PAP-516

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# Unit 2 Suction-Draft Tube Replacement Trashrack Vibration Test
# Mt. Elbert Pumped-Storage Powerplant

by

R. V. Todd
B. W. Mefford

November 3, 1987

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(12-81)
Bureau of Reclamation

INFORMATIONAL ROUTING

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PAP file
PAP-516

D-252

NOV 3 1987

Memorandum

To: Regional Director, Billings, Montana
Attention: MB-200

From: Acting Chief, Division of Electrical, Mechanical, and Plant Design

Subject: Report of Field Vibration Test of Suction-draft Tube Replacement Trashracks for Unit 2 - Mt. Elbert Pumped-storage Powerplant - Fryingpan-Arkansas Project, Colorado

U.S. GPO 1986-773-540

Enclosed is a memorandum report entitled "Unit 2 Suction-draft Tube Replacement Trashrack Vibration Test - Mt. Elbert Pumped-storage Powerplant." This report concludes the field vibration testing performed in December of 1986. The report was prepared by personnel from the Hydraulics Branch of the Division of Research and Laboratory Services and the Mechanical Branch of the Division of Electrical, Mechanical, and Plant Design.

From the test data, it was determined that there was no resonance response of the trashrack over the full range of unit power generation. The highest stresses recorded were due to nonperiodic loading at 80 percent unit load. Fatigue analysis of the measured stresses indicate no fatigue damage to the trashrack should occur prior to the 50-year design life.

The new technology of the replacement trashracks was also used in the design of the trashracks for the pump-generating plant at Waddell Dam. Based on the tests of the replacement trashracks at Mt. Elbert, we are satisfied that the new trashracks for the pump-generating plant at Waddell Dam will have a fatigue life exceeding their 50-year design life.

A E Rickett

Enclosure (01074)

Copy to: Regional Director, Boulder City, Nevada, Attention: LC-200 (01075)
Project Manager, Loveland, Colorado (01076)
Chief, Division of Water and Land Technical Services, E&R Center
(with copy of report to each)

Blind copies to codes on attached sheet.

Blind to: D-215
D-250
D-252 (Todd)
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D-1300
D-1500
D-1530
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D-1531 (PAP file)
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UNIT 2 SUCTION-DRAFT TUBE REPLACEMENT TRASHRACK VIBRATION TEST

MT. ELBERT PUMPED-STORAGE POWERPLANT

By R. V. Todd and B. W. Mefford

## Background

The suction-draft tube trashrack in the left outlet opening of Unit 2 failed after one year in service. The trashrack installation was composed of three separate trashrack sections stacked vertically. These trashracks were of the same design and construction as those for Unit 1 which has been in service for 5 years. No damage has occurred to the trashracks of Unit 1. A trashrack from Unit 1 was instrumented and tested over a generating load range from 60 to 115 percent of full load in 1980 (1). The trashrack was subjected to random vibrations which resulted in three vertical (heave) modes and one fore and aft (plunge) mode being excited. Maximum stresses were found to occur during operation of the unit at 80 percent (80 megawatts) of full load. All stress levels measured were below the fatigue strength limits of the trashrack. The prototype data indicated that the trashracks for Unit 1 would not fail in fatigue. The trashracks for Unit 2 were not tested as the two units are similar in design.

After the trashracks of Unit 2 failed, new stronger trashracks were designed to replace them, figure 1. The three replacement trashracks are 50 percent heavier than the original ones and have the following new features:

1. Five hold-down fittings are located on the top of the upper trashrack and bolted to the concrete headwall. These fittings restrain vertical movement of the trashracks.

2. Nine 12-inch-long hemispherical aluminum bronze bearings are located at the top of the lower and middle trashracks. The bearings allow rotation in the fore and aft directions and give vertical contact continuity between the trashrack sections.

3. A 6-inch x 0.75-inch bar on the bottom of the lower trashrack ensures uniform contact between the concrete sill and the lower trashrack.

4. The transverse bars were notched to provide a recessed joint for the vertical trashbars.

Before the new trashracks were installed, a rudimentary frequency survey was made of one of the trashrack sections at the site. The trashrack was lying horizontal with simple supports under the four corners. A calibrated impact hammer was used to excite the structure. Roving excitation in combination with a fixed location response accelerometer was used for the survey. Three plunge modes were identified at 13.6, 30.4, and 61.6 Hz. These compare with theoretical values from a finite element model of the trashrack section of 12 (0-0), 30 (0-2) and 62 (1-2) Hz. The numbers in parenthesis represent the plunge modal shape, figure 2.

## Operating Load Tests

Measurements of the actual stress under operational loads were obtained by instrumenting the middle trashrack section, figure 3. The trashrack was instrumented with 12 unidirectional strain gauges attached to vertical trashbars and 6 accelerometers attached to the horizontal bars. The trashracks were installed in December 1986.

Simultaneous measurements from the strain gauges, accelerometers and four existing draft tube toe piezometers were recorded on a magnetic tape recorder. Four of the analog signals could also be selected for real-time spectral analysis on FFT (Fast Fourier Transform) analyzers. Data were collected with Unit 2 running, at increments of 10 percent load (10 megawatt steps). The unit setting was held constant at each load for about 15 minutes for data collection and real-time data analysis. Unit 1 was not operating during the testing period. At the beginning of the tests the forebay and afterbay reservoirs were at elevations 9632.97 and 9195.78 feet, respectively. Following the tests the reservoir elevations were: forebay, 9631.27 feet and afterbay, 9195.96 feet.

## Results

The analog data recorded during the operational load tests were analyzed in terms of periodic and nonperiodic vibration. Analysis of the periodic component of the signals was done using FFT spectrum analyzers in an ensemble averaging mode. The accelerometer measurements produced dominant frequencies of 12 and 31 Hz in the plunge direction, figure 4. The only discrete periodic acceleration measured in the heave direction occurred at 10 Hz. The largest amplitude signal was measured at 12 Hz. The maximum acceleration level occurred with a sharp increase in the acceleration activity at 80 percent load. Although other accelerometer signals peaked at 40 percent load, all of the signals sharply increased at 80 percent load.

All periodic stresses measured less than 20 $lb/in^2$ peak. Stresses which correlated to the accelerometer data were measured at 12 and 31 Hz. Additional stress frequencies which were not correlated with accelerometer data were measured at 6, 16, 18 and 22 Hz.

Periodic pressure fluctuations were measured at frequencies of 11 and 34 Hz on the left wall (looking upstream) of the draft tube, figure 5. Peak periodic pressures measured on the center pier and right wall occurred at 6 to 7 Hz, figure 6. Even though the 11 and 34 Hz frequencies are close to natural frequencies of the trashrack there was no resonance response of the trashrack.

## Nonperiodic Stresses

To analyze the impact of the random stress loading of the trashrack, histograms of measured stress versus frequency of occurrence were used. The analog signals recorded on magnetic tape were passed through a 50 Hz analog filter and then digitized at 20 Hz. The signals were sampled for a period of 102.4 seconds, giving a total sample size per channel of 2,048 data points.

Peak stresses measured during the sample period ranged up to 2,500 $lb/in^2$. The maximum nonperiodic stresses measured were about two orders of magnitude higher than the averaged periodic stresses. It was not possible to determine the deflected shape of the trashrack based on the nonperiodic stresses as there was no correlation between the different sets of strain gauges.

## Service Life

A fatigue failure evaluation for the trashrack was made using the measured stress spectrums. The evaluation was made in accordance with standards issued by the ECCS (European Convention for Constructional Steelwork) (2). To predict the service life of the trashrack it was necessary to determine the fatigue critical area of the trashrack. The joint between the vertical bars and the notched transverse bars is the most fatigue critical.

Based on reference 2, there are two types of construction details which apply to the fatigue critical joint:

1. Detail category No. 36 (fillet welded construction) - Root cracking in the weld throat area due to loading in the transverse bar.

(2). Detail category No. 71 (full penetration weld construction) - Toe cracking in the load carrying members.

Because the deflected shape of the trashrack is unknown for the nonperiodic loading, there may be higher stresses at other locations than those measured. Therefore, for a conservative analysis, fatigue limits corresponding to the more critical detail, Category No. 36, were used for analyzing the entire joint. If stress data were available over a larger area of the trashrack, limiting stress values given for detail Category No. 71 would have applied to the vertical bars.

## Fatigue Analysis

Based on ECCS guidelines, no fatigue assessment is required if all nominal stress ranges are less than 26 $N/mm^2$ (3.77 $kip/in^2$) or if all nominal stress ranges are less than the constant amplitude fatigue limit for a given construction detail. The nominal stress range is defined as the algebraic difference between the maximum positive and negative stress levels measured over the sample period. The constant amplitude fatigue limit is defined as the fatigue strength at 5 million cycles.

When the nominal stresses measured during the load tests exceeded the preceding limits the fatigue life of the detail was estimated based on the ECCS fatigue strength equation:

$$N = C\Delta\sigma^{-5}$$

where $N$ = total number of constant amplitude stress cycles

C = constant coefficient based on the detail category

$\Delta\sigma$ = fatigue strength (N/mm$^2$)

The fatigue strength equation defines the experimental mean fatigue life minus two standard deviations of a construction detail.

The time series stress-strain data filtered at 20 Hz was used for fatigue analysis of the trashrack. From the data a nominal stress was calculated for each strain gauge location for every 10 percent increment of load on the unit.

Nominal stresses that exceeded the 26 N/mm$^2$ (3.77 kip/in$^2$) guideline were measured on the trashrack only during the testing at 80 percent load. Of the 12 strain gauges only gauges number 2, 4, 6, 7 and 9 gave stress readings greater than 26 N/mm$^2$ (3.77 kip/in$^2$), figures 7-11. Therefore the fatigue strength analysis of the trashrack was narrowed down to the previously listed strain gauge locations and operation at 80 percent load.

The data signals to be analyzed were passed through a 5-Hz smoothing filter. Histograms of frequency versus peak to peak stress were then developed using the filtered data, tables 1-5. The stress spectrum from each location was further modified in accordance with ECCS guidelines by deleting the stress ranges less than 15 N/mm$^2$ (2.17 kip/in$^2$). The mean of the modified stress spectrum was then used as an estimate of the equivalent constant amplitude stress in the fatigue strength equation. Strain gauge location No. 2 yielded the highest average stress, 19.8 N/mm$^2$ (2.88 kip/in$^2$). From the fatigue strength equation, this stress is equivalent to a 2.3 percent probability of failure after 22 million cycles or 3.3 years of constant operation at 80 percent load. Based on the 1986 operation log of Unit 2, the cumulative time of operation at 80 percent load was 184 hours. From the standpoint of fatigue and assuming a similar time of operation in the future, the service life of the new trashracks is estimated to be in excess of 150 years. The fatigue life far exceeds the 50-year design life normally used for Bureau trashracks.

## Conclusions

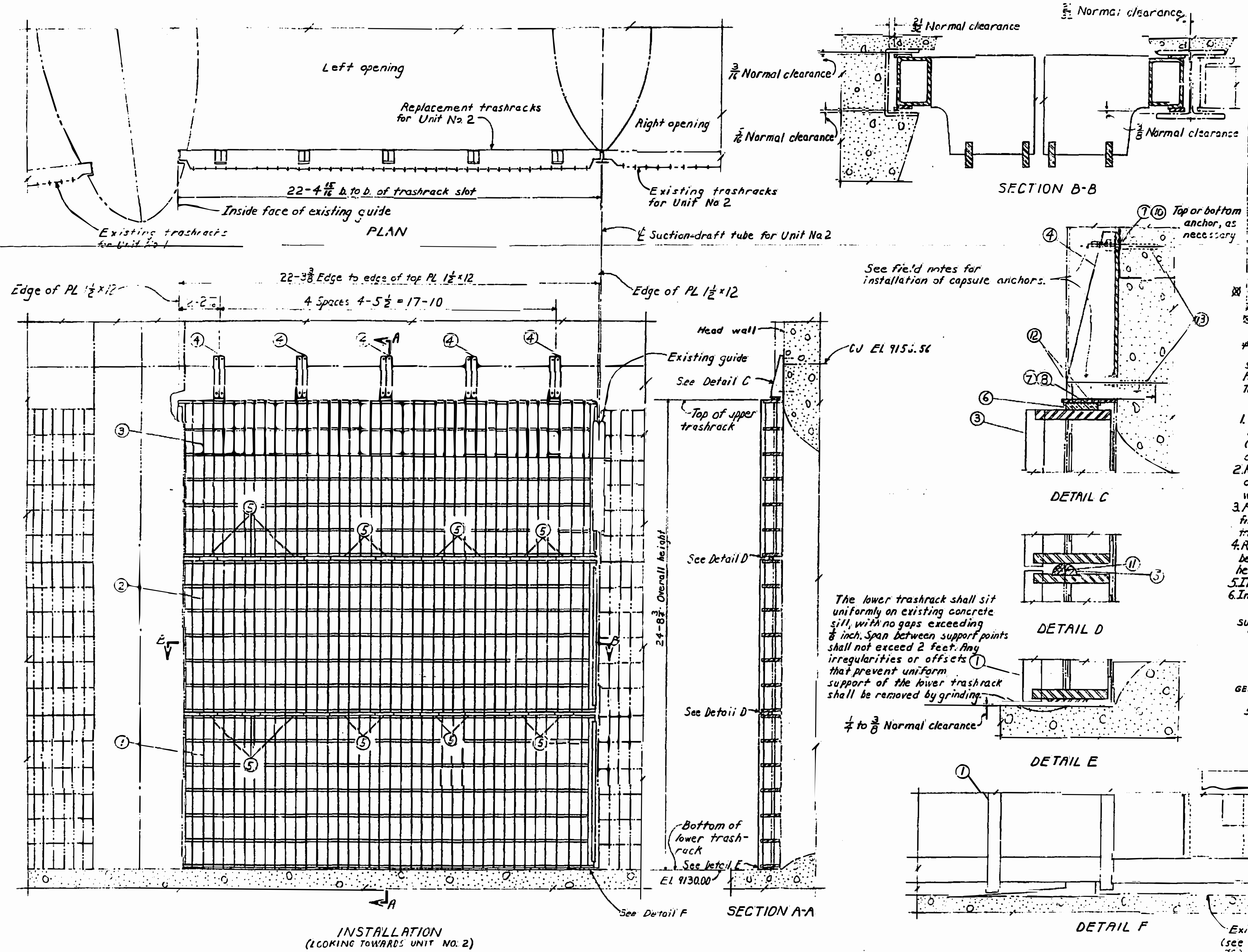
There was no resonance response of the trashracks over the full range of unit power generation. The highest stresses recorded were due to nonperiodic loading at 80 percent unit load. Fatigue analysis of the measured stresses indicate no fatigue damage to the trashrack should occur prior to the 50-year design life.

Prior to the operational load test, periodic loading resulting in a resonance response of the trashrack was assumed to be the probable fatigue failure mechanism. The operational load test was designed to provide prototype data for use in conjunction with a finite element modal analysis model of the trashrack section. The small number and location of transducers on the trashrack were setup to give the deflected shape and complete stress description of the trashrack for the periodic loading condition. Stresses resulting from random loading cannot be mapped over the trashrack using the modal shape assumption. Future testing of draft-tube trashracks subjected to generating loads should be formulated to determine both periodic and nonperiodic responses of the trashrack.

## References

1. Todd, R. V., B. W. Mefford, T. J. Isbester, "Mt. Elbert Trashrack Vibration Studies," ASCE Hydraulics Division Conference, Applying Research to Hydraulics Practice, Jackson, Mississippi, 1982.

2. European Convention for Constructional Steelwork, "Recommendations For the Fatigue Design of Steel Structures", First Edition, 1985.




LIST OF PARTS FOR THREE REPLACEMENT TRASHRACKS

| PART NO. | DRAWING NUMBER | NO. REQ'D | DESCRIPTION | MATERIAL* | EST. WT. POUNDS |
|---|---|---|---|---|---|
| 1 | 382-D-4739 | 1 | Lower trashrack | Structural steel | [illegible] |
| 2 | " | 1 | Middle trashrack | | 2,100 |
| 3 | 382-D-4740 | 1 | Upper trashrack | | 2,152 |
| 4 | " | 5 | Hold-down fitting | | [illegible] |
| 5 | " | 13 | Semicylindrical bearing | [illegible] bronze | 365 |
| 6 | " | 5 | Flat bearing | | 50 |
| 7 | " | 10 | Shim - 16 Gage | | 5 |
| 8 | " | 10 | Shim - 22 Gage | | 3 |
| 9 | No Detail | 10 | Circular shim - [illegible] × 7/8 ID × 1/16 Thk. | | 1 |
| 10 | " | 10 | Circular shim - [illegible] OD × 7/8 ID × 1/32 Thk. | Stainless steel [illegible] | 0.57 |
| 11 | " | 54 | 1/2-13UNC-3A × 1 5/8 Hex. socket head cap screw | | 1 |
| 12 | " | 20+5 | 3/8-16UNC-2A × 1 1/8 Hex head cap screw | | 0.38 |
| ⊠ 13 | " | 20 | 3/4 Dia × 10 1/4 Capsule anchor# with locking nut. | Stainless Steel AISI 30- | 26 |

*See detail of part for material specification.
⊠At installation, coat threads of nuts only with a suitable grease or anti-seize compound, see notes on -4740.
#The capsule anchor shall be Molly Parabond Capsule Anchor, capsule No. M20-34 with stud-nut-washer assembly SS3410-M20, as manufactured Emhart, Molly Division Headquarters, 504 Mt. Laurel Ave., Temple, PA 19560; or equal.
Total estimated weight for three replacement trashracks ........ 37,393 lbs.

FIELD NOTES

1. Position hold-down fitting and flat bearing assembly, parts 4, 6, and 12 on upper trashrack 3 at location shown on Installation View. Drill holes 6 1/2 inches deep (minimum) for capsule anchors, in accordance with the manufacturer's instructions, in the concrete head wall using the hold-down fitting as a location template.
2. Remove all dust and particles from holes in concrete. Install 3/4 inch diameter capsule anchors 13 and allow the capsule epoxy to cure, all in accordance with the manufacturer's instructions.
3. Place shims, 9 and 10, where necessary to ensure firm support of hold-down fitting 4 with concrete, with flat bearing 6 in uniform contact with top of upper trashrack 3.
4. Remove hex. head cap screws 12. Insert shims 7 and 8 as necessary to obtain bearing contact between hold-down fitting 4 and capsule anchor bolt 13. Replace hex. head cap screws 12, and center punch to prevent loosening.
5. Install washers and tighten capsule anchor nuts to 80 foot-pounds of torque.
6. Install locking nuts.

LIST OF DRAWINGS

SUCTION-DRAFT TUBE
LEFT OPENING OF UNIT NO. 2
REPLACEMENT TRASHRACKS
INSTALLATION-LIST OF PARTS ........ 382-D-4738
LOWER AND MIDDLE TRASHRACKS-DETAILS ........ 382-D-4739
UPPER TRASHRACK-FITTING-BEARINGS-ASSEMBLIES ........ 382-D-4740

REFERENCE DRAWINGS

GENERAL ARRANGEMENT
TRANSVERSE SECTION THRU ℄ UNIT NO. 1 ........ 382-D-975
SERVICE DECK EL. 9212.5 ........ 382-D-978
SUCTION-DRAFT TUBE-
TRASHRACK GUIDES ........ 382-D-1210

ALWAYS THINK SAFETY

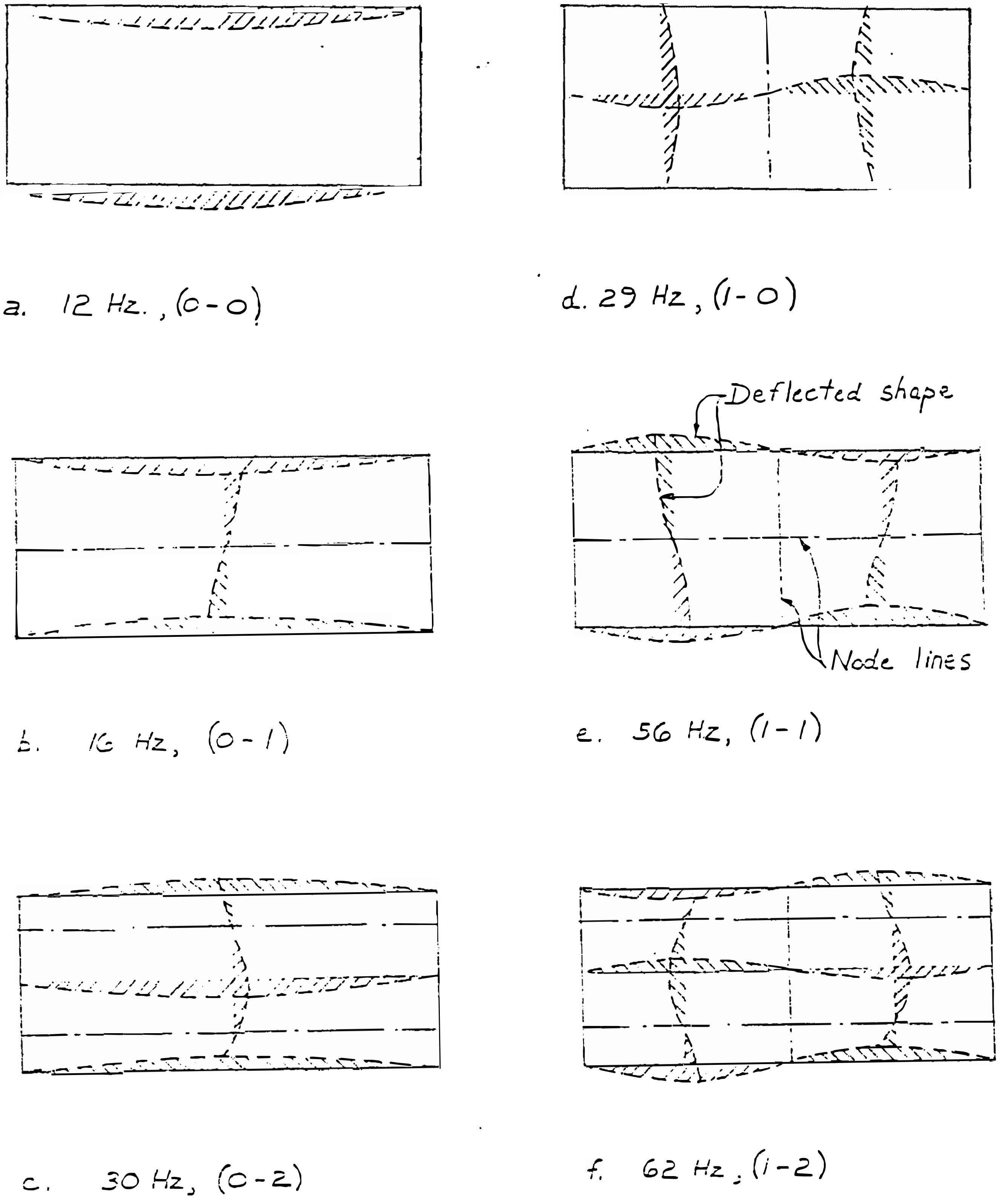
UNITED STATES
DEPARTMENT OF THE INTERIOR
BUREAU OF RECLAMATION
FRYINGPAN-ARKANSAS PROJECT-COLORADO
EAST SLOPE POWER SYSTEM
MT. ELBERT PUMPED-STORAGE POWER PLANT
SUCTION-DRAFT TUBE
LEFT OPENING OF UNIT No. 2
REPLACEMENT TRASHRACKS
INSTALLATION-LIST OF PARTS

DESIGNED K.I. [illegible] TECHNICAL APPROVAL [illegible]
DRAWN J.P. Martinez SUBMITTED J.C. Wadge

DENVER, COLORADO APR. 25, 1986 SHEET 1 OF 1 382-D-4738

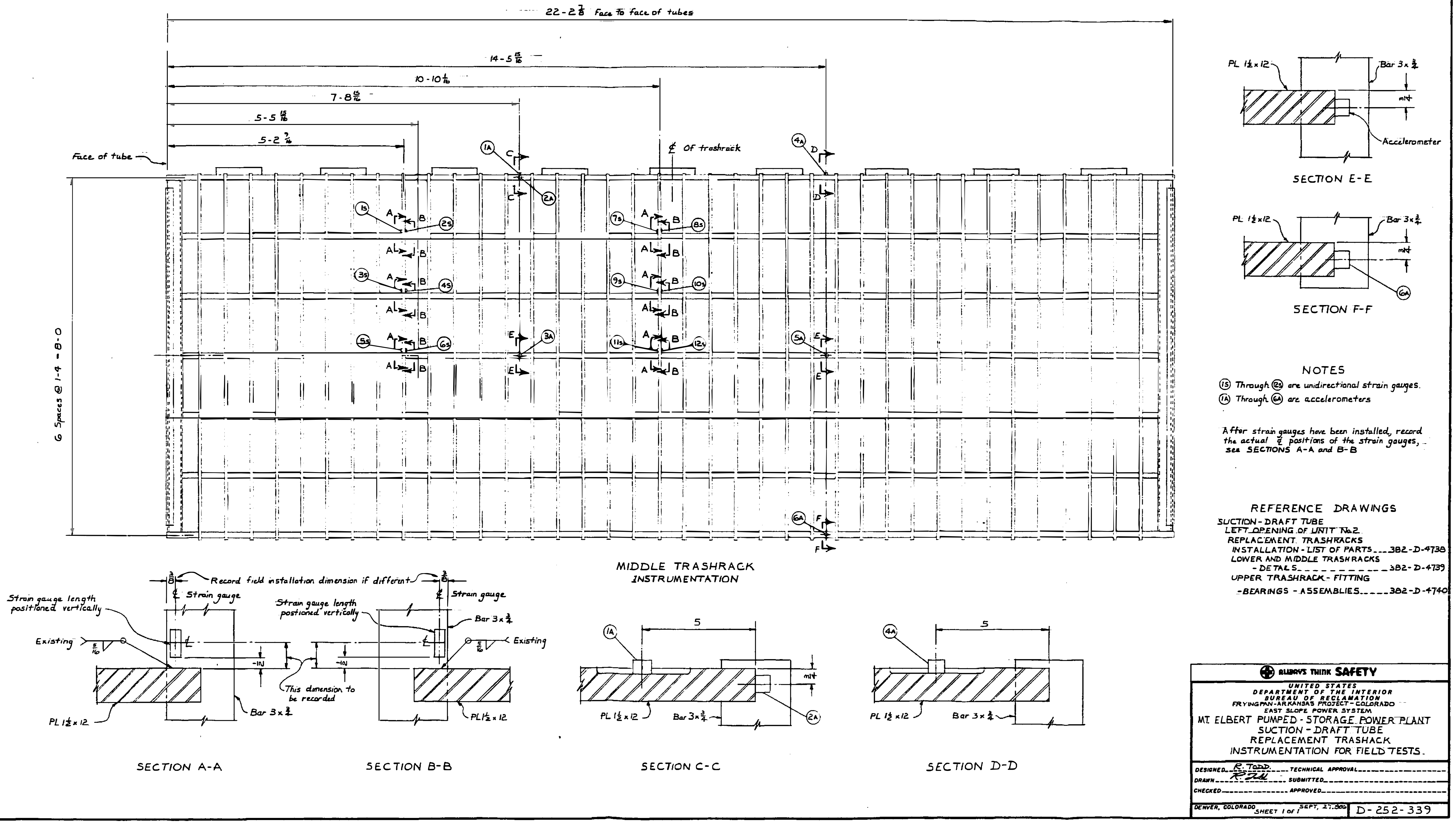
Figure 1

K




Numbers in parenthesis represent plunge modal shape

Figure 2. - Theoretical frequencies for plunge modes.



22-2 7/8 Face to face of tubes
14-5 15/16
10-10 1/16
7-8 15/16
5-5 15/16
5-2 9/16
Face of tube
℄ Of trashrack
6 Spaces @ 1-4 = 8-0
MIDDLE TRASHRACK INSTRUMENTATION
SECTION E-E
PL 1½ x 12
Bar 3 x ¾
Accelerometer
SECTION F-F
NOTES
(1S) Through (12S) are unidirectional strain gauges.
(1A) Through (6A) are accelerometers
After strain gauges have been installed, record the actual ℄ positions of the strain gauges, see SECTIONS A-A and B-B
REFERENCE DRAWINGS
SUCTION-DRAFT TUBE
LEFT OPENING OF UNIT No.2
REPLACEMENT TRASHRACKS
INSTALLATION - LIST OF PARTS ___ 382-D-4738
LOWER AND MIDDLE TRASHRACKS - DETAILS ___ 382-D-4739
UPPER TRASHRACK - FITTING - BEARINGS - ASSEMBLIES ___ 382-D-4740
Record field installation dimension if different
℄ Strain gauge
Strain gauge length positioned vertically
Existing
This dimension to be recorded
SECTION A-A
SECTION B-B
SECTION C-C
SECTION D-D
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FRYINGPAN-ARKANSAS PROJECT - COLORADO
EAST SLOPE POWER SYSTEM
MT. ELBERT PUMPED-STORAGE POWER PLANT
SUCTION - DRAFT TUBE
REPLACEMENT TRASHACK
INSTRUMENTATION FOR FIELD TESTS.
DESIGNED R. TODD
DRAWN
CHECKED
TECHNICAL APPROVAL
SUBMITTED
APPROVED
DENVER, COLORADO SEPT. 27, 1983 SHEET 1 of 1
D-252-339


Figure 3.

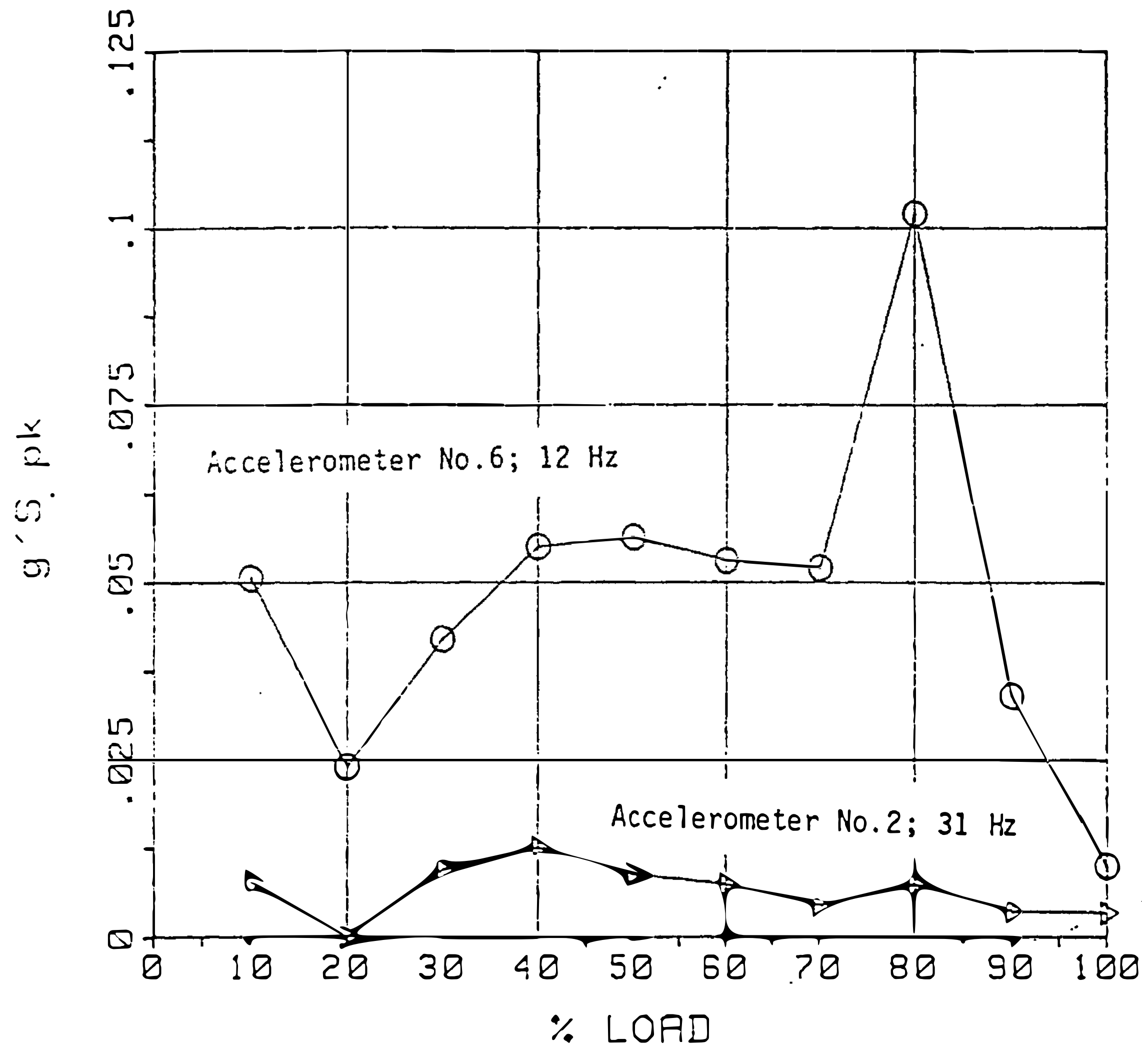


Figure 4. - Dominant periodic accelerations in the plunge mode.

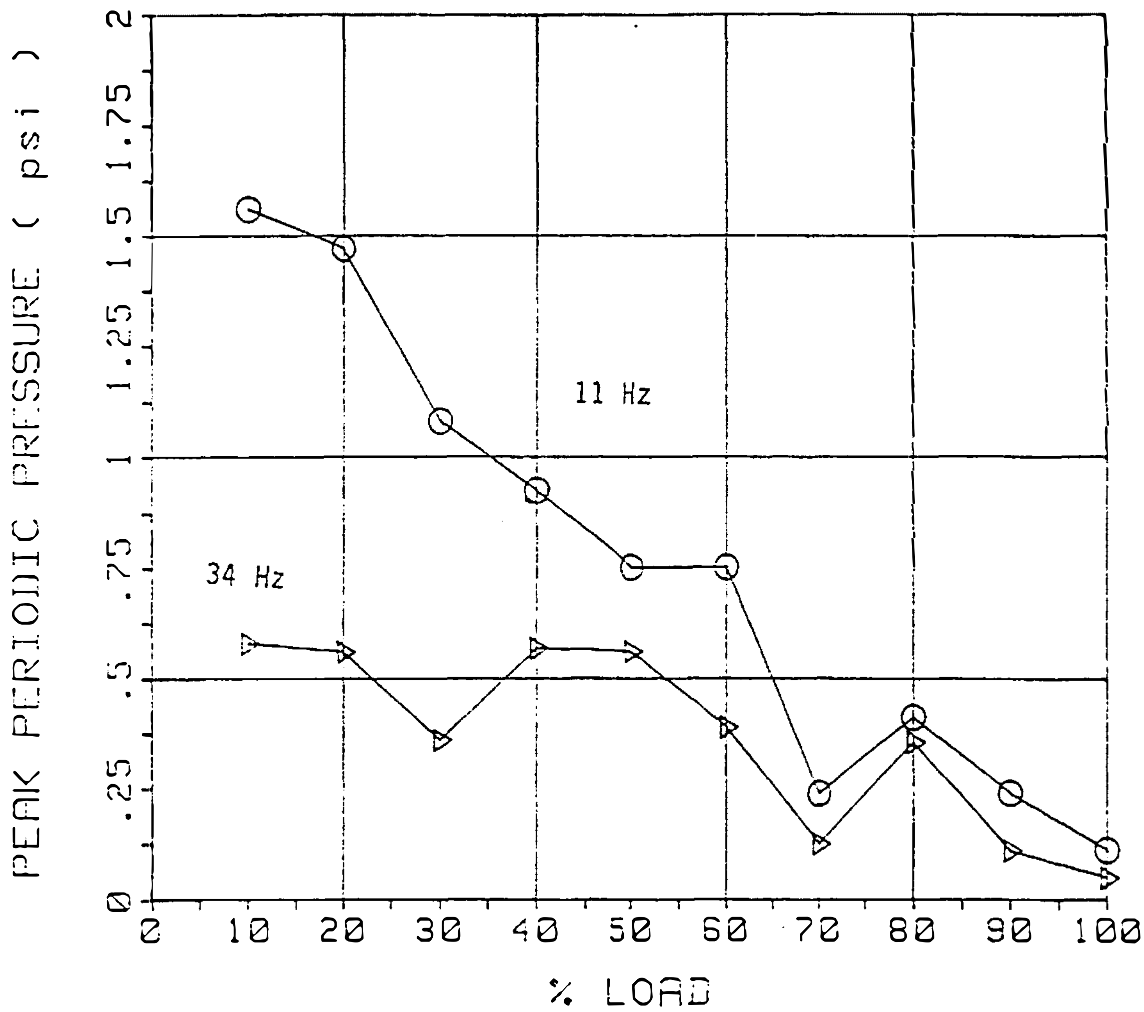


Figure 5. - Dominant periodic pressure fluctuations on the left wall of the draft tube toe.

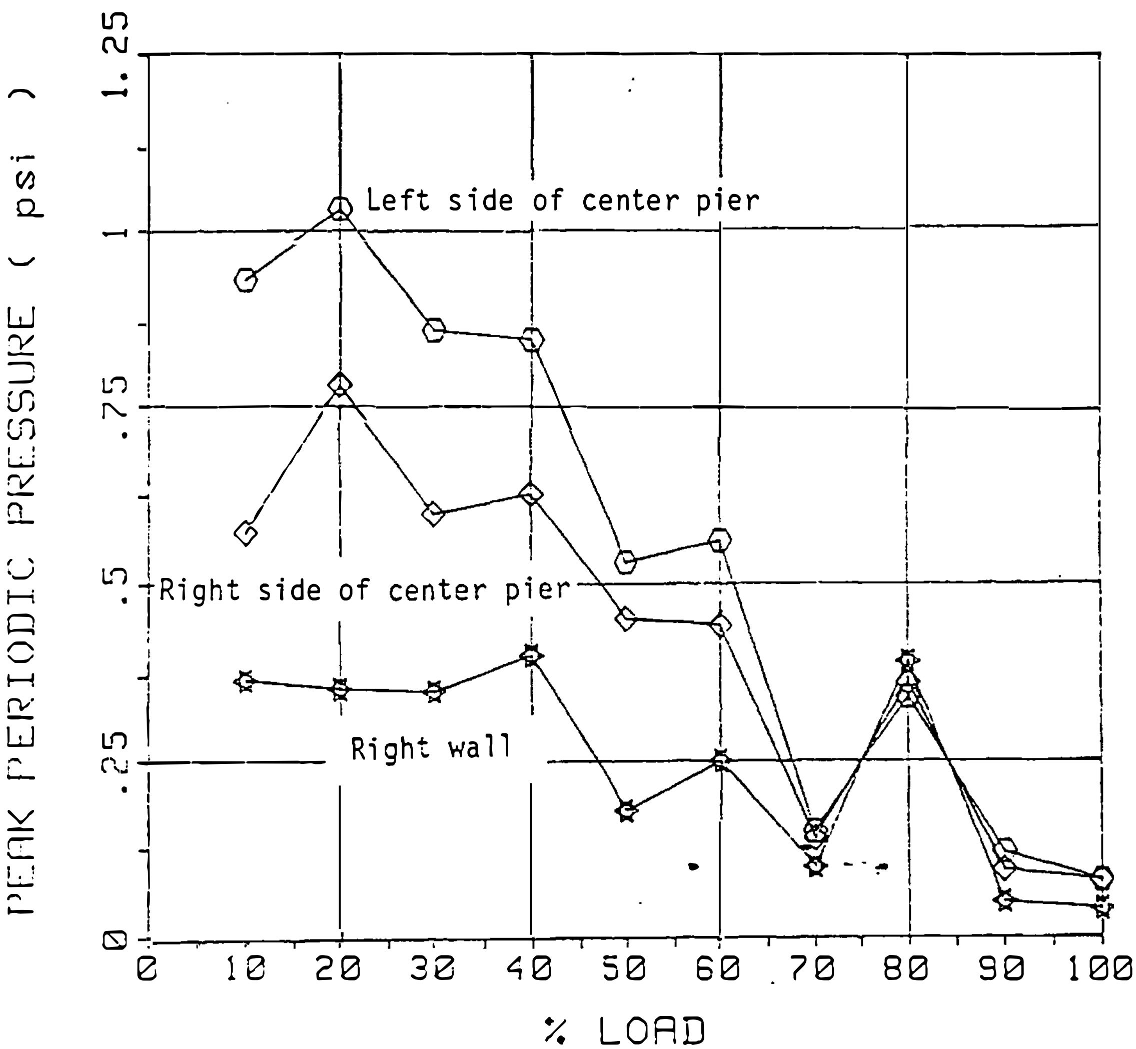


Figure 6. - Periodic pressure fluctuations measured between 6 and 7 Hz on the draft tube center pier and right wall.

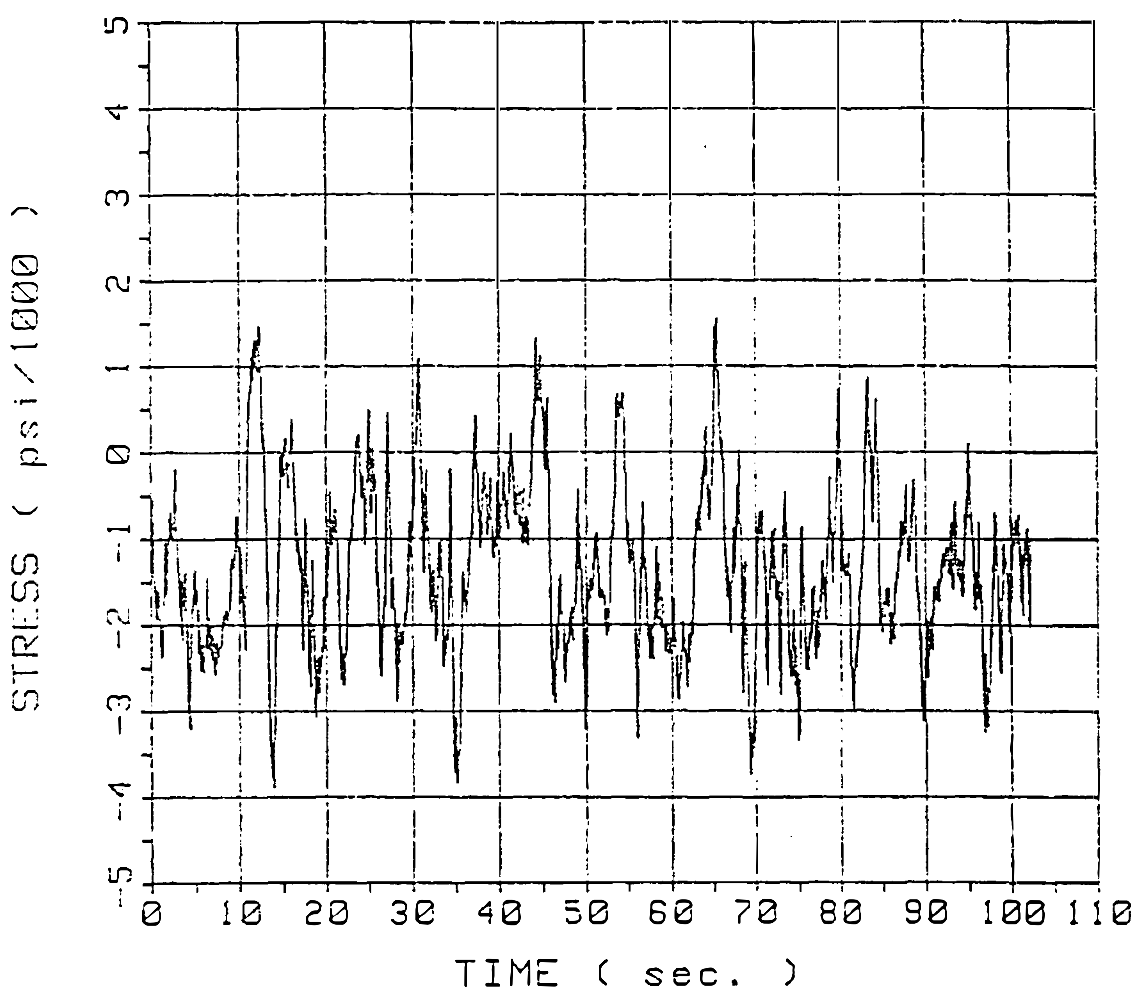


Figure 7. - Sampled time series at 80 percent load for strain gauge No. 2.

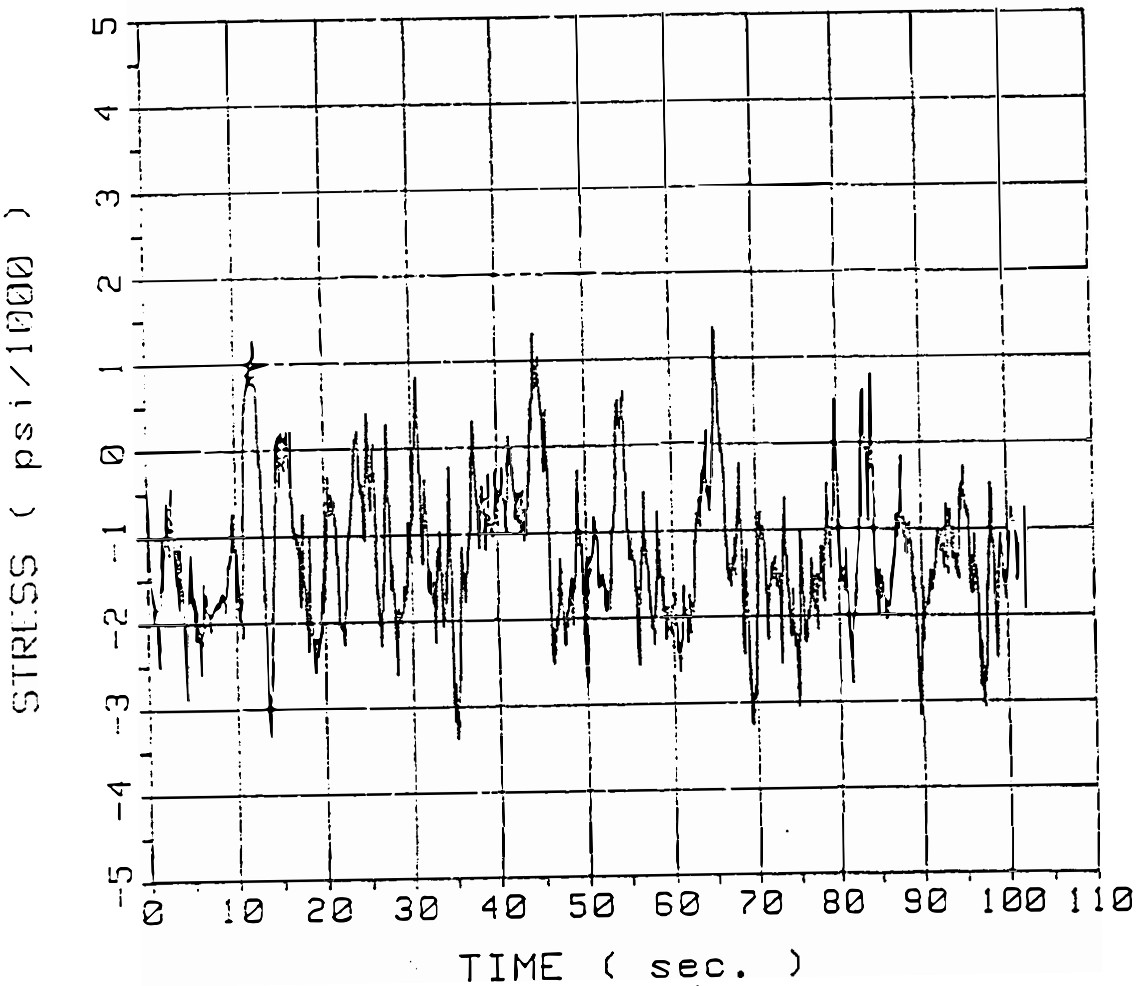


Figure 8. - Sampled time series at 80 percent load for strain gauge No. 4.

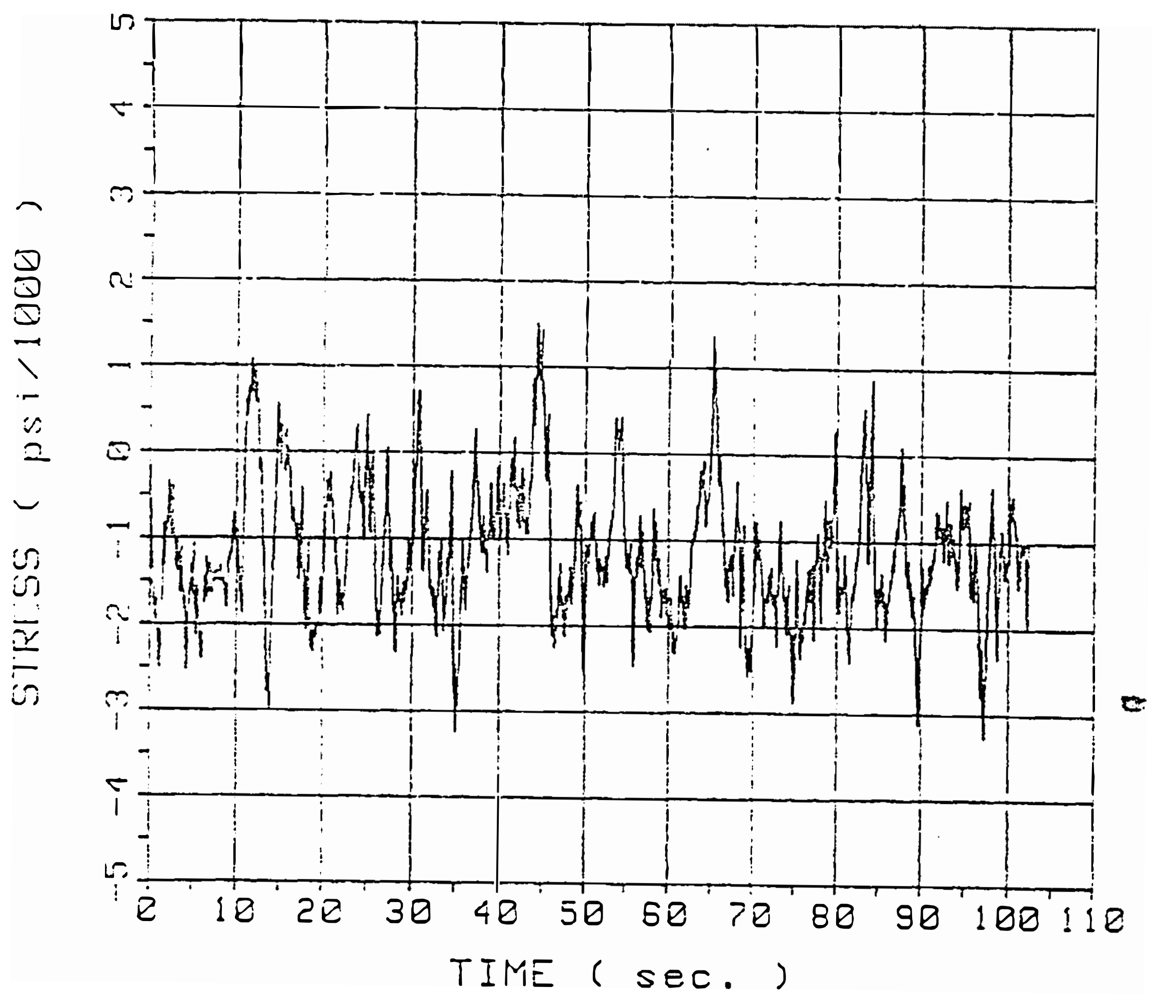


Figure 9. - Sampled time series at 80 percent load for strain gauge No. 6.

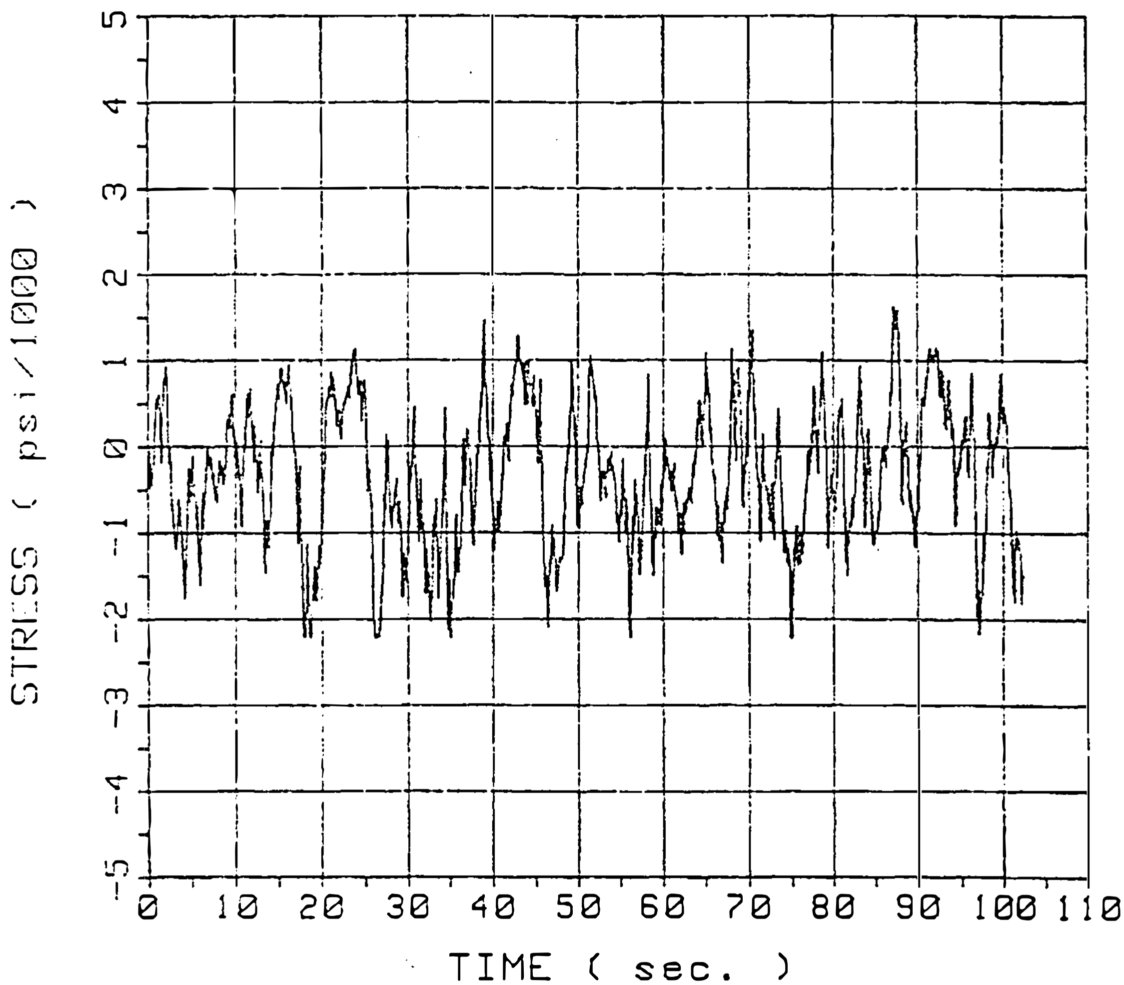


Figure 10. - Sampled time series at 80 percent load for strain gauge No. 7.

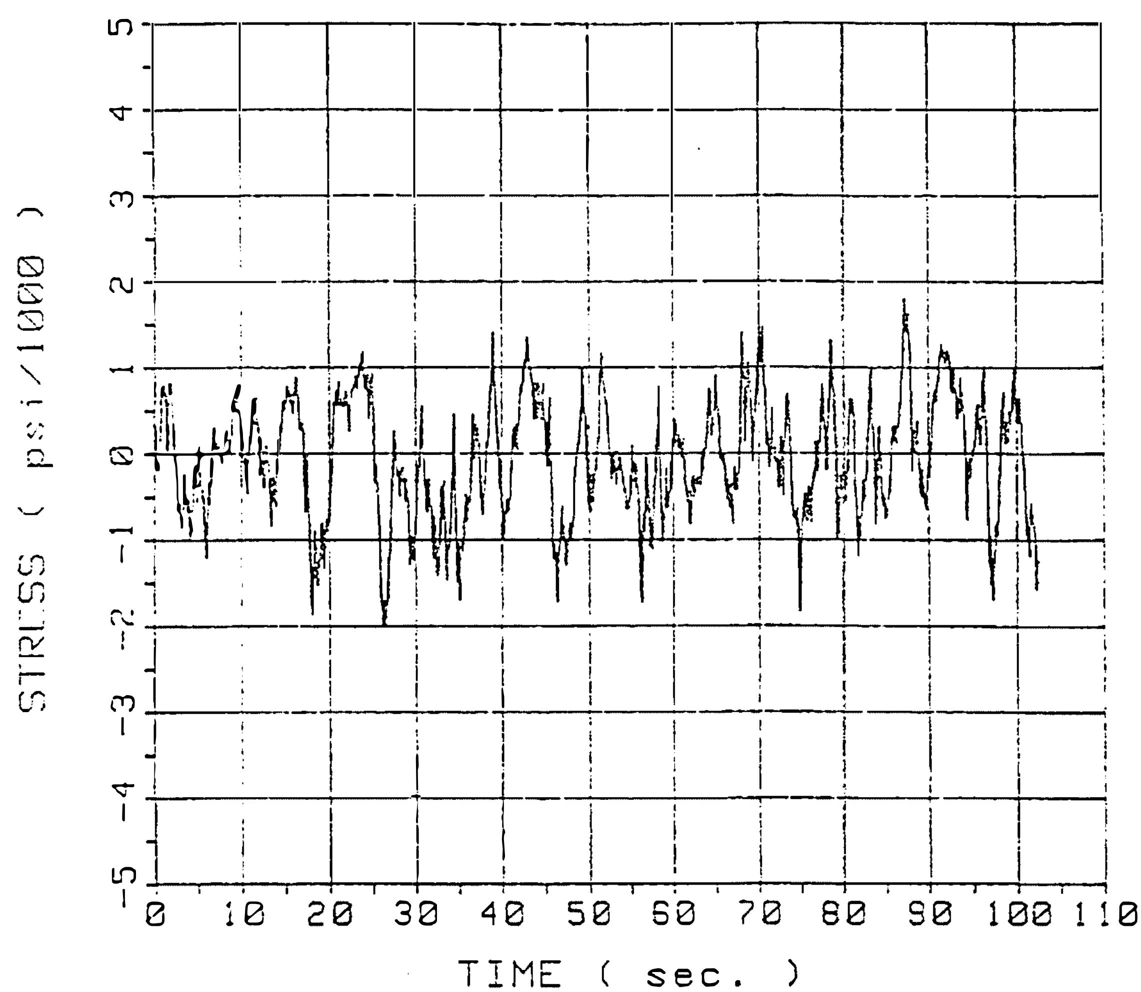


Figure 11. - Sampled time series at 80 percent load for strain gauge No. 9.

************************* HISTOGRAM TABLE *************************

| CELL WIDTH STRESS psi/1000 | | COUNTS pk-pk | PERCENT OF TOTAL | CUMULATIVE PERCENT |
|---|---|---|---|---|
| 0.00 | .35 | 26 | 15.20 | 15.20 |
| .35 | .70 | 35 | 20.47 | 35.67 |
| .70 | 1.06 | 35 | 20.47 | 56.14 |
| 1.06 | 1.41 | 20 | 11.70 | 67.84 |
| 1.41 | 1.76 | 14 | 8.19 | 76.02 |
| 1.76 | 2.11 | 18 | 10.53 | 86.55 |
| 2.11 | 2.46 | 7 | 4.09 | 90.64 |
| 2.46 | 2.82 | 6 | 3.51 | 94.15 |
| 2.82 | 3.17 | 3 | 1.75 | 95.91 |
| 3.17 | 3.52 | 4 | 2.34 | 98.25 |
| 3.52 | 3.87 | 2 | 1.17 | 99.42 |
| 3.87 | 4.22 | 0 | 0.00 | 99.42 |
| 4.22 | 4.58 | 0 | 0.00 | 99.42 |
| 4.58 | 4.93 | 0 | 0.00 | 99.42 |

Table 1. - Peak to peak stress histogram with 5 Hz smoothing, strain gauge No.2.

************************ HISTOGRAM TABLE ************************

| CELL WIDTH STRESS psi/1000 | | COUNTS pk-pk | PERCENT OF TOTAL | CUMULATIVE PERCENT |
|---|---|---|---|---|
| 0.00 | .30 | 25 | 14.45 | 14.45 |
| .30 | .60 | 39 | 22.54 | 36.99 |
| .60 | .90 | 28 | 16.18 | 53.18 |
| .90 | 1.20 | 26 | 15.03 | 68.21 |
| 1.20 | 1.50 | 16 | 9.25 | 77.46 |
| 1.50 | 1.80 | 11 | 6.36 | 83.82 |
| 1.80 | 2.11 | 11 | 6.36 | 90.17 |
| 2.11 | 2.41 | 7 | 4.05 | 94.22 |
| 2.41 | 2.71 | 3 | 1.73 | 95.95 |
| 2.71 | 3.01 | 3 | 1.73 | 97.69 |
| 3.01 | 3.31 | 3 | 1.73 | 99.42 |
| 3.31 | 3.61 | 0 | 0.00 | 99.42 |
| 3.61 | 3.91 | 0 | 0.00 | 99.42 |
| 3.91 | 4.21 | 0 | 0.00 | 99.42 |

Table 2. - Peak to peak stress histogram with 5 Hz smoothing, strain gauge No.4.

********************** HISTOGRAM TABLE **********************

| CELL WIDTH STRESS psi/1000 | | COUNTS pk-pk | PERCENT OF TOTAL | CUMULATIVE PERCENT |
|---|---|---|---|---|
| 0.00 | .25 | 28 | 15.30 | 15.30 |
| .25 | .50 | 44 | 24.04 | 39.34 |
| .50 | .76 | 25 | 13.66 | 53.01 |
| .76 | 1.01 | 28 | 15.30 | 68.31 |
| 1.01 | 1.26 | 14 | 7.65 | 75.96 |
| 1.26 | 1.51 | 8 | 4.37 | 80.33 |
| 1.51 | 1.76 | 8 | 4.37 | 84.70 |
| 1.76 | 2.02 | 13 | 7.10 | 91.80 |
| 2.02 | 2.27 | 6 | 3.28 | 95.08 |
| 2.27 | 2.52 | 1 | .55 | 95.63 |
| 2.52 | 2.77 | 4 | 2.19 | 97.81 |
| 2.77 | 3.02 | 2 | 1.09 | 98.91 |
| 3.02 | 3.28 | 1 | .55 | 99.45 |
| 3.28 | 3.53 | 0 | 0.00 | 99.45 |

Table 3. - Peak to peak stress histogram with 5 Hz smoothing, strain gauge No.6.

**************************** HISTOGRAM TABLE ****************************

| CELL WIDTH STRESS psi/1000 | | COUNTS pk-pk | PERCENT OF TOTAL | CUMULATIVE PERCENT |
|---|---|---|---|---|
| 0.00 | .21 | 12 | 7.45 | 7.45 |
| .21 | .42 | 31 | 19.25 | 26.71 |
| .42 | .63 | 22 | 13.66 | 40.37 |
| .63 | .83 | 15 | 9.32 | 49.69 |
| .83 | 1.04 | 14 | 8.70 | 58.39 |
| 1.04 | 1.25 | 14 | 8.70 | 67.08 |
| 1.25 | 1.46 | 13 | 8.07 | 75.16 |
| 1.46 | 1.67 | 8 | 4.97 | 80.12 |
| 1.67 | 1.88 | 9 | 5.59 | 85.71 |
| 1.88 | 2.08 | 6 | 3.73 | 89.44 |
| 2.08 | 2.29 | 10 | 6.21 | 95.65 |
| 2.29 | 2.50 | 4 | 2.48 | 98.14 |
| 2.50 | 2.71 | 1 | .62 | 98.76 |
| 2.71 | 2.92 | 1 | .62 | 99.38 |

Table 4. - Peak to peak stress histogram with 5 Hz smoothing, strain gauge No.7.

************************ HISTOGRAM TABLE ************************

| CELL WIDTH STRESS psi/1000 | | COUNTS pk-pk | PERCENT OF TOTAL | CUMULATIVE PERCENT |
|---|---|---|---|---|
| 0.00 | .20 | 13 | 7.98 | 7.98 |
| .20 | .39 | 41 | 25.15 | 33.13 |
| .39 | .59 | 24 | 14.72 | 47.85 |
| .59 | .79 | 12 | 7.36 | 55.21 |
| .79 | .99 | 18 | 11.04 | 66.26 |
| .99 | 1.18 | 11 | 6.75 | 73.01 |
| 1.18 | 1.38 | 10 | 6.13 | 79.14 |
| 1.38 | 1.58 | 12 | 7.36 | 86.50 |
| 1.58 | 1.77 | 6 | 3.68 | 90.18 |
| 1.77 | 1.97 | 5 | 3.07 | 93.25 |
| 1.97 | 2.17 | 6 | 3.68 | 96.93 |
| 2.17 | 2.37 | 3 | 1.84 | 98.77 |
| 2.37 | 2.56 | 1 | .61 | 99.39 |
| 2.56 | 2.76 | 0 | 0.00 | 99.39 |

Table 5. - Peak to peak stress histrogram with 5 Hz smoothing, strain gauge No.9.