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LOFT TECHNICAL REPORT LTR 141-92

RE&C INTERNAL REPORT RE-A-78-205

MARCH 26, 1979

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STRESS ANALYSIS OF THE RETAINING
STUD FOR THE ECC RAKE

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DEPARTMENT OF ENERGY

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Title:

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STRESS ANALYSIS OF THE RETAINING STUD FOR THE ECC RAKE

I. SUMMARY

The stress analysis of the retaining stud on the ECC Rake has been completed. The analysis used thermal loading of Ref. 3 and mechanical loading obtained from Ref. 1. The mechanical force on the stud is due to drag, lift and vortex shedding forces. The weld joining the stud to the pipe was determined to be the critical section. The weld is a fusion type weld which has the same strength properties as a full penetration butt weld. The analysis was performed using a sketch provided by LOFT. The configuration analyzed is shown on Fig. 6.

The retaining stud and weld were found to be structurally adequate to withstand the specified LOCE loading.

II. METHOD OF ANALYSIS

Two methods were employed to determine the stresses in the stud due to thermal and mechanical loading. The stresses due to thermal loading were determined by using a SAAS III, Ref. 4, axisymmetric finite element computer model, shown on Fig. 1. This type of computer model was used because of the axisymmetric temperature distribution. The stresses due to the mechanical loads, from Ref. 1, were determined using hand analysis techniques. Hand analysis techniques were used due to the simplicity of the loading and the fact that the mechanical loading is not axisymmetric.

The stresses were calculated and classified in accordance with Subsection NF of the ASME Code. Subsection NF does not require that secondary or peak stresses be considered. Therefore, the secondary stresses and fatigue were evaluated in accordance with Subsection NB of Section III of Reference 2.

COMPUTER MODEL
FIGURE 1

LTR 141.92

FIGURE 2

LIR 141.92

FIGURE 3

LTR 141-92

FIGURE 4

LTR 141.92

IN

-3516.00
-2989.00
-2267.00
-1160.00
-399.00
-399.00
-1160.00
-2267.00
-2989.00
-3516.00

; STRESS=
-1905.11

EAR INNER
F STRESS=
-1905.11
EAR OUTER
F STRESS=
-1905.11

PEAK STRESS IN=
-1610.89
PEAK STRESS OUT=
-1610.89

PLOT?
0=YES 1=NO
SFG3 TO SUPPRESS
PRINT

R-Z SYMMETRIES

FIGURE 5

LTR 141-92

STUD DETAIL

316 S.S.TL SEAT - 200131-31
I.D. = .376-.377
PRESS .003-.005 OUT-OF-ROUND
IN TRIANGULAR PATTERN

RETAINING STUD FOR THE ECC RAKE

FIGURE 6

III. CONCLUSIONS

The retaining stud on the ECC Rake meets the stress criteria of Subsection NF of Ref. 2. The maximum stress in the weld, which is the critical section, due to LOCE loading, which is the most severe transient, is below the endurance limit. Therefore, no cyclic limitations exist on the stud or weld.

The retaining stud is structurally adequate with the maximum stresses being much less than the allowable.

IV. REFERENCES

1. SAI-085-78-PA, "ECC Pitot Tube Rake Assembly Design Report", by Science Applications, Inc, May 1978.
2. American Society of Mechanical Engineers, ASME Boiler and Pressure Vessel Code, Section III, "Nuclear Power Plant Components", 1977.
3. C. M. Martin, "Thermal Analysis of Retaining Stud for the ECC Pitot-Tube Rake Assembly During LOCE", LOFT Technical Report LTR 144-16, August 14, 1978.
4. SAAS III, Applied Mechanics Branch Version, Release 6, Version 2, Source Listing Included in Appendix B.

CALCULATION WORK SHEET

Page 1 of Pages

Subject ECC Stud Stress Analysis

Date

Prepared By D P FINICLE

Checked

Work Request

From the SASS Model shown on Figure 1, the stresses due to thermal loads, in the weld region, are

ELEMENT	σ_x	σ_z	σ_{rz}	σ_e
68	12155	-7533	-399	12155
69	13179	-7418	-1160	13411
70	15003	-6890	-2267	15877
71	18796	-5264	-2989	20581
72	25275	496	-3516	30257
80	10109	-5983	-738	10109
81	10643	-5514	-1583	11079
82	11716	-4253	-3575	13065
83	13079	-2703	-6493	16119
84	16199	6905	-10257	23599

These two groups of 5 elements are on each side of the weld. It appears like the first group, 68-72, has the highest stress level. This group will be used to represent the stress in the weld.

Only $\frac{1}{2}$ of the stud is modeled, therefore in calculating the ave stress, bending peak stress, double the # of elements must be used. NOTE, The bending component will be zero due to the fact that the model is axi-symmetric.

LOFT TECHNICAL REPORT LOFT PROGRAM

FORM EG&G-229
(Rev. 12-76)

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STRESS ANALYSIS OF THE RETAINING STUD FOR THE ECC RAKE		LTR 141-92
		RE-A-78-205
AUTHOR		GWA NO.
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PERFORMING ORGANIZATION		DATE
Applied Mechanics Branch <i>9-5-78</i>		March 26, 1979
LOFT APPROVAL		
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3/8
OK

Seismic Review

ABSTRACT

A stress analysis of the retaining stud on the ECC Rake has been completed. The analysis considered thermal and mechanical loads that the stud is subjected to during a LOCE. The stud was analyzed to the requirement of Subsection NF of the (1977) ASME Code, Ref. 2. The stud was found to be structurally adequate.

DISPOSITION OF RECOMMENDATIONS

No disposition required.

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APPENDIX A

STRESS CALCULATIONS

Subject _____ Date _____

Prepared By D P FINICLE Checked _____ Work Request _____

From ref 1,

the drag force is 44 lb
the lift force is 55 lb.
Vortex Shedding is 6 lb.

} applied over $\frac{1}{2}$ below
} in the same direction

also from reference 1, the rake

$$Q_1 = 9.3 \text{ in}$$

$$L_2 = 10.7 \text{ in}$$

$$A_1 = 2.62 \text{ m}^2$$

$$A_2 = .6381 \text{ m}^2$$

LIFT $I_1 = .7696 \text{ in}^4$ LIFT $I_2 = .06933 \text{ in}^4$

DRAG $I_1 = .7519 \text{ in}^4$ DRAG $I_2 = .1480 \text{ in}^4$

NOTE: The cross section is different for drag and lift forces.

The above beam is statically indeterminate. CASTIGLIANO'S THEOREM will be used to determine the reaction force at the stud.

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CALCULATION WORK SHEET

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Subject _____ Date _____

Prepared By D P FINCLE Checked _____ Work Request _____

SECTION	M	$\frac{\partial M}{\partial V_C}$	M	$\frac{\partial M}{\partial V_C}$	$\sum M \frac{\partial M}{\partial V_C} \frac{dx}{EI}$
C to B	$V_C x - \frac{5.14 x^2}{2}$	x	$V_C x^2 - \frac{5.14 x^3}{2}$		$\frac{1}{EI} \int_0^{10.7} (V_C x^2 - 2.57 x^3) dx$
B to A	$V_C x + 10.7 V_C$ $- 55(x + 5.35)$	$(x + 10.7)$	$V_C x^2 + 21.4 V_C x - 55 x^2$ $- 882.5 x + 114.5 V_C - 3148$		$\frac{1}{EI} \int_0^{9.3} () dx$

$$\frac{1}{EI_2} \int_0^{10.7} (V_c x^2 - 2.57 x^3) dx = 0$$

$$I_2 = .06933$$

$$I_1 = .7696$$

$$\frac{1}{I_2} \left[\frac{V_C X^3}{3} - \frac{2.57 X^4}{4} \right]_0^{10.7} = \frac{1}{I_2} [408 V_C - 8422] = \underline{5884 V_C - 12147}$$

$$\frac{1}{EI} \int_0^{23} (V_c x^2 + 21.4 V_c x - 55x^2 - 883x + 114.5 V_c - 3148) dx$$

$$\frac{1}{I_1} \left[\frac{V_c X^3}{3} + \frac{21.4 V_c X^2}{2} - \frac{55 X^3}{3} - \frac{883 X^2}{2} + 114.5 V_c X - 3148 X \right]_0^{9.3}$$

$$= \frac{1}{I_1} [268V_c + 9.25V_c - 14747 - 38185 + 1065V_c - 29611]$$

$$= 2934 V_c - 107254$$

$$\Sigma = (2934 + 5884) V_c - (107254 + 121477) = 0$$

$$V = 25.94 \text{ lb}$$

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CALCULATION WORK SHEET

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Subject _____ Date _____

Prepared By D P FINICLE Checked _____ Work Request _____

SECTION	M	$\frac{\partial M}{\partial V_c}$	$M \frac{\partial M}{\partial V_c}$	$\sum M \frac{\partial M}{\partial V_c} \frac{dx}{EI}$
C to B	$V_c x - \frac{4.11 x^2}{2}$	X	$V_c x^2 - \frac{4.11 x^3}{2}$	$\frac{1}{EI} \int_0^{10.3} (V_c x^2 - \frac{4.11 x^3}{2}) dx$
B to A	$V_c x + 10.7 V_c - 44(x + 5.35)$	$(x + 10.7)$	$V_c x^2 + 21.4 V_c x - 44 x^2$	$\frac{1}{EI} \int_0^{\dots} (\dots) dx$
			$- 706 x + 114.5 V_c - 2519$	

$$\frac{1}{EI_2} \int_0^{10.7} (V_c x^2 - 2.05 x^3) dx = \frac{1}{I_2} \left[\frac{V_c x^3}{3} - \frac{2.05 x^4}{4} \right]_0^{10.7} = \frac{1}{I_2} [408 V_c - 6717]$$

$$= \underline{2756V_c - 45385}$$

$$\text{III, } \int_0^{9,3} (V_c x^2 + 21,4 V_c x - 44x^2 - 706x + 114,5 V_c - 2519) dx$$

$$\frac{1}{I_1} \left[\frac{V_c X^3}{3} + \frac{21.4 V_c X^2}{2} - \frac{44 X^3}{3} - \frac{706 X^2}{2} + 114.5 V_c X - 2519 X \right]_0^{9.3}$$

$$\frac{1}{I_1} [268V_c + 925V_c - 11797 - 30530 + 1065V_c - 23427]$$

$$= \underline{3003V_3 - 87450}$$

$$\Sigma = (3003 + 2756) V_c - (87450 + 45385) = 0$$

$$\therefore V_0 = 23.11 \text{ kV}$$

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CALCULATION WORK SHEET

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Subject _____ Date _____

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the 6lb. Vortex Shedding Force is in the same direction as the lift force making a total of 61b in that direction.

Ratting the reaction on pg 4 $\frac{6}{55}(25.94) = 28.81\text{lb.}$

$$\therefore V_{RES} = \sqrt{28.8^2 + 23.1^2} = 36.916$$

∴ Overturning Moment = $35.9 \times .38'' = 14'' \#$

Using Section Properties from pg 2,
stresses due to overturning.

NOTE: Shear Stress in the stud is ≈ 370 psi ave.; This is low compared to the other stresses and has been deleted.

element.	σ_z (PSL)
a $\in$ 68	± 270 .
b $\in$ 69	± 810
c $\in$ 70	± 1348
d $\in$ 71	± 1894
e $\in$ 72	± 2417

Combining these stresses with those on page 1

Coord.	element #	σ_r	σ_z	σ_{rz}	σ_t
.01875	e	25875	-1921	-3516	30257
.05625	d	18796	-7158	-2989	20581
.09375	c	15003	-8238	-2267	15877
.13125	b	13179	-8228	-1160	13411
.16875	a	12155	-7803	-399	12155
.20625	68	12155	-7263	-399	12155
.24375	69	13179	-6608	-1160	13411
.28125	70	15003	-5492	-2267	15877
.31875	71	18796	(+) -3370	-2989	20581
.35625	72	25875	+2913	-3516	30257

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Since this stud is not a typical component support, Secondary stress and peak stresses will be evaluated. They will be evaluated in accordance with NB of ref. 2.

Of the stresses listed on the previous pages and on figures 2 thru 5 only those which are due to the applied lateral force on the Stud, are considered Primary. This force results in a bending stress in the weld. These stresses are listed on the center of page 6.

Calculate P_B .

from PG 6 $\sigma_z = 2417 \text{ psi}$

S.I = 2417 = P_B Since there aren't any other P_B stresses present.

$$P_m + P_B < 1.5 S_m$$

from Tbl I-1.2 $S_{\text{up}} @ 550^\circ \text{F} = 13.9 \text{ ksi}$

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Sm is for SA240, Type 316 SST, which is the Plate Material. The Stud is SA193 Gr BMB Bolting Material which is much higher strength.

$$R_m + D_B = 2417 \text{ psi} < \underbrace{1.5(13900)}_{\text{per NF}} = 20850 \text{ psi} \quad \begin{matrix} \text{E NF} \\ \text{E NF} \end{matrix}$$

All other stresses, which are due to thermal, are secondary or peak stresses. Subsection NF does not require these stresses be evaluated. The secondary and peak stresses will be evaluated per Section NB of ref 2.

CALCULATE $P_L + P_B + Q$

from fig 2 thru 5

$$\begin{aligned} \sigma_w &= 16015 \text{ psi} \\ \sigma_z &= -8414 \text{ " } \\ \sigma_t &= 17145 \text{ " } \\ \sigma_{rz} &= -1905 \text{ " } \end{aligned}$$

using a HP 9815 program to calculate the principle stresses

$$\sigma_1 = 1714.5 \text{ psi}$$

$$\sigma_z = -8562 \text{ psi} \quad \therefore P_L + P_B + Q = 17145 - (-8562) \\ = 25710 \text{ psi}$$

$$\sigma_3 = 16,162 \text{ psi}$$

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$\therefore$ Secondary stresses are OK.

$$\therefore S_A = 32615/2 = 16310 \text{ psi}$$

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$$E \approx E_{\text{CHART}} \rightarrow \text{Fig I - 9.2}$$

From Fig I-9.2 ref 2

Cycles = 10^6

APPENDIX B

SOURCE LISTING FOR SAAS III

Doug Finicle BFA (7)

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