EG&G Idaho, Inc.

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INTERNAL TECHNICAL REPORT

Title: LOFT SMALL BREAK TEST THERMOCOUPLE INSTALLATION

Organization: Applied Mechanics Branch

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LOFT TECHNICAL REPORT

Title LOFT SMALL BREAK TEST THERMOCOUPLE INSTALLATION	LTR No LO-87-80-135
	RE-A-80-044
Author R. M. Fors	Released By LOFT CDCS
	Date May 28, 1980
Performing Organization Applied Mechanics Branch 5/5/80	Project System Engineer
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LMD Mgr. PSB Mgr.

ABSTRACT

The subject thermocouple design has been analyzed for maximum expected hydraulic loading and found to be adequate. The natural frequency of the thermocouple was found to be between the vortex shedding frequencies for the gas and liquid phase so that a tendency for resonance will exist. However, since the thermocouple support will have a restricted displacement, stresses found are below the endurance limit and, thus, are acceptable in respect to fatigue life as well as primary stress due to pressure loading.

DISPOSITION OF RECOMMENDATIONS

No disposition required. RGR/SH per telecon 5.29.80

LO-87-80135

CONTENTS

1. INTRODUCTION

The subject thermocouple design is described in Section 3 of this report as received from R. Clemens. Hydraulic loads and vortex shedding frequencies were determined by J. C. Watkins.

A natural frequency calculation was made and found to be in the same order of magnitude as the vortex shedding frequencies. Thus, the support provided by the housing for the thermocouple support is required to limit bending moment and related stresses of the thermocouple support.

The natural frequency calculation and the moment resulting from pressure loading was determined by making a small SAP-IV model and running modal extraction and static load cases respectively.

2. SCOPE OF INVESTIGATION

This investigation considers only hydraulic loading and corresponding vibrational considerations. Thermal loading is considered to be negligible.

3. ANALYSIS

3.1 Thermocouple Assembly Description

The thermocouple is a 0.0625 inch diameter, 304L stainless steel tube with a $\frac{0.008}{0.012}$ inch wall thickness. It is filled with MgO and contains two 0.010 diameter thermocouple wires. It is housed in a 316 stainless steel support which in turn penetrates the fluid chamber (body). A $\frac{0.001}{0.003}$ diametral clearance between the thermocouple sheath and the support is filled with gold braze. The end of the thermocouple is closed for a distance of $\frac{0.010}{0.031}$ inch. That part of the support contained in the body is $\frac{0.1865}{0.186}$ diameter with a 0.0005 maximum tolerance. The inner end of the support extends 0.2 inch into the fluid chambers. It tapers from $\frac{0.1865}{0.186}$ inch diameter at the body wall to $\frac{0.096}{0.091}$ inch diameter at its end. The thermocouple extends 0.050 inch beyond the end of the support. It is gold brazed from the $\frac{0.1865}{0.186}$ inch diameter at the end of the support to the 0.0625 diameter at the thermocouple tip, so as to extend the tapered contour of the support end. The gold braze is an eutectic alloy - 82% gold - 18% nickel.

3.2 Description of Model

The thermocouple was modeled as a cantilever beam with 21-nodes and 33 beam elements. Node 1 is at the free end and Node 20 at the fixed end. Node 21 is a ficticious node inserted to establish the -2- plane off the beam elements. Beams 1 through 5, and 20 through 33 represent the thermocouple sheath, while beams 6 through 19 represent the thermocouple support. Since the thermocouple sheath is bonded to the thermocouple support by gold braze, they use common nodes. The masses of the gold braze, magnesium oxide and thermocouple wires were added to that of the thermocouple sheath.

On the final runs a boundary element and an additional node was added to control displacement.

3.3 Assumptions

The analysis was based on the following assumptions:

1. The structure will act as a cantilever.

2. The thermocouple support may be in contact with the body wall in the stress free position. Hence, a displacement equal to the maximum diametral clearance must be considered to be feasible. It follows that the thermocouple will be displacement limited.

3. Any water between the thermocouple support and the body will be driven out during oscillations.

4. Inertias are minimum.

5. Masses are maximum.

6. Inertia of the gold braze will not be considered. This assumption was necessitated by the unavailability of a Modulus of Elasticity for Gold Braze.

7. Hydraulic data are maximum and viable at 300°F.

3.4 Data

Material Densities

Material	Wt. Density
Stainless Steel	0.279
Gold Braze	0.6287
82% Gold	0.6965
18% Nickel	0.3178
MgO	0.1293

Hydraulic Data - 300°F

Water Phase

Frequency, Hz

Minimum	7511
Maximum	14100

Pressure, lb/sq.in.

Steady drag force	428.8
Oscillatory lift force	252.8
Oscillatory drag force	25.28

Gas Phase

Frequency, Hz

Minimum	7215
Maximum	7796

Pressure, lb/sq.in.

Steady drag force	1.44
Oscillatory lift force	0.9256
Oscillatory lift force	0.09256

4. RESULTS

A natural frequency of 12520 Hz was determined for the unsupported beam and a natural frequency of 75100 Hz was found for the beam supported so as to represent contact at the inside diameter of the body. From a pressure computer run of the unsupported cantilever with concentrated loads equivalent to 100 psi pressure a maximum stress, 3012 psi, was found at the fixed end of the support. The displacement at the contact point with 100 psi pressure is 0.000108 inch.

Since the total hydraulic pressure is greater than 500 psi it follows that the gap between the thermocouple support and the body will be closed at the end of each oscillation. Therefore two final computer runs were made with a 0.0005 inch displacement at Node 10 combined with a hydraulic pressure of 583.7 psi acting in each direction to simulate a second mode vibration superposed on the first mode. The 583.7 psi includes a magnification factor of 1.4 on the oscillatory components of the hydraulic force. This factor taken from page 54 of the referenced text[1] was used because it is presumed that the natural frequency will tend toward the supported case during the part of the cycle when the thermocouple support is in contact with the support.

5. CONCLUSIONS

The maximum stress (also stress intensity range) in the thermocouple support is 16660 psi. This is less than the Section III Class 1 Code[2] design stress allowable in bending (1.5S) of 25050 psi. The alternated stress, $\frac{16660}{2}$ = 8330 psi is less than the fatigue stress, S_a, for austenitic steels at 10^6 cycles.

Stresses in the thermocouple sheath were an order of magnitude less than those in the support. It is therefore concluded that the design satisfied the Code requirements.

6. REFERENCES

1. William T. Thomson, "Vibration Theory and Applications," Prentice Hall Inc., 1965.

2. American Society of Mechanical Engineers," Section III, Nuclear Power Plant Components, Division 1," 1977.

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APPENDIX A

SAP-IV COMPUTER PROGRAM LISTING - MICROFICHE

176 CDC SAPIV SOURCE LISTING - 4/29/80

SAPIV MODULE SAP4S3L

APPENDIX B

SAP-IV RESULTS

MICROFICHE

Run RMF1WDR 4/10/80

Natural frequency - unsupported

Run RMF1WKW 4/10/80

Natural frequency - supported

Run RMF1WØS 4/10/80

Pressure run - 100 psi

Run RMF1WJR 4/17/80

Pressure run 583.7 psi

Negative displacement - 0.0005 inch

Run RMF1WJT 4/17/80

Pressure run 583.7 psi

Positive displacement - 0.0005 inch

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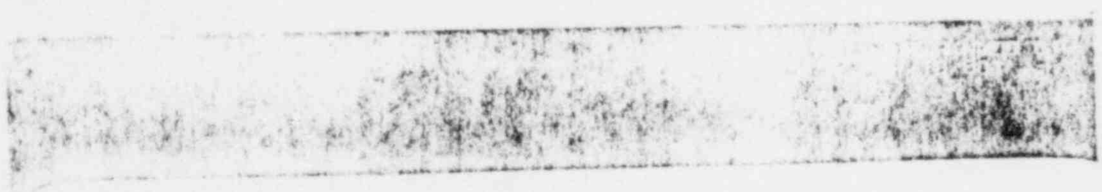
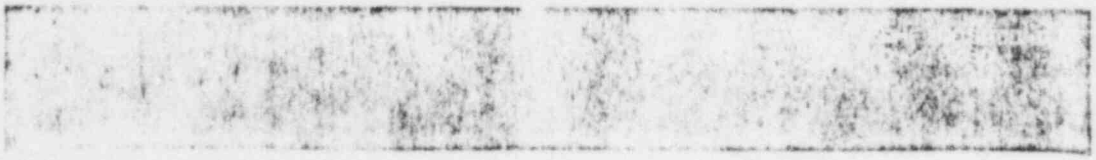
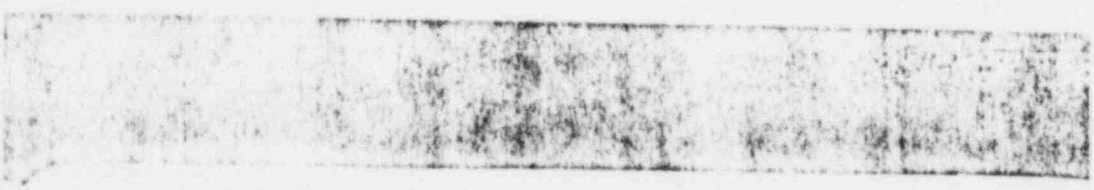
RMF1WDR
Natural Frequency - unsupported



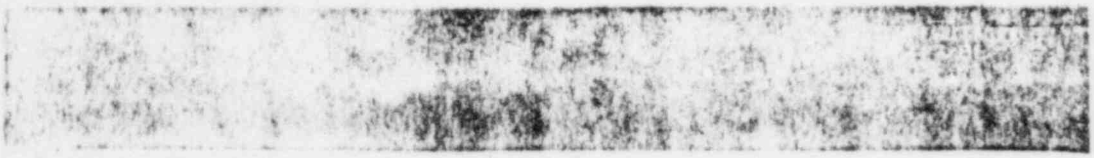
RMF1WKW
Natural Frequency - Supported



RMF1WØS
Pressure Run - 100 psi



RMF1W3R
Pressure Run 583.7 psi
Negative Displacement 0.0005 inch



RMF1W3T

Pressure Run 583.7 psi

Positive Displacement 0.0005 inch