SSC-238

( SL-7-1 )

# DESIGN AND INSTALLATION OF A SHIP RESPONSE INSTRUMENTATION SYSTEM ABOARD THE SL-7 CLASS CONTAINERSHIP S.S. SEA-LAND McLEAN



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This report is one of a group of Ship Structure Committee Reports which describes the SL-7 Instrumentation Program. This program, a jointly funded undertaking of Sea-Land Service, Inc., the American Bureau of Shipping and the Ship Structure Committee, represents an excellent example of cooperation between private industry, regulatory authority and government. The goal of the program is to advance understanding of the performance of ships' hull structures and the effectiveness of the analytical and experimental methods used in their design. While the experiments and analyses of the program are keyed to the SL-7 Containership and a considerable body of data will be developed relating specifically to that ship, the conclusions of the program will be completely general, and thus applicable to any surface ship structure.

The program includes measurement of hull stresses, accelerations and environmental and operating data on the SS Sea-Land McLean, development and installation of a microwave radar wavemeter for measuring the seaway encountered by the vessel, a wave tank model study and a theoretical hydrodynamic analysis which relate to the wave induced loads, a structural model study and a finite element structural analysis which relate to the structural response, and installation of long term stress recorders on each of the eight vessels of the class. In addition, work is underway to develop the initial correlations of the results of the several program elements.

Results of each of the program elements will be published as Ship Structure Committee Reports and each of the reports relating to this program will be identified by an SL- designation along with the usual SSC- number. A list of all of the SL- reports published to date is included on the back cover of this report.

This report describes the details of the instrumentation installation on the vessel. The data collected will be the subject of separate reports which will be published later.

W. F. REA, III
Rear Admiral, U. S. Coast Guard
Chairman, Ship Structure Committee

SSC-238

(SL-7-1)

Technical Report

on

Project SR-211, "SL-7 Data Collection Program"

to the

Ship Structure Committee

# DESIGN AND INSTALLATION OF A SHIP RESPONSE INSTRUMENTATION SYSTEM ABOARD THE SL-7 CLASS CONTAINERSHIP S.S. SEA-LAND McLEAN

by

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under

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1973

## ABSTRACT

This report describes the transducers, cabling, signal-conditioning, and recording elements of the instrumentation system installed aboard the SL-7 Containership *S.S. SEA-LAND McLEAN*. It includes a detailed summary of the strain-gage bridge circuits, locations of all transducers, and a description of the various operating modes and options available for recording data from more than 100 strain gages, accelerometers, and motion sensors.

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## I. INTRODUCTION

The S.S. SEA-LAND McLEAN (Figure 1) is a member of a new class of high-speed, large-capacity container vessels required by the continuing growth of the shipping industry. Characteristics of this vessel are provided in Table I. The instrumentation system described in this report is part of a research program which takes advantage of the opportunity to evaluate fully, from both analytical and experimental approaches, the design and response of this unique vessel during the early phases of its development and deployment. Included in the series of studies bearing on the SL-7 class vessels are: Finite Element Analysis, Structural Model Tests, Bending-Moment Tank Model Tests, Computer-Simulated Load Response Analysis, Full-Scale Vessel Instrumentation and Data Collection, and Data Analysis and Correlation.

It is with the full-scale instrumentation and data collection that this report concerns itself. More specifically, it describes the instrumentation portion only, as installed prior to the first voyage. A tabulation of full-scale ship parameters selected for measurement appears in Table II. The instrumentation system was designed to measure these parameters within the framework of the additional criteria set forth in Table III. Detailed system design was begun in June 1971, and the system was installed aboard the vessel during May 1972.

## II. GENERAL

The major components of the shipboard instrumentation system are located in the Instrument Room on the starboard side of the after deckhouse in an area designated as the "slop chest". The instrumentation console (Figure 2) is bolted to a welded foundation, and is oriented in the fore-and-aft direction. Transducer inputs are received by way of fixed cabling at three large deck-to-overhead junction boxes mounted on the port bulkhead of the instrument room. Distribution of signals to the console is made by cables from these junction boxes, which are designated JB 13, 14, and 15. Power for console operation is provided by a separate power distribution panel mounted adjacent to the junction boxes. The locations of the various transducers, junction boxes, and associated cabling are shown in Figures 3 and 4.

## III. CABLING TECHNIQUES

The onboard cabling required was separated into two phases: ship cabling, and transducer cabling. Each is discussed in the following sections.

### A. Ship Cabling

To provide a relatively permanent and finished form of cabling, a ship cabling system was developed. This system consists of junction boxes (JB's) at various locations along the vessel, and multiconductor cables from these to the Instrument Room. This system was installed with the other ship wiring using the same routing wherever practical. This system is semi-permanent, and can be used for other functions once the instrumentation system has been removed.

The great majority of junction boxes are located in the port and starboard box girders, with a few additional JB's located in the vicinity of specialized transducers (see Figure 4). All cables carry the prefix number 612, and are so marked at every termination. Cable diagrams for this system are carried as an integral part of the ship's wiring documentation.

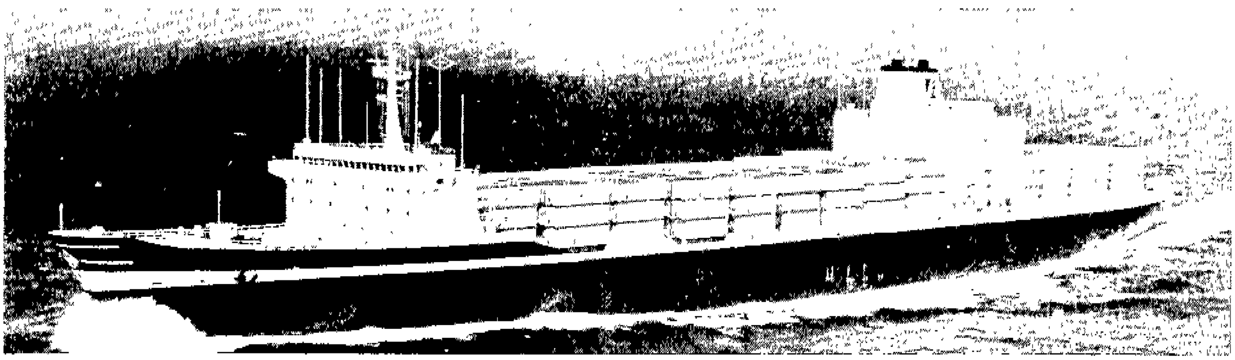


FIGURE 1 - *S. S. SEA-LAND McLEAN*

TABLE I - CHARACTERISTICS OF *S. S. SEA-LAND McLEAN*

| | |
|---|---|
| Name· | SEA-LAND McLEAN |
| Builder: | Rotterdam Dry Dock (Hull 330) |
| Class: | SL-7 Containership |
| Length, overall | 946' 1-1/2" |
| Length, between perpendiculars | 880' 6" |
| Beam, molded | 105' 6" |
| Depth to main deck, forward | 64' 0" |
| Depth to main deck, aft | 68' 6" |
| Draft, design | 30' 0" |
| Draft, scantling | 34' 0" |
| Dead weight - long tons | 27,315 |
| Displacement (34' 0" draft) - long tons | 50,315 |
| Machinery | Two separate cross-compound steam turbines driving two propeller shafts |
| Shaft horsepower-maximum continuous, both shafts | 120,000 |
| Propeller RPM | 135 |
| Speed, maximum, knots | 33 |
| Center of gravity - full load | 399.32' forward of aft perpendicular 42.65' above base line |

Container Capacity

| | 8' x 8.5' x 35' | 8' x 8.5' x 40' | Total |
|---|---|---|---|
| Below deck | 554 | 140 | 694 |
| Above deck | 342 | 60 | 402 |
| TOTAL | 896 | 200 | 1,096 |

## TABLE II - SIGNAL DESCRIPTION

GAGE GROUP 1 (Recorder No. 1)

| Channel(s) | |
|---|---|
| 1 | Vertical Bending: Longitudinal stress gages, P&S, under deck, near midship (Frame 186 1/4), in box girder wired to eliminate longitudinal horizontal bending; primary reference stress; provides data comparable to SSC Project SR-153 and ABS 5-Vessel program. This signal serves as a common reference with each group of gages. |
| 2 | Midship Torsional Shear: Shear rosettes amidship (Frame 186 1/4) P&S, on sideshell at neutral axis wired into single bridge to eliminate shear associated with vertical bending. Will show shear associated with torsion and horizontal bending. Primary value is in comparison with similar SS BOSTON data. |
| 3 | Wave Height: Open channel to accommodate output of a wave height sensor. |
| 4,5 | Roll and Pitch: Pendulums, roll and pitch angle transducers located close to vertical and longitudinal vessel CG (Frame 178). Rigid body motions. Similar to BOSTON data; useful in container load evaluation. |
| 6,7 | Hull Accelerations: Vertical and transverse accelerometers located at vessel CG (Frame 178), similar to array used on BOSTON. Vertical unit required for heave acceleration. |
| 8,9 | Hull Accelerations: Vertical and transverse accelerometers located forward (Frame 290). Rigid body as well as whipping motions. Useful for comparison with WOLVERINE STATE and BOSTON data, and probably indicative of most severe accelerations on vessel. |
| 10 | Multiplexed Ship Parameters: RPM, rudder angle, wind speed and direction. |
| 11 | Horizontal Bending: Longitudinal stress gages, P&S, near midship (Frame 186 1/4), at neutral axis; wired to provide a longitudinal horizontal bending signal. |
| 12,13 | Shear-Forward: Shear rosettes near forward quarter point (Frame 265-266), P&S, on sideshell, at neutral axis. P&S recorded separately since shear associated with vertical bending may be of major interest here; signals can be recombined on playback to produce shear component associated with vertical bending or torsion. |

## TABLE II - (CONT'D)

GAGE GROUP 2 (Recorder No. 2, Mode A)

| Channel(s) | |
|---|---|
| 1 | Vertical Bending: Reference signal |
| 2,3,4,5,6,7 | Longitudinal Stress Gages: Six stress gages at deck, neutral axis, and bottom (lower sideshell), P&S, amidship (Frame 186 1/4). Recorded separately, but data can be combined to provide signals proportional to longitudinal vertical bending, longitudinal horizontal bending, and warping longitudinal stresses. Neutral axis gages added to simplify direct evaluation of transverse stresses and subsequent separation of vertical and warping stresses. First time this array has been used. |
| 8,9 | Shear-Aft: Shear rosettes near after quarter point (Frame 87-88) P&S, on sideshell, at neutral axis*P&S recorded separately. Torsional shear was initial concern, but present interest is in shear associated with vertical bending as well. Separate recording permits recombination of signals to produce shear component associated with vertical bending or torsion. *Actual location 18.2' above N.A. |
| 10,11 | Deckhouse Accelerations: Vertical and transverse accelerometers mounted high near centerline in the forward house, and transverse and longitudinal accelerometers in the after house. Any two of the four signals may be recorded at one time. Primary interest is in possible springing or higher frequency vibratory effects. |
| 12,13 | Box Girder Shear: Shear rosettes located on overhead and deck of starboard box girder. Each recorded independently; a torsional shear in the box girder can be reduced from these signals. |

GAGE GROUP 3 (Recorder No. 2, Mode B)

| Channel(s) | |
|---|---|
| 1 | Vertical Bending: Reference signal. |
| 2 thru 13 | After Hatch Corner: Four, three-arm strain gage rosettes will be placed in an athwartship array under the deck between Frame 143-144, just forward of the after house. Of interest here is the transfer of longitudinal stress (from all sources--torsion, vertical bending, etc.) from the box beam ligament structure in way of the holds to the relatively complete and rigid hull at the house. The gross hatch corner stress concentration will also be evaluated port and starboard. Original suggestion of ABS, |

## TABLE II - (CONT'D)

Channel(s)

but this and following locations shown to be of concern in California model work and British, German, and Japanese model and full-scale tests.

GAGE GROUP 4 (Recorder No. 2, Mode C)

This gage group is the same as Gage Group 3, except that the rosettes are located at one of the following positions:

5 Rosettes at Frame 226-227 (hatch transition)

5 Rosettes at Frame 258-260 (hatch transition) and

4 Rosettes at Frame 290-291 (aft of Fwd Deckhouse)

Since Gage Group 4 consists of 14 rosettes with 3 elements per rosette for a total of 42 separate signals; some means was required to allow for a selection of inputs into the 12 recorder channels available.

A patching unit designated the "Rosette Selection Box" (RSB) has been installed in the starboard box girder at approximately Frame 272. This unit takes the 14 rosette signals as inputs and by means of patching cable allows the operator to select any 4 rosettes as input to the recorder. The only restriction is that all elements, i.e., the A, B, and C arms of any rosette must be recorded together.

GAGE GROUP 5 (Recorder No. 2, Mode D)

| Channel(s) | |
|---|---|
| 1 | Vertical Bending: Reference signal. |
| 2,3,4,5 | Gages in Transverse Deck Girder: Four single gages mounted at the corners of a transverse deck girder, Frames 242-244. Double-S bending in girder used as measure of torsional hull deflection at that frame. Similar to BOSTON arrays. Or, by PSU selection, four single strain gages around the hull section at Frame 240 (2 top, 2 bottom) to measure strain distribution at this location. |
| 6,7,8,9 | Gages in Transverse Deck Girder: Same as above at Frames 194-196. |
| | In addition to the four corner gages, four additional single element gages have been placed at the midpoint of each dimension of the girder. Four 2-element shear gages have been installed at the quarter points of the two side walls. |

## TABLE II - (CONCLUDED)

| | |
|---|---|
| | In a manner similar to the rosette selection technique it was again necessary to select four of twelve signals available for recording. This time a similar Girder Selection Box (GSB) was installed in the starboard box girder at Frame 194.<br><br>The selection was limited to three possible combinations due to wiring and bridge requirements. The three possible patches are:<br><br>(1) 4 corner gages<br>(2) 4 midpoint gages<br>(3) 4 shear gages<br><br>It is possible to mix signals but additional changes are required at the signal conditioning equipment. |
| 10,11,12,13 | Gages in Transverse Deck Girder: Same as above at Frames 78-80. |



## TABLE III - ADDITIONAL DESIGN CRITERIA FOR THE INSTRUMENTATION SYSTEM

1. The system should be semiautomatic, and suitable for data collection on manned voyages during the 1972-73 and 1973-74 operating seasons.
2. The data should be in a format compatible with previous investigations to make maximum use of programs and techniques already developed.
3. The system should have both flexibility and expansion capability so that as data are obtained and analyzed changes and additions to the parameters monitored could be accomplished with a minimum of difficulty.

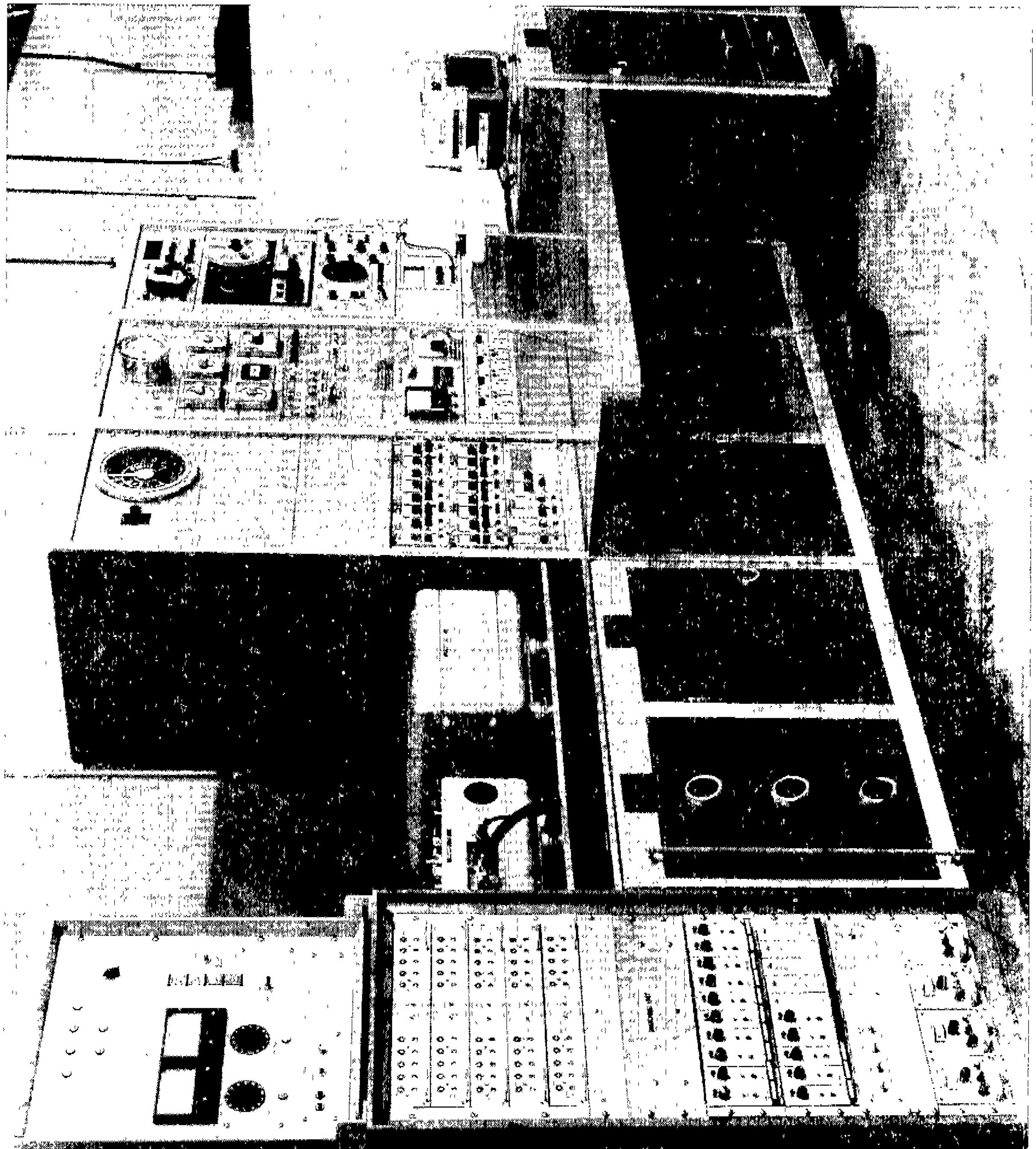


FIGURE 2 - SL-7 INSTRUMENTATION SYSTEM

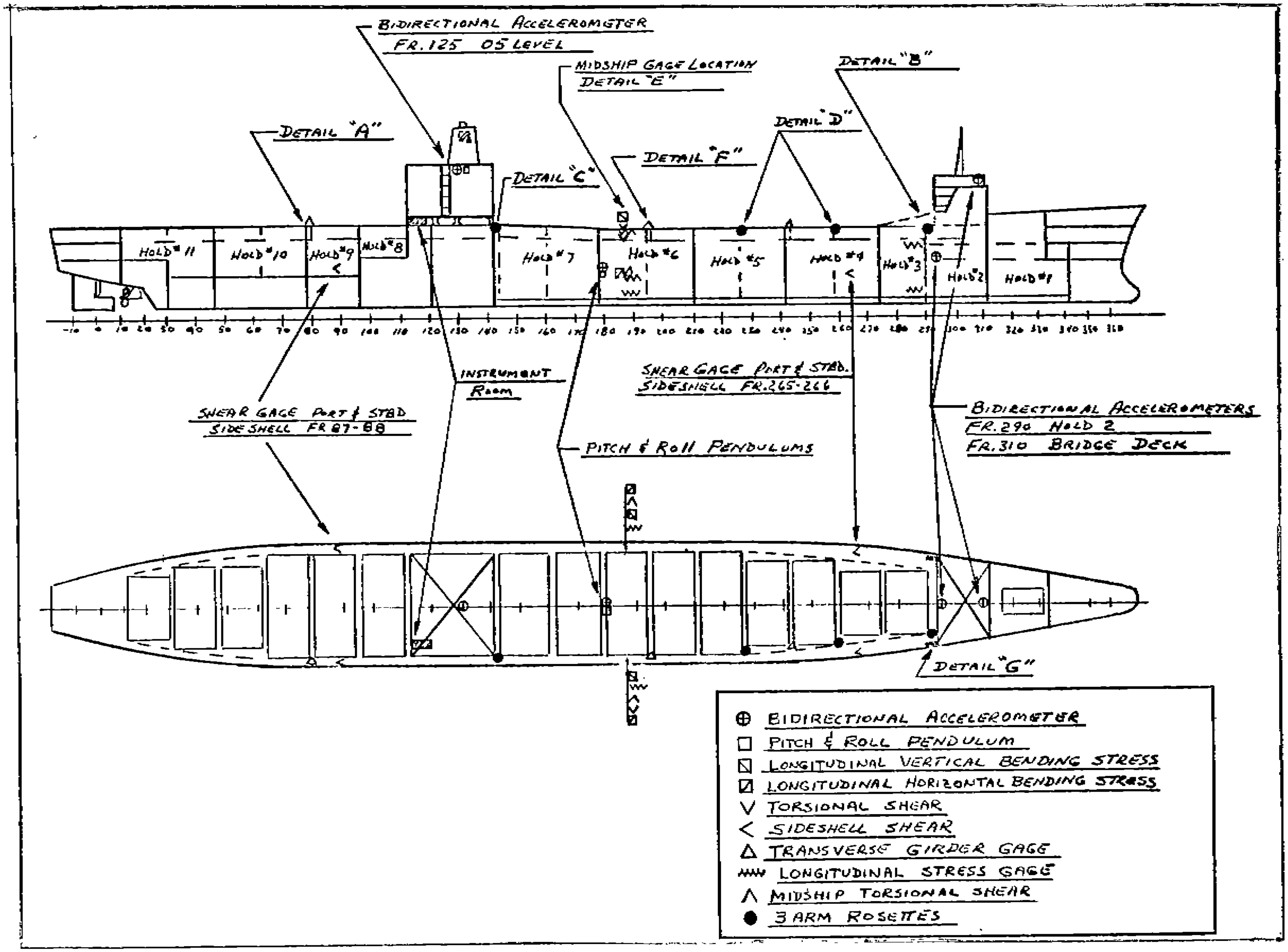



FIGURE 3A - TRANSDUCER LOCATIONS, GENERAL

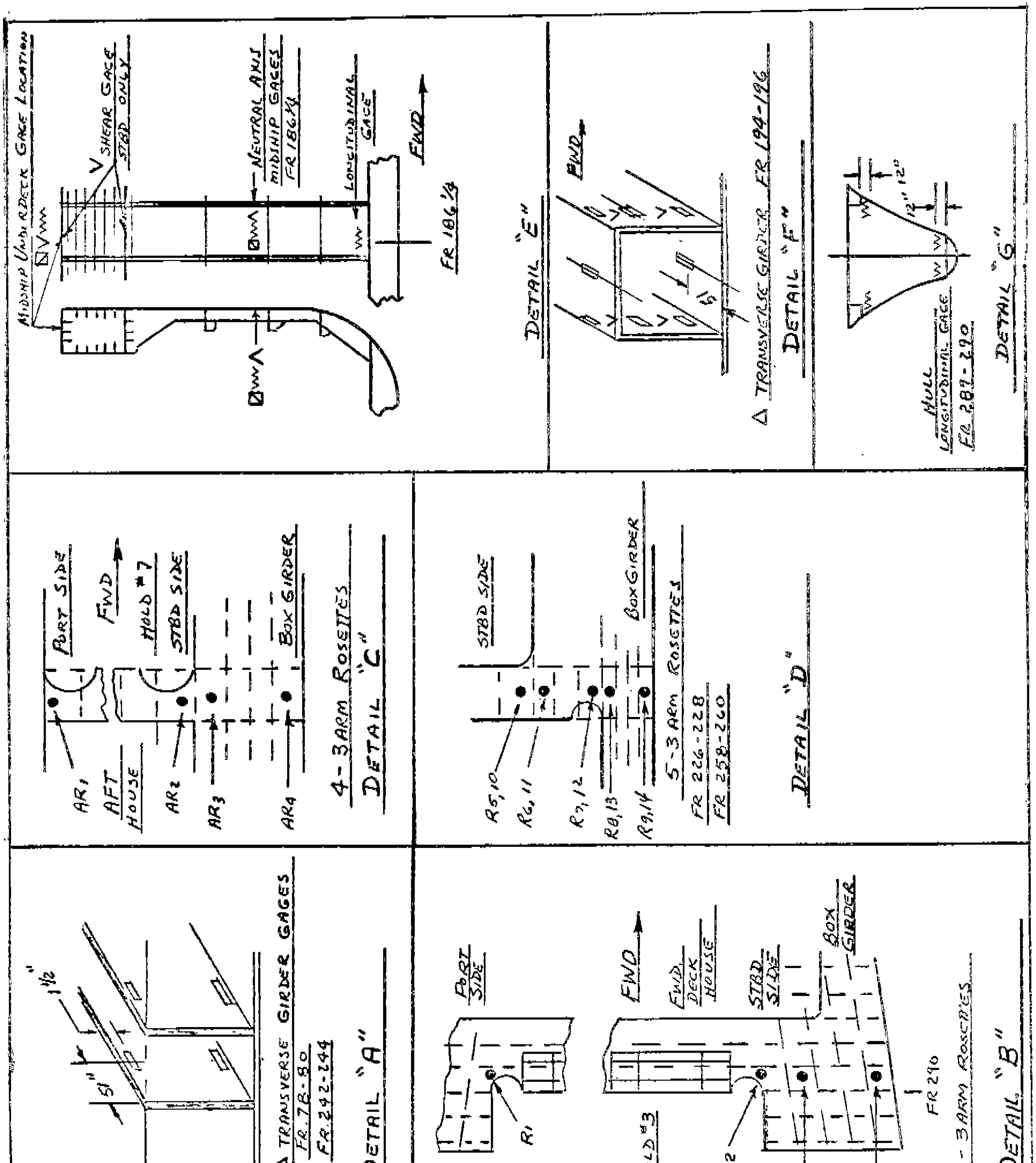



FIGURE 3B - TRANSDUCER LOCATIONS, DETAILED

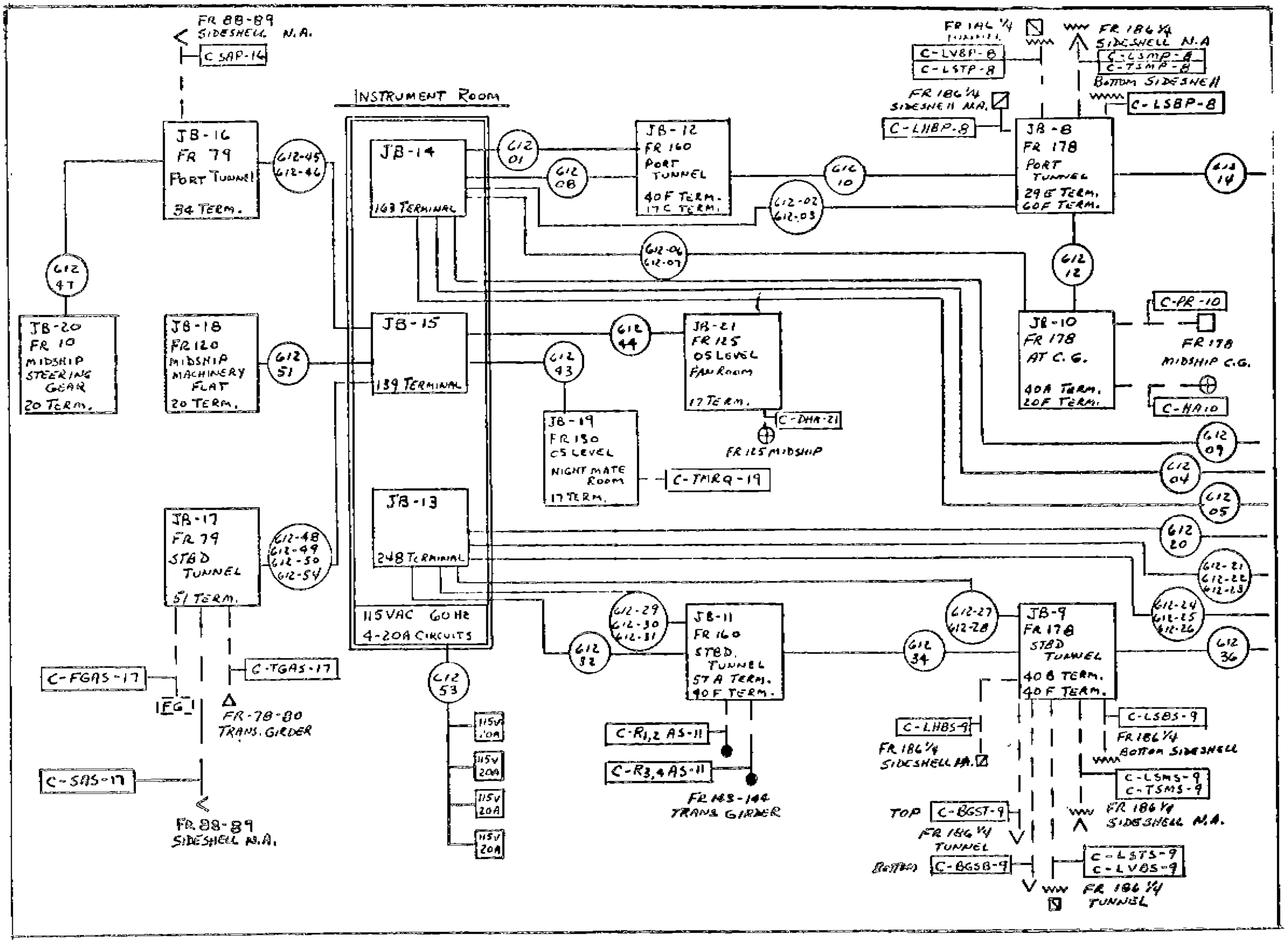


FIGURE 4A - TRANSDUCER, JUNCTION BOX, AND CABLE DIAGRAM, AFT SECTION

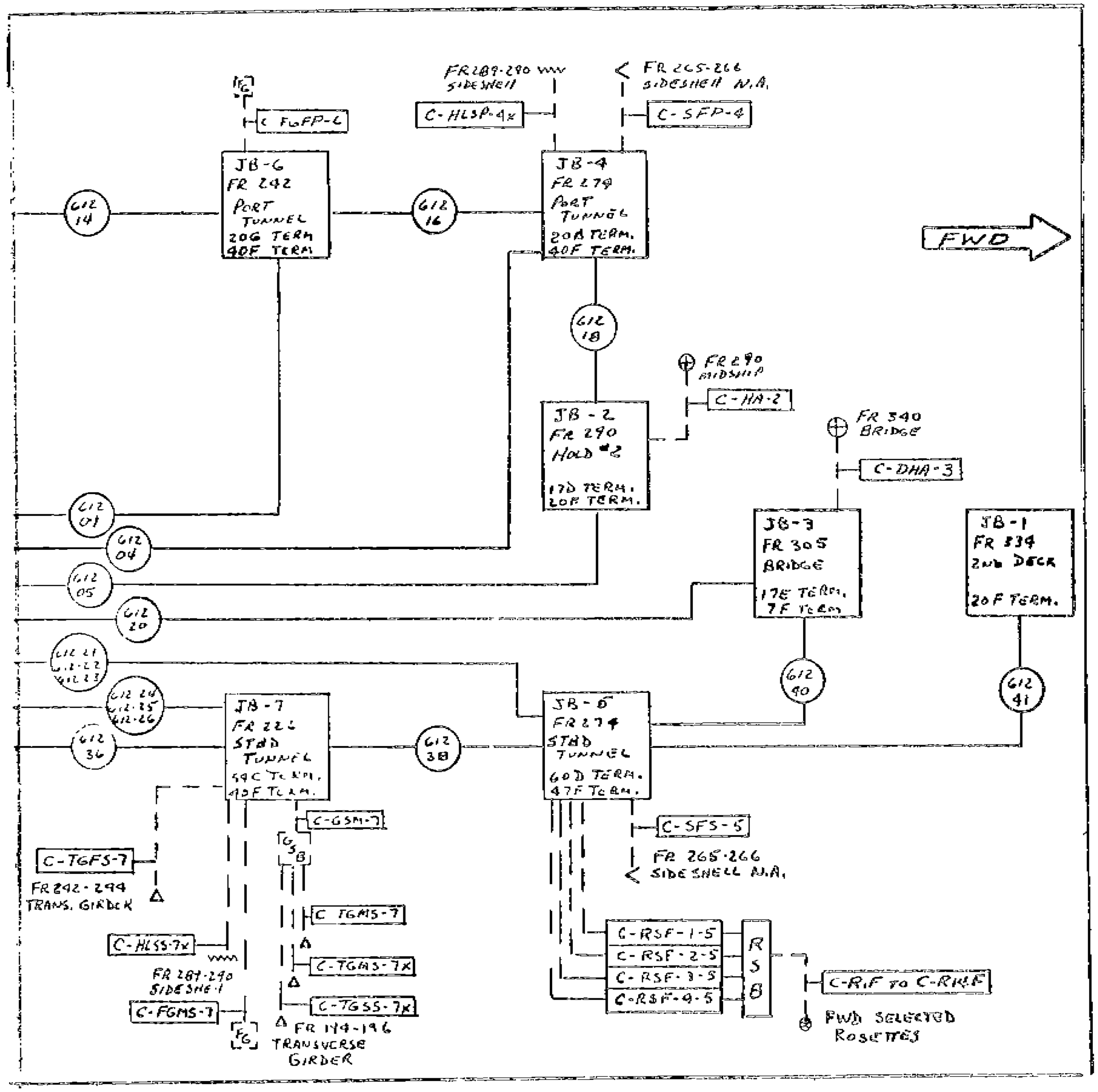



FIGURE 4B - TRANSDUCER, JUNCTION BOX, AND CABLE DIAGRAM, FORWARD SECTION

B. Transducer Cabling

In order to connect the transducers to the junction boxes and from there to the instrumentation console, a series of Intermediate Junction Boxes (IJB's) was installed in the vicinity of the transducers. This technique permitted standardization of the strain-gage cable lengths and connection of the individual gages into half- and full-bridge circuits in the IJB's.

Each IJB carries a number and letter designation. The number refers to the junction box (JB) it feeds, and the letter indicates its size and capability. The transducer cables run from the IJB's to the JB's along routings selected to minimize interference, and to maintain the watertight integrity of the box girders and various hold locations. All wiring to JB's and IJB's has been marked to agree with the drawings to facilitate maintenance. All cable entrances to JB's and IJB's are through watertight fittings which also provide the necessary mechanical support. Passage through watertight bulkheads is accomplished using watertight fittings of the type already in use aboard the vessel.

## IV. INSTRUMENTATION EQUIPMENT

As previously stated, the major portions of the instrumentation system are located in the Instrument Room (Figure 2), with various transducer assemblies located throughout the ship. A remote monitor unit has been installed in the night mate's quarters (05 level aft), which will be used as the instrumentation engineer's berthing area during manned voyages.

A. System Console

The system console is divided into three functional areas. The left-hand portion of the console, as viewed facing the unit (see Figure 5), contains most of the signal-conditioning and recording equipment. The large box-like unit at the top left is the Program Status Unit (PSU). This unit monitors all signals and provides local control for setup and test operations. In addition, selection of the inputs for Channels 2D, 3D, 4D, 5D, 10A, and 11A is made from the front of the PSU. A series of lighted indicators informs the operator which of four possible sets of measurements (Modes A, B, C, or D) has been selected for Recorder No. 2, and a pushbutton provides a means of changing the operating mode manually during setup and test. The two large panel meters and their associated selector switches enable the operator to monitor the inputs of Channels 1-13 on both recorders.

The lower two-thirds of the left cabinet contains the 50 channels of strain-gage signal-conditioning equipment. This equipment provides the necessary excitation, control, and amplification circuits for 50 individual strain-gage bridge circuits.

Because only 25 separate signals can be recorded simultaneously on the two magnetic tape recorders, it was necessary to provide an efficient means of changing the inputs to one of the recorders (No. 2). A multisection stepping switch, capable of operation either manually or on a timed basis, was assembled and integrated into the strain-gage signal-conditioning equipment.

The center portion of the console (Figure 6) is the operational control area. The heart of the system is the control panel located in the middle of the console beneath the clock. This unit selects the Mode for Recorder No. 2, and

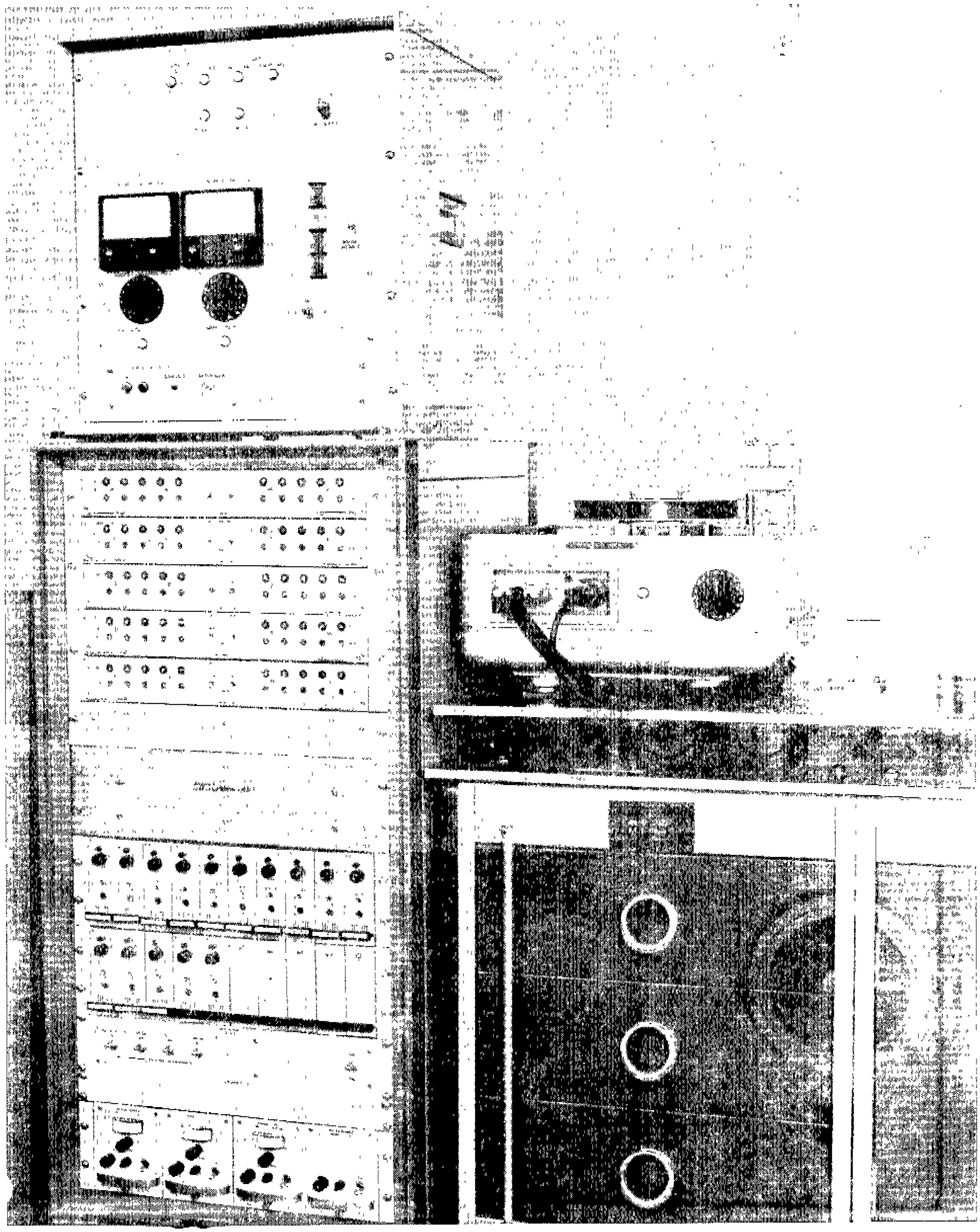


FIGURE 5 - STRAIN GAGE, OPERATING, MONITORING, AND RECORDING EQUIPMENT

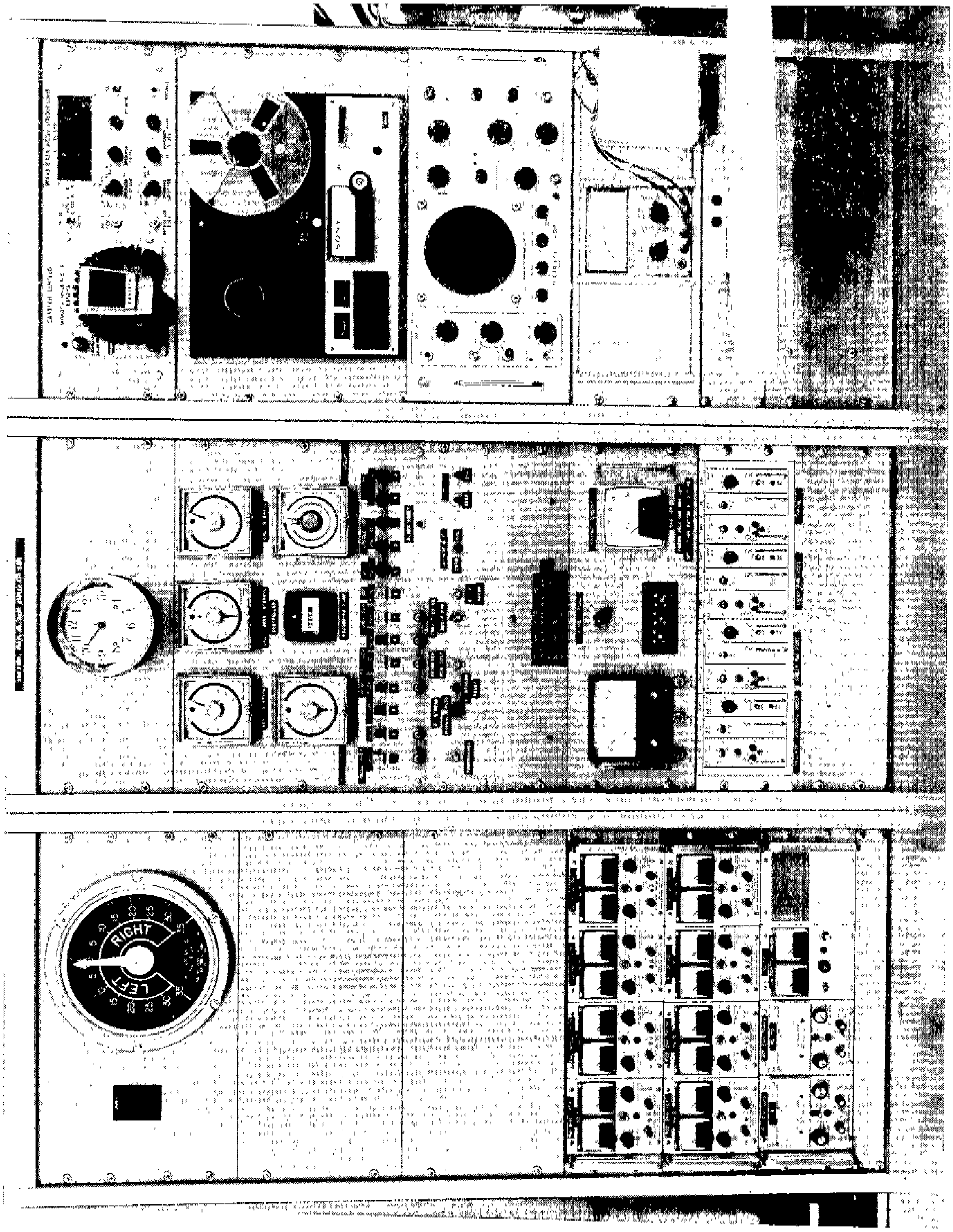



FIGURE 6 - SYSTEM CONTROL AREA

provides all of the indications required to monitor the operation of the system. Some of the capabilities of this unit will be discussed below under the heading "System Operation".

Beneath the control panel (also referred to as the "Programmer") are two panels associated with an additional four channels of strain-gage circuitry. The upper panel also contains the meter and selector switch used to choose a triggering channel for operation in the "high-stress" mode. In addition, the left-hand cabinet of Figure 6 contains the following items:

1. A visual indication of rudder angle.

2. RPM indicators from both shafts, to be installed in the location directly below the rudder angle indicator. These RPM indicators will be identical to the units already installed aboard the vessel, and will interface to the same circuits.

3. Wind speed and direction indicators will be installed in the other blank panel.

4. At the bottom of the left-hand cabinet are various power supplies used to energize transducers and other electronic units within the system.

The right-hand cabinet of Figure 6 contains a wave data acquisition system. This receiver and tape recorder may be used later in the program to acquire wave acceleration data from wave buoys. The recorder can be used for voice narrations during calibration and other special tests. The other panels of this cabinet contain an oscilloscope, vacuum tube voltmeter, and fluorescent light. Figure 7 shows an additional tape machine and oscillograph to the right of the main console. These are used for reproducing data tapes aboard ship to verify system operation and for quick-look analysis of the data. All tape recorders and the oscillograph have been shock-mounted.

### B. Ship-Motion Transducers

In addition to the strain gages, transducers to measure ship motions have been placed in moisture-tight NEMA Type 4 enclosures at various locations throughout the ship (see Figures 3 and 4). Four of these enclosures contain accelerometers and their associated circuitry. Each box is attached to a steel mounting plate which has been welded to the overhead by the shipyard. A hinged cover provides access to the transducers and the various internal adjustments.

A fifth enclosure contains angle-sensing pendulum devices for measuring pitch and roll. This unit is mounted near the vessel's center of gravity. The specifications for the accelerometers and pendulum units may be found in Appendix A.

### C. Signal Monitor and Alarm Unit

This remote monitoring unit is installed in the operator's quarters and allows monitoring of the selected triggering channel, providing an indication whenever the system is in a recording mode. If the system is left in the "high-stress" mode (see Section VI) and begins recording due to the presence of a large

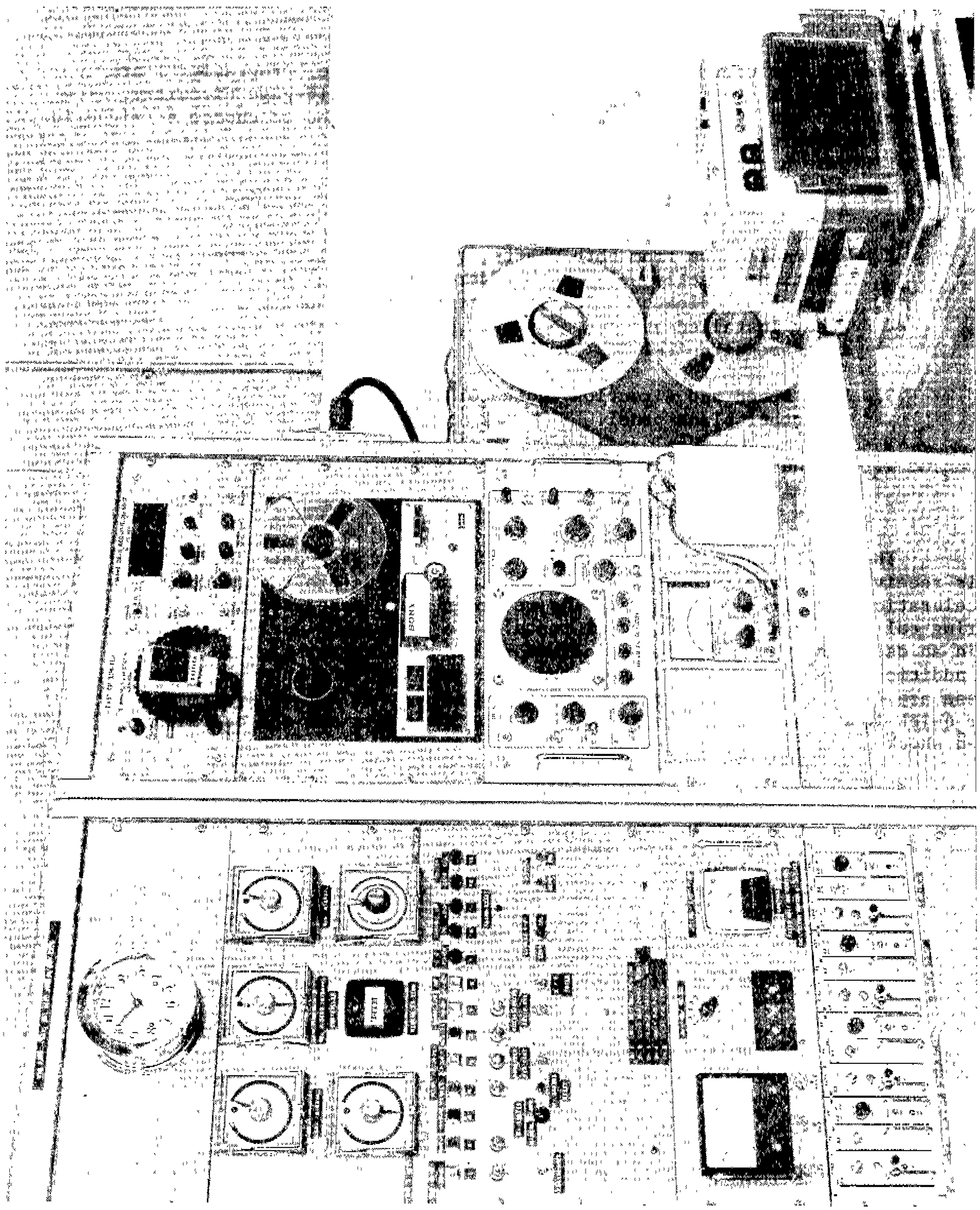


FIGURE 7 - PLAYBACK AND ANALYSIS EQUIPMENT

signal, an alarm is initiated at both the console and in the operator's quarters, and a high-stress indicator is energized. A parallel reset pushbutton at both locations allows the operator to silence the alarm. This monitoring system must be turned ON and OFF in the Instrument Room, and performs strictly a monitoring function.

## V. TRANSDUCERS

The various strain-gage bridge circuits (described in detail in Appendix B) and the additional transducers have their outputs permanently assigned to recording channels. A single set of measurements has been assigned to Recorder No. 1, with no changes or options. The second recorder, however, operates sequentially with four groups of input signals. The selections were based primarily on groupings required to perform the various data analysis tasks. A common channel, vertical longitudinal bending stress, is recorded on both recorders in all modes to provide a reference signal.

All signals designated "Gage Group 1" are recorded on Recorder No. 1. Gage Groups 2, 3, 4, and 5 are recorded on Recorder No. 2 in Modes A, B, C, and D, respectively.

### A. Functional Description and Channel Assignment

Table II provides a brief rationale for the various transducers installed aboard the SEA-LAND McLEAN. This description, in conjunction with Figures 3 and 4, presents a concise picture of the overall transducer installation.

Table IV is a somewhat similar tabulation by recorder Channel and Mode which gives additional information as to the available options and method of selection in those cases in which a recording channel must record more than one measurement. Table V provides a listing of the various signals and their equipment assignment. This information is required for the setup and monitoring of excitation levels and amplifier gains.

### B. Neutral Axis and Center-of-Gravity Locations

There is frequent reference in figures and tables to gages located at the neutral axis (NA), in particular for the shear gages aft at Frame 87-88, forward at Frame 265-266, and amidships at Frame 186-1/4. The following are the neutral axis locations:

| | |
|---|---|
| Frame 87-88: | 10.8 metres above base line |
| Frame 186-1/4: | 8.8 metres above base line |
| Frame 265-266: | 11.6 metres above base line |

For practical use at the time of installation, these basic dimensions were changed to distances above the tank top at each location by subtracting the tank top heights above the base line:

| | | |
|---|---|---|
| Frame 87-88: | (Deep Tank No. 4) | Tank top 8.37 metres ABL |
| Frame 186-1/4: | (Double Bottom No. 4) | Tank top 1.86 metres ABL |
| Frame 265-266: | (Double Bottom No. 2) | Tank top 1.86 meters ABL |

# TABLE IV - RECORDER CHANNEL ASSIGNMENTS

NO. 1 RECORDER CHANNEL ASSIGNMENT - ONLY MODE

| CHANNEL | FUNCTION | OPTIONS | METHOD OF SELECTION |
|---|---|---|---|
| 1 | Longitudinal Vertical Bending Stress | | |
| 2 | Midships Torsional Shear | NONE | |
| 3 | Wave Height | | |
| 4 | Roll | H | |
| 5 | Pitch | A | |
| 6 | Hull Accel. Mid. Vert. | R | |
| 7 | Hull Accel. Mid. Trans. | D | |
| 8 | Hull Accel. Fwd. Vert. | | |
| 9 | Hull Accel. Fwd. Trans. | W | |
| 10 | Ship's Operating Parameters Multiplex Ch. | I | |
| 11 | Longitudinal Horz Bending Stress | R E | |
| 12 | Shear Fwd. - Port | D | |
| 13 | Shear Fwd. - Stbd. | | |
| 14 | Compensation | | |

# TABLE IV - (CONT'D)

NO. 2 RECORDER CHANNEL ASSIGNMENT - "A" MODE

| CHANNEL | FUNCTION | OPTIONS | METHOD OF SELECTION |
|---|---|---|---|
| 1 | Longitudinal Vertical Bending Stress | | |
| 2 | Long. Gage Stbd. Deck (Stress) (Top) | | |
| 3 | Long. Gage Stbd. N.A. (Stress) (Mid) | | |
| 4 | Long. Gage Stbd. Bottom (Stress) | | |
| 5 | Long. Gage Port Deck (Stress) (Top) | | |
| 6 | Long. Gage Port N.A. (Stress) (Mid) | | |
| 7 | Long. Gage Port Bottom (Stress) | | |
| 8 | Shear-Aft-Port | | |
| 9 | Shear-Aft-Stbd | | |
| 10 | Deck House Accel. Fwd. (Vert.) | Deck House Accel. Aft - Long | Any 2 by Coax Patch on PSU (Patch Status Unit) |
| 11 | Deck House Accel. Fwd. (Trans.) | Deck House Accel. Aft - Trans. | When Recording Wave Height FWD Accelerations are desired. |
| 12 | Box Girder Shear Top | | |
| 13 | Box Girder Shear Bottom | | |
| 14 | Compensation | | |

TABLE IV - (CONT'D)

NO. 2 RECORDER CHANNEL ASSIGNMENT - "B" MODE

| CHANNEL | FUNCTION | OPTIONS | METHOD OF SELECTION |
|---|---|---|---|
| 1 | Longitudinal Vertical Bending Stress | | |
| | Aft Rosettes: | | |
| 2 | No. 1 Element A | NONE | |
| 3 | No. 1 Element B | H | |
| 4 | No. 1 Element C | A | |
| 5 | No. 2 Element A | R | |
| 6 | No. 2 Element B | D | |
| 7 | No. 2 Element C | | |
| 8 | No. 3 Element A | W | |
| 9 | No. 3 Element B | I | |
| 10 | No. 3 Element C | R | |
| 11 | No. 4 Element A | E | |
| 12 | No. 4 Element B | D | |
| 13 | No. 4 Element C | | |
| 14 | Compensation | | |

TABLE IV - (CONT'D)

NO. 2 RECORDER CHANNEL ASSIGNMENT - "C" MODE

| CHANNEL | | OPTIONS | METHOD OF SELECTION |
|---|---|---|---|
| 1 | Long. Vertical Bending Stress | -- | |
| | Fwd Selected Rosettes: | | |
| 2 | No. 1 Element A | Any 4 of 14 Fwd Rosettes may be selected | Selected by connector patch in Rosette Selection Box (RSB) located in stbd tunnel near Junction Box 5 |
| 3 | No. 1 Element B | | |
| 4 | No. 1 Element C | $R_1$-$R_4$ FR 290-292 | |
| 5 | No. 2 Element A | $R_5$-$R_9$ FR 258-260 | |
| 6 | No. 2 Element B | $R_{10}$-$R_{14}$ FR 226-227 | |
| 7 | No. 2 Element C | | |
| 8 | No. 3 Element A | | |
| 9 | No. 3 Element B | | |
| 10 | No. 3 Element C | | |
| 11 | No. 4 Element A | | |
| 12 | No. 4 Element B | | |
| 13 | No. 4 Element C | | |
| 14 | Compensation | | |

TABLE IV - (CONCLUDED)

NO. 2 RECORDER CHANNEL ASSIGNMENT - "D" MODE

| CHANNEL | FUNCTION | OPTIONS | METHOD OF SELECTION |
|---|---|---|---|
| 1 | Long. Vertical Bending Stress | | |
| | Transverse Girder: | | |
| 2 | Fwd No. 1 | Hull Long. Gage Stbd - Top | Two position selector switch on Program Status Unit (PSU) selects 4 single strain gages around hull at FR. 290 |
| 3 | Fwd No. 2 | Hull Long. Gage Stbd - Bottom | |
| 4 | Fwd No. 3 | Hull Long. Gage Port - Top | |
| 5 | Fwd No. 4 | Hull Long. Gage Port - Bottom | |
| 6 | Mid Selected No. 1 | Any 4 of 12 signals, 8 single gages and 4 shear rosettes in transverse girder FR. 194-196 | Selected by connector patch in Girder Selection Box (GSB) located in starboard tunnel at FR. 194-196 |
| 7 | Mid Selected No. 2 | | |
| 8 | Mid Selected No. 3 | | |
| 9 | Mid Selected No. 4 | | |
| 10 | Aft No. 1 | | |
| 11 | Aft No. 2 | | |
| 12 | Aft No. 3 | | |
| 13 | Aft No. 4 | | |
| 14 | Compensation | | |

TABLE V - SIGNAL CONDITIONING

50 CHANNEL EQUIPMENT FUNCTION ASSIGNMENTS RECORDER NO. 2

| Rack | Position | TB | Amplifier | CH | Function | |
|---|---|---|---|---|---|---|
| 0 | 0 | 1 | 1 | 2A | Long. Stress Gage Stbd Top | (LSTS) |
| | 1 | 2 | 2 | 3A | Long. Stress Gage Stbd Mid Stress | (LSMS) |
| | 2 | 3 | 3 | 4A | Long. Stress Gage Stbd Bottom Stress | (LSBS) |
| | 3 | 4 | 4 | 5A | Long. Stress Gage Port Top | (LSTP) |
| | 4 | 5 | 5 | 6A | Long. Stress Gage Port Mid | (LSMP) |
| | 5 | 6 | 6 | 7A | Long. Stress Gage Port Bottom | (LSBP) |
| | 6 | 7 | 7 | 8A | Shear Aft Port | (SAP) |
| | 7 | 8 | 8 | 9A | Shear Aft Stbd | (SAS) |
| | 8 | 9 | 11 | 12A | Box Girder Shear Top | (BGST) |
| | 9 | 10 | 12 | 13A | Box Girder Shear Bottom | (BGSB) |
| 1 | 0 | 11 | 1 | 2B | Aft Rosette No. 1 A | |
| | 1 | 12 | 2 | 3B | B | |
| | 2 | 13 | 3 | 4B | C | |
| | 3 | 14 | 4 | 5B | No. 2 A | |
| | 4 | 15 | 5 | 6B | B | |
| | 5 | 16 | 6 | 7B | C | |
| | 6 | 17 | 7 | 8B | No. 3 A | |
| | 7 | 18 | 8 | 9B | B | |
| | 8 | 19 | 9 | 10B | C | |
| | 9 | 20 | 10 | 11B | No. 4 A | |

TABLE V - (CONT'D)

| Rack | Position | TB | Amplifier | CH | Function |
|---|---|---|---|---|---|
| 2 | 0 | 21 | 11 | 12B | B |
| | 1 | 22 | 12 | 13B | C |
| | 2 | 23 | 1 | 2C | Fwd Selected Rosette No. 1 A |
| | 3 | 24 | 2 | 3C | B |
| | 4 | 25 | 3 | 4C | C |
| | 5 | 26 | 4 | 5C | No. 2 A |
| | 6 | 27 | 5 | 6C | B |
| | 7 | 28 | 6 | 7C | C |
| | 8 | 29 | 7 | 8C | No. 3 A |
| | 9 | 30 | 8 | 9C | B |
| 3 | 0 | 31 | 9 | 10C | C |
| | 1 | 32 | 10 | 11C | No. 4 A |
| | 2 | 33 | 11 | 12C | B |
| | 3 | 34 | 12 | 13C | C |
| | 4 | 35 | 1 | 2D | Fwd Trans. Girder or Fwd Hull Long. Gages on PSU Switch No. 1 |
| | 5 | 36 | 2 | 3D | No. 2 |
| | 6 | 37 | 3 | 4D | No. 3 |
| | 7 | 38 | 4 | 5D | No. 4 |
| | 8 | 39 | 5 | 6D | Mid Selected Trans. Girder at CSB No. 1 |
| | 9 | 40 | 6 | 7D | No. 2 |
| 4 | 0 | 41 | 7 | 8D | No. 3 |
| | 1 | 42 | 8 | 9D | No. 4 |
| | 2 | 43 | 9 | 10D | Trans Girder Aft No. 1 |
| | 3 | 44 | 10 | 11D | No. 2 |
| | 4 | 45 | 11 | 12D | No. 3 |
| | 5 | 46 | 12 | 13D | No. 4 |

TABLE V - (CONCLUDED)

| Rack | Position | TB | Amplifier | CH | Function |
|---|---|---|---|---|---|
| 4 | 6 | 47 | 13 | 1 | Long. Vert. Bending Stress (Both Recorders) |
| | 7 | 48 | 14 | 11 | Long. Horiz. Bending Stress (Recorder No. 1) |
| | 8 Spare | 49 | | | |
| | 9 Spare | 50 | 15 Spare | | |

4-CHANNEL RACK RECORDER NO. 1

| Position | Signal Conditioner | Power Supply | Amplifier | CH | Function |
|---|---|---|---|---|---|
| 1 | 1 | 1 | 1 | 2 | Midships Torsional Shear |
| 2 | 2 | 2 | 2 | 12 | Shear Fwd Port |
| 3 | 3 | 3 | 3 | 13 | Shear Fwd Stbd |
| 4 Spare | | | | | |

Distances from the tank tops to the neutral axis, therefore, are (in feet):

| | |
|---|---|
| Frame 87-88: | 7.9 feet above tank top |
| Frame 186-1/4: | 22.76 feet above tank top |
| Frame 265-266: | 31.94 feet above tank top |

Due to the erroneous use of the wrong tank top height, the shear gages at the aft location were placed 18.2 feet above the calculated level of the neutral axis. The data from these gages will be monitored carefully and compared with that from the other vertical shear gages.

It was originally planned to locate two transducer boxes at the loaded center-of-gravity of the vessel, 399.32 feet forward of the aft perpendicular and 42.65 feet above the base line, in Hold No. 7. Since there must be some structure present to which to attach the boxes, the forward side of Frame 178 was selected, in Hold No. 6. This location is accessible under all conditions, and is compatible with planned cable routings. The longitudinal location of Frame 178 is 31 feet farther forward than the true loaded center-of-gravity, and the vertical location of the transducer boxes is 5.5 feet lower than the desired height. In addition, transducer boxes which, ideally, should be mounted on the centerline are slightly to port because of interfering structure. Corrections for the actual locations of these transducer boxes will be made during data analysis. Exact box locations are tabulated in Table VI.

C. Transducer Summary

The following sections and the data in Tables VI and VII identify all signals completely. Table VIII lists the abbreviations used in the tables and figures to identify each signal. When more than one signal of a type is used, a number designation follows, as, for example, when four gages are installed around a transverse girder location. In the case where two gages are wired into a shear or dyadic configuration, one of several means of identifying the individual gages is used. In some cases the gages are identified as the forward- or aft-oriented component relative to the ship. If orientation is along a horizontal axis, the gages are identified by a "T" or "B" for "top" or "bottom" component. In the case where two shear stress configurations are wired to form a complete bridge, an additional numbering system has been applied identifying the gages by number and by location, either port or starboard side.

When gages have been installed to form a 3-arm rosette the elements are identified by the letters A, B, and C. In all cases the "A" component is oriented fore-and-aft, the "B" component at a 45-degree angle to the left (counterclockwise), and the "C" component in an athwartships direction 45 degrees (counterclockwise) to the left of the "B" component.

1. Strain Gage Signals

Table VII summarizes all of the pertinent information associated with each strain gage signal.

2. Transducer Signals

Table VI provides a complete tabulation of the characteristics of the various transducer assemblies. Pertinent electrical characteristics are listed as well as the exact location of each transducer box. Calibration signals for these devices are obtained by generating a fixed voltage level at the console to simulate transducer output of a known value, and using this output to set up the various recording channels.

TABLE VI - TRANSDUCER INFORMATION (Revised 1/15/73)

| Signal | Location | Transducer | Range | Full-Scale | Sensitivity |
|---|---|---|---|---|---|
| Forward Hull Vertical Acceleration | No. 2 Cargo Hold Second Deck, 14-1/2" Fwd of FR. 290, 40" Port of ℄ ; 65'3" Above Base Line on Overhead | Setra Model 100, S/N 072 Accelerometer | ± 5g's | 1.50 VDC | 0.300 V/g (1g offset due to mounting) |
| Forward Hull Transverse Acceleration | Same | Setra Model 100, S/N 071 Accelerometer | ± 5g's | 1.45 VDC | 0.290 v/g (No offset) |
| Midship Hull Vertical Acceleration | No. 6 Cargo Hold 23 1/2" Fwd FR. 178 11 1/2" Port of ℄ 30' 11" Above Tank Top | Setra Model 100, S/N 068 Accelerometer | ± 2g's | 2.10 VDC | 1.05 v/g (1g offset) |
| Midship Hull Transverse Accelerations | Same | Setra Model 100, S/N 070 Accelerometer | ± 2g's | 2.114 VDC | 1.057 v/g (No offset) |
| Forward Deckhouse Vertical Acceleration | Wheelhouse Overhead 04 Level, on ℄ at FR 307 1/2 | Setra Model 100, S/N 069 Accelerometer | ± 5g's | 1.375 VDC | 0.275 v/g (1g offset) |
| Forward Deckhouse Transverse Acceleration | Same | Setra Model 100, S/N 1361 Accelerometer | ± 2.5g's | 1.60 VDC | 0.640 v/g (No offset) |
| Aft Deckhouse Longitudinal Acceleration | Fan Room Overhead 05 Level, 1" to Port of ℄, FR 130 | Setra Model 100, S/N 1362 Accelerometer | ± 2.5g's | 1.60 VDC | 0.642 v/g (No offset) |
| Aft Deckhouse Transverse Acceleration | Same | Setra Model 100, S/N 1360 Accelerometer | ± 2.5g's | 1.72 VDC | 0.686 v/g (No offset) |
| Midship Pitch | 26" Fwd of FR 178 26" to Port of ℄ 30' 11" Above Tank Top | Humphrey Pendulum Model CP17-0601-1 S/N H3390 | ± 45° | ± 2.25 VDC | 0.05 V/degree |
| Midship Roll | Same | Humphrey Pendulum Model CP17-0601-1 S/N H2075 | ± 45° | ± 2.25 VDC | 0.05 V/degree |

TABLE VII - STRAIN GAGE SIGNALS

| Signal | Channel | Location | Circuit (App. B) | Calibration Resistor (ohms) | Calibration Level (psi) |
|---|---|---|---|---|---|
| Recorder No. 1 | | | | | |
| LVBP/LVBS | 1 | Overhead, port and stbd tunnel, FR 186 1/4 | 1 | 309K | 8,200 |
| TSMP/TSMS | 2 | Port and stbd sideshell Hold 6, N.A., FR 186 1/4 | 3 | 71.5K | 5,000 |
| LHBP/LHBS | 11 | Port and stbd sideshell Hold 6, N.A., FR 186 1/4 | 2 | 309K | 8,200 |
| SFP | 12 | Port sideshell, Hold 4 FR 265-266 | 4 | 143K | 5,000 |
| SFS | 13 | Stbd sideshell, Hold 4 FR 265-266 | 4 | 143K | 5,000 |
| Recorder No. 2 | | | | | |
| LVBP/LVBS | 1A,B,C,D | Overhead, port and stbd tunnel, FR 186 1/4 | 1 | 309K | 8,200 |
| LSTS | 2A | Overhead, stbd tunnel, FR 186 1/4 | 5 | 154K | 8,200 |
| LSMS | 3A | Stbd sideshell, Hold 6 N.A., FR 186 1/4 | 5 | 154K | 8,240 |
| LSBS | 4A | Stbd sideshell, Hold 6, near bottom, FR 186 1/4 | 5 | 154K | 8,240 |
| LSTP | 5A | Overhead, port tunnel, FR 186 1/4 | 5 | 154K | 8,240 |
| LSMP | 6A | Port sideshell, Hold 6, N.A., FR 186 1/4 | 5 | 154K | 8,240 |
| LSBP | 7A | Port sideshell, Hold 6, near bottom, FR 186 1/4 | 5 | 154K | 8,240 |
| SAP | 8A | Port sideshell, Hold 9, 18' above N.A., FR 87-88 | 4 | 143K | 5,000 |
| SAS | 9A | Stbd sideshell, Hold 9, 18' above N.A., FR 87-88 | 4 | 143K | 5,000 |
| BGST | 12A | Overhead, stbd tunnel, FR 186 1/4 | 4 | 143K | 5,000 |
| BGSB | 13A | Deck, stbd tunnel, FR 186 1/4 | 4 | 143K | 5,000 |

TABLE VII - (CONCLUDED)

| Signal | Channel | Location | Circuit (App. B) | Calibration Resistor (ohms) | Calibration Level (psi) |
|---|---|---|---|---|---|
| AR1A,B,C, | 2B,3B,4B | Port end, transverse girder, FR 143-144 | 6 | 182K | 10,000 |
| AR2A,B,C, | 5B,6B,7B | Stbd end, transverse girder, FR 143-144 | 6 | 182K | 10,000 |
| AR3A,B,C | 8B,9B,10B | Stbd tunnel, inboard, FR 143-144 | 6 | 182K | 10,000 |
| AR4A,B,C | 11B,12B,13B | Stbd tunnel, outboard, FR 143-144 | 6 | 182K | 10,000 |
| R1FA,B,C, | 2C,3C,4C | Overhead, port hatch corner, Hold 2, FR 290 | 6 | 182K | 10,000 |
| R2FA,B,C, | 5C,6C,7C | Overhead, stbd hatch corner, Hold 2, FR 290 | 6 | 182K | 10,000 |
| R3FA,B,C | 8C,9C,10C | Overhead, stbd tunnel, inboard, FR 290 | 6 | 182K | 10,000 |
| R4FA,B,C | 11C,12C,13C | Overhead, stbd tunnel, outboard, FR 290 | 6 | 182K | 10,000 |
| R5FA,B,C | | Overhead, trans. girder stbd end, FR 258-260 | 6 | | |
| R6FA,B,C | | Overhead, trans. girder, stbd end, FR 258-260 | 6 | | |
| R7FA,B,C | | Overhead, trans. girder, stbd end, FR 258-260 | 6 | | |
| R8FA,B,C | | Overhead, stbd tunnel inboard, FR 258-260 | 6 | | |
| R9FA,B,C | | Overhead, stbd tunnel outboard, FR 258-260 | 6 | | |
| R10FA,B,C | | Overhead, trans. girder stbd end, FR 226-227 | 6 | | |
| R11FA,B,C | | Overhead, trans. girder stbd end, FR 226-227 | 6 | | |
| R12FA,B,C | | Overhead, trans. girder stbd end, FR 226-227 | 6 | | |
| R13FA,B,C | | Overhead, stbd tunnel inboard, FR 226-227 | 6 | | |
| R14FA,B,C | | Overhead, stbd tunnel outboard FR 226-227 | 6 | | |
| TGFS-1,2,3,4 | 2D - 5D | Stbd side, trans. girder FR 242-244 | 6 | 182K | 10,000 |
| HLSS-T | 2D | Stbd side, top Hold 3 aft FR 290 | 6 | 182K | 10,000 |
| HLSS-B | 3D | Stbd side, bottom, Hold 3 aft FR 290 | 6 | 182K | 10,000 |
| HLSP-T | 4D | Port side, top, Hold 3 aft FR 290 | 6 | 182K | 10,000 |
| HLSP-B | 5D | Port side, bottom, Hold 3 aft FR 290 | 6 | 182K | 10,000 |
| TGMS-1,2,3,4 | 6D - 9D | Stbd end trans. girder, FR 194-196 | 6 | 182K | 10,000 |
| TGMS-1x,2x, 3x,4x, | 6D - 9D | ↓ | 6 | 182K | 10,000 |
| TGSS-1x,2x, 3x,4x | 6D - 9D | ↓ | 4 | 143K | 5,000 |
| TGAS-1,2,3,4 | 10D - 13D | Stbd side, trans. girder FR 78-80 | 6 | 182K | 10,000 |

TABLE VIII - SIGNAL NOMENCLATURE

| Symbol | Meaning |
| --- | --- |
| AR | Aft Rosette |
| BGSB | Box Girder Shear Bottom |
| BGST | Box Girder Shear Top |
| HLSP | Hull Longitudinal Strain Port |
| HLSS | Hull Longitudinal Strain Starboard |
| LHBP | Longitudinal Horizontal Bending Port |
| LHBS | Longitudinal Horizontal Bending Starboard |
| LSBP | Longitudinal Stress Bottom Port |
| LSBS | Longitudinal Stress Bottom Starboard |
| LSMP | Longitudinal Stress Mid Port |
| LSMS | Longitudinal Stress Mid Starboard |
| LSTP | Longitudinal Stress Top Port |
| LSTS | Longitudinal Stress Top Starboard |
| LVBP | Longitudinal Vertical Bending Port |
| LVBS | Longitudinal Vertical Bending Starboard |
| $R_{1-14}F$ | Rosette 1-14 Forward |
| SAP | Shear Aft Port |
| SAS | Shear Aft Starboard |
| SFP | Shear Forward Port |
| SFS | Shear Forward Starboard |
| TGAS | Transverse Girder Aft Starboard |
| TGFS | Transverse Girder Forward Starboard |
| TGMS | Transverse Girder Midship Starboard |
| TGSS | Transverse Girder Shear Starboard |
| TSMP | Torsional Shear Mid Port |
| TSMS | Torsional Shear Mid Starboard |

3. Ship Parameters

Several ship operating parameters will be monitored and multiplexed onto a common data channel on Recorder No. 1. The following is a brief description of the instruments to be used to provide these signals.

a. Rudder Angle

A Hose-McCann Model 27R rudder angle repeater has been installed in the console. A modification to its mechanical linkage was made so that a potentiometer could be attached through a shaft coupling. The repeater is energized from the existing rudder angle transmitter, and the new potentiometer provides only a slight additional shaft load.

The center-tapped four-arm potentiometer is excited by a DC voltage, and the polarity-sensitive output is proportional to rudder angle signal. The visual display allows the operator to monitor this function for logbook entries. The exact levels to be used will be reported after some operational experience is gained.

b. Shaft RPM

Two Henschel propeller shaft RPM indicators, identical to units installed elsewhere on the ship, will be installed in the instrumentation console. These units have an output scale factor of 6.0 volts per 100 RPM. The visual displays are calibrated at 150-0-150 RPM. Each indicator will provide a DC voltage to the multiplexer proportional to RPM. The visual display permits the operator to monitor these functions at all times.

c. Wind Speed and Direction

A wind speed and direction system will be installed when scheduling permits. The system will be the Bendix Aerovane System, modified to provide outputs suitable for recording on magnetic tape. Both indicators will be installed on a console panel. The wind direction indicator will provide a zero-to-360 degree display, the cardinal points indicated. The DC output will be from zero to 3.6 volts. The wind speed indicator will have a range of zero to 120 knots with an electrical output of from zero to 10 volts DC.

d. Course

The final operating parameter to be measured is course. The original intent was to obtain this signal from the gyro system and record it on the multiplex channel. However, the gyro system aboard the ship is presently handling its total repeater capacity, and there is no way to obtain a course signal without installing an additional gyro.

Since there already exists a strip chart recorder as part of the gyro system, course information will be obtained from these records after they are no longer needed by the ship. Course data will be entered via punched cards into the computer program in a manner similar to the handling of other logbook data.

## VI. SYSTEM OPERATION

This section describes the various operating modes of the system, and the means by which signals are selected for recording. Before each voyage the instrumentation engineer, or system operator, will be given instructions as to the signals to be recorded, and any changes to be made during the voyage. These instructions will be based on analysis of previous data. The operator will maintain an accurate log of system status and performance.

### A. Signal Selection

The operator has several methods by which a selection of signals can be made. These are presented here for a concise listing of his choices.

1. Program Status Unit (PSU)

a. By coaxial patch cables, the operator selects which two of the four deckhouse acceleration signals he will record on Channels 10A and 11A.

b. By positioning a selector switch on the front panel of the PSU, the operator selects whether he will record the four corner signals from the transverse girder at Frames 242-244, or the four single strain gages around the hull section just aft of Frame 290 on Channels 2D, 3D, 4D, and 5D.

2. Girder Selection Box

In the girder selection box, starboard box girder, the operator selects via patch cables which four of the twelve signals available from the transverse girder at Frames 194-196 he will monitor. Selected signals are recorded on Channels 6D, 7D, 8D, and 9D.

3. Rosette Selection Box

At the rosette selection boxes, also in the starboard box girder, the operator selects which four of the fourteen rosette gages installed will be recorded during the "C" mode on Channels 2 to 13 of Recorder No. 2.

Any or all of the above selections can be changed during the voyage by the operator with a minimum of difficulty. Logbook entries will be made when any signals are changed and a listing of all signals recorded will accompany each reel of data tape.

B. System Operating Modes

Before discussing the various operating modes, the data "interval" which is used for all operating modes should be explained. To facilitate data analysis and to conform to previous standards, the data interval (or record) length will be 30 minutes of real time. The first minute of each interval will be a "zero" period. During this period all inputs are removed and the various amplifier outputs are recorded for future determination of system noise and DC stability. The second minute of the interval is used for calibration. Various methods described in Appendix B generate output signals at preset levels. This information is used in analysis for data scaling. To facilitate automatic data reduction the calibration level is not constant during the whole calibration period but rather is turned ON and OFF 10 times during the minute. This modulation of the calibration signals provides a means for identifying these signals for the data analysis routines. During the remaining 28 minutes of the interval, data are recorded in normal fashion. Both tape recorders operate at 0.3 inches per second using frequency modulation techniques in order to obtain the required low-frequency response. Data bandpass is 0 to 50 Hertz.

1. Automatic

The primary mode of system operation is the "Automatic" mode. The system is placed in this mode by the operator shortly after leaving port and it generally remains in this mode until just before re-entering port. The purpose of having an automatic mode is to allow for a statistical sampling of data based on a known time-separation of data intervals. The system has been adjusted initially to start a data-taking period every four hours. Because of the great number of signals to be monitored, the system requires four 30-minute data intervals to record at least one interval of all channels assigned.

Recorder No. 1 records the same information for the four intervals. Recorder No. 2 is automatically switched to a different set of signals for each interval and thus records Modes A, B, C, and D. After the first few voyages it is anticipated that the number of signals can be reduced and consolidated on Modes A and B. The data sampling, therefore, can be for a period of one hour of every four instead of the initial two out of four. In the Automatic mode, no operator functions are required other than to make logbook entries, insure proper operation, and maintain an adequate supply of tape on both recorders.

2. Manual

The system is placed on "Manual" or continuous record mode when sea conditions are such that data is of particular interest. In this mode the system will continue to cycle through the A, B, C, and D recorder modes until reset to Automatic or shut down. It is generally advisable to go into this mode when sea states correspond to Beaufort Numbers 7 or 8, and to continue recording while data is at interesting levels. It is most important to watch tape usage when on manual, for the two tape recorders are running continuously.

3. High-Stress

In order to provide a means for initiating a recording cycle only when high signal levels are present, a "High-Stress" mode was incorporated into the system. In this mode the system is energized, but not recording until the selected signal exceeds preset limits. One of five signals may be selected for this task:

1) Longitudinal vertical bending
2) Longitudinal horizontal bending
3) Midships torsional shear
4) Shear forward port
5) Shear forward starboard

The signal to be used as a trigger is selected by means of a five-position switch on the center panel of the operator's console (see Figure 6). The signal is then displayed on the large panel meter to the left of the selector switch. By the use of two adjustable limit arm settings, the exact level at which recording will begin is determined by the operator. Once operation has been initiated in the high-stress mode, recording will continue until the system completes a "D" Mode interval of recording. The system will then switch into the "A" mode. If the high-stress condition still exists the system will go through another two-hour record cycle. If the high-stress signal is no longer present, the system will revert to a standby mode and cease recording.

The "High-Stress" mode is frequently used as a standby condition in which all portions of the system are ready but no actual recording takes place.

## VII. ADDITIONS*

Plans are being made to add several additional features to the overall instrumentation system.

A. Ocean Wave Height Radar System

Of primary interest is a means to measure wave height during recording cycles. An "Ocean Wave Height Radar System" (OWHRS) is being developed under separate contract by the Naval Research Laboratory in Washington, D. C. Upon successful development and installation of this device aboard the SEA-LAND McLEAN, wave height information will be recorded on one of the data channels of Recorder No. 1.

The OWHRS measures the distance from a ship's deck to the nearby ocean surface. These high-resolution range data will be used along with ship motion data gathered by inertial sensors to determine the height of the ocean waves. The principal characteristics of the OWHRS are:

* Note: Subsequent to the drafting of this report, the three systems described in this section were installed and operated satisfactorily. These systems, and the data collected thereby, will be the subjects of separate reports. Ed.

| | |
|---|---|
| Wave length | 3 Centimetres |
| Pulse Width | 2 Nanoseconds |
| Pulse Repetition | 10 KHz |
| Peak Power | 100 Watts |
| Antenna Diameter | 60 Centimetres |
| Antenna Beamwidth | 3.5 Degrees |
| Receiver Noise Figure | 8 dB |
| Range Resolution | 30 Centimetres |
| Data Rate | 100 Hz |

The transmitter-receiver will be mounted behind the parabolic antenna at the outboard forward corners of the wing of the bridge (03 level). The cabinet containing power supplies, timing circuits, and signal processing circuits will be located inside the forward deckhouse.

The antenna beam will be directed in azimuth to be perpendicular to the bow wake, and in elevation to be 70 degrees below the horizon. The output analog range signal connects to the bridge junction box.

B. Tucker Wave Meter

As a supplement to the OWHRS, it is planned to install a Tucker Wave Meter. This device consists of pressure transducers and accelerometers mounted below the waterline port and starboard amidships. The pressure transducers sense the increase and decrease of pressure due to waves. Ship motions are subtracted automatically by the accelerometers, resulting in an output analog signal proportional to wave height.

C. Scratch Gages

Two mechanical scratch gages will be installed on the SEA-LAND McLEAN adjacent to the midship vertical longitudinal bending stress gages. The scratch gages consist of simple extensometers with mechanical amplification which cause a stylus to make a mark on sensitive paper. Over a given period of time the total strain range experienced is indicated by the length of the line scratched on the paper. A battery-driven clock and motor mechanism then steps the paper ahead for the next time interval.

Scratch gage data from the SEA-LAND McLEAN will be correlated with electrical stress data from the instrumentation system. Once the proper relationship is established, measurement of the length of the scratched line will establish the total stress range experienced due to all causes. A scratch gage will be installed aboard each vessel in the SL-7 class to gather, quickly and inexpensively, many ship-years of stress data.

APPENDIX A

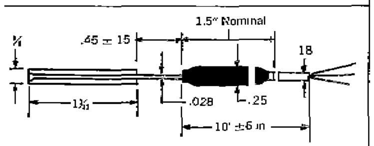
STRAIN GAGE AND TRANSDUCER SPECIFICATIONS

## MICRODOT INC. WELDABLE STRAIN GAGES

### SG 189 Series

**120 Ohm Quarter-Bridge "Flexlead Strain Gage"**

**For Static and Dynamic Measurements from 0° to 180°F.**




**DESCRIPTION**

Microdot Inc. Model SG 189 "Flexlead Strain Gage" represents a substantial breakthrough in waterproofing strain gages on an economical basis. The "Flexlead Strain Gage" is a pre-tested, waterproofed assembly that combines the ease of installation of Microdot Inc. Weldable Strain Gages with a minimal cost. This gage is hermetically sealed and mechanically protected throughout and is suitable for measurements over a temperature range of 0° to 180°F and to pressures of 100 psi.

This quarter bridge, self-temperature compensated gage employs a nickel-chrome alloy one piece strain filament, housed in a stainless steel shell. The gage is either compensated for use on a test specimen with 6 ppm or 9ppm/°F. temperature coefficient of expansion (specified on order).

This gage will function in hot water, sea water, concrete, or like media, and is ideally suited for reinforcing bar applications.

**ECONOMICS**

The "Flexlead Strain Gage" allows the test engineer to immediately perform strain tests which require water proofing, with a lower attrition rate at less installed cost than ever before. Engineering and technician time may now be spent testing rather than preparing for and waiting to test!

The low base cost of this gage, combined with the 5 to 10 minute total installation time, will effect an excellent cost savings to every user while greatly increasing the reliability of the installation due to the pre testing of the strain gage.

**INTEGRAL LEAD WIRE/CABLE**

The "Flexlead Strain Gage" has a standard cable length of 10 feet as delivered from stock. The vinyl jacketed cable consists of three 22 AWG twisted, stranded, tinned copper conductors with color coded vinyl insulation on each lead wire.

**RUGGED CONSTRUCTION**

Construction of the "Flexlead Strain Gage" is so rugged that it can withstand direct hammer blows. Design and construction features include inherent shielding of a one-piece filament encased in its shell by highly compacted magnesium oxide insulating powder. The gages are designed to perform under severe moisture, shock and vibration conditions

EVERY MICRODOT INC. STRAIN GAGE IS PRE TESTED AT THE FACTORY TO ITS MAXIMUM OPERATING TEMPERATURE TO ASSURE PROPER OPERATION IN ITS INTENDED APPLICATION.

**SIMPLE, RAPID INSTALLATION**

The "Flexlead Strain Gage" itself can be easily installed in less than two minutes using ordinary low energy capacitive discharge spot welding equipment. A series of spot welds quickly makes the gage an integral part of the test structure, assuring 100% transmission of experienced strains. No adhesives nor complicated bonding or curing processes are required. A clean, unoxidized surface is all that is necessary for rigid attachment. Metal straps are available for attaching the cable to a flat surface, or "Flex Ties" are available for tying the lead wire to a diameter, such as a reinforcing bar. (See accessories below.)

**RECOMMENDED ACCESSORIES**

1. Microdot Inc. Model SG 066-L cable extension kit
2. Microdot Inc. Model SG 080 installation kit, including sample weld flanges, metal straps (weldable) for securing the cable, and installation instructions. Each kit contains sufficient material for installation of ten Model SG 189 strain gages.
3. Microdot Inc. Model SG 081 reinforcing bar installation kit, same as above, except plastic "Flex Ties" are substituted for metal cable straps. Each kit contains sufficient material for installation of ten Model SG 189 strain gages.
4. Microdot Inc. Model SG 090 bridge completion network individually matched to each gage. Completely sealed and potted

FIGURE - A-1

## SG 189 STRAIN GAGE

### ELECTRICAL SPECIFICATIONS

Strain Gage Resistance.
Filament resistance, 120 ohm ±3.5 ohm

Excitation Current:
Rated value up to 50 milliamps
Maximum value, 100 to 300 milliamps depending upon environmental temperature and test specimen material

Insulation Resistance:
100 megohms minimum at ambient temperature and 50 VDC

### PERFORMANCE SPECIFICATIONS

Gage Factor:
Nominal value, 1.8
Tolerance control from reported value ± 3%

Rated Strain Level:
6000 microinches per inch

Fatigue Life:
Exceeds 10 cycles at ±1000 microinches per inch

Transverse Sensitivity:
Negligible (line weld between strain tube and mounting flange)

### ENVIRONMENTAL SPECIFICATIONS

Compensated Temperature Range:
Static & dynamic measurements: 0° to 180°F. at 1 ATMS.
Humidity 100% @ 180 F @ 100 psi
Apparent Strain with Temperature:

The Model SG 189 strain gage is factory adjusted to a specific unmounted terminal slope value within a tolerance of ±50 microinches/inch. When the unit is mounted the terminal slope is 0 within ± 80 microinches/inch over the range of 75° to 180°F.

Gage Factor Change with Temperature:
Gage factor varies inversely with temperature approximately 1% per 100°F over the compensated temperature range.

Additional Environments:
The strain gages have been subjected to the following environments and levels without deterioration of performance.

Linear Sinusoidal Vibration: 35 g, 20 to 2000 cps
Static Acceleration: 50 g
Shock: 100 g half sine, 7 millisecond duration
Acoustic Noise: 150 db

### MECHANICAL SPECIFICATIONS

**Strain Gage Configurations:**
Reference dimensional outline drawings are shown on front.

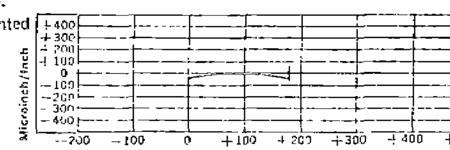
**Electrical Connections:**
(Color Code)
Red—Active
Black—Common
White—Common

**Strain Gage Mounting Flange Material:**
Stainless steel AISI Type 321

**Test Specimen Materials:**
Intended for mounting on weldable ferrous and non-ferrous materials excluding aluminum and magnesiu

### ORDERING INFORMATION

Model No. SG 189 followed by —6 or —9 to denote 6 9 ppm temperature coefficient of expansion of test specimen material.

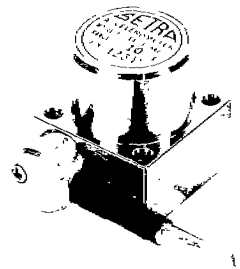



**Apparent Strain vs. Temperature Curves (Typical) °F**

FIGURE - A-1-A

# LINEAR ACCELEROMETER

# Model 100




APPROX. HALF SCALE

## INTRODUCTION

SETRA's linear accelerometer Model 100 is a unique concept in transducer design combining the salient features of many types of accelerometers. Powered by dc excitation, Model 100 produces a high level dc output signal proportional to the sensed acceleration vector. The transducer faithfully responds to input stimulus from steady state *up to the natural frequency of the seismic system.* The gas squeeze film damping insures a reasonably constant amplitude response over the entire temperature range of −65 to +250F.

## DESCRIPTION

Model 100 accelerometer is used in much the same way as a strain gage transducer. Both types of transducers are four terminal networks which can be grounded at only one point, either at an input or at an output terminal, but not at both points. Power supply requirements are also identical. A single supply can be used to excite one or many transducers in parallel.* At the output terminals the Model 100 accelerometer delivers approximately 100 times the output signal voltage and 10,000 times the output power of a strain gage transducer. *Noise and power frecuency pick up problems are* virtually non existent when using this instrument.

Read out equipment required for the Model 100 is extremely simple, anything from a voltmeter to an oscilloscope may be used. The output can be used to power a control loop or a relay without amplification. Signal transmission by cable to remote read out equipment is quite simple because of the high power level of the output signal. Special cable with controlled capacitance is not required as is often the case with some other types of accelerometers.

* *Under this condition the output terminal pairs must not have a common connection*

## FEATURES

The outstanding features of the Model 100 include:

- Response to steady state acceleration.
- High natural frequency.
- High output signal voltage with low output impedance.
- DC output with dc excitation.
- Temperature insensitive damping.
- High overload capability.
- Compact, lightweight.
- Low cost.
- Low excitation power requirement.

FIGURE - A-1-B

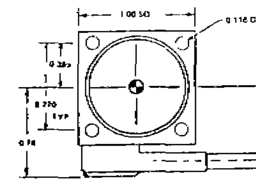
## OPERATING PRINCIPLE

The non pendulous acceleration sensor consists of a differential capacitor in which the moving plate is *constrained to rectilinear motion* between two fixed plates by a unique system of flexures. A new principle of transduction* utilizing the most advanced integrated circuitry and solid state components results in a compact design with a high degree of accuracy and reliability.

*Because of the unique design of the acceleration* sensor, the transducer is completely immune to damage caused by static overload. The sensor is mounted in the stainless steel instrument housing in a way that isolates it from the effects of mounting strain and thermal shock and yet does *not impair the transmission of the highest* frequencies

*Patents pending

| STANDARD ACCELERATION RANGES | MAXIMUM STATIC ACCELERATION | APPROXIMATE NATURAL FREQUENCY |
|---|---|---|
| ±1g | ±100g | 220 Hz |
| ±2.5g | ±100g | 350 Hz |
| ±5g | ±100g | 490 Hz |
| ±10g | ±100g | 700 Hz |
| ±25g | ±200g | 1100 Hz |
| ±50g | ±250g | 1550 Hz |
| ±100g | ±500g | 2200 Hz |

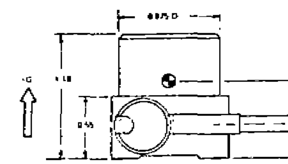



ELECTRICAL CONNECTIONS

White . . . . Positive excitation Yellow . .

Black . . . . Negative excitation Brown .

Acceleration in the direction of arrow produces




C G OF SEISMIC MASS

WEIGHT EXCLUSIVE OF CABLE IS APPROX

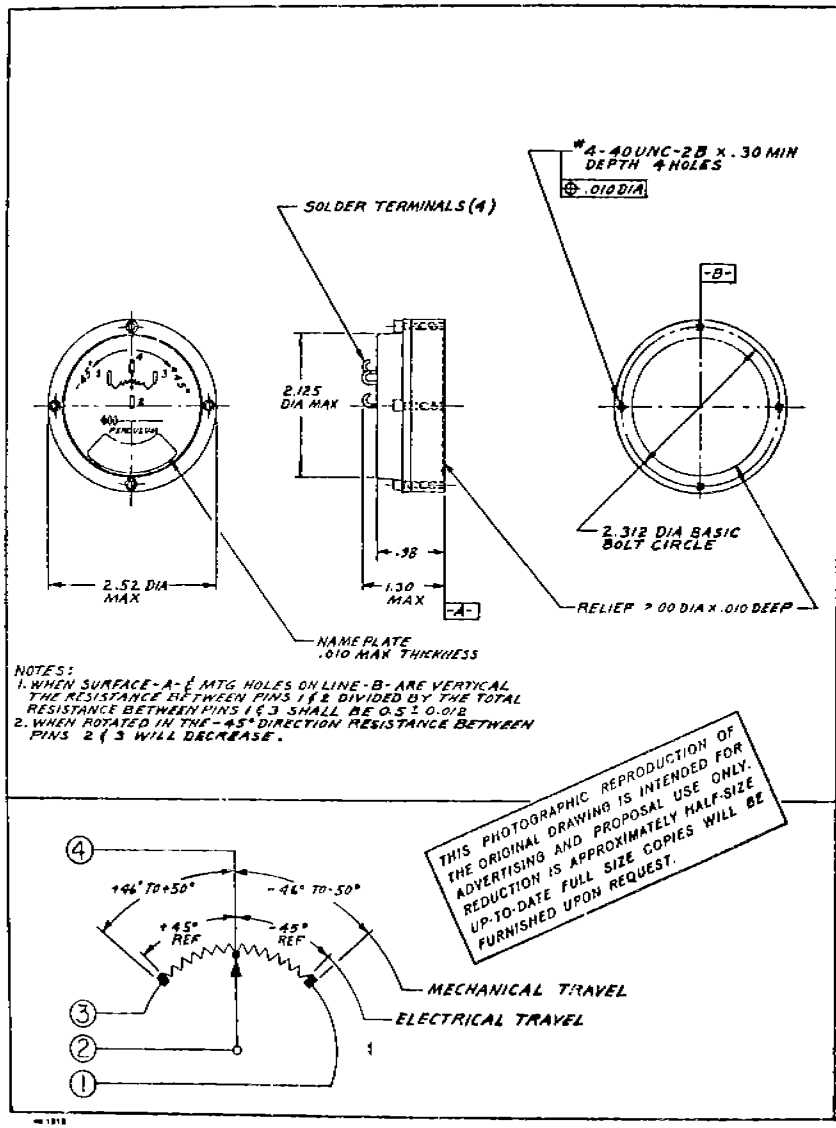
## PERFORMANCE SPECIFICATIONS

| | |
|---|---|
| Ranges | ± 1g to ± 100g |
| Direction of Sensitivity | Perpendicular to the base. |
| Tranverse Acceleration Response | < 0.01g/g. |
| Damping | Gas squeeze film: 0.7 ± 0.1 of critical at 77F. Ratio in approximately 15%/100F. |
| Excitation* | 6 volts dc at approx 20 ma. |
| Full Range Output | Approx ± 1.5 volts ** |
| Output Impedance | Approx 400Ω. |
| Zero Output | < ± 150 mv at 77F with zero acceleration |
| Ambient Temperature Limits | -65F to +250F. |
| Thermal Zero Shift | < 2% of full range/100F from -65F to +250F |
| Thermal Coefficient of Sensitivity | < 1% of full range/100F from -65F to +250F. |
| Combined Non-Linearity and Hysteresis | < 0.75% *of full range output.* |
| Electrical Connections | Two feet of 4-conductor shielded cable (shield grounded |
| Output Noise | < 5 mv RMS. |
| Weight | Approx 3 oz. exclusive of cable. |

*Will not be damaged by excitation up to 8 volts dc or by reversed excitation current limited to 250 ma

**Calibrated into a 50 000Ω load, operable into load impedance of 10,000Ω or greater, output terminals can be shorted without c

FIGURE - A-1-C




SPECIFICATIONS

| | | |
|---|---|---|
| *1.0 | RANGE | ±45° ±0.5 |
| 2.0 | POTENTIOMETER | |
| *2.1 | RESISTANCE | 2000 OHMS ±5% |
| 2.2 | POWER DISSIPATION | 0.5 WATT AT +130°F |
| *2.3 | CENTER TAP | ±0.25% OF TOTAL ELECTRICAL TRAVEL FROM THEORETICAL ELECTRICAL CENTER |
| 3.0 | ACCURACY | THE MAXIMUM DEVIATION OF ANY CALIBRATION POINT SHALL BE WITHIN ±1% OF A STRAIGHT LINE DRAWN THROUGH THE COORDINATES OF -45° OUTPUT AND +45° OUTPUT. THIS TOLERANCE BAND APPLIES BETWEEN -44° AND +44°. |
| 4.0 | DAMPING | SHALL DECREASE AMPLITUDE OF OSCILLATION AT RATE OF 29% TO 63% OF EACH PRECEDING HALF CYCLE OVER TEMPERATURE RANGE OF +20°F TO +130°F |
| 5.0 | NATURAL FREQUENCY | 2 CPS MINIMUM OVER TEMPERATURE RANGE OF +20°F TO +130°F |
| *6.0 | NOISE | 100 OHMS MAXIMUM AT 1°/SECOND MAXIMUM WITH 1 MILLIAMP CONSTANT WIPER CURRENT |
| 7.0 | ENVIRONMENTAL CONDITIONS | |
| 7.1 | VIBRATION (NON-OPERATING) | 10 TO 30 CPS, .060 INCH EXCURSION, PEAK TO PEAK, 9 PERIODS, 10 MINUTES EACH, IN 3 MUTUALLY PERPENDICULAR AXES. 30 TO 100 CPS AT 3G, 18 PERIODS, 10 MINUTES EACH, IN 3 MUTUALLY PERPENDICULAR AXES |
| 7.2 | SHOCK (NON-OPERATING) | 100G FOR 10 MS, ANY 3 MUTUALLY PERPENDICULAR AXES |
| 7.3 | TEMPERATURE | |
| 7.3.1 | STORAGE | -65°F TO +160°F FOR 48 HOURS |
| 7.3.2 | OPERATING | +20°F TO +130°F |
| 8.0 | INSULATION RESISTANCE | 30 MEGOHMS MINIMUM WITH 500 VDC ±10% IMMEDIATELY FOLLOWING 500V RMS AT 60 CPS HI-POT FOR 1 MINUTE DURATION; ANY TERMINAL TO CASE |
| 9.0 | WEIGHT | 0.75 POUNDS MAXIMUM |
| *10.0 | SEALING | TO BE SILICON OIL-FILLED AND HERMETICALLY SEALED AND SHALL NOT LEAK OR DEFORM UNDER 24 INCHES OF Hg VACUUM FOR 20 MINUTES OVER TEMPERATURE OF +20°F TO +130°F |
| 11.0 | REMARKS | |
| 11.1 | ITEMS MARKED WITH (*) ARE CHECKED IN PRODUCTION TESTS. OTHER ITEMS FOR REFERENCE MAY BE CHECKED ON ORDER BY QUALIFICATION TESTS. | |

ENVELOPE DRAWING PENDULUM

U.S. NAVAL TORPEDO STA. KEYPORT, WASHINGTON

SCALE 1/1 — C — LP17-0601-1 — C

FIGURE - A-1-D

# APPENDIX B

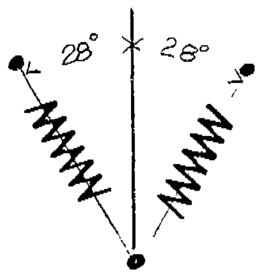
## STRAIN GAGE BRIDGE CIRCUITS AND RELATIONSHIPS

### GAGE CONFIGURATIONS

The single-element Micro-Dot strain gage (see specifications in Appendix A) has been selected as the standard sensing element for the SL-7 Instrumentation System. Gages with cable lengths of 10, 25, and 50 feet were utilized in the system.

The gage elements were used in six configurations:

Circuit No. 1 (Figure B-1): Dyadic Pairs, Port and Starboard, Opposite Arms




In many applications in this system a stress gage rather than a strain gage was required. In order to obtain an equivalent stress gage effect and at the same time use the strain gage elements, two gages were placed in the dyadic configuration.

The operation consists of placing each strain gage at an angle 28° to the axis of interest. This angle was obtained from the equation

$$\text{Cos } 2\Theta = \frac{1-\mu}{1-\mu}$$

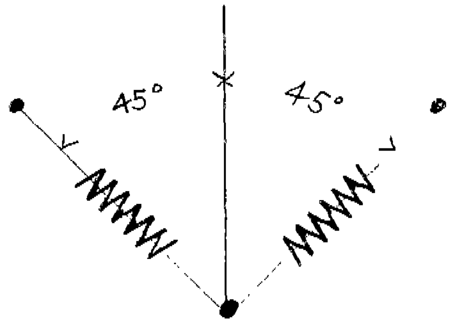
where $\theta$ is the angle between a gage element and $\mu = 0.28$, Poisson's ratio for steel.

Circuit 1 was used for the Longitudinal Vertical Bending Stress signal. With the active arms opposite each other, the vertical components of longitudinal bending add, and the horizontal components subtract. A complete discussion of the dyadic gage may be found in an article entitled "The Dyadic Gage" by Sidney B. Williams in the proceedings of the Society for Experimental Stress Analysis, Volume I, No. 2, p. 43 (1944).

Circuit No. 2 (Figure B-2): Dyadic Pairs, Port and Starboard, Adjacent Arms

This circuit is similar to Circuit No. 1. By putting the active arms adjacent to each other the horizontal components of longitudinal bending add (since they are of opposite mechanical polarity) and the vertical components subtract.

Circuit No. 3 (Figure B-3): Shear, Full-Bridge




If two single gages are oriented 90° to each other, and each 45° to a common axis, then in the presence of pure shear one gage will see tension and the other compression. This fact has been used in the arrangement of Circuit No. 3, Figure B-3B-3. The two gages are arranged as shown and the signal obtained is the desired shear signal along the common axis. If two such arrangements, one port the other starboard, are combined as shown in Figure B-3, an output proportional-to-torsional shear is obtained. By changing the order of the gages in the circuit, a vertical shear signal can be obtained.

Circuit No. 4 (Figure B-4) Shear, Half-Bridge

By completing the bridge with dummy resistors, a shear signal from one side only can be obtained. The two independent signals from the two sides can be recombined during data analysis to produce either torsional or vertical shear.

Circuit No. 5 (Figure B-5) Single Dyadic, One Location

If stress data from one location is to be obtained, the two elements of a dyadic pair can be electrically split so that they occupy opposite arms of a bridge. This configuration was used for the longitudinal stress gage array at FR. 186.

Circuit No. 6 (Figure B-6): Single Strain Gages

In this configuration the single element gage is used directly as the active arm of a 4-arm bridge circuit. The other bridge arms are made up of 120-ohm bridge completion resistors. Gage orientation is along the axis of interest.

STRAIN GAGE CIRCUIT OUTPUTS AND CALIBRATION LEVELS

The following are the basic relationships used in designing the signal-conditioning and calibration circuits:

| Circuit | Output | Calibration |
| --- | --- | --- |
| Dyadic stress | $\frac{V_o}{V_i} = \frac{N(GF)(1-\mu)\sigma_x}{4E}$ | $\sigma_c = \frac{ER_g}{N(GF)(1-\mu)R_{cal}}$ |
| Shear stress | $\frac{V_o}{V_i} = \frac{N(GF)(1+\mu)\sigma_x}{4E}$ | $\sigma_c = \frac{ER_g}{N(GF)(1+\mu)R_{cal}}$ |
| Strain | $\frac{V_o}{V_i} = \frac{1}{4}\frac{\Delta R}{R} = \frac{(GF)\varepsilon}{4}$ | $\varepsilon_c = \frac{R_g}{(GF)R_{cal}}$ |

The following definitions apply to these relationships:

$V_o$ = output voltage from bridge, volts

$V_i$ = input, or excitation voltage to bridge, volts

N = number of active arms

(GF) = gage factor

$\mu$ = Poisson's Ratio

$\sigma_x$ = stress in the x direction, psi

E = Young's Modulus

$\sigma_c$ = calibration stress level, psi

$R_g$ = total gage resistance of active arm, ohms

$\Delta R$ = change in strain gage resistance, ohms

R = initial strain gage resistance, ohms

$\varepsilon$ = strain, inches per inch

$\varepsilon_c$ = calibration strain level, inches per inch

$R_{cal}$ = shunt calibration resistor, ohms

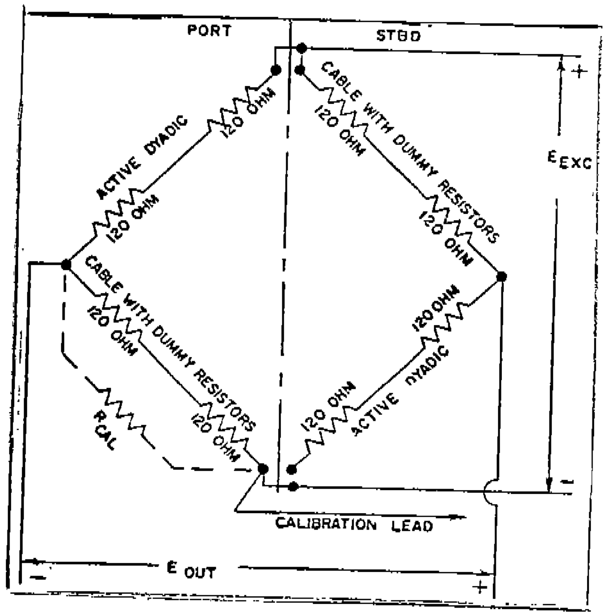



FIGURE B-1 - STRAIN GAGE CIRCUIT NO.1

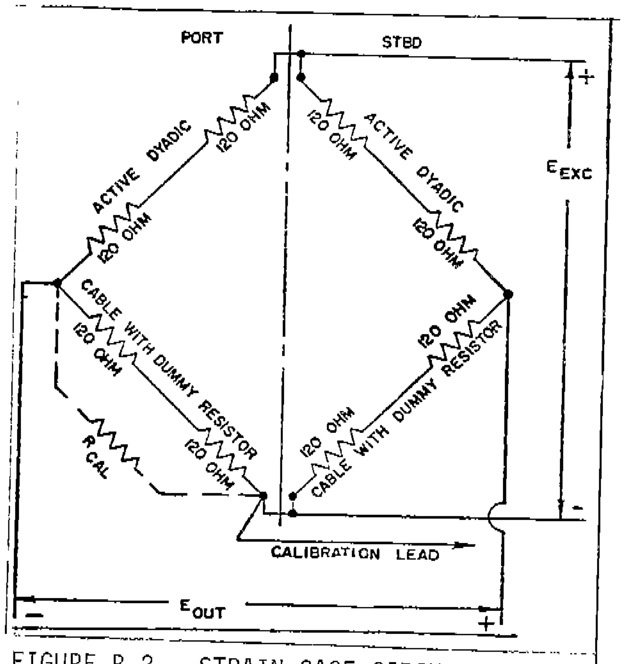



FIGURE B-2 - STRAIN GAGE CIRCUIT NO.2

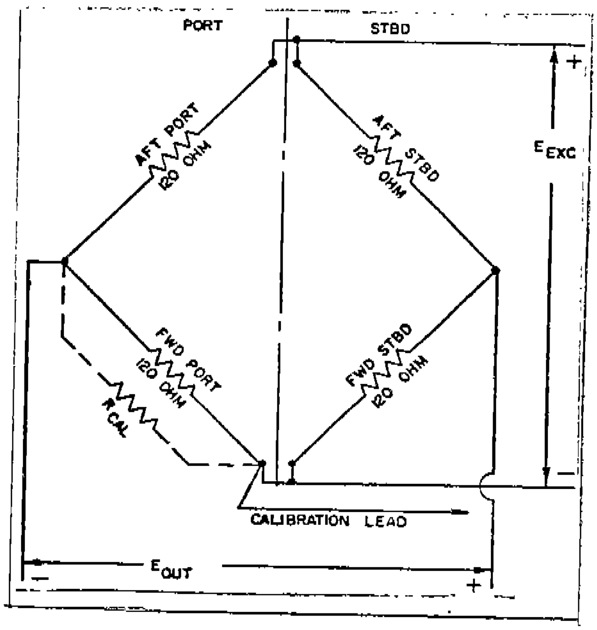



FIGURE B-3 - STRAIN GAGE CIRCUIT NO.3

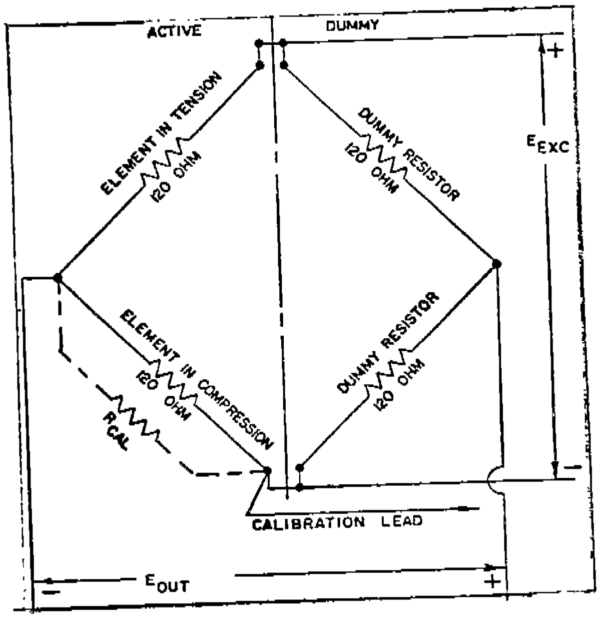



FIGURE B-4 - STRAIN GAGE CIRCUIT NO.4

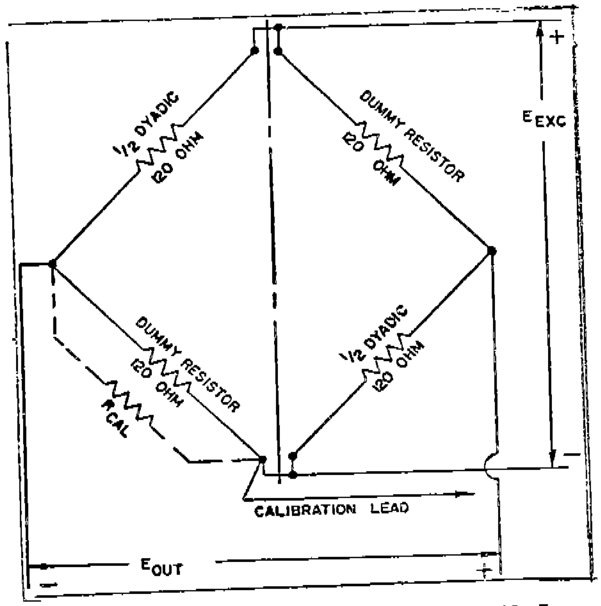



FIGURE B-5 - STRAIN GAGE CIRCUIT NO.5

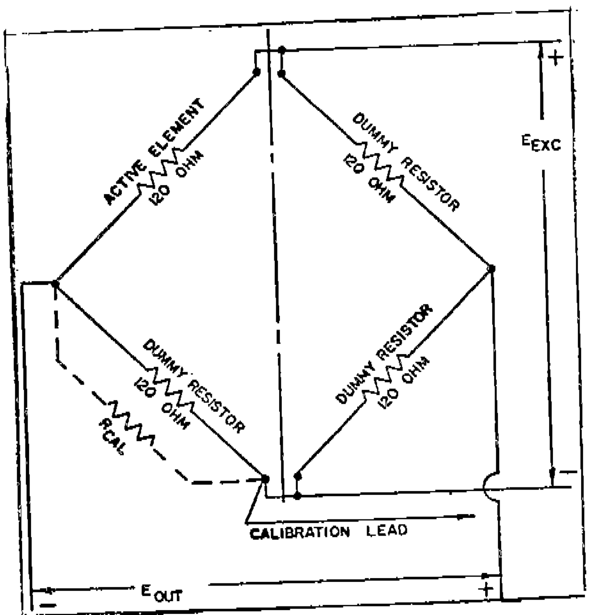



FIGURE B-6 - STRAIN GAGE CIRCUIT NO.6

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4. DESCRIPTIVE NOTES *(Type of report and inclusive dates)*
Technical

5. AUTHOR(S) *(First name, middle initial, last name)*

R. A. Fain

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13. ABSTRACT

This report describes the transducers, cabling, signal-conditioning, and recording elements of the instrumentation system installed aboard the SL-7 Containership S.S. SEA-LAND McLEAN. It includes a detailed summary of the strain-gage bridge circuits, locations of all transducers, and a description of the various operating modes and options available for recording data from more than 100 strain gages, accelerometers, and motion sensors.

Security Classification

| 14 KEY WORDS | LINK A | | LINK B | | LINK C | |
|---|---|---|---|---|---|---|
| | ROLE | WT | ROLE | WT | ROLE | WT |
| | | | | | | |

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(PAGE 2)

Security Classification

## SHIP STRUCTURE COMMITTEE PUBLICATIONS

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SSC-229, *Evaluation and Verification of Computer Calculations of Wave-Induced Ship Structural Loads* by P. Kaplan and A. I. Raff. 1972. AD 753220.

SSC-230, *Program SCORES - Ship Structural Response in Waves* by A. I. Raff, 1972. AD 752468.

SSC-231, *Further Studies of Computer Simulation of Slamming and Other Wave-Induced Vibratory Structural Loadings on Ships in Waves* by P. Kaplan and T. P. Sargent. 1972. AD 752479.

SSC-232, *Study of the Factors which Affect the Adequacy of High-Strength, Low Alloy, Steel Weldments for Cargo Ship Hulls* by E. B. Norris, A. G. Pickett, and R. D. Wylie. 1972. AD 752480.

SSC-233, *Correlation of Model and Full-Scale Results in Predicting Wave Bending Moment Trends* by D. Hoffman, J. Williamson, and E. V. Lewis. 1972. AD 753223.

SSC-234, *Evaluation of Methods for Extrapolation of Ship Bending Stress Data* by D. Hoffman, R. Van Hooff, and E. V. Lewis. 1972. AD 753224.

SSC-235, *Effect of Temperature and Strain Upon Ship Steels* by R. L. Rothman and R. E. Monroe. 1973. AD 768891.

SSC-236, *A Method for Digitizing, Preparing and Using Library Tapes of Ship Stress and Environment Data* by A. E. Johnson, Jr., J. A. Flaherty, and I. J. Walters. 1973. AD 767388.

SSC-237, *Computer Programs for the Digitizing and Using of Library Tapes of Ship Stress and Environment Data* by A. E. Johnson, Jr. J. A. Flaherty, and I. J. Walters. 1973. AD 768863.

## SL-7 PUBLICATIONS TO DATE

SL-7-1, (SSC-238) - *Design and Installation of a Ship Response Instrumentation System Aboard the SL-7 Class Containership S.S. SEA-LAND McLEAN* by R. A. Fain. 1974.

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