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August 17, 1973

Mr. G. W. Reinmuth
Chief, Technical Assistance Branch
United States Atomic Energy Commission
Directorate of Regulatory Operations
Washington, D. C. 20545

Reference: AEC Contract AT(11-1)-1658
Task A
Consulting Services
Assignment DC-105A
PAR: 73-74 A

Subject: Preliminary Review of Feedwater Sparger of Millstone Unit 1 of Northeast Utility Service Company (NUSCO)

Attachments: No. 1 -- Fatigue Life

No. 2 -- Relationship between Strain Gage Readings and Radial Deflection

No. 3 -- References

Dear Mr. Reinmuth:

As discussed in our telephone conversation of August 13, the purpose of this letter is to record the main findings of our preliminary review of the feedwater sparger of Millstone Unit 1.

The following personnel were involved in two meetings of August 10, 1973 at Millstone Unit 1:

Messrs. E. J. Ferland, Assistant Superintendent, Unit 1, NUSCO

**R. Foster, Operations Supervisor, Unit 1, NUSCO

*T. Ng, Engineer, NUSCO

*E. DeBarba, Engineer, NUSCO

*J. Gilman, Engineer, GE/APED

*S. Mather, Engineer, GE/APED

*B. Price, Engineer, GE/APED

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W. J. Foley, Consultant, Parameter, Inc.

**Part Time
*Afternoon Only

As Item No. 1, let us discuss our observations about the effect of the feedwater sparger on safety of Millstone Unit 1.

The third set of spargers, described by Figure 3 on page 10 of Reference 1, has been in operation for about one week. Because sparger vibration has been found to be unacceptably high at 90% power, Unit 1 is being run at 80% power. The intention is to restrict alternating stress caused by mechanical vibration to 10000 psi.

As shown by the arbitrary calculation on Sheet 3 of Attachment No. 1, the cumulative usage factor has an acceptable value of 1.0 for 40 years of continuous vibration at 150 cps with an alternating stress of 18,000 psi combined with 1000 cycles of thermal stress which has a half-amplitude of 92,000 psi. For this arbitrary calculation, non-vibratory mechanical stresses are assumed to be zero. Evaluation of final GE/APED results will be expedited by this calculation.

As summarized by Reference 3, visual/TV examinations are planned for refueling outage (in June 1974) and interim monitoring by means of hot test instrumentation and differential pressure gages has been implemented. Surveillance instrumentation designed to detect small pressure drops caused by cracks is described by Figure 4 on Page 8.2 of Reference 2. Criteria for continued operation are summarized on Page 8.5 of Reference 2. Design analysis for the third set of spargers is summarized on Page B-6 of Reference 2.

On the basis of these observations about Item No. 1, the writer feels that GE/APED and NUSCO have been prudent in planning continued operation at 80% power with Feedwater

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Sparger No. 3 and that Unit 1 is being safeguarded properly. The writer presumes that thermal stresses caused by startup transients will be minimized and that any significant vibration change caused by wear of pinned supports of the sparger will be detected by (still operable) strain gages. Monitoring for cracks by means of differential pressure gages will have to be done faithfully, especially if the strain gages fail in this harsh environment.

As <u>Item No. 2</u>, let us discuss whether failure of the Millstone Unit 1 feedwater sparger is <u>generic</u>.

Our questioning brought out the GE/APED reply that a few other power stations have feedwater spargers somewhat similar to the Millstone Unit 1 sparger. The GE/APED representatives qualified their reply by pointing out that comparison is complicated by many variables. It appears to us that further information is required before it can be argued that Millstone Unit 1 has a unique characteristic which leads to failure of the feedwater sparger.

It is significant that the feedwater sparger now in use at Millstone Unit 1 is not preloaded. The previous spargers at Millstone were preloaded initially but lost their preload during service. It appears that the concept of feedwater sparger preload has been disproved by the Millstone Unit 1 failures. Whether this concept is <u>generic</u> is a question of interest.

As <u>Item No. 3</u>, let us discuss whether sparger vibration could be <u>forced</u> by the feedwater pump. On page 4.1 of Reference 2, GE/APED reports that "pressure transducers on the feed lines showed small blips at the blade-passing frequency, but there is no evidence that this affects vibration response of the spargers." To our questioning, GE/APED replied that no appreciable motion of external feedwater piping was observed. The writer feels that possible effect of the pump should not be dismissed too quickly.

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As background for Item No. 4, please review Attachment No. 2. Radial deflection of the sparger appears to be large enough to intensify flow induced vibration. When we questioned the "venturi effect" of the 1/2" wide annular space between sparger and vessel wall, GE/APED replied that the sparger was only one foot below liquid level, was subjected to only 1 ft/sec. flow and was not affected by the steam separator downcomers. At this time, Mr. Tack Ng (NUSCO) argued that the radially directed sparger jets caused enough turbulence to create large dynamic forces. He was not disputed by GE/APED. Further discussion is required to clarify the mechanism of feedwater sparger vibration.

As Item No. 5, the effect of the new feedwater sparger support bracket on the vessel wall should be mentioned. Vessel stresses at this bracket are discussed qualitatively on Page B-46 of Reference 2 and are said to satisfy Code requirements.

Discussion of the preceding five (5) items has brought out the main observations of our Millstone visit of August 10.

Four (4) copies of this letter and attachments are enclosed for your distribution. Mr. Lofy and I will be pleased to reply to whatever questions arise.

Very truly yours,

Walter J. Foley

Walter J. Foley, P.E.
Consulting Engineer
Parameter, Inc.

FATIGUE LIFE OF FEEDWATER SPARGER
DESIGN NO. 3, MILLSTONE UNIT 1

ON THE BASIS OF EXTRAPOLATED DESIGN FATIGUE DATA, GE/APED HAS SELECTED AN ALLOWABLE PEAK-TO-PEAK STRESS OF 20000 PSI.

ACCORDINGLY, $S_a = 20000/2$
$= 10000$ PSI *REF 2, PAGE 6.1

FROM EXTRAPOLATED CURVE "A" ON SHEET 4,

$N = 2.2 \times 10^9$ CYCLES, FOR $S_a = 10000$ PSI

LET n' = CYCLES PER YEAR, WITHOUT SHUTDOWN

Y = ALLOWABLE YEARS OF SERVICE, WITHOUT SHUTDOWN

f = FORCED FREQUENCY OF VIBRATION, CYCLES PER SECOND (CPS OR HERTZ)

THEN $n' = \left(f \, \frac{CYCLES}{SEC}\right)\left(3600 \, \frac{SEC}{HR}\right)\left(24 \, \frac{HR}{DAY}\right)\left(365 \, \frac{DAYS}{YR}\right)$

$= 31.536 \, f \times 10^6$

$Y = N/n' = 2.2 \times 10^9 / 31.536 \, f \times 10^6$

$= 69.76/f$

TABULATING Y FOR TYPICAL VALUES OF f,

f, CPS	50	100	150	FROM HARSH CURVE "A"
Y, YEARS	1.39	0.69	0.46	

BECAUSE CURVE "A" HAS BEEN EXTRAPOLATED WITHOUT TAKING ENDURANCE LIMIT INTO ACCOUNT, RESULTS TABULATED ABOVE ARE VERY HARSH.
AS EXTRAPOLATED CURVE "B" SHOWS, INFINITE LIFE APPEARS TO BE JUSTIFIABLE AT $S_a = 18000$ PSI.

* REFERENCES ARE LISTED IN ATTACHMENT NO. 3

FATIGUE LIFE OF FEEDWATER SPARGER, CONT'D

LET US RECALCULATE VALUES OF "Y" FOR AN EXTRAPOLATED CURVE WHICH INTERSECTS THE 10000 PSI LINE AT 10^{11} CYCLES, ABOUT MIDWAY BETWEEN HARSH CURVE "A" AND REALISTIC CURVE "B".

THEN $Y = N/n' = 1 \times 10^{11} / 31.536\, f \times 10^6$

$= 3171/f$

AGAIN TABULATING Y FOR TYPICAL VALUES OF f,

f, CPS	50	100	150	FROM CURVE ABOUT MIDWAY BETWEEN HARSH CURVE "A" AND REALISTIC CURVE "B"
Y, YEARS OF LIFE	63.4	31.7	21.1	

AS A THIRD WAY TO EVALUATE FATIGUE LIFE OF THE SPARGER, LET US USE THE 18000 PSI ENDURANCE LIMIT OF EXTRAPOLATED CURVE "B" AS OUR VALUE OF S_a & S_{alt}^{v} FOR VIBRATION.

THEN, FOR 40 YEARS OF CONTINUOUS SERVICE AT 150 CPS WITH $S_{alt} = 18000$ PSI,

$n_v' = 31.536 \times 150 \times 10^6$

$= 4730.4 \times 10^6$ CYCLES PER YEAR

$n_v = 40\, n_v'$

$= 189.216 \times 10^9$ CYCLES, IN 40 YEARS

U_v = CUMULATIVE USAGE FACTOR, FOR VIBRATION ONLY

$= n_v / N_v = 189.216 \times 10^9 / \infty$

$= \underline{0}$

FATIGUE LIFE OF FEEDWATER SPARGER, CONT'D

NOW LET US CALCULATE CUMULATIVE USAGE FACTOR U_T CAUSED BY (SAY) 1000 CYCLES OF THERMAL STRESS WITH A VALUE OF S^T_{alt} = 102,000 PSI.

FROM THE DESIGN FATIGUE CURVE ON SHEET 4,
N_T = 1000 CYCLES AT S_a = 110,000 PSI (= 92000 + 18000).

THEN $U_T = n_T/N_T = 1000/1000$

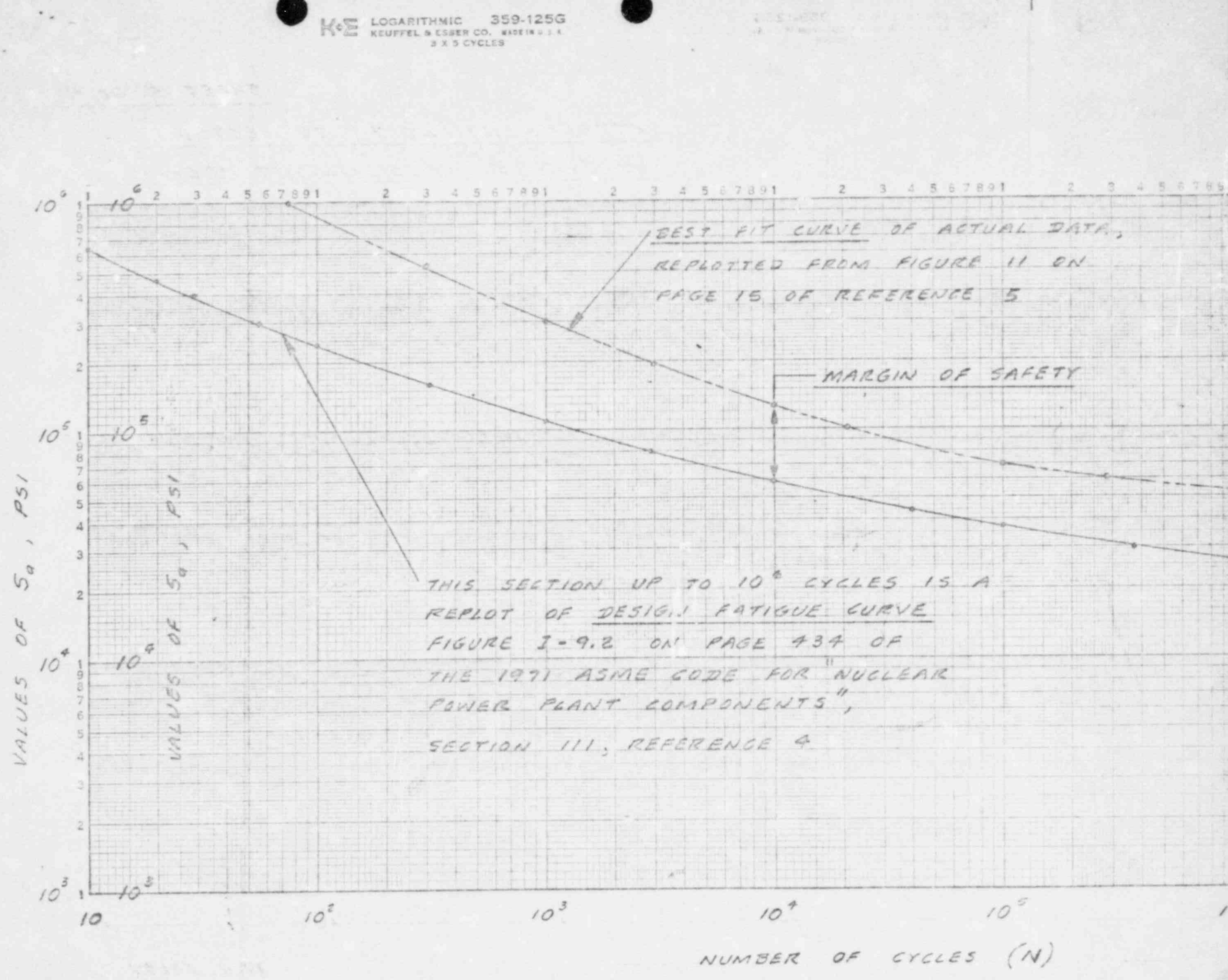
$= 1.0$

$U = U_V + U_T$

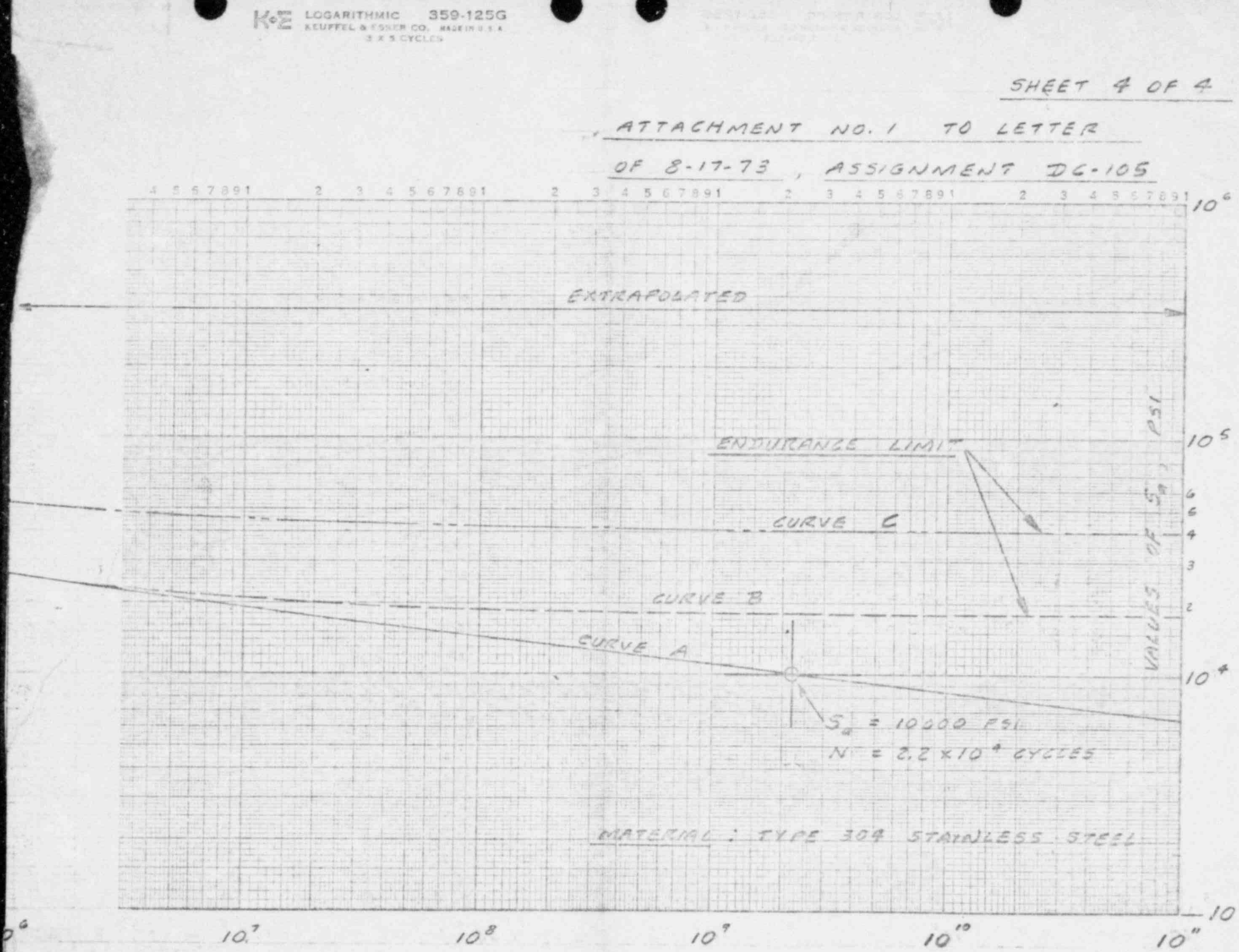
$= 0 + 1.0$

$= \underline{1.0}$ O.K., IF NON-VIBRATORY MECHANICAL STRESSES ARE ASSUMED TO BE NEGLIGIBLE

NOTE THAT THIS PRELIMINARY STUDY OF FATIGUE LIFE WILL BE USEFUL IN EVALUATING GE/APED RESULTS WHEN THEY ARE REPORTED IN FINAL FORM. ALTHOUGH IT APPEARS THAT GE/APED HAS EXTRAPOLATED THE ASME SECTION III DESIGN FATIGUE CURVE CONSERVATIVELY, THEIR METHOD OF EXTRAPOLATION IS NOT KNOWN TO THE WRITER.


K+E LOGARITHMIC 359-125G
KEUFFEL & ESSER CO. MADE IN U.S.A.
3 X 5 CYCLES
BEST FIT CURVE OF ACTUAL DATA,
REPLOTTED FROM FIGURE 11 ON
PAGE 15 OF REFERENCE 5
MARGIN OF SAFETY
THIS SECTION UP TO 10⁶ CYCLES IS A
REPLOT OF DESIGN FATIGUE CURVE
FIGURE I-9.2 ON PAGE 434 OF
THE 1971 ASME CODE FOR "NUCLEAR
POWER PLANT COMPONENTS",
SECTION III, REFERENCE 4
VALUES OF Sa, PSI
NUMBER OF CYCLES (N)
10
10²
10³
10⁴
10⁵
10⁶
10³
10⁴
10⁵
10⁶

ATTACHMENT NO. 1 TO LETTER OF 8-17-73, ASSIGNMENT DC-105



W. J. FOLEY

8-16-73

BY W. FOLEY DATE 8-1[illegible]-73 SUBJECT
CHKD. BY .... DATE .... ATTACHMENT NO. 2
PARAMETER 73-74A TO LETTER OF 8-17-73

JOB NO. AT(11-1)-1658-A
ASSIGNMENT DC-105

RELATIONSHIP BETWEEN UNIT BENDING STRAIN (ϵ) OF FEEDWATER SPARGER TO RADIAL DEFLECTION (δ) DESIGN NO. 3, MILLSTONE UNIT 1

AS SHOWN BY FIGURE 3 ON PAGE 10 OF REFERENCE 1, THE NEW SUPPORT BRACKET IS LOCATED 6°15' FROM THE CENTERLINE OF THE SPARGER. LET US ANALYZE THE LONGER ARC OF SPARGER AS A SIMPLE BEAM, WITH THE SLOTTED END PINNED AND THE OTHER END SUPPORTED BY THE NEW BRACKET. WITH REASONABLE ERROR, LET US ASSUME THAT THE STRAIN GAGES ARE LOCATED AT MID-ARC. REFERENCE 6, PAGE 106, CASE 13

THEN δ = RADIAL DEFLECTION (IN.) AT MID-ARC

$$= \frac{5Wl^3}{384EI} \quad \text{---} (1)$$

σ = BENDING STRESS (PSI) AT MID-ARC

$$= E\epsilon \quad \text{---} (2)$$

$$Z = 2I/d_o \quad \text{---} (3)$$

$$\sigma = \frac{Wl}{8Z} = \frac{Wld_o}{16I} \quad \text{---} (4)$$

EQUATING (2) & (4),

$$E\epsilon = \frac{Wld_o}{16I}$$

$$\epsilon = \frac{Wld_o}{16EI} = \left(\frac{Wl}{EI}\right)\left(\frac{d_o}{16}\right) \quad \text{---} (5)$$

REARRANGING (1),

$$\delta = \left(\frac{Wl}{EI}\right)\left(\frac{5l^2}{384}\right) \quad \text{---} (1a)$$

SUBSTITUTING (5) IN (1a),

$$\delta = \left(\epsilon \times \frac{16}{d_o}\right)\left(\frac{5l^2}{384}\right)$$

$$= 0.208333 \times \frac{l^2}{d_o} \times \epsilon \quad \text{---} (1b)$$

RELATIONSHIP BETWEEN ϵ AND δ, CONT'D

l = LENGTH OF ARC
$\approx$ 96.00 IN., ESTIMATED

d_o = O.D. OF SPARGER
= 6.625 IN.

ϵ = STRAIN GAGE READING, IN./IN.

SUBSTITUTING ABOVE QUANTITIES IN (1b),

$$\delta = 0.208333 \times \overline{\frac{96.00}{6.625}}^2 \times \epsilon$$

$$= 290\,\epsilon$$

SUBSTITUTING PEAK VALUE OF ϵ,

$$\delta = 290 \times 0.000150$$

$$= \underline{0.044 \text{ IN.}}$$

C = RADIAL CLEARANCE (IN.) BETWEEN O.D. OF SPARGER AND I.D. OF VESSEL
= <u>0.500 IN.</u>

$$\delta/c = 0.044/0.500$$

$$= \underline{0.09}$$

NOTE THAT RATIO δ/c IS LARGE ENOUGH TO HAVE SIGNIFICANT EFFECT ON FLOW-INDUCED VIBRATION. FLOW-INDUCED VIBRATION IS INTENSIFIED BY VIBRATORY CHANGE IN AREA OF FLOW PATH BETWEEN SPARGER AND VESSEL WALL.

REFERENCES

1. INTERIM REPORT, FEEDWATER SPARGER FAILURE, MILLSTONE NUCLEAR POWER STATION UNIT 1
2. INTERIM REPORT, ADDENDUM 1, JUNE 29, 1973, FEEDWATER SPARGER FAILURE, MILLSTONE NUCLEAR POWER STATION UNIT 1
3. LETTER OF TRANSMITTAL OF REFERENCE 2, TO MR. DONALD J. SKOVHOLT, AEC/DRL, FROM MR. D.C. SWITZER, THE MILLSTONE POINT COMPANY, JUNE 29, 1973, DOCKET NO. 50-245
4. THE AMERICAN SOCIETY OF MECHANICAL ENGINEERS, NUCLEAR POWER PLANT COMPONENTS, ASME BOILER AND PRESSURE VESSEL CODE, SECTION III, 1971 EDITION
5. THE AMERICAN SOCIETY OF MECHANICAL ENGINEERS, CRITERIA OF SECTION III OF THE ASME BOILER AND PRESSURE VESSEL CODE FOR NUCLEAR VESSELS, 1964
6. ROARK, R.J., FORMULAS FOR STRESS AND STRAIN, FOURTH EDITION, 1965, McGRAW-HILL BOOK COMPANY