76)
FRONT COVER	$(1.25)(.8) - \frac{(10)(\pi)(.0625^2)}{2}$ 0.963 in^2
TORSION BAR COVER	$(.44)(.3) - 2(\pi)(.0625^2)$ 0.108 in^2
SHAFT COVER END	$(.4 - .156)(.312) + \frac{\pi}{2}(.156^2)$ $- \pi(.0625^2)$ 0.102 in^2

2. CROSS FLOW

COMPONENT	FLOW AREA
SHROUD	7.523 in^2 (plenum) 6.915 in^2 (piping)
FRONT COVER	$(.4)(1.25) - \frac{5(\pi)(.0625^2)}{2}$ 0.469 in^2
SHAFT COVER	$(2.464)(.4) - 9(\pi)(.0625^2)$ 0.875 in^2
END PLATE	$(1.03 - .4)(.8) + \frac{\pi}{2}(.4^2)$ 0.755 in^2

HYDRAULIC LOADS

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AXIAL FLOW LOADS ($C_b = 2.5$)
(lbf)

LOCATION OF DTT	SHROUD	FRONT COVER	TORSION BAR COV.	SHAFT COVER END
PC-1	21.4	28.7	3.2	3.0
PC-2	21.4	28.7	3.2	3.0
PC-3	21.4	28.7	3.2	3.0
BL-1	137.4	184.5	20.7	19.5
BL-2	137.4	184.5	20.7	19.5
CS-1	35.2	47.3	5.3	5.0

CROSS-FLOW LOADS ($C_b = 2.5$)
lbf

LOCATION OF DTT	SHROUD	FRONT COVER	SHAFT COVER	END PLATE
PC-1	206.1	14.0	26.1	22.5
PC-3	206.1	14.0	26.1	22.5

WELD AREAS

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WELD NO.	LENGTH (in)	AREA (in ²)
W-1 + W-10 (PC-1, PC-3)	6.06	0.364
W-1 + W-10 (ALL OTHERS)	3.25	0.195
W-2	0.942	0.047
W-3	1.26	0.040
W-4	2.50	0.080
W-5 + W-9	1.314 (gross) 0.76 (net)	0.082
W-6	0.64	0.021
W-7	0.736	0.024
W-8	0.978	0.031
NOTE: W-2 → W-9 ARE SAME FOR ALL METERS		

PRIMARY
STRESSES

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PRIMARY STRESS DUE TO AXIAL FLOW ONLY (psi)				
LOCATION OF DTT	SHROUD (W-1, W-10) K=1.0	FRONT COV (W-4) K=4.0	TOR. BAR COV. (W-6) K=4.0	SHAFT COV. END (W-8) K=4.0
PC-1	59.	1,436.	608.	388.
PC-2	110.	1,436.	608.	388.
PC-3	59.	1,436.	608.	388.
BL-1	704.	9,228.	3,936.	2,514.
BL-2	704.	9,228.	3,936.	2,514.
CS-1	181.	2,364.	1,008.	644.
TYPE OF STRESS	SHEAR	NORMAL	NORMAL	NORMAL

PRIMARY STRESS DUE TO CROSS-FLOW ONLY (psi)				
LOCATION OF DTT	SHROUD (W-1, W-10) K=4.0	FRONT COV. (W-4) K=1.0	SHAFT COV. (W-8) K=4.0	END PLATE (W-3, W-7) K=4.0
PC-1	2,264.	175.	1,273.	1,408.
PC-3	2,264.	175.	1,273.	1,408.
TYPE OF STRESS	NORMAL	SHEAR	SHEAR	NORMAL

K, Stress concentration factors based on Gott-4-70
and discussion with R. Rahl.

WELD EVALUATION

(Fatigue only)

Assumes 35m limit on $Q_{thermal}$ is not necessary and prediction of stress above 35m does not adversely affect fatigue evaluation.

PC-1 LOCATION

$$\Delta T = 240^{\circ}F$$

$$p_d = 11.92 \text{ psi}$$

$$C_d = 2.5$$

$$K = 4.0$$

RAHL, GOTT, "WORST CASE"

ALLOWABLE CYCLES
FOR PC-1 LOCATION

WELD NO	HYDRAULIC STRESS	THERMAL STRESS	STRESS INTENSITY (S) (psi)	ALLOWABLE # CYCLES
1, 10	CROSS FLOW $\sigma_N = 2,300$	$T = 34,700$	✓ 69,400.	$S_a = 32,000$ 2.5×10^5
2	0	$T = 269,000.$	✓ 269,000	$S_a = 124,000$ 600
3	CROSS FLOW $\sigma_N = 1,400.$	0	1400.	$> 10^6$
4	AXIAL FLOW $\sigma_N = 1,440.$	$T = 32,200$	✓ 64,400.	$S_a = 32,200$ 2.6×10^5
5, 9	CROSS FLOW $T = 1,273$	$T = 50,600$	✓ 104,000.	$S_a = 52,000$ 1.8×10^4
6	AXIAL FLOW $\sigma_N = 608$	$T = 31,300$	✓ 62,600.	$S_a = 31,300$ 2.8×10^5
7	CROSS FLOW $\sigma_N = 1,400$	$T = 60,800$	✓ 122,000.	$S_a = 61,000$ 8.5×10^3
8	AXIAL FLOW $\sigma_N = 388.$	0.	388.	$> 10^6$

ASSUMES ELASTIC PREDICTION IS VALID

FOR $Q_{TH} > 35_m$

$$35_m = 45,900 \text{ psi}$$

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BL-1 LOCATION

$\Delta T = 75^\circ$ (BASED ON BL-1 PRESS)

$p_d = 38.3 \text{ psi}$

$C_d = 2.5$

$K = 4.0$

$L.F. = 2.0$

"WORTH CASE", RDNL, GOTT.

WELD #	HYDRAULIC STRESS (AXIAL FLOW)	THERMAL STRESS	STRESS INTENSITY	# CYCLES
1, 10	$\tau = 704$	$T = 21,900$	$\sqrt{43,800}$	$S_a = 20,100$ $> 10^6$
2	0	$\sigma_n = 84,200$	$\sqrt{84,200}$	$S_a = 38,700$ 8.0×10^4
3	0	0	0	$S_a = 0$ $> 10^6$
4	$\sigma_n = 9,228$	$\tau = 19,100$	$\sqrt{22,200}$	$S_a = 19,200$ $> 10^6$
5, 9	0	$\tau = 15,800$	$\sqrt{31,600}$	$S_a = 14,500$ $> 10^6$
6	$\sigma_n = 3,936$	$\tau = 9,200$	$\sqrt{18,800}$	$S_a = 8,600$ $> 10^6$
7	0	$\tau = 19,000$	$\sqrt{38,000}$	$S_a = 17,500$ $> 10^6$
8	$\sigma_n = 3,514$	0	$\sqrt{3,514}$	$S_a = 1/50$ $> 10^6$

ASSUMES ELASTIC PREDICTION OF

S_a IS VALID FOR $Q_{TH} > 35_m$

APPENDIX B

SUPPORTING THERMAL/HYDRAULIC ANALYSIS

INTEROFFICE CORRESPONDENCE

date March 7, 1977
to R. L. Crumley
from K. A. Hedquist *K. A. Hedquist*
subject THERMAL ANALYSIS OF LOFT DTT AT LOCATION PC-1 and BL-1
OF L1-1 TEST KAH-1-77

References:

- a) "LOFT Piping Drag-Disk, Turbine Flow Meter Assembly",
ANC Drawing 204645, Rev. L, May 22, 1972.
- b) Personal Communication, J. S. Martinell to K. A. Hedquist
February 9, 1977.
- c) J. S. Martinell letter to R. L. Crumley; JSM-2-77, "Evaluation
of LOFT Piping Type DTT Shroud and Cover Welds", February 10, 1977.
- d) R. L. Moore, COUPLE II - A Two Dimensional or Axisymmetric
Finite Element Steady-State and Transient Heat Conduction
Code With Inverse Capabilities and Dynamic Dimensioning for
Use on an IBM 360/75 Computer, (To be published).
- e) S. A. Naff, Quick Look Report, LOFT Loss of Coolant
Experiment L1-1, March 11, 1976.
- f) Personal Communication, J. K. Jacoby to N. E. Pace,
February 2, 1977.
- g) R. T. French, An Evaluation of Piping Heat Transfer,
Piping Flow Regimes and Steam Generator Heat Transfer for
the Semiscale Mod-1 Isothermal Tests, ANCR-1229, August 1975.

This letter is to document the thermal transient analyses of the LOFT piping type DTT's as defined in References (a) and (b) which were done in support of the stress analysis as reported in Reference (c).

A horizontal cut through the DTT body and shroud was taken and a two dimensional symmetric finite element model was made (see Fig. 1 and 2). The small covers and extensions that protrude from the main body of the DTT were neglected in the computer model. They were taken into account by assuming the DTT body solid whereas it actually has small voids within. The model was used in the COUPLE II Code (Reference (d)) to obtain transient temperature histories throughout the body and shroud. Several computer runs were made using the fluid temperature histories at the PC-1 and BL-1 location from the LOFT L1-1 test (Reference (e)). The PC-1 location is the intact loop

Page 2
R. L. Crumley
March 7, 1977
KAH-1-77

cold leg vessel inlet and BL-1 is the broken loop cold leg vessel exit. The time scale of these temperature histories was modified by a factor of .73 to represent a larger break area (Reference (f)).

Since the heat transfer coefficients are difficult to obtain for the varied locations and surfaces of the DTT turbine meter, a lower limit of 400 Btu/hr ft² °F was used as a constant value during the LOCE transient for both locations (PC-1 and BL-1). Figure 3, taken from Reference (g), shows the measured piping heat transfer coefficient at the intact loop cold leg vessel inlet from the Semiscale test that corresponds to the LOFT L1-1 test. By using this lower limit, a slightly conservative estimate of the temperatures within the DTT body will result.

The stress analysis calculations required the difference between the shroud and the average body temperature. Temperatures at interior points within the DTT body and shroud were volume weighted to obtain an average temperature. Figures 4 and 6a show the fluid, average shroud, and average body temperatures for locations PC-1 and BL-1, respectively. The maximum difference between the average body and shroud temperature was 240°F for location PC-1 and 75°F for location BC-1. Figures 5 and 6b show the average body and shroud temperature difference throughout the transient. Lower temperature differences may be obtained by using higher film coefficients at times during the transient, but because of the uncertainty of calculating these coefficients, the conservative lower limit as shown in Figure 3 will result in a maximum bound for the shroud and body temperature difference.

KAH-prk

cc: R. D. Wesley* R. C. Guenzler*
K. B. Wilson* G. B. Shull*
N. E. Pace *NEP* H. A. Rau*
W. C. Kettenacker *wck* L. P. Leach*
J. S. Martinell J. R. Karvinen*
J. K. Jacoby* T. L. Kinnaman
S. A. Naff
K. A. Hedquist (2)
J. L. Liebenthal*

(* without attachment)

FIGURE 1 - LOFT DRAG DISK TURBINE FLOWMETER (DTT) BODY AND SHROUD

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FIGURE 2 - COUPLE II MODEL OF DRAG DISK TURBINE FLOWMETER (DTT) BODY AND SHROUD

FIGURE 3 - FILM COEFFICIENTS AT INTACT LOOP COLD LEG VESSEL INLET
FROM SEMISCALE TESTS (Reference (g) Figure 7)

FIGURE 4 LOFT DTT BODY / SHROUD TEMPERATURES
(CALCULATED FROM COURSE II COMPUTER RUN)
CONSTANT FILM COEFF. of 400 BTU/HR FT² °F

FLUID DATA FROM RC-8 TEST LL-1 TIME
MULTIPLIED BY .79 TO SIMULATE LARGER
FLECK AREA

KAH 6 FEB 77

FIGURE 5 LEFT DTT BODY AND SHROUD TEMPERATURE DIFFERENCE
LOCATION: PC-1
(CALCULATED FROM COUPLE II COMPUTER RUN)

KAH 6128 71

46 1320

FIGURE 6a (a) DT AVERAGE BODY SHROUD AND FLUID TEMPERATURE LOCATION 11.2 OF TEST 11.2 (h=400 BRINE FAN) (FROM COURSE 11 CONTINUED RUN)

FIGURE 6b (a) DT TEMPERATURE DIFFERENCE BETWEEN BODY AND SHROUD LOCATION 11.2

K-E 10 X 10 TO 1/2 INCH 7 X 10 INCHES
HAPPOLD & ESSER CO. MADE IN U.S.A.

Attachment
March 7, 1977
KAH-1-77
Page 1 of 10

THIS ATTACHMENT CONTAINS:

1. Method of Calculating the Average Body Temperature for the LOFT DTT
2. Input Echos of Data Used for Runs* 04 and 05, Locations PC-1 and BL-1
3. Listing of Model Nodes and Elements

* Note Runs 01 thru 03 used higher film coefficients that were not included as part of the report.

LTR 141-80

METHOD OF CALCULATING THE AVERAGE BODY TEMPERATURE OF LOFT DTT

AREA WEIGHTED TEMPERATURE AVERAGE

NODE LOCATIONS (INCHES)

	R	Z
5	.5394	0.0
48	.4046	.1067
102	.2697	.2400
134	.1349	.3200

AREA CALCULATIONS

$$\textcircled{A} \quad 1.1 * (.4 - .32) + 2 * (.32 * .1349) = .17434$$

$$\textcircled{B} \quad (1.1 - .1349 * 2) * (.32 - .24) + 2 * .24 * (.2697 - .1349) = .13112$$

$$\textcircled{C} \quad (1.1 - 2 * .2697) * (.24 - .1067) + 2 * .1067 * (.4046 - .2697) = .10352$$

$$\textcircled{D} \quad (1.1 - 2 * .4046) * .1067 = .03103$$

$$\text{TOTAL} \quad .4400 \text{ IN}^2$$

$$1.1 * .4 = .44 \text{ IN}^2 \text{ CHECK.}$$

LTR 141-80

AVERAGE BODY TEMPERATURE

$$T_{AVE} = \frac{(A) * T_{134} + (B) T_{102} + (C) T_{48} + (D) T_5}{(A) + (B) + (C) + (D)}$$

T_{NODE} WAS THE NODE TEMPERATURE
DURING THE TRANSIENT

AVERAGE SHROUD TEMPERATURE WAS
FOUND BY AVERAGING THE TEMPERATURES
OF NODE 193, 200, 223 and 230

$$T_{SHROUD} = (T_{193} + T_{200} + T_{223} + T_{230}) / 4$$

THE FOLLOWING 7 PAGES CONTAIN ECHOS
OF THE COUPLE II INPUT DATA FOR RUNS
04 and 05 WHICH CORRESPOND TO LOCATIONS
PC-1 and BL-1 of the LOFT 'LI-1 TEST.

THE FLUID TEMPERATURES AT THESE LOCATIONS
WERE USED. ALSO A LISTING OF THE NODE
AND ELEMENT INFORMATION IS GIVEN.

LTR 141-80

AVERAGE BODY TEMPERATURE

$$T_{AVE} = \frac{(A) * T_{134} + (B) T_{102} + (C) T_{48} + (D) T_5}{(A) + (B) + (C) + (D)}$$

T_{NODE} WAS THE NODE TEMPERATURE DURING THE TRANSIENT

AVERAGE SHROUD TEMPERATURE WAS FOUND BY AVERAGING THE TEMPERATURES OF NODE 193, 200, 223 and 230

$$T_{SHROUD} = (T_{193} + T_{200} + T_{223} + T_{230}) / 4$$

THE FOLLOWING 7 PAGES CONTAIN ECHOS OF THE COUPLE II INPUT DATA FOR RUNS 04 and 05 WHICH CORRESPOND TO LOCATIONS PC-1 and BL-1 OF THE LOFT 'LI-1 TEST. THE FLUID TEMPERATURES AT THESE LOCATIONS WERE USED. ALSO A LISTING OF THE NODE AND ELEMENT INFORMATION IS GIVEN.

000000001111111122222222333333334444444455555555666666777777778
1234567890123456789012345678901234567890123456789012345678901234567890

** INPUT ECHO RUN 04 ** COUPLE II CODE **

TITLE
LOFT DRAG DISK THREE DDT MAKE ASSEMBLY RUN 04
LOCE - ECC FEB. 3 1977 COUPLE II

AUTOMESH

30	16	4	10.	0.	0.	0.	0.	1
1	10.	0.	1	16	0.	.4		1
1	16	.0	.4	8	16	.944	.4	1
8	16	.944	.4	8	1	.944	0.00	1
10	16	1.007	.40	10	1	1.007	0.0	1
8	14	.944	.35	10	14	1.007	.35	1
10	16	1.007	.4	11	16	1.037	.4	1
11	16	1.037	.4	11	14	1.100	.35	1
10	14	1.007	.35	11	14	1.1	.35	1
11	14	1.1	.35	11	1	1.1	0.0	1
11	16	1.037	.4	20	16	1.7	.75	3
11	14	1.1	.35	20	14	1.7	.7	3
30	16	2.45	0.0	30	14	2.4	0.0	1
9	1	.9755	0.0	9	16	.9755	.4	1
8	1	.944	0.0	1	1	0.0	0.0	1

1	1	11	1	14	0.0
1	1	8	14	16	0.0
1	10	30	14	16	0.0
2	8	10	14	16	0.0

MATERIAL

2 1
1 1.0 316 STAINLESS STEEL
2.3148E-5 2.3148E-5 578.70E-6 1 1 2
2 1.0 GAP IN WALL
1.0E-7 1.0E-7 1.0E-7

STEP

0.0 50. 1.0 1 540. -10 2

FUNCTIONS

1	8	2			
200.	8.9	300.	9.35	400.	9.8
450.	10.	500.	10.23	550.	10.45
600.	10.7	650.	10.9		
2	8	2			
200.	57.494	300.	58.842	400.	60.123
450.	61.013	500.	61.664	550.	62.055
600.	62.663	650.	63.335		
3	9	1			
0.	540.	7.3	530.	14.6	520.
21.9	480.	25.55	400.	29.2	300.
32.85	200.	36.5	100.	37.96	70.
4	3	1			
0.0	400.	25.	400.	50.	400.

CONVECTSETS

00000000111111112222222233333333444444445555555566666666777777778
1234567890123456789012345678901234567890123456789012345678901234567890

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0000000001111111112222222223333333334444444445555555556666666667777777778
 1234567890123456789012345678901234567890123456789012345678901234567890

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1	1	1	16	1.5290E-6	4	1.0	3
1	16	8	16	1.5290E-6	4	1.0	3
8	14	8	16	1.5290E-6	4	1.0	3
8	14	10	14	1.5290E-6	4	1.0	3
10	14	10	16	1.5290E-6	4	1.0	3
10	16	30	16	1.5290E-6	4	1.0	3
11	1	11	14	1.5290E-6	4	1.0	3
11	14	30	14	1.5290E-6	4	1.0	3

PLOTS

4	1						
3							
600.	500.	450.	400.	350.	300.	250.	200.
150.	100.	50.					
1	6	11	16	21	26	31	41

COUPLE

END OF DATA

0000000001111111112222222223333333334444444445555555556666666667777777778
 1234567890123456789012345678901234567890123456789012345678901234567890

C O U P L E II

LOFT DRAG DISK THREE CDT RAKE ASSEMBLY RUN 04
 EOLE - ECC FEB. 3 1977 COUPLE II

B L A N K C A R D

94

5 4 10
 LTR 141-80

00000011111111112222222222333333333344444444445555555555666666666677777777778
 12345678901234567890123456789012345678901234567890123456789012345678901234567890

*** INPUT ECHO RUN OS *** COUPLE II CODE ***

TITLE
 LOFT DRAG DISK THREE DTT RAKE ASSEMBLY RUN OS
 LOCE - ECC FFB. 7 1977 COUPLE II

AUTOMESH

30	16	4	1	0.	0.	0.	0.	1
1	1	0.	0.	1	16	0.	.4	1
1	16	.0	.4	8	16	.944	.4	1
8	16	.944	.4	8	1	.944	0.00	1
10	16	1.007	.40	10	1	1.007	0.0	1
10	16	1.007	.4	11	16	1.037	.4	1
11	16	1.037	.4	11	14	1.100	.35	1
10	14	1.007	.35	11	14	1.1	.35	1
11	14	1.1	.35	11	1	1.1	0.0	1
11	16	1.037	.4	20	16	1.7	.75	3
11	14	1.1	.35	20	14	1.7	.7	3
30	16	2.45	0.0	30	14	2.4	0.0	1
9	1	.9755	0.0	9	16	.9755	.4	1
8	1	.944	0.0	1	1	0.0	0.0	1

1	1	11	1	14	0.0
1	1	8	14	16	0.0
1	10	30	14	16	0.0
2	8	10	14	16	0.0

MATERIAL

2	1	316 STAINLESS STEEL
1	1.0	578.70E-6
2.3148E-5	2.3148E-5	1 1 2
2	1.0	GAP IN WALL
1.0E-7	1.0E-7	1.0E-7

STEP	0.0	100.	2.0	1 540.	-10	2
------	-----	------	-----	--------	-----	---

FUNCTIONS

4	1	8	2		
200.	8.9	300.	9.35	400.	9.8
450.	10.	500.	10.23	550.	10.45
600.	10.7	650.	10.9		
2	8	2			
200.	57.494	300.	58.842	400.	60.123
450.	61.013	500.	61.664	550.	62.055
600.	62.683	650.	63.335		
3	11	1			
0.0	540.	7.3	535.	14.6	520.
21.9	480.	29.2	415.	36.5	370.
49.6	340.	52.6	280.	54.8	340.
73.0	320.	110.	310.		
4	3	1			
0.0	400.	25.	400.	50.	400.

CONVECT SETS

000000000111111111112222222222333333333344444444445555555555666666666677777777778
 12345678901234567890123456789012345678901234567890123456789012345678901234567890

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 12345678901234567890123456789012345678901234567890123456789012345678901234567890

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1	1	1	16	1.9290E-6	4	1.0	3
1	16	8	16	1.9290E-6	4	1.0	3
8	14	8	16	1.9290E-6	4	1.0	3
8	14	10	14	1.5290E-6	4	1.0	3
10	14	10	16	1.9290E-6	4	1.0	3
10	16	30	16	1.9290E-6	4	1.0	3
11	1	11	14	1.9290E-6	4	1.0	3
11	14	30	14	1.9290E-6	4	1.0	3

PLOTS

	600.	500.	450.	400.	350.	300.	250.	200.
1	1	6	11	16	21	26	31	41

COUPLE

END OF DATA

0000000001111111112222222222333333333344444444445555555555666666666677777777778
 12345678901234567890123456789012345678901234567890123456789012345678901234567890

COUPLE II

LOFT DRAG DISK THREE DTT RAKE ASSEMBLY RUN 05
 LOCE - ECC FEB. 7 1977 COUPLE II

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BLANK CARD

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MESH - JTPUT DATA
COUPLE II

** MODEL NODES ** LOFT DTT **

LOFT DRAG DISK THREE DYT RAKE ASSEMBLY
LDCE - ECC FEB. 7 1977

RUN 05
COUPLE II

NODE DATA

NODE NUMBERS, I-J, R-Z COORDINATE INFORMATION

I	J	NODE	R	Z	I	J	NODE	R	Z	I	J	NODE	R	Z
1	1	1	0.0	0.0	2	1	2	1.349E-01	0.0	3	1	3	2.697E-01	0.0
4	1	4	4.046E-01	0.0	5	1	5	5.394E-01	0.0	6	1	6	6.743E-01	0.0
7	1	7	8.091E-01	0.0	8	1	8	9.440E-01	0.0	9	1	9	9.755E-01	0.0
10	1	10	1.007E 00	0.0	11	1	11	1.100E 00	0.0					
1	2	12	0.0	2.667E-02	2	2	13	1.349E-01	2.667E-02	3	2	14	2.697E-01	2.667E-02
4	2	15	4.046E-01	2.666E-02	5	2	16	5.394E-01	2.667E-02	6	2	17	6.743E-01	2.666E-02
7	2	18	8.091E-01	2.667E-02	8	2	19	9.440E-01	2.667E-02	9	2	20	9.755E-01	2.667E-02
10	2	21	1.007F 00	2.667E-02	11	2	22	1.100F 00	2.692F-02					
1	3	23	0.0	5.333E-02	2	3	24	1.349E-01	5.334E-02	3	3	25	2.697E-01	5.333E-02
4	3	26	4.046E-01	5.333E-02	5	3	27	5.394E-01	5.333E-02	6	3	28	6.743E-01	5.333E-02
7	3	29	8.091E-01	5.333E-02	8	3	30	9.440E-01	5.333E-02	9	3	31	9.755E-01	5.333E-02
10	3	32	1.007E 00	5.333E-02	11	3	33	1.100E 00	5.385E-02					
1	4	34	0.0	8.000E-02	2	4	35	1.348E-01	7.999E-02	3	4	36	2.697E-01	7.999E-02
4	4	37	4.046E-01	7.999E-02	5	4	38	5.394E-01	8.000E-02	6	4	39	6.743E-01	8.000F-02
7	4	40	8.091E-01	8.000E-02	8	4	41	9.440E-01	8.000E-02	9	4	42	9.755E-01	8.000E-02
10	4	43	1.007E 00	8.000F-02	11	4	44	1.100E 00	8.077E-02					
1	5	45	0.0	1.067E-01	2	5	46	1.349E-01	1.067E-01	3	5	47	2.697E-01	1.067E-01
4	5	48	4.046E-01	1.067E-01	5	5	49	5.394E-01	1.067E-01	6	5	50	6.743E-01	1.067E-01
7	5	51	8.091E-01	1.067E-01	8	5	52	9.440E-01	1.067E-01	9	5	53	9.755E-01	1.067E-01
10	5	54	1.007F 00	1.067E-01	11	5	55	1.100E 00	1.077E-01					
1	6	56	0.0	1.333E-01	2	6	57	1.349E-01	1.333F-01	3	6	58	2.697E-01	1.333E-01
4	6	59	4.046E-01	1.333E-01	5	6	60	5.394E-01	1.333E-01	6	6	61	6.743E-01	1.333E-01
7	6	62	8.091E-01	1.333E-01	8	6	63	9.440E-01	1.333E-01	9	6	64	9.755E-01	1.333E-01
10	6	65	1.007E 00	1.333E-01	11	6	66	1.100E 00	1.346E-01					
1	7	67	0.0	1.600E-01	2	7	68	1.349E-01	1.600E-01	3	7	69	2.697E-01	1.600E-01
4	7	70	4.046E-01	1.600E-01	5	7	71	5.394E-01	1.600E-01	6	7	72	6.743E-01	1.600E-01
7	7	73	8.091E-01	1.600E-01	8	7	74	9.440E-01	1.600E-01	9	7	75	9.755E-01	1.600E-01
10	7	76	1.007E 00	1.600E-01	11	7	77	1.100E 00	1.615E-01					
1	8	78	0.0	1.867E-01	2	8	79	1.349E-01	1.867E-01	3	8	80	2.697E-01	1.867E-01
4	8	81	4.046E-01	1.867E-01	5	8	82	5.394E-01	1.867E-01	6	8	83	6.743E-01	1.867E-01
7	8	84	8.091E-01	1.867E-01	8	8	85	9.440E-01	1.867E-01	9	8	86	9.755E-01	1.867E-01
10	8	87	1.007E 00	1.867E-01	11	8	88	1.100E 00	1.885E-01					
1	9	89	0.0	2.133E-01	2	9	90	1.349E-01	2.133E-01	3	9	91	2.697E-01	2.133E-01
4	9	92	4.046E-01	2.133E-01	5	9	93	5.394E-01	2.133E-01	6	9	94	6.743E-01	2.133E-01
7	9	95	8.091E-01	2.133E-01	8	9	96	9.440E-01	2.133E-01	9	9	97	9.755E-01	2.133E-01
10	9	98	1.007E 00	2.133E-01	11	9	99	1.100F 00	2.154E-01					
1	10	100	0.0	2.400E-01	2	10	101	1.349E-01	2.400F-01	3	10	102	2.697E-01	2.400E-01
4	10	103	4.046E-01	2.400F-01	5	10	104	5.394E-01	2.400E-01	6	10	105	6.743E-01	2.400E-01
7	10	106	8.091E-01	2.400E-01	8	10	107	9.440E-01	2.400E-01	9	10	108	9.755E-01	2.400E-01
10	10	109	1.007E 00	2.400E-01	11	10	110	1.100E 00	2.423E-01					
1	11	111	0.0	2.667E-01	2	11	112	1.349E-01	2.667E-01	3	11	113	2.697E-01	2.667E-01
4	11	114	4.046E-01	2.667E-01	5	11	115	5.394E-01	2.667E-01	6	11	116	6.743E-01	2.667E-01
7	11	117	8.091E-01	2.667E-01	8	11	118	9.440E-01	2.667E-01	9	11	119	9.755E-01	2.667E-01

I	J	NODE	P	Z	I	J	NODE	P	Z	I	J	NODE	P	Z
10	11	120	1.007E 00	2.667E-01	11	11	121	1.100E 00	2.692E-01	3	12	124	2.697E-01	2.933E-01
1	12	122	0.0	2.933E-01	2	12	123	1.349E-01	2.933E-01	6	12	127	6.743E-01	2.933E-01
4	12	125	4.046E-01	2.933E-01	5	12	126	5.394E-01	2.933E-01	9	12	130	9.755E-01	2.933E-01
7	12	128	8.091E-01	2.933E-01	8	12	129	9.440E-01	2.933E-01					
10	12	131	1.007E 00	2.933E-01	11	12	132	1.100E 00	2.962E-01	3	13	135	2.697E-01	3.200E-01
1	13	133	0.0	3.200E-01	2	13	134	1.349E-01	3.200E-01	6	13	138	6.743E-01	3.200E-01
4	13	136	4.046E-01	3.200E-01	5	13	137	5.394E-01	3.200E-01	9	13	141	9.755E-01	3.200E-01
7	13	139	8.091E-01	3.200E-01	8	13	140	9.440E-01	3.200E-01					
10	13	142	1.007E 00	3.200E-01	11	13	143	1.100E 00	3.231E-01	3	14	146	2.697E-01	3.467E-01
1	14	144	0.0	3.467E-01	2	14	145	1.349E-01	3.467E-01	6	14	149	6.743E-01	3.467E-01
4	14	147	4.046E-01	3.467E-01	5	14	148	5.394E-01	3.467E-01	9	14	152	9.755E-01	3.467E-01
7	14	150	8.091E-01	3.467E-01	8	14	151	9.440E-01	3.467E-01	12	14	155	1.153E 00	4.299E-01
10	14	153	1.007E 00	3.500E-01	11	14	154	1.100E 00	3.500E-01	15	14	158	1.372E 00	6.157E-01
13	14	156	1.217E 00	5.017E-01	14	14	157	1.291E 00	5.640E-01	18	14	161	1.646E 00	6.976E-01
16	14	159	1.459E 00	6.556E-01	17	14	160	1.551E 00	6.831E-01	21	14	164	1.931E 00	6.620E-01
19	14	162	1.743E 00	6.989E-01	20	14	163	1.838E 00	6.870E-01	24	14	167	2.177E 00	5.147E-01
22	14	165	2.019E 00	6.244E-01	23	14	166	2.102E 00	5.750E-01	27	14	170	2.343E 00	2.808E-01
25	14	168	2.243E 00	4.447E-01	26	14	169	2.298E 00	3.662E-01	30	14	173	2.400E 00	0.0
28	14	171	2.375E 00	1.902E-01	29	14	172	2.394E 00	9.596E-02	3	15	176	2.697E-01	3.733E-01
1	15	174	0.0	3.733E-01	2	15	175	1.349E-01	3.733E-01	6	15	179	6.743E-01	3.733E-01
4	15	177	4.046E-01	3.733E-01	5	15	178	5.394E-01	3.733E-01	9	15	182	9.755E-01	3.733E-01
7	15	180	8.091E-01	3.733E-01	8	15	181	9.440E-01	3.733E-01	12	15	185	1.130E 00	4.528E-01
10	15	183	1.007E 00	3.733E-01	11	15	184	1.068E 00	3.750E-01	15	15	188	1.359E 00	6.371E-01
13	15	186	1.198E 00	5.240E-01	14	15	187	1.275E 00	5.859E-01	18	15	191	1.642E 00	7.166E-01
16	15	189	1.450E 00	6.763E-01	17	15	190	1.544E 00	7.030E-01	21	15	194	1.933E 00	6.774E-01
19	15	192	1.741E 00	7.168E-01	20	15	193	1.838E 00	7.037E-01	24	15	197	2.185E 00	5.260E-01
22	15	195	2.024E 00	6.385E-01	23	15	196	2.108E 00	5.877E-01	27	15	200	2.356E 00	2.871E-01
25	15	198	2.253E 00	4.544E-01	26	15	199	2.310E 00	3.742E-01	30	15	203	2.425E 00	0.0
28	15	201	2.390E 00	1.945E-01	29	15	202	2.412E 00	9.819E-02	3	16	206	2.697E-01	4.000E-01
1	16	204	0.0	4.000E-01	2	16	205	1.349E-01	4.000E-01	6	16	209	6.743E-01	4.000E-01
4	16	207	4.046E-01	4.000E-01	5	16	208	5.394E-01	4.000E-01	9	16	212	9.755E-01	4.000E-01
7	16	210	8.091E-01	4.000E-01	8	16	211	9.440E-01	4.000E-01	12	16	215	1.099E 00	4.823E-01
10	16	213	1.007E 00	4.000E-01	11	16	214	1.037E 00	4.000E-01	15	16	218	1.340E 00	6.703E-01
13	16	216	1.171E 00	5.556E-01	14	16	217	1.252E 00	6.186E-01	18	16	221	1.637E 00	7.489E-01
16	16	219	1.435E 00	7.097E-01	17	16	220	1.535E 00	7.360E-01	21	16	224	1.940E 00	7.055E-01
19	16	222	1.739E 00	7.480E-01	20	16	223	1.841E 00	7.335E-01	24	16	227	2.202E 00	5.471E-01
22	16	225	2.034E 00	6.646E-01	23	16	226	2.122E 00	6.114E-01	27	16	230	2.382E 00	2.987E-01
25	16	228	2.273E 00	4.726E-01	26	16	229	2.333E 00	3.893E-01	30	16	233	2.450E 00	0.0
28	16	231	2.418E 00	2.025E-01	29	16	232	2.441E 00	1.023E-01					

BLANK CARD

ELEMENT DATA

** MODEL ELEMENTS ** LOFT DTT **

ELEMENT NO(EL), CORNER NODAL NOS(I,J,K,L), MATERIAL, NO(MAT), AND CONDUCTIVITY ANGLES(BETA)

EL	I	J	K	L	MAT	BETA	EL	I	J	K	L	MAT	BETA	EL	I	J	K	L	MAT	BETA	EL	I	J	K	L	MAT	BETA
1	1	2	13	12	1	0.	2	2	3	14	13	1	0.	3	3	4	15	14	1	0.	4	4	5	16	15	1	0.
5	5	6	17	16	1	0.	6	6	7	18	17	1	0.	7	7	8	19	18	1	0.	8	8	9	20	19	1	0.
9	9	10	21	20	1	0.	10	10	11	22	21	1	0.	11	12	13	24	23	1	0.	12	13	14	25	24	1	0.
13	14	15	26	25	1	0.	14	15	16	27	26	1	0.	15	16	17	28	27	1	0.	16	17	18	29	28	1	0.
17	18	19	30	29	1	0.	18	19	20	31	30	1	0.	19	20	21	32	31	1	0.	20	21	22	33	32	1	0.
21	23	24	35	34	1	0.	22	24	25	36	35	1	0.	23	25	26	37	36	1	0.	24	26	27	38	37	1	0.
25	27	28	39	38	1	0.	26	28	29	40	39	1	0.	27	29	30	41	40	1	0.	28	30	31	42	41	1	0.
29	31	32	43	42	1	0.	30	32	33	44	43	1	0.	31	34	35	46	45	1	0.	32	35	36	47	46	1	0.
33	36	37	48	47	1	0.	34	37	38	49	48	1	0.	35	38	39	50	49	1	0.	36	39	40	51	50	1	0.
37	40	41	52	51	1	0.	38	41	42	53	52	1	0.	39	42	43	54	53	1	0.	40	43	44	55	54	1	0.
41	45	46	57	56	1	0.	42	46	47	58	57	1	0.	43	47	48	59	58	1	0.	44	48	49	60	59	1	0.
45	49	50	61	60	1	0.	46	50	51	62	61	1	0.	47	51	52	63	62	1	0.	48	52	53	64	63	1	0.
49	53	54	65	64	1	0.	50	54	55	66	65	1	0.	51	56	57	68	67	1	0.	52	57	58	69	68	1	0.
53	58	59	70	69	1	0.	54	59	60	71	70	1	0.	55	60	61	72	71	1	0.	56	61	62	73	72	1	0.
57	62	63	74	73	1	0.	58	63	64	75	74	1	0.	59	64	65	76	75	1	0.	60	65	66	77	76	1	0.
61	67	68	79	78	1	0.	62	68	69	80	79	1	0.	63	69	70	81	80	1	0.	64	70	71	82	81	1	0.
65	71	72	83	82	1	0.	66	72	73	84	83	1	0.	67	73	74	85	84	1	0.	68	74	75	86	85	1	0.
69	75	76	87	86	1	0.	70	76	77	88	87	1	0.	71	78	79	90	89	1	0.	72	79	80	91	90	1	0.
73	80	81	92	91	1	0.	74	81	82	93	92	1	0.	75	82	83	94	93	1	0.	76	83	84	95	94	1	0.
77	84	85	96	95	1	0.	78	85	86	97	96	1	0.	79	86	87	98	97	1	0.	80	87	88	99	98	1	0.
81	89	90	101	100	1	0.	82	90	91	102	101	1	0.	83	91	92	103	102	1	0.	84	92	93	104	103	1	0.
85	93	94	105	104	1	0.	86	94	95	106	105	1	0.	87	95	96	107	106	1	0.	88	96	97	108	107	1	0.
89	97	98	109	108	1	0.	90	98	99	110	109	1	0.	91	100	101	112	111	1	0.	92	101	102	113	112	1	0.
93	102	103	114	113	1	0.	94	103	104	115	114	1	0.	95	104	105	116	115	1	0.	96	105	106	117	116	1	0.
97	106	107	118	117	1	0.	98	107	108	119	118	1	0.	99	108	109	120	119	1	0.	100	109	110	121	120	1	0.
101	111	112	123	122	1	0.	102	112	113	124	123	1	0.	103	113	114	125	124	1	0.	104	114	115	126	125	1	0.
105	115	116	127	126	1	0.	106	116	117	128	127	1	0.	107	117	118	129	128	1	0.	108	118	119	130	129	1	0.
109	119	120	131	130	1	0.	110	120	121	132	131	1	0.	111	122	123	134	133	1	0.	112	123	124	135	134	1	0.
113	124	125	136	135	1	0.	114	125	126	137	136	1	0.	115	126	127	138	137	1	0.	116	127	128	139	138	1	0.
117	128	129	140	139	1	0.	118	129	130	141	140	1	0.	119	130	131	142	141	1	0.	120	131	132	143	142	1	0.
121	133	134	145	144	1	0.	122	134	135	146	145	1	0.	123	135	136	147	146	1	0.	124	136	137	148	147	1	0.
125	137	138	149	148	1	0.	126	138	139	150	149	1	0.	127	139	140	151	150	1	0.	128	140	141	152	151	1	0.
129	141	142	153	152	1	0.	130	142	143	154	153	1	0.	131	144	145	175	174	1	0.	132	145	146	176	175	1	0.
133	146	147	177	176	1	0.	134	147	148	178	177	1	0.	135	148	149	179	178	1	0.	136	149	150	180	179	1	0.
137	150	151	181	180	1	0.	138	151	152	182	181	2	0.	139	152	153	183	182	2	0.	140	153	154	184	183	1	0.
141	154	155	185	184	1	0.	142	155	156	186	185	1	0.	143	156	157	187	186	1	0.	144	157	158	188	187	1	0.
145	158	159	189	188	1	0.	146	159	160	190	189	1	0.	147	160	161	191	190	1	0.	148	161	162	192	191	1	0.
149	162	163	193	192	1	0.	150	163	164	194	193	1	0.	151	164	165	195	194	1	0.	152	165	166	196	195	1	0.
153	166	167	197	196	1	0.	154	167	168	198	197	1	0.	155	168	169	199	198	1	0.	156	169	170	200	199	1	0.
157	170	171	201	200	1	0.	158	171	172	202	201	1	0.	159	172	173	203	202	1	0.	160	174	175	205	204	1	0.
161	175	176	206	205	1	0.	162	176	177	207	206	1	0.	163	177	178	208	207	1	0.	164	178	179	209	208	1	0.
165	179	180	210	209	1	0.	166	180	181	211	210	1	0.	167	181	182	212	211	2	0.	168	182	183	213	212	2	0.
169	183	184	214	213	1	0.	170	184	185	215	214	1	0.	171	185	186	216	215	1	0.	172	186	187	217	216	1	0.
173	187	188	218	217	1	0.	174	188	189	219	218	1	0.	175	189	190	220	219	1	0.	176	190	191	221	220	1	0.
177	191	192	222	221	1	0.	178	192	193	223	222	1	0.	179	193	194	224	223	1	0.	180	194	195	225	224	1	0.
181	195	196	226	225	1	0.	182	196	197	227	226	1	0.	183	197	198	228	227	1	0.	184	198	199	229	228	1	0.
185	199	200	230	229	1	0.	186	200	201	231	230	1	0.	187	201	202	232	231	1	0.	188	202	203	233	232	1	0.

TOTAL NUMBER OF NODES = 233
TOTAL NUMBER OF ELEMENT = 188

Aerojet Nuclear Company

Interoffice Correspondence

June 9, 1976

L. J. Ybarrondo
CSC-TSB

LOFT DRAG DISC TURBINE METER SHROUD WELDS - Gott-4-76

As a result of the failure of the LOFT PC-3 drag disc turbine (DDT) flowmeter shroud, calculations have been made to determine the weld area required on the shrouds of the other DDT flowmeters to prevent another similar occurrence. The maximum fluid forces on the flowmeters in the blowdown pipe, operating loop, and core simulator locations have been estimated, at their respective locations, for both best estimate (nominal) and worst case conditions during steady state, blowdown, or ECC injection conditions. The stresses in the shroud welds have been calculated on each flowmeter for the following conditions: 1) present condition taking credit only for the estimated good weld area, 2) best fix assuming all good edge remaining on the flowmeter body can be welded, and 3) proposed new weld design. The following table summarizes the safety factors for each flowmeter and each condition.

It can be seen that the PC-2 flowmeter is the only one with adequate welds and can be reinstalled into the loop with no rework. Also, PC-1 and BL-2 cannot be repaired without removing the shroud and rewelding. Flowmeter BL-1 can be fixed by additional welding (.035 inch throat thickness new weld, total length 1.73 inch outboard side and 1.46 inch inboard side) without removing the shroud.

The proposed new weld design should be satisfactory for the core simulator and BL-2 flowmeters. The safety factors listed for the PC-1 flowmeter are based on loads estimated at the PC-3 location. However, the loads on the PC-1 flowmeter should be between those estimated at the PC-3 and PC-2 locations. Therefore, the proposed new weld design should be satisfactory for the PC-1 flowmeter, particularly in view of the fact that the proposed weld design provides more weld area than presently exists on the PC-1 shroud, and that the PC-1 flowmeter has remained intact during the L1-1 and L1-2 blowdowns.

For the DDT flowmeter at location PC-3, the highest forces on the shroud should occur during normal operation at the highest pump speed. The flow at PC-3 will be highly turbulent and swirling effects caused by the 90° bend at the steam generator outlet will probably not be damped out at the PC-3 location. The actual flow pattern at the PC-3 location is unknown. Also, vibration forces caused by turbulence cannot be defined.

Before the failure of the PC-3 meter, two meters had been installed in the PC-3 location. During steady state operation, both of these meters measured a velocity about half that measured at PC-1 and PC-2. This indicates that a large amount of crossflow was occurring at the PC-3 meter preventing a good velocity measurement by this instrument. Also, crossflow on the PC-3 shroud will result in a much higher fluid force than flow parallel to the shroud would give. Due to the uncertainty in determining the maximum fluid and vibration forces on the PC-3 flowmeter, there is still a significant risk that the PC-3 flowmeter may not stay intact for extended operation. Also, since there are good indications that the PC-3 flowmeter is in a poor location to obtain a good flow measurement, it is strongly recommended that the PC-3 flowmeter not be installed in the LOFT primary coolant system for either steady state or blowdown operation.

Recommendations

- CS: Attach shroud with new procedure calling for 3.5 inch weld of .035 inch minimum thickness.
- PG-1: Attach shroud with new procedure or install PC-3 instrument here with added weld (minimum 1.29 inch outboard and 1.46 inch inboard).
- PC-2: OK as is.
- PC-3: Omit instrument at this location or use full length welds on shroud.
- BL-1: Add weld to present shroud (minimum length of new weld 1.73 inch outboard and 1.46 inch inboard).
- BL-2: Attach shroud with new procedure calling for 3.5 inch weld of .035 inch minimum thickness.

The assumptions and calculations for this analysis are shown in the attachment. Best estimate and worst case values used for various factors in the analysis are given in the attachment.

R. C. Gottula

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Thermal Analysis Branch

R. G. Rahl
R. G. Rahl
Applied Mechanics Branch

jh

cc: LFBurdge
HMBurton
RLGump

RCGuenzler
DWHood
JRKarvinen

JLLiebenthal
CAMoore
MLStanley

RPWadkins
RCGottula
RGRahl
LPLeach

SUMMARY OF SAFETY FACTORS FOR SHROUD WELDS

L. J. Ybarra
Gott-4-76
June 9, 1976
Page 3

LOCATION	LOADS (lbs)		AREA REQ'D		PRESENT		BEST FIX**		NEW DESIGN	
	Nominal	Worst	Nominal	Worst	S.F.N	S.F.W	S.F.N (L _{NW})*	S.F.W (L _{NW})*	S.F.N	S.F.W
CS-1	21.1	41.6	.0070	.0221	-	-	-	-	17.5	4.7
PC-1***	152.8	254.7	.0508	.1355	0	0	.6(⁰ _{.23})	.2(⁰ _{.23})	2.4	.8
PC-2	12.8	25.0	.0043	.0133	10.1	3.4	-	-	28.5	7.9
PC-3	152.8	254.7	.0508	.1355	.14	.05	2.2(^{1.31} _{1.46})	.7(^{1.29} _{1.46})	2.4	.8
BL-1	69.8	137.4	.0232	.0731	.4	.1	5.4(^{1.69} _{1.46})	1.5(^{1.73} _{1.46})	5.3	1.4
BL-2	69.8	137.4	.0232	.0731	1.6	.04	1.7(^{.5} ₀)	.5(^{.5} ₀)	5.3	1.4
Consider PC-3 Instr in PC-2 Location	12.8	25.0	.0043	.0133	1.6	0.5	24.9(^{1.31} _{1.46})	7.2(^{1.29} _{1.46})	-	-

***These loads are thought to be between PC-2 and PC-3 load values.

**Best Fix assumes good edges welded as indicated by L_{NW}

*Length of additional new weld (outboard add. weld)
(inboard add. weld) (inches)

LTR 141-80

CALCULATIONS FOR LOFT DRAG DISC
TURBINE METER SHROUD WELDS

CONTENTS

- I. Summary Table of Safety Factors
- II. Basic Assumptions and Definitions Used in This Analysis
- III. Fluid Loads on DDT Shroud
- IV. Parallel Flow Frontal Area Calculations
- V. "New Design" (3.5 inch total weld length x .035 inch thickness)
Evaluation
- VI. Present Acceptability Evaluation
- VII. Shaft Cover and Front Cover Piece Welds

I. SUMMARY OF SAFETY FACTORS FOR SHROUD WELDS

LOCATION	LOADS (lbs)		AREA REQ'D (in ²)		PRESENT		BEST FIX **		NEW DESIGN	
	NOMINAL	WORST	NOM	WORST	S.F. _N	S.F. _W	S.F. _N (L _{NW})*	S.F. _W (L _{NW})*	S.F. _N	S.F. _W
CS-1	21.1	41.6	.0070	.0221	—	—	—	—	17.5	4.7
PC-1 ***	152.8	254.7	.0508	.1355	0	0	.6 (0 .23)	.2 (0 .23)	2.4	.8
PC-2	12.8	25.0	.0043	.0133	10.1	3.4	—	—	28.5	7.9
PC-3	152.8	254.7	.0508	.1355	.14	.05	2.2 (1.31 1.46)	.7 (1.29 1.46)	2.4	.8
BL-1	69.8	137.4	.0232	.0731	.4	.1	5.4 (1.69 1.46)	1.5 (1.73 1.46)	5.3	1.4
BL-2	69.8	137.4	.0232	.0731	.1	.04	1.7 (.5 0)	.5 (.5 0)	5.3	1.4
Consider PC-3 instr. in PC-2 location	12.8	25.0	.0043	.0133	1.6	0.5	24.9 (1.31 1.46)	7.2 (1.29 1.46)		

*** These Loads are thought to be between PC-2 & PC-3 load values

** Best Fix Assumes Good Edges Welded As Indicated By L_{NW}

* Length of Additional New Weld (outboard add. weld
inboard " ") (in.)

BY: PER DATE: 6-7-76 SUBJECT: LOFT PLATE Meter SHEET NO. 3 OF 3
CHKD. BY: DATE SHROUDS JOB NO. LTR 141-80

II. BASIC ASSUMPTIONS AND DEFINITIONS USED IN THIS INVESTIGATION

SAFETY FACTOR (S.F.): Defined in this case as
 allowable stress/calculated stress

ALLOWABLE STRESS: AISC allowable shear stress of $0.4F_y$ used where F_y = mat'l yield stress (304SS) at $550^\circ\text{F} = 18,800\text{psi}$
 $\therefore$ allowable stress = $.4(18800) = 7520\text{psi}$

NOMINAL CASE: Nominal values are used for parameters listed below

WORST CASE: Conservative error limits are added to nominal values

Parameter	Nominal	Worst
Drag Coefficient (C_D)	1.5	2.5
New Weld Min Thickness	.035	.030
Old Weld Min Thickness	.020	.020
Stress Concentration Factor	2.5	4.0
Water Density	measured value	$+0.6 \text{ #/ft}^3$
Flow rate	measured values	$+8 \%$

NEW DESIGN: Calls for 3.5" total weld length

PRESENT WELDS: Evaluation based on measured weld lengths excluding "burnouts" and "cold lap" and assuming each side must take $\frac{1}{2}$ load

III.

PROBLEM: DETERMINE THE MAXIMUM FLUID FORCE ON EACH FLOW METER SHROUD TO PREDICT THE REQUIRED WELD AREA.

1. CORE SIMULATOR

STEADY STATE VELOCITIES ARE HIGHER THAN THOSE DURING BLOWDOWN.

MAX. VEL PRIOR TO LI-1 = 34 FT/SEC AT A LOOP FLOW RATE OF 2.13×10^6 LB/HR.

∴ FOR PUMPS OPERATING AT HIGH SPEED WITH LOOP FLOW = 3.9×10^6 LB/HR:

$$\text{MAX. VEL.} = \frac{3.9}{2.13} (34) = 62.25 \text{ FT/SEC}$$

$$\rho = 47 \text{ LB/FT}^3$$

$$(\rho V^2)_{\text{MAX}} = (47)(62.25)^2 = 182,128 \text{ LB/FT-SEC}^2$$

ASSUME FLOW PARALLEL TO SHROUD:

$$\begin{aligned} \text{NOMINAL } C_D &= 1.5 \\ \text{WORST CASE } C_D &= 2.5 \end{aligned}$$

$$\begin{aligned} \text{SHROUD FRONTAL AREA} &= .7174 \text{ IN}^2 \\ &(\text{SEE P. 11}) \end{aligned}$$

$$F_{\text{NOM.}} = \frac{C_D \rho V^2 A}{2gc} = \frac{(1.5)(47)(62.25)^2 (.7174)}{(144)(64.4)} = \underline{\underline{21.13 \text{ LB F}}}$$

ASSUME 8% ERROR ON VEL. MEASUREMENT AND 16 LB/FT³ ON DENSITY:

$$F_{\text{WORST CASE}} = \frac{(2.5)(47.6)(67.23)^2 (.7174)}{(144)(64.4)} = \underline{\underline{41.61 \text{ LB F}}}$$

2. BLOWDOWN PIPE (BL-1 AND BL-2)

HIGHEST PV^2 IS DURING BLOWDOWN.

MEASURED SPIKE FOR L1-2 COLD LEG = 162,000 lbm/ft-sec^2
WITH DRAG DISC.

DENSITOMETER + TURBINE MEASUREMENTS GIVE:

$$PV^2 = (47)(80)^2 = 300,800 \text{ lbm/ft-sec}^2$$

ASSUME 8% MEASUREMENT ERROR ON VEL.
AND .6 lb/ft^3 ON DENSITY;

$$(PV^2)_{\text{WORST CASE}} = (47.6)(86.4)^2 = 355,332 \text{ lbm/ft-sec}^2$$

ASSUME FLOW PARALLEL TO SHROUD.

NOMINAL $C_D = 1.5$

WORST CASE $C_D = 2.5$

SHROUD FRONTAL AREA = .7174 in^2

$$F_{\text{NOM.}} = \frac{(1.5)(47)(80)^2(.7174)}{(144)(64.4)} = 34.9 \text{ lbf}$$

WITH DYNAMIC LOAD FACTOR = 2, $F_{\text{NOM.}} = 69.81 \text{ lbf}$

$$F_{\text{WORST CASE}} = \frac{(2.5)(47.6)(86.4)^2(.7174)}{(144)(64.4)} = 68.72 \text{ lbf}$$

WITH DYNAMIC LOAD FACTOR = 2, $F_{\text{WORST CASE}} = 137.4 \text{ lbf}$

3. OPERATING LOOP

- (a) DURING LI-1 ECC INJECTION, VELOCITY SPIKES OF 115 FT/SEC WERE SEEN WITH $\rho = .71 \text{ LBM/FT}^3$.

$$\Rightarrow \rho V^2 = (.71)(115)^2 = 9390 \text{ LBM/FT-SEC}^2$$

THIS IS A VERY LOW MOMENTUM FLUX.

THE HIGHEST MOM. FLUX OCCURS DURING HIGH SPEED PUMP TESTS.

- (b) THE HIGHEST FORCES ON PC-1, PC-2, AND PC-3 FLOW METERS OCCUR DURING STEADY STATE OPERATION. THE HIGHEST VELOCITY MEASURED DURING HIGH SPEED PUMP TESTS WAS 48.5 FT/SEC AT PC-1. ASSUMING AN 8% ERROR, THE MAXIMUM CENTERLINE VELOCITY THAT CAN OCCUR IN THE PRIMARY PIPE IS 52.4 FT/SEC.

TO DETERMINE THE FLUID FORCE ON THE SHROUD, THE DIRECTION OF FLUID FLOW ON THE SHROUD MUST BE KNOWN. THE FLOW AT PC-3 WILL BE HIGHLY TURBULENT AND SWIRLING EFFECTS CAUSED BY THE 90° BEND AT THE STEAM GENERATOR OUTLET WILL PROBABLY NOT BE DAMPED OUT AT THE PC-3 LOCATION. THE ACTUAL FLOW PATTERN AT THE PC-3 LOCATION IS UNKNOWN. ALSO, VIBRATION FORCES CAUSED BY TURBULENCE CANNOT BE DEFINED.

BEFORE THE FAILURE OF THE PC-3 METER, TWO METERS HAD BEEN INSTALLED IN THE PC-3 LOCATION. DURING STEADY STATE OPERATION, BOTH OF THESE METERS MEASURED A VELOCITY ABOUT HALF THAT MEASURED AT PC-1 AND PC-2. THIS INDICATES THAT A LARGE AMOUNT OF CROSSFLOW WAS OCCURRING AT THE PC-3 METER PREVENTING A GOOD VELOCITY MEASUREMENT BY THIS INSTRUMENT. ALSO, CROSSFLOW ON THE PC-3 SHROUD WILL RESULT IN A MUCH HIGHER FLUID FORCE THAN FLOW PARALLEL TO THE SHROUD WOULD GIVE. SINCE VIBRATION FORCES, INCLUDING THOSE CAUSED BY THE PRIMARY PUMPS CANNOT BE DEFINED, THE FLUID FORCE ON THE PC-3 SHROUD WILL BE CALCULATED ASSUMING 100% CROSSFLOW AT 52.4 FT/SEC.

ASSUME: NOMINAL $C_D = 1.5$ WORST CASE $C_D = 2.5$
 CROSS FLOW FRONTAL AREA = $(1.5)(4.88) = 7.32 \text{ IN}^2$

$$F_{\text{NOMINAL}} = \frac{(1.5)(47)(48.5)^2(7.32)}{(144)(64.4)} = 152.8 \text{ LBF}$$

$$F_{\text{WORST CASE}} = \frac{(2.5)(47)(52.4)^2(7.32)}{(144)(64.4)} = \underline{\underline{254.7 \text{ LBF}}}$$

THIS FORCE SHOULD BE USED TO DETERMINE THE REQUIRED WELD AREA ON THE SHROUDS FOR THE FLOW METERS AT THE PC-3 LOCATION.

DUE TO THE UNCERTAINTY IN DETERMINING THE MAXIMUM FLUID AND VIBRATION FORCES ON THE PC-3 FLOW METER, THERE IS STILL A SIGNIFICANT RISK THAT THE PC-3 FLOW METER MAY NOT STAY INTACT FOR EXTENDED OPERATION. ALSO, SINCE THERE ARE GOOD INDICATIONS THAT THE PC-3 FLOW METER IS IN A POOR LOCATION TO OBTAIN A GOOD FLOW MEASUREMENT, IT IS STRONGLY RECOMMENDED THAT THE PC-3

FLOW METER NOT BE INSTALLED IN THE LOFT PRIMARY COOLANT SYSTEM FOR EITHER STEADY STATE OR BLOWDOWN OPERATION.

THE MAXIMUM FORCE ON PC-1 SHOULD BE ASSUMED TO BE THE SAME AS THAT ON PC-3 SINCE PC-1 IS JUST DOWNSTREAM OF A 45° PIPE BEND WHERE A HIGH DEGREE OF TURBULENCE IS PROBABLE. HOWEVER, THE MAXIMUM FORCE ON THE PC-1 SHROUD IS MOST LIKELY LESS THAN THAT ON PC-3, BUT HIGHER THAN THAT ON PC-2.

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THE MAXIMUM FORCE ON THE PC-2 SHROUD
CAN BE CALCULATED ASSUMING THE FLOW IS
PARALLEL TO THE SHROUD.

ASSUME NOMINAL $C_D = 1.5$
WORST CASE $C_D = 2.5$

$$F_{\text{NOMINAL}} = \frac{(1.5)(47)(48.5)^2(.7174)}{(144)(64.4)} = 12.8 \text{ LBF}$$

$$F_{\text{WORST CASE}} = \frac{(2.5)(47)(52.4)^2(.7174)}{(144)(64.4)} = \underline{\underline{25 \text{ LBF}}}$$

FRONTAL AREA CALCULATIONS

Q

1316

1270

A hand-drawn diagram of a trapezoid. The top horizontal base is labeled '436'. The bottom horizontal base is labeled '416'. The left slanted side is labeled '6364 rad'. The right slanted side is labeled '6324 rad'. A vertical line segment inside the trapezoid, representing the height, is labeled '416'.

$$A_2 = \frac{1}{2} (1.1316)(1.1270) + \frac{7^2}{2} (2(1.262) - \sin(2(1.262))) = .014 \text{ in}^2$$

$$A_5 = (.215 - .004)(.009) = .0019 \text{ in}^2$$

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$$\text{Frontal Area } A_F = 2A_1 + 4A_2 + 2A_3 + 52A_5 + A_4$$

$$= 2(.031) + 4(.014) + 2(.014) + 52(.0019) + .2278$$

$$A_F = \underbrace{.062 + .056 + .028 + .099}_{.2448} + .2278 = .4726 \text{ in}^2$$

$$\begin{array}{r} .2448 \\ .044 \\ \hline .2928 \end{array}$$

$$\text{Avg Area} = 52(1.5) \cdot .0019 =$$

Grill. pc.

$$\text{Exit Area } A_X = A_F - A_4 = .4726 - .2278 = .2448 \text{ in}^2$$

Total Shroud Flow Exposed Area

$$\begin{aligned} &= A_X + A_F = .7174 \text{ in}^2 \\ &= .00498 \text{ ft}^2 \end{aligned}$$

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V. $A_{reg'd}$ is based on the following

$$A_{reg'd} = \frac{(SCF) \times F}{7520}$$

where SCF = stress concentration Factor

F = Load (lbs)

7520 = Allowable Shear stress (psi)

$$\text{Nominal Safety Factor, } S.F._n = \frac{.035 \times 3.5}{A_{reg'd}}$$

where $.035 \times 3.5$ = nominal area available

$$\text{"Worst" Safety Factor, } S.F._w = \frac{.03 \times 3.5}{A_{reg'd}}$$

where $.03 \times 3.5$ = estimated "worst" area available

CALCULATION WORK SHEET

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VI. Present Acceptability Evaluation

CS : Shroud not installed
 Will be done by new procedure

PC-1 : Good weld outboard = 1.10" -
 Edge remaining = 0"
 Good weld inboard = 0.3" may be no
 Edge remaining = .23" good due to cold lap

- Assumptions :
- 1) Each side must be able to carry $\frac{1}{2}$ of total load.
 - 2) Nominal stress Concentration Factor = 2.5
 - 3) Worst stress Concentration Factor = 4.0
 - 4) Allowable shear stress = $0.4 \sigma_y = 7520 \text{ psi}$
 - 5) Present throat minimum = .020" (nom)

All
Locations

Req'd Length of Good Weld Each side

$$L_{\text{req'd}} = \frac{FK}{2F_v(.02)}$$

where F = force on weld
 K = stress conc. factor
 $F_v = .4 \sigma_y = 7520 \text{ psi}$
 $.02$ " = present throat min
 2 = division for only one side

CALCULATION WORK SHEET

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PC-1 : (cont)

F_n = nominal load
 = 152.8

F_w = worst load
 = 254.7

nominal

worst

$$L_{req'd} = \frac{152.8(2.5)}{(2)7520(.02)} = 1.27''$$

$$= \frac{254.7(4.0)}{(2)7520(.02)} = 3.39''$$

Note that the above lengths correspond to safety factor of 1.0 and that this corresponds to allowable stress, not to failure stress or yield stress. Allowable shear stress is $\sim 2/3$ of yield stress in shear.

Best Fix on PC-1 w/o shroud removal would result in .53" of weld on one side.

Unacceptable

PC-1 Shroud must be removed and reworked.

Present

$$SF_n = 0$$

$$SF_w = 0$$

w/.02x.23 new
 .3 Cold Lap Fix

$$SF_n = \frac{.53}{1.27} = .4$$

$$SF_w = \frac{.53}{3.39} = .2^{.16}$$

w/.035x.23 new
 .3 Cold Fix
 .030T worst

$$SF_n = \frac{.70}{1.27} = .6$$

$$SF_w = \frac{.65}{3.39} = .2^{.19}$$

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PC-2:

$F_n = 12.8$

$F_w = 25.0$

$$\text{nom. } L_{\text{req'd}} = \frac{12.8 (2.5)}{2(7520) .02} = .11"$$

$$\text{worst } L_{\text{req'd}} = \frac{25}{12.8} \left(\frac{4}{2.5} \right) (.1064) = .33"$$

PC-2

1.54" Good Weld Outboard Side
 1.63" " " Inboard "

$$\text{Nominal } S.F. = \frac{1.51}{.11} = 10.1$$

$$\text{Worst } S.F. = \frac{1.51}{.33} = 3.4$$

Sufficient weld length

CALCULATION WORK SHEET

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PC-3: Loads Same As PC-1

∴ Nom $L_{req'd} = 1.27"$

Worst $L_{req'd} = 3.39"$

Outboard: Good Weld .44
 Good Edge 1.42"

Present:

$$SF_n = \frac{.18}{1.27} = .14$$

$$SF_w = \frac{.18}{3.39} = .05$$

Inboard: Good Weld .18
 Good Edge 1.46"

Present Weld Insufficient

If good edge welded with .02t $L_{total} = 1.64"$

$$\text{Nom, } SF_n = \frac{1.64}{1.27} = 1.3 \quad \text{Worst } SF_w = \frac{1.64}{3.39} = .5$$

If good edge welded w/.035t (nom) .030t worst

$$\text{equiv. } L_{total} = .18 + \frac{.035}{.02} 1.46 = 2.74"$$

$$\text{or } .18 + (.03/.02) 1.46 = 2.37"$$

$$\frac{1}{2} \text{ Nom } SF_n = \frac{2.74}{1.27} = 2.2 \quad \text{worst } SF_w = \frac{2.37}{3.39} = .7$$

$$2.74 - .44 = 2.30 \quad \text{or Equ. } .02t \quad L \quad 2.37 - .44 = 1.93$$

$$\frac{.02}{.03}(1.93) = 1.29$$

$$\frac{.02}{.035}(2.3) = 1.31$$

CALCULATION WORK SHEET

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BL-1:

$$F_n = 69.8$$

$$F_w = 137.4$$

nom. $L_{req'd} = \frac{69.8 (2.5)}{2(7520) .02} = .58"$

worst $L_{req'd} = \frac{137.4 (4.0)}{2(7520) .02} = 1.83"$

Outboard: .2 Good Weld includes .20 underfill
 1.8 Good Edge

Present: $S.F._n = .4$ $S.F._w = .1$

w/.02 x 1.8 additional weld

$$S.F._n = \frac{2.0}{.58} = 3.5$$

$$S.F._w = \frac{2.0}{1.83} = 1.1$$

w/.035 x 1.8 additional weld (.030t worst)

$$1.8 \times 1.75 = 3.15$$

$$S.F._n = \frac{3.35}{.58} = 5.8$$

$$S.F._w = \frac{2.9}{1.83} = 1.6$$

Can probably be Fixed by adding weld.

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BL-1: (cont)

Inboard : .60 Good Weld
 1.46 Good Edge

Present: $S.F._n = 1.0$ $S.F._w = .3$

w/.02 x 1.46 additional weld

$$S.F._n = \frac{2.06}{.58} = 3.6$$

$$S.F._w = \frac{2.06}{1.83} = 1.1$$

w/.035 x 1.46
 added weld

$$S.F._n = \frac{3.16}{.58} = 5.4$$

(.030t worst)

$$S.F._w = \frac{2.79}{1.83} = 1.5$$

BL-2: Forces & Legd's same as BL-1

Outboard: Good Weld: .08"
 Good Edge: .50"

Inboard: Good Weld: .62
 Good Edge: .95

Present: $S.F._n = \frac{.08}{.58} = .1$ $S.F._w = \frac{.08}{1.83} = .04$

w/.02 x .5 added weld

$$S.F._n = \frac{.58}{.58} = 1.0$$

$$S.F._w = \frac{.58}{1.83} = .3$$

w/.035 x .5 added weld (.030t, worst)

$$S.F._n = \frac{.96}{.58} = 1.7$$

$$S.F._w = \frac{.83}{1.83} = .5$$

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Consider PC-3 instrument in PC-2 location. This is done to facilitate judging the advisability of putting PC-3 with added weld in PC-1 location. PC-1 loads are judged to be somewhere between PC-2 loads and PC-3 loads.

nom. $L_{req'd} = .11$ worst $L_{req'd} = .33$

Present $S.F._n = \frac{.18}{.11} = 1.6$

$S.F._w = \frac{.18}{.33} = .5$

Added Weld $S.F._n = \frac{2.74}{.11} = 24.9$

$S.F._w = \frac{2.37}{.33} = 7.2$

CALCULATION WORK SHEET

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SUBJECT LOFT ρV^2 MeterPAGE 20 OF PAGESDATE 6-8-76PREPARED BY R G RahlCHECKED WORK REQUEST VII Shaft Cover Welds:

$$\text{Sideflow Area} = .332 \times 2.464 - 9\left(\frac{\pi}{4}\right) .125^2 = .708 \text{ in}^2$$

Ratio Areas of shaft Cover And
Shroud To Obtain Loads

$$A_{\text{shroud}} = 7.29 \text{ in}^2$$

$$\text{Max nominal load} = \frac{.708}{7.29} 152.8 = 14.8 \#$$

$$\text{Max "worst" load} = \frac{.708}{7.29} 254.7 = 24.7 \#$$

Based on worst

$$A_{\text{req'd}} = \frac{4(24.7)}{7520} = .0131 \text{ in}^2 \quad \text{For S.F.} = 1.0$$

$$\times 2 = \underline{\underline{.0263 \text{ in}^2}} \quad \text{For S.F.} = 2.0$$

Presently called for 6 - .03 x .25 Fillets

$$A_{\text{weld}} = 6(.25)[.707(.03)] = .0318 \text{ in}^2$$

$$> .0263 \text{ in}^2 \quad \text{OK}$$

Front Cover Piece:

$$\text{Sideflow } A = 1.25(.4) = .5 \text{ in}^2$$

$$\text{Max "worst" load} = \frac{.5}{7.29} 254.7 = 17.5 \#$$

$$A_{\text{req'd}} = \frac{4(17.5)}{7520} = .0093 \text{ in}^2$$

For SF = 1.0

$$\times 2 = .0186 \text{ in}^2$$

For SF = 2.0

$$A_{\text{weld}} = 6(.12) .03 = .0216 \text{ in}^2$$

$$> .0186$$

OK

INTEROFFICE CORRESPONDENCE

date October 22, 1976

to M. L. Schulz

from R. C. Gottula *RG*

subject FLUID LOADS ON LOFT DTT SHROUDS LOCATED ABOVE "A" AND "C" FUEL ASSEMBLIES - GOTT-10-76

Reference: (a) "LOFT Drac Disc Turbine Meter Shroud Welds", GOTT-4-76, June 9, 1976.

The maximum momentum fluxes at the DTT shrouds have been estimated for the transducers located in the LOFT reactor vessel upper structure above the "A" and "C" fuel assemblies to determine weld requirements for the shroud attachment. Momentum fluxes have been calculated for both steady state and blowdown conditions. The steady state calculation assumed the highest loop flow rate to be 3.9×10^6 lbm/hr. The following blowdown conditions were considered:

1. 200% simulated cold leg break
2. 200% simulated hot leg break
3. 100% simulated hot leg break

The momentum fluxes for these conditions are summarized on page 4 of the attachment.

All of the momentum fluxes are less than the maximum momentum flux calculated for the DTT shroud located in the blowdown pipe (Reference a). Therefore, the weld requirements given in Reference a for the DTT located in the blowdown pipe should also be satisfactory for the DTT shrouds located in the upper structure above the "A" and "C" fuel assemblies.

If LOFT ever runs a blowdown test where only the hot leg blowdown valve is opened, these weld requirements should be reanalyzed.

jr

Attachment
as stated

cc: R. L. Crumley
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CALCULATIONS FOR FLUID LOADS ON THE DAAG DISC TURBINE METER SHROUDS DURING STEADY STATE AND BLOWDOWN OPERATION

1. STEADY STATE OPERATION

ASSUMPTIONS:

- (a) MAXIMUM LOOP FLOW RATE = 3.9×10^6 LB/HR
- (b) 5% CORE BY-PASS FLOW
- (c) FLOW IS PARALLEL TO FLOW METER SHROUD

THE MAXIMUM CORE AVERAGE MASS VELOCITY IS:

$$G_{AVE} = \frac{(0.95)(3.9 \times 10^6)}{1.7656 \text{ FT}^2} = 2.098 \times 10^6 \text{ LB/HR-FT}^2$$

HESSON (REF. LTR 111-62) DETERMINED THE LOFT CORE OUTLET FLOW SPLIT TO BE AS FOLLOWS:

ASSEMBLY TYPE	OUTLET VELOCITY RELATIVE TO CORE AVE.
A	1.01
B	1.04
C	.91

THE "A" ASSEMBLY FLOW AREA = .264 FT²

THE "C" ASSEMBLY FLOW AREA = .054 FT²

THE "A" ASSEMBLY EXIT FLOW RATE IS:

$$\dot{M}_A = \frac{(1.01)(2.098 \times 10^6)(.264)}{3600} = 155.39 \text{ LB/SEC}$$

THE "C" ASSEMBLY EXIT FLOW RATE IS:

$$\dot{M}_C = \frac{(0.91)(2.098 \times 10^6)(.054)}{3600} = 28.64 \text{ LB/SEC}$$

ASSUME ALL OF THE FLOW EXITING THE "A" ASSEMBLY FLOWS THROUGH THE 5.5 IN. DIA. ORIFICE IN THE "A" UPPER STRUCTURE. ALSO, ASSUME THE FLOW METER IS AT THE VENA CONTRACTA DOWNSTREAM OF THE ORIFICE AND THE ORIFICE HAS A CONTRACTION COEFFICIENT OF .6.

THE FLUID VELOCITY AT THE FLOW METER IS:

$$V_A = \frac{\dot{m}}{\rho A} = \frac{155.39 \text{ LB/SEC}}{(42.7 \frac{\text{LB}}{\text{FT}^3}) \left(\pi \frac{5.5^2}{4 \times 144} \text{ FT}^2 \right) (.6)} = 36.76 \text{ FT/SEC}$$

THE MAXIMUM STEADY STATE MOMENTUM FLUX AT THE FLOW METER ABOVE THE "A" ASSEMBLY IS:

$$\rho V^2 = (42.7) (36.76)^2 = 57,700 \text{ LBM/FT-SEC}^2$$

ASSUME ALL OF THE FLOW EXITING THE "C" ASSEMBLIES FLOWS THROUGH THE 3 IN. DIA. ORIFICES IN THE "C" UPPER STRUCTURE. ALSO, ASSUME THE FLOW METER IS AT THE VENA CONTRACTA AND THE ORIFICE HAS A FLOW COEFFICIENT OF .6.

THE FLUID VELOCITY AT THE FLOW METER IS:

$$V_C = \frac{\dot{m}}{\rho A} = \frac{28.64}{(42.7) \left(\pi \frac{3^2}{4 \times 144} \right) (.6)} = 22.77 \text{ FT/SEC}$$

THE MAXIMUM STEADY STATE MOMENTUM FLUX AT THE FLOW METER ABOVE THE "C" ASSEMBLY IS:

$$\rho V^2 = (42.7) (22.77)^2 = 22,139 \text{ LBM/FT-SEC}^2$$

2. BLOWDOWN OPERATION

THE MAXIMUM MOMENTUM FLUXES AT THE FLOW METERS DURING BLOWDOWN HAVE ALSO BEEN CALCULATED FOR THE FOLLOWING BLOWDOWN CONDITIONS WITH AN INITIAL LOOP FLOW RATE AND POWER LEVEL OF 2.15×10^6 LB/HR AND 55 MW RESPECTIVELY:

- (a) 200% SIMULATED COLD LEG BLOWDOWN
- (b) 200% SIMULATED HOT LEG BLOWDOWN
- (c) 100% SIMULATED HOT LEG BLOWDOWN

PLOTS OF FLUID DENSITY AND VELOCITY AT THE TOP OF THE CORE HAVE BEEN OBTAINED FROM CLINTON KEELER FROM THE RELAP PREDICTIONS FOR THESE BLOWDOWNS. THE VELOCITIES SHOWN IN THE ATTACHED FIGURES ARE AT THE UPPER TIE PLATE.

FOR CASES (b) AND (c) ABOVE, THE MAXIMUM MOMENTUM FLUX OCCURS AT THE BEGINNING OF THE BLOWDOWN AT A CORE FLOW RATE OF ABOUT 875 LB/SEC WITH FLOW IN THE NORMAL DIRECTION. ASSUMING THE SAME FLOW SPLIT AT THE CORE OUTLET AS FOR STEADY STATE CONDITIONS, THE MOMENTUM FLUXES AT THE FLOW METERS ASSUMING HOMOGENEOUS FLOW ARE:

$$\begin{aligned} \text{MOM. FLUX}_{"A"} &= \frac{(1.01)^2 (.264 \text{ FT}^2)^2 \left(875 \frac{\text{LB}}{\text{SEC}}\right)^2}{(1.7656 \text{ FT}^2)^2 \left(42 \frac{\text{LB}}{\text{FT}^3}\right) \left(\pi \frac{5.5^2}{4 \times 144} \text{ FT}^2\right)^2 (.6)^2} \\ &= 42,425 \text{ LB-M/FT-SEC}^2 \end{aligned}$$

$$\begin{aligned} \text{MOM. FLUX}_{"C"} &= \frac{(1.91)^2 (.054)^2 (875)^2}{(1.7656)^2 (42) \left(\pi \frac{3^2}{4 \times 144}\right)^2 (.6)^2} \\ &= 16,278 \text{ LB-M/FT-SEC}^2 \end{aligned}$$

FOR CASE (a) ABOVE, THE MAXIMUM MOMENTUM FLUX OCCURS IN REVERSE FLOW AT A FLOW RATE OF 1620 LB/SEC. SINCE THE UPPER STRUCTURE ABOVE THE "B" ASSEMBLIES HAS THE CONTROL ROD DRIVE MECHANISMS, ASSUME THAT ALL OF THE FLOW IS EVENLY DISTRIBUTED IN THE "A" AND "C" ASSEMBLIES WITH A FLOW AREA OF .7 FT².

ASSUMING HOMOGENEOUS FLOW, THIS RESULTS IN A VELOCITY OF:

$$V = \frac{\dot{m}}{\rho A} = \frac{1620 \text{ LB/SEC}}{(24 \frac{\text{LB}}{\text{FT}^3})(.7 \text{ FT}^2)} = 96.4 \text{ FT/SEC}$$

THE MOMENTUM FLUX IS:

$$QV^2 = (24)(96.4)^2 = 223,031 \text{ LBM/FT-SEC}^2$$

SUMMARY

	MAXIMUM MOMENTUM FLUX (LBM/FT-SEC ²)			
	STEADY STATE	200% COLD LEG BREAK	200% HOT LEG BREAK	100% HOT LEG BREAK
DTT ABOVE "A" ASSEMBLY	57,700	223,031	42,425	42,425
DTT ABOVE "C" ASSEMBLY	22,139	223,031	16,278	16,278

THESE MOMENTUM FLUXES ARE ALL LESS THAN THAT CALCULATED FOR THE DTT'S IN THE BLOWDOWN PIPES WHICH WAS 355,332 LB/FT-SEC² (REF. 1). THEREFORE, THE WELD REQUIREMENTS GIVEN IN REF. 1 FOR THE DTT SHROUDS IN THE BLOWDOWN PIPES SHOULD ALSO BE ADEQUATE FOR THESE DTT'S ABOVE THE "A" AND "C" FUEL ASSEMBLIES.

128

VELOCITY AT TOP OF CORE (FT/SEC) FV3

ISERLOFT 2

RELAP4/C05 01/02/76 02/04/76

200% COLD LEG BREAK

LTR 141-80

621
129
MASS FLOW RATE - TOP OF CORE (LBM/SEC) JW3

ISERLOFT 2

RELAP4/C05 01/02/76 02/04/76

200 / COLD LEG BREAK

LTR 141-80

130
DENSITY - TOP THIRD OF CORE (LBM/FT³) AR3

ISERLOFT 2

RELAP4/C05 01/02/76 02/04/76

200% COLD LEG BREAK

LTR 141-80

131

DENSITY - UPPER PLENUM (LBM/FT³) AR4

ISERLOFT 2

RELAP4/C05 01/02/76 02/04/76

200% COLD LEG BREAK

LTR 141-80

132 JF3
CORE OUTLET VELOCITY (FT/SEC)

200(HCT LEG BREAK ISER-LOFT

EXP*P4/C E 12/15/75 12/23/75

LTR 141-80

133
MASS FLOW RATE - TOP OF CORE (LBM/SEC) JUL 75

200% HOT LEG BREAK 1SER-LOFT

EXP-P4/C E 12/15/75 12/23/75

LTR 141-80

DENSITY - TOP THIRD OF CORE (LBM/FT³) AR3

2001 HOT LEG BREAK ISCR-LOFT

EXP-P4/C E 12/15/75 12/23/75

135
AR4
DENSITY - UPPER PLENUM (LBM/FT3)

2001 HOT LEG BREAK 1SER-LOFT

EXP-P4/C E 12/15/75 12/23/75

LTR 141-80

136

VELOCITY AT TOP OF CORE (FT/SEC) FV3

750.
500.
250.
0.
-250.

0.0 5.0 10.0 15.0 20.0 25.0 30.0 35.0 40.0 45.0

TIME AFTER RUPTURE (SECONDS)

ISERLOFT 4 100 HOT LEG BREAK

RELAP4/C05 01/02/76 02/18/76

LTR 141-80

JW3
MASS FLOW RATE - TOP OF CORE (LBM/SEC)

ISERLOFT 4 100% HOT LEG BREAK

RELAP4/C05 01/02/76 02/18/76

LTR 141-80

AR3
DENSITY - TOP THIRD OF CORE (LBM/FT³)

ISERLOFT 4 100 HOT LEG BREAK

RELAP4/C05 01/02/76 02/18/76

LTR 141-80

AR4
DENSITY - UPPER PLENUM (LBM/FT³)

ISERLOFT 4 100 HOT LEG BREAK

RELAP4/C05 01/02/76 02/18/76

LFR 141-80