Research Report

EVERGREEN POINT BRIDGE
MAINTENANCE PROBLEMS

ANNUAL REPORT

AUGUST 1975

Public Transportation and Planning Division

Washington State
Department of Transportation

WA-RD-44.2

In cooperation with
U.S. Department of Transportation
Federal Highway Administration

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16. Abstract

This report completely describes the instrumentation on the drawspan of the Evergreen Point Bridge. The design and construction of the data recording system, with the complete calibration of the measurement and collection system is given. Initial data collection and preliminary analysis is set out. The analysis was subsequently abandoned, the data was retained.

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EVERGREEN POINT BRIDGE MAINTENANCE PROBLEMS

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PROGRESS REPORT
(First Annual Report)

Research Project Y-1640
Phase I

Prepared for
Washington State Highway Commission
Department of Highways
In cooperation with
U.S. Department of Transportation
Federal Highway Administration

August 1975

CONTENTS

LIST OF FIGURES

* on deposit with the Washington State Highway Department

INTRODUCTION

The work reported comprises the first year of a study to examine the performance of the drawspan of the Evergreen Point Bridge across Lake Washington during storms. These storms predominate from the south to south west direction where a fetch of 4 miles results in wave battering. Fig. 1 shows the general location of the bridge. The region of interest is the 7518' of floating structure and particularly 200' drawspan arrangement near mid-lake. Fig. 2 provides an impression of the drawspan. The operation requires raising of the two 105' steel grid deck and longitudinal movement of the drawspans into the vacated space. The performance of the drawspan mechanism - particularly the trunnion devices - was the concern of this project. The study involves:

a) the instrumentation of the bridge
b) the accumulation and analysis of data
c) predictions of extremes
d) design of a fatigue experiment

The work completed between August 1974 and 1975 is reported here. A final report at the completion of the project will synthesize the whole undertaking; thus, the present report is a catalogue of progress to date without too much interpretation.

The instrumentation was designed and put together by Mr. Derald Christensen. He was also responsible for that data accumulated and analyzed. Mr. R. Vasu worked on stage (d), the fatigue experiment design. To the extent that extreme predictions have been undertaken, they have been worked on by both Christensen and Vasu. Mr. H. Smith helped with the instrument-

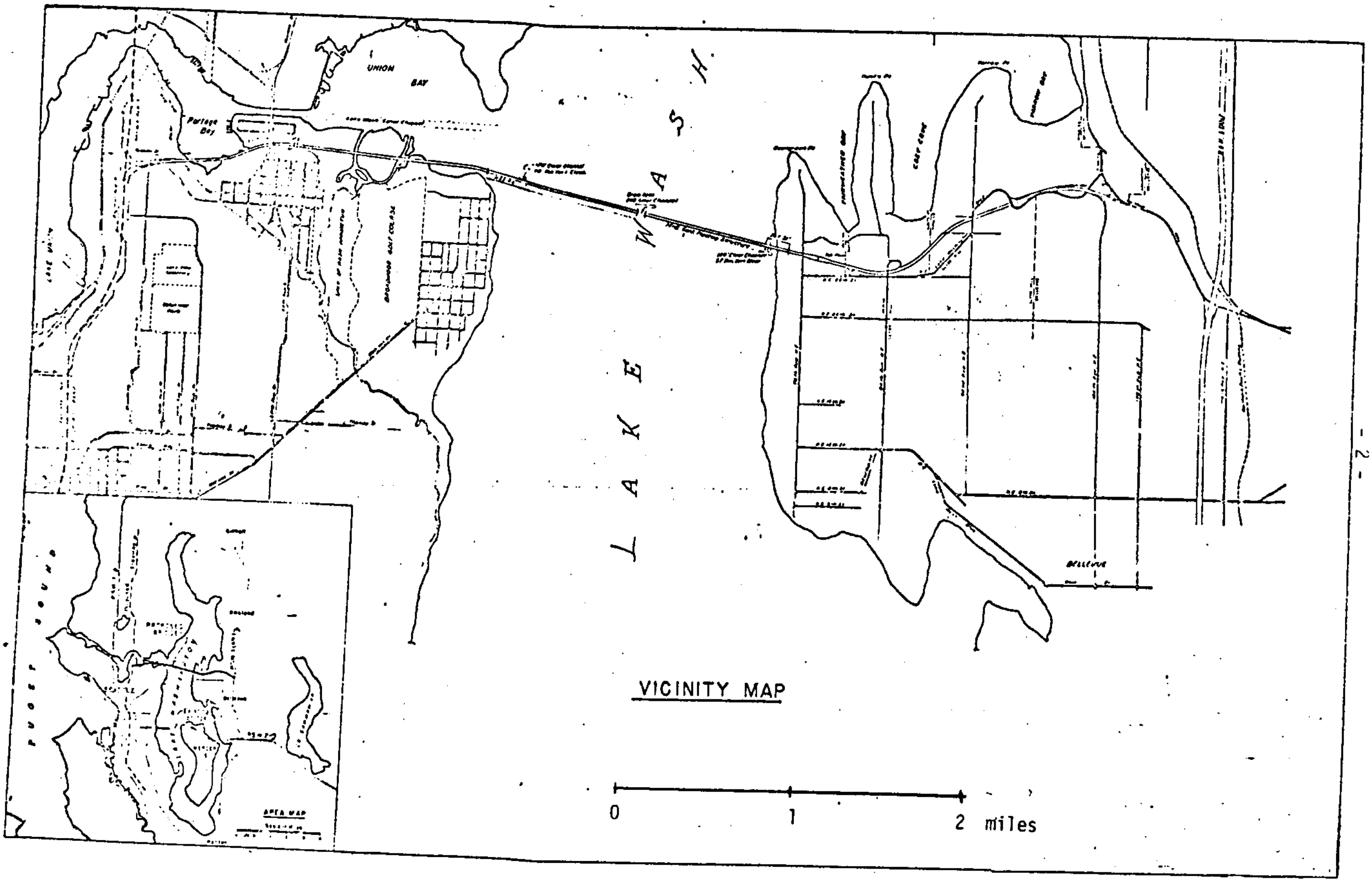


FIG. 1 BRIDGE LOCATION

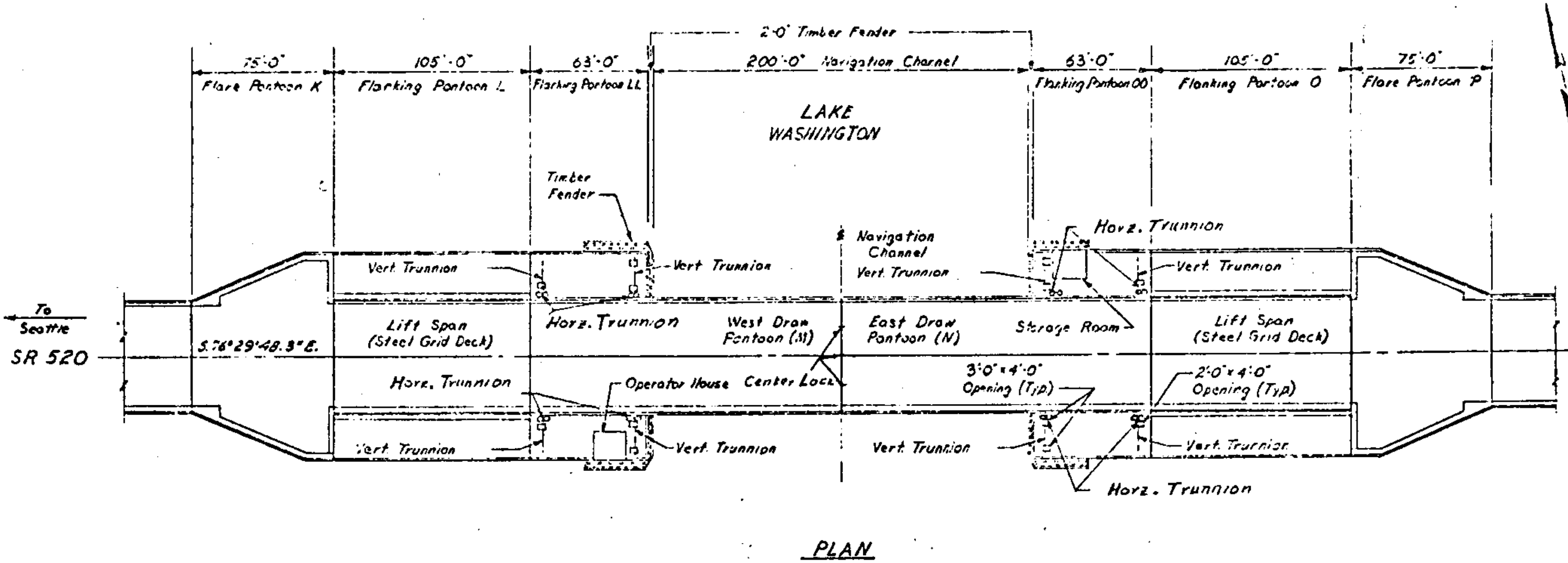


FIG. 2 DRAWSPAN FEATURES

ation and the determination of the relevant properties of the pontoon reaction cables. Crucial to the success of the project to date has been the co-operation provided by the Washington State Highway Department. The liason with the Highway Department and the contractors working on replacing parts of the drawspan mechanism was essential for the successful completion of the instrumentation. Mr. Gary F. Demich of the Highway Department provided that liason and was also active in the actual instrumentation.

INSTRUMENTATION

The object of the instrumentation was two fold. First, to obtain signals of the natural phenomena associated with battering of the bridge. For a start the wind velocity (direction and speed) was considered important information as this could be correlated with past recordings at the bridge. Additionally, wave force measurements would be valuable. These would possibly allow analytical relations with the wind to be developed, or, if these are not possible, statistical correlations between wave force and wind which would then result in extreme force predictions.

The second object was to determine the strains in crucial portions of the drawspan mechanism which had previously shown distress. An intention of this work is that such strain measurements will be compared with wind measurements and hence extremes of strain established. The moving parts of the drawspan are essentially guiding trunnions - both vertical and horizontal. Previous troubles and failures had occurred in the plates of the horizontal trunnions and the anchorage bolts of the vertical trunnions. Also, the center locking devices between the two arms of the drawspan as well as the end lock had been distressed. These parts had been replaced and changed in geometry and arrangement from the original installation. In fact, whilst the instrumentation was being carried out, new installations of these and other parts were being made. Fig. 2 identifies the location of these troubled parts.

Appendix A deals in detail with the steps taken in arriving at the instrumentation package for recording the two types of data required. The recorder system designed has 44 channels of 8-bits each together with a 12-bit clock channel. These 44 channels were used as follows:

2	-	wind speed and direction
2	-	wave pressure transducers
4	-	anchor cable
18	-	horizontal trunnions
12	-	vertical trunnion anchorage rods
3	-	center locks
1	-	end lock
2	-	support beams of vertical trunnions

The first eight of these channels are recording input data of wind velocity and wave force. The wave transducers produce a direct force measurement whereas the anchor cable displacements are intended to provide an indirect measurement of wave forces. The remaining channels are for the measurement of strains in the drawspan mechanism. Attention has been fixed on the parts which have previously caused trouble but the support beam of vertical trunnions has also been instrumented. Fig. 3 shows the layout of this channel arrangement on the bridge. The following table provides a key to Fig. 3.

The anemometer employed to measure wind velocity (W1, W2) was manufactured by Weather Measure Corp. model W121-5D. It reads over the range

Channel Number	Mark	Measurement
1	W1	Wind Speed
2	W2	Wind direction
3	1HL1	Horizontal trunnion strains
4	1HT1	
5	2HL1	
6	2HT1	
7	3HL1	
8	3HT1	
9	3HL2	
10	3HT2	
11	3HRL1	
12	3HRL2	
13	3HRL3	
14	3HRT1	
15	3HRT2	
16	3HRT3	
17	4HL1	
18	4HT1	
19	4HL2	
20	4HT2	
21	1V1	Vertical trunnion tension rod strains
22	1V2	
23	2V1	
24	2V2	
25	3V1	
26	3V2	
27	3V3	
28	3V4	
29	4V1	
30	4V2	
31	4V3	
32	4V4	
33	C1	Center lock strains
34	C2	
35	C3	
36	L1	End lock strains
37	S1	Vertical trunnion support beam strains
38	S2	
39	P1	Wave pressure transducers
40	P2	
41	A1	Anchor cable displacements
42	A2	
43	A3	
44	A4	

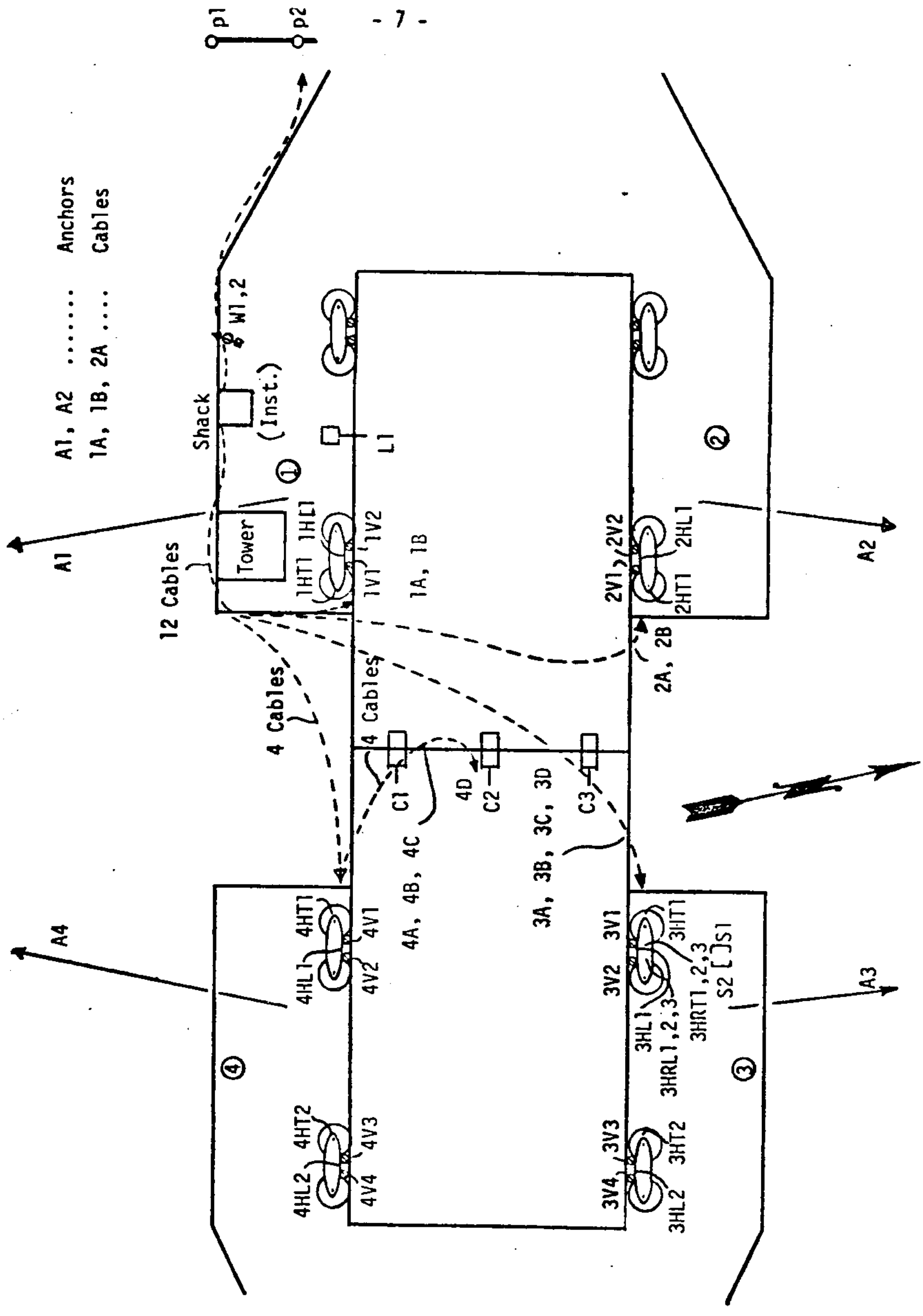
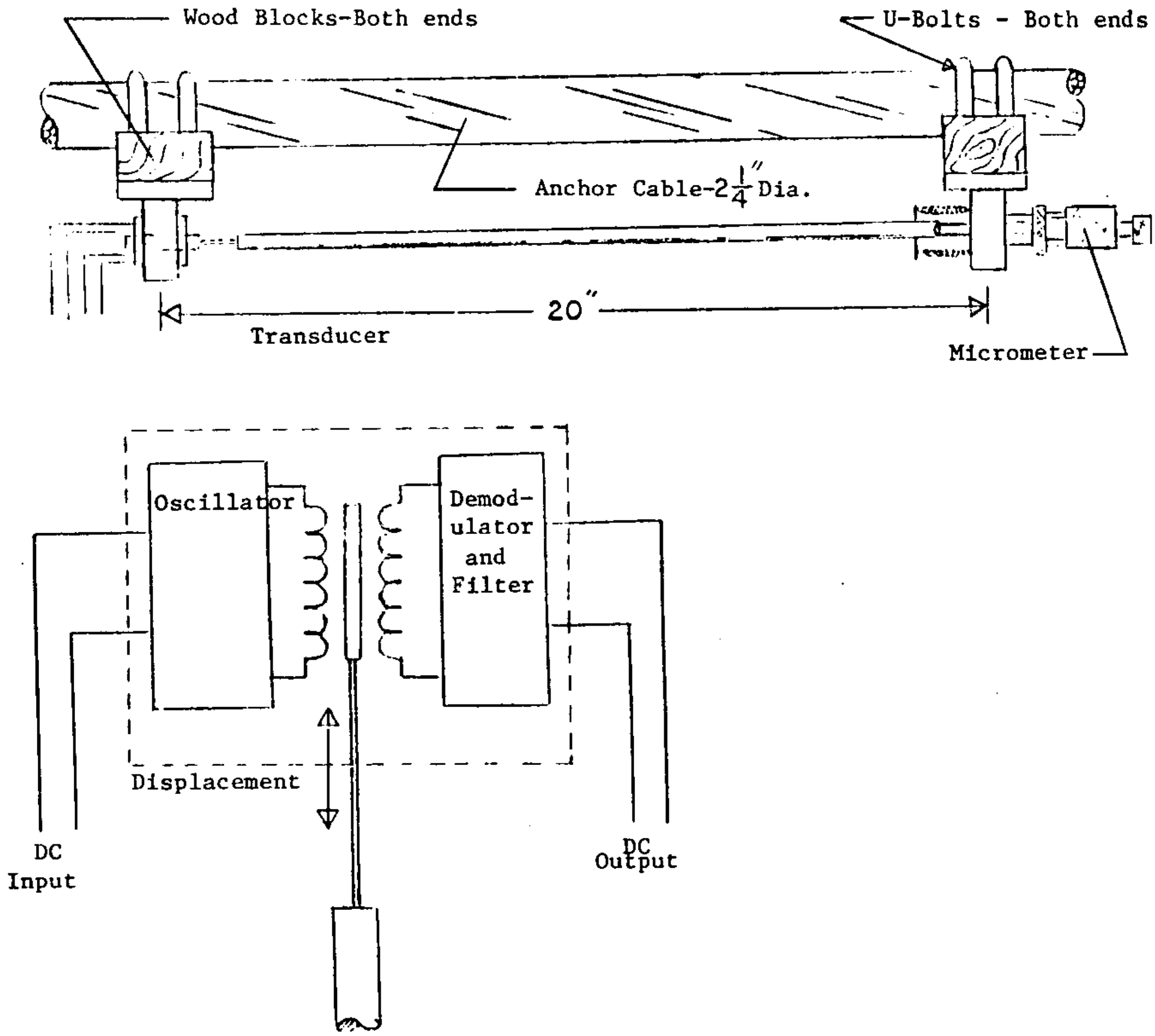


FIG. 3 CHANNEL ARRANGEMENT

zero to 80 m.p.h. The wave pressure is measured by Viatron pressure transducers, PTB 102G. These have a range of 0-15 psi with an instrument maximum of 23 psi. The final input is from the measurement of anchor cable displacements (A1, A2, A3, A4). These measurements are over a 20" gage on the cable in the pontoon. Fig. 4 shows the transducer arrangement where the change in gage length is recorded as a signal from the L.V.D.T.

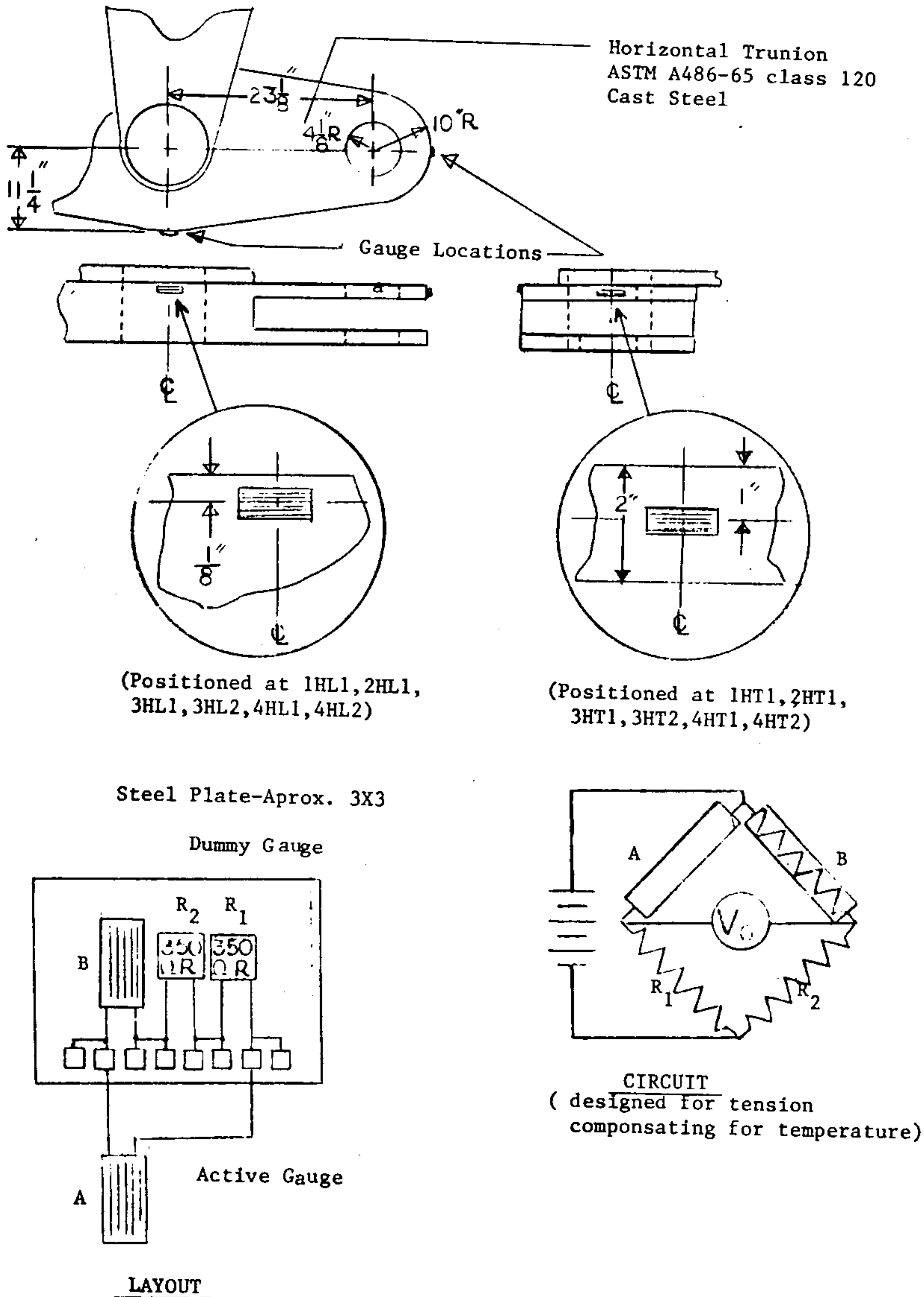
Strain measurements were made with gages from Micro-Measurements Division of Vishay Intertechnology, Inc. The horizontal trunnion and end lock were CEA-06-250 UW-350 single gages, CEA-06-125 UR-350 rosettes; the tension on the center locks and anchorages was measured by EA-06-250 TB-350 gages.

The positioning was made from considerations of likely strain fields. In particular locations where rapid changes of strain were anticipated were avoided because of the subsequent difficulties in interpretation. Fig. 5 shows the location, circuit and general layout of uni-directional gages on the sides of the horizontal trunnion plates (1HL1, 2HL1, 3HL1, 3HL2, 4HL1, 4HL2, 1HT1, 2HT1, 3HT1, 3HT2, 4HT1, 4HT2). Fig. 6 shows similar information for two rosette gages on the horizontal trunnion plates (3HRL1, 3HRT1, 3HRL2, 3HRT2, 3HRL3, 3HRT3). The location of these gages on the surface of the plates was considered carefully. An analysis using the finite element technique on the plate loaded by moving surface N a uniform amount in the x direction, revealed the stress distributions in Fig. 7. The sections A-A and B-B have small stress gradients at the point of gage location. Also around these locations very little change of principal axes occurred. These results indicated that a minor error in gage location would not negate the results. Any gage placed on CC would be critically dependent on location and orientation and this position was avoided.



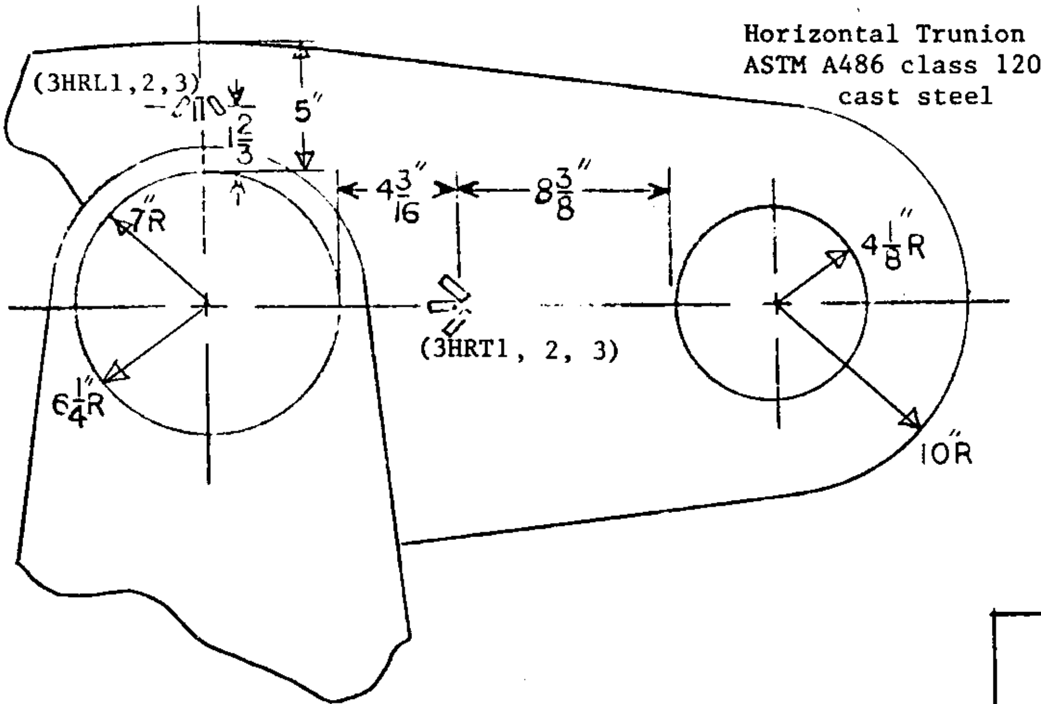
ANCHOR CABLE DISPLACEMENT TRANSDUCER

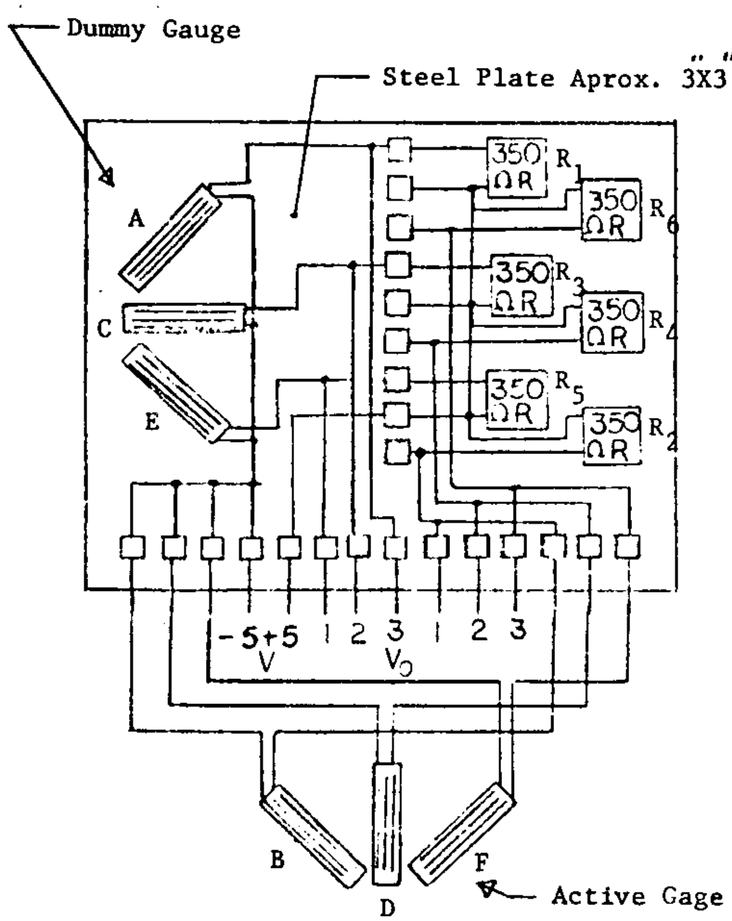
FIG. 4



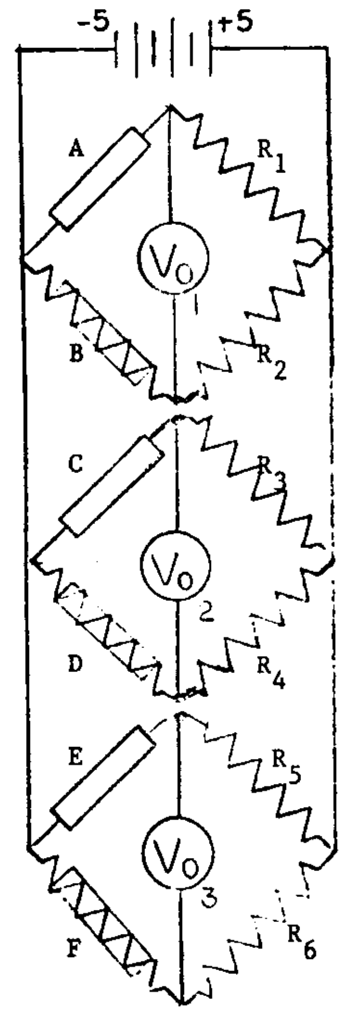
HORIZONTAL TRUNION GAGES

FIG. 5





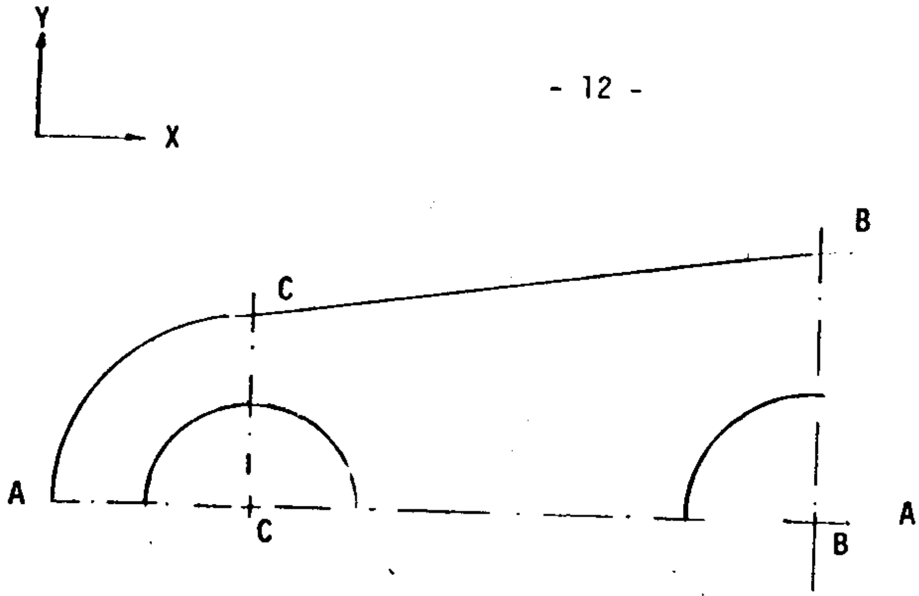
LAYOUT



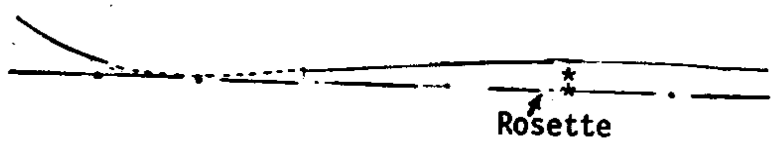
CIRCUIT
(designed for tension
compensating for temperature)

HORIZONTAL TRUNION
ROSSETE GAGES

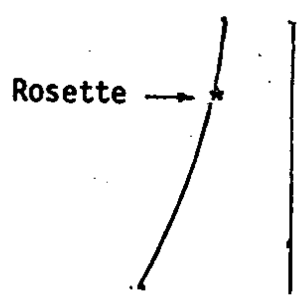
FIG. 6



SECTION OF HORIZONTAL TRUNION



σ_{Max} ON AA



σ_{Max} ON BB

FIG. 7 STRESS DISTRIBUTION OF HORIZONTAL TRUNNION

σ_{Max} ON CC

The vertical trunnion anchor rod gages (1V1, 1V2, 2V1, 2V2, 3V1, 3V2, 3V3, 3V4, 4V1, 4V2, 4V3, 4V4), center lock gages (C1, C2, C3) and the vertical trunnion anchorage beams (S1, S2)were designed to determine tension. The layout, circuitry and locations are shown on Figs. 8, 9 and 10. Finally, the end lock gage (L1) was designed to measure bending effects as shown on Fig. 11.

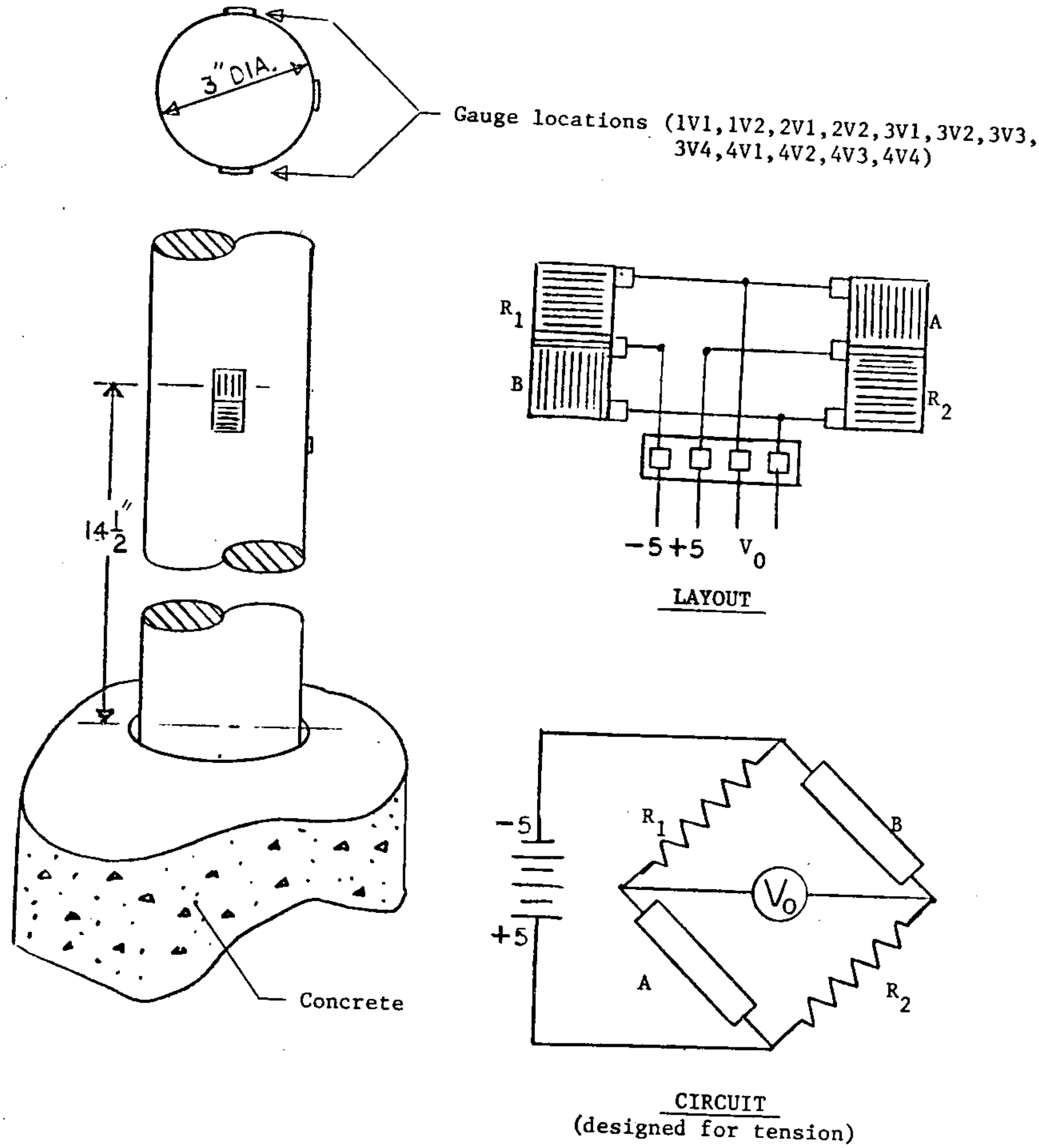
This account of the use of the 44 channels indicates the initial measurement scheme. As data are acquired, changes will be made in order that critical observations are not overlooked.

Housing for the recording system is in an instrument shack located by the central tower on the south west side of the drawspan (Fig. 3).

DATA ACCUMULATION AND ANALYSIS

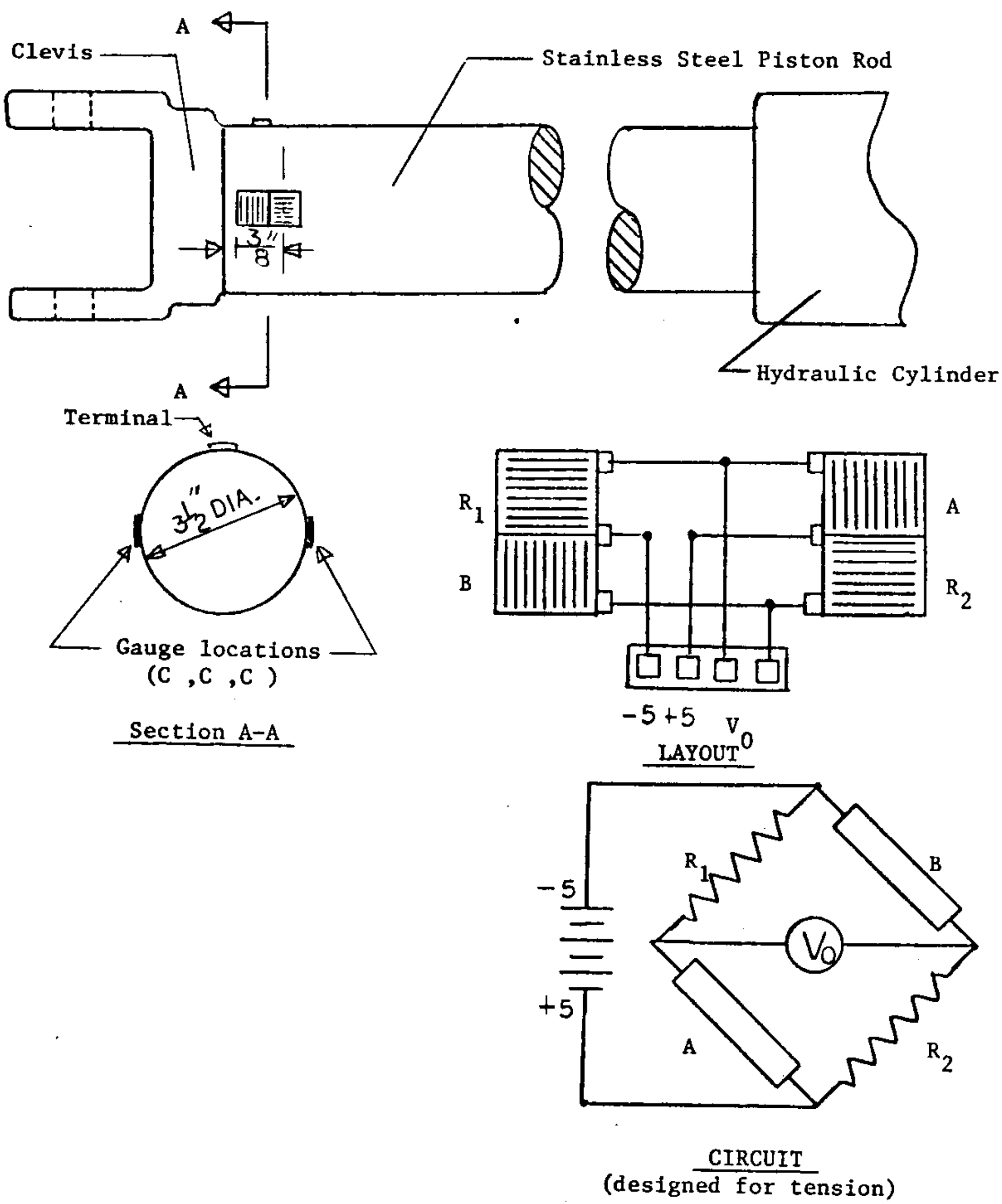
The sampling arrangement for data accumulation has been described in Appendix A. The initial purposes were to ascertain that the instrumentation was functioning properly and that the data obtained was of a useful character. The following table indicates the tape readings obtained. All instrumentation worked during these recordings.

Tape	From	To
EG1	20:30, 3-21-75	16:30, 3-24-75
EG2	15:30, 3-25-75	11:30, 3-26-75
EG3	13:00, 4-2-75	15:00, 4-2-75
EG4	15:30, 4-2-75	11:00, 4-28-75
EG5	11:00, 4-28-75	12:00, 5-3-75
EG6	12:00, 5-3-75	10:30, 5-5-75



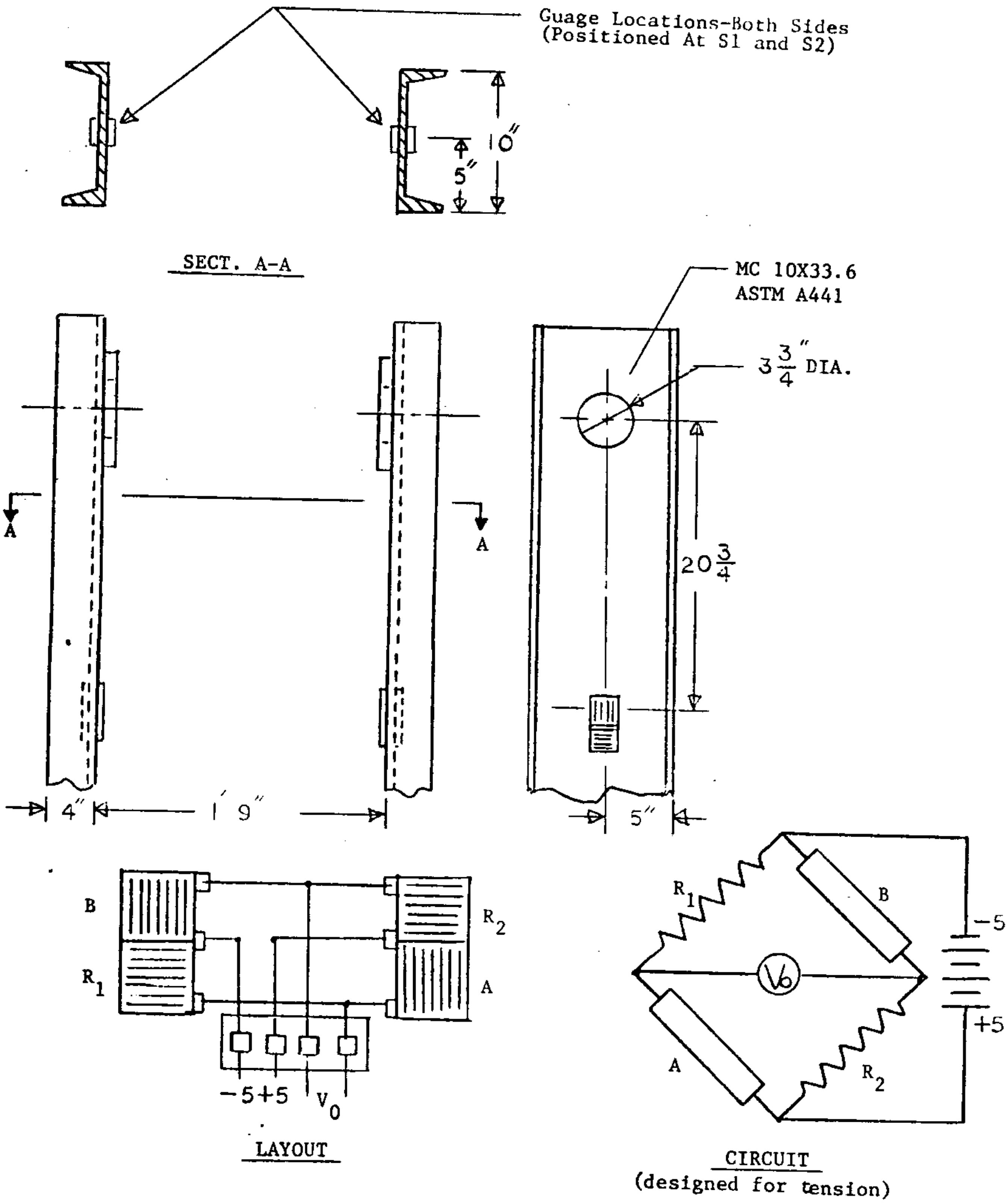
VERTICAL TRUNION ROD GAGES

FIG. 8



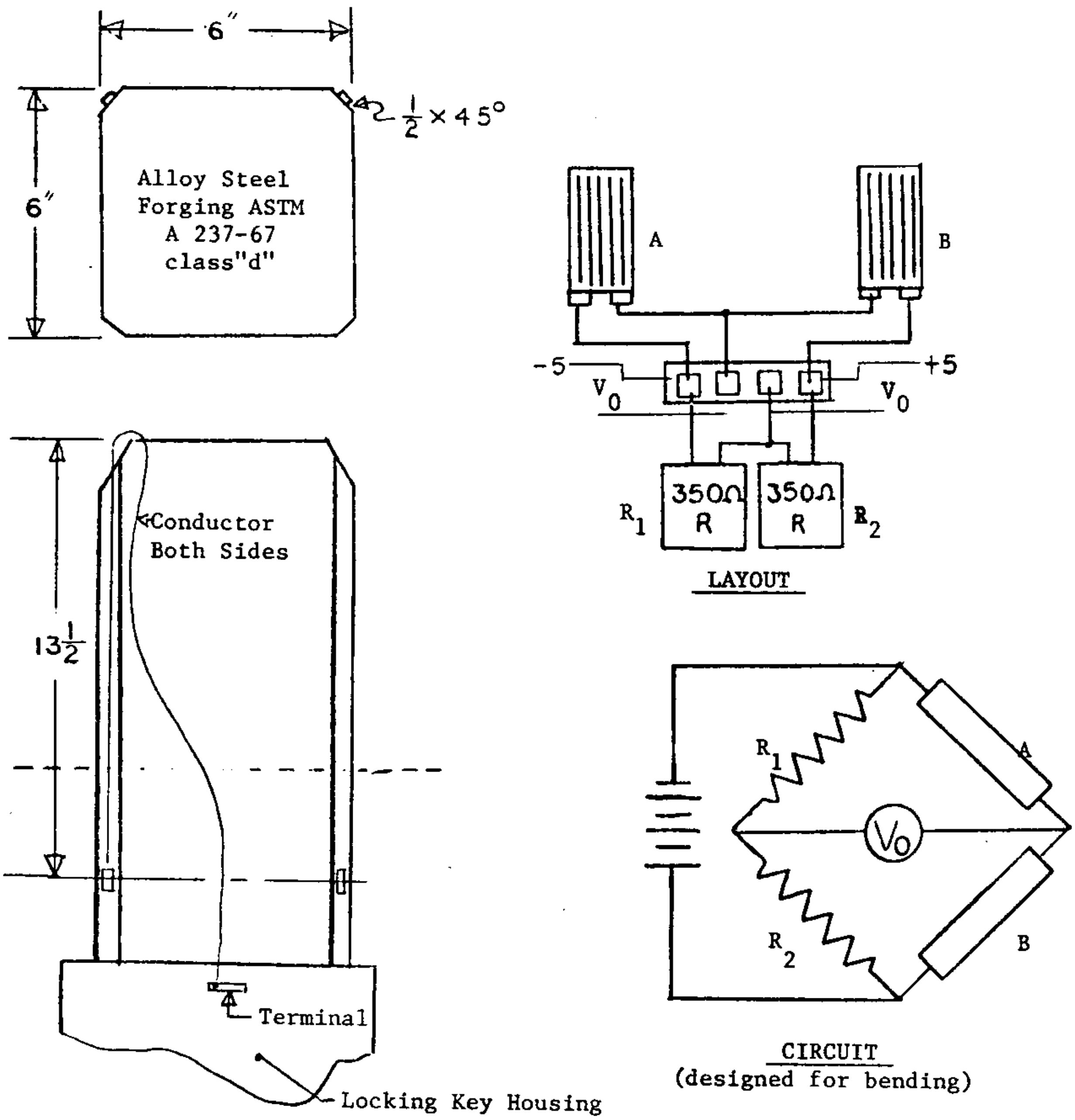
CENTER LOCK GAGES

FIG. 9



VERTICAL TRUNION REAR ANCHORAGE GAGES

FIG. 10



NOTE: Conductors were cemented in channel to locking key end and looped back to allow for key to be drawn into housing during operation.

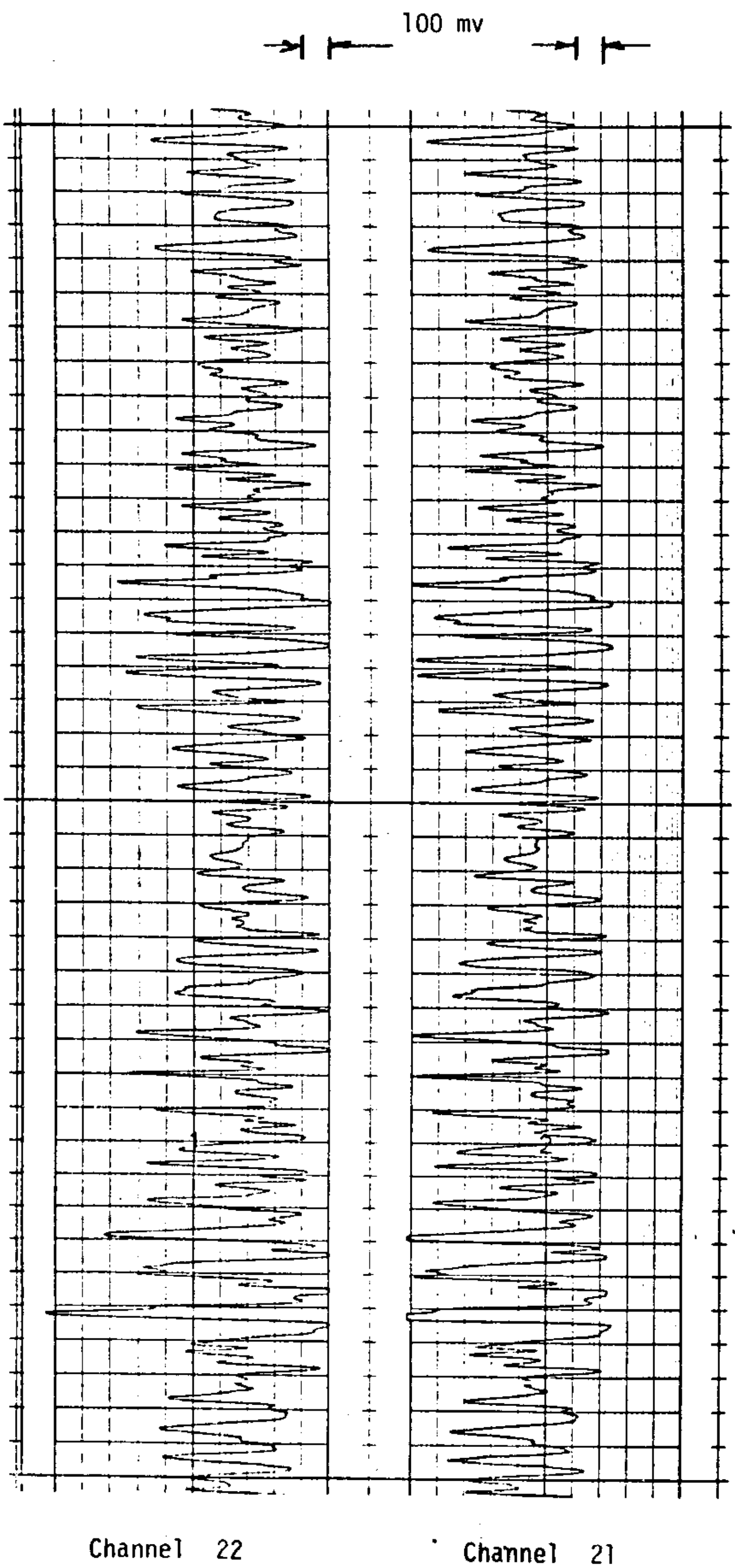
END LOCK GAGE

FIG. 11

The usefulness of the accumulated data was examined. In the first place a subjective anticipation of member performance was made and then the data were examined. The extent that a greement occurred confirmed the intuitive picture. When a different behaviour was exhibited then the reasoning and the test set-up were carefully scanned.

The high winds were expected to be from the South-West quarter. The highest gust velocity in the past was 87 m.p.h. and the highest one hour average was 47 m.p.h. From the north, the highest speed in the last ten years was about 40 m.p.h. The recordings made were well within these peaks and the wind direction for high speeds was in the correct quarter. For instance, tape EG6 has a maximum wind of 35.15 m.p.h. and a mean of 24.27 m.p.h. It was concluded that the wind measurements were valid. The wave force transducers are in operation; significant data have not been gathered in this year of work. The wind and wave forces in the reaction cables were considered to be superimposed on to an initial force of 120 kips. Inspection of the data outputs showed a regular cyclic straining about the initial value. Full calibration requires static tests on the cable in order to determine the effective modulus in the loading range. (Appendix C)

The recording of strains on the parts of the drawspan selected for instrumentation was expected to produce a continuous cyclic record under the influence of wind and wave loading. This expectation was realized when initial forces were acting on the element. Thus, in the anchor rods for the vertical trunnions and reaction cables, where high prestressing existed, such continuous cyclic signals about the initial value were obtained. The horizontal trunnion signals showed an intermittent shock loading. The strip charts on Fig. 12 indicate these signals. This suggests that these elements are subjected to battering rather than to the continuous oscillation. The



Record 5-3-75: Wind Speed 20-25 m.p.h. (steady)
Tape speed: 125 mm/min.

FIG. 12(a) STRIP CHART OF STRAINS
(VERTICAL TRUNNION ANCHORS)

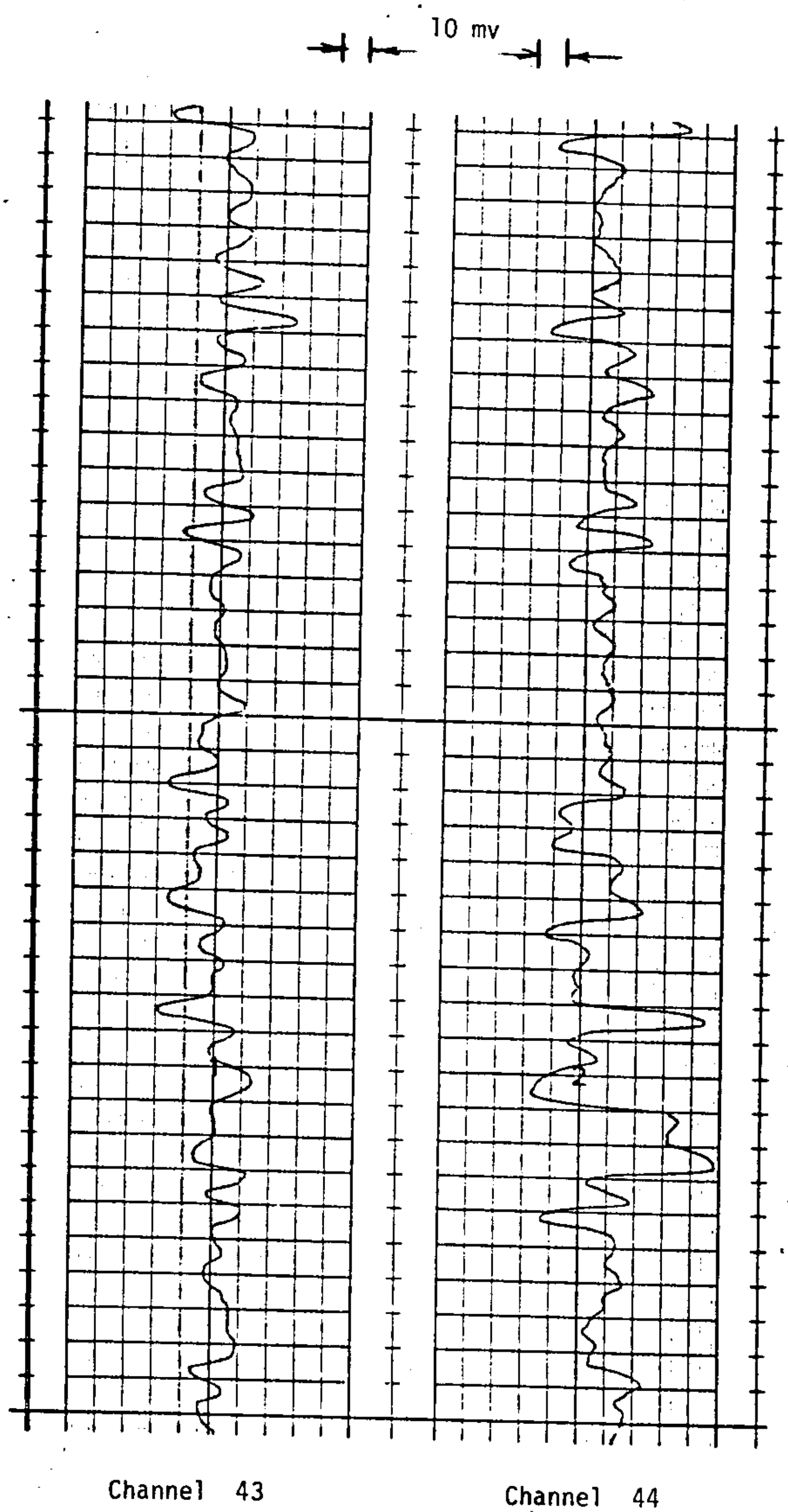


FIG. 12(b) STRIP CHART OF STRAINS
(ANCHOR CABLE)

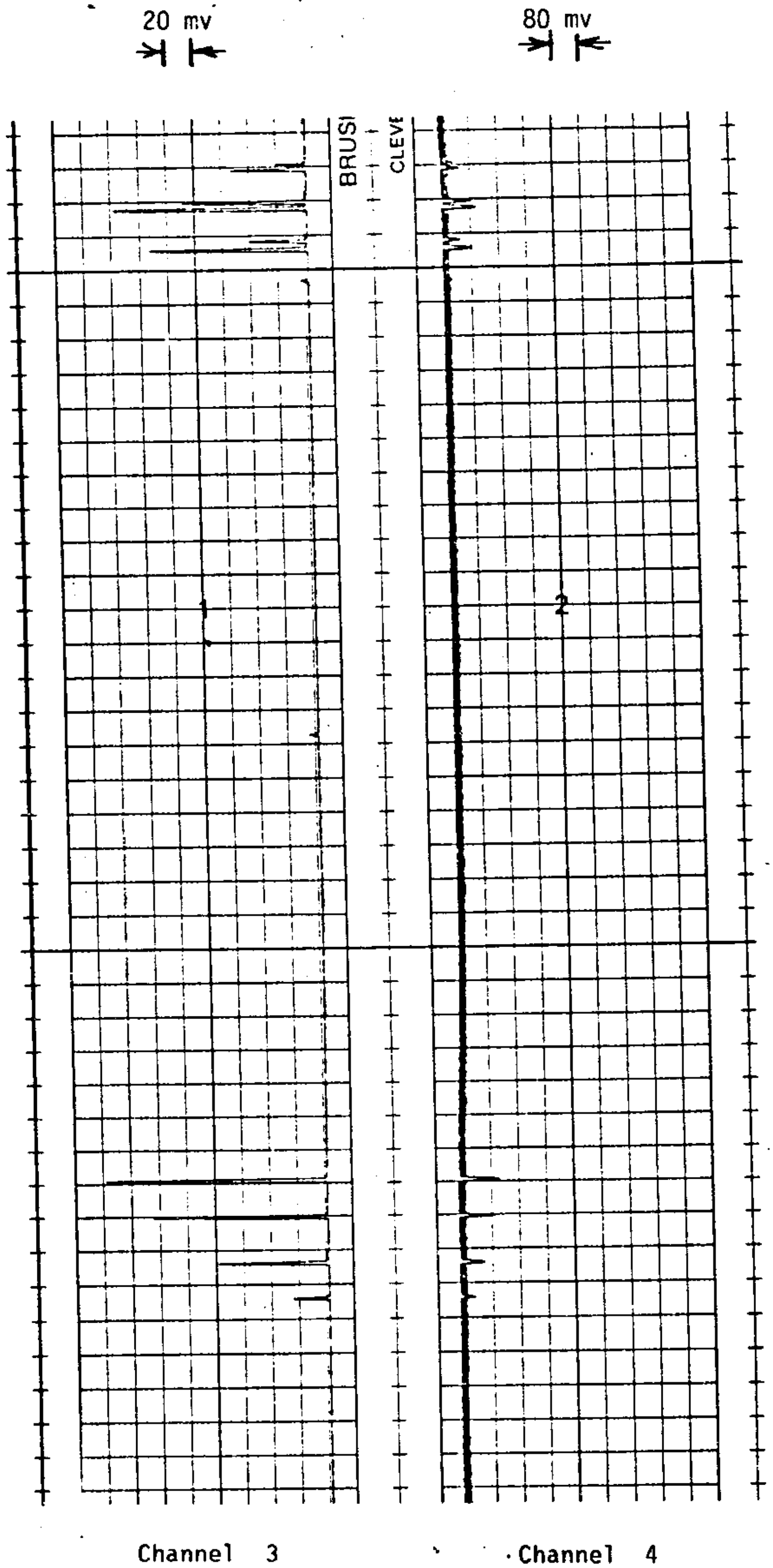


FIG. 12(c) STRIP CHART OF STRAINS (HORIZONTAL TRUNNION) subsequent damage may not be a result of a classical fatigue problem but rather a problem of low cycle impact load failure. As well as providing some insight into the method of element failure these initial observations have indicated an important limitation on the data acquisition system. The present system records digitally at 2 Hertz. This means that the character of the intermittent recordings on the battered members may be concealed. Alternatives for recording this type of data are now being considered. An increase in the frequency of recording will provide better delineation of the signal but saturate the recorder capacity quickly. Direct continuous strip chart recording is possible but provides voluminous data which are difficult to analyze efficiently. This problem is under attention.

The data analysis has been by traditional statistical methods. Presented in the computer print out sheet are the means, maximum and minimum values and standard deviations for 1738 and 2047 samples in tape EG6. The units are volts and the scaling factors are in the table.

Channel	Calibration Factors	Formula	Units
1	10	$10\ V_o$	m.p.h.
2	313	$313\ V_o$	^{o}From North
3-20	1.88×10^{-4}	$1.88 \times 10^{-4} V_o$	in./in.
21-32	15.172	$^*15.172\ V_o$	kip
33-35	19.220	$^{**}19.220\ V_o$	kip
36	9.4×10^{-5}	$9.4 \times 10^{-5}\ V_o$	in./in.
37, 38	7.4×10^{-5}	$9.4 \times 10^{-5}\ V_o$	in./in.
39, 40	not calibrated		
41-44	25.5	$^*25.5\ V_o$	kip

* Using $E = 29 \times 10^6$ p.s.i.; diameter = 3"
** Using $E = 27 \times 10^6$ p.s.i.; diameter = 3.5"

Appendix B shows the program for reading the data, analysis and providing these statistical measures.

SUMMARY OF STATISTICAL DATA FOR EVERGREEN FLOATING BRIDGE PROJECT EG6
NUMBER OF SAMPLES = 1738
TIME IN HOURS FROM START OF TAPE 0

CHANNEL	1	2	3	4	5	6	7	8	9	10
CH.NAME	W1	W2	1HL1	1HT1	2HL1	2HT1	3HL1	3HT1	3HL2	3HT2
MAX.VALUE	3.515E+00	7.945E-01	6.640E+00	4.143E+00	5.451E+00	4.059E+00	4.197E+00	4.056E+00	4.677E+00	4.094E+00
MIN.VALUE	.0	2.735E-01	6.189E+00	3.995E+00	4.129E+00	3.897E+00	3.842E+00	3.927E+00	4.097E+00	3.865E+00
MEANVALUE	2.427E+00	5.639E-01	6.224E+00	4.077E+00	4.254E+00	3.985E+00	3.866E+00	4.008E+00	4.164E+00	4.023E+00
STDEV	9.305E-01	4.944E-02	4.842E-02	1.795E-02	2.230E-01	2.066E-02	4.145E-02	1.898E-02	8.909E-02	2.296E-02

CHANNEL	11	12	13	14	15	16	17	18	19	20
CH.NAME	3HRL1	3HRL2	3HRL3	3HRT1	3HRT2	3HRT3	4HL1	4HT1	4HL2	4HT2
MAX.VALUE	4.232E+00	3.457E+00	4.127E+00	4.190E+00	3.356E+00	3.996E+00	4.944E+00	4.029E+00	4.292E+00	4.125E+00
MIN.VALUE	-2.501E-02	3.232E+00	3.966E+00	3.995E+00	3.227E+00	3.834E+00	4.008E+00	3.868E+00	3.747E+00	3.996E+00
MEANVALUE	3.920E+00	3.272E+00	3.987E+00	4.043E+00	3.283E+00	3.954E+00	4.100E+00	3.975E+00	4.020E+00	4.068E+00
STDEV	3.598E-01	1.996E-02	2.272E-02	2.353E-02	1.888E-02	2.134E-02	1.345E-01	2.284E-02	4.035E-02	1.693E-02

CHANNEL	21	22	23	24	25	26	27	28	29	30
CH.NAME	1V1	1V2	2V1	2V2	3V1	3V2	3V3	3V4	4V1	4V2
MAX.VALUE	8.224E+00	8.224E+00	8.127E+00	8.224E+00	6.159E+00	7.708E+00	6.340E+00	4.674E+00	1.411E-01	7.814E+00
MIN.VALUE	.0	.0	.0	.0	.0	.0	2.438E+00	3.835E+00	1.208E-02	9.204E-03
MEANVALUE	3.339E+00	4.046E+00	3.188E+00	3.333E+00	3.839E+00	3.604E+00	4.137E+00	4.136E+00	1.217E-02	3.622E+00
STDEV	1.308E+00	1.334E+00	1.224E+00	1.155E+00	9.851E-01	8.725E-01	4.406E-01	9.455E-02	3.189E-03	8.520E-01

CHANNEL	31	32	33	34	35	36	37	38	39	40
CH.NAME	4V3	4V4	C1	C2	C3	L1	S1	S2	P1	P2
MAX.VALUE	7.152E+00	6.648E+00	4.280E+00	5.843E+00	4.439E+00	5.033E+00	4.441E+00	4.942E+00	7.125E-02	4.103E-02
MIN.VALUE	2.798E+00	1.520E+00	3.797E+00	5.764E+00	3.938E+00	2.195E+00	3.054E+00	3.491E+00	6.754E-03	8.777E-03
MEANVALUE	4.037E+00	3.939E+00	3.937E+00	5.831E+00	4.157E+00	3.835E+00	3.984E+00	4.296E+00	6.810E-03	8.795E-03
STDEV	6.362E-01	5.710E-01	6.481E-02	1.613E-02	6.146E-02	1.999E-01	2.157E-01	2.083E-01	1.729E-03	7.736E-04

CHANNEL	41	42	43	44
CH.NAME	A1	A2	A3	A4
MAX.VALUE	3.632E+00	1.577E+00	5.772E+00	7.942E-03
MIN.VALUE	3.503E+00	1.448E+00	4.063E+00	7.942E-03
MEANVALUE	3.595E+00	1.519E+00	4.941E+00	7.942E-03
STDEV	1.933E-02	1.415E-02	1.855E-01	9.804E-17

SUMMARY OF STATISTICAL DATA FOR EVERGREEN FLOATING BRIDGE PROJECT EG6
NUMBER OF SAMPLES = 2047
TIME IN HOURS FROM START OF TAPE 0

CHANNEL	1	2	3	4	5	6	7	8	9	10
CH.NAME	W1	W2	1HL1	1HT1	2HL1	2HT1	3HL1	3HT1	3HL2	3HT2
MAX.VALUE	2.935E+00	6.036E-01	4.129E+00	4.123E+00	4.759E+00	4.063E+00	4.065E+00	4.063E+00	4.294E+00	4.096E+00
MIN.VALUE	1.870E+00	3.196E-01	4.032E+00	4.031E+00	4.137E+00	3.967E+00	3.969E+00	3.999E+00	4.069E+00	3.967E+00
MEANVALUE	2.459E+00	5.216E-01	4.047E+00	4.07[illegible]E+00	4.199E+00	4.035E+00	4.002E+00	4.035E+00	4.099E+00	4.037E+00
STDEV	2.478E-01	4.034E-02	1.813E-02	1.606E-02	1.023E-01	1.508E-02	1.315E-02	1.199E-02	3.813E-02	1.507E-02

CHANNEL	11	12	13	14	15	16	17	18	19	20
CH.NAME	3HRL1	3HRL2	3HRL3	3HRT1	3HRT2	3HRT3	4HL1	4HT1	4HL2	4HT2
MAX.VALUE	4.128E+00	3.354E+00	4.064E+00	4.095E+00	3.386E+00	4.063E+00	4.267E+00	4.063E+00	4.097E+00	4.124E+00
MIN.VALUE	4.031E+00	3.290E+00	3.967E+00	3.999E+00	3.257E+00	3.934E+00	4.009E+00	3.967E+00	3.968E+00	4.031E+00
MEANVALUE	4.358E+00	3.312E+00	3.993E+00	4.064E+00	3.307E+00	4.014E+00	4.054E+00	4.017E+00	4.012E+00	4.082E+00
STDEV	1.724E-02	1.729E-02	1.673E-02	1.523E-02	1.742E-02	1.906E-02	3.073E-02	1.926E-02	1.834E-02	1.817E-02

CHANNEL	21	22	23	24	25	26	27	28	29	30
CH.NAME	1V1	1V2	2V1	2V2	3V1	3V2	3V3	3V4	4V1	4V2
MAX.VALUE	7.643E+00	7.966E+00	7.998E+00	7.998E+00	7.067E+00	6.712E+00	5.376E+00	4.390E+00	2.080E-03	6.903E+00
MIN.VALUE	.0	3.225E-01	3.870E-01	2.580E-01	2.875E+00	2.842E+00	3.602E+00	3.971E+00	2.080E-03	2.775E+00
MEANVALUE	3.480E+00	4.506E+00	3.420E+00	3.569E+00	3.890E+00	3.688E+00	4.051E+00	4.115E+00	2.080E-03	3.675E+00
STDEV	1.095E+00	1.113E+00	1.030E+00	9.738E-01	7.665E-01	6.885E-01	2.573E-01	5.421E-02	1.245E-16	7.511E-01

CHANNEL	31	32	33	34	35	36	37	38	39	40
CH.NAME	4V3	4V4	C1	C2	C3	L1	S1	S2	P1	P2
MAX.VALUE	6.033E+00	6.064E+00	4.095E+00	5.961E+00	4.321E+00	4.278E+00	4.353E+00	4.580E+00	2.048E-03	1.103E-03
MIN.VALUE	3.357E+00	3.256E+00	3.611E+00	5.336E+00	3.967E+00	3.440E+00	3.289E+00	3.612E+00	2.048E-03	1.103E-03
MEANVALUE	4.059E+00	3.933E+00	3.850E+00	5.356E+00	4.132E+00	3.866E+00	4.018E+00	4.287E+00	2.048E-03	1.103E-03
STDEV	4.730E-01	4.393E-01	6.440E-02	1.395E-02	5.325E-02	5.710E-02	1.703E-01	1.691E-01	7.743E-17	2.642E-16

CHANNEL	41	42	43	44
CH.NAME	A1	A2	A3	A4
MAX.VALUE	4.577E+00	4.480E+00	4.415E+00	4.542E+00
MIN.VALUE	3.481E+00	3.384E+00	3.641E+00	3.575E+00
MEANVALUE	3.938E+00	3.966E+00	3.994E+00	4.109E+00
STDEV	1.376E-01	1.210E-01	8.731E-02	1.129E-01

The statistical parameters obtained are defined from the moments of the data where the n^{th} moment

$$m_n = \sum_i x_i^n \; p_i$$

and $p_i = \frac{N_i}{N}$ with N_i the number of observations of x_i and $N = \sum_i N_i$. The mean is m_1 and the standard deviation is $(m_2 - m_1^2)^{1/2}$.

The computer print out has to be interpreted as changes of reading about the mean for all channels except 1 and 2. These two channels when scaled, give direct readings of wind velocity.

PREDICTIONS OF EXTREMES

Methods of making the important extreme predictions have been considered without any application. Initially correlation between wind and strains has to be established. Then the long term single wind data will have to be interpolated into the long term data that is available.

The relationship between wind, wave and strains will be established by observation of the relative change of means and standard deviation. Additionally, a measure of relationship will be given by the coefficient of correlation

$$\rho = \frac{\mu_{11}}{\sigma_1 \, \sigma_2}$$

These terms will now be defined. Consider the wind speed as a random variable X taking on values x and strains as random variable Y taking on values y. In N samples there are N_{ij} with $X = x_i$ and $Y = y_j$. Then

$$P_{ij} = \frac{N_{ij}}{N}$$

.

The moments of the data on wind and load are

$$m_{ln} = \sum_{i,j} p_{ij} \; x_i^{\,l} \; y_j^{\,n}$$

and the central moments of the data are

$$\mu_{ln} = E\,[\,(X - m_{10})^l \; (Y - m_{01})^n\,]$$

where
$$E\,[\,g\,(X,\,Y)\,] = \sum_{i,j} p_{ij} \; g(x_i \,;\, y_j)$$

Then

$$\sigma_1 = \mu_{20}^{\frac{1}{2}} \quad , \quad \sigma_2 = \mu_{02}^{\frac{1}{2}}$$

If there is no correlation between X and Y (i.e. X and Y are independent) then $\mu_{11} = \rho = 0$. However, as we cannot say that X and Y are independent when $\rho = 0$ only, as

$$\mu_{11} = E\,(X,\,Y) - E\,(X)\,E(Y)$$

Instead we say that X and Y are uncorrelated. The coefficient of correlation is bounded by

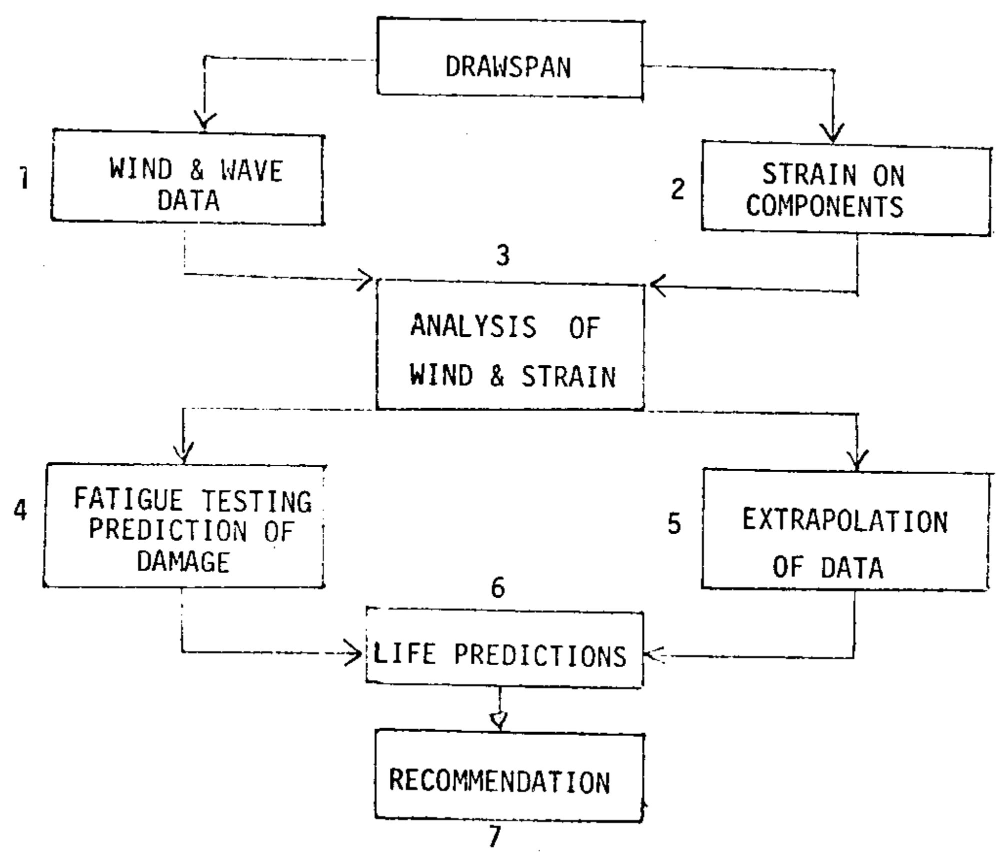
$$-1 \leq \rho \leq 1$$

and the opposite of independence occurs when $\rho^2 = 1$. Then X is causatively tied to Y.

Any statistical relation between wind, wave and strains will be valuable. Already available are wind readings on an anemometer of the Climatological Office of the National Weather Service placed 48' above the lake on the drawspan of the Evergreen Point Bridge. These readings are from 1965 to date and give the wind speed and direction at 8 a.m. and 4 p.m. daily and are then arranged as percentage frequency distributions of wind speeds. Such distributions are for bi-monthly and annual periods. These data can be arranged in a probability function and the maximum wind speed for definite use periods obtained. Additionally, for use periods statements of the number of occurences of various wind speeds can be made. These results, when realted to the strain - wind association, already determined, should lead to a strain history and hence predictions of extremes of useful life.

FATIGUE EXPERIMENT DESIGN

The prediction of extreme life require adequate understanding of the response of critical elements of the drawspan mechanism to input histories. This can be accomplished by laboratory experiments of these parts of the elements. Of importance is the subjecting the test specimens to the same statistical input as the field parts. With this approach the details of the predictions of extremes can be completed. The schematic shows these operations.



Essentially the work of this year has concentrated an operations 1, 2 and 3 in detail and 4 and 5 in outline. Appendix D outlines a fatigue test program. It should be pointed out that this program is properly applicable to the prestressed members - vertical trunnion anchorages and reaction anchorage cables - where the straining is oscillatory. The battering of the horizontal trunnion elements is not covered by the classical statistical arguments and the test apparatus must be different. These matters are presently being studied.

CONCLUSION

This interim work reports in detail the instrumentation of the Evergreen Point Bridge drawspan and the functioning of the instruments. Recordings made and analyzed indicate a battering as well as continuous loading mechanism. The capacity design has been outlined for the continuous loading case.

APPENDIX A

DESIGN OF DATA RECORDING SYSTEM

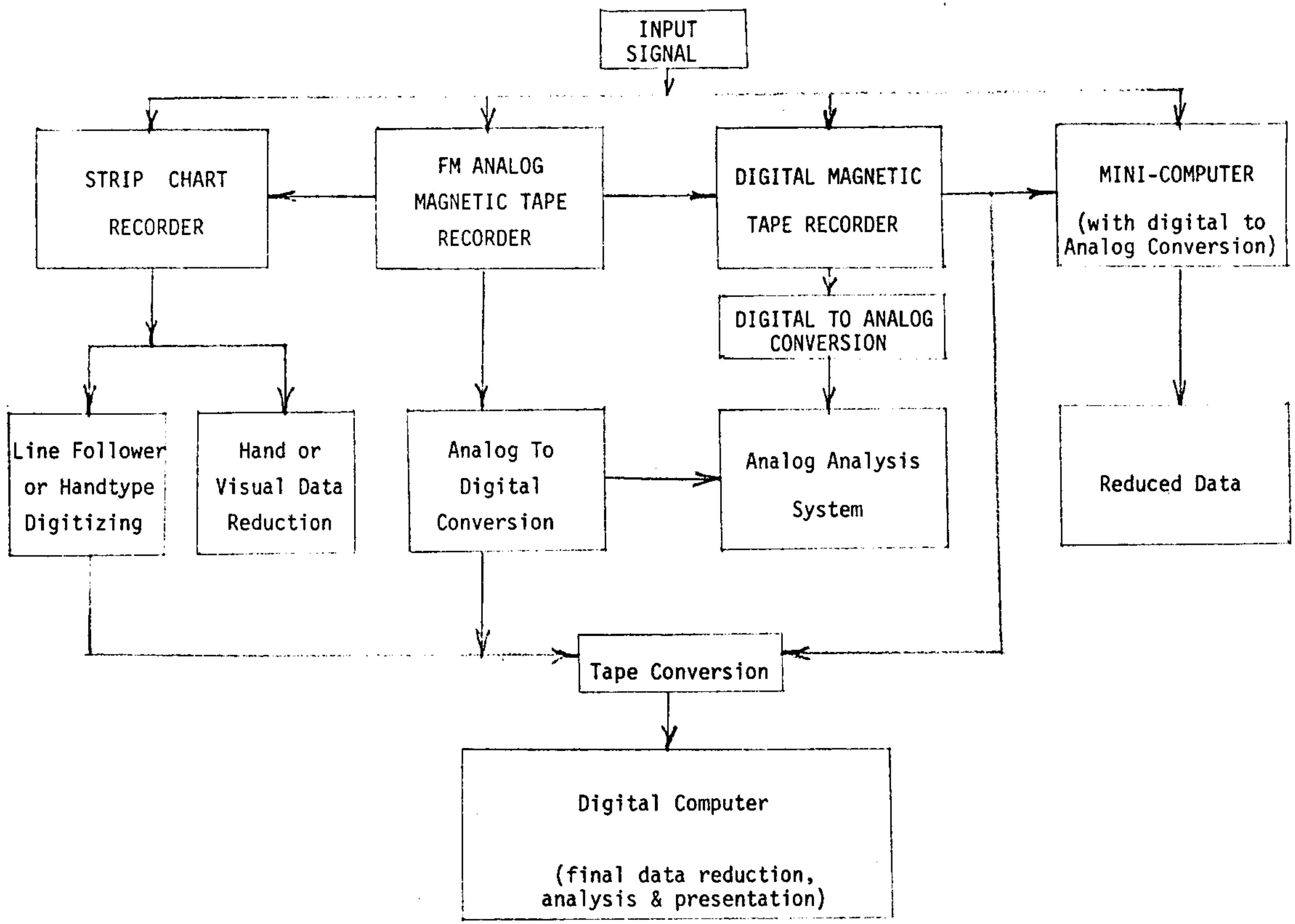
by

Derald R. Christensen

Any electronic equipment for an instrumentation system must be reliable and perform the objective of the design. To varying degrees systems can be altered to fit a particular installation. However, to make a final decision on any package the designer must consider many facets of the particular project and how the final data is to be handled, stored and analyzed. This means that the final data handling and analysis, be it with hardware or software or a combination of both methods, must be considered as a basic part of the initial instrumentation package design. There are four basic techniques of actually recording and handling data. From these several methods of reducing the data are available. The chart shows the alternative methods available for each technique.

The strip chart recorder is far too cumbersome when working with large data output and would result in unrealistic time demands for data reduction. However, this method of recording is extremely accurate and does provide at a glance information about the process being recorded. The FM tape recorder has the definite advantage of allowing the use of any of the available analysis techniques. Also, the signals can be electrically manipulated prior to either using analog type analysis or digital conversion and then digital computer analysis. Additionally, the original data are always retained. The disadvantages are:

1) That each recorder is limited to 14 channels.


INPUT SIGNAL
STRIP CHART RECORDER
FM ANALOG MAGNETIC TAPE RECORDER
DIGITAL MAGNETIC TAPE RECORDER
MINI-COMPUTER (with digital to Analog Conversion)
DIGITAL TO ANALOG CONVERSION
Line Follower or Handtype Digitizing
Hand or Visual Data Reduction
Analog To Digital Conversion
Analog Analysis System
Reduced Data
Tape Conversion
Digital Computer (final data reduction, analysis & presentation)

2) That over 500 feet of one inch wide magnetic tape is required for each hour of recording for each 14 channel recorder at the required 1-3/4 inch per second tape speed.

3) That additional hardware, in essence a digital recorder or mini computer, is required to get the data into a digital format.

4) That high power requirements for field operation are required.

5) That the system is less reliable than most digital systems.

6) That the system is hard to calibrate and to keep calibrated.

7) That the recorder cost is comparable to that of a complete digital recording system with several times the input channel capacity.

8) That the electronics for the input measuring devices or transducers has to be a completely separate package.

A mini computer located at the recording site is very desirbale in many installations, but the high degree of sophistication and the resulting expense associated with such a system are not always justified. An alternative of incorporating a mini computer system into the tape conversion step would provide the maximum amount of freedom and ease in analyzing the recorded data. However, this requires a large initial capital expenditure.

The conclusion here, for the size of system being designed for this project, is to record the data in a digital format and to use a main computer facility for the data reduction and analysis. In this way, the complete instrumentation package can be designed around a single system with maximum reliability and minimum cost per input channel. The disadvantage in using a digital format is that once a particular sampling interval is selected, higher sampling rates can be attained through either digital to analog conversion techniques or statistically means to estimate intermediate points. Both give rise to some uncertainty as to the validity of the output. This requires that the initial system is designed properly.

The digital system used in this project is the Sea Data Corporation's incremental four track digital cassette recorder, model 610. The main advantage of this particular system are:

1) size (the recorder itself is only 4.4" high by 3.9" x 3.7")
2) inexpensive ($1200 with recorder and data stream control electronics)
3) 11.5 million bits per tape (standard size cassette, 0.15" wide tape)
4) high speed (300 steps/sec. at 4 bits/step)
5) high density (800 steps/inch or 3200 bits/inch)
6) modular construction (as many input channels as desired up to a maximum sample word size of 400 bits)
7) low power requirements (power only consumed during 3.3 ms motor steps: 2.0 Amp-hrs from 9-15 volt source to record 300 feet of tape over any time period. A stack of alkaline C-cells provides adequate safety margin at 0^oC)
8) only six moving parts (no gears: direct cap stan drive)
9) all parts field replaceable without realignment
10) transducer electronics can be incorporated into the recorder design
11) design flexibility
12) data capacity expandable in 11.5 million bit blocks with only one transport and motor driver card required per block (≈ $700/block)

13) full line of electronic cards available, thus increasing design flexibility.

14) high accuracy (less than 1 sample in 10000 lost in field experience of tape conversion)

15) 4 hours of continuously sampled data on one 300 foot tape. (This using 44 8-bit data channel, a 12 bit clock and sampling twice a second).

The recording package itself is in a component or modular form which allows flexibility in design configuration. The design requirements for this project did not lend themselves directly to any available single system recording package, that was also inexpensive. The combining of available systems would have resulted in a specialized, complicated and probably unreliable package. Additionally, the tape density and the speed of the recorder actually made could not be matched by any manufactured type. Due to anticipated future instrumentation changes and to the variety of measurements to be made, a very flexible package was designed and built.

The instrumentation package used consists of an incremental digital cassette recorder, three printed circuit cards (which control the recorder and data stream to the recorder) and a clock card that generates the pulses which control the data shifting and other time oriented functions of the recorder. Associated with each pair of input channels there are single cards of two frequency counters and shift registers each. The shift registers are adjustable from 4-16 bits. The remainder of the electronics associated with both the operation of the recorder and the transducers was designed and built at the University of Washington with the idea of taking full advantage of the flexibility of the Sea Data recording system.

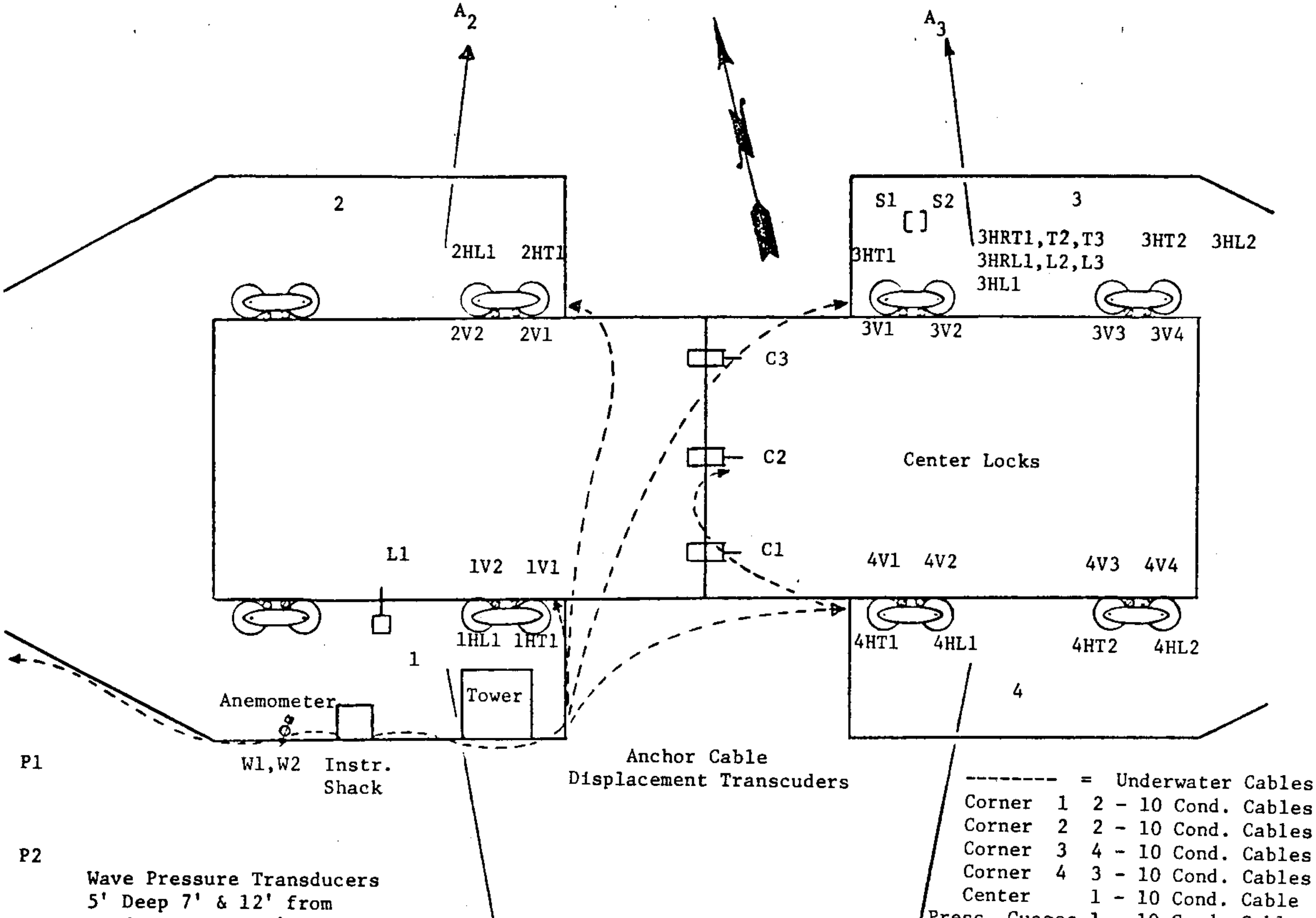
The operation provides for the input signals to be fed into a bridge amplifier card should thus be required by the type of transducer employed for that channel (space is available on all channels for such a card). From here the signal is run through a signal conditioning card, where the bias or offset of the signal can be adjusted, the polarity reversed and an amplification from 0 to 10 applied. This amplification is used in the field for scale factor or calibration adjustment. Additionally, this card is used as the input for the transducers not using a bridge circuit or requiring large amplification. Then a blank card or a card containing additional electronics depending on the type of measurement, is used in place of the amplifier card. The signal is subsequently fed into a volatage to frequency converter which operates on 0 to 10 volt input to give a corresponding 0 to 10000 cps output. This frequency is counted on the following card and stored in a shift register. All the input channel signals are stored at the same time in their respective registers and upon a signal from the clock are shifted, in a serial fashion, onto the tape. This means that all the shift registers for each input channel are wired together and the data is shifted, 4 bits at a time, from one register to the next, directly onto the 4-tracks of the cassette tape. The tape recorder records 300 steps/second at a density of 800, 4-bit steps/inch.

This operation enables addition or subtraction of input channels to be readily made. The maximum number of channels is limited by the stepping speed, size of shift registers used and the time required to count the input frequencies (adequate time must be allowed for counting the input frequencies to enable full use of the shift registers over the range of the input signal level).

The recorder system designed for this project has 44, 8-bit input channels plus a 12-bit clock channel. The 8-bit shift registers has a maximum count of 256 (counting the zero bit), which gives a resolution of 1/256 times the maximum output allowed for in the calibration adjustment for each transducer. The registers recycle if run over scale and this can be allowed for in the tape conversion software package. Each data sample (word) is made up of a 5 step gap, 2 step preamble (both are used by the cassettee reader in tape conversion), 91 step data block (2 steps per 8 bit register times 44 inputs plus 3 steps for the clock) and a 1 step longitudinal character check. This provides a total of 99, 4-bit steps per data sample (the recorder has 4 tracks or 4 bits are recorded for each 3.3 ms step of the recorder) and is the maximum allowable word length. The channels are sampled twice a second and 2047 samples are taken each recorder start whilst in the sequence sampling mode. A continuous mode is also available. In this mode a total of 4 hours of continuous data can be recorded on one 300 feet cassette. For the sequence mode the individual records are 17 minutes long, thus giving a total of 14 records per cassette. The sampling rate and the number of samples per record can be altered by simple changes on the power control card.

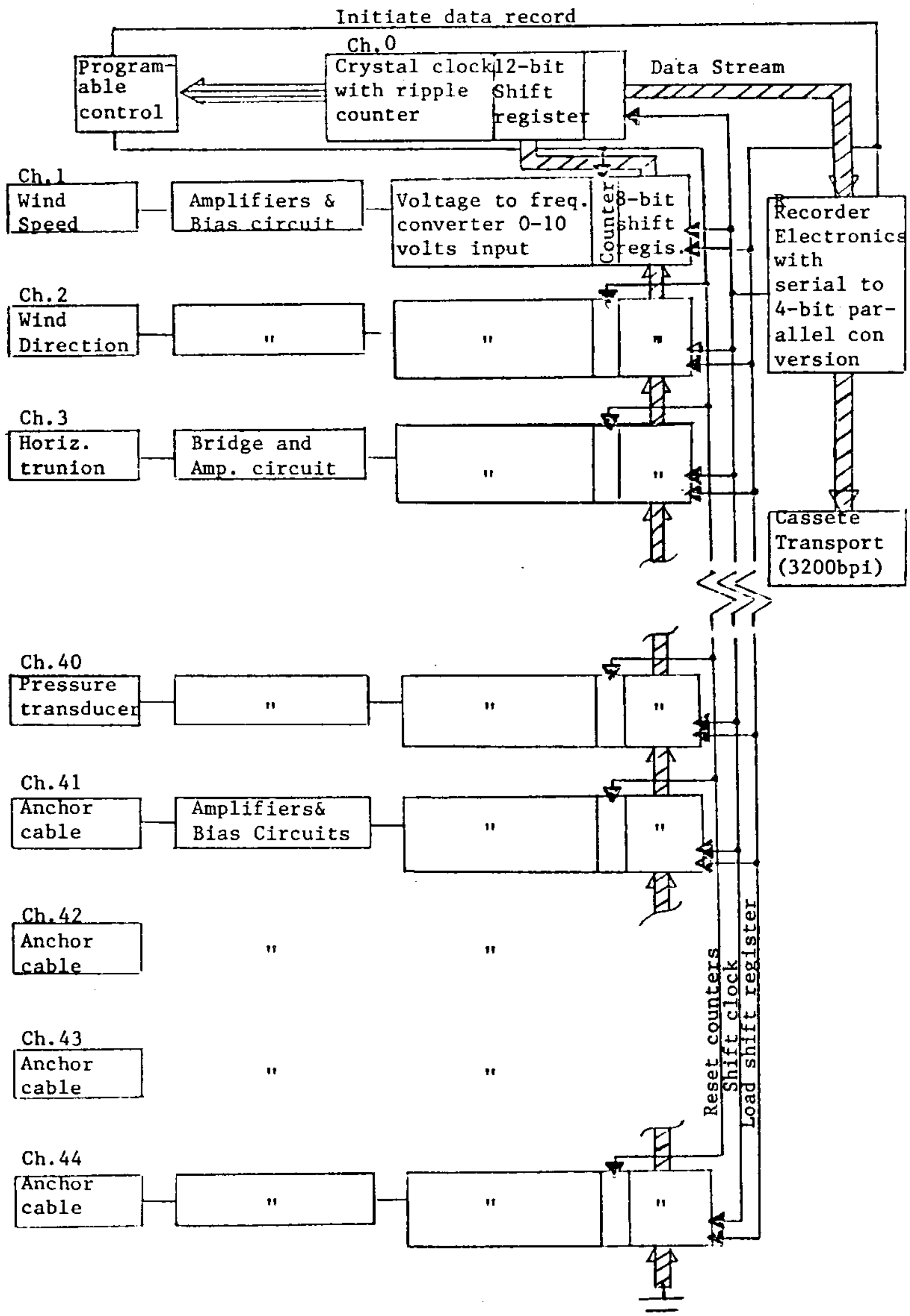
The recorder can be manually or automatically controlled. With the remote control switch on, the recorder is initiated automatically by the wind indicator (this could be carried out with any of the input transducers). The recorder is set to respond to a given wind speed. Once this wind speed is attained, it is sampled for a preset length of time. If the wind stays above this value for the given time interval the system is turned on and 2047 samples are taken. One hour after the first record, the system checks the wind. If the wind speed is above the pre-set level then a second record is made. This continues until the wind drops below the preset level of the system. The adjustments for the triggering level and sampling period are made on the wind speed monitoring card. At present the system is set to initiate at a wind speed of 20 mph. It samples the wind for one minute before a record is actually started.

Figs. A1 and A2 show the instrumentation and recording package layout. Further, Fig. A3 (on deposit with the Washington State Highway Department) gives complete wiring details of cards, etc.



EVERGREEN FLOATING BRIDGE
Instrumentation Layout

FIG. A1



Instrumentation and recording package layout.

FIG. A2

APPENDIX B

TAPE READING AND STATISTICAL PROGRAMS

```
      PROGRAM LOGBP(INPUT,OUTPUT,TAPE1,TAPE2,TAPE3,TAPE4,TAPE15,
     1TAPE5=INPUT,TAPE6=OUTPUT)
C
C       PROGRAM TO READ BINARY DATA LOGGER CHARACTERS FROM 7-TRACK
C       TAPE (TAPE1,556 BPI,STRANGER) GENERATED USING THE WINDFIELD
C       HILL 4-TRACK CONVERTER.
C       COMPUTES AND WRITES ON TAPE(TAPE2,800 BPI, BINARY , SCOPE)
C       CLOCK,
C       ERROR RECORDS ARE MARKED WITH ASTERISKS
C
C ******VARIABLES TO BE READ IN  *********
C
C      THE WORD SAMPLE CORRESPONSE  TO  A SINGLE SAMPLE OF AL  THE INPUT
C      CHANNELS, WHILE A RECORD CONSISTS OF THE GROUP OF SAMPLES OBTAINE          D
C      EACH TIME THE RECORDER IS TURNED ON AND OFF.
C       NCOM=8A10  - OUTPUT IDENTIFICATION
C       NDATA  -  NUMBER OF CASSETTE SAMPLES/RECORD
C       NSKIP  -  NUMBER OF 4-TRACK TAPE SAMPLES TO BE SKIPPED.
C      NFSKIP = 15 - NUMBER OF 7-TRACK TAPE FILES TO BE SKIPPED.
C
C ******VARIABLES SET IN DATA STATEMENTS *******
C
C  MAIN PROGRAM
C       NX(NVAL) - ARRAY OF THE NUMBER OF 4 BIT CHARACTERS (OR BYTES) IN
C       NVAL       - THE NUMBER OF INPUT CHANNELS PER CASSETTE SAMPLE(OR          RECORD)
C       NRECTOT       - NUMBER OF SAMBLES IN EACH 7-
C                       TRACK TAPE FILE. EACH 7-TRACK TAPE FILE HAS TO
C                       THE SUM OF NX(I) PLUS TWO BYTES ON
C                       HAVE .LE. 400 BYTES. EACH CASSETTE RECORD GIVES
C                       THE 7-TRACK TAPE WITH THE ACTUAL CASSETTE DATA
C                       BEING STORED IN THE LAST FOUR ROWS OF THE 7-TRACK
C                       TAPE. THEREFORE, EACH 7-TRACK TAPE FILE HAS
C                       NRECTOT      CASSETTE RECORDS IN  IT, WHICH GIVES
C                       A TOTAL OF (NRECTOT)X(SUM OF NX(I)) BYTES/FILE.
C       PARI = .TRUE. - THIS VARAIBLE IS USED IN THE SYSTEM S.R. ERRBIT
C                        (1,PARI) WHICH INABLES THE PROGRAM TO RECOVER
C                        FROM PARITY ERRORS.
C ******S.R. GETCAS  ********
C       NW = 41 - WORD POSITION IN BUFFER ARRAY BUF(40)
C
C       NWORDS = 40 - MAX. NUMBER OF WORDS THAT CAN BE READ IN, THAT IS
C                      MAX. BUFFER LENGTH. THE BUFFER IN STATEMENT READS
C                      10 CHARACTERS OR BYTES PER CDC WORD, THEREFORE
C                      GIVING A TOTAL OF 400 CAHRACTERS  READ IN EACH
C                      TIME BUFFER IN IS CALLED WHICH IS THE 7-TRACK
C                      TAPE FILE LENGTH.
C      NC =     - CHARACTER POSITION IN BUFFER ARRAY POSITION NW
C      NREC       - IS USED TO COUNT THE NUMBER OF CASSETTE RECORDS IN
C                    EACH 7-TRACK FILE.  MUST INITIALLY  BE SET TO A
C                    NUMBER .GT. NRECTOT
C *****ARRAYS ******
C       NX(NVAL) - DEFINED ABOVE
C       NZ(NVAL) - DATA ARRAY CONTAINING THE ORIGINAL BINARY (INTEGER)
C                   VALUES RECORDED ON THE CASSETTE TAPE.
C       ZN(NVAL) - DATA ARRAY USE TO STORE THE CONVERTED DATA PTS.
```

****

```
      C
      C        BUF(40) - ARRAY USED BY BUFFER IN FOR READING THE 7-TRACK FILES
      C        NNN(5) -
      C
      C ******MISC. VARIABLES ***********
      C
      C        NTYPE - PARAMETER DEFINING THE TYPE OF DATA RETURNED IN NZ( )
      C                ARRAY AND NCHECK  (OUTPUT)
      C                 = 1, ONE GOOD CASSETTE RECORD RETURNED (NO ERRORS)
      C                 = 2, ONE ERROR CASSETTE RECORD IS RETURNED(CHECK PARITY
      C                      ERROR WORD(NCHECK))
      C                 = 3, EOF ENCOUNTERED, NO DATA RETURNED.
      C
      C        NCHECK = PARITY/ERROR  INTEGER WORD(4BITS)  (OUTPUT)
      C                 00   FLAG BIT IN PROPER SEQUENCE
      C                 01   EXCESS DATA ON CASSETTE RECORD
      C                 02   LOW SIGNAL LEVEL(DROP OUT)
      C                 04   COUNTER ERROR (NOT ENOUGH)
      C                 10   CASSETTE PARITY ERROR
      C                 76   7-TRACK RECORD DOES NOT CONTAIN EXPECTED
      C                      NUMBER OF CHARACTERS
      C                 77   LAST CASSETTE RECORD IN 7-TRACK TAPE RECORD
      C                      DOES NOT HAVE FLAG BIT
      C                 76/77   ARE ADDITIONAL TO THOSE PROVIDED BY THE TAPE
      C                         READER. COMBINATIONS OF THE FIRST 5 ERROR
      C                         MESSAGES CAN OCCUR.
      C       NDATA - TOTAL NUMBER OF CASSETTE RECORDS TO BE READ.
      C       NWORDS = LENGTH(1) - THE NUMBER OF CM WORDS TRANSMITTED TO THE
      C                            PROGRAM BLOCK.
      C       NSCA = 0  -  SCALING
      C       NSCA = 1  -  NO SCALING
      C       MLIST = 0 - LIST ORIGINAL DATA WITH NO STATISTICS.
      C               1 - LIST ORIGINAL DATA AND COMPUTES STATISTICS.
      C               2 - LIST ORIGINAL DATA AND COMPUTES STATISTICS PLUS A
      C                   LISTING OF THE EDITED DATA POINTS IS GIVEN.
      C               3 - LISTING OF ALL STATISTICS AND THE FINAL EDITED DATA.
      C           .GE. 4 - ONLY THE STATISTICS ARE LISTED
      C
      C      TAPE1 - INPUT TAPE
      C      TAPE2 - STORE ORIGINAL DATA,I,ZN,NCHECK - REWOUND BEFORE EACH REC
      C      TAPE3 - STORE EDITTED DATA,ICH,IRP,NDATA,(A(J),J=1,NDATA)
      C      TAPE4 - STORE STATISTICS FOR ALL RECORDS
      C      NCH  NREC,NDATA,NBAD,NDIV,RANGE,TIME,TIDVAR,XMAX,XMIN,XMEAN,STDEV
      C
 3           DIMENSION BUF(40),NNN(5),KHAN(50),NCHAN(44)
 3           COMMON/CCM1/NW,NWORDS,NC,NREC,NSCA,SCALE(50),NCOM(8),MLIST,NBAD
 3           COMMON/CCM2/NX(50),NZ(50),ZN(50),NDATA,NVAL,NRECTOT,NTYPE,NCHECK
 3           COMMON/C3/XMAX(50),XMIN(50),XMEAN(50),STDEV(50),NK(300),NDIV,RANGE
 3           COMMON/C4/NK2(300),IR2,KNCH,YMEAN(50),NPROJ,NCH
 3           COMMON A(1)
 3           DATA PARI/.TRUE./
 3           DATA NW,NWORDS,NC/41,40,0/
 3           LOGICAL PARI
 3           READ(5,600) (NCOM(I),I=1,8)
11           READ(5,605) NCHAN
17           READ(5,601)NVAL,NRECTOT,NPROJ
```

EGFUP

```
      READ(5,602) (NX(I),I=1,NVAL)
      NREC = NRECTOT + 3
      READ(5,603) (SCALE(I),I=1,NVAL)
      PRINT 100,NVAL,NRECTOT
      PRINT 101, (NX(I),I=1,NVAL)
      MREC = 0
      REWIND 3
      REWIND 4
  997 READ(5,604) NSCA,NDATA,NSKIP,NFSKIP,MLIST,NDIV,RANGE
      DO 4 I = 1,300
    4 NK(I) = NK2(I) = 0
      DO 29 I = 1,50
      NZ(I) = 0
   29 ZN(I) = 0.
      NCH = NVAL - 1
      REWIND 2
      IF(EOF,5)999,998
  998 PRINT 125, NDATA,NSKIP,NFSKIP
      IF(NSCA.EQ.1.AND.MLIST.GT.0)WRITE(6,1002)
      LREC = MREC + 1
      PRINT 126, LREC
      PRINT 102, (NCOM(I),I=1,8)
      PRINT 124, (SCALE(M),M=1,NVAL)
      CALL ERREIT(1,PARI)
      IF(MLIST.LE.2)2,3
    2 PRINT 104
  104 FORMAT(1H1)
      PRINT 103
      PRINT 303
      PRINT 304
C
C *****SKIP NFSKIP FILES  *****************
C
    3 NPAR = 0
      IF(NFSKIP.EQ.0)GO TO 334
      DO 335 I = 1,NFSKIP
  397 BUFFER IN (1,1) (BUF(1),BUF(40))
  330 CALL SECOND(DUM)
      IF(UNIT,1) 390,397,335,336
  336 NPAR = NPAR+1
      IF(NPAR.LE.10)GO TO 397
      STOP
  335 CONTINUE
C
C ********SKIP NSKIP CASSETTE RECORDS.
C
  334 IF(NSKIP.EQ.0)GO TO 333
      DO 910 I = 1,NSKIP
  910 CALL TAPRD
  333 REWIND 15
      NDAD = 0
      IF(MLIST.GT.2)30,50
   30 DO 31 I = 1,NDATA
      NDA? = 4
      CALL TAPRD
      DO 32 K = 1,NVAL
```

B3

```
541          ZN(K) = NZ(K)
543       32 ZN(K) = ZN(K)*SCALE(K)
550          GO TO(40,41,330),NTYPE
557       40 WRITE(2) I,(ZN(M),M=1,NVAL),NCHECK
574          GO TO 31
575       41 WRITE(15) I,(ZN(M),M=1,NVAL),NCHECK
412          NBAD = NBAD+1
424       31 WRITE(2) I,(ZN(M),M=1,NVAL),NCHECK
434          GO TO 830
434       50 DO 900 I = 1,NDATA
436          INCK = I
436          CALL TAPRD
437          DO 6 KZ = 1,NVAL
441          ZN(KZ) = NZ(KZ)
443        6 ZN(KZ) = ZN(KZ)*SCALE(KZ)
450          IF(MLIST.EQ.0.AND.NTYPE.LT.3)7,8
457        7 CONTINUE
457          GO TO (9,10,11),NTYPE
466        9 PRINT 106, NCHECK,I,(ZN(M),M=1,20)
500          PRINT 306, (ZN(M),M=21,40)
506          PRINT 307, (ZN(M),M=41,NVAL)
521          GO TO 900
522       10 PRINT 107, NCHECK,I,(ZN(M),M=1,20)
534          PRINT 306, (ZN(M),M=21,40)
542          PRINT 307, (ZN(M),M=41,NVAL)
555          GO TO 900
556       11 STOP
560        8 CONTINUE
560          GO TO (810,820,830),NTYPE
       C
       C *********GOOD DATA ROUTINE ******
       C
567      810 PRINT 106,NCHECK,I,(ZN(M),M=1,20)
601          PRINT 306,(ZN(M),M=21,40)
607          PRINT 307,(ZN(M),M=41,NVAL)
622          WRITE(2) I,(ZN(M),M=1,NVAL),NCHECK
637          GO TO 900
       C
       C ******BAD DATA ROUTINE *******
       C
640      820 PRINT 107, NCHECK,I,(ZN(M),M=1,20)
652          PRINT 306,(ZN(M),M=21,40)
660          PRINT 307,(ZN(M),M=41,NVAL)
673          WRITE(15) I,(ZN(M),M=1,NVAL),NCHECK
710          NBAD = NBAD+1
712          IF(NBAD.GT.300)GO TO 5
715          NK(NBAD) = I
716        5 WRITE(2) I,(ZN(M),M=1,NVAL),NCHECK
733      900 CONTINUE
       C
       C ****** LIST ERROR CASSETTE RECORDS. **************
       C
736      830 PRINT 108
742          IF(MLIST.EQ.0)GO TO 997
743          PRINT 109, I,NBAD
753          IF(NBAD.EQ.0)GO TO 706
```

- B4 -

EGF&P

```
 754         REWIND 15
 756         PRINT 110
 762         PRINT 103
 766         PRINT 303
 772         PRINT 304
 776         DO 706 J = 1,NBAD
1000         READ(15) I,(ZN(M),M=1,NVAL),NCHECK
1015         PRINT 106, NCHECK,I,(ZN(M),M=1,20)
1027         PRINT 306,(ZN(M),M=21,40)
1035         PRINT 307,(ZN(M),M=41,NVAL)
1050     700 CONTINUE
1053     706 IF(INCK.LE.(NDATA/10)) GO TO 999
1060         IF(NTYPE.GE.3)NDATA = INCK-1
1063         CALL STAT(MREC)
1065         GO TO 997
       C 999 IF(MLIST.EQ.0)GO TO 28
1066     999 CONTINUE
1066         MR = MREC
1070         REWIND 4
1072      12 DO 13 I = 1,NVAL
1074      13 KHAN(I) = I
1100         DO 14 J = 1,MR
1101         I1 = 1
1102         I2 = 10
1103         READ(4) MREC,NDATA,NBAD,NCH,TIME,TIOVAR,(XMAX(M),M=1,NCH),
            1(XMIN(M),M=1,NCH),(XMEAN(M),M=1,NCH),(STDEV(M),M=1,NCH)
1153         PRINT 400,(NCOM(I),I=1,8),NDATA,TIME
1165         DO 14 K = 1,5
1167         PRINT 401,(KHAN(I),I=I1,I2)
1201         PRINT 406, (NCHAN(I),I=I1,I2)
1214         PRINT 402,(XMAX(I),I=I1,I2)
1227         PRINT 403,(XMIN(I),I=I1,I2)
1242         PRINT 404,(XMEAN(I),I=I1,I2)
1255         PRINT 405,(STDEV(I),I=I1,I2)
1270         I1 = I1+10
1272         I2 = I2+10
1273         IF(I2.GT.40)I2 = 44
1276      14 CONTINUE
1303      28 IF(MLIST.EQ.2.OR.MLIST.EQ.3)GO TO 26
1313         STOP
1315      26 PRINT 113
1321         REWIND 3
1323         DO 25 I = 1,MREC
1325         PRINT 114, I
1332         DO 25 K = 1,NCH
1334         READ(3) ICH,IRR,NDATA,(A(J),J=1,NDATA)
1354         PRINT 111, NDATA,K
1364         PRINT 112, (A(J),J=1,NDATA)
1377      25 CONTINUE
1404     102 FORMAT(5X,8A10//)
1404     103 FORMAT(T3,*ERROR*,T9,*REC.*/T3,*FLAG*,T9,*NO.*,T15,*CH1*,T21,*CH2*
            1,T27,*CH3*,T33,*C4*,T39,*CH5*,T45,*CH6*,T51,*CH7*,T57,*CH8*,T63,*C
            2H9*,T69,*CH10*,T75,*CH11*,T81,*CH12*,T87,*CH13*,T93,*CH14*,T99,*CH
            315*,T105,*CH16*,T111,*CH17*,T117,*CH18*,T123,*CH19*,T129,*CH20*//)
1404     107 FORMAT(1X,1H*,O2,1X,I5,20F6.0)
1404     106 FORMAT(2X,O2,1X,I5,20F6.0)
```

EGFGP

```
1404     108 FORMAT(1H1,9X,26H**************************/10X,1H*,24X,1H*/
            110X,26H*  ERROR SAMPLES SUMMARY */10X,1H*,24X,1H*/
            210X,26H**************************//)
1404     109 FORMAT(10X,*TOTAL NUMBER OF CASSETTE SAMPLES = *,
            115,//10X,*NUMBER OF ERROR CASSETTE SAMPLES = *,I5//)
1404     110 FORMAT(10X,*CONTENTS OF ERROR CASSETTE SAMPLES*//)
1404     111 FORMAT(//10X,I5*  DATA POINTS FOR CHANNEL *I4//)
1404     112 FORMAT(10X,10F10.2)
1404     113 FORMAT(1H1)
1404     114 FORMAT(///10X*RECORD NUMBER *I4//)
1404     124 FORMAT(5X*SCALE FACTORS*//5X,12F10.5//)
1404     125 FORMAT(1H1,4X*NO. OF CASSETTE SAMPLES READ*12X,I5/5X*NO. OF 4-TRAC
            1K TAPE SAMPLES SKIPPED*5X,I5/5X*NO. OF 7-TRACK TAPE FILES SKIPPED*
            27X,I5//)
1404     126 FORMAT(5X*RECORD NO. *I5//)
1404     303 FORMAT(T14,*CH21*,T20,*CH22*,T26,*CH23*,T32,*CH24*,T38,*CH25*,T44,
            1*CH26*,T50,*CH27*,T56,*CH28*,T62,*CH29*,T68,*CH30*,T74,*CH31*,T80,
            2*CH32*,T86,*CH33*,T92,*CH34*,T98,*CH35*,T104,*CH36*,T110,*CH37*,T1
            316,*CH38*,T122,*CH39*,T128,*CH40*//)
1404     304 FORMAT(T13,*CH41*,T19,*CH42*,T25,*CH43*,T31,*CH44*//)
1404     306 FORMAT(11X,20F6.0)
1404     307 FORMAT(12X,20F6.0)
1404     400 FORMAT(1H1,////////10X*SUMMARY OF STATISTICAL DATA FOR  *8A10/10X*
            1NUMBER OF SAMPLES = *I5/10X*TIME IN HOURS FROM START OF TAPE *F10.
            20///)
1404     401 FORMAT(/6X*CHANNEL   *10(I8,3X))
1404     402 FORMAT(6X*MAX.VALUE*10E11.3)
1404     403 FORMAT(6X*MIN.VALUE*10E11.3)
1404     404 FORMAT(6X*MEANVALUE*10E11.3)
1404     405 FORMAT(6X*STDEV    *10E11.3)
1404     406 FORMAT(6X*CH.NAME  *10(3X,A5,3X))
1404     500 FORMAT(8A10)
1404     601 FORMAT(3I5)
1404     602 FORMAT(16I5)
1404     603 FORMAT(12F6.0)
1404     604 FORMAT(6I5,F5.0)
1404     605 FORMAT(16A5)
1404     100 FORMAT(1H1,4X,*NUMBER OF INPUT CHANNELS*,19X,I5/5X,*NUMBER OF SAMP
            1LES IN EACH 7-TRACK TAPE FILE*,I5/5X,
            2*ARRAY CONTAINING NUMBER OF 4-BIT CASSETTE CHARACTERS PER RECORDED
            3 INPUT CHANNEL*//)
1404     101 FORMAT(5X,20I5)
1404    1002 FORMAT(3X,*NO SCALING OF FINAL EDITED DATA */)
1404    1003 FORMAT(5X,*COMPUTER OUTPUT OPTION  NUMBER*,I3,*   (SEE PROGRAM WRI
            1TE UP)*//)
1404         STOP
1406         END
```


EGFHP

APPENDIX C

ANCHOR CABLE MODULUS

A length of the anchor cable was tested statically to determine the calibration of the L.V.D.T. on channels 41-44. The test arrangement was conventional except that special grips for the 6 cable length had to be manufactured. Before readings were obtained the cable was pulled to 250 kips several times to set the wires. This set was preserved by testing above 100 kip. loading. Below this loading the displacement results were not reproducible. The loading coincided with the field situation where an initial force of 120 kips exists about which cyclic behavior is registered. The test range was 100-300 kips. Displacement transducer output was measured through a voltmeter and the readings were taken to coincide with 25 kip. increments.

Fig. C1 shows typical results of the eighth and ninth cycles with 6 volt. input. Fig. C2 is of the displacement transducer arrangement.

Cable data are:

127 - 3/16" diameter wires wound into a single strand of 2-1/4" diameter.

Net area = 3.51 $in.^2$

Gross area = 3.98 $in.^2$

The effective modulus of elasticity obtained were:

5 volt input $E = 27.53 \times 10^3$ k.s.i.

6 volt input $E = 27.32 \times 10^3$ k.s.i.

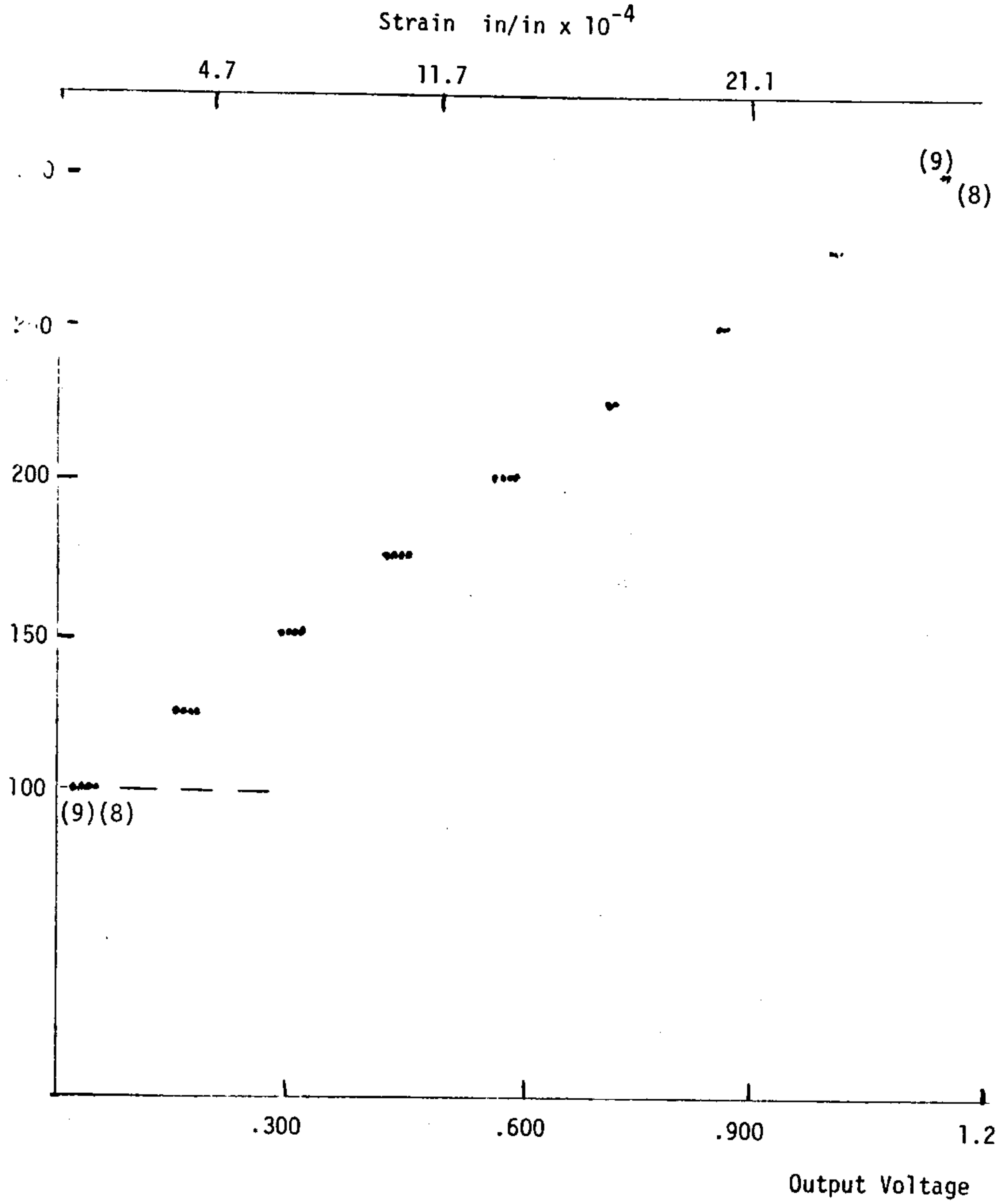


FIG. C 1

TYPICAL RESULTS OF CABLE TEST

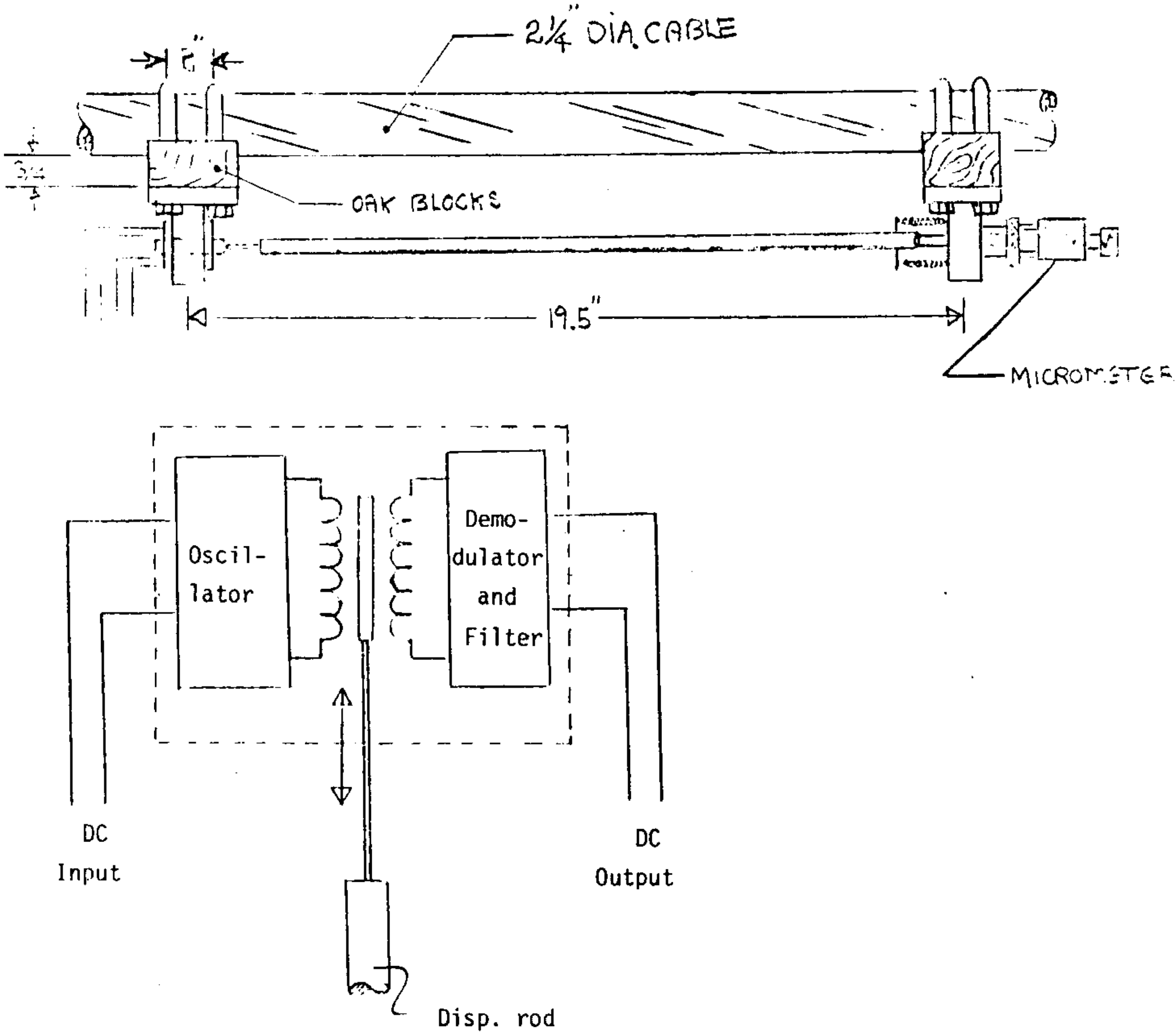


FIG. C 2

DISPLACEMENT TRANSDUCER

APPENDIX D

FATIGUE EXPERIMENT DESIGN

by

C. B. Brown and R. Vasu

The test program proposed can be applied to the elements of the bridge considered as possibly critical in fatigue. In the first instance the vertical trunnion anchor rods, central lock connectors and the horizontal trunnion equalizer frames would be considered. The last of these would have only one component tested. The test specimens for the lock and anchor rods would be prepared according to ASTM E-466-72T 1974 specification. The specimens for the frame component will be prototypes.

Test machinery has to be restricted to that available. Essentially these are a Universal Testing machine and a loading frame in the load range required. Loading is by a coupled jack in the pulsator range of 250-500 c.p.m. The anchorage rod and lock connection specimens will be tested on the loading frame in the set-up of Fig. D1. The limited capacity of the frame will make it necessary to test the prototype of the horizontal trunnion frame component in the U.T.M. Fig. D2 shows the set up for this experiment. In both arrangements one end of the specimen will be pinned and the other end driven by the pulsating jack.

The pulsator is within the anticipated loading range. Essentially it has a jack of variable stroke (0-400 cm^3) which provides a maximum pressure of 200 kg/cm^2. As stated previously the rate is in the range 250-500 c.p.m. Variable input is arranged by servo feed back controls and accurate load indication is achieved by a Amsler measuring valve unit.

The input involves the load level and cycles at that load level. The load level is related in this work to the strain measurements at critical sections. These measurements have been analyzed and statistics produced. The measure of the variability of the strain about a mean level is given by the variance (p. 25):

$$\sigma^2 = m_2 - m_1^2$$

A function $C(\tau)$ may be constructed for a strain signal, X, at time t and at $t + \tau$ over a signal of length T as

$$C(\tau) = \lim_{T \to \infty} \frac{1}{T} \int_{-T/2}^{T/2} X(t)\, X(t + \tau)\, dt$$

This may be reduced to

$$C(\tau) = \int_{-\infty}^{\infty} P(f)\, e^{i2\pi f\tau}\, df$$

where

$$P(f) = \lim_{T \to \infty} \frac{1}{T} \left| \int_{-T/2}^{T/2} X(t)\, e^{-i2\pi f\tau}\, dt \right|^2$$

The representation $P(f) \cdot df$ is of the contribution to σ^2 between frequencies f and $f + df$. Then

$$\sigma^2 = \int_0^{\infty} P(f)\, df$$

Thus the oscillatory strains and hence forces are indicated by the variance. The frequency content of the variance is given by the spectral density, $P(f)$. The proportion of the variance between frequencies 0 and f_1 is $\sigma_1^2 = \int_0^{f_1} P(f)\, df$ and hence it may be claimed that forces described by

σ_1^2 and above occur at frequencies above f_1 . For a time of T_1 , the number of cycles above σ_1^2 will be $f_1 T_1$.

The above approach allows a loading history to be prescribed which can be readily associated with the actual conditions.

Consideration of the longevity of the structural element due to fatigue requires that the damage at any time be describable. Such a measure of damage gives zero for the initial state and unity at failure. If there are N cycles for this measure $D = 1$ then for $N_i < N$ the value of $D < 1$ and

$$D = D \left(\frac{N_i}{N}\right)$$

The N cycles are with maximum stress level S and

$$N = N(S)$$

This means that a function can be developed for the dependence of the number of cycles to failure for a maximum oscillatory stress S. A stress limit, S_L , exists where $N \to \infty$. This is the fatigue limit. In the real loading situation the probable number of cycles per second at S_i is $p(S_i)$. Miner's rule is a linear statement for fatigue failure under varying levels of stress. Thus,

$$\sum_i \frac{N_i}{N(S_i)} = 1$$

is the law where N_i is the number of cycles at S_i and $N(S_i)$ the number of cycles to failure at a repetition of S_i . Then

$$N_i = p(S_i)\, T_i$$

where T_i is the time of oscillation at S_i . From this

$$D_i = \frac{T_i\, p(S_i)}{N(S_i)}$$

and

$$\frac{D_i}{T_i} = \frac{p\ (S_i)}{N\ (S_i)}$$

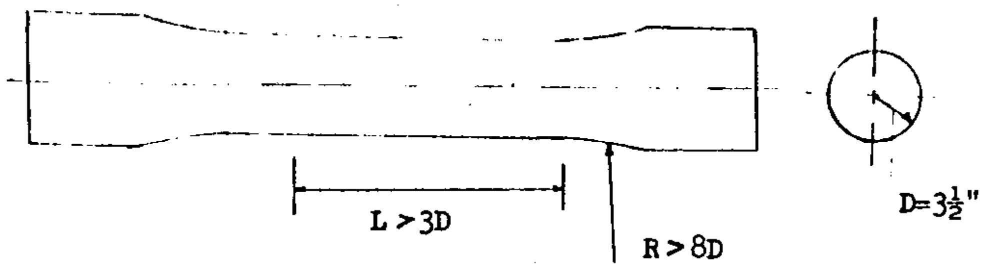
As $\sum_i T_i = T$, the time to failure, and $\sum_i D_i = 1$ at failure, then

$$\frac{1}{T} = \sum_i \frac{p(S_i)}{N(S_i)}$$

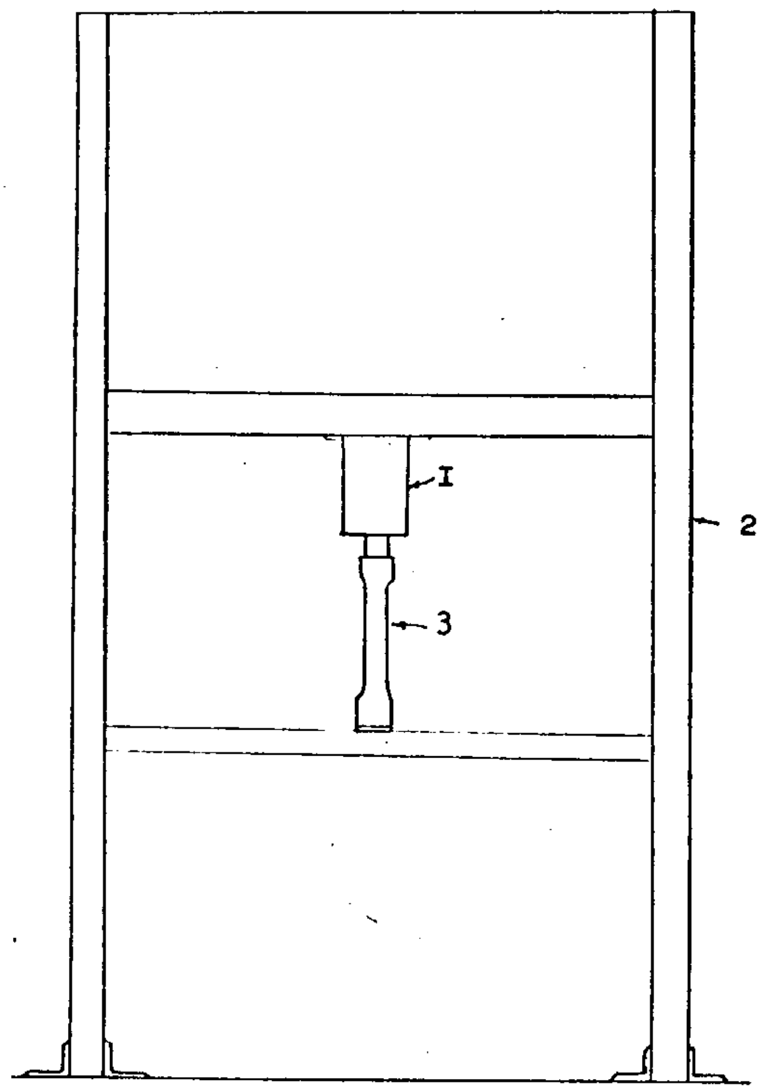
and hence the time to failure is

$$T = \left\{ \sum_i \frac{p(S_i)}{N(S_i)} \right\}^{-1}$$

For this prediction a law for $N(S_i)$ must be obtained from the experimental work envisaged in this Appendix.



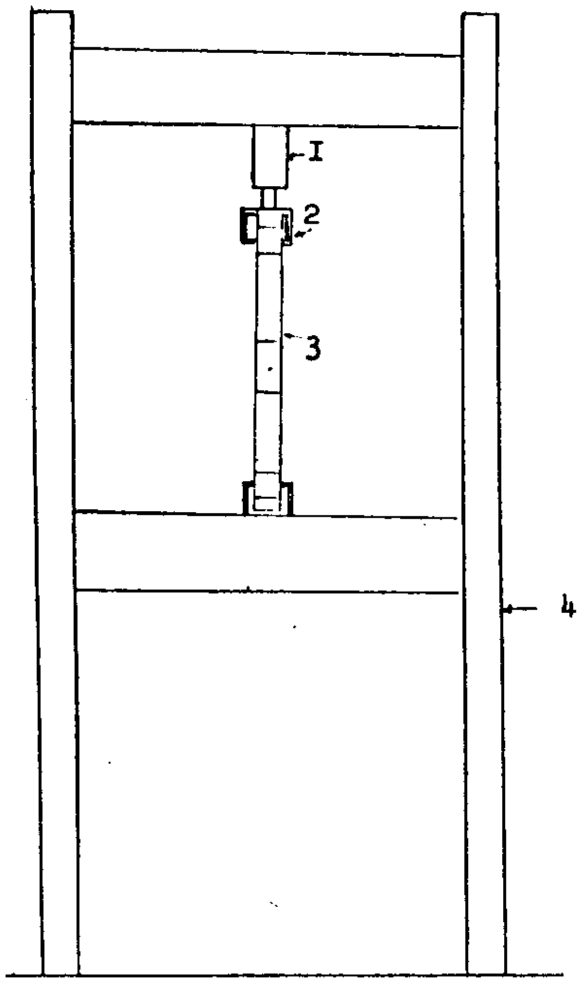
SPECIMEN: ANCHOR ROD AND CONNECTING ROD



TEST SET UP FOR ANCHOR ROD & CONNECTING ROD

I. JACK
2. LOADING FRAME
3. SPECIMEN

FIG. D 1



TEST SET UP FOR EQUILIZER FRAME(HORIZONTAL TRUNION)

I. JACK
3. SPECIMEN
2. FIXTURES
4. UNIVERSAL TESTING MACHINE

FIG. D 2