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CURTIS,N.W. Pennsylvania Power & Light Co.
RECIP.NAME RECIPIENT AFFILIATION
SCHWENCER,A. Licensing Branch 2

SUBJECT: Forwards supplemental response to SER Open Item 3.10.1(3). Fatigue cycling effects on NSSS equipment due to safety relief loads (License Condition 23(a)) discussed.

SEE REL

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Norman W. Curtis
Vice President-Engineering & Construction-Nuclear
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JUN 09 1983

Director of Nuclear Reactor Regulation
Attention: Mr. A. Schwencer, Chief
Licensing Branch No. 2
Division of Licensing
U.S. Nuclear Regulatory Commission
Washington, D.C. 20555

SUSQUEHANNA STEAM ELECTRIC STATION
NSSS EQUIPMENT FATIGUE EVALUATION-SUPPLEMENTARY DATA
LICENSE CONDITION (23)(a) AND SER ITEM 3.10.1(3)
ER 100450 FILE 148-01
PLA-1698

Reference: 1) PLA-1222, dated 7/29/82 from N. W. Curtis to A. Schwencer

Dear Mr. Schwencer:

This letter and its attachments contain the data requested by the NRC to supplement our response (Reference 1) to your concerns regarding the fatigue cycling effects on NSSS equipment due to SRV loads (License Condition 23(a) and SER Item 3.10.1(3)).

1.0 Number of SRV Events for BWR-4 Reactors

Derivation of the HPCI turbine fatigue test requirements indicated that 900 SRV actuations were appropriate for equipment fatigue design in BWR-4 plants. This value is based on empirical data from the operation of Browns Ferry and Peach Bottom.

Based on observed response time histories of components due to SRV loads, two (2) significant peak load cycles on equipment outside containment and four (4) significant peak load cycles on equipment inside containment can be expected for one (1) SRV actuation. Consequently, the number of peak load cycles due to SRV actuations postulated for the 40 years of plant operation is 3600 for equipment inside containment and 1800 for equipment outside containment. Observing that the significant load cycles from an SRV discharge occur within the first half second of the event, the fatigue aging required time in a response spectrum test is approximately 450 seconds (7.5 minutes).

B001
1/1

2.0 Equipment Fatigue Analysis and Testing - Supplementary Information

The following information is provided as a quantitative backup to demonstrate that the SRV fatigue aging requirement of Paragraph 1.0 is met for the equipment previously identified in Reference 1.

2.1 Analysis:

Fatigue analyses were performed for the five components listed in section 1 of Reference 1. Based on an environment with 1800 significant stress cycles (as explained above for equipment outside containment), the maximum usage factor (or cumulative damage factor) was 0.33 which occurred on the RCIC pump holddown bolts (5500 cycles allowed for the calculated fatigue stress). The calculations are contained within Attachment 1.

2.2 Test:

Supportive data is given below for equipment whose fatigue life adequacy was demonstrated using methods of extended duration testing.

2.2.1 MSIV-LCS Blower (E32-C001/C002)

Extended duration testing was performed on the blower. The total test time was 40 minutes and was achieved as follows:

a) 4 Upset Condition Tests (OBE + SRV) for 5 minutes each at 2g's input.

b) 4 Faulted Condition Tests (SSE + SRV + LOCA) for 5 minutes each at 3g's input.

These g-levels are far in excess of the 0.11g ZPA of the required SRV spectra. See the SQRT form in Attachment 2. For the sine sweep test method which was performed in the range of 3.8 to 33 hertz, several thousand cycles minimum per each 5 minute test was imposed on the test specimen such that the cumulative number of cycles greatly exceeded the required 3,600 cycles from Section 1.0. Neither structural nor operability failure occurred during this testing.

2.2.2 Electrical Cabinets

Additional extended duration testing of the cabinets with mounted devices was performed to demonstrate fatigue life adequacy of this equipment. Test programs and results are described below.

2.2.2.1 4.16KV Switchgear

The extended duration test is verified on pages 2 and 3 of the SQRT form in Attachment 3. A biaxial sine sweep test covering the amplified portions of the SRV spectrum (4 to 70 Hz) was performed in both the side-to-side/vertical and front-to-back/vertical orientations in the single cell configuration and in the front-to-back/

vertical orientation only for the multiple cell configuration. The SRV fatigue tests were performed by sweeping up and down at a sweep rate of one octave per minute for 30 minutes. The input acceleration level was approximately 0.08 g. This sinusoidal input level would produce a spectral acceleration level of approximately 2 g at 2% damping, which is well above the SRV + LOCA levels of approximately 0.9 g.

2.2.2.2 125 VDC Power Distribution Panel

Upon completion of the first combined load qualification test, SRV fatigue tests were performed using multi-frequency biaxial motion (XY and ZY). Each test was run for 60 minutes by repeating the test table input motion which had a TRS enveloping the required SRV RRS. Enveloping was checked at the beginning, middle, and end of each test. Refer to the SQRT form and spectra in Attachment 4.

2.2.2.3 Power Range Monitoring Cabinet

Qualification testing of this NSSS cabinet was completed in the week of March 27, 1983. Successful fatigue cycling tests were performed using two biaxial time history motions (H&V) for 15 minutes in each plane. The input waveforms had a TRS designed to envelope the following RRS.

g_h	f
0	2
.25	5
.75	8
.75	12
.16	50 (ZPA)

g_v	f
0	2
.6	6
1.5	10
1.5	20
.16	50 ZPA

The test plan and panel RRS were determined to be adequate for Susquehanna prior to the test.

2.2.3 Valve Motor Operators

Extended duration testing was conducted during dynamic qualification of Limitorque motor operators as follows.

Fatigue was not considered a concern for the metal parts of the actuator due to the low stresses involved. The critical parts are the plastic parts, limit switch rotors, limit switch finger base and torque switch. For the unit selected, an SMB-2-60, the orientation most severe for fatigue is the vertical direction. Therefore the test was done only in the vertical direction. The g loading of 3g was a conservative load based on the fact that the actual SRV-only loads are less than 3g.

The test excitation was in the form of a sine sweep from 10 to 70 to 10 hertz at a sweep rate of one octave per minute which imposed approximately 30,000 cycles on the operator. These load cycles are significant regardless of frequency because the operator fundamental frequency was previously found to be in excess of 100 hertz. The test unit was operated after this testing.

2.2.4 <u>MSIV Actuator</u>

The referenced letter describes that credit was taken for additional testing to cover SRV fatigue cycling on the actuator.

Since the required vertical input motion to the inclined actuator is approximately an order to magnitude greater than the horizontal component, it dominates the critical stress in the yoke rods. Repeating this input after horizontal rotation of the test specimen for each upset and faulted condition test, therefore, results in twice as many yoke rod stress cycles than will occur on the SSES MSIV actuator for the design condition of five upset and one faulted-condition load events. The horizontal and vertical upset and faulted RRS and TRS for the actuator are shown in Attachment 5.

Therefore, credit for SRV aging is taken for 5 upset tests and 1 faulted test. Since an upset test is equivalent to 60 SRV events while a faulted test is equivalent to 50 SRV events, this additional qualification testing is equivalent to 350 SRV events.

Further testing run on the test specimen is equivalent to another 390 SRV events as shown below, giving a total of 740 equivalent SRV events produced by the testing.

2 - 50% Upset Tests	=	120 SRV events
2 - 40% Upset Tests	=	120 SRV events
2 - 50% Faulted Tests	=	100 SRV events
1 - 40% Faulted Tests	=	50 SRV events
		390 Total

In regard to test levels, the MSIV upper mass g-level calculated in the piping analysis was approximately 9 g's using an SRSS combination. With an actuator fundamental frequency of 10 hz, the full level faulted testing subjected this mass to more than twice this value as shown by the TRS in the attachment, and this was verified by the accelerometer records.

Therefore, the above-reduced level tests are sufficient to cover SRV excitation while the higher g-levels associated with the qualification tests can be considered equivalent to additional SRV stress cycles on a fatigue usage factor basis, concluding that the required number of 900 SRV events were met by the testing.

2.2.5 CRD Vent and Drain Valves

SRV fatigue cycling will be part of the upcoming dynamic qualification test on the SSES CRD vent and drain valves. The current test plan calls for horizontal and vertical time history waveforms simultaneously input to the test table for a cumulative time of 15 minutes. This test will be repeated after a 90 degree rotation of the test specimen. The TRS will envelope the following generic RRS during testing of the later model valves in SSES Unit 2:

Horizontal

g's	Freq. (Hz)
1	5
8	10
8	40
2.5	60
2.5	(ZPA)

Vertical

g's	Freq. (Hz)
1	5
6	10
6	40
2.5	60
2.5	(ZPA)

while the TRS will envelope the following conservative RRS during testing of the earlier model valves in SSES Unit 1:

Horizontal and Vertical

g's	(Freq. (Hz)
0.3	5 hz
2.4	10
2.4	40
0.75	60 (ZPA)

3.0 Conclusion

The data contained within and attached to this letter supports our position (Reference 1) that all NSSS equipment will perform satisfactorily under the fatigue cycling effects due to SRV loads. This letter fulfills and completes our actions under License Condition 23(a) and SER Item 3.10.1(3).

Very truly yours,

N W Curtis

N. W. Curtis
Vice President, Engineering and Construction-Nuclear

cc: Mr. R. L. Perch - NRC
Mr. A. Lee - NRC

Attachments:

Attachment 1:

Part 1 RHR Heat Exchanger Fatigue Life Evaluation due to SRV Actuations

Part 2 RHR Pump/Motor Fatigue Life Evaluation due to SRV Actuations

Part 3 Core Spray Pump/Motor Fatigue Life Evaluation due to SRV Actuations

Part 4 HPCI Pump Fatigue Life Evaluation due to SRV Actuations

Part 5 RCIC Pump Fatigue Life Evaluation due to SRV Actuations

Attachment 2: SQRT Form for the MSIV LCS Blower

Attachment 3: SQRT Form for the 4.16 kV Switchgear

Attachment 4: SQRT Form and SRV Response Spectra for the 125 VDC Distribution Panels

Attachment 5: MSIV Required Response Spectra

ATTACHMENT 1

PART 1

GENERAL ELECTRIC CO.
Nuclear Energy Business Operations
ENGINEERING CALCULATION SHEET

NUMBER: SUSQ. RHR HEAT EXCHANGER DATE: 4-21-83

SUBJECT: SUSQ. RHR HEAT EXCHANGER - FATIGUE LIFE EVALUATION DUE TO SRV ACTUATIONS. BY: DRD SHEET 1 OF 3

GENERAL: THE TASK HAS BEEN PERFORMED PER PWA # 3849KR, REV. C WHICH CALLS FOR PERFORMING FATIGUE LIFE EVALUATION DUE TO SRV ACTUATIONS. OVER 40 YEARS LIFE OF THE PLANT.

FROM FATIGUE POINT OF VIEW, THE FOLLOWING COMPONENTS WERE DEEMED VERY CRITICAL; REST OF THE COMPONENTS OR LOCATIONS WILL NOT HAVE SIGNIFICANT IMPACT DUE TO SRV ACTUATIONS.

- LOWER SUPPORT BRACKET WELD
- LOWER SUPPORT BRACKET BOLTS.

LOWER SUPPORT RESTRAINS THE SUBJECT EQUIPMENT IN ALL SIX DIRECTIONS AND HENCE WILL BE SUBJECTED TO HIGHEST LOADS.

(SEE NEXT SHEET.)

NOTE: TUBE SHEET & TUBE STRESS CALCULATIONS FROM OTHER PLANTS (e.g. ZIMMER RHR HEAT EXCHANGER NEW LOADS ANALYSIS, DRF # E12-12 VOL. 2) SHOWS THAT TUBE SHEETS AND TUBE STRESSES WILL BE VERY LOW FOR THE GIVEN SRV LOADS.

VERIFIED BY [signature]
CHECKING 4-29-83

VERIFIED BY: ____________

NEO-87 (REV 8/81)

GENERAL ELECTRIC CO.
Nuclear Energy Business Operations
ENGINEERING CALCULATION SHEET

NUMBER ______ DATE 4-21-83
SUBJECT SUSQ. RHR HEAT EXCHANGER - FATIGUE LIFE EVALUATION DUE TO SRV ACTUATIONS. BY DRD SHEET 2 OF 3

1. LOWER SUPPORT BRACKET WELD:

CALCULATED WELD STRESS = 5990 psi
(REF: DRF# E12-42, SEC. 5.3).
ABOVE STRESS IS DUE TO STATIC (NOZZLE LOADS, DEAD WT.) plus SSE, SRV AND WLA LOADS.

CONSERVATIVELY USING THE SAME STRESS VALUE AND APPLYING STRESS CONCENTRATION FACTOR OF 2.7* (USE HIGHEST FACTOR)

σ_{peak} = 5990 x 2.7 = 16173. psi (CONSERVATIVELY. MAX. PRINCIPAL STRESS WAS USED RATHER THAN MAX PRINCIPAL STRESS DIFFERENCE).

ALTERNATING STRESS = $S_a = \frac{16173}{2}$ = 8087. psi. ≤ 8050 psi

THIS ALLOWABLE VALUE (8050 psi, HALF RANGE) IS FOR STRESS REVERSAL CYCLES > 20,000** TO 100,000. ACTUAL NUMBER OF CYCLES EXPECTED OVER 40 YEAR PLANT LIFE IS NOT AVAILABLE; HOWEVER, IT IS EXPECTED TO BE LESS THAN 20,000 CYCLES.

* REF: PRESSURE VESSEL DESIGN HANDBOOK BY H.H. BEDNAR, TABLE 10.6, PAGE. 257.

** REF: ASME SEC III, DIV I APPENDICES, ARTICLE XVII-3000 TABLE XVII-3220-1. (ALSO SEE TABLE XVII-3240-1 FOR ALLOWABLE STRESS).

2. LOWER SUPPORT BRACKET BOLT:

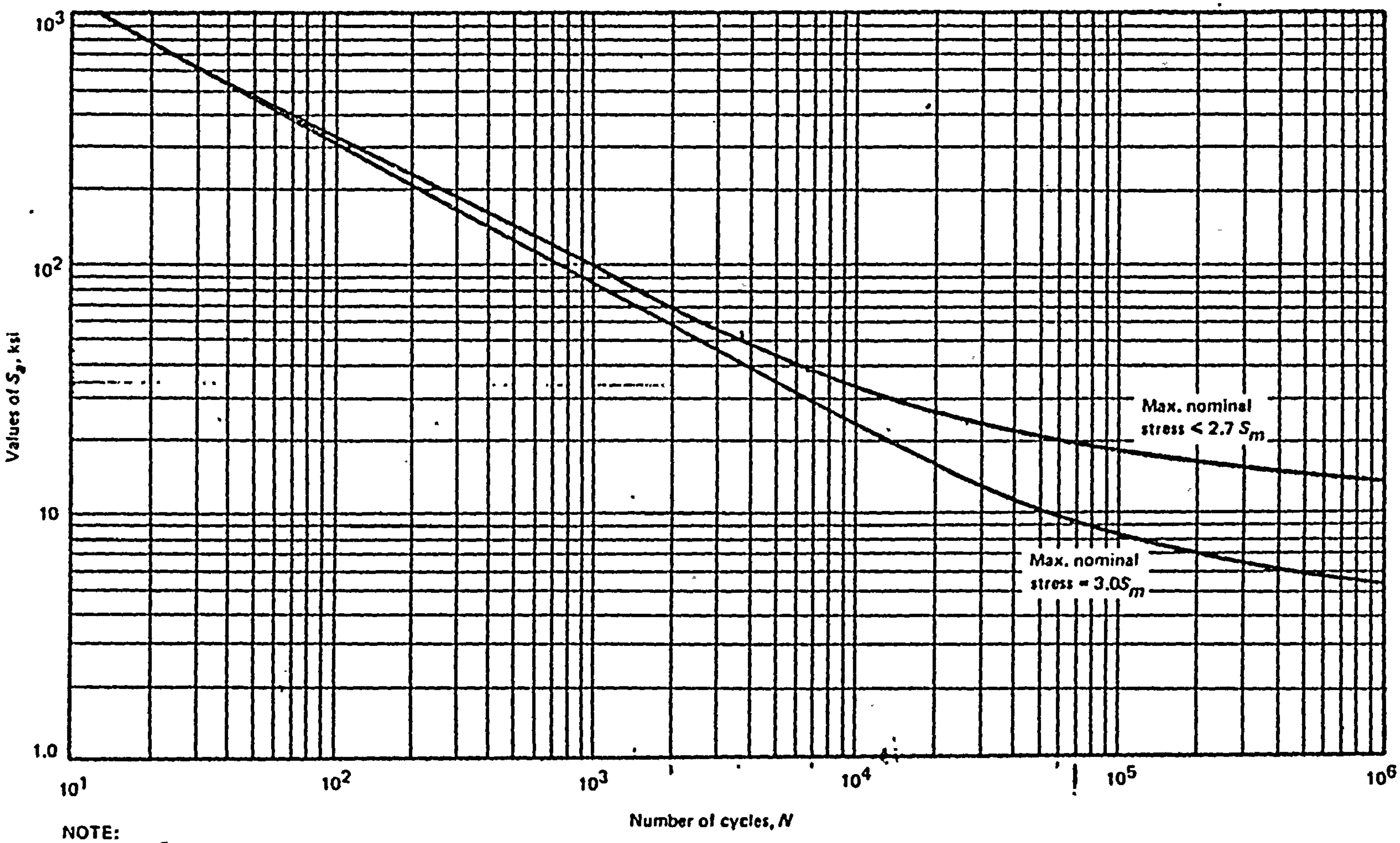
CALCULATED STRESS = 13115 psi (TENSILE)
CONSERVATIVELY USING THE ABOVE STRESS VALUE AND APPLYING STRESS CONCENTRATION FACTOR OF 4

PEAK STRESS = 13115 x 4 = 52460 psi
$S_a = \frac{52460}{2}$ = 26230 psi.

MAT: SA-193, GR B-7, FROM FATIGUE CURVE (SHT. 3 of 3)
FOR S_a = 26230, N = ≤ 20,000 CYCLES

VERIFIED BY H.T. 8-29-83

NEO-87 (REV 8/83)



NOTE:
E = 30 X 10⁶ psi

FIG. I-9.4 DESIGN FATIGUE CURVE FOR HIGH STRENGTH STEEL BOLTING FOR TEMPERATURES NOT EXCEEDING 700°F
Table I-9.1 Contains Tabulated Values and a Formula for Accurate Interpolation of These Curves

SHT 3 OF 3

1-2/24

NUMBER ______ DATE 2-25-83
SUBJECT SUSQ. RHR P/M FATIGUE LIFE EVALUATION DUE TO SRV ACTUATIONS. BY DRD SHEET 1 OF 5

GENERAL: THE TASK HAS BEEN PERFORMED PER PWA # 3849 KR REV. 0 WHICH CALLS FOR PERFORMING FATIGUE LIFE EVALUATION DUE TO SRV ACTUATIONS.

NUMBER OF SRV CYCLES OVER 40 YEARS LIFE IS ASSUMED TO BE 1800, WHICH IS CONSERVATIVE AND OBTAINED FROM THE OPERATING PLANT EXPERIENCE.

THE FOLLOWING CRITICAL LOCATIONS WERE EVALUATED BASED ON HIGHER STRESSES AND MATERIAL:

- SUCTION BARREL SHELL @ MAX. STRESS LOCATION.
- DISCHARGE HEAD FLANGE BOLTING.
- TOP STAGE CASE AND BOLTING.
- MOTOR STAND

NOTE: STRESSES IN THE DISCHARGE HEAD SHELL ARE SMALLER THAN THE STRESSES IN SUCTION BARREL SHELL; HENCE DISCHARGE HEAD SHELL NOT EVALUATED.

STRESS CALCULATIONS:

SUCTION BARREL SHELL: CONSERVATIVELY STRESSES DUE TO ALL DYNAMIC LOADS (SSE, SRV, LOCA) AND STATIC LOADS (NOZZLE LOADS, DEAD WT, PRESSURE, HYDRAULIC DOWN THRUST) WERE CALCULATED.

$\sigma = 17671$ psi (REF: DRF # E12-43, REV. 1, SEC 5.1, ELEM # 8J).

$\sigma_{peak} = 17671 \times 4 = 70684$ psi

$S_a = \frac{70684}{2} = 35342$ psi

MAT: ASTM A516 GR. 70

VERIFIED BY HT 3-2-83

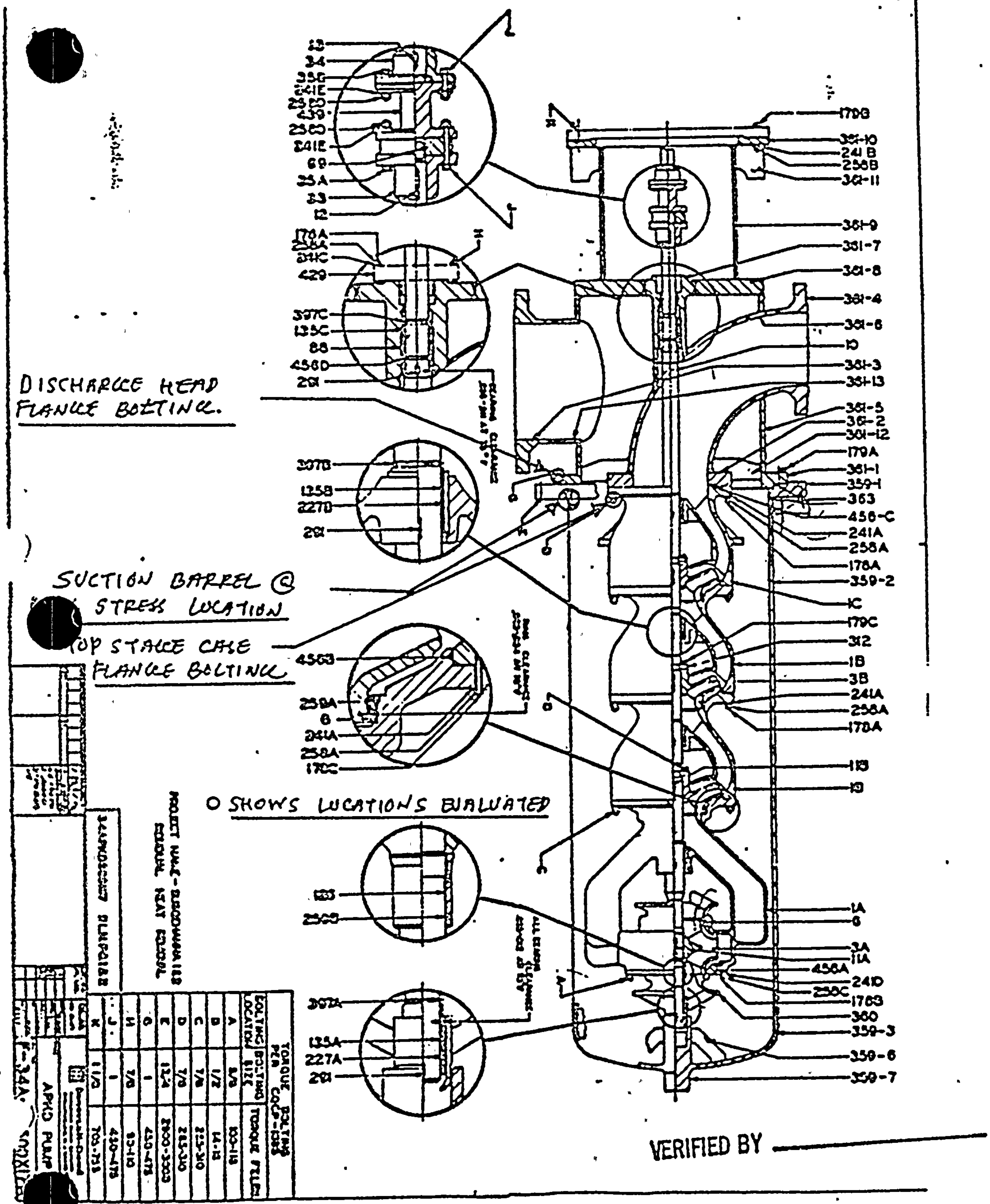
FROM FATIGUE CURVE (ATTACHMENT-1) FOR $S_a = 35342$ psi, N = 14,000 CYCLES

USAGE FACTOR = $\frac{1800}{14000} = 0.13 < 1$.

1-3/24

DRF # E12-43

SHT. 2 OF 5



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GENERAL ELECTRIC CO.
Nuclear Energy Business Operations
ENGINEERING CALCULATION SHEET

NUMBER ____ DATE 2-25-83
SUBJECT SUSQ. RHR p/m FATIGUE LIFE EVALUATION DUE TO SRV ACTUATIONS. BY DRD SHEET 3 OF 5

DISCHARGE HEAD FLANGE BOLTING: CONSIDERING STATIC AND SRV LOADS ONLY. (REF: DRF # E12-43 REV. 1, SEC. 5.6 SPRING ELEMENTS)

R_1 = R_1 DUE TO STATIC LOADS + R_1 DUE TO SRV LOADS.
= 116,043 − 2(55053)* − 37140* + 2300 = −28903 LBS. ≠ 0

* (SUBTRACTING DEAD WT AND HYDRAULIC DOWN THRUST FROM TOTAL R_1, BOLTS ARE IN COMPRESSION AND CAN BE SUBTRACTED FROM THE ACTUAL TENSION DUE TO BENDING MOMENT. BUT, CONSERVATIVELY ASSUME $R_1 = 0$)

M_2 = 2176714 + 54900 = 2231614 IN. LBS

M_3 = 1065587 + 54600 = 1120187 IN. LBS.

$$P_{EQ} = p + \frac{16\left[M_2^2 + M_3^2\right]^{1/2}}{\pi G^3} + \frac{4R_1}{\pi G^2}$$ VERIFIED BY H.T. 3-2-83

$$= 220 + \frac{\left[2231614^2 + 1120187^2\right]^{1/2}}{\pi \times 49.25^3} + 0$$

= 227 psi

FROM THE DRF FOR P_{EQ} = 389 psi σ = 23195
FOR P_{EQ} = 227 psi, $\sigma = \frac{227}{389} \times 23195$ = 13535 psi

σ_{peak} = 13535 × 4 = 54140 psi
$S_a = \frac{54140}{2}$ = 27070 psi
FROM FATIGUE CURVE (ATTACHMENT 3) FOR S_a = 27070 psi
N = > 15,000 CYCLES

USAGE FACTOR = $\frac{1800}{15000}$ = 0.12 < 1.

TOP STAGE CASE BOLTING:

σ = 40123 psi (REF: DRF # E12-43, SEC 5.19, ELEM # 24 J)
ABOVE STRESS IS AS A RESULT OF SIMULTANEOUSLY APPLIED SSE, SRV, LOCA AND OTHER STATIC LOADS. CONSIDERING ONLY STATIC AND SRV LOADS; WE HAVE,

R_1 = R_1 DUE TO SRV LOADS + R_1 DUE TO STATIC LOADS
= 357 + 6417 = 6776 LBS

M_2 = 42400 + 273 = 42673 IN.LBS

M_3 = 47200 + 645 = 47845 IN.LBS.

VERIFIED BY H.T. 3-2-83

$$P_{EQ} = P_{DES} + \frac{16\left[M_2^2+M_3^2\right]^{1/2}}{\pi a^3} + \frac{4R_1}{\pi a^2}$$

$$= 280 + \frac{16\left[42673^2+47845^2\right]^{1/2}}{\pi \times 21^3} + \frac{4\times 6776}{\pi \times 21^2}$$

= 325 psi

FROM DRF P_{EQ} = 777 psi σ = 40123 psi
P_{EQ} = 325 psi $\sigma = \frac{325}{777} \times 40123 = 16782$ psi

σ_{PEAK} = 16782×4 = 67128 psi
$S_a = \frac{67128}{2}$ = 33564 psi

FROM FATIGUE CURVE (ATTACHMENT. 3) FOR S_a = 33564 psi
N = 9000 CYCLES

USAGE FACTOR = $\frac{1800}{9000}$ = 0.2 < 1.

1-6/24

NUMBER ______ DATE 2-25-83
SUBJECT SUSQ. RHR P/M FATIGUE LIFE EVALUATION DUE TO SRV ACTUATIONS. BY DRD SHEET 5 OF 5

TOP STAGE CASE: CONSERVATIVELY TAKE STRESSES FROM THE DRF # E12-43 REV.1, SEC 5.18. ELEM # 24 J.

∴ σ = 7012 psi (@ MAX DIAMETER LOCATION)

∴ AT THIS LOCATION NO STRESS CONC. IS EXPECTED TO OCCUR DUE TO LACK OF DISCONTINUITY. HOWEVER, CONSERVATIVELY USE STRESS CONC FACTOR OF 2

$\sigma_{peak} = 7012 \times 2 = 14024$ psi

$S_a = \frac{14024}{2} = 7012$ psi.

MATERIAL: CAST IRON

FROM FATIGUE CURVE (ATTACHMENT-2) FOR $S_a = 7012$ psi $N = > 10^6$

∴ S_a IS BELOW ENDURANCE LIMIT.

NOTE: THE FATIGUE CURVE (ATTACHMENT-2) IS PLOTTED FROM THE TEST RESULTS AND DOES NOT HAVE ANY SAFETY FACTOR. THEREFORE, USING SAFETY FACTOR OF 2, ENDURANCE LIMIT FOR NOTCHED SPECIMEN REDUCES FROM 17,000 TO 8500 psi.

MOTOR STAND: FROM DRF # E12-43, REV.1 SEC 5.11

σ = 5717 psi

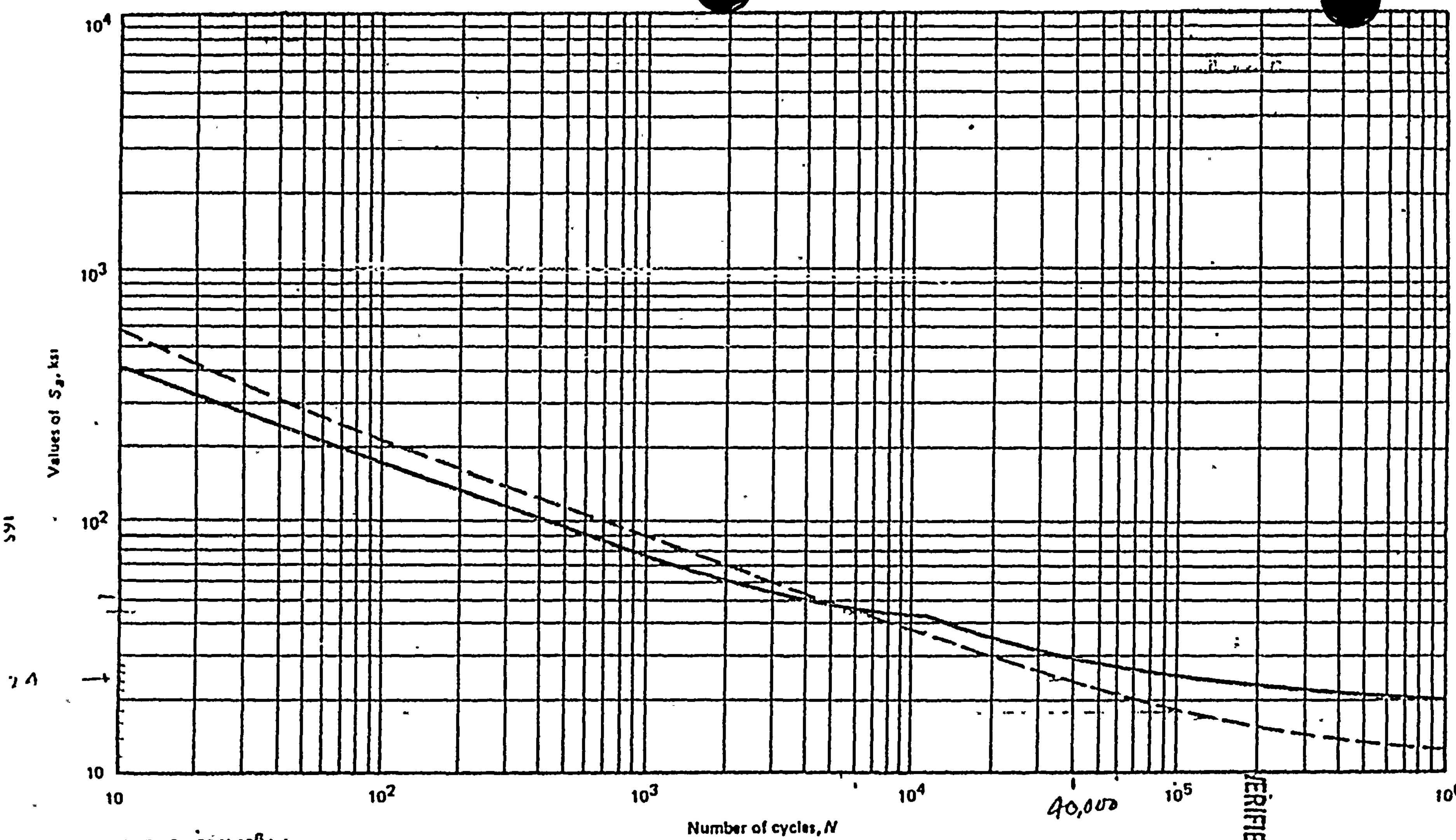
RHR MOTOR STAND HAS SAME MATERIAL AS LPCS MOTOR STAND.

∴ FROM LPCS MOTOR STAND CALC. σ = 4505, N = > 10^6 CYCLES

∴ FOR RHR MOTOR STAND σ = 5717 psi, WE HAVE SIGNIFICANTLY HIGH FATIGUE LIFE. (AT LEAST > 10^5 CYCLES)

HENCE USAGE FACTOR = $\frac{180}{10^5} \approx 0$

VERIFIED BY H.T. 3-2-83



NOTE: E = 30 X 10^6 ksi
— — UTS < 80.0 ksi
—— UTS 115.0–130.0 ksi
Interpolate for UTS 80.0–115.0 ksi

FIG. I-9.1 DESIGN FATIGUE CURVES FOR CARBON, LOW ALLOY, AND HIGH TENSILE STEELS FOR METAL TEMPERATURES NOT EXCEEDING 700°F

Table I-9.1 Contains Tabulated Values and a Formula for Accurate Interpolation of These Curves

VERIFIED BY M.T. 3-2-83

proach is to use the tensile strength (or fatigue limit) and, after determining the section modulus of the actual shape, to apply the proper bending formula. However, because of the difficulty in obtaining a meaningful value for the tensile strength in tests of small specimens, the load computed in this manner will usually be somewhat lower than the actual load required to rupture the part, unless unfavorable residual stresses are present in the finished part.

Elongation of gray iron at fracture is very small (of the order of

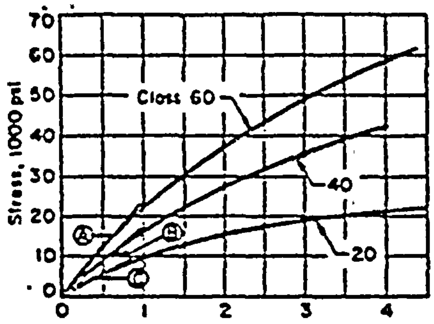


Fig. 10. Typical stress-strain curves for three classes of gray iron in tension. Modulus of elasticity is measured to points A, B and C, representing ¼ of the tensile strength.

0.006 in. per in.) and hence is seldom reported. The designer cannot use the numerical value of permanent elongation in any quantitative manner.

Torsional Shear Strength. As shown in Table 12, most gray irons have high torsional shear strength. Many grades have torsional strength greater than some grades of steel. This characteristic, along with low notch sensitivity, makes gray iron a suitable material for shafting of various types, particularly in the grades of higher tensile strength. Most shafts are subjected to dynamic torsional stresses and the designer should consider carefully the exact nature of the loads. For the higher-strength irons, stress concentration factors associated with changes of shape in the part are important for torque loads as well as for bending and tension loads.

Modulus of Elasticity. Typical stress-strain curves for gray iron are shown in Fig. 10. Gray iron does not obey Hooke's law and the modulus in tension is usually determined arbitrarily as the slope of the line connecting the origin of the stress-strain curve with the point corresponding to ¼ of the tensile strength. Some engineers use the slope of the stress-strain curve near the origin for determining the modulus of elasticity.

As indicated in Table 12, the modulus of gray iron varies considerably more than for most metals. Thus, in using observed strain to calculate stress, it is essential to measure the modulus of the particular gray iron specimen being considered. The numerical value of the modulus in torsion is always less than in tension, just as it is for steel.

Hardness of gray iron, as measured by Brinell or Rockwell testers, is an average result of the soft graphite in the iron and the metallic matrix. Variations in graphite size and distribution will cause wide variations in hardness (particularly Rockwell hardness) even though the hardness of the metallic matrix is constant. To illustrate this effect, the microhardness of the matrix of five types of hardened iron, as compared with Rockwell C measurements on the same iron, is shown in Table 13.

It is apparent that if any hardness correlation is to be attempted, the graphite must be constant as to type and amount in the irons being compared. It is recommended that Brinell hardness be used when possible.

Fatigue Limit in Reversed Bending

Because fatigue limits are expensive to determine, the designer usually has incomplete information on this property. Typical S-N curves for gray iron under completely reversed cycles of bending stress are shown in the graph on left in Fig. 11, in which each point represents the data from one specimen. The effects of temperature on fatigue limit and tensile strength are shown in the right-hand graph in Fig. 11.

Axial loading or torsional loading cycles are frequently encountered in designing parts of cast iron, and in many instances these are not completely reversed loads. Types of regularly repeated stress variation usually can be expressed as a function of a mean stress and a stress range. Wherever possible the designer should use actual data from the limited information available. Without precisely applicable test data, an estimate of the reversed bending fatigue limit of machined parts may be made by using about 35% of the minimum specified tensile strength of the particular grade of gray iron being considered. This is probably a safe value rather than an average of the few data available concerning the fatigue limit for gray iron.

Table 13. Comparison of Rockwell Hardness of Gray Irons, as Influenced by Graphite

Type of graphite	Total carbon, %	Rockwell C hardness (a)	Matrix converted (b)
A	3.06	45.2(c)	61.5
A	3.53	43.1	61.9
A	4.00	22.0	62.0
D	3.20	54.0	62.5
D	3.60	48.7	60.5

(a) Measured by conventional Rockwell C test. (b) Hardness of matrix, measured with superficial hardness tester and converted to Rockwell C. (c) Although this value was obtained in the specific test cited, it is not typical of gray iron of 3.06% C. Ordinarily the hardness of such iron is Rockwell C 48 to 50.

An approximation of the effect of range of stress on the fatigue limit may be obtained from diagrams such as Fig. 12. The tensile strength is plotted on the horizontal axis to represent the fracture strength under static load (which corresponds to zero stress range). The reversed

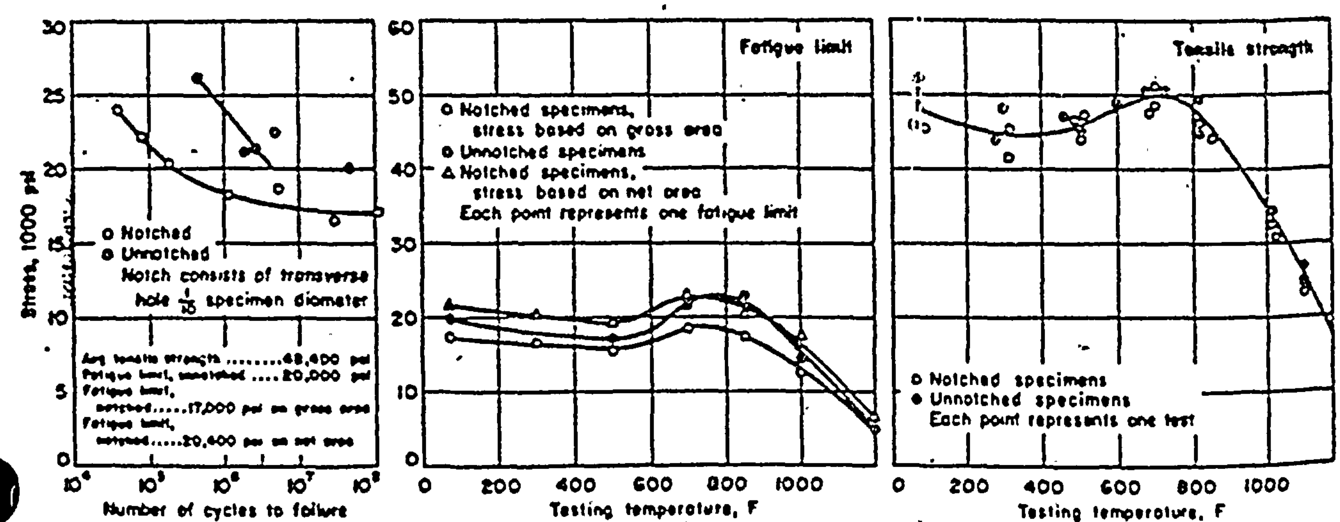
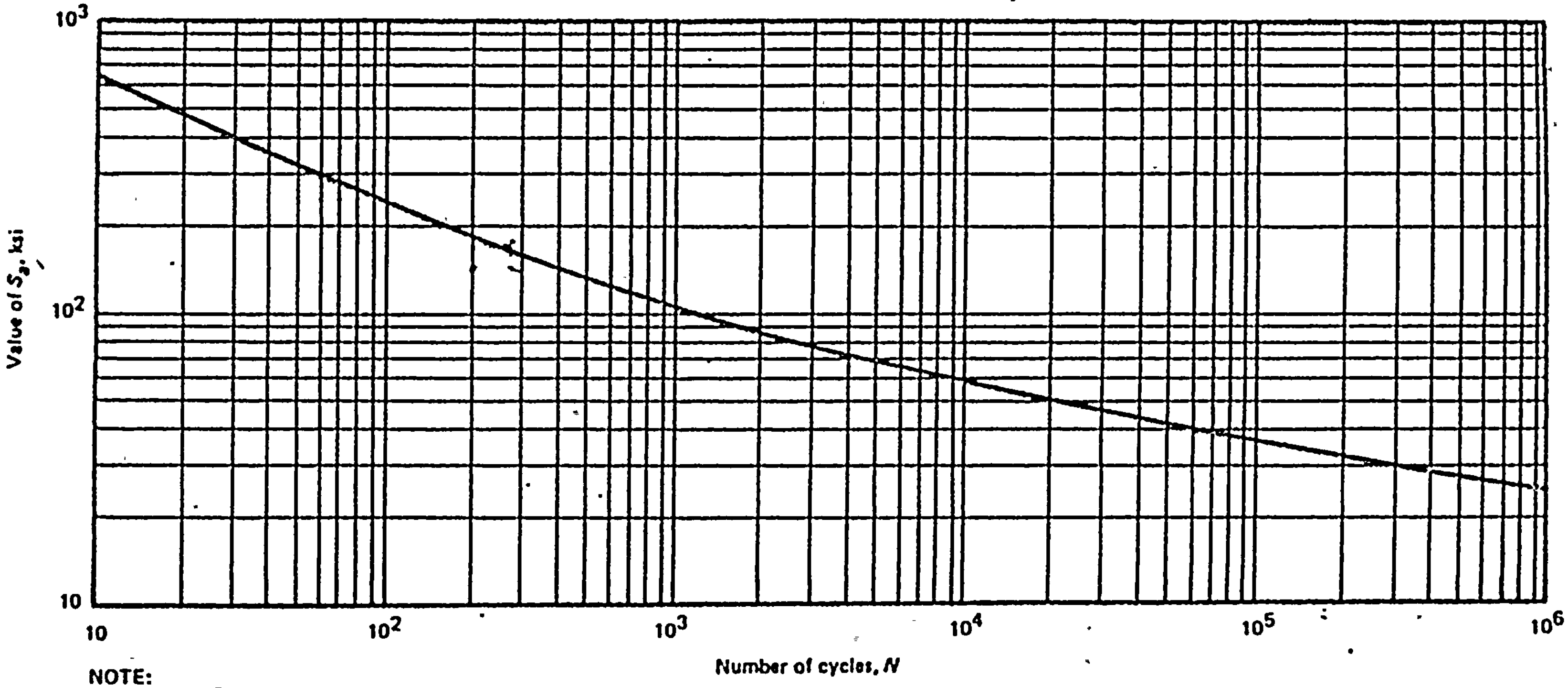


Fig. 11. S-N curves and effects of temperature on fatigue limit of gray iron of the tensile strength shown. Composition: 3.34 C, 1.52 Si, 1.85 Mn, 0.07 P, 0.12 S, 0.31 Cr, 0.20 Ni, 0.37 Cu. (W. Leighton Collins and James O. Smith, Proc. ASTM, 41, 797, 1941)

ATTACHMENT 3



NOTE:
$E = 26.0 \times 10^6$ psi

FIG. I-9.2 DESIGN FATIGUE CURVE FOR AUSTENITIC STEELS, NICKEL–CHROMIUM–IRON ALLOY, NICKEL–IRON–CHROMIUM ALLOY, AND NICKEL–COPPER ALLOY FOR TEMPERATURES NOT EXCEEDING 800°F

Table I-9.1 Contains Tabulated Values and a Formula for Accurate Interpolation of This Curve

VERIFIED BY H.T. 3-2-83

PART 3

Nuclear Energy Business Operations
ENGINEERING CALCULATION SHEET

NUMBER ______ DATE 2/25/83
SUBJECT SUSQ. LPCS P/M FATIGUE LIFE EVALUATION DUE TO SRV ACTUATIONS BY DRD SHEET 1 OF 12

GENERAL: THE TASK HAS BEEN PERFORMED PER PWA # 3K49KR REV. 0 WHICH CALLS FOR PERFORMING FATIGUE LIFE EVALUATION DUE TO SRV ACTUATIONS OVER 40 YEARS LIFE.

TO BEGIN THE TASK WITH, CERTAIN CRITICAL LOCATIONS WERE SELECTED BASED ON STRESS VALUE AND MATERIAL OF THE COMPONENTS. FORCES AND MOMENTS WERE TAKEN FROM THE DRF # E21-27 WHICH CONTAINS COMPLETE STATIC AND DYNAMIC ANALYSES FOR THE SUBJECT PUMP/MOTOR. STATIC LOADS SUCH AS SUCTION AND DISCHARGE NOZZLE, PRESSURE, DEAD WT, HYDRA. DOWN THRUST AND DYNAMIC LOADS SUCH AS SSE, SRV AND LOCA WERE USED IN THE ANALYSIS.

NUMBER OF SRV CYCLES OVER 40 YEARS LIFE IS CONSIDERED TO BE 1500 WHICH IS CONSERVATIVE AND OBTAINED FROM THE OPERATING PLANT EXPERIENCE.

THE FOLLOWING CRITICAL STRESS LOCATIONS WERE EVALUATED:

- SUCTION BARREL SHELL AT MAX STRESS LOCATION (SEE NEXT SHEET.)
- DISCHARGE HEAD SHELL
- MOTOR STAND AT WELDS.
- PUMP TOP STAGE CASE BOWLS AND BOLTING
- DISCHARGE HEAD FLANGE BOLTS.

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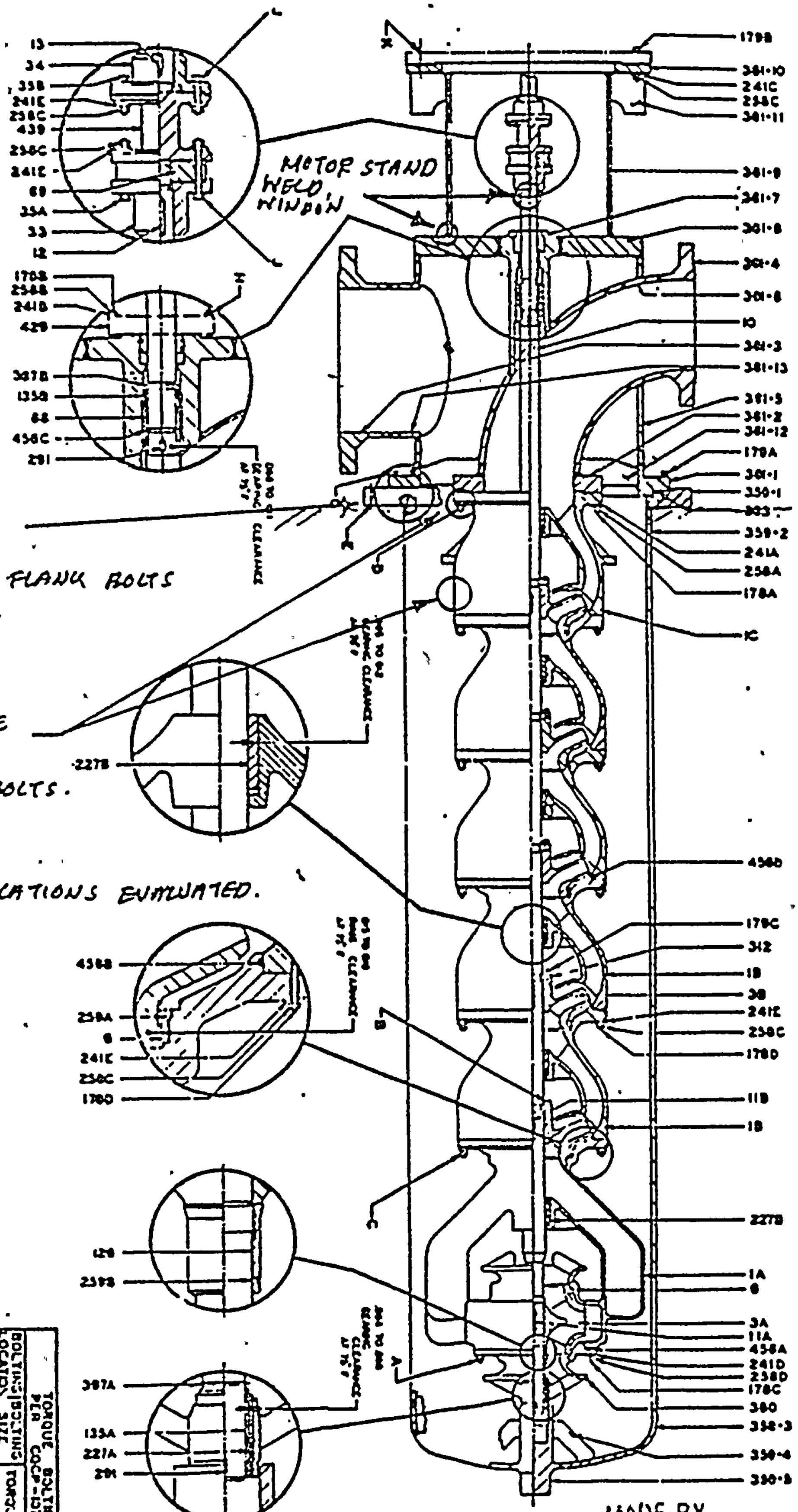
NEO-87 (REV 8/81)



- DISCHARGE HEAD SHELL
- DISCHARGE HEAD FLANG BOLTS
- SUCTION BARREL.
- TOP STAGE CASE @ MAX. DIA.
- TOP STAGE CASE BOLTS.

O SHOWS LOCATIONS EVALUATED.

BOLTING LOCATION	BOLTING SIZE	TORQUE FT-LB
A	1/2	48-58
B	3/8	7-8
C	7/8	285-315
D	1	450-475
E	1 1/4	1000-1250
G	1	450-475
H	3/4	50-70
J	7/8	285-315
K	7/8	285-315

TORQUE BOLTING PER COCP-1513

APKD PUMP

F-25

500X24

MADE BY ______

VERIFIED BY H.T. 3-1-85

1-12/24

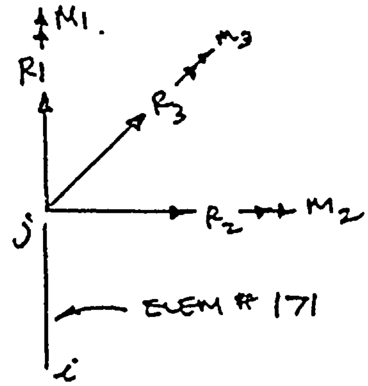
NUMBER: DATE: 2/25/83

SUBJECT: SUB.Q. LPCS p/m FATIGUE LIFE EVALUATION DUE TO SRV ACTUATIONS. BY: DRD SHEET 3 OF 12

SUCTION BARREL SHELL: TAKING STATIC LOADS AND SRV LOADS FROM DRF # E21-27, SEC 5.0. (ELEM # 171J).

R_1 = R_1 DUE TO STATIC LOADS + R_1 DUE TO SRV LOADS.
= 4008 + 139 = 4147 LBS.

R_2 = 191 LBS
R_3 = 204 LBS
M_1 = 0 IN. LBS
M_2 = 17401 IN. LBS
M_3 = 16302 IN. LBS.



LOCAL AXES ORIENTATION.

RESULTING STRESSES:

$$\sigma_e = \frac{[M_2^2+M_3^2]^{1/2}\, r_o}{I} + \frac{R_1}{A}$$

$$= \frac{[17400^2+16300^2]^{1/2}\, 14.969}{1444} + \frac{4147}{13}$$

= 566 PSI

$$\tau = \frac{(R_2^2+R_3^2)^{1/2}}{A/2} = \frac{(191^2+204^2)^{1/2}}{6.5} = 44 \text{ psi}$$

$$\sigma_{principal} = \left(\frac{\sigma_e}{2}\right) + \sqrt{\left(\frac{\sigma}{2}\right)^2+\tau^2} = 570 \text{ psi}$$

$$\sigma_{hoop} = \frac{Pr_m}{t} = \frac{125 \times 14.9}{0.1388} = 13419 \text{ psi}$$

$$\sigma_{long} = \frac{13419}{2} = 6710 \text{ psi}$$

σ_{RAD} = −125 psi

MAX PRINCIPAL STRESS DIFFERENCE = 13419 + 125 = 13544 psi

PEAK STRESS = σ_{peak} = 13544 × 4 = 54176 psi

$$S_a = \frac{54176}{2} = 27088 \text{ psi}$$ [MAT: A516 GR. 70]

FROM FATIGUE CURVE (ATTACHMENT. 1) FOR S_a = 27088 psi

N = >20,000 psi

USAGE FACTOR = $\frac{1800}{20,000}$ = 0.09

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VERIFIED BY H.T. 3-1-83

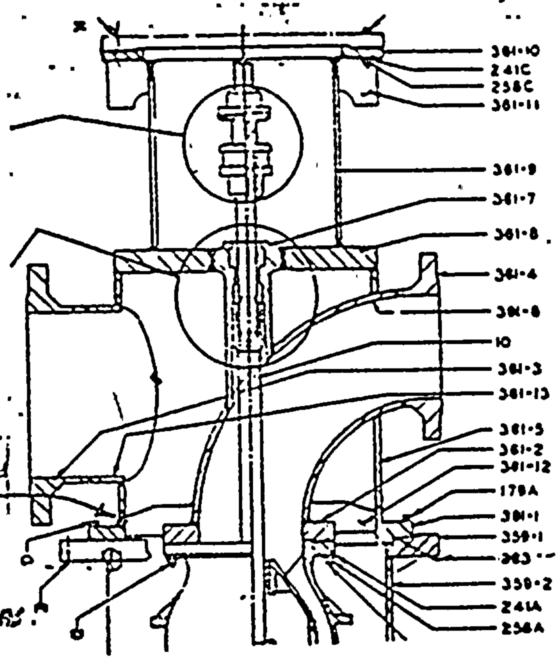
 1-13/24

NUMBER ______ DATE ______
SUBJECT SUSQ. LPCS P/M - FATIGUE LIFE EVALUATION DUE TO SRV ACTUATIONS. BY DRD SHEET 4 OF 12

MAX. STRESS IN DISCHARGE HEAD SHELL: (DRF # E21-27 SEC 5.3)

FORCES AND MOMENTS FROM SPRING ELEMS.

*R_1 = 5942 LBS M_1 = 267987 IN-LBS
R_2 = 9760 LBS M_2 = 785577 + 191002**
R_3 = 13653 LBS   = 976579 IN-LBS
  M_3 = 453066 + 204501**
  = 657567 IN-LBS



* R_1 IS OBTAINED FROM SUBTRACTING DEAD WT. OF MOTOR AND DISCHARGE HEAD (ASSUMED 8000 LBS) FROM NOZZLE FORCES AND DYNAMIC LOADS.
THUS, 2853 + 6717 + 4372 − 8000 = 5942 LBS.

** DYNAMIC MOMENT LOADING FROM SUCTION BARREL
(REF: DRF # E21-27 SEC 5.0 PAGES 18, 19. NEW NOZZLE LOADS USED)

$$\sigma_\ell = \frac{\left[M_2^2 + M_3^2\right]^{1/2} r_0}{I} + \frac{R_1}{A}$$

{CROSS SECTIONAL PROPERTIES OBTAINED FROM THE DRF}

$$= \frac{\left[976579^2 + 657567^2\right]^{1/2} \times 15}{4172} + \frac{5942}{38.1}$$

$$= 4389 \text{ psi}$$

$$\tau = \frac{M_1 r_0}{2I} + \frac{\left[R_2^2 + R_3^2\right]^{1/2}}{A/2}$$

$$= \frac{267987 \times 15}{2 \times 4172} + \frac{\left[9760^2 + 13653^2\right]^{1/2}}{0.5 \times 38.1}$$

$$= 1363 \text{ psi}$$

NOTE: FORCES AND MOMENTS USED IN THE CALC. ARE AS A RESULT OF SSE, SRV, LOCA AND STATIC LOADINGS; HENCE VERY CONSERVATIVE. ONLY SRV AND STATIC LOADS NEED BE CONSIDERED FOR FATIGUE LIFE EVALUATION DUE TO SRV LOAD.

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VERIFIED BY KT 1-1-82

NUMBER ____ DATE 2/25/83
SUBJECT SUSQ. LPCS P/M FATIGUE LIFE EVALUATION DUE TO SRV ACTUATIONS BY DRD SHEET 5 OF 12

$$\sigma_{principal} = \frac{\sigma}{2} + \sqrt{\left(\frac{\sigma}{2}\right)^2 + \tau^2}$$

$$= \frac{4389}{2} + \sqrt{\left(\frac{4389}{2}\right)^2 + 1363^2}$$

$$= 4778 \text{ psi}$$

$$\sigma_{hoop} = \frac{pr}{t} = \frac{125 \times 15}{0.34}$$

[CORRODED THICKNESS = 0.5 − 2×0.08 = 0.34]

$$= 5514 \text{ psi}$$

$$\sigma_{long} = \frac{5514}{2} = 2757 \text{ psi}$$

THUS,
THREE PRINCIPAL STRESSES IN LONGITUDINAL, HOOP AND RADIAL DIRECTION ARE:

$\sigma_{long} = 4778 + 2757 = 7535$ psi

$\sigma_{hoop} = 5514$ psi

$\sigma_{RADIAL} = -125$ psi

MAX. STRESS DIFFERENCE = 7535 + 125 = 7660 psi

PEAK STRESS = σ_{PEAK} = 7660 X STRESS. CONC. FACTOR
= 7660 × 4
= 30640 psi

$\sigma_{ALT} = S_a = \frac{30640}{2} = 15320$ psi

[MATERIAL = ASTM A516 GR.70
ASSUME UTS < 80 KSI.]

USING ATTACHED CURVE (SEE ATTACHEMENT 1), FOR S_a = 15320 psi
S_a IS BELOW ENDURANCE LIMIT. $N = > 10^5$ CYCLES.

USAGE FACTOR = $\frac{1800}{10^5} \approx 0$

MADE BY ____
VERIFIED BY H.T.-D.P.

1-15/24

NUMBER DISCHARGE HEAD FLANGE BOLT CALC. DATE

SUBJECT SUSQ. LPCS P/M FATIGUE LIFE BY DRD SHEET 6 OF 12
EVALUATION DUE TO SRV ACTUATIONS.

CONSIDERING FORCES AND MOMENTS DUE TO STATIC AND SRV LOADS ONLY.
FORCES AND MOMENTS FROM SPRING ELEMENTS (SEC. 5.3)

$F_1 = (9570 - 8000) + 792 = 2362$ LBS
$M_2 = 498827 + 17800 = 516627$ IN. LBS
$M_3 = 395256 + 23600 = 418856$ IN. LBS

* DEAD WT OF PUMP/MOTOR ABOVE THE FOUNDATION HAS BEEN SUBTRACTED FROM THE NOZZLE LOADS IN VERT. DIRECTION.

$$P_{EQ} = p + \frac{16\left[M_2^2 + M_3^2\right]^{1/2}}{\pi G^3} + \frac{4F_1}{\pi G^2} \qquad G = \text{GASKET DIA} = 30.813''$$

$$= 125 + \frac{16\left[516627^2 + 418856^2\right]^{1/2}}{\pi \times (30.813)^3} + \frac{4 \times 2362}{\pi \times (30.813)^2}$$

$$= 244 \text{ psi.}$$

FROM THE DRF SEC. 5-6 FOR $P_{EQ} = 350$ $\sigma = 28994$ psi

$\therefore P_{EQ} = 244$ $\sigma = \frac{244}{350} \times 28994$
$= 20213$ psi

APPLYING STRESS CONC. FACTOR OF 4

$\sigma_{PEAK} = 20213 \times 4 = 80852$ psi
$S_a = \frac{80852}{2} = 40426$ psi.

FROM FATIGUE CURVE (ATTACHMENT-3) FOR $S_a = 40426$ psi
$N = 6000$ CYCLES.

USAGE FACTOR $= \frac{1800}{6000} = 0.3 < 1$.

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GENERAL ELECTRIC CO.
Nuclear Energy Business Operations
ENGINEERING CALCULATION SHEET

NUMBER ________ DATE 2/25/83

SUBJECT SUSQ. LPCS P/M. - FATIGUE EVALUATION DUE TO SRV ACTUATION. BY DRD SHEET 7 OF 12

MOTOR STAND: MOTOR STAND IS WELDED TO TOP AND BOTTOM DISCHARGE HEAD PLATES. ASSUMING FILET WELDS, STRESS CONCENTRATION FACTOR OF 4 WILL BE USED TO CALCULATE S_a (ALTERNATING STRESS).

MAX. STRESS IN MOTOR STAND IS DIRECTLY TAKEN FROM THE DRF # E21-27, SECTION 5.11. THIS STRESS IS DUE TO ALL OF STATIC LOADS PLUS DYNAMIC LOADS (SSE, SRV, LOCA) AND HENCE VERY CONSERVATIVE. IN CASE OF HIGHER LOADS IN FUTURE, ONLY STATIC PLUS SRV LOADS COULD BE CONSIDERED TO EVALUATE FATIGUE LIFE DUE TO SRV ACTUATIONS.

$\sigma_{principal} = 4505$ psi (FROM DRF # E21-27, SECTION 5.11)

PEAK STRESS = $4 \times 4505 = 18020$ psi

$S_a = \frac{18020}{2} = 9010$ psi

NOW, MAT = A516-GR70

FROM THE FATIGUE CURVE (ATTACHMENT-1) IT CAN BE SEEN THAT $S_a = 9010$ psi IS BELOW ENDURANCE LIMIT.

PUMP TOP STAGE CASE ITEM: PUMP BOWL CASINGS ARE MADE OF ASTM - A48-CL30B WHICH IS GREY CAST IRON. TYPICAL S-N CURVES FOR GREY CAST IRON IS ATTACHED.

$\sigma_{max} = 5536$ psi @ MAX DIA. LOCATION (DRF # E21-27, SEC 5.18)

THE S-N CURVES (ATTACHMENT-2) WERE OBTAINED FROM THE TEST RESULTS AND DID NOT INCLUDE ANY SAFETY FACTOR. THEREFORE, APPLYING SAFETY FACTOR OF 2, ENDURANCE LIMIT REDUCES FROM 17 KSI TO 8.5 KSI FOR NOTCHED SPECIMEN. ALTHOUGH THERE IS NO STRESS CONCENTRATION EXPECTED TO OCCUR; FOR CONSERVATISM, APPLY STRESS CONCENTRATION FACTOR OF 2.

PEAK STRESS $\sigma_{peak} = 5536 \times 2 = 11072$ psi.

FROM FATIGUE CURVE (ATTACHMENT-2) FOR $S = 11072$ psi, $N => 10^5$ CYCLE

USAGE FACTOR = $\frac{1800}{10^5} \approx 0$.

MADE BY ________

VERIFIED BY H.T. 3-6-83

1-17/24

NUMBER SUSQ. CS PUMP DATE 7/10/80

SUBJECT STRESS CALCS BY M. PATEL SHEET ~~1~~ OF ~~6~~

TOP STG CASE BOWL:

CONSIDERING FORCES AND MOMENTS ONLY DUE TO ELMT # 178 J STATIC AND SRV LOADS

R_1 = ~~(3937)~~ 2883 LBS M_1 = ~~(211)~~ 4 IN-LBS

R_2 = ~~(2185)~~ 165 LBS M_2 = ~~(73229)~~ 7829 IN.LBS

R_3 = ~~(1232)~~ 164 LBS M_3 = ~~(95413)~~ 9513 IN-LBS

$$M = \left[M_2^2 + M_3^2\right]^{\frac{1}{2}} = \text{(118695)}\ 12320 \text{ IN.LBS}$$

$$V = \left[R_2^2 + R_3^2\right]^{\frac{1}{2}} = \text{(2534)}\ 233 \text{ IN.LBS}$$

(A) CALCULATE STRESS AT MAX DIA

$$t_{min} = .75 - 2X.08$$
$$= .59$$

$$D_o = 2 \times 9.38 - .16 = 18.6 \text{ in.}$$

$$D_i = 18.76 - 2X.75 + .16 = 17.42 \text{ in.}$$

$$A = \frac{\pi}{4}(D_o^2 - D_i^2) = 33.38 \text{ in}^2$$

$$I = \frac{\pi}{64}(D_o^4 - D_i^4) = 1355 \text{ in}^4$$

SUS. CS P/M
DRF21-27
SECTION 5.0
PAGE 69 OF 104

MADE BY

VERIFIED BY H-T. 5-1-83

ENGINEERING CALCULATION SHEET

NUMBER: SUSQ. CS PUMP DATE: 7/10/86

SUBJECT: STRESS CALCS. BY: M. PATEL SHEET: 5 OF 6

$$\sigma_l = \frac{P d_i}{4 t_{min}} + \frac{M d_o}{2I} + \frac{R_1}{A}$$

$$= \frac{{}^*500 \times 17.42}{4 \times .59} + \frac{\overset{12320}{\cancel{116{,}695}} \times 18.6}{2 \times 1355} + \frac{\overset{2883}{\cancel{3937}}}{33.38}$$

$$= \overset{2768}{\cancel{3{,}690}} + \overset{85}{\cancel{815}} + \overset{86}{\cancel{1.8}}$$

$$= \overset{2939}{\cancel{4623}} \text{ PSI}$$

~~For failure ... Principal Stress doesn't ... w/ ...~~

$$\sigma_\phi = \frac{P d_i}{2 t_{min}} = \overset{5536}{\cancel{7{,}381}} \text{ PSI}$$

$$\tau = \frac{V}{A} = \frac{\overset{233}{\cancel{2884}}}{33.38} = \overset{7}{\cancel{86}} \text{ PSI}$$

PRINCIPAL STRESS:

$$\sigma_1 = \left(\frac{\sigma_\phi + \sigma_l}{2}\right) + \left[\left(\frac{\sigma_\phi - \sigma_l}{2}\right)^2 + \tau^2\right]^{\frac{1}{2}}$$

$$= \left(\frac{\overset{5536}{\cancel{7381}} + \overset{2939}{\cancel{4623}}}{2}\right) + \left[\left(\frac{\overset{5536 - 2939}{\cancel{7381 - 4623}}}{2}\right)^2 + \overset{}{\underset{7}{\cancel{86}}}^2\right]^{\frac{1}{2}}$$

$$= ~~6002 + 1382~~$$

$$= \underset{5536}{\cancel{7384}} \text{ PSI}$$

* DIFFERTIAL PRESSURE WHICH IS $P_{DISCH} - P_{SUC} = 500 - 125 = 375$ psi SHOULD BE USED. USING $p = 375$ psi

$\sigma_{MAX\ PRINCIPAL} = \underset{5536}{\cancel{5540}}$ psi

SUS. CS P/M
DRF21-27
SECTION 5.0
PAGE 70 OF 104

MADE BY

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ENGINEERING CALCULATION SHEET

NUMBER SUSQ. CS PUMP DATE 7/10/80

SUBJECT STRESS CALCS. BY M. PATEL SHEET 8 OF 6

(B) CALC. STRESS AT MIN DIA.

$t_{min} = .75 - .16 = .59$

$D_o = 2 \times 6.50 - .16 = 12.84$

$D_i = 13 - 2 \times .75 + .16$

$= 11.66$ in

$A = \frac{\pi}{4}(D_o^2 - D_i^2) = 22.75$

$I = \frac{\pi}{64}(D_o^4 - D_i^4) = 427$

$$\sigma_l = \frac{P d_i}{4 t_{min}} + \frac{M d_o}{2I} + \frac{R_1}{A}$$

$$= \frac{500 \times 11.66}{4 \times .59} + \frac{118695 \times 12.84}{2 \times 427} + \frac{3937}{22.75}$$

$= 2470 + 1785 + 173$

$= 4428$ PSI

$$\sigma_\phi = \frac{P d_i}{2 t_{min}} = 4,940 \text{ PSI}$$

$$\tau = \frac{V}{A} = \frac{2834}{22.75} = 127$$

MADE BY

VERIFIED BY H.T. 3-1-83

PRINCIPAL STRESS:

$$\sigma = \left(\frac{\sigma_\phi + \sigma_l}{2}\right) + \left[\left(\frac{\sigma_\phi - \sigma_l}{2}\right)^2 + \tau^2\right]^{\frac{1}{2}}$$

$$= \frac{4940 + 4428}{2} + \left[\left(\frac{4940 - 4428}{2}\right)^2 + (127)^2\right]^{\frac{1}{2}}$$

$$= 4684 + 286.$$

$$= 4970 \quad PSI$$

IN SERIES CASES, THE R_1, R_2, R_3, M_1, M_2 & M_3 ARE LOWER THAN TOP CASE SO THERE IS NO NEED OF ADDITIONAL STRESS CALCULATION FOR SERIES CASE.

MATERIAL: A 48 CL. 30-B

Tensile Strength = 30,000 PSI

$S_{allowable} = \frac{1}{4} \times 30{,}000 = 7{,}500$ PSI

$S = 1.2\,S = 9{,}000$ PSI

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NUMBER ______ DATE 2/25/83

SUBJECT SUSQ. LPCI p/m FATIGUE LIFE EVALUATION DUE TO SRV ACTUATIONS BY DRD SHEET 12 OF 12

TOP STAGE CASE BOLTING: FORCES AND MOMENTS DUE TO STATIC AND SRV LOADS

$P_1 = 2804 + 79 = 2883$ LBS (DRF # E21-27, SEC. 5.19)
$M_2 = 419 + 7410 = 7829$ IN-LBS
$M_3 = 483 + 9030 = 9513$ IN-LBS.

$$P_{EQ} = P + \frac{16[M_2^2 + M_3^2]^{1/2}}{\pi a^3} + \frac{4P_1}{\pi a^2}$$

$$= 375 + \frac{16[7829^2 + 9513^2]^{1/2}}{\pi \times 14^3} + \frac{4 \times 2883}{\pi \times 14^2}$$

$$= 395 \text{ psi}$$

FROM THE DRF FOR $P_{EQ} = 621$, $\sigma = 25932$ psi

THUS FOR $P_{EQ} = 395$, $\sigma = \frac{395}{621} \times 25932$
$= 16495$ psi

$\sigma_{PEAK} = 16495 \times 4$
$= 65980$ psi

$S_a = \frac{65980}{2}$ psi $= \simeq 33{,}000$ psi [MATERIAL: SA 193 - GR B-7]

FROM FATIGUE CURVE (ATTACHMENT. 3) FOR $S_a = 33{,}000$ psi
$N = 10{,}000$ CYCLES.

USAGE FACTOR $= \frac{1800}{10{,}000} = 0.18 < 1$.

MADE BY ______
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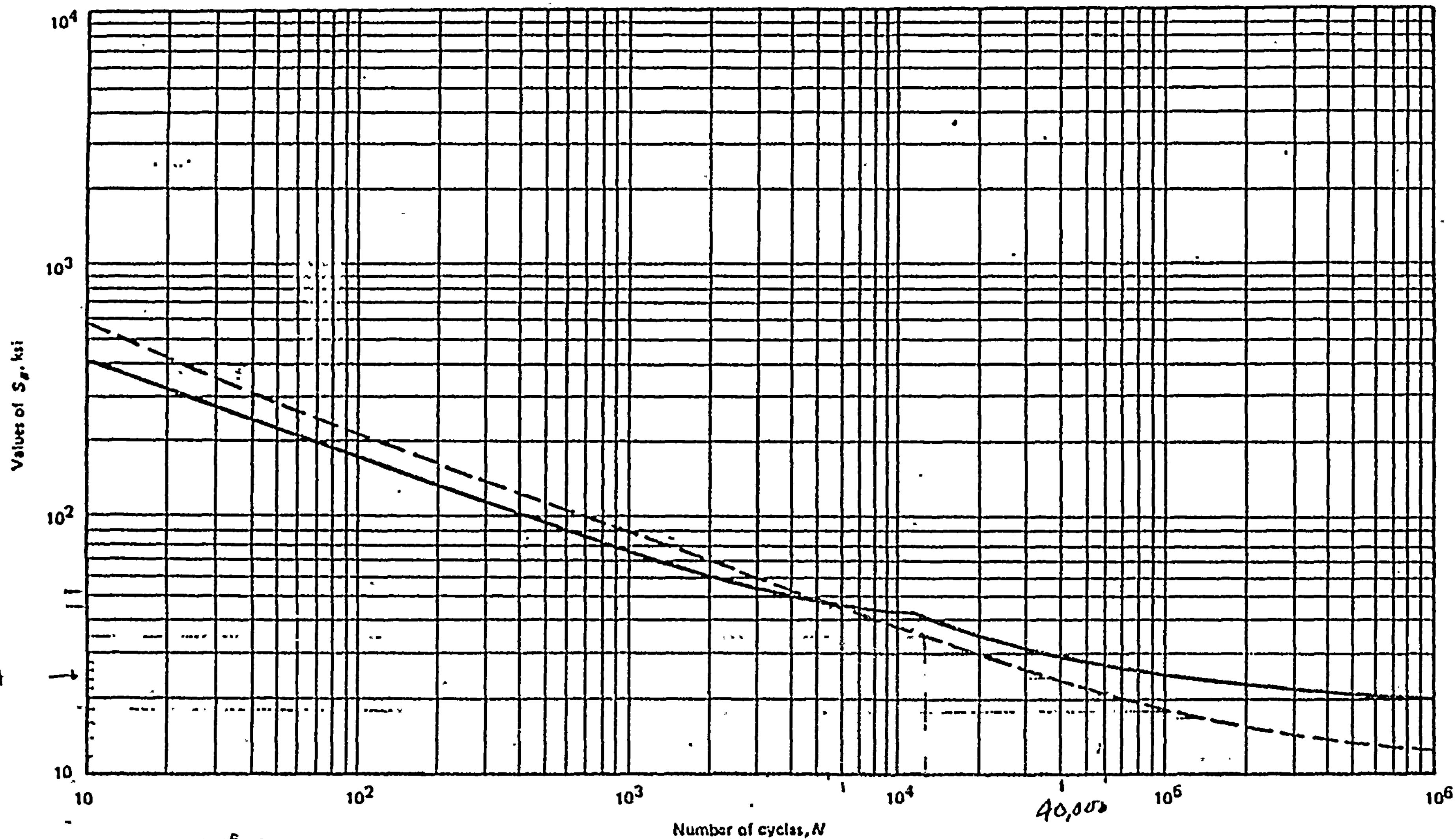
NEO-87 (REV 8/81)

VERIFIED BY H.T. 1-3-83
MADE BY

ATTACHMENT 1

1-22/24



NOTE: E = 30 X 10^6 ksi
— — UTS < 80.0 ksi
—— UTS 115.0–130.0 ksi
Interpolate for UTS 80.0–115.0 ksi

FIG. I-9.1 DESIGN FATIGUE CURVES FOR CARBON, LOW ALLOY, AND HIGH TENSILE STEELS FOR METAL TEMPERATURES NOT EXCEEDING 700°F
Table I-9.1 Contains Tabulated Va[illegible] a Formula for Accurate Interpolation of [illegible] Curves

proach is to use the tensile strength (or fatigue limit) and, after determining the section modulus of the actual shape, to apply the proper bending formula. However, because of the difficulty in obtaining a meaningful value for the tensile strength in tests of small specimens, the load computed in this manner will usually be somewhat lower than the actual load required to rupture the part, unless unfavorable residual stresses are present in the finished part.

Elongation of gray iron at fracture is very small (of the order of

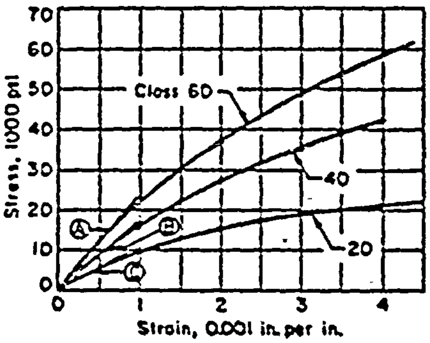


Fig. 10. Typical stress-strain curves for three classes of gray iron in tension. Modulus of elasticity is measured to points A, B and C, representing ¼ of the tensile strength.

0.006 in. per in.) and hence is seldom reported. The designer cannot use the numerical value of permanent elongation in any quantitative manner.

Torsional Shear Strength. As shown in Table 12, most gray irons have high torsional shear strength. Many grades have torsional strength greater than some grades of steel. This characteristic, along with low notch sensitivity, makes gray iron a suitable material for shafting of various types, particularly in the grades of higher tensile strength. Most shafts are subjected to dynamic torsional stresses and the designer should consider carefully the exact nature of the loads. For the higher-strength irons, stress concentration factors associated with changes of shape in the part are important for torque loads as well as for bending and tension loads.

Modulus of Elasticity. Typical stress-strain curves for gray iron are shown in Fig. 10. Gray iron does not obey Hooke's law and the modulus in tension is usually determined arbitrarily as the slope of the line connecting the origin of the stress-strain curve with the point corresponding to ¼ of the tensile strength. Some engineers use the slope of the stress-strain curve near the origin for determining the modulus of elasticity.

As indicated in Table 12, the modulus of gray iron varies considerably more than for most metals. Thus, in using observed strain to calculate stress, it is essential to measure the modulus of the particular gray iron specimen being considered. The numerical value of the modulus in torsion is always less than in tension, just as it is for steel.

Hardness of gray iron, as measured by Brinell or Rockwell testers, is an average result of the soft graphite in the iron and the metallic matrix. Variations in graphite size and distribution will cause wide variations in hardness (particularly Rockwell hardness) even though the hardness of the metallic matrix is constant. To illustrate this effect, the microhardness of the matrix of five types of hardened iron, as compared with Rockwell C measurements on the same iron, is shown in Table 13.

It is apparent that if any hardness correlation is to be attempted, the graphite must be constant as to type and amount in the irons being compared. It is recommended that Brinell hardness be used when possible.

Fatigue Limit in Reversed Bending

Because fatigue limits are expensive to determine, the designer usually has incomplete information on this property. Typical S-N curves for gray iron under completely reversed cycles of bending stress are shown in the graph on left in Fig. 11, in which each point represents the data from one specimen. The effects of temperature on fatigue limit and tensile strength are shown in the right-hand graph in Fig. 11.

Axial loading or torsional loading cycles are frequently encountered in designing parts of cast iron, and in many instances these are not completely reversed loads. Types of regularly repeated stress variation usually can be expressed as a function of a mean stress and a stress range. Wherever possible the designer should use actual data from the limited information available. Without precisely applicable test data, an estimate of the reversed bending fatigue limit of machined parts may be made by using about 35% of the minimum specified tensile strength of the particular grade of gray iron being considered. This is probably a safe value rather than an average of the few data available concerning the fatigue limit for gray iron.

Table 13. Comparison of Rockwell Hardness of Gray Irons, as Influenced by Graphite

Type of graphite	Total carbon, %	Rockwell C hardness (a)	Matrix converted(b)
A	3.06	45.2(c)	61.5
A	3.53	43.1	61.8
A	4.00	32.0	62.0
D	3.20	34.0	63.5
D	3.60	42.7	60.5

(a) Measured by conventional Rockwell C test. (b) Hardness of matrix, measured with superficial hardness tester and converted to Rockwell C. (c) Although this value was obtained in the specific test cited, it is not typical of gray iron of 3.06% C. Ordinarily the hardness of such iron is Rockwell C 48 to 50.

An approximation of the effect of range of stress on the fatigue limit may be obtained from diagrams such as Fig. 12. The tensile strength is plotted on the horizontal axis to represent the fracture strength under static load (which corresponds to zero stress range). The reversed

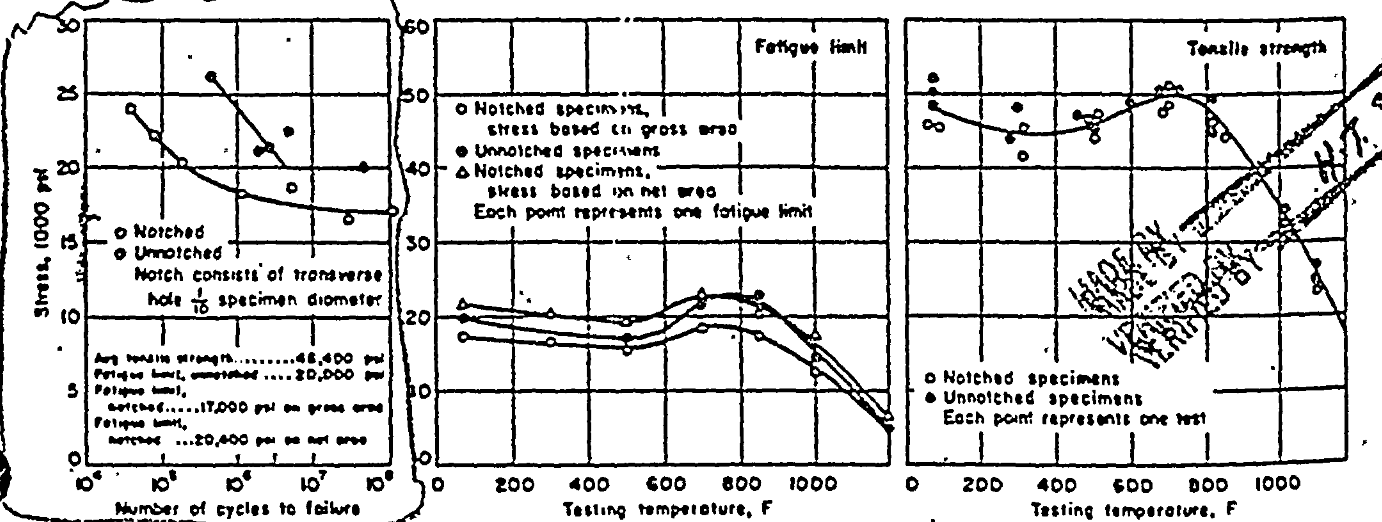
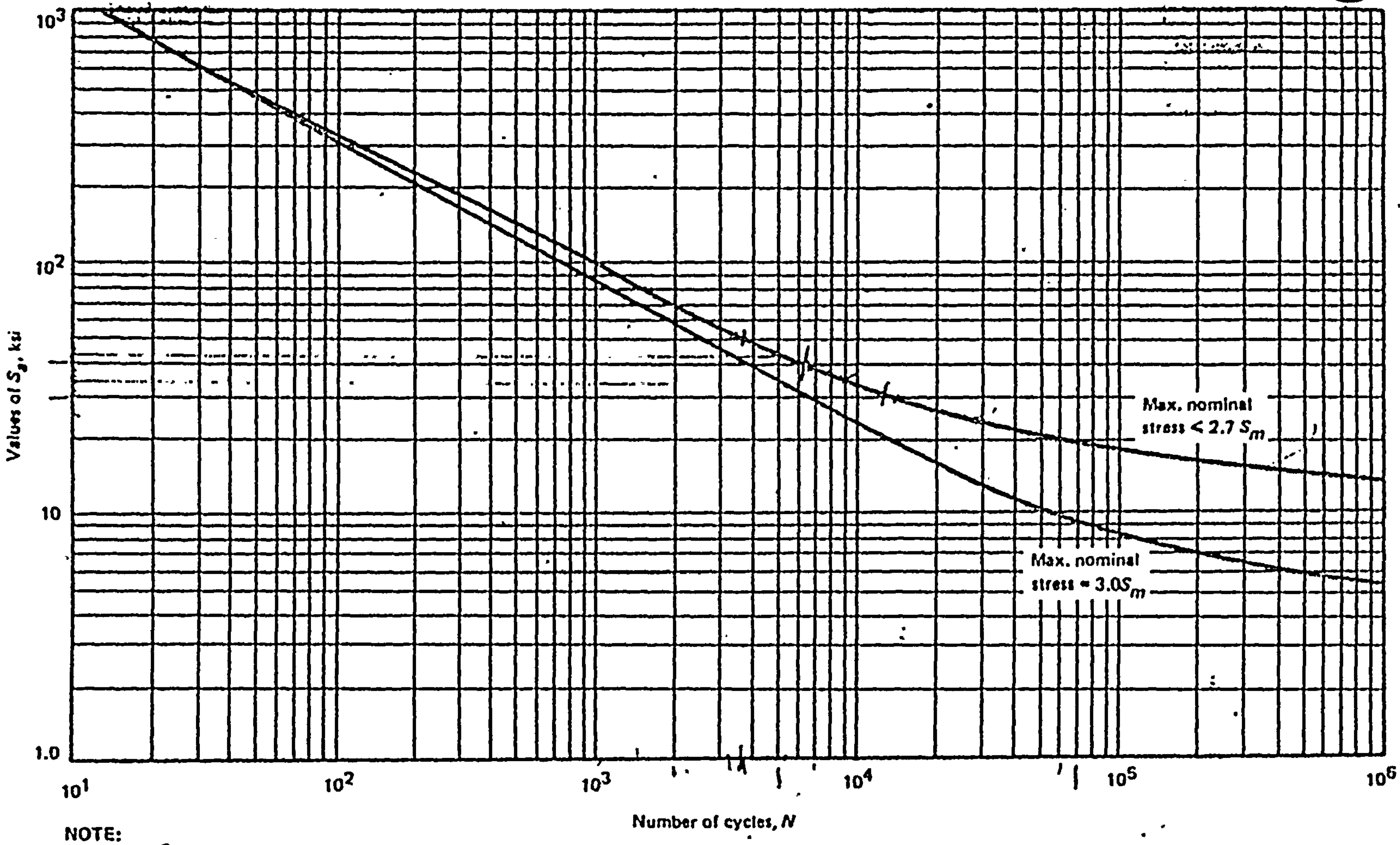


Fig. 11. S-N curves and effects of temperature on fatigue limit of gray iron of the tensile strength shown. Composition: 2.84 C, 1.52 Si, 1.05 Mn, 0.07 P, 0.12 S, 0.31 Cr, 0.20 Ni, 0.37 Cu. (W. Leighton Collins and James O. Smith, Proc. ASTM, 41, 797, 1941)

ATTACHMENT 3



NOTE:
E = 30 X 10⁶ psi

FIG. I-9.4 DESIGN FATIGUE CURVE FOR HIGH STRENGTH STEEL BOLTING FOR TEMPERATURES NOT EXCEEDING 700°F
Table I-9.1 Contains Tabulated Values and a Formula for Accurate Interpolation of These Curves

MADE BY ________

VERIFIED BY H.T. 3-1-93

GENERAL ELECTRIC CO.

Nuclear Energy Business Operations

ENGINEERING CALCULATION SHEET

NUMBER SUSQ. HPCI PUMP DATE 4-20-83

SUBJECT SUSQ. HPCI PUMP - FATIGUE LIFE EVALUATION DUE TO SRV ACTUATIONS. BY DRD SHEET 1 OF 8

FOLLOWING CRITICAL LOCATIONS WERE EVALUATED BASED UPON THE STRESS VALUE AND MATERIAL OF THE PUMP COMPONENTS.

1. MAIN PUMP HOLD DOWN BOLTS
2. BOOSTER PUMP HOLD DOWN BOLTS.
3. MAIN PUMP PEDESTAL.
4. BOOSTER PUMP PEDESTAL
5. MAIN PUMP MOUNTING FOOT
6. BOOSTER PUMP MOUNTING FOOT.

VENDOR PERFORMED STATIC AND DYNAMIC (RESPONSE SPECTRUM) ANALYSIS WERE USED TO CALCULATE STRESSES AT DIFFERENT CRITICAL LOCATIONS. RESPONSE SPECTRAS USED IN THE ANALYSIS IN BOTH HORIZONTAL AND VERTICAL DIRECTIONS WERE SIGNIFICANTLY HIGHER THAN THE APPLICABLE REQUIRED RESPONSE SPECTRAS (SEE ATTACHED RESPONSE SPECTRA CURVES). ACTUAL SUCTION AND DISCHARGE NOZZLE LOADS, DEAD WT, PRESSURE AND TORQUE LOADS WERE USED IN THE STATIC ANALYSIS.

(SEE NEXT SHEET).

VERIFIED BY H. [signature] CHECKING 4-29-83

GENERAL ELECTRIC CO.
Nuclear Energy Business Operations
ENGINEERING CALCULATION SHEET

NUMBER ________ DATE 4-21-83

SUBJECT SUSQ. HPCI PUMP - FATIGUE LIFE EVALUATION DUE TO SRV ACTUATIONS. BY DRD SHEET 2 OF 8

1. BOOSTER PUMP HOLD DOWN BOLTS: (REF: DRF # E51-74, SEC. 4.1)
CALCULATED STRESS DUE TO STATIC + DYN. LOADS = 15929 psi
CONSERVATIVELY USING THE ABOVE STRESS AND APPLYING STRESS CONCENTRATION FACTOR OF 4,
PEAK STRESS = 15929 x 4 = 63716 psi
ALTERNATING STRESS $S_a = \frac{63716}{2} = 31858$ psi.
MATERIAL: SA-307, GR. B. (ULTIMATE TENSILE STRENGTH = 60,000 psi) DRD H.T.
FROM FATIGUE CURVE (SEE SHT ~~3~~ 5 OF 8) DRD H.T. 5-20-83
FOR $S_a = 31858$ psi, N = 16,000 CYCLES.

~~FATIGUE USAGE FACTOR = $\frac{1800}{16,000}$ = 0.113 < 1~~

2. MAIN PUMP HOLD DOWN BOLTS: (REF: DRF # E51-74, SEC. 4.1)
CALCULATED STRESS DUE TO STATIC PLUS DYN. LOADS = 14813 psi
$S_a = \frac{14813 \times 4}{2} = 29626$ psi ≈ 30,000 psi. FROM FATIGUE CURVE (SHT ~~3~~ 5 OF 8) FOR $S_a = 30,000$ psi N = 20,000 CYCLES. (SAME MATERIAL AS ABOVE.)

H.T. 5-20-83

3. BOOSTER PUMP PEDESTAL:

CALCULATED STRESS DUE TO STATIC + DYN. LOADS = 10,414 psi.*
CONSERVATIVELY USING THE ABOVE STRESS VALUE AND APPLYING STRESS CONC. FACTOR OF 4 (BECAUSE PEDESTAL IS WELDED TO THE BASE PLATE).

PEAK STRESS = 10,414 x 4 = 41656 psi
ALTERNATING STRESS = $\frac{41656}{2}$ = 20828 psi
MATERIAL: ASTM A-36, FROM FATIGUE CURVE (SEE SHT. 5 OF 8).
FOR $S_a = 20828$ psi, N = 58,000 CYCLES. ~~FATIGUE USAGE FACTOR = $\frac{1800}{58000}$ = 0.03 < 1~~

* -REF: STATIC AND DYN. ANALYSIS PERFORMED BY THE VENDOR, VPF # 3076-267-
CONSERVATIVELY MAX. PRINCIPAL STRESS VALUE USED RATHER THAN MAX. PRINCIPAL STRESS DIFFERENCE.

4. MAIN PUMP PEDESTAL: SINCE ACTUAL STRESS IS LESS THAN THE BOOSTER PUMP PEDESTAL STRESS; USE N = 58,000 CYCLES (CONSERVATIVE)

(NEXT SHEET)

VERIFIED BY H.T. 4-29-83

NEO-87 (REV 8/81)

GENERAL ELECTRIC CO.
Nuclear Energy Business Operations
ENGINEERING CALCULATION SHEET

NUMBER ______ DATE ______

SUBJECT: SUSQ. HPCI PUMP - FATIGUE LIFE EVALUATION DUE TO SRV ACTUATIONS. BY: DRD SHEET 3 OF 8

MAIN PUMP MOUNTING FOOT:

CALCULATED STRESS = 19918 psi (REF:- STATIC AND DYNAMIC ANALYSIS PERFORMED BY THE VENDOR, VPF # 3076-267-1). THE ABOVE STRESS IS AS A RESULT OF DEAD WT, NOZZLE LOADS AND DYNAMIC LOADS. DYNAMIC LOADS USED BY THE VENDOR ARE SIGNIFICANTLY HIGHER THAN THE SRV CURVE (SEE SHEETS 6, 7, 8 OF 8).

SINCE RESPONSE SPECTRUM ANALYSIS WAS PERFORMED, IT IS DIFFICULT TO ESTIMATE STRESSES DUE TO ACTUAL SRV LOADING. CONSERVATIVELY USING ABOVE STRESS VALUE

APPLYING STRESS CONC. FACTOR OF 4 (@ THE WELD)

PEAK STRESS = 19918 × 4 = 79672 psi

$S_a = \frac{79672}{2} = 39836$ psi

MATERIAL: ASTM 216 OR WCB, FROM FATIGUE CURVE (SHT. 5 OF 8)

FOR $S_a = 39836$ psi $N \approx 8{,}000$ CYCLES.

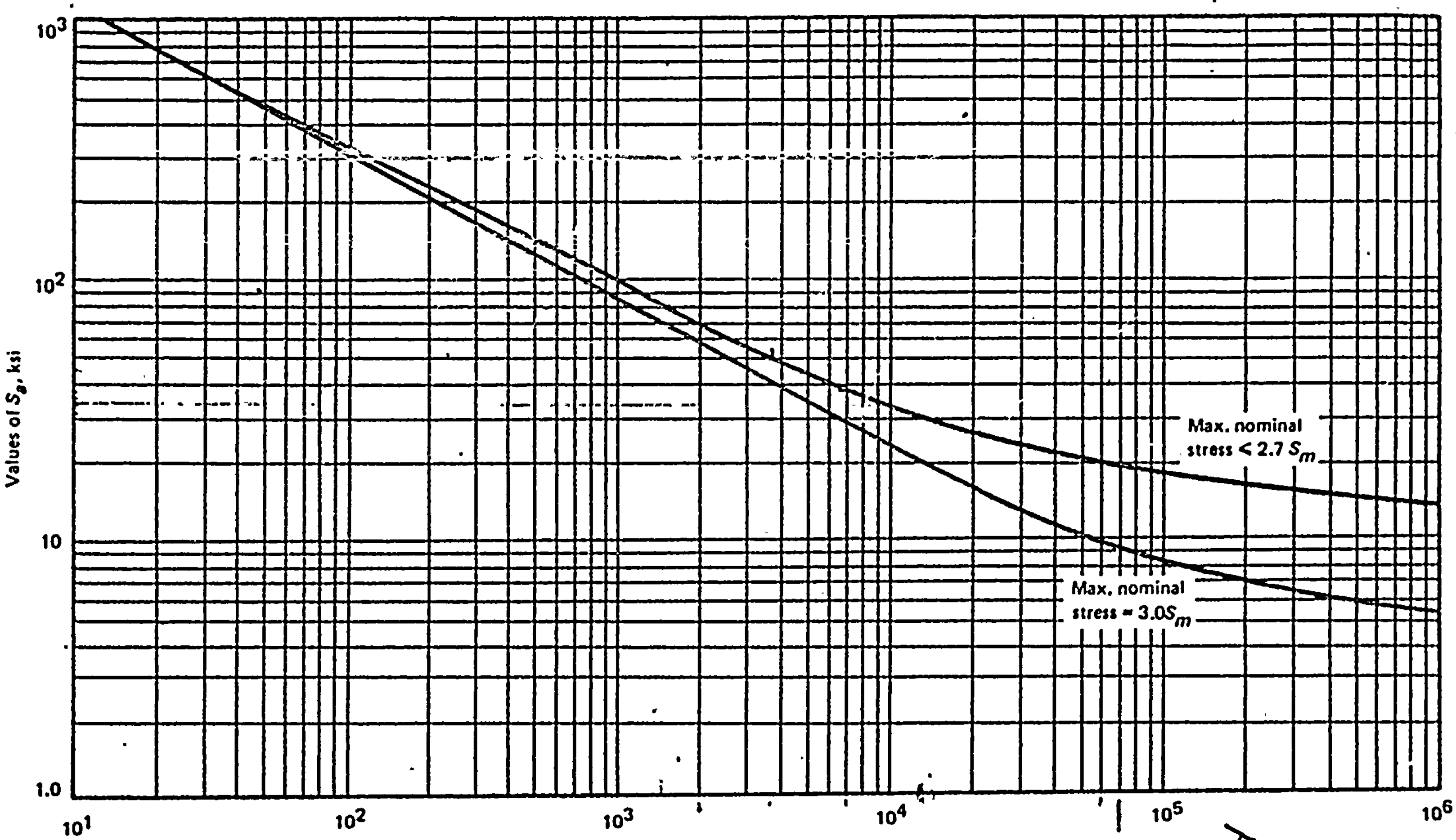
BOOSTER PUMP MOUNTING FOOT:

CALCULATED STRESS = 15870 psi WHICH IS LESS THAN MAIN PUMP MOUNTING FOOT STRESS

CONSERVATIVELY USE N = 8,000 CYCLES (SEE ABOVE CALCULATION)

VERIFIED BY H.T. 4-29-83

HPCI PUMP



NOTE:
$E = 30 \times 10^6$ psi

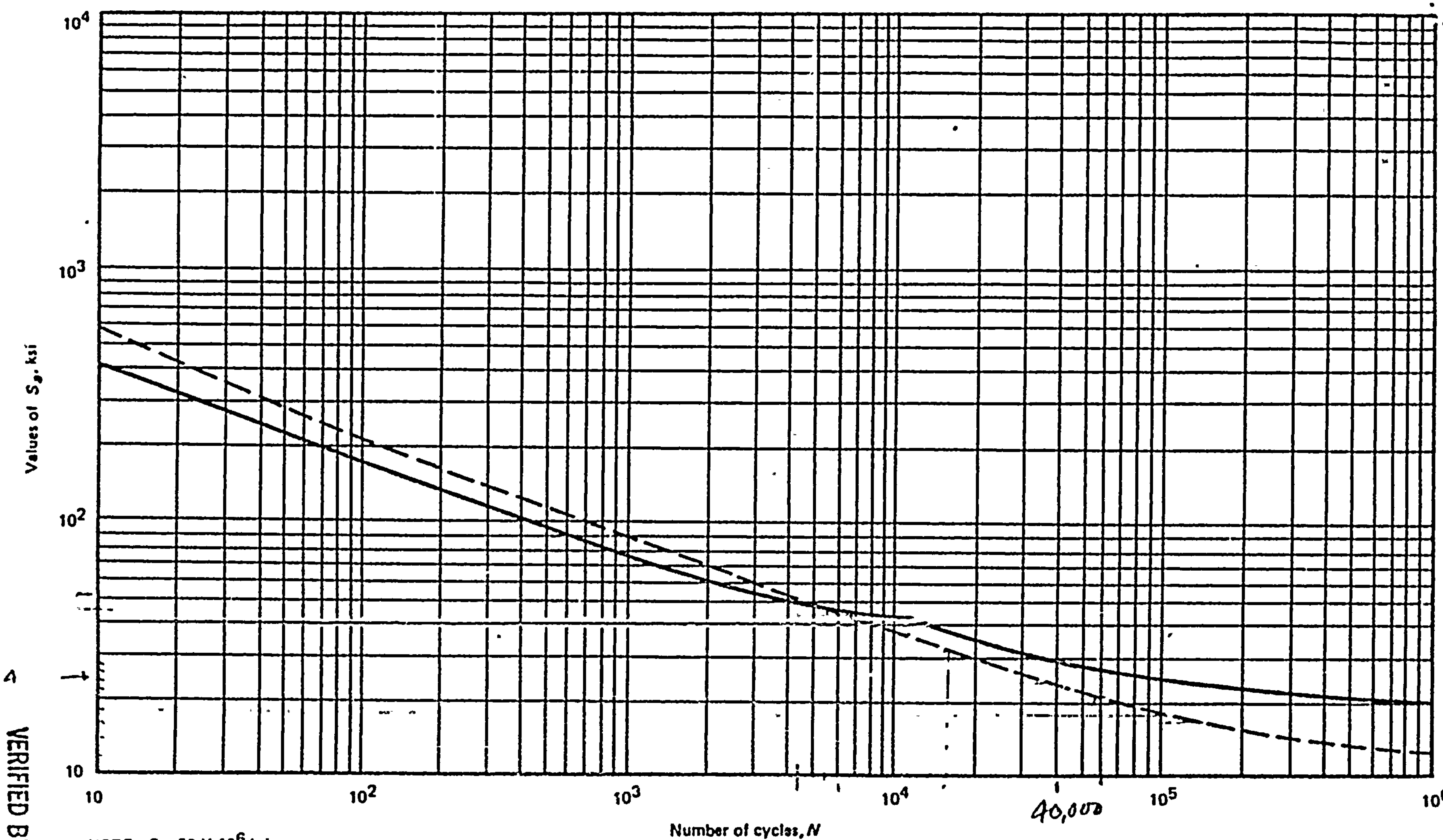
THIS CURVE IS NOT USED.

FIG. I-9.4 DESIGN FATIGUE CURVE FOR HIGH STRENGTH STEEL BOLTING FOR TEMPERATURES NOT EXCEEDING 700°F
Table I-9.1 Contains Tabulated Values and a Formula for Accurate Interpolation of These Curves

VERIFIED BY H.T. 4-29-83

SHEET 4 OF 8

DRD
H.T.
5-20-83



NOTE: $E = 30 \times 10^6$ ksi
— — UTS < 80.0 ksi
—— UTS 115.0–130.0 ksi
Interpolate for UTS 80.0–115.0 ksi

FIG. I-9.1 DESIGN FATIGUE CURVES FOR CARBON, LOW ALLOY, AND HIGH TENSILE STEELS FOR METAL TEMPERATURES NOT EXCEEDING 700°F
Table I-9.1 Contains Tabulated Values and a Formula for Accurate Interpolation of These Curves

Fig. I-9.1

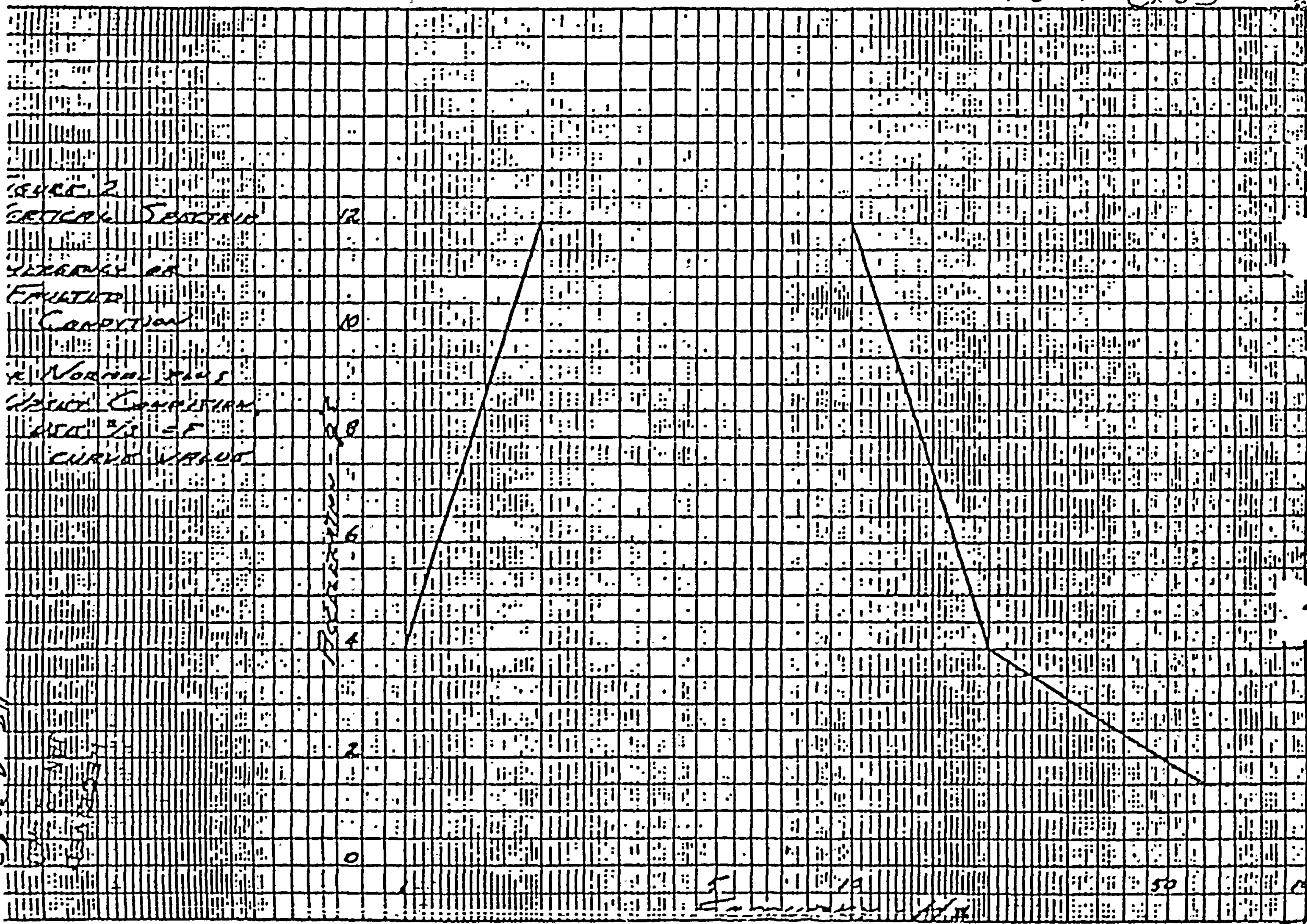
VERIFIED BY H.T. Harrell 4-29-83

SHEET 5 OF 8

HPCI PUMP (RJ)

NR-46919 Rev. 1

SHEET 6 OF 8



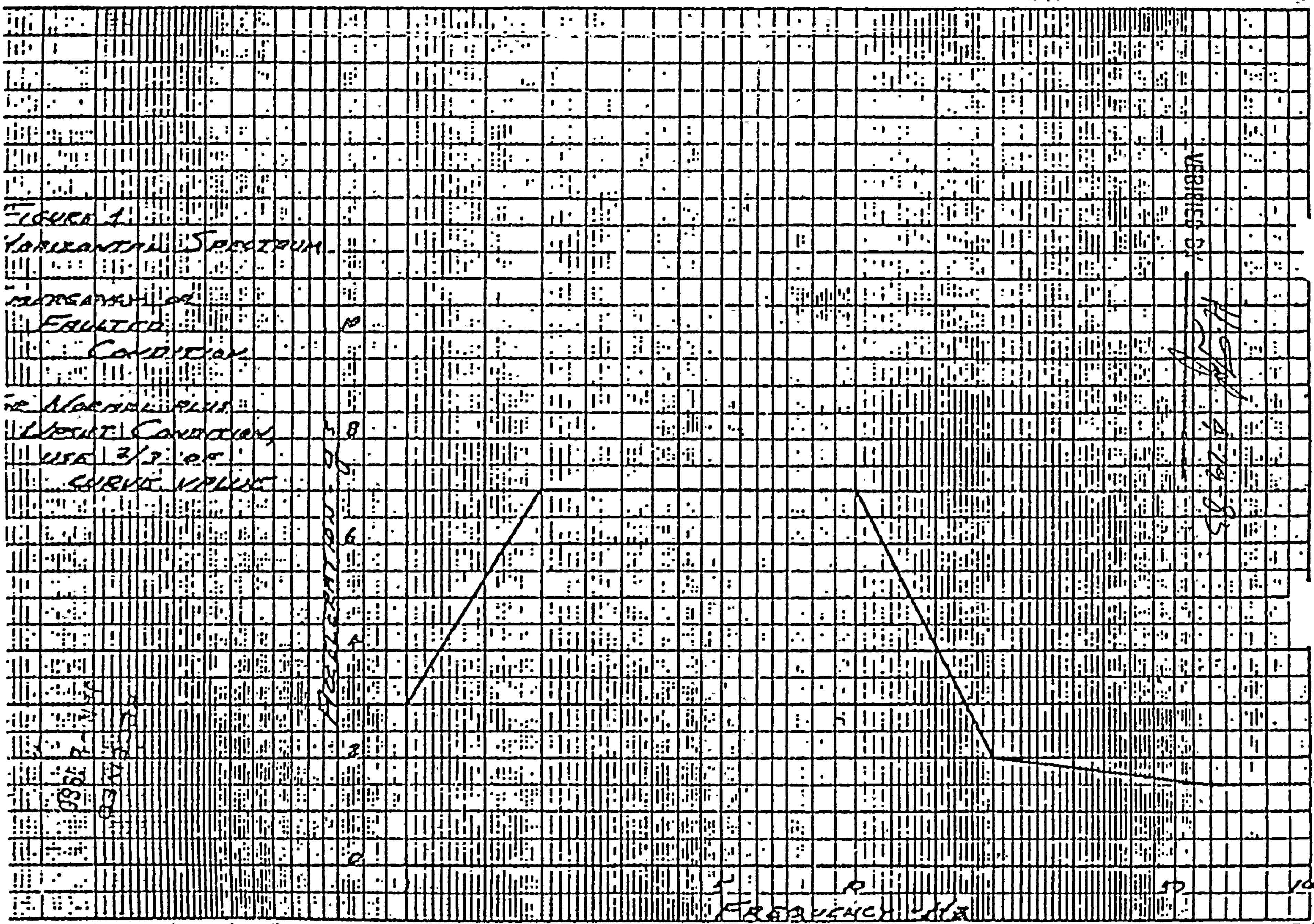
VERIFIED BY 4-29-83

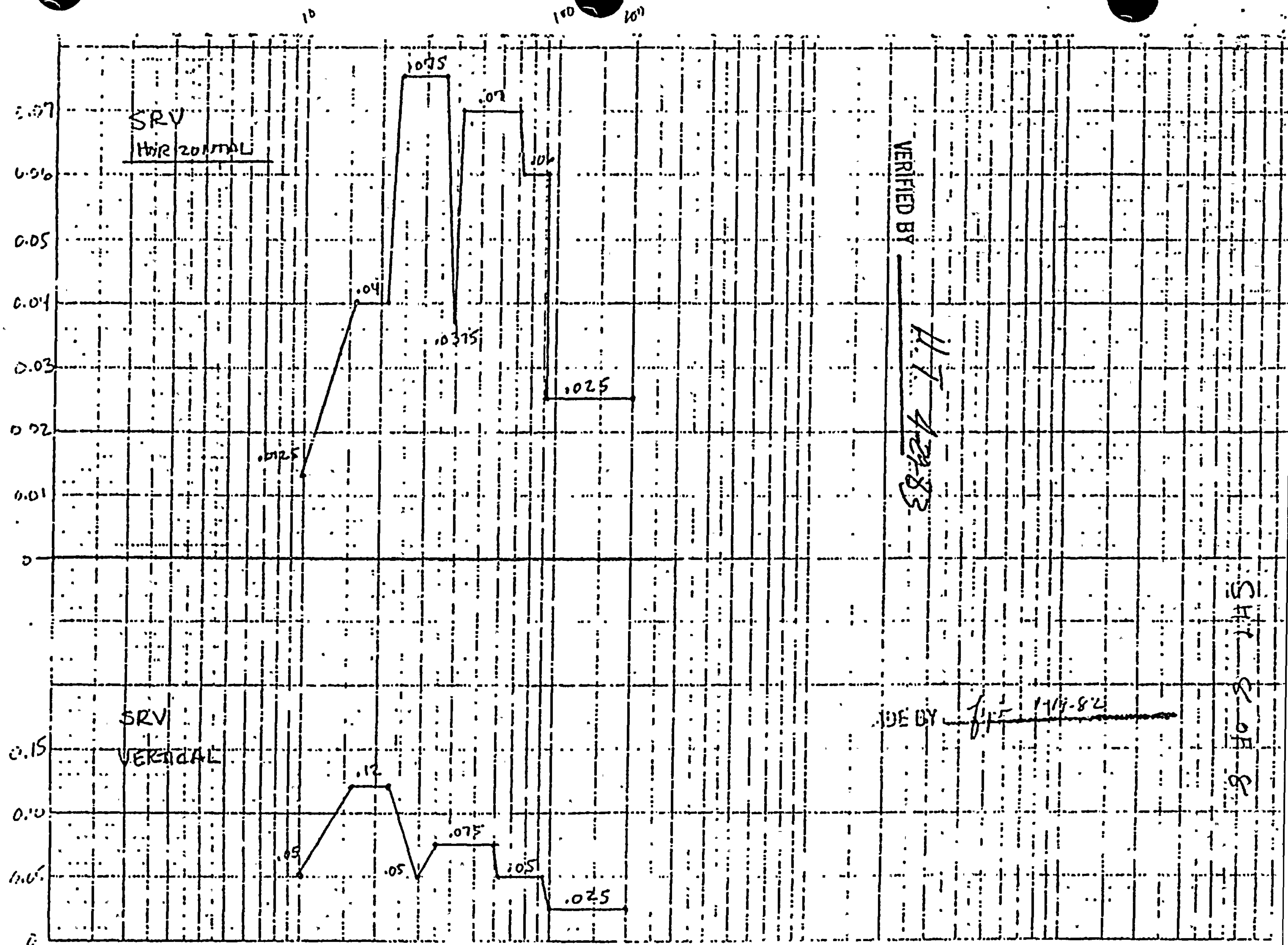
SCHENECTADY, N. Y. U.S.A.

HPCI PUMP (BJ)

NR 436919 Rev. 1

SHT 7 OF 8





SRV
HORIZONTAL
0.07
0.06
0.05
0.04
0.03
0.02
0.01
0
.0125
.04
.075
.0375
.07
.06
.025
SRV
VERTICAL
0.15
0.10
0.05
0
.05
.12
.05
.075
.05
.025
VERIFIED BY
MADE BY

GENERAL ELECTRIC CO.
Nuclear Energy Business Operations
ENGINEERING CALCULATION SHEET

NUMBER: SUSQ. RCIC PUMP. DATE 4-19-83

SUBJECT: SUSQ. RCIC PUMP - FATIGUE LIFE EVALUATION DUE TO SRV ACTUATIONS. BY DRD SHEET 1 OF 11

GENERAL: THE TASK HAS BEEN PERFORMED PER PWA # 3847KK, REV. WHICH CALLS FOR PERFORMING FATIGUE LIFE EVALUATION DUE TO SRV ACTUATIONS OVER 40 YEARS LIFE.

TO BEGIN THE TASK WITH, CERTAIN CRITICAL LOCATIONS WERE SELECTED BASED ON THE ACTUAL STRESS VALUE AND MATERIAL OF THE COMPONENTS. FORCES AND MOMENTS WERE TAKEN FROM THE ORF # E51-72 WHICH CONTAINS COMPLETE STATIC AND DYNAMIC ANALYSES FOR THE SUBJECT EQUIPMENT. STATIC LOADS SUCH AS SUCTION AND DISCHARGE NOZZLE LOADS (Fo, Mo LOADS), PRESSURE, DEAD WT, TORQUE AND DYNAMIC LOADS SUCH AS LOCA, SSE, AND SRV LOADS WERE USED IN THE ANALYSIS.

THE FOLLOWING CRITICAL STRESS LOCATIONS WERE EVALUATED.

- PUMP HOLD DOWN BOLTS.
- ANCHOR BOLTS.
- MOUNTING FEET WELD STRESS.
- PUMP PEDESTAL WELD STRESS.

NOTE: EQUIVALENT STATIC COEFFICIENT ANALYSIS WAS PERFORMED USING 1.5 X PEAK ACCELERATION VALUE DUE TO SSE + SRV + LOCA TO ASSESS THE EFFECTS OF DYNAMIC LOADS.

CHECKING
VERIFIED BY [signature] 4-29-83

NEO-87 (REV 8/81)

GENERAL ELECTRIC CO.

Nuclear Energy Business Operations

ENGINEERING CALCULATION SHEET

NUMBER ______ DATE ______

SUBJ. SUSQ. RCIC PUMP - FATIGUE LIFE EVALUATION DUE TO SRV ACTUATIONS. BY DRD SHEET 2 OF 11

1. PUMP HOLD DOWN BOLTS:

CALCULATED TENSILE STRESS = 33,662 psi (REF: DPF # E51-72, SEC. 5.1).

THE ABOVE STRESS IS AS A RESULT OF 3.0 g (1.5 × 2.0 = 3.0 g) HORIZONTAL AND VERTICAL ACCELERATION VALUES AND STATIC LOADS. CONSIDERING ONLY SRV LOADING (1.5 × 0.12 = 0.18 g, SEE ATTACHED RS), CALCULATED STRESS = 20,623 psi (SEE ATTACHED CALCULATION SHEETS 3, 4 OF 11)

Applying STRESS CONCENTRATION FACTOR OF 4 FOR BOLTS,

PEAK STRESS = 20,623 × 4 = 82,492 psi.

ALTERNATING STRESS $S_a = \frac{82,492}{2} = 41,246$ psi

BOLT MATERIAL: SA-449

FROM FATIGUE CURVE (SHT 11 OF 11)

FOR $S_a = 41,246$ psi, N = 5500 CYCLES.

2. ANCHOR BOLTS:

CALCULATED STRESS = 15,052 psi (SEE ATTACHED CALCULATIONS FOR ANCHOR BOLTS, SHT. 5, 6 OF 11).

Applying STRESS CONCENTRATION FACTOR OF 4,

PEAK STRESS = 15,052 × 4 = 60,208 psi

ALTERNATING STRESS = $\frac{S_p}{2} = \frac{60,208}{2} = 31,104$ psi

BOLT MATERIAL: SA-36, FROM FATIGUE CURVE (SHT. 10 OF 11)*

FOR $S_a = 30,104$ psi, N = 16,000 CYCLES.

* SINCE BOLT MATERIAL IS NOT HIGH STRENGTH, FATIGUE CURVE SHT. 10 OF 11 WAS USED.

PREPARED BY: D. DESAI 5-20-83

VERIFIED BY H.T. 5-20-83

REWROTE

NEO-87 (REV 8/81)

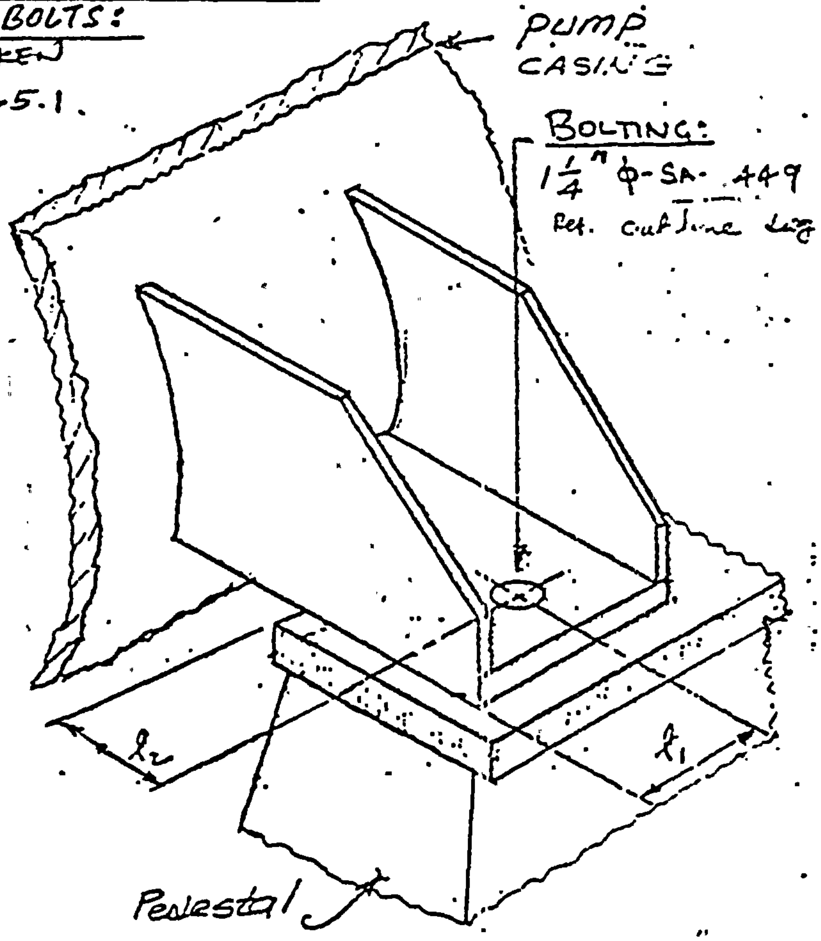
GENERAL ELECTRIC CO.
Nuclear Energy Business Operations
ENGINEERING CALCULATION SHEET

MADE BY [signature] 5-20-83
VERIFIED BY [initials] 5-20-83 ~~REWROTE~~ [initials]

NUMBER ________ DATE ________
SUBJECT SUSQ. RCIC PUMP - FATIGUE LIFE EVALUATION DUE TO SRV ACTUATIONS. BY DRD SHEET 3 OF 11

PUMP HOLD DOWN BOLTS:

FOLLOWING LOADS WERE TAKEN FROM DRF # E51-72, SEC-5.1.



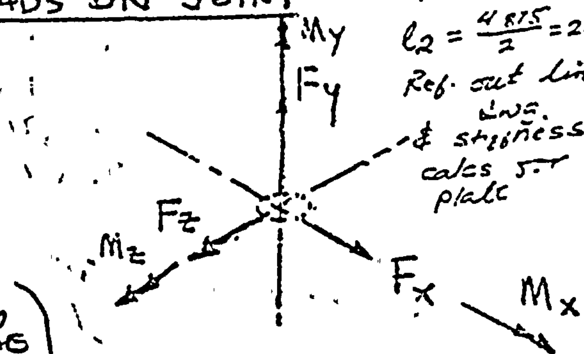
STATIC LOADS:

$F_x = R_1 = 3{,}352$ LBS
$F_y = R_3 = 10{,}900$ LBS
$F_z = R_2 = 2{,}278$ LBS
$M_x = M_1 = 19{,}220$ IN. LBS
$M_y = M_3 = 0$
$M_z = M_2 = 17{,}010$ IN. LBS.

DYNAMIC LOADS:
(DUE TO SSE, SRV, LOCA LOADS)

$F_x = R_1 = 3{,}106$ LBS
$F_y = R_3 = 6{,}756$ LBS
$F_z = R_2 = 4{,}617$ LBS
$M_x = M_1 = 13{,}706$ IN. LBS
$M_y = M_3 = 0$
$M_z = M_2 = 13{,}885$ IN. LBS.

LOADS ON JOINT



$l_1 = 3$"
$l_2 = \frac{4.875}{2} = 2.438$
Ref. out line dwg. & stiffness calcs for plate

ABOVE DYNAMIC LOADS ARE AS A RESULT OF 3.0 g HORIZ. AND 3.0 g VERT. ACCELERATION LOADING.

CONSIDERING ONLY SRV LOADS:

HORIZ. ACCELERATION = 0.079 g
VERT. ACCELERATION = 0.12 g
(SEE ATTACHED RESPONSE SPECTRA)

USING STATIC COEFFICIENT METHOD
g VALUE TO BE USED = 1.5 × 0.12 = 0.18 g (CONSERVATIVELY HIGHER VALUE USED.)

∴ SRV LOADS TO BE USED IN FATIGUE CALCULATIONS ARE:

$R_1 = \frac{0.18}{3.0} \times 3106 = 186$ LBS $M_1 = 0.06 \times 13{,}706 = 822$
$R_2 = 0.06 \times 4617 = 277$ LBS $M_2 = 0.06 \times 13{,}885 = 833$ IN. LBS
$R_3 = 0.06 \times 6756 = 405$ LBS. $M_3 = 0$

NED-87 (REV 8/81)

GENERAL ELECTRIC CO.
Nuclear Energy Business Operations
ENGINEERING CALCULATION SHEET

NUMBER ________ DATE ________

SUBJECT SUSQ. RCIC PUMP - FATIGUE LIFE EVALUATION DUE TO SRV ACTUATIONS. BY DRD SHEET 4 OF 11

TOTAL FORCES AND MOMENTS TO BE USED IN FATIGUE LIFE CALCULATION ARE (STATIC + SRV LOADS):

$F_x = R_1 = 3,352 + 186 = 3,538$ LBS
$F_y = R_3 = 10,900 + 405 = 11,305$ LBS
$F_z = R_2 = 2,278 + 277 = 2,555$ LBS
$M_x = M_1 = 19,220 + 822 = 20,042$ IN.LBS
$M_y = M_3 = 0$
$M_z = M_2 = 17,010 + 833 = 17,843$ IN.LBS.

MADE BY [signature] 5-20-83
VERIFIED BY H.T. 5-20-83
REWROTE.

BOLT TENSILE FORCE :

$$T = F_y + \frac{M_x}{l_1} + \frac{M_z}{l_2}$$

$$= 11,305 + \frac{20,042}{3} + \frac{17,843}{2.438}$$

$$= 25,304 \text{ LBS.}$$

TENSILE STRESS $= \frac{T}{A} = \frac{25,304}{1.227} = 20623$ psi $< 40,000$ psi $\left[A = \frac{\pi}{4}d^2 = \frac{\pi}{4}(1.25)^2 = 1.227 \text{ IN}^2 \right.$

NOTE: BOLT NOMINAL AREA RATHER THAN THREAD MIN. AREA USED FOR HIGH STRENGTH BOLTS. REF: AISC, SPEC. SEC 1.5.2

SHEAR STRESS $= \frac{V}{A} = \frac{(F_x^2 + F_z^2)^{1/2}}{A}$

$$= \frac{3,538^2 + 2,555^2}{1.227} = 3,557 \text{ psi} < 15,000 \text{ psi.}$$

ALLOWABLE BOLT STRESS PER AISC, SPEC. SEC 1.5.2 TABLE 1.5.2.1:

FOR BOLT MATERIAL SA-449
TENSILE STRESS = 40,000 psi
SHEAR STRESS = 15,000 psi

NEO-87 (REV 8/81)

NUMBER ______ DATE ______

SUBJECT SUSQ. RCIC PUMP - FATIGUE LIFE EVALUATION DUE TO SRV ACTUATIONS. BY DRD SHEET 5 OF 11

ANCHOR BOLT STRESS CALCULATIONS:

FOLLOWING LOADS WERE TAKEN FROM THE DRF # E51-72. THESE LOADS ARE AS A RESULT OF STATIC (NOZZLE LOADS, DEAD WT.) AND DYNAMIC LOADS. DYNAMIC LOADS WERE INPUT AS 3.0 g HORIZONTAL AND 3.0 g VERTICAL ACCELERATION LOADING. STATIC COEFFICIENT METHOD WAS USED RATHER THAN RESPONSE SPECTRUM OR ANY OTHER DYNAMIC ANALYSIS METHOD.

STATIC LOADS = 7,998 LBS

CONSIDERING ONLY SRV LOADS, PEAK HORIZONTAL AND VERTICAL ACCELERATION VALUES ARE 0.079 g HORIZ. AND 0.12 g VERTICAL (SEE ATTACHED RES. SPECTRA CURVE).

SRV LOADS TO BE USED ARE 1.5 x 0.12 = 0.18 g. (CONSERVATIVELY HIGHER VALUE USED).

SRV LOADS:

$X: \frac{0.18}{3.0} \times 8564 = 514$ LBS

$Y: \frac{0.18}{3.0} \times 4201 = 252$ LBS

$Z: \frac{0.18}{3.0} \times 5887 = 353$ LBS.

TOTAL SRV = 1,119 LBS.

TOTAL STATIC + SRV = 7,998 + 1,119 = 9,117 LBS.

(SEE NEXT SHEET.)

MADE BY DRDesai 5-20-83

VERIFIED BY H.T. 5-20-83

REWROTE.

PROJECT SUSQUEHANNA JOB NO. 8856
SUBJECT RCIC PUMP (1P203) FOUNDATION SHEET NO. 3
UNIT 1

CHECK ANCHOR BOLTS

Anchor bolt • 1" ϕ - A36 MAT'L. (REF: BECH. CIVIL DWG: CR-101-SH-13)

Tensile area of bolt = 0.6057 in^2 (REF: PG. 4-3 AISC MANUAL 7th ...
shear " " " = 0.7854 in^2 (" " ")

Force on critical bolt:
Tensile load = 9,117 lbs
shear " = 8640 lbs ← CONSERVATIVELY OLD NUMBERS USED.

Tensile stress = $\frac{9117}{0.6057}$ = 15,052 psi (f_t)

shear " = $\frac{8640}{0.7854}$ = 11,001 psi (f_v)

Allowable tensile stress = 0.85 x 36 = 30.6 ksi (F_t)
" shear " = 0.5 x 36 = 18 ksi (F_v)
{REF: PG. 31 BECH. CIVIL & STRUCT. DES. CRITERIA. REV ...}

VERIFIED BY H.Z. 4-29-83

BOLT INTEGRITY CALCULATIONS REMOVED. WAS NOT NECESSARY FOR FATIGUE LIFE CALCULATIONS.

DRD 5-20-83
H.T. 5-20-83

NUMBER ______ DATE 4-20-83
SUBJECT SUSQ. RCIC PUMP - FATIGUE LIFE EVALUATION DUE TO SRV ACTUATIONS. BY DRD SHEET 7 OF 11

3. MOUNTING FEET (AT THE WELD):

CALCULATED STRESS = 6208* psi (REF: DRF # E51-72, SEC 5.1.2)

THE ABOVE STRESS IS DUE TO STATIC PLUS SSE, SRV AND LOCA LOADS (3.0 g HORIZ. AND VERT.). CONSERVATIVELY USING THE SAME STRESS

PEAK STRESS = 6208 × 4 = 24832 psi WHERE 4 IS A STRESS CONCENTRATION FACTOR.

ALTERNATING STRESS = $S_a = \frac{24832}{2} = 12416$ psi

MATERIAL: SA 216 OR WCA. FROM FATIGUE CURVE (SHT. 10 OF 11)
S_a = 12416 psi, N = 10^6 CYCLES.

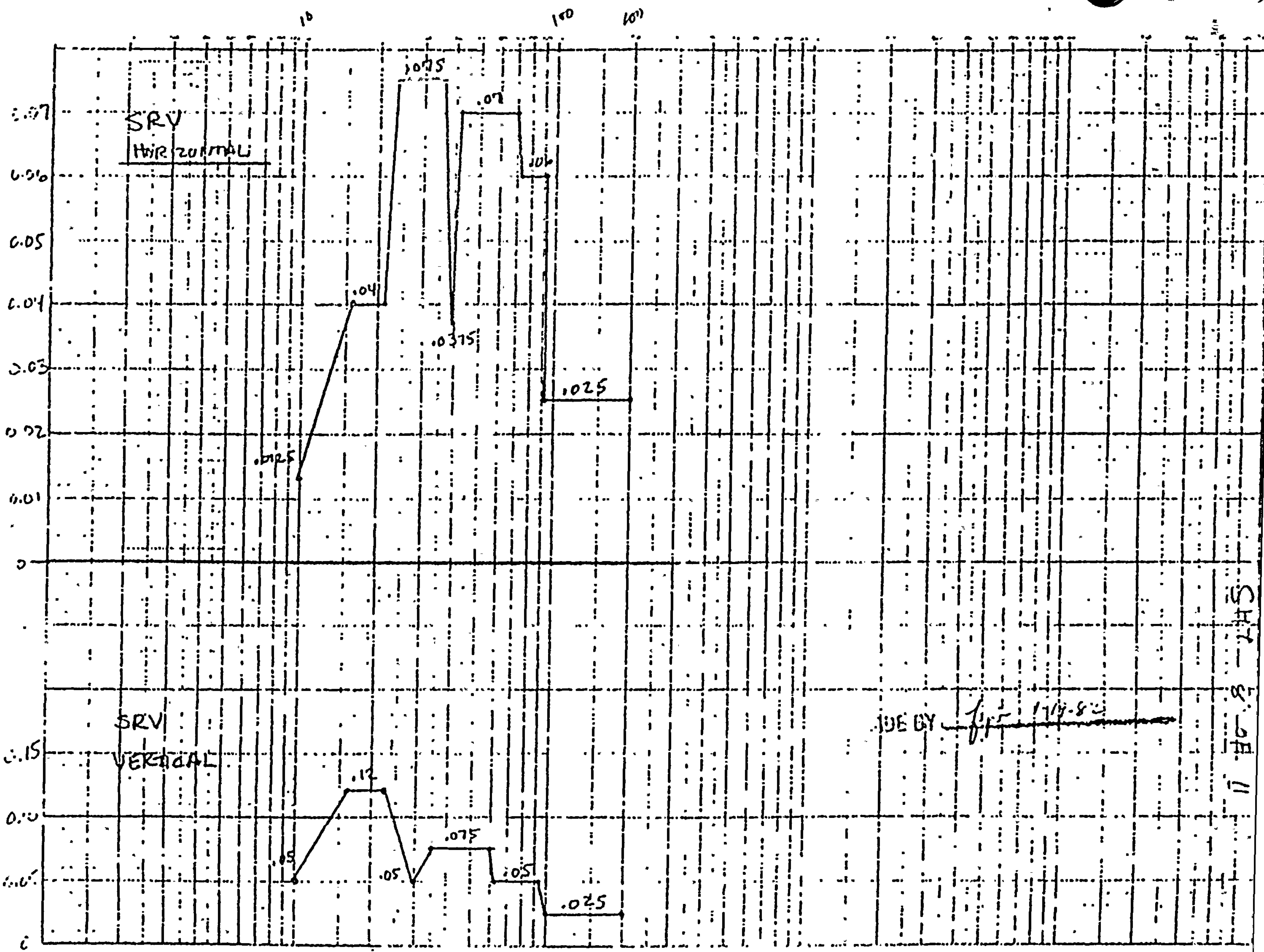
4. PEDESTAL (AT THE WELD):

CALCULATED $\text{STRESS}_{\text{WELD}}$ = 1868 psi STRESS IS VERY LOW, O.K.

N = 10^6 BY INSPECTION

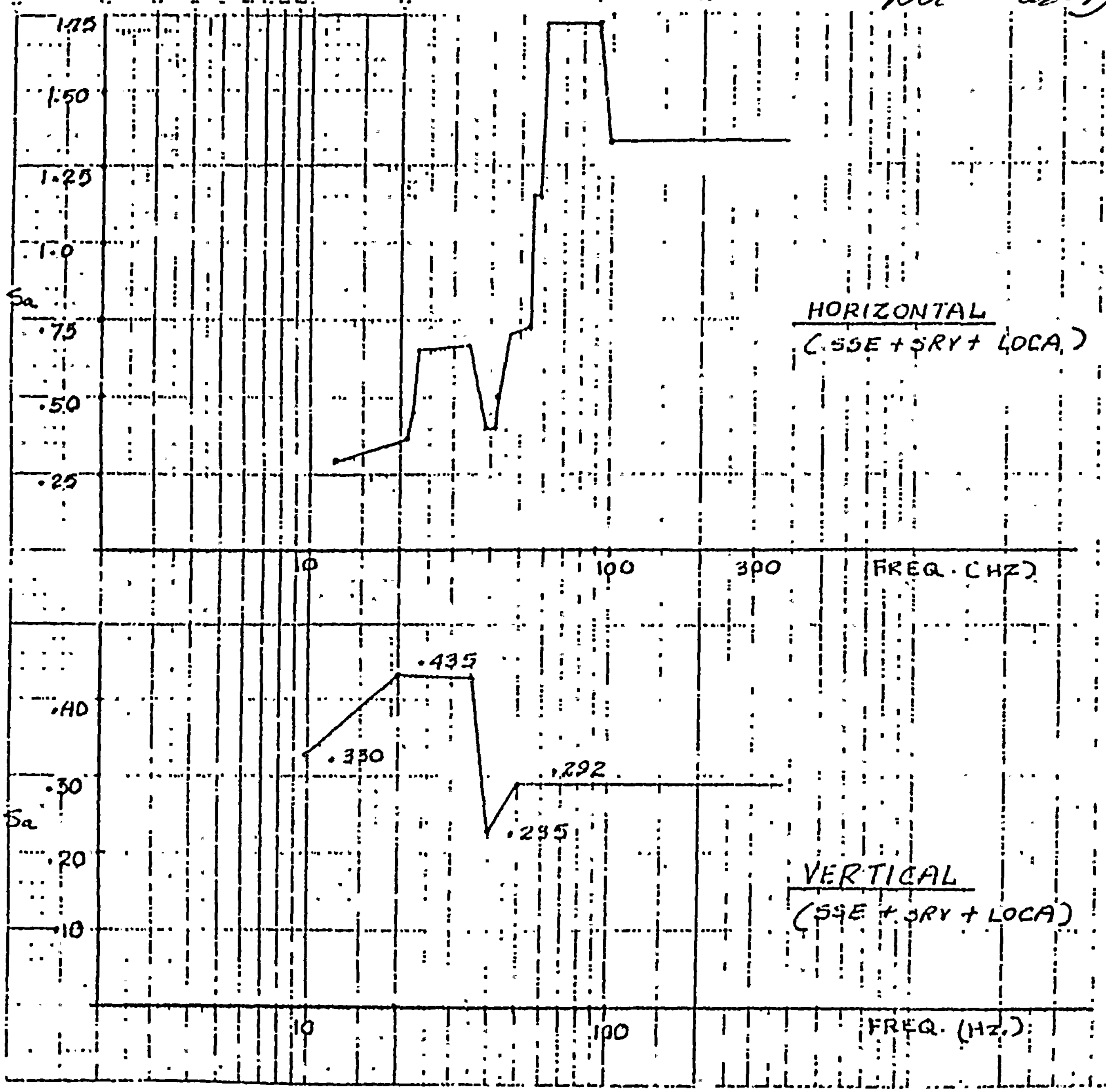
* CONSERVATIVELY MAX. PRINCIPAL STRESS WAS USED RATHER THAN MAX. PRINCIPAL STRESS DIFFERENCE.

VERIFIED BY H.T. 4-29-83


SRV
HORIZONTAL
SRV
VERTICAL
0.07
0.06
0.05
0.04
0.03
0.02
0.01
0
0.15
0
.0125
.04
.075
.0375
.07
.06
.025
.05
.12
.05
.075
.05
.025
10
100
DE BY

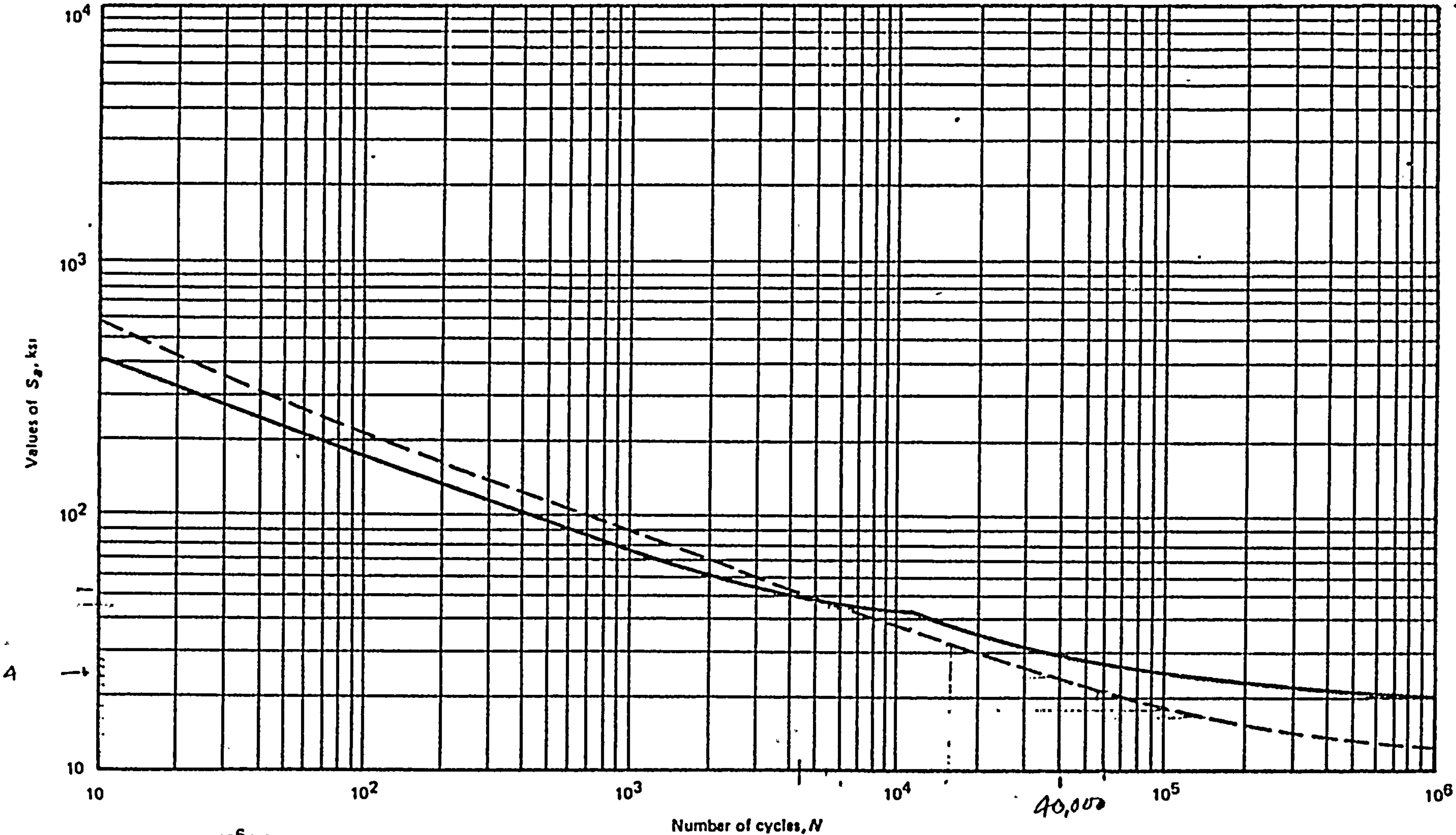
COMBINED RS

NOT USED



#	Freq.	Acc.
1	12 36	.306
2	21.35	.376
3	22.00	.456
4	23.00	.654
5	35.00	.663
6	40.00	.484
7	41.30	.484
8	42.25	.513
9	46.0	.709
10	52.40	.734
11	54	1.156
12	55	1 156
13	60	1.730
14	90	1.730
15	100	1 365

MADE BY V M Patel 1/20/82

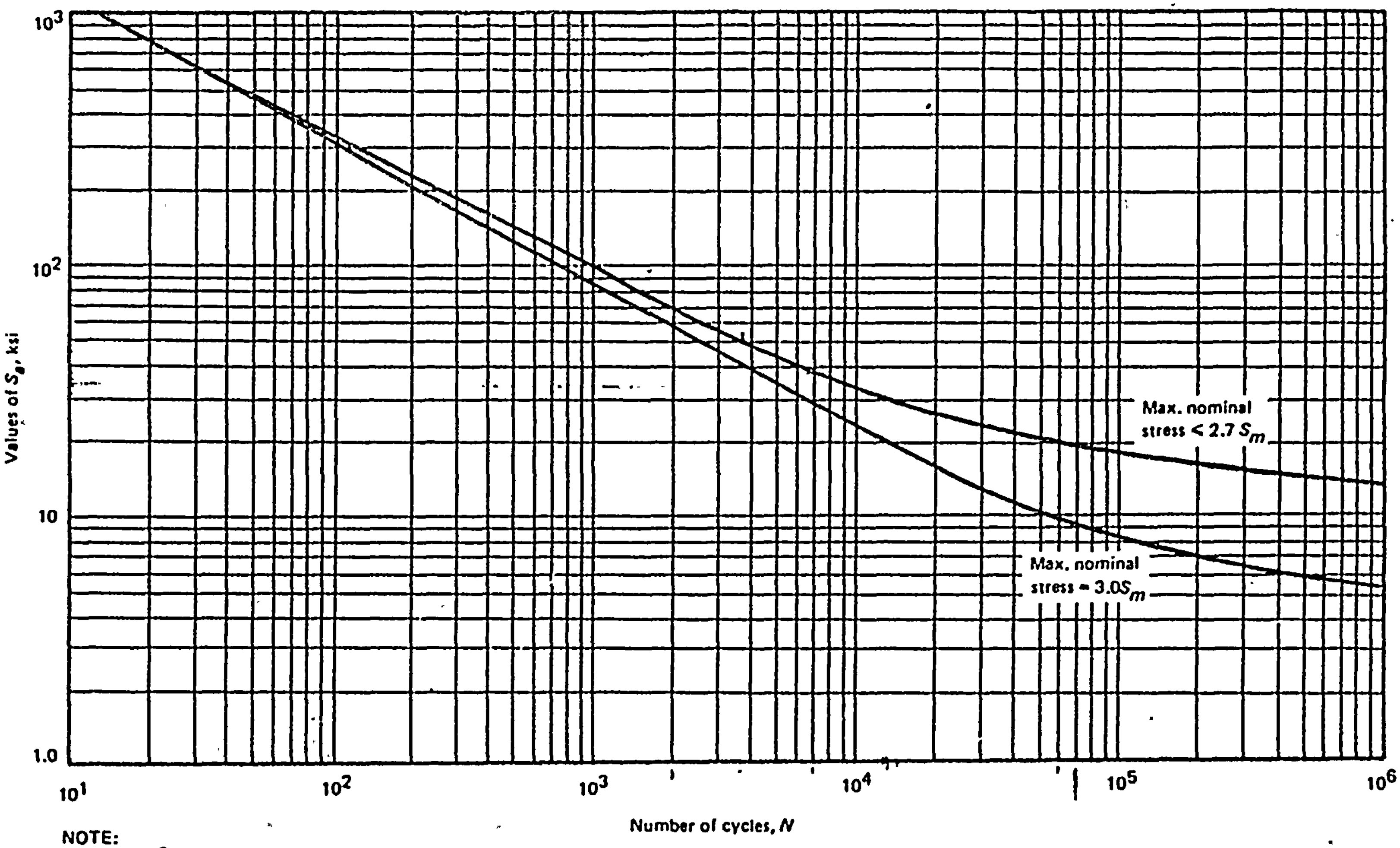


NOTE: $E = 30 \times 10^6$ ksi
— — UTS < 80.0 ksi
—— UTS 115.0–130.0 ksi
Interpolate for UTS 80.0–115.0 ksi

FIG. I-9.1 DESIGN FATIGUE CURVES FOR CARBON, LOW ALLOY, AND HIGH TENSILE STEELS FOR METAL TEMPERATURES NOT EXCEEDING 700°F
Table I-9.1 Contains Tabulated Values and a Formula for Accurate Interpolation of These Curves

SHT. 10 OF 11

VERIFIED BY H.T. 4-29-83



NOTE:
E = 30 X 10^6 psi

FIG. I-9.4 DESIGN FATIGUE CURVE FOR HIGH STRENGTH STEEL BOLTING FOR TEMPERATURES NOT EXCEEDING 700°F
Table I-9.1 Contains Tabulated Values and a Formula for Accurate Interpolation of These Curves

SHT. 11 OF 11

VERIFIED BY H.T. 4-29-83.

ATTACHMENT 2

2-1/5

MPL: E32-C001
E32-C002

Qualification Summary of Equipment

I. Plant Name: Susquehanna 1 & 2 — Type:

1. Utility: PP&L — PWR

2. NSSS: GE — 3. A/E: Bechtel — BWR 4 MK II

II. Component Name: Blower, MSIV Leakage Control System

1. Scope: [X] NSSS [ ] BOP

2. Model Number: 2 CH 6 041-1U — Quantity: E32-C001 1, E32-C002 2

3. Vendor: GE Lompoc, Ca.

4. If the component is a cabinet or panel, name and model No. of the devices included: N/A

5. Physical Description a. Appearance Blower With Motor

b. Dimensions 14.74" width, 13.76" length & 14.82" height

c. Weight 120 lbs.

6. Location: Building: Reactor Building, Outside of Containment

Elevation: 719 ft. & 733 ft.

7. Field Mounting Conditions [x] Bolt (No. 4, Size ½)
[ ] Weld (Length)
[x] Inlet & outlet threaded to pipe

8. a. System in which located: MSIV Leakage Control System

b. Functional Description: the blower takes suction from the main steam lines and discharge any steam/air mixture leaking through the MSIV to the standby gas treatment sys.

c. Is the equipment required for [ ] Hot Standby [x] Cold Shutdown

[ ] Both [ ] Neither

9. Pertinent Reference Design Specifications: 21A3762

12/80

III. Is Equipment Available for Inspection in the Plant: [X] Yes [ ] No

IV. Equipment Qualification Method:

[X] Test [ ] Analysis [ ] Combination of Test and Analysis

Qualification Report*: VPF 3830-14-1
(No., Title and Date) Blower, MSIV-LCS. Seismic Loading Qualification Test Report on Blower MSIV Leakage Control

Company that Prepared Report: Approved Engineering Test Lab

Company that Reviewed Report: General Electric

V. Vibration Input:

1. Loads considered: a. [ ] Seismic only
   b. [ ] Hydrodynamic only
   c. [x] Combination of (a) and (b)

2. Method of Combining RRS: [ ] Absolute Sum [x] SRSS [ ] ______ (other, specify)

3. Required Response Spectra (attach the graphs): See Ref. Doc 4 thru 6 & Note 1

4. Damping Corresponding to RRS: OBE N/A SSE N/A

5. Required Acceleration in Each Direction: [x] ZPA [ ] Other ______ (specify)

	S/S	F/B	V
OBE	-	-	-
SSE	0.47g	0.47g	0.09g
SSE & LOCA & SRV SRSS	E-W = 0.65g	0.65g	0.28g

6. Were fatigue effects or other vibration loads considered?

[x] Yes [ ] No

If yes, describe loads considered and how they were treated in overall qualification program: The overall test time was 40 minutes. This is far in excess of the anticipated duration of Seismic Vibration and hydrodynamic vibrations

*NOTE: If more than one report complete items IV thru VII for each report.

NOTE 1: As the equipment is rigid within the frequency range of interest only ZPA is considered. Damping coefficient is not pertinent

12/80

VI. If Qualification by Test, then Complete*:

1. [x] Single Frequency Sine Sweep [ ] Multi-Frequency: [ ] random [ ] sine beat [ ] ________

2. [ ] Single Axis [x] Multi-Axis

3. No. of Qualification Tests: OBE 4 SSE 4 Other Each test run lasted 5 minutes (specify)

4. Frequency Range: 3 .8 - 33HZ

5. Natural Frequencies in Each Direction (Side/Side, Front/Back, Vertical): Note 1

S/S = ∿1000 HZ F/B = ∿1000 HZ V = ∿1000 HZ

6. Method of Determining Natural Frequencies

[x] Lab Test [ ] In-Situ Test [ ] Analysis

7. TRS enveloping RRS using Multi-Frequency Test [ ] Yes (Attach TRS & RRS graphs) [ ] No N/A

8. Input g-level Test: OBE S/S = 2.0g F/B = 2.0g V = 2.0g

SSE S/S = 3.0g F/B = 3.0g V = 3.0g

9. Laboratory Mounting:

1. [x] Bolt (No. 4, Size ½) [ ] Weld (Length ______) [ ] ______

10. Functional operability verified during the test: [x] Yes [ ] No [ ] Not Applicable

11. Test Results including modifications made: After the test was completed there was no evidence of structural damage

12. Other test performed (such as aging or fragility test, including results): An independent test was run to determine the natural frequency using an external shock excitation method, the natural frequency was determined to be about 1000 HZ ± 10% (Ref. 2)

*Note: If qualification by a combination of test and analysis also complete Item VII.

Note 1: No natural frequency observed during resonance search. Listed values were determined from external shock excitation

VII. If Qualification by Analysis, then complete:

1. Method of Analysis: N/A

[ ] Static Analysis [ ] Equivalent Static Analysis

[ ] Dynamic Analysis: [ ] Time-History [ ] Response Spectrum

2. Natural Frequencies in Each Direction (Side/Side, Front/Back, Vertical):

S/S = ________ F/B = ________ V = ________

3. Model Type: [ ] 3D [ ] 2D [ ] 1D

[ ] Finite Element [ ] Beam [ ] Closed Form Solution

4. [ ] Computer Codes: ________

Frequency Range and No. of modes considered: ________

[ ] Hand Calculations -

5. Method of Combining Dynamic Responses: [ ] Absolute Sum [ ] SRSS
[ ] Other: ________ (specify)

6. Damping: OBE ____ SSE ____ Basis for the damping used: ________

7. Support Considerations in the model: ________

8. Critical Structural Elements:

A.

Identification	Location	Governing Load or Response Combination	Seismic Stress	Total Stress	Stress Allowable

B.

Max. Critical Deflection	Location	Maximum Allowable Deflection to Assure Functional Operability

MPL: E32-C001/C002

TABLE 1

SUSQUEHANNA

MSIV LC SYSTEM BLOWER SQRT

The ZPA of all the spectra given by Dynamic Load Analysis on Susquehanna are combined by the SRSS method to obtain the appropriate acceleration for the evaluation.

SPECTRA ZPA (Ref. 4, 5, & 6)

	Vert. (g)	Hori. (g)	
SSE	0.09	0.47	
LOCA			
Steam Flow	0.05	E-W 0.03	
		N-S 0.02	
Chugging	0.24	E-W 0.42	
		N-S 0.13	
SRV			
3 Adj. Valves	0.03	0.03	
Symmetric (SRV ALL)	0.11	-0-	
	SRSS 0.28	SRSS 0.65	
Test Qualified Acceleration	3	3	(From Ref. 3)

ATTACHMENT 3

Qualification Summary of Equipment

I. Plant Name: SUSQUEHANNA Type:

1. Utility: PP&L PWR

2. NSSS: GE 3. A/E: BECHTEL BWR X

II. Component Name: 4.16 KV Switchgear 2A201, Cubicle 2A20110

1. Scope: [ ] NSSS [X] BOP

2. Model Number: 50-DHP-250 Quantity: 12

3. Vendor: Westinghouse

4. If the component is a cabinet or panel, name and model No. of the devices included:

   As noted at bottom of sheet*

5. Physical Description a. Appearance Self stand cabinet

   b. Dimensions 2' W x 6.5' D x 7.5' H per cubicle

   c. Weight ≃ 2000 lbs per cubicle

6. Location: Building: Reactor building

   Elevation: 719'-1" & 749'-1"

7. Field Mounting Conditions [ ] Bolt (No._____, Size______)
   [x] Weld (Length______) Plug weld
   [ ] (See attachment #2 from DWG: C-804 Rev .20)

8. a. System in which located: 4.16 KV Power Distribution System

   b. Functional Description: 4.16 KV Power Distribution

   c. Is the equipment required for [ ] Hot Standby [ ] Cold Shutdown [x] Both [ ] Neither

9. Pertinent Reference Design Specifications: Spec. E-403, E-109

   G-22,

* 1A201, 1A202, 1A203, 1A204, 1A205, 1A206,
2A201, 2A202, 2A203, 2A204, 2A205, 2A206.

PF2/23-1

Devices covered:
△2 Items 1, 2, 4, 6, 14, 17, 18, 37, 56, 57, 59, 60
63, 77, 78, 79, 86, 91, 95, 106, 110, 114, 115, 123, 125,
141, 142, 143, 146, 148, 154, 158 & 160. (See VP E-403-8-3 Pg 32)
△2 Total - 33 Devices

3-2/4

Sheet 2
Form: E109-1
Rev. 1

III. Is Equipment Available for Inspection in the Plant: [x] Yes [ ] No

IV. Equipment Qualification Method:

[x] Test [ ] Analysis [ ] Combination of Test & Analysis

Qualification Report* ______

(No., Title and Date) 57577-1, Seismic & Hydrodynamic Qualification of 4.16KV switchgear, dated 2/6/81 (Bechtel V.P. #8856-E-403-8-3)

Company that Prepared Report Wyle Laboratories

Company that Reviewed Report Bechtel Power Corporation, San Francisco

V. Vibration Input:

1. Loads considered: a. [x] Seismic only

   b. [ ] Hydrodynamic only

   c. [x] Combination of (a) and (b)

2. Method of combining RRS: [x] Absolute Sum [ ] SRSS [ ] ______ (Other, specify)

3. Required Response Spectra (attach the graphs): See attachment #1 - Phase II attachment # 6 - Phase III

4. Damping Corresponding to RRS: OBE 1/2% SSE 1%
   OBE + SRV + LOCA - 2% SSE + SRV + LOCA - 2%

5. Required Acceleration in Each Direction: [ ] ZPA [ ] Other (Specify)
   (See attachment #1)
   OBE S/S = ______ F/B = ______ V = ______
   SSE S/S = ______ F/B = ______ V = ______
   as per required response spectra.

6. Were fatigue effects or other vibration loads considered?

   [x] Yes [ ] No

   If yes, describe loads considered and how they were treated in overall qualification program: A biaxial sine sweep test covering amplified portion of SRV spectrum (4-70 Hz) was performed in SS/V & F/B,V at a sweep rate of 1 octave/minute for 30 minutes

*NOTE: If more than one report complete items IV thru VII for each report.

VI. If Qualification by Test, then Complete*:

1. [ ] Single Frequency [x] Multi-Frequency [x] random [ ] sine beat [ ] ______

2. [ ] Single Axis [x] Multi-Axis

3. No. of Qualification Tests: OBE 5 SSE 2 Other ______ (Specify)
(Five upset conditions followed by two faulted condition)

4. Frequency Range: 1 to 100 Hz.

5. Natural Frequencies in Each Direction (Side/Side, Front/Back, Vertical):
From in-situ measurements.
multicell S/S = 45, 63, 75 F/B = 23, 37, 45 & 51Hz V = Greater than 80 Hz
single cell 13, 16, 26, 32, 48 26, 31, 38 & 50, 59.

6. Method of Determining Natural Frequencies

[ ] Lab Test [x] In-Situ Test [ ] Analysis

7. TRS enveloping RRS using Multi-Frequency Test [x] Yes (Attach TRS & RRS graphs (See attachment # 3-Phase II attachment #7-Phase III) [ ] No

8. Input g-level Test: OBE S/S = ______ F/B = ______ V = ______

SSE S/S = ______ F/B = ______ V = ______
(See attachment #3-Phase II attachment #7-Phase III)

9. Laboratory Mounting:

1. [x] Bolt (No. 4, Size 1/2Ø) [ ] Weld (Length ______) [ ] ______
Grade 5 bolts

10. Functional operability verified: [x] Yes [ ] No [ ] Not Applicable

11. Test Results including modifications made: See attachment #4 & #5.

12. Other test performed (such as aging or fragility test, including results):

(1) In-situ test for the simulation of in service conditions for the shaker table test (2) Extended duration test for simulating SRV repetitions.

*NOTE: If qualification by a combination of test and analysis also complete Item V11.

VII. If Qualification by Analysis, then complete: (Not Applicable)

1. Method of Analysis:

   [ ] Static Analysis [ ] Equivalent Static Analysis

   [ ] Dynamic Analysis [ ] Time-History [ ] Response Spectrum

2. Natural Frequencies in Each Direction (Side/Side, Front/Back, Vertical):

   S/S = ______ F/B = ______ V = ______

3. Model type: [ ] 3D [ ] 2D [✓] 1D

   [ ] Finite Element [ ] Beam [ ] Closed Form Solution

4. [ ] Computer Codes: ______

   Frequency Range and No. of modes considered: ______

   [ ] Hand Calculations

5. Method of Combining Dynamic Responses: [ ] Absolute Sum [ ] SRSS
   [ ] Other: ______ (Specify)

6. Damping: OBE ______ SSE ______ Basis for the damping used: ______

7. Support Considerationns in the model: ______

8. Critical Structural Elements:

A.

Identification	Location	Governing Load or Response Combination	Seismic Stress	Total Stress	Stress Allowable

B.

Max. Critical Deflection	Location	Maximum Allowable Deflection to Assure Functional Operability

ATTACHMENT 4

SUSQUEHANNA STEAM ELECTRIC STATION

UNITS 1 AND 2

DYNAMIC QUALIFICATION OF EQUIPMENT

FOR UNIT 1 & COMMON

COMPONENT NAME: 125 V dc Distribution Panels

BECHTEL PURCHASE ORDER NO.: 8856-E-120

SQRT FORM NUMBER(S): E120-1

The Qualification Report(s) identified above have been evaluated by Bechtel and the component identified above has been requalifed, where necessary, to show that the component is capable of meeting the requirements of the Susquehanna Equipment Qualification Program for Dynamic Loads and the NRC Seismic Qualification Review Team (SQRT) Program.

PREPARED BY: RBGoel / P. [illegible] DATE: 7-17-81 / 7/17/81

REVIEWED BY: [illegible] / [illegible] DATE: 7/17/81 / 7/17/81

APPROVED BY: [illegible] DATE: 7/21/81 / 7/21/81

Sheet 1
Form: E-120-1

Qualification Summary of Equipment

I. Plant Name: SUSQUEHANNA — Type:

1. Utility: PP&L — PWR ____
2. NSSS: GE — 3. A/E: BECHTEL — BWR X

II. Component Name: 125 V dc Distribution Panels (E120)

1. Scope: [ ] NSSS [X] BOP
2. Model Number: CDP-222 (125V DC) Model # FC-20 (24 V DC) Quantity: 8
3. Vendor: ITE-GOULD
4. If the component is a cabinet or panel, name and model No. of the devices included:

   See V.P. 8856-E-120-2 (Attachment #1)

5. Physical Description a. Appearance Panel

   b. Dimensions (W x D x H) 20" x 10" x 90"

   c. Weight 550 lbs

6. Location: Building: Control Structure

   Elevation: Elev. 771'

7. Field Mounting Conditions [x] Bolt (No. 6, Size 3/8") Bolts Wall Mounted
   [ ] Weld (Length ____)
   [ ] ____

8. a. System in which located: Electrical Power Distribution

   b. Functional Description: 125 dc distribution panel

   c. Is the equipment required for [ ] Hot Standby [ ] Cold Shutdown [x] Both [ ] Neither

9. Pertinent Reference Design Specifications: 8856-E120

*Tag Nos.

1D614	2D614
1D624	2D624
1D634	2D634
1D644	2D644

PF2/23-1

Sheet 2
Form: E120-1

III. Is Equipment Available for Inspection in the Plant: [x] Yes [ ] No

IV. Equipment Qualification Method:

[x] Test [ ] Analysis [ ] Combination of Test & Analysi

Qualification Report* Bechtel Document #8856-E404-14-4

(No., Title and Date) Wyle #26340-5 (seismic & hydrodynamic loading test report of 125 V dc Dist. Panel) 4/13/81

Company that Prepared Report Wyle Laboratories

Company that Reviewed Report Bechtel Power Corporation, San Francisco

V. Vibration Input:

1. Loads considered: a. [x] Seismic only

   b. [ ] Hydrodynamic only

   c. [x] Combination of (a) and (b)

2. Method of combining RRS: [x] Absolute Sum [ ] SRSS [ ] ________ (Other, specify)

3. Required Response Spectra (attach the graphs): See attachment #2

4. Damping Corresponding to RRS: OBE ½% SSE 1%
   OBE + SRV + LOCA - 2% SSE + SRV + LOCA - 2%

5. Required Acceleration in Each Direction: [ ] ZPA [ ] Other (Specify)

   OBE S/S = ________ F/B = ________ V = ________
   SSE S/S = ________ F/B = ________ V = ________
   see attachment #2

6. Were fatigue effects or other vibration loads considered?

   [x] Yes [ ] No

   If yes, describe loads considered and how they were treated in overall qualification program: The specimen was subjected to a multifrequency biaxial random motion for sixty minutes in the FB/V and SS/V configuration. The TRS enveloped the SRV spectra. (see attachment #4)

*NOTE: If more than one report complete items IV thru VII for each report.

Sheet 3
Form: E120-1

VI. If Qualification by Test, then Complete*:

1. [ ] Single Frequency [x] Multi-Frequency [x] random [ ] sine beat [ ] ______

2. [ ] Single Axis [x] Multi-Axis

3. No. of Qualification Tests: OBE ______ SSE 6 Other ______ (Specify)
   (Six faulted conditions)

4. Frequency Range: 1 to 100 Hz

5. Natural Frequencies in Each Direction (Side/Side, Front/Back, Vertical):

   S/S = 16,32,37,63 F/B = 19,23,30,36,58 V = 19,32,50,75,90

6. Method of Determining Natural Frequencies

   [x] Lab Test [ ] In-Situ Test [ ] Analysis

7. TRS enveloping RRS using Multi-Frequency Test [ ] Yes (Attach TRS & RRS graphs
   See attachment #3 [ ] No

8. Input g-level Test: OBE S/S = ______ F/B = ______ V = ______

   SSE S/S = ______ F/B = ______ V = ______

   See attachment #3

9. Laboratory Mounting:

   1. [x] Bolt (No. 6 , Size ¼" dia) [ ] Weld (Length ______) [ ] ______

10. Functional operability verified: [x] Yes [ ] No [ ] Not Applicable

11. Test Results including modifications made: The specimen was qualified without compromise on structural and functional integrity.

12. Other test performed (such as aging or fragility test, including results):

    Extended duration test for 60 minutes (see attachment #4)

*NOTE: If qualification by a combination of test and analysis also complete Item Vll.

VII. <u>If Qualification by Analysis, then complete:</u> (Not applicable)

1. Method of Analysis:

   [ ] Static Analysis [ ] Equivalent Static Analysis

   [ ] Dynamic Analysis [ ] Time-History [ ] Response Spectrum

2. Natural Frequencies in Each Direction (Side/Side, Front/Back, Vertical):

   S/S = ________ F/B = ________ V = ________

3. Model type: [ ] 3D [ ] 2D [ ] 1D

   [ ] Finite Element [ ] Beam [ ] Closed Form Solution

4. [ ] Computer Codes: ________

   Frequency Range and No. of modes considered: ________

   [ ] Hand Calculations

5. Method of Combining Dynamic Responses: [ ] Absolute Sum [ ] SRSS
   [ ] Other: ________ (Specify)

6. Damping: OBE ________ SSE ________ Basis for the damping used: ________

7. Support Considerationns in the model: ________

8. Critical Structural Elements:

A.	Identification	Location	Governing Load or Response Combination	Seismic Stress	Total Stress	Stress Allowable

B.	Max. Critical Deflection	Location	Maximum Allowable Deflection to Assure Functional Operability

WYLE LABORATORIES

Report No.26340-5
Page No.

CUSTOMER BECHTEL Job No. 26347

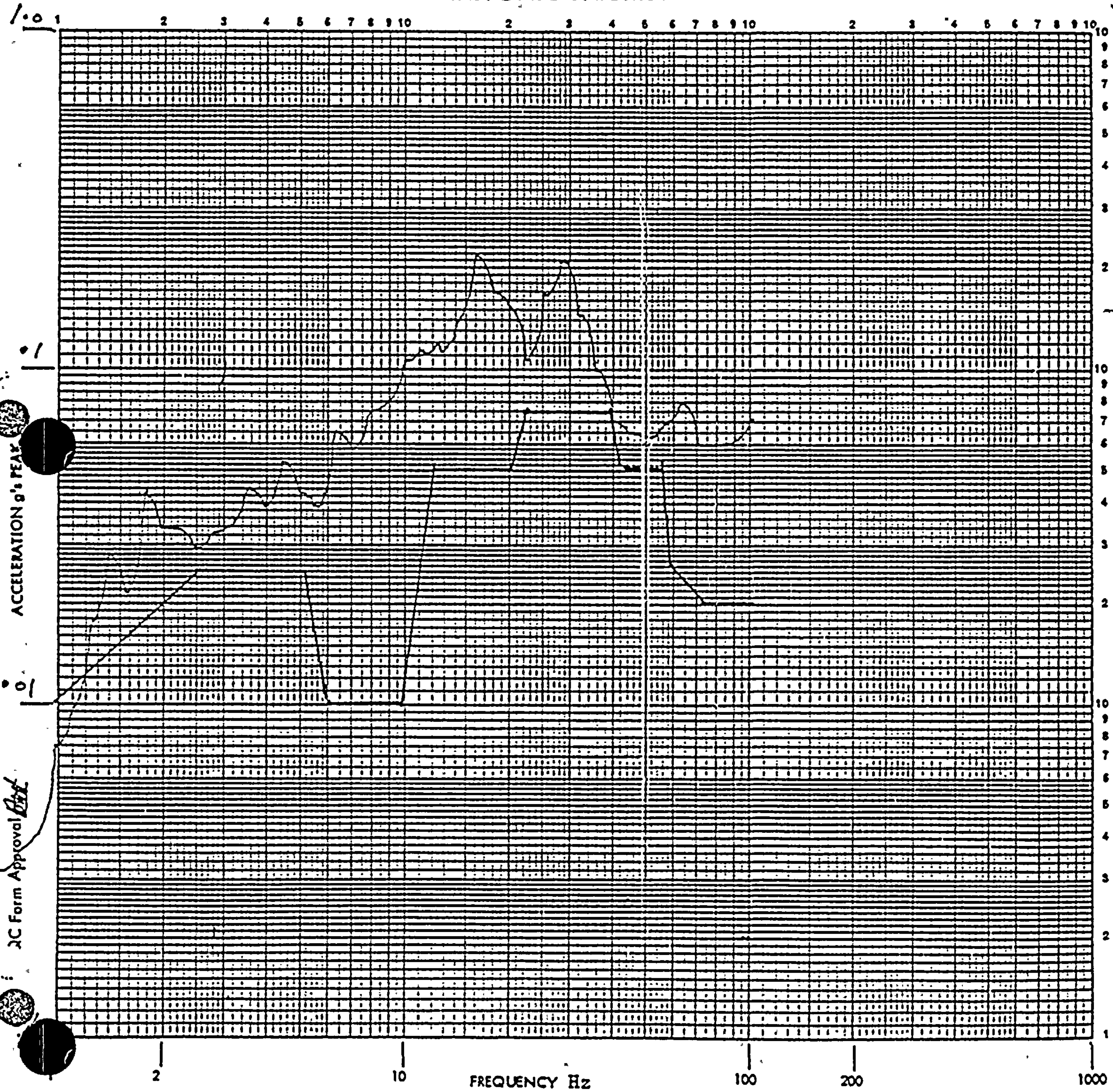
Full Scale 1.0 g Accel. No. 1 X Control (✓) Response ( )

Operator ELLIS Specimen 125 VDC DISTRIBUTION PANEL

Date 2-8-81 Damping 2 % Axis of Test HORIZ. X-Y

SRV FATIGUE TEST
(START OF 60 MINUTES)

RESPONSE SPECTRUM



QC Form Approval

WYLE LABORATORIES

Report No. 26340-5
Page No.

CUSTOMER BECHTEL Job No. 26347

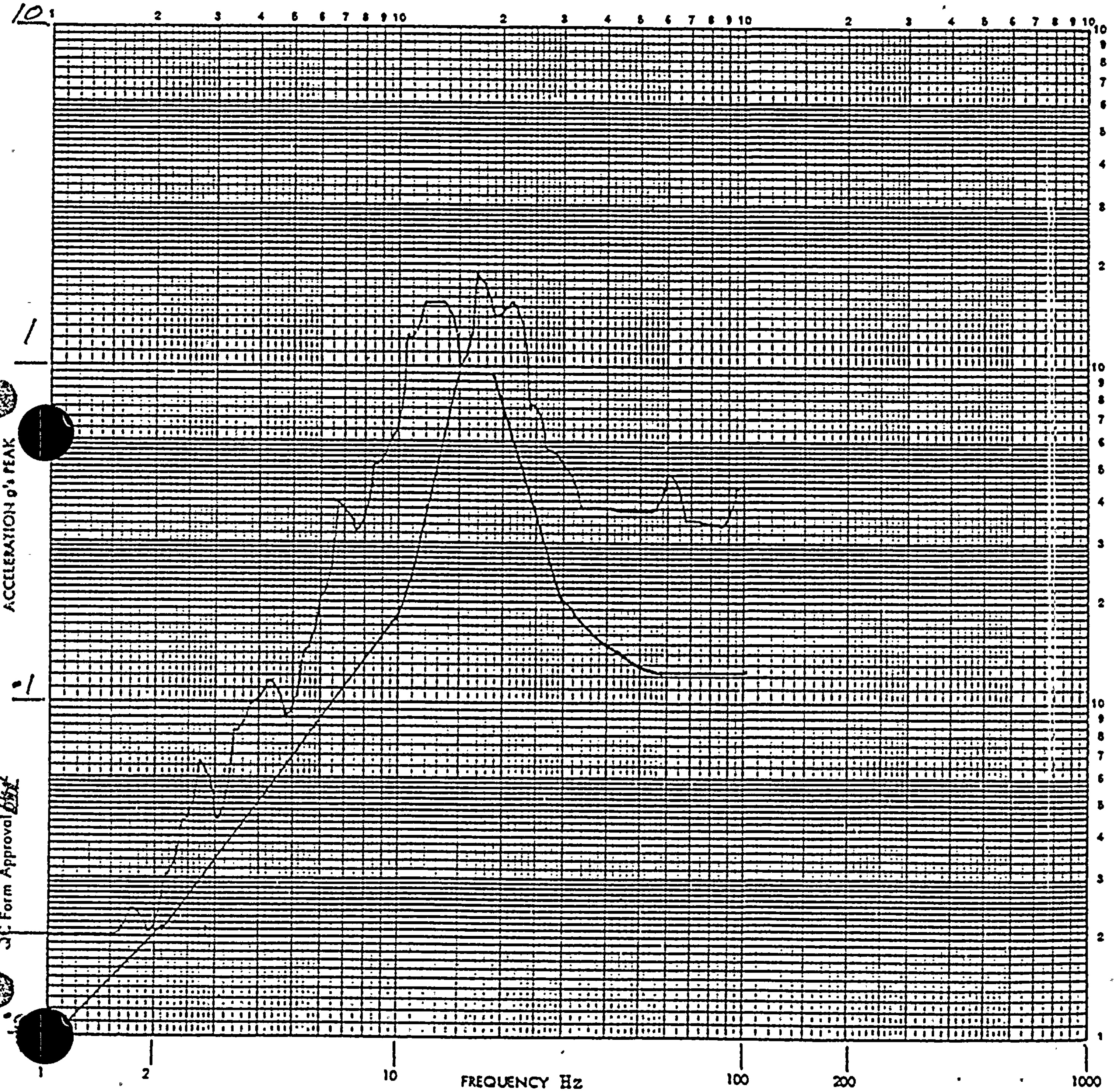
Full Scale 10 g Accel. No. 2Y Control (✓) Response ( )

Operator ELLIS Specimen 125VDC DISTRIBUTION PANEL

Date 2-8-81 Damping 2 % Axis of Test VERT X-Y

SRV FATIGUE TEST
START OF 60 MINUTE TEST

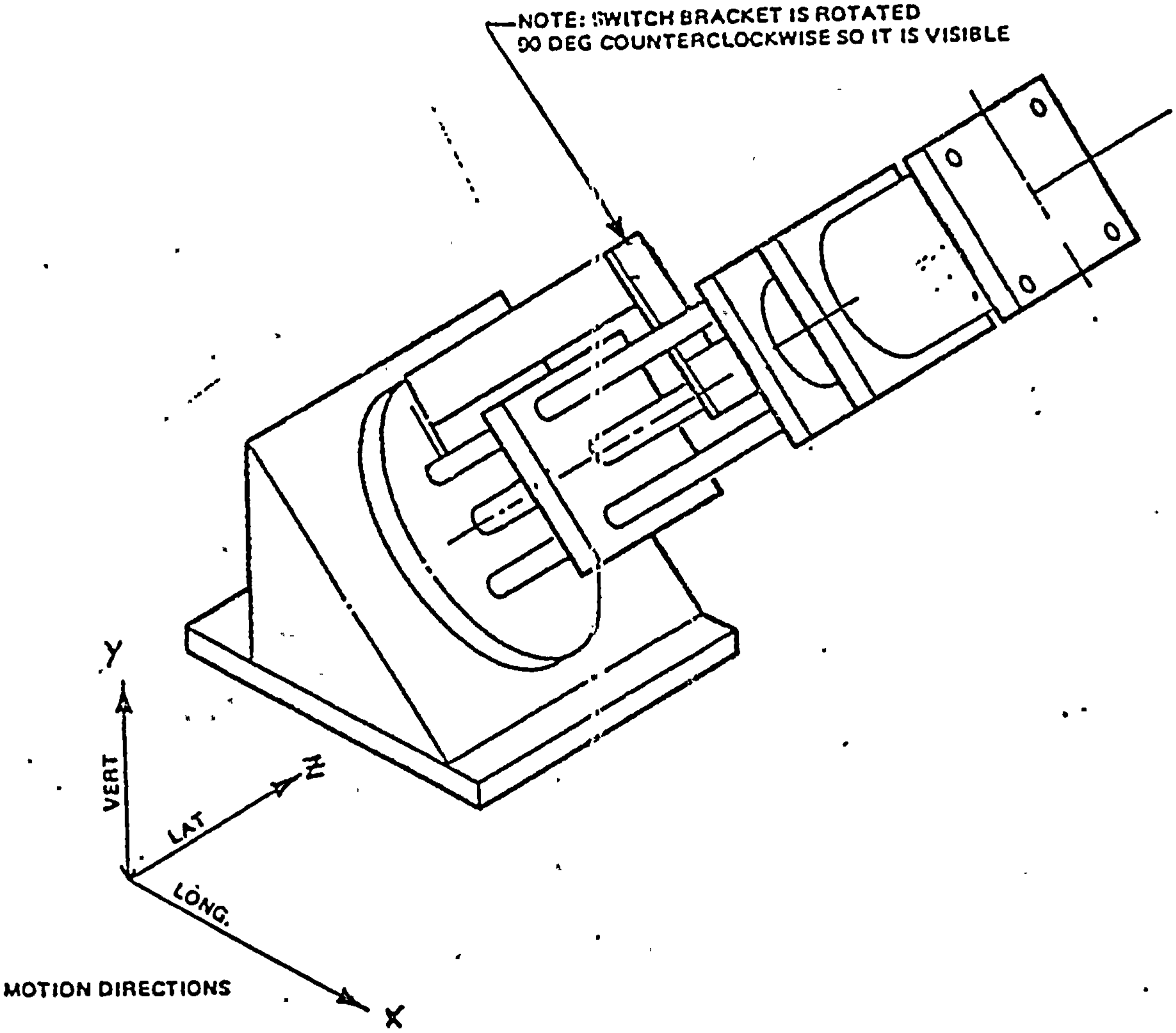
RESPONSE SPECTRUM



Form Approval

ATTACHMENT 5

FIGURE 39
MOTION DIRECTIONS

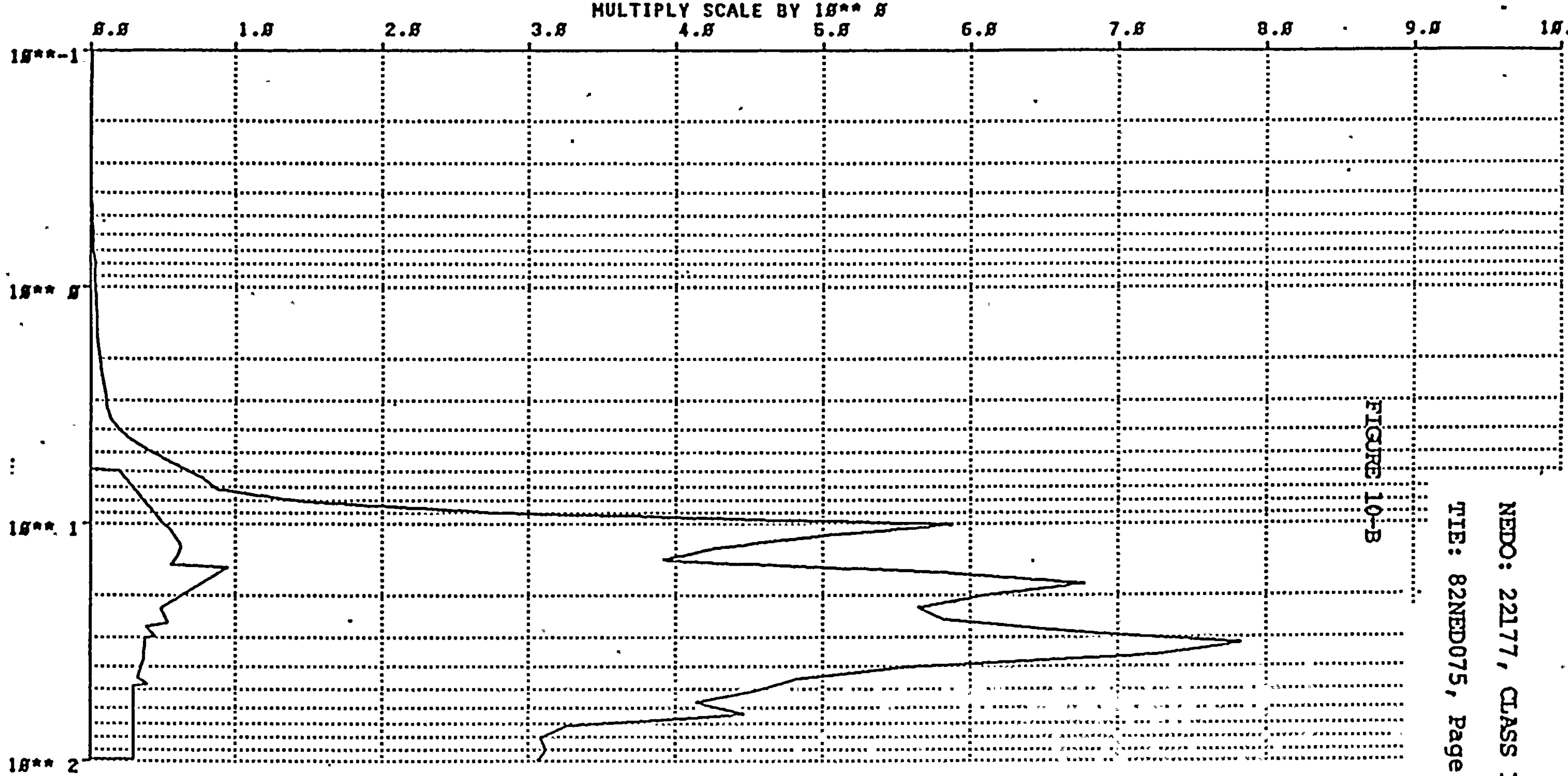


RUN [illegible] TPP524.0926 OBE 90X XA-YC DATE 6/1[illegible] 16:10: 0 HORIZONTAL CHANNEL 3 TAB HZ1

DECIMATION RATIO 2 7412 POINTS ANALYZED DELTA T [illegible] 1/ 6 OCTAVE 100.00 HZ LP FILTER 6 POLES

4.00 X DAMPING START TIME 0.000 SEC END TIME 29.648 SEC 0 RECORDS SKIPPED 218 RECORDS ANALYZED

100.0 X AND 0.0 X RRS PLOTTED



SEMI-CLOSED METHOD APPROXIMATION : 7-22-80 REVISION

FIGURE 10-B

NEDO: 22177, CLASS I, AUG. 1982

TIE: 82NED075, Page 119 of 535

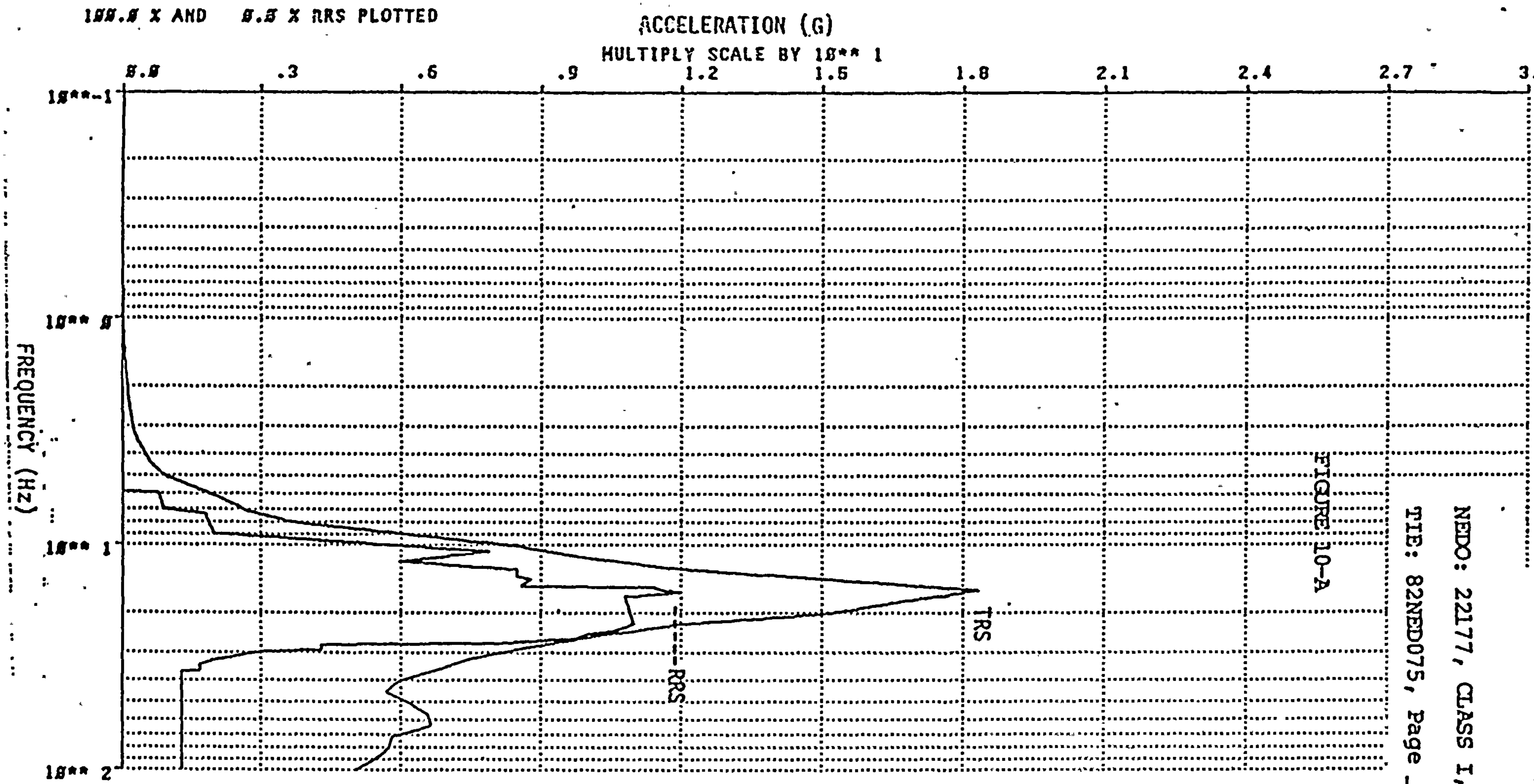
5-2/5

RUN [redacted]26 TPP524.0926 OBE 90% XA-YC DATE 6[redacted]/82 16:10:0 VERTICAL CHANNEL 4 TAB Y[redacted]

[redacted]TION RATIO 2 7412 POINTS ANALYZED DELTA [redacted]004 1/ 6 OCTAVE 100.00 HZ LP FILTER [redacted] POLES

4.00 % DAMPING START TIME 0.000 SEC END TIME 29.640 SEC 0 RECORDS SKIPPED 218 RECORDS ANALYZED

100.0 % AND 0.0 % RRS PLOTTED



SEMI-CLOSED METHOD APPROXIMATION : 7-22-88 REVISION

NEDO: 22177, CLASS I, AUG. 1982

TIE: 82NED075, Page 118 of 535

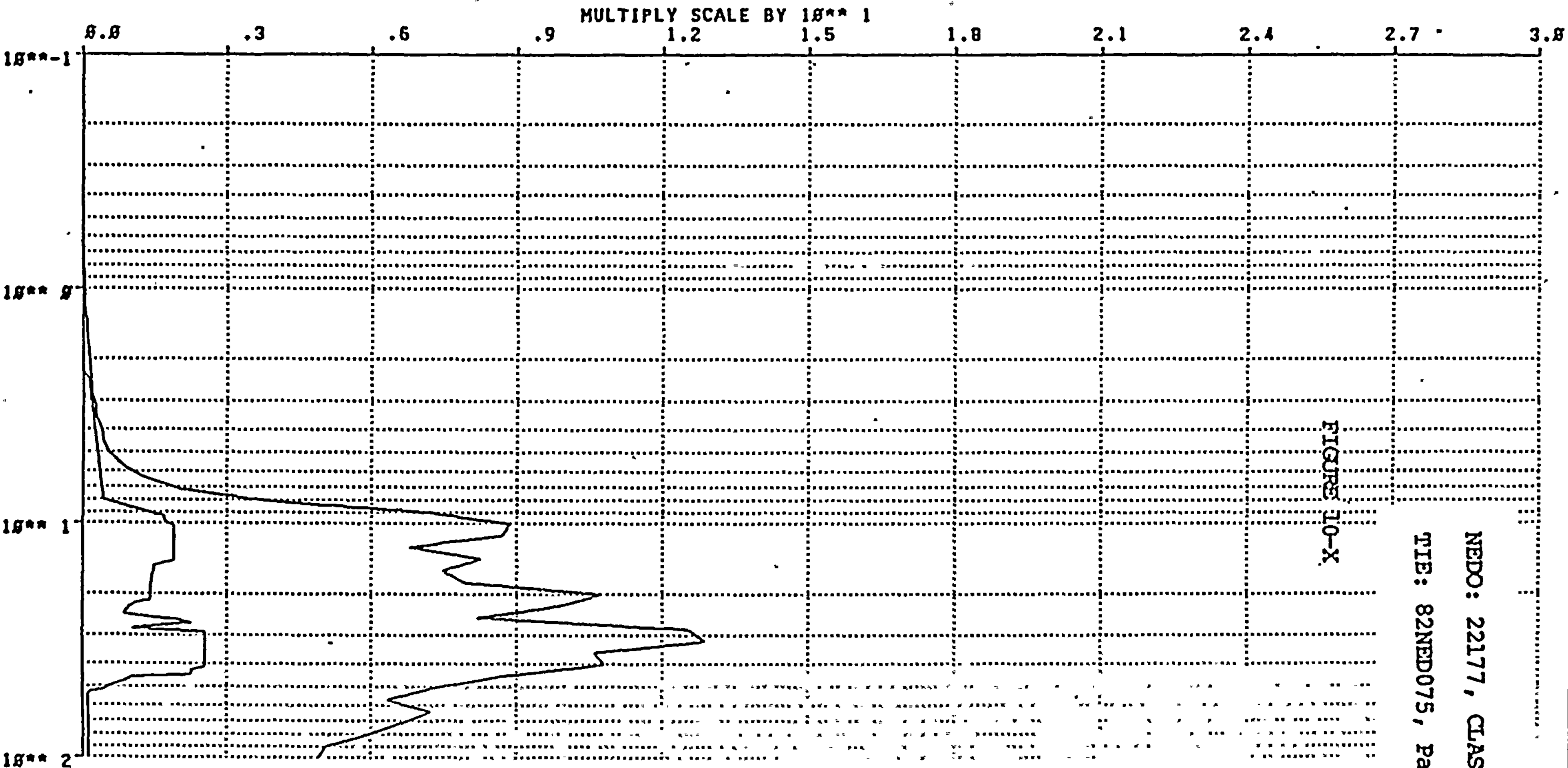
5-3/5

R... TPP524.Ø926 MSIV SSEX ØXXA-1ØØXY DATE ...82 9:5Ø: Ø HORIZONTAL CHANNEL 3 TAB HZ...

D...ATION RATIO 2 7514 POINTS ANALYZED DELTA ...ØØ4 1/ 6 OCTAVE 1ØØ.ØØ HZ LP FILTER ... POLES

4.ØØ X DAMPING START TIME Ø.ØØØ SEC END TIME 3Ø.Ø56 SEC Ø RECORDS SKIPPED 221 RECORDS ANALYZED

1ØØ.Ø X AND Ø.Ø X RRS PLOTTED



SEMI-CLOSED METHOD APPROXIMATION : 7-22-8Ø REVISION

FIGURE 10-X

NEDO: 22177, CLASS I, AUG. 1982

TIE: 82NED075, Page 141 of 535

5-4/5

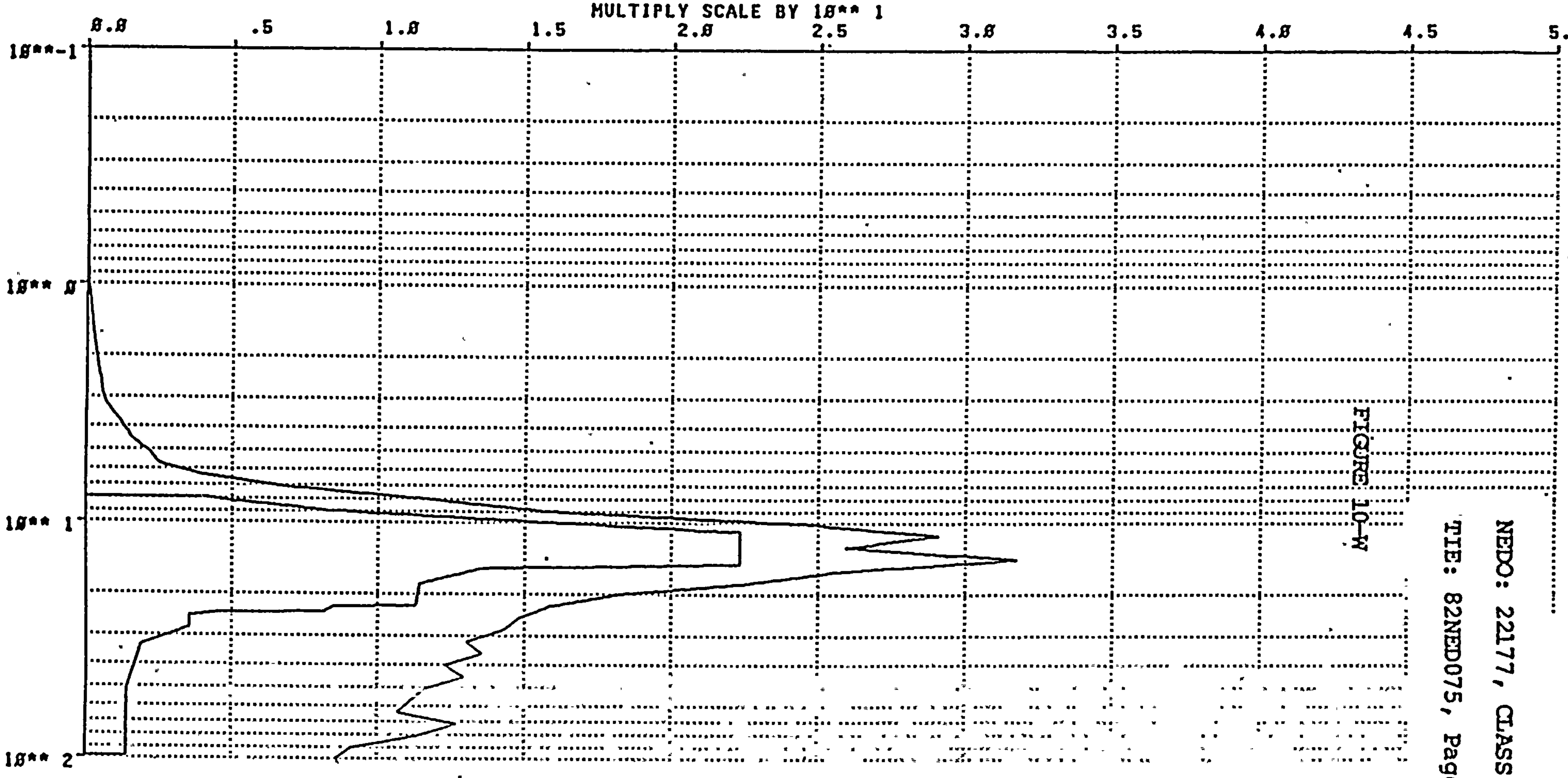
[illegible]

RU TPP524.0926 | MSIV SSEX 0XXA-100XY | DATE 82 | 9:50: 0 | VERTICAL CHANNEL 4 | TAB V

DEC ATION RATIO 2 | 7514 POINTS ANALYZED | DELTA T .004 | 1/ 6 OCTAVE | 100.00 HZ LP FILTER | 6 POLES

4.00 X DAMPING | START TIME 0.000 SEC | END TIME 30.056 SEC | 0 RECORDS SKIPPED | 221 RECORDS ANALYZED

100.0 X AND 0.0 X RRS PLOTTED



SEMI-CLOSED METHOD APPROXIMATION : 7-22-90 REVISION

FIGURE 10-W

NEDO: 22177, CLASS I, AUG. 1982

TIE: 82NED075, Page 140 of 535

5-5/5

[illegible]