INTERIM REPORT

Accession No. LTR 1111-62

Contract Program or Project Title: LOFT PROGRAM

Subject of this Document: (Title) "Stress Analysis of Instrumentation Support Structures and Center Fuel Module Upper Core Support Structure Modifications"

Type of Document: Analysis

Author(s): R. K. Blandford

Date of Document: March 1980

Responsible NRC Individual and NRC Office or Division: G. D. McPherson

This document was prepared primarily for preliminary or internal use. It has not received full review and approval. Since there may be substantive changes, this document should not be considered final.

Prepared for
U.S. Nuclear Regulatory Commission
Washington, D.C. 20555

INTERIM REPORT

EG&G Idaho

INTEROFFICE CORRESPONDENCE

R-5407

date MAR 25 1980

to DISTRIBUTION

from LOFT CDCS, TAN 602, Ext. 6177 S. K. Hathaway

subject DOCUMENT TRANSMITTAL

The following documents released by LOFT CDCS, are hereby transmitted for your use and information:

DOCUMENT NO.	REV	CHG	DATE
LTR 1111-62	1		3-25-80
"Stress Analysis of Instrumentation Support Structures and Center Fuel Module Upper Core Support Structure Modifications"			R.K. Blandford

REMARKS: No disposition required.

DISTRIBUTION

J. L. Hansen
W. Amidei w/o Att.
B. O. Anderson
E. C. Anderson w/o Att.
J. G. Arendts
B. L. Chamberlain w/o Att.
G. A. Dinneen
D. B. Engelman
B. L. Freed-Orig.+7
R. T. French
R. C. Gottula
R. C. Guenzler
J. C. Haire
S. W. Hills
G. L. Hunt w/o Att.
F. K. Hyer w/o Att.
N. C. Kaufman w/o Att.
S. T. Kelppe
J. L. Liebenthal
A. S. Lockhart
J. H. Linebarger
D. W. Marshall w/o Att.
S. Matovich
G. D. McPherson
J. C. Morrow
S. A. Naff
N. E. Pace w/o Att.
T. F. Pointer
G. Rieger
P. Schally
D. G. Satterwhite w/o Att.
W. A. Spencer
J. C. Stachew w/o Att.
K. C. Sumpter
R. E. Tiller
S. R. Wagoner w/o Att.
G. Weimann
L. Winters
B. J. Yohn
J. R. Barker - 3
R. K. Blandford
R. G. Rahl
M. M. Laughlin - 3
J. O. Carlson
D. B. Jarrell
H. A. Rau
M. L. Russell UAB
E. D. Uldrich
J. R. Fredell
R. L. Drexler
T. Sudoh - 2

FORM EG&G-954
(Rev 2-77)

EG&G Idaho, Inc.

(LTR)

Report No. 1111-62, Rev. 1

Date: March 25, 1980

RELEASED BY LOFT CDCS

RE&C Internal Report RE-A-79-012

USNRC-P-394

INTERNAL TECHNICAL REPORT

Title: STRESS ANALYSIS OF INSTRUMENTATION SUPPORT STRUCTURES AND CENTER FUEL MODULE UPPER CORE SUPPORT STRUCTURE MODIFICATIONS

Organization: Applied Mechanics Branch

Author: R. K. Blandford/

THIS REVISION COMPLETELY SUPERSEDES ALL PREVIOUS ISSUES OF LTR 1111-62

Checked By: R. G. Rahl/

Approved By: R. C. Guenzler/

cc: J. G. Arendts
J. R. Barker (3)
R. K. Blandford
R. C. Guenzler
M. M. Laughlin (3)
R. G. Rahl

[redacted]

EG&G Idaho, Inc.

LOFT TECHNICAL REPORT
LOFT PROGRAM

FORM EG&G-229
(Rev 06-79)

TITLE	REPORT NO.
STRESS ANALYSIS OF INSTRUMENTATION SUPPORT STRUCTURES AND CENTER FUEL MODULE UPPER CORE SUPPORT STRUCTURE MODIFICATIONS	LTR 1111-62, Rev. 1 RE-A-79-012

AUTHOR	Charge Number
R. K. Blandford	
PERFORMING ORGANIZATION: Applied Mechanics 12/28/79	DATE RELEASED BY LOFT CDCS March 25, 1980
LOFT APPROVAL	

1-7-80 FE&OB Mgr. 1-9-80 FD&AB Mgr. RSB Mgr. PSB Mgr. P&CSB Mgr.

See incorporated DRR-L-3876

ABSTRACT

A stress analysis of the instrumentation support structures added to the LOFT center fuel module upper core support structure and the modifications to the upper structure was performed. Stresses resulting from thermal and gamma heating were found negligible while hydraulic conditions were considered the primary source of load.

Stress levels in the support structures were found to be small based on conservative analysis (less than 2300 psi). It is concluded that the proposed instrumentation support structures are structurally sound and comply with requirements of the ASME Code.

This revision to LTR 1111-62 is made to include the lug attachment weld change on Page A-8, to add a check on the LVDT holddown spring on Page A-8, and to change the torque calculation on Bolt 209250-18, Page A-11, to reflect the actual reduced engagement length of .148 inch.

DISPOSITION OF RECOMMENDATIONS

No disposition required. RKB

THIS REVISION COMPLETELY SUPERSEDES ALL PREVIOUS ISSUES OF LTR 1111-62.

CONTENTS

STRESS ANALYSIS OF INSTRUMENTATION SUPPORT STRUCTURES AND CENTER FUEL MODULE UPPER CORE SUPPORT STRUCTURE MODIFICATIONS

I. INTRODUCTION

Additional LVDT and UDD instrumentation has been proposed for the LOFT Center Fuel Module. The instrumentation will be located in the upper core support structure and it is the purpose of this report to determine the structural integrity of the instrumentation supports as well as the modified upper structure. Details of the instrumentation supports and modifications to the upper core support structure are contained in Drawings 209250 and 209282 (Ref's 1 and 2).

The subjects covered by this analysis consist of: (1) a single and a double LVDT support described in Ref. 1 and attached to the lower orifice plate of the upper structure and (2) a UDD and thermocouple mounting described in Ref. 2 and located approximately 49 inches above the bottom of the upper structure.

II. LOAD CONDITIONS

1. HYDRAULIC LOADS

The primary source of loading of the instrumentation supports is the result of hydraulic forces acting on the instrument and instrument support surfaces exposed to reactor fluid flow. These forces were evaluated from:

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

where C_d = Drag Coefficient (Assumed 2.5)

A = Flow Area

$\rho V^2/2g_c$ = Dynamic Pressure.

The dynamic pressure terms were obtained from Reference 3 with the maximum reported value being used for this analysis.

2. THERMAL LOADS

Both thermal and gamma heating were considered in this analysis. Gamma heating was concluded negligible based on the results of Reference 4. Stresses resulting from thermal heating were also concluded negligible since the support structures are cantilever nature and relatively free to expand. In addition, a discussion with H. Rhodes, Thermal Analysis Branch, indicated that heating and cooling of the supports could be considered fairly uniform.

Thermal loading of the UDD instruments themselves results in reactive loading of the supports. These loads were obtained from Reference 5 and were considered in this analysis.

III. STRESS ANALYSIS

Conservative linear elastic techniques were used to analyze the instrumentation supports and modifications to the upper structure. Details of the analysis are included in Appendix A.

The stresses arising from application of the loads discussed in Section II were found to be less than 2300 psi and ASME Code[6] requirements could be judged satisfied.

IV. RESULTS AND CONCLUSIONS

An evaluation of the instrumentation supports and modified upper core support structure for the loadings of Section II found the structures sound. The proposed supports and modifications can withstand the expected loadings and meet ASME Code requirements.

V. REFERENCES

1. EG&G Idaho, Inc. Drawing 209250, LOFT LVDT and UDD Mounting Details Upper Core Support Structure Center Fuel Assembly.

2. EG&G Idaho, Inc. Drawing 209282, LOFT UDD and Thermocouple Mounting Details Upper Core Support Structure Center Fuel Assembly.

3. J. S. Martinell, "LOFT Drag-Disc Turbine Transducer Shroud and Cover Weld Analysis and Evaluation", LOFT Technical Report LTR 141-80, November 27, 1978.

4. H. F. Rhodes, "Thermal Analysis of Mounting Plate and Instrument Holder in Upper Core Support Structure for LOFT Core III, LOFT Technical Report LTR 1111-66, July 3, 1979.

5. W. R. Mosby, "Stress Analysis of Ultrasonic Density Detector for LOFT Core Inlet Steady-State and LOCE Conditions", LOFT Technical Report LTR 141-86, March 26, 1979.

6. American Society of Mechanical Engineers, ASME Boiler and Pressure Vessel Code, Section III, "Nuclear Power Plant Components", 1977.

The following References are in Appendix A, only:

7. R. K. Blandford letter to J. O. Carlson, RKB-10-78, Stress Review of Center Fuel Module Upper Core Support Structure Modifications, September 14, 1978.

8. MPR Associates, "Design Report for LOFT Fuel Assembly Upper Support Structures", LOFT Technical Report LTR 1111-32, Rev. 1, May 16, 1978.

9. J. E. Shigley, Mechanical Engineering Design, McGraw-Hill Book Co., 2nd Edition, 1972.

10. G. D. Rogers, Torque Load Relationship for Stainless Steel Fasteners, ASME Publication, Winter Annual Meeting, November 1969.

APPENDIX A

SUPPORTING ANALYSIS

SINGLE AND DOUBLE LVDT SUPPORTS

REF DRAWING 209250

LOAD SOURCES LVDT SUPPORT:

1) ATTACHED UDD INSTRUMENT
2) FLUID HYDRAULIC FORCES
3) LVDT HOLDDOWN SPRINGS
4) THERMAL AND GAMMA HEATING

GAMMA HEATING WAS SHOWN TO BE NEGLIGIBLE IN REF 4

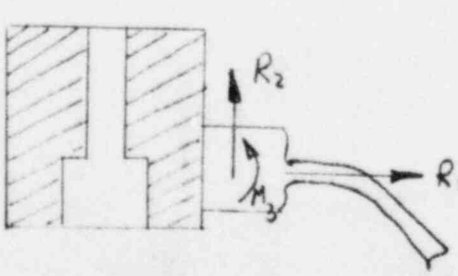
SINCE THE LVDT SUPPORT IS CANTILEVERED AND FREE TO EXPAND AND SINCE HEATING AND COOLING WILL BE FAIRLY UNIFORM THERMAL STRESSES ARE JUDGED NEGLIGIBLE.

THE HOLDDOWN SPRING IS A 25.5 lb/in SPRING FORCE 1.0 IN FREE LENGTH SPRING COMPRESSED TO .75 IN AT INSTALLATION

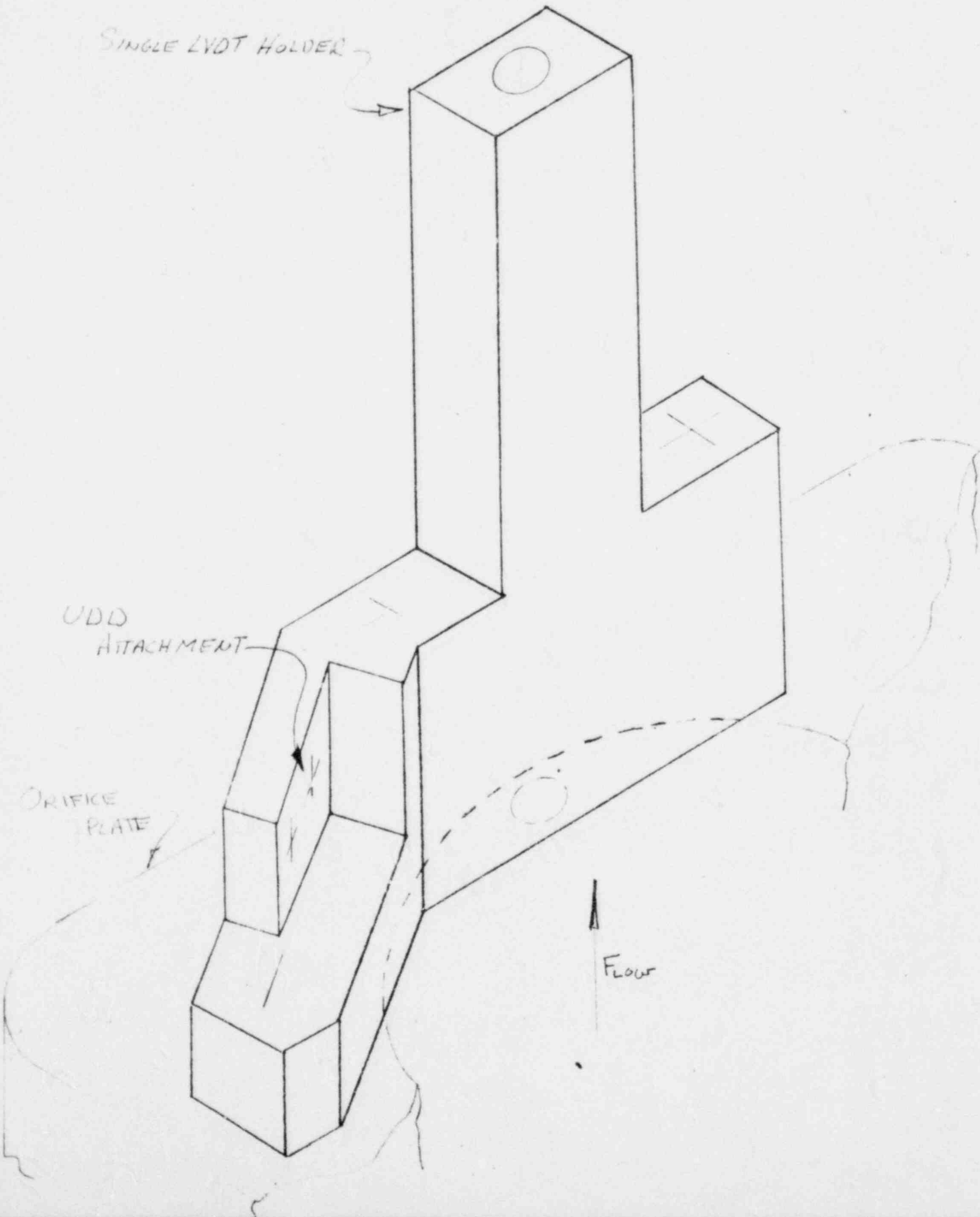
$P_{spring} = (25.5)(1.0-.75) = 6.4\ lb$ small

LOADS FROM ATTACHED UDD

LOADS ON THE UDD ARE OBTAINED FROM LTR 141-86, REF 5

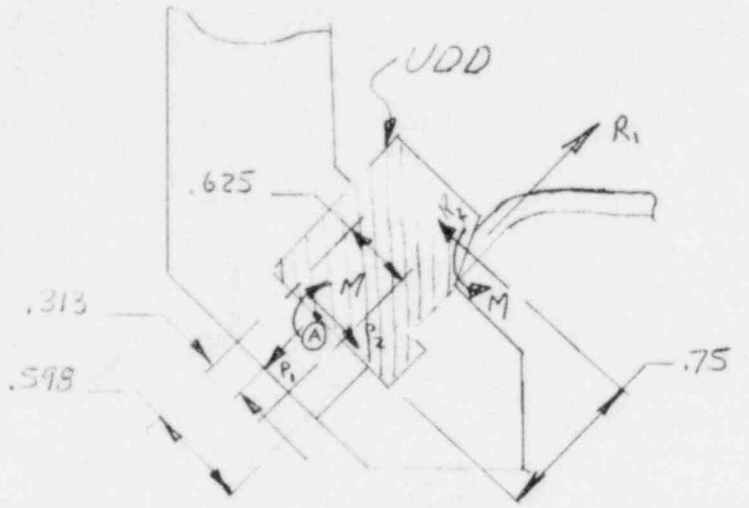


$R_1 = -9.7\ lb$
$R_2 = -10.1\ lb$
$M_3 = -8.5\ in\,lb$


SINGLE LVDT HOLDER
UDD ATTACHMENT
ORIFICE PLATE
FLOW

SINGLE AND DOUBLE LVDT SUPPORTS

FOR THE LVDT SUPPORT OF 209250



LOADS AT POINT (A)

$P_1 = R_1 = -9.7\ lb$

$P_2 = R_2 = -10.1\ lb$

$M = M_3 + R_2(.75) + R_1(.598)$

$M = (-8.5) + (-10.1)(.75) + (-9.7)(.598)$

$M = -21.9\ in\ lb$

HYDRAULIC LOADS ON EXPOSED AREA OF LVDT SUPPORT

FLOW PROPERTIES ARE OBTAINED FROM LTR 1111-80, REF 3

THE HYDRAULIC FORCE ACTING ON THE EXPOSED AREA OF THE LVDT HOLDER IS GIVEN BY:

$$P_D = \frac{1}{2g_c} \rho V^2 C_d A$$

$\frac{1}{2g_c} \rho V^2 = 24.05\ psi$ (REF 3, pg 18)

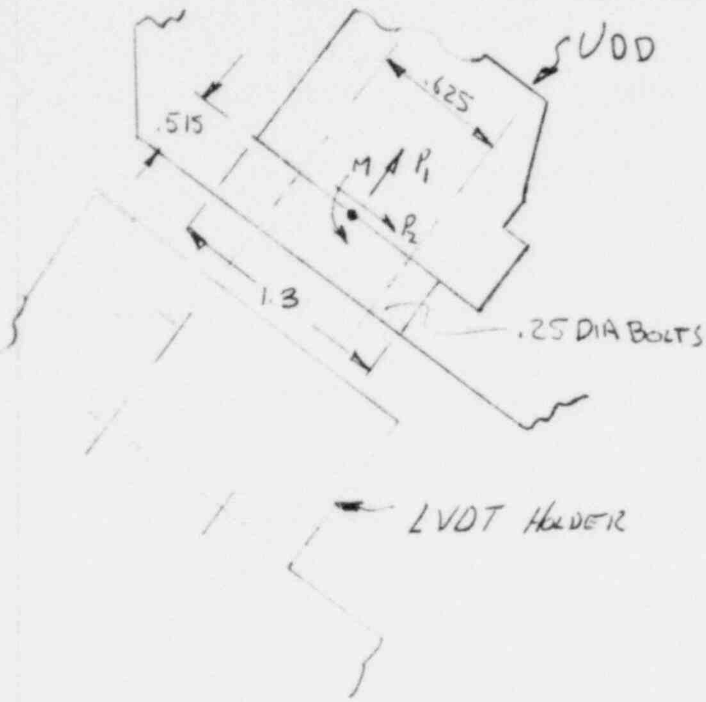
$C_d = 2.5$

ESTIMATED AREA = $1.5\ in^2$

$P_D = (24.05)(2.5)(1.5) = 90.2\ lb$

SINGLE AND DOUBLE LVDT SUPPORTS

UDD ATTACHMENT BOLTS



$P_1 = 9.7$ lb
$P_2 = 10.1$ lb
$M = 21.9$ in lb

ASSUME BOLT LOADS AS FOLLOWS

SHEAR $= 10.1/3 = 3.4$ lb

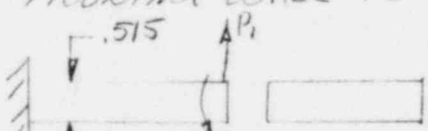
TENSION $P_1 + M/.625$
$= 9.7 + 21.9/.625$
$= 45$ lb

TENSION & SHEAR AREA $.0362 \text{ in}^2$
SHEAR STRESS $= 3.4/.0362 = 94$ PSI
TENSION STRESS $= 45/.0362 = 1243$ PSI

STRESSES ARE SMALL

.515 MOUNTING WALL

FOR PURPOSES OF ANALYSIS ASSUME THE UDD MOUNTING WALL TO BE CANTILEVERED WITH END LOAD P_1, AND MOMENT M.



$I = \frac{1}{12}(1.26)(.515)^3 = .0143 \text{ in}^4$

$M_{max} = 21.9 + 9.7(1.3) = 34.5$ in lb

$\sigma_b = \frac{(34.5)(.515/2)}{.0143} = 621$ psi
small

LVDT ATTACHMENT TO ORIFICE PLATE

CONSIDER ONLY 2 BOLTS TO CARRY LOAD

SHEAR LOAD FROM UDD $= \sqrt{9.7^2 + 10.1^2} = 14.0$ lb

TENSILE LOAD $= 90.2$ lb

LOAD PER BOLT: SHEAR $= 7$ lb
TENSION $= 45.1$ lb

SINGLE AND DOUBLE LVDT SUPPORTS

ASSUMING A 3/8 316 SST ASME SA-193 16 UNC OR
EQUIVALENT BOLT
STRESS AREA = .0773 IN²

TENSILE STRESS 45.1/.0773 = 583 PSI
SHEAR STRESS 7/.0773 = 91 PSI LOW E OK

THE DOUBLE LVDT HOLDER SEES SIMILAR LOADS
AND STRESSES.

MODIFIED ORIFICE PLATE & UPPER STRUCTURE

MODIFICATION OF THE CENTER FUEL ASSEMBLY ORIFICE PLATE TO ACCOMODATE THE LVDT HOLDERS IS SHOWN ON DWG 204250 SHEET 2 AND CONSISTS OF 1) REDUCING THE INSTRUMENT CHANNEL SECTION IN THE AREA OF THE ORIFICE PLATE AND 2) LOCATING SEVERAL BOLT HOLES AND NOTCHES IN THE PLATE & UPPER STRUCTURE WALL.

THE REDUCED SECTION OF THE INSTRUMENT CHANNEL WAS REVIEWED AND FOUND STRUCTURALLY SOUND IN LETTER RKB-10-78 REF 7.

THE ORIFICE PLATE IS ANALYZED IN LTR 1111-32 (REF 8) THE MAXIMUM STRESS DUE TO PRESSURE LOADING WAS FOUND TO BE 1280 psi WITH AN ASME CODE ALLOWABLE OF 16100 psi. IT IS NOT EXPECTED THAT THE DIRECT LOADING OF THE MOUNTING PLATE OR STRESS CONCENTRATIONS DUE TO THESE HOLES WILL INCREASE THE STRESS LEVELS TO THE 16100 psi ALLOWABLE.

UDD AND THERMOCOUPLE MOUNTING 209282

PRIMARY LOADING OF THE UDD MOUNTING IS FROM

1) LOAD FROM THE UDD
2) HYDRAULIC LOAD FROM FLUID FLOW

LOADS FROM THE ATTACHED UDD ARE ASSUMED AS SHOWN ON PAGE 3.
THE HYDRAULIC LOAD IS CALCULATED AS

$P_D = \frac{1}{2g_c} \rho V^2 C_d A$

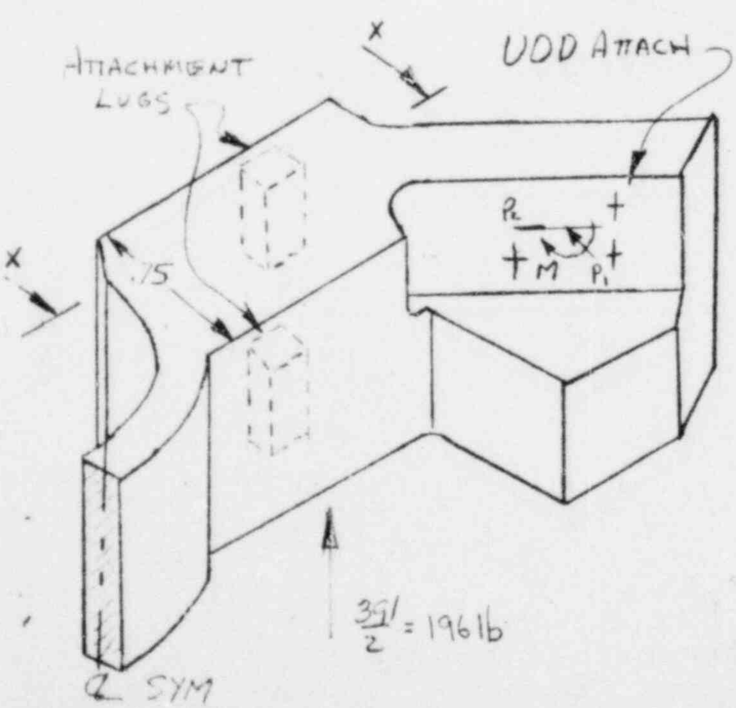
THE DYNAMIC PRESSURE TERM $\frac{1}{2g_c} \rho V^2$ IS ASSUMED AS THE MAXIMUM VALUE OF 24.05 psi REPORTED IN LTR 141-80, (REF 3)

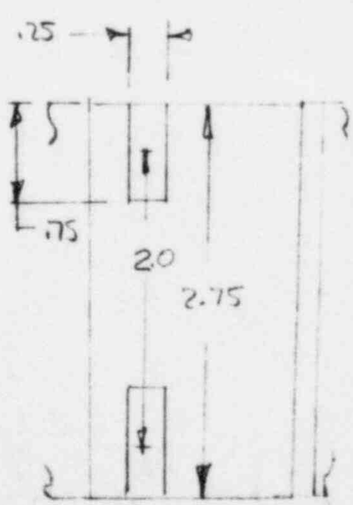
C_d IS TAKEN AS 2.5
A IS ESTIMATED FROM 209282 AS 6.5 in^2

THE HYDRAULIC LOAD IN THE DIRECTION OF FLOW IS

$P_D = (24.05)(2.5)(6.5) = 391$ lb

OR AN EQUIVALENT UNIFORM BOTTOM PRESSURE OF 391/6.5 = 60.2 lb/in^2





VIEW XX

UDD AND THERMOCOUPLE MOUNTING 201282

ATTACHMENT LUGS

FROM Pg 3 $P_1 = 9.7$ lb
$P_2 = 10.1$ lb
$M = 21.9$ in lb

SHEAR LOAD ON LUG = $P_V = \sqrt{10.1^2 + 196^2} = 196.3$ lb
$f_V = 196 / (.25)(.75)(2) = 517$ psi

small ok

CHECK WELDS - LUG ATTACHMENT TO [illegible] STRUCTURE

ASSUME .06 FILLET WELD ONE SIDE OF EACH LUG

SHEAR LOAD ON LUG = 196.3/2 = 98 lb
TENSION LOAD ON WELD (ASSUME AS FOLLOWS)
(391/2)(1.0)/2 47.7 = 103 lb

$f_s = 98/(.707)(.06)(.75) = 3080$ psi
$f_t = 108/(.707)(.06)(.75) = 3394$ psi

$f_w = \sqrt{3080^2 + 3394^2} = 4583$ psi

ALLOWABLE WELD STRESS = 21000 psi OK

CHECK LVDT HOLD DOWN SPRING

SPRING FREE LENGTH = 1.00 in
COMPRESSED LENGTH = .75 in
SPRING RATE = 38 lb/in

SPRING FORCE DOWN ON LVDT = (1.0 - .75)(38) = 9.5 lb

ASSUME A FORCE UP ON THE LVDT DUE TO FLUID FLOW ON AN AREA OF $\pi (.32/2)^2 = .0804$ in^2

$P_D = \frac{1}{2 g_c} \rho V^2 C_d A$
where $\frac{1}{2 g_c} \rho V^2 = 24.05$ psi (Pg A7)
$C_d = 2.5$

$P_D = (24.05)(2.5)(.0804) = 4.83$ lb
$4.83 < 9.5$

OK

BOLT TORQUE VALUES

PER REF 6 SUBSECTION NG 3232.2 (b)

"FOR TORQUING DURING INSTALLATION OF FASTENERS, THE MAXIMUM VALUE OF MEMBRANE STRESS INTENSITY SHALL BE NO GREATER THAN 1.2 TIMES THE LIMITS OF NG 3231.1 (a) AT INSTALLATION TEMPERATURE."

PER SUBSECTION NG 3232.1 (a)

"THE MAXIMUM VALUE OF MEMBRANE STRESS INTENSITY AVERAGED ACROSS EITHER THE AREA OF THE FASTENER SHANK OR THE TENSILE STRESS AREA OF THE THREADS SHALL BE NO GREATER THAN THE LESSER OF EITHER .9 Sy OR 2/3 Su . . . ."

AT 100°F FOR 316 SST, ASME SA 193 GR B8M

S_y = 30 KSI
S_u = 75 KSI } REF 6

$.9 S_y = .9(30) = 27$ KSI ← LIMITING VALUE
$2/3\, S_u = 2/3(75) = 50$ KSI

THE CODE LIMIT ON MEMBRANE STRESS INTENSITY IS:

$$(1.2)(27) = 32.4 \text{ KSI}$$

THE FORCE, F, IN THE BOLT SHANK CAN BE RELATED TO THE APPLIED TORQUE BY:

$$T = CFd \quad \text{REF 9}$$

C = COEFFICIENT DEPENDENT ON FRICTION
d = NOMINAL BOLT DIAMETER

FROM REF 10 FOR STAINLESS STEEL BOLTS WITH 2 COATS OF NEOLUBE

$$C = .247$$

Bolt Torque Values

Since $F = \sigma_t A_b$ the bolt tensile stress can be expressed:

$$\sigma_t = \frac{T}{.247 d A_b} = \frac{4T}{.247 \pi d^3}$$

The shear stress in the bolt can be expressed: Ref 9

$$\tau = \frac{Tr}{J} = \frac{2T}{\pi r^3}$$

The stress intensity can now be written

$$\sigma_1 - \sigma_2 = 2\sqrt{\left(\frac{\sigma_t}{2}\right)^2 + (\tau)^2}$$

$$S_I = 2\sqrt{\left(\frac{2T}{.247 \pi d^3}\right)^2 + \left(\frac{2T}{\pi r^3}\right)^2}$$

$$S_I = 32.4\ KSI = 2\sqrt{\left(\frac{2T}{.247 \pi d^3}\right)^2 + \left(\frac{2T}{\pi r^3}\right)^2}$$

For 209250-18, -19 .25-28 UNC Take $d = .25$, $r = .125$

$$\left(\frac{32400}{2}\right)^2 = 27210 T^2 + 106243 T^2$$

$$\underline{T \quad 44 \text{ in lb}}$$

For 209250-20, -21 .375-16 UNC Take $d = .375$, $r = .1875$

$$\left(\frac{32400}{2}\right)^2 = 2389 T^2 + 9327 T^2$$

$$\underline{T = 150 \text{ in lb}}$$

BOLT TORQUE VALUES

FOR 209250-18-19 .25-28 UNC

ENGAGEMENT (-18) = .148 IN
(-19) = 1 dia = .25 IN

$\tau_{ALL} = .6 S_m = .6(16600) = 9960$ psi SA 240

THE ALLOWABLE AXIAL LOAD BASED ON THREAD SHEAR*

(-18) $F_{ALL} = \frac{\pi(.2307)(.148)(9960)}{2} = 534$ lb

$F = \frac{T}{.247d} = \frac{44}{(.247)(.25)} = 712$ lb

712 > 534 SO DETERMINE ALLOWABLE TORQUE

$T = (534)(.247)(.25) = 32$ in lb

(-19) $F_{ALL} = \frac{\pi(.2307)(.25)(9960)}{2} = 902$ lb

$F = \frac{T}{.247d} = \frac{44}{(.247)(.25)} = 712$ lb

712 < 902 OK

FOR 209250-20-21 .375-16 UNC
ENGAGEMENT = .875 IN
D = .3412 IN

$F_{ALL} = \frac{\pi(.3412)(.875)(9960)}{2} = 4670$ lb

$F = \frac{T}{.247d} = \frac{150}{(.247)(.375)} = 1619$ lb

1619 < 4670 OK

MAX BOLT TORQUES SHOULD BE AS FOLLOWS;

209250-18	.25-28 UNC	32 in lb
209250-19	.25-28 UNC	44 in lb
209250-20, -21	.375-16 UNC	150 in lb

* BOLT THREAD SHEAR AREA IS DETERMINED FROM

$A_s = \frac{\pi D l}{2}$ l = ENGAGEMENT LENGTH
D = AVE of MAJOR & MINOR DIA.