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TECHNICAL REPORT

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DESIGN AND INSTALLATION OF

A SHIP RESPONSE INSTRUMENTATION SYSTEM

ABOARD THE CONTAINER VESSEL

S.S. BOSTON

PROGRESS REPORT NO. 1

13 DECEMBER 1968

TELEDYNE MATERIALS RESEARCH COMPANY

A TELEDYNE COMPANY

DEPARTMENT OF THE NAVY
NAVAL SHIP SYSTEMS COMMAND
WASHINGTON, D. C. 20360

DESIGN AND INSTALLATION OF A SHIP RESPONSE INSTRUMENTATION SYSTEM ABOARD THE CONTAINER VESSEL S.S. BOSTON

Progress Report No. 1

by

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and B. H. Schofield

For the Period

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Technical Report
E-1123-1

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SUMMARY

Progress during this reporting period consisted of design, procurement, and installation of a ship response instrumentation system aboard the container vessel S.S. BOSTON. Included in this report are the following: a detailed description of the system, consisting of the parameters to be measured; the type and location of the transducers installed; components and functional operation of the data acquisition and recording system; data analysis procedures; and equipment specifications.

In addition, a description of the procedure and the results of the first transducer calibration attempt are presented.

ADMINISTRATIVE INFORMATION

The effort reported herein is being performed under Naval Ship Systems Command, Contract N00024-68-C-5486, Project Serial No. F-35422306, Task 2022, SR 182. Teledyne Materials Research internal project number is 1123/136. Contract control is by the Naval Ship Engineering Center, NAVSEC 6132, Department of the Navy, Washington, D. C. 20360. Mr. John Vasta is the Contract Administrator.

Teledyne Materials Research professional personnel performing this effort are Messrs. F. C. Bailey, B. H. Schofield, J. Q. Cragin, H. G. LaMontagne and R. A. Fain. The primary goal of this investigation is to obtain stress and motion data on this class of vessel and to supplement comparable investigations performed or now being performed on other types of vessels by the same sponsoring agency, i.e., Contract N00024-68-C-5231, Project Serial No. S-F013 0304, Task 2022, SR-153 and SR-172 Ship Response Statistics and Slamming Studies.

Technical Report
No. E-1123-1

1.0 INTRODUCTION

The S.S. BOSTON represents a relatively new species of ocean-going vessel which emerged concomitantly with the novel container mode of cargo transportation. Of particular significance is the manifest departure in structural configuration of container ships from the conventional class of cargo ships; notably, the virtual lack of main deck support structure. Because of this structural anomaly, there is considerable interest in the effect such a change will produce in the behavioral characteristics of such vessels. The following sections describe the progress to date of the fabrication and installation of the instrumentation system designed to measure the stress and motion characteristics of the container vessel S.S. BOSTON.

The S.S. BOSTON, Figure 1, is owned and operated by Sea-Land Service Incorporated. Formerly this vessel was the S.S. GENERAL M.M. PATRICK, a C4-SA2 personnel carrier, and was subsequently converted to a C4-X2 container ship by Todd Shipyards Corporation, Galveston Division.

The basic design criteria for this system are twofold:

1.1 Create a semi-automatic data collection system to be used for manned voyages on the North Atlantic during the 1968-1969 season.

1.2 Provide data in a format compatible with the data collected from other instrumented vessels.

Design of the instrumentation system was initiated June 27, 1968. Installation of transducer components commenced in mid-July, 1968, at

Todd's Galveston Yard with final check out and initial data collection originally scheduled for the ship's first European voyage in late October, 1968.

Presumably because of shipyard construction priorities and urgency in the delivery of the vessel to the owner, a substantial portion of the instrumentation cabling, which was to be performed by the yard, was not completed. The vessel was immediately placed into service on a Newark, New Jersey-San Juan, Puerto Rico run. During the loading operations for this voyage a substantial portion of the Teledyne recording equipment was anchored in position in the instrument room. Teledyne engineers then accompanied the ship on one voyage with the intention of completing the shipyard cabling; however, time was not sufficient to finish the work. Subsequently, and upon a few hours' notice the vessel was rescheduled from the New Jersey-San Juan route to a European run. During this latter voyage an agreement was reached with Sea-Land for the completion of the shipyard cabling and final instrumentation wiring on the following European trip. On November 26, 1968, two TMR engineers boarded the vessel to undertake the cabling and place the instrumentation into operation.

At the present time all instrumentation, with the exception of the wave buoy system, is aboard the S.S. BOSTON and all wiring is completed with the exception of the midship transducers (accelerometer and pendulums). Because of the risk involved working the midship area while at sea, the latter will be connected during a port visit.

2.0 GENERAL

Both the recording and signal-conditioning equipment, assembled in a console unit, are located in an instrument room port side, upper deck, just forward of frame 195. Adjacent space has been modified to provide living quarters for personnel operating the equipment. Transducers are located at selected sites throughout the ship, Figure 2A. The location, type, and function of each are more fully discussed in the following sections. Semi-permanent cabling running from the vicinity of transducers to the instrument room via junction boxes provide the necessary interconnections. Figure 2B shows a layout plan of the personnel and equipment accommodations aboard the S.S. BOSTON.

3.0 TRANSDUCERS

The transducers in this system are divided into two categories. The first class consists of stress gages arranged in bridge circuits to provide the desired stress for a specific moment orientation relative to the ship, i.e., vertical or horizontal moment. Stress gages are located in housings (see Drawing D-2700) on both the top side and under deck surfaces of the main deck approximately 14-1/2" inboard of the side plate and 15 inches aft of frame 105. Gages in these housings are formed into two bridge circuits which provide outputs induced by vertical and horizontal longitudinal bending moments. See Figures 3A and 3B. The use of gages on both surfaces of the deck plate precludes a possible error due to plate unfairness in the gaging area. The bridge circuits also contain temperature compensation gages to prevent thermal variations from biasing the data. In addition, each stress gage element is self-temperature compensating for steel applications.

Torsional shear gages are located in housings positioned on the inboard side of both the port and starboard side plate 20.3 feet above the keel line and 15 inches aft of frame 105. The gages themselves are 2-arm, 45 degrees from vertical, strain gages combined into a single 4-element bridge circuit in a configuration sensitive to torsional stress. A discussion of the torsion transducer installation is presented in Appendix A. See Appendix B and Figure 3C for further details of the torsion transducer.

Additional gages are located in the starboard and port tunnels to measure stresses at local areas. These units are not in housings but are single active gage elements with an associated temperature-compensating gage welded to the area of interest; the elements are then waterproofed and covered. These gages are read as half-bridges with bridge completion resistors located in the instrument room. Finally, two additional stress gages are located on the main deck, starboard side forward in the vicinity of #2 hatch coaming. These gages were incorporated into the data system in order to obtain a measure of the level of shear flow in the structure at the point where the open channel section of the hull terminates into the typical box beam section.

The second class of transducers are those located throughout the ship to provide information as to the structural or physical response of the vessel to the operational environment simultaneously with the measurement and recording of the structural stresses. These transducers provide vertical and horizontal (athwartship) acceleration at the bow, midships and stern, and pitch and roll angle midships. An equally significant portion of this class of transducers is the wave height buoy measuring system. This system consists of two basic items: 1) free floating wave buoys and, 2) a receiver-recorder system. The free floating buoys contain an accelerometer transducer and a radio transmitter unit with associated whip antenna. Figure 4 shows an outline sketch of such a buoy. As the buoy translates vertically with the waves, after launching from the ship, a signal is transmitted to the receiver unit aboard ship and recorded on magnetic tape. Subsequent analysis of these data provides an accurate measure of the wave height environment which is obtained for correlation with the data acquired from other transducers.

Two additional transducers are located in the tunnels; one port, one starboard, on the underdeck between frames 105 and 106. These devices measure longitudinal displacement of the deck over a 30-inch gage length to supplement the data obtained from the stress gages mounted in this vicinity.

A functional block diagram (Drawing D2749) is included to show the manner in which transducers are assembled to form a recording system.

The functional flow diagrams (Drawings D2750 SH1-SH6) included show the actual signal path from transducer to the instrument room and tape deck. Appendix B provides additional information as to the transducers used aboard this vessel.

4.0 INSTRUMENT ROOM EQUIPMENT

With the exception of the transducers, junction boxes and cabling, the remainder of the Teledyne Instrument System is located in the instrument room. Various units are packaged into a five-bay console unit which is the dominant feature of this room. Drawings D2751 SH1-SH3 included in this document, outline the various units found in the console. The equipment selected performs one of two functions i.e. it is directly involved in the excitation, conditioning or monitoring of transducer signals, or it is check out equipment used in the set-up, calibration and maintenance of the entire system. Additional portable instrumentation has been placed aboard the vessel to assist in system maintenance. Power to the console is supplied from the ship's hotel service in the form of four 20-ampere circuits of 115 V, 60 Hz from four circuit breakers in power panel C-TM1. This power is distributed throughout the console to various units. The console contains adequate protection of each active circuit as well as visual indications as to the status of each circuit (pilot lamps). (See SH3 Drawing D2751).

A key item in this system is the Ampex Model FR 1300, 14-channel FM tape recorder mounted on the right side of the console. (See Figure 5). A copy of the specifications of this unit is found in Appendix C.

The data channel assignment is as shown on the recording system block diagram, Drawing D2749. It is envisioned that most recording will be at a tape speed of 1-7/8 ips with its associated frequency response of 0 to 625 Hz. In the event that frequencies of higher magnitude are deemed of interest, the recording speed can be increased proportionally.

The various panels and units within the console are connected via a series of cables. Table 1 summarizes the characteristics and functions of these cables and presents an insight into the complexity of the system.

5.0 JUNCTION BOXES AND SHIP'S CABLING

The locations of junction boxes and their associated cabling are shown on Drawing D2699A. A comprehensive listing of junction boxes is provided in Table 2 and descriptive information on the cabling in Table 3.

6.0 SYSTEM OPERATION

The system, as previously stated, is semi-automatic in design. The variety of mode operations is controlled by the programmer unit shown in Figure 6. In the automatic mode the system is turned on for a specified interval at preset hours. Initial settings have been selected for an interval of 15 minutes every four hours with the tape recorder set to run at 1-7/8 ips. During this 15-minute interval three data periods are recorded. Each data period presently consists of 15 seconds of zero; i.e., open-circuiting of transducer signal lines and removal of excitation from bridge circuits; one minute of calibration, i.e., shunting of one arm of the bridge circuits with a specified resistance, or, in the case of the accelerometers, substitution of a calibration voltage; and a period of 3 minutes 45 seconds of data collection. During the 60 seconds of calibration the bridge-shunting resistance is cycled on and off approximately 10 times to create a series of calibration spikes which are used to trigger in-house data analysis equipment. All of the times selected are variable with the operator having complete flexibility of time settings.

In addition, upon the occurrence of a signal (from a selected bridge circuit) higher than a preset stress level, the system generates an alarm and automatically goes into a recording sequence. The length of this sequence is again controllable and is presently set for 15 minutes. At the end of this period the equipment is reset; in the event the high stress condition still exists, a repeat cycle is immediately initiated.

At any time, the operator can switch the system to manual and go into a continuous recording mode. Even in this manual mode, the zero-calibration sequence is performed at the set interval so that all data will be compatible in format.

The system starts and stops the tape recorder as required and keeps track of total time recorded.

The wave monitoring system is a separate integral unit and contains its own 2-track audio tape recorder. This system is placed into operation when a wave buoy is launched from the vessel. The transmitted information is recorded as long as signal strength permits; in the order of 30 to 40 minutes. It is planned to launch four buoys during this winter season when the sea conditions are Beaufort State 6 or above.

In addition to data recorded on the two tape recorders, log book readings, recorded once each watch, will provide information as to ship's position and speed, the relative wind direction and speed and the conditions of the sea at that time.

7.0 ON-BOARD DATA ANALYSIS

During non-recording intervals aboard the vessel it is planned to have the operator perform "quick look" data analysis. This analysis involves placing the recorder in a play-back mode and playing the data into an oscillograph to create chart paper data traces. Up to six data channels at a time can be presented in this manner. The operator, by analyzing these traces, can determine the condition of each of his data channels. Changes in gain, calibration or general maintenance can then be accomplished to ensure that the system is in top running condition.

In addition, a time correlation with log book data will be performed to ensure that trace response is compatible with wind and sea conditions.

8.0 IN-HOUSE DATA REDUCTION

Since it will be possible to acquire data on a selective basis, and since the items of primary interest in this instance are maximum values and the relation of ship and container data, it is expected that the bulk of the analysis can be performed by the engineer aboard ship, who will be equipped with oscillograph playback equipment. However, if required, the probability analyzer is available in the laboratory to permit rapid searches for maximum values and for developing certain other statistical parameters of the data. At the conclusion of each voyage, the tapes and log books will be returned to Teledyne Materials Research at Waltham, Massachusetts. The tapes will be re-run on a compatible Ampex Model 1260 Tape Recorder (see Figure 7). The processed information is placed on a punched card suitable for computer input. In addition, ship, wind, and sea information for each data period is also punched on the card. Thus, when a reel of tape has been processed, one punched card contains the information from each data period. These cards are fed into an in-house IBM Computer. The computer printout contains the values of peak-to-peak and RMS stress levels for each stress channel corresponding to the various sea states.

The wave buoy tapes will be analyzed by a computer program in order to produce wave spectra information for correlation with the stress data.

9.0 S.S. BOSTON CALIBRATION

Strain gage data were recorded from the partly completed instrumentation systems on the S.S. BOSTON during the period from August 8 to 29, 1968, for the purpose of obtaining a physical calibration of the system. Strain data acquired while statically bending the ship with known loads permits a comparison with computer calculations of the structure's behavior. Specifically, the calibration was required not only to provide verification of the integrity of the measuring system in comparison to computed values, but to evaluate the effectiveness of strain gages on one side of a shell plate in presenting heart-of-plate data. Figure 8 shows the calibration conditions used. Conditions shown in b, e, and h were selected for the computer analysis.

Vessel calibrations are carried out, whenever possible, on calm, cloudy nights in order to minimize the effects of differential thermal distributions. Since the load conditions on the S.S. BOSTON were to be varied at a very slow rate, the calibration had to be undertaken over a 21-day period while ballast mud was being placed in the double-bottom spaces of the vessel. In an attempt to improve the possibility of salvaging meaningful data under these conditions, stress measurements were taken at frequent intervals in the hope that thermal effects could be separated from stress changes resulting from the known loads. As will be noted in the following discussions, this was not possible probably because of the numerous other factors involved, such as changes in vessel position and continued addition of structural material during the calibration.

Although some meaningful data were acquired, it is felt that the system should be recalibrated under more tightly controlled and optimized conditions. This recalibration should be performed with known weight containers and ideally performed in an overnight period to minimize thermal problems.

The strain gages themselves are matched to the coefficient of expansion of the structure but the vessel still sees "real" strains imposed by differential heating of the vessel. In many cases in the August period, the thermally-induced strains were higher than the ballast load-induced strains.

It is also recommended that proper stiffnesses, weights and locations be used. An independent naval architect familiar with torsion of ships with large deck openings should review the analysis for adequacy.

The current Designers & Planners' data are superimposed on the heart-of-plate experimental strain data in Figures 12, 13 and 14. Agreement with this quite fundamental analysis is unacceptable, as well as some unexplainable scatter within the sets of gages at any particular location that should all sense the same strain magnitude.

The Designers & Planners' calculated starboard deck data are compression in sense due to the large contribution of what they term "deck stress due to torsion." This value is added to port and subtracted from starboard deck stress, greatly influencing, somewhat questionably, the value and sign of the deck stress.

A recalibration of the system should be performed for the following reasons:

1. Too many extreme thermal cycles in the August period tend to mask the load-induced strain data.
2. Wiring of the system is now completed; thus the problems with temporary cabling will not be repeated.
3. All future data generated by the system will be based upon the results of a good calibration.

This vessel recalibration and predicted stress correlation should have the following ground rules:

Typical of any transducer application of strain gages, exercise of the system improves its performance. A study of the back-to-back gages on the S.S. BOSTON shows that the inside to outside error is gradually reduced to essentially one value after as few as three cycles of thermal and/or physical strain. The final difference is approximately $5\mu\varepsilon$, equal to the minor scale division on the readout equipment. See Figures 9, 10, and 11.

Because of shipyard production problems, internal cabling of the vessel was not finalized at calibration time, so port and starboard data were acquired as one-half bridge rather than the desired full bridge configuration. As one-half bridges, the torsion transducers bonded to the side shell are sensitive to both vertical shear and torsion of the vessel. Ordinarily, these would be separable, but here, with the unknown thermal effects superimposed, it is impossible to obtain explicit values for all the contributing factors.

Designers and Planners, Inc. of New York were asked by Sea-Land to use their computer facilities to predict stresses in the gaged locations for correlation with the experimental data. An existing bending program was used without modification for the state-of-flux structural condition of the vessel. Ballast load inputs used were not from the S.S. BOSTON, but from a non-identical sister ship, the NEWARK.

It is recommended that a combined torsion and bending program be used by Designers & Planners to predict more closely calibration loading stresses.

1. Calibrate overnight during a period of reasonably constant temperature.

2. Use containers with known loads, located at known distances from the midship datum.

3. Modify the Designers & Planners' computer program to include torsion and have the technique approved by a structural specialist.

4. Most important is to accept the fact that a quality calibration is of prime value, and have no other major shipboard activity progressing during the calibration period.

10.0 CONCLUSIONS

At the present time the instrumentation system has been installed aboard the S.S. BOSTON, wired, checked out and is expected to be in operation collecting data on the run from Europe beginning December 9. The only exception to completion is the final wiring of the midship accelerometers and pendulum devices as noted in the body of this report.

It is anticipated that during the next report period the midship transducers will be placed into operation, and that data analysis will be underway contemporaneously with the collection of additional data aboard the S.S. BOSTON.

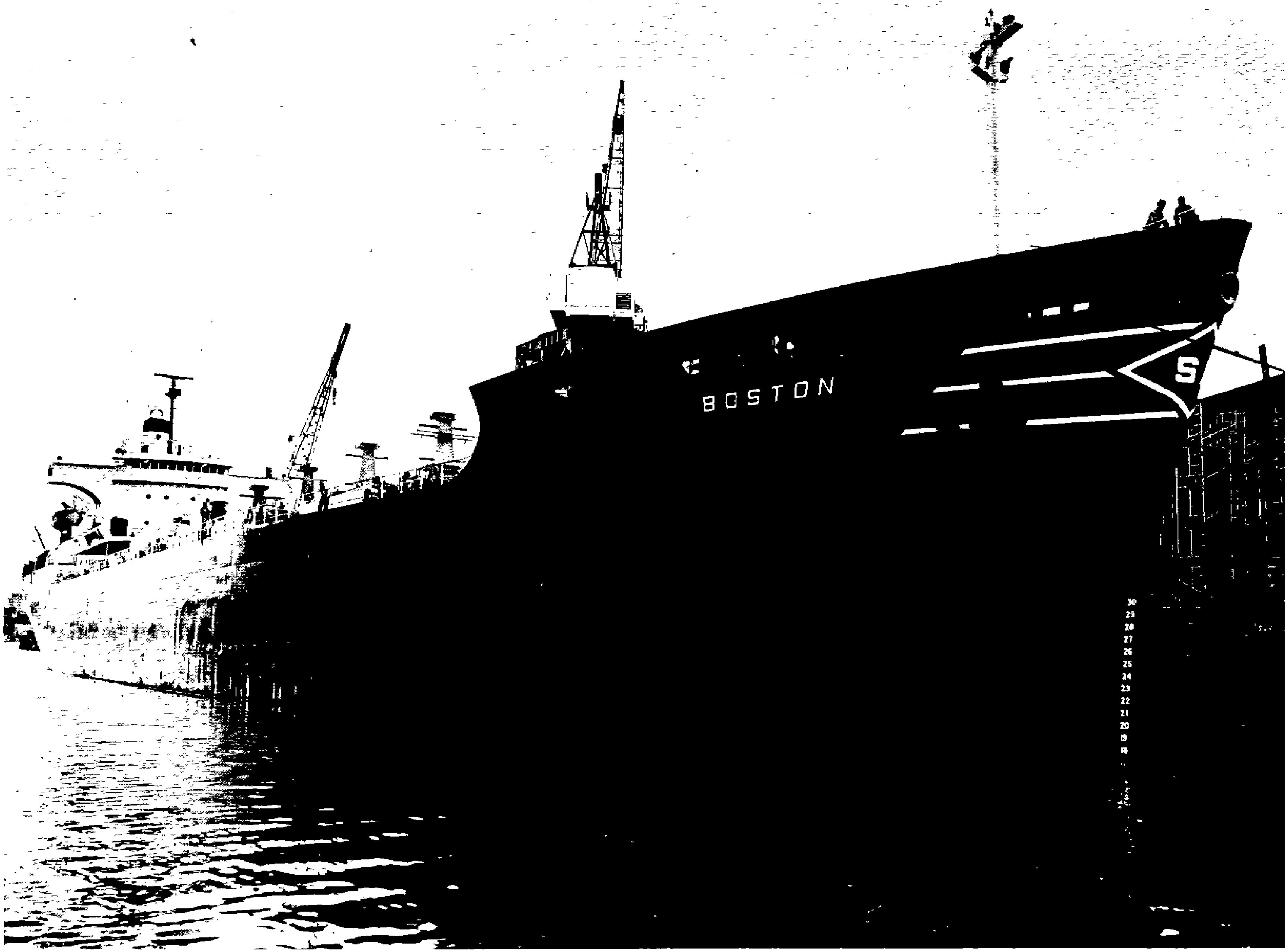


FIGURE 1. CONTAINER VESSEL S.S. BOSTON

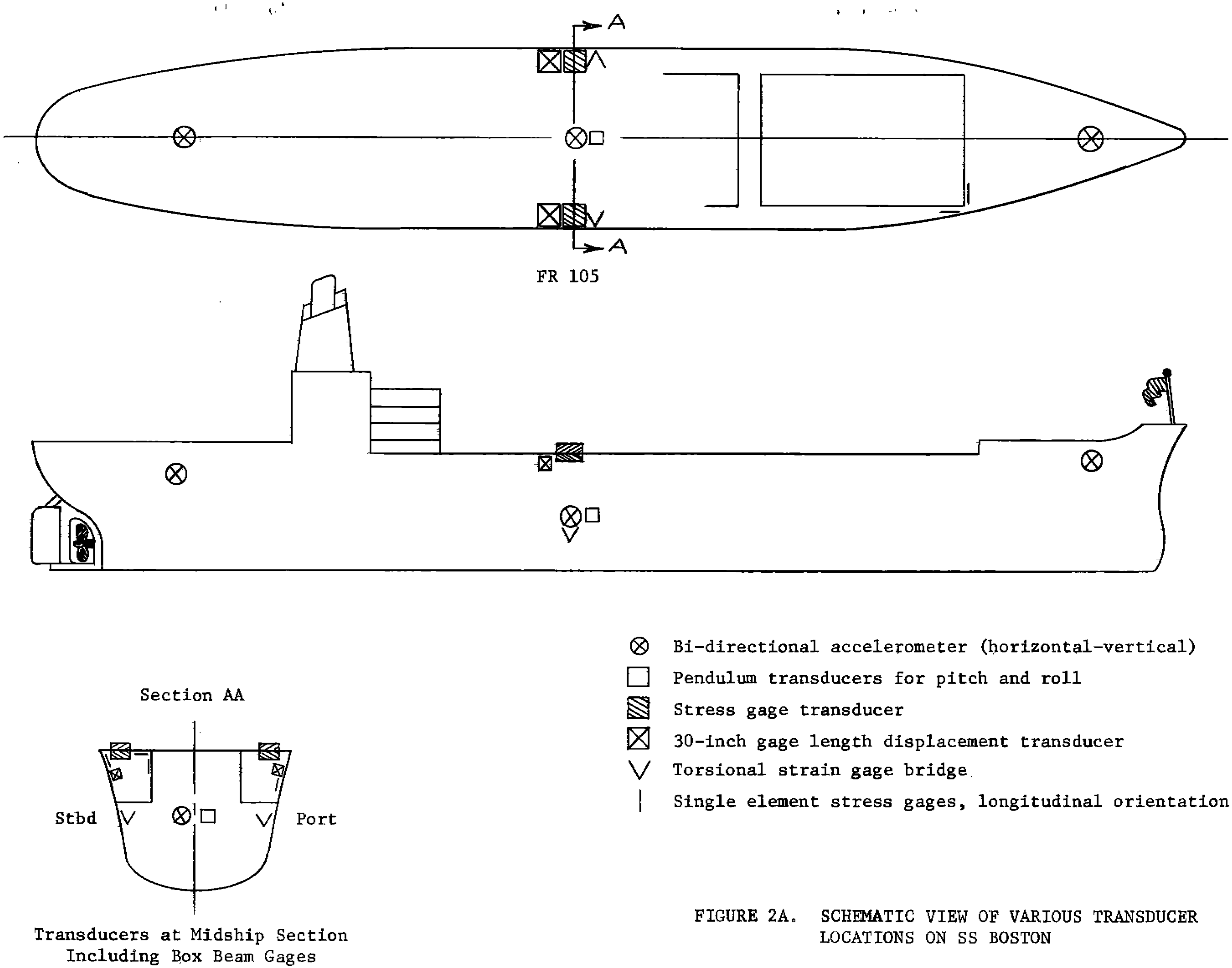


FIGURE 2A. SCHEMATIC VIEW OF VARIOUS TRANSDUCER LOCATIONS ON SS BOSTON

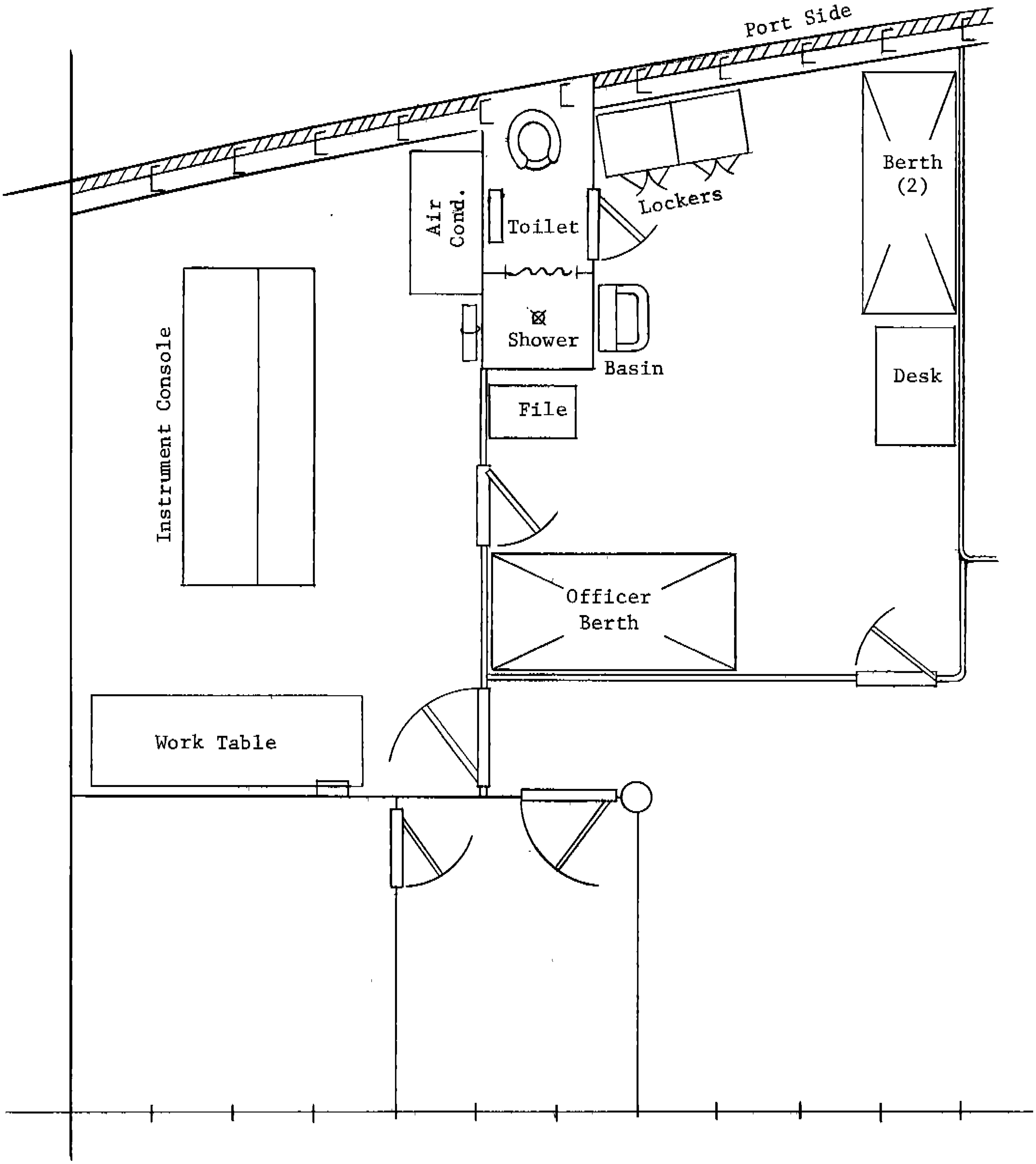
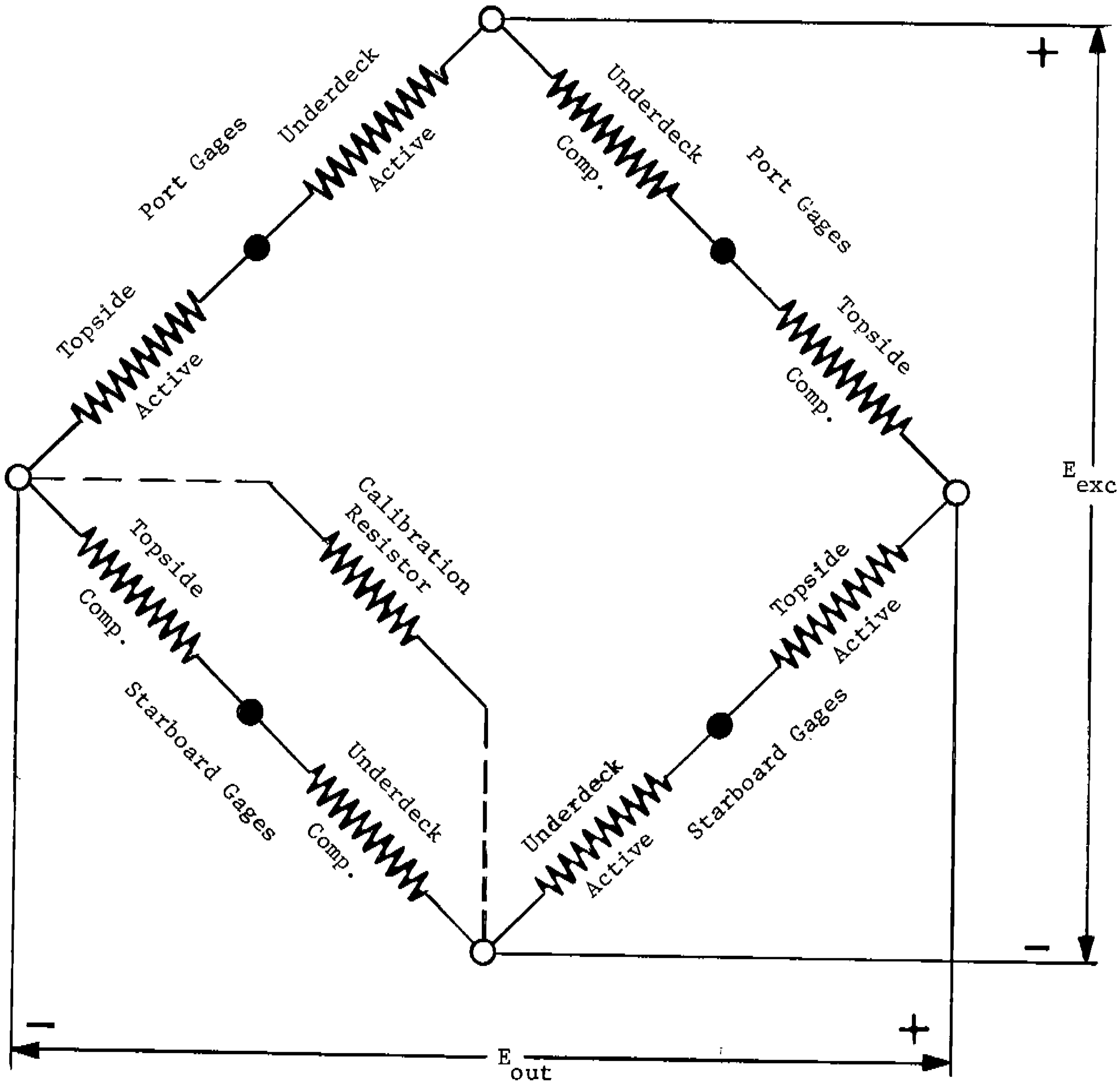
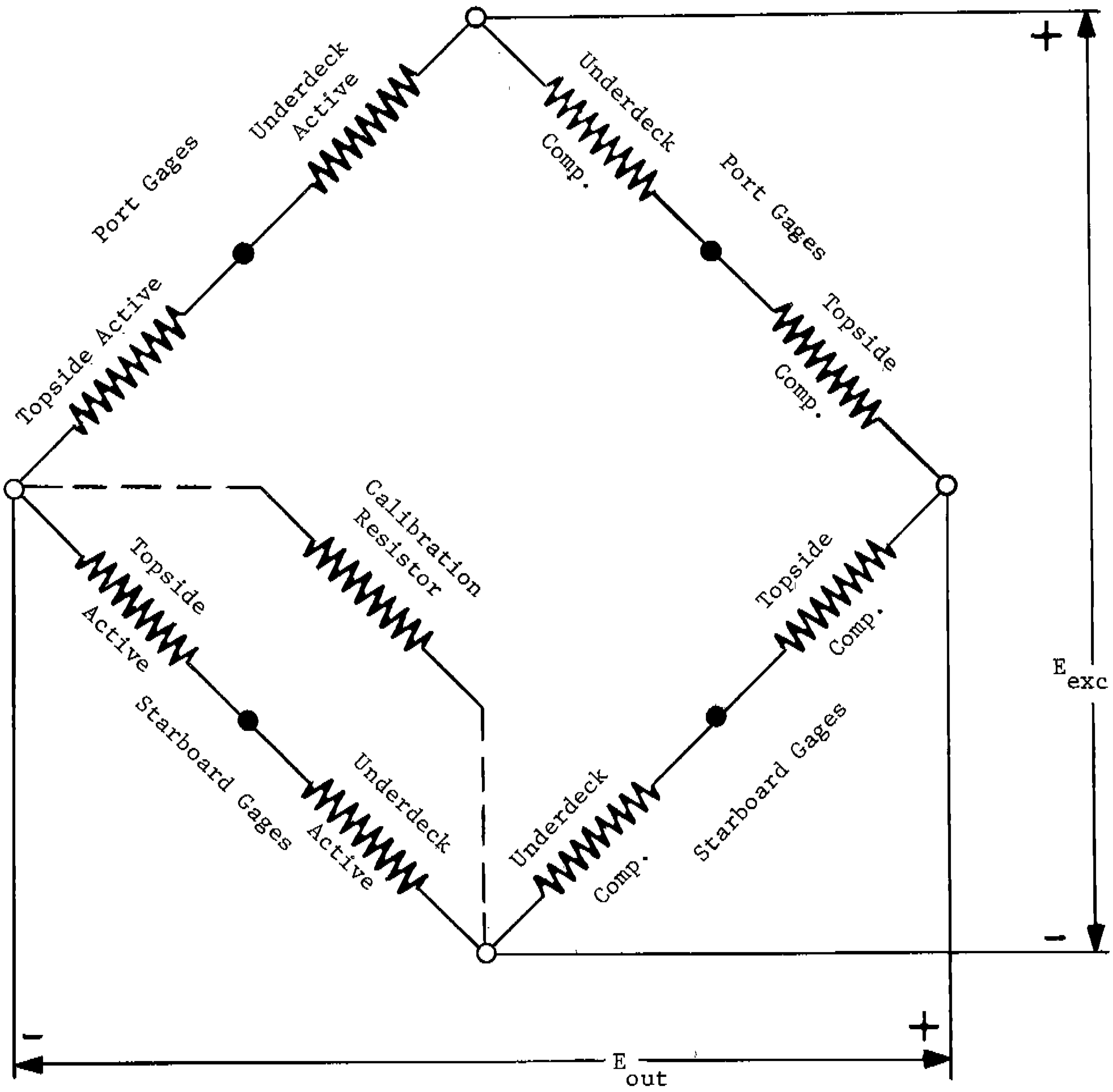


FIGURE 2B. SKETCH SHOWING LAYOUT OF INSTRUMENTATION ROOM AND SCIENTIST/OBSERVER LIVING QUARTERS ON SS BOSTON



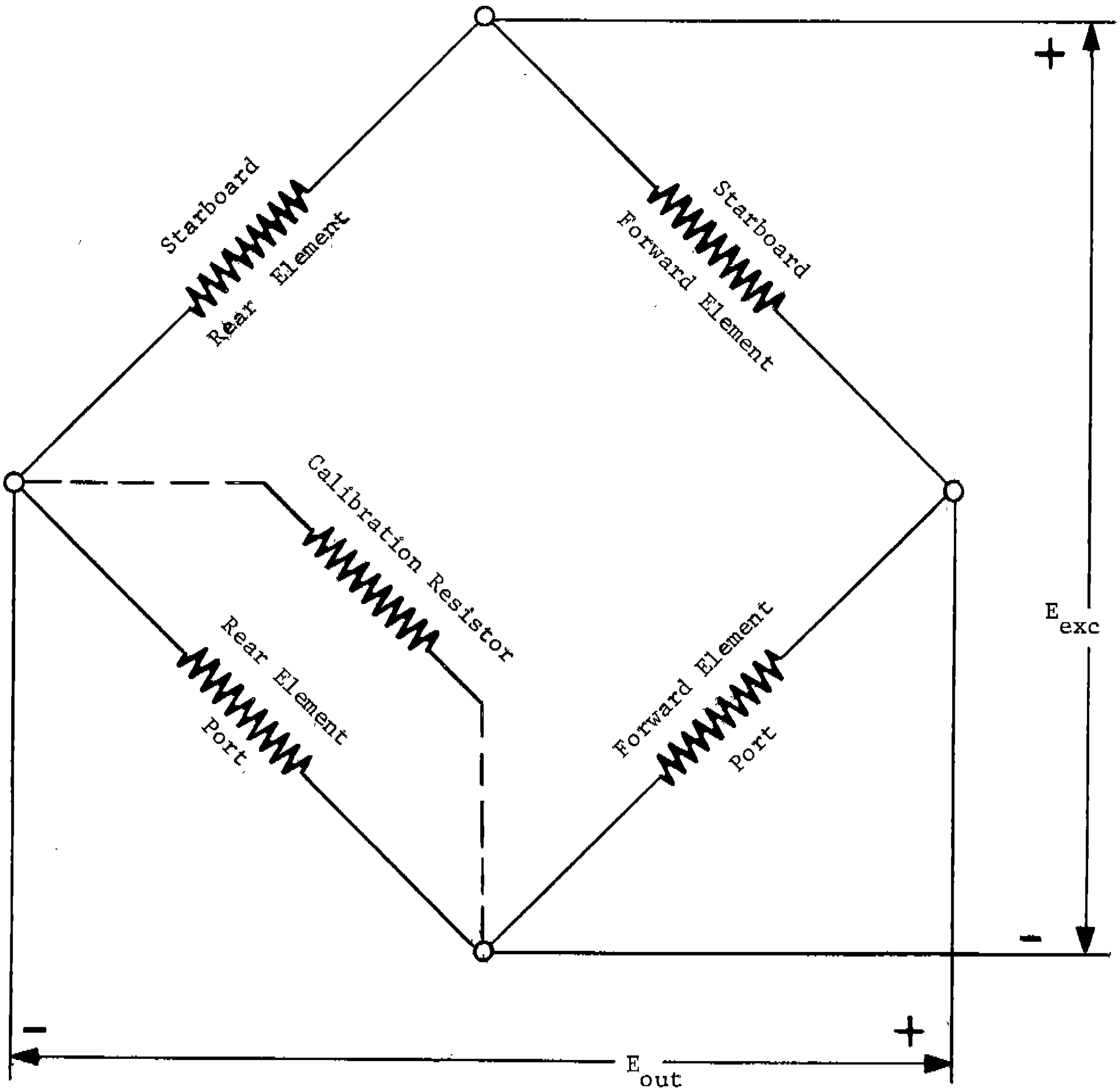
Note: All Bridge Elements are 448 ohm Stress Gages

FIGURE 3A. BRIDGE CIRCUIT - VERTICAL LONGITUDINAL BENDING



Note: All Bridge Elements are 448 ohm Stress Gages

FIGURE 3B. BRIDGE CIRCUIT-HORIZONTAL LONGITUDINAL BENDING



Note: Gages at both locations are two-arm strain gages, each arm 120 ohms set at 45° to the local vertical

FIGURE 3C. BRIDGE CIRCUIT-TORSIONAL STRESS

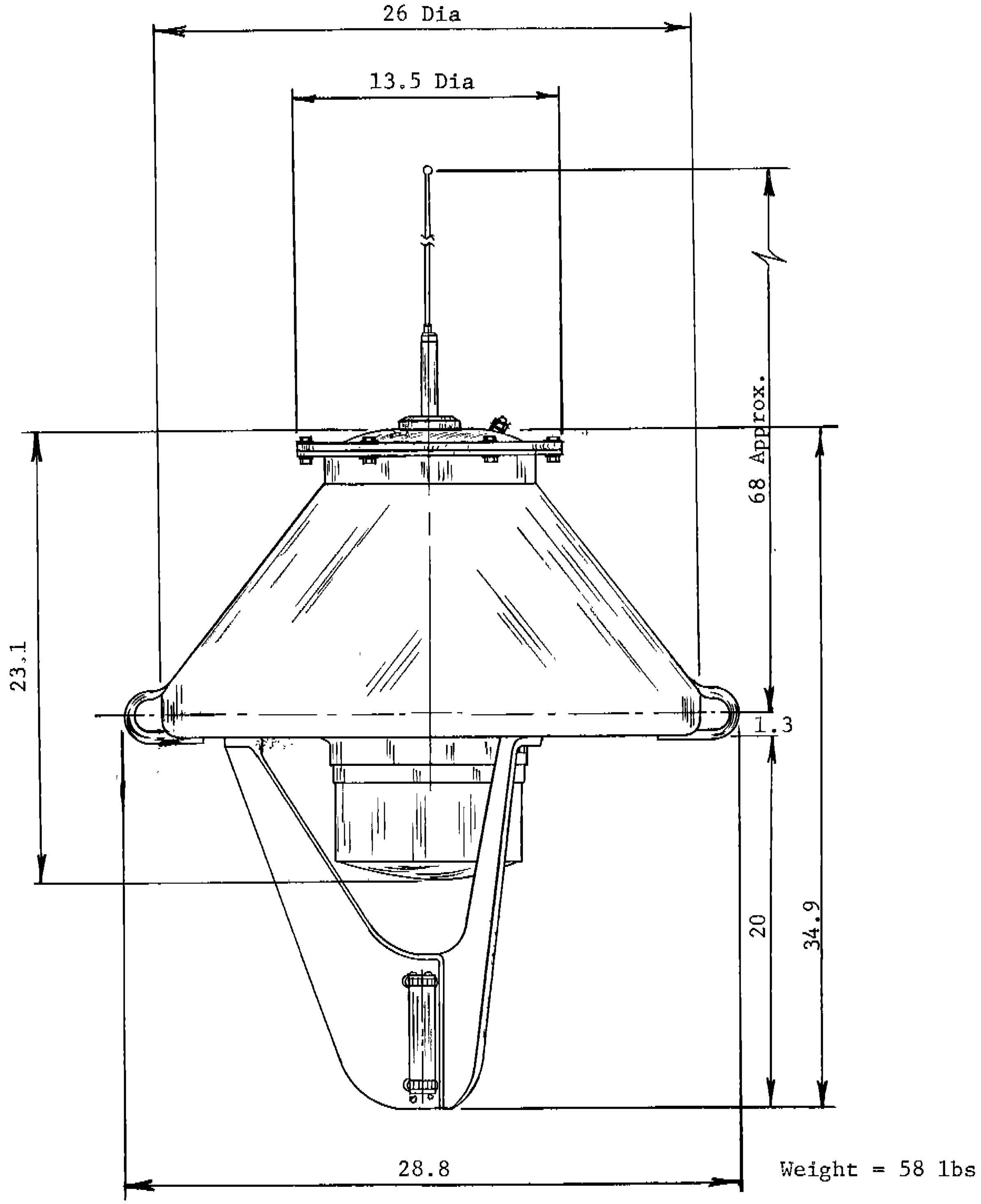


FIGURE 4. SKETCH OF WAVE HEIGHT MEASURING BUOY

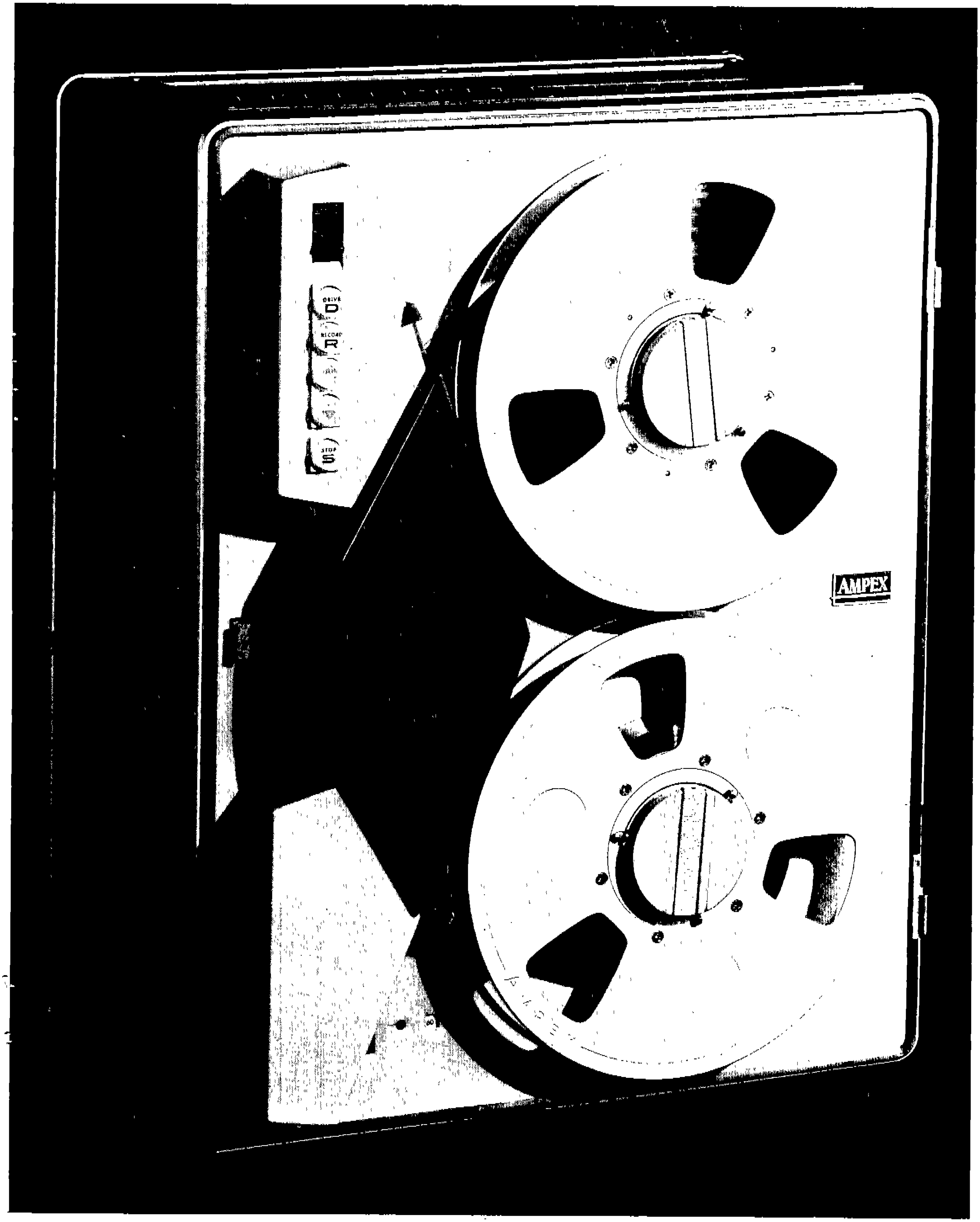
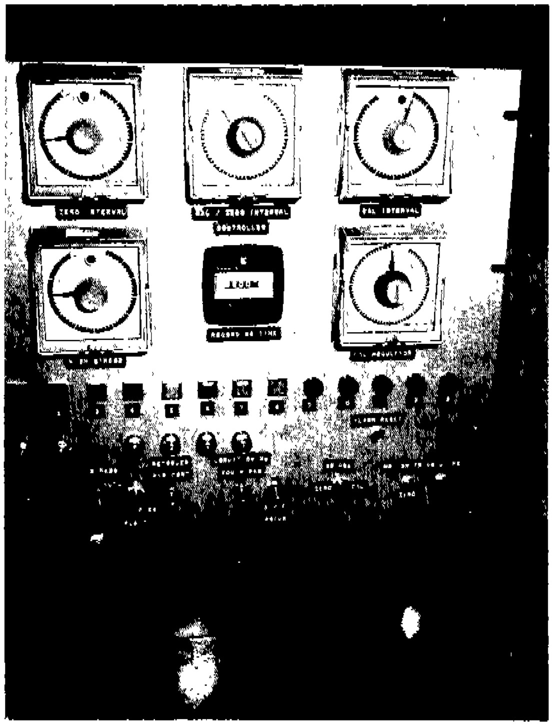
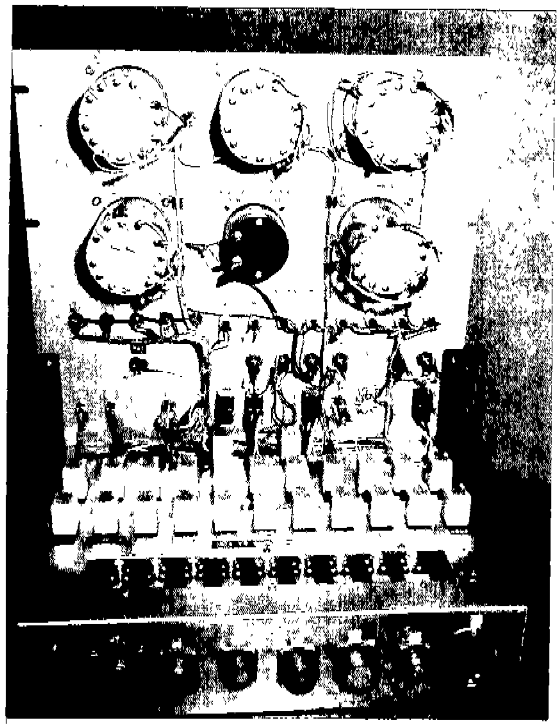


FIGURE 5. 14-CHANNEL SHIPBOARD TAPE RECORDER
AMPEX MODEL FR 1300



(a) Front Panel of Unit



(b) Rear View of Unit

FIGURE 6. PROGRAMMER UNIT

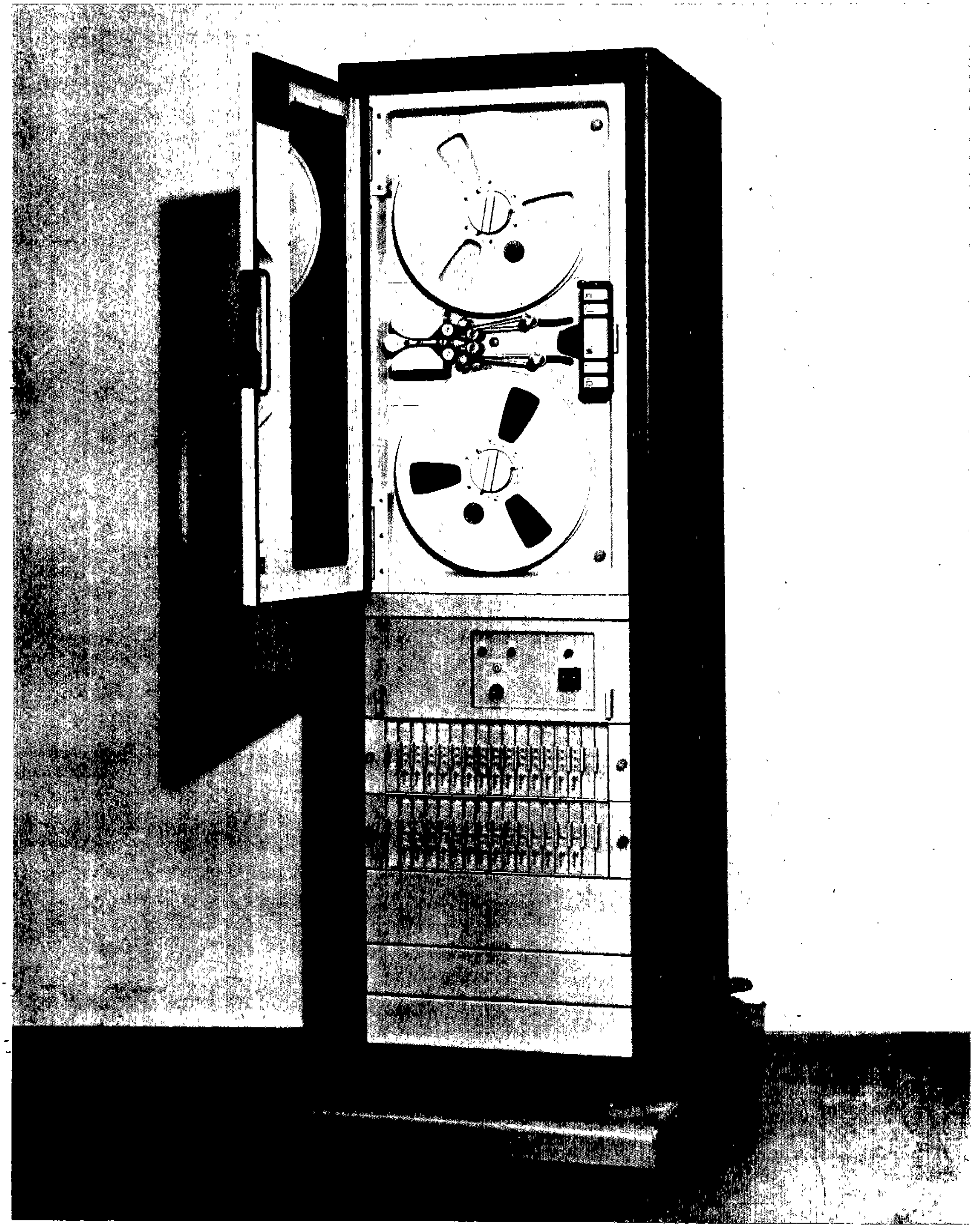


FIGURE 7. DATA ANALYSIS TAPE RECORDER
AMPEX MODEL 1260

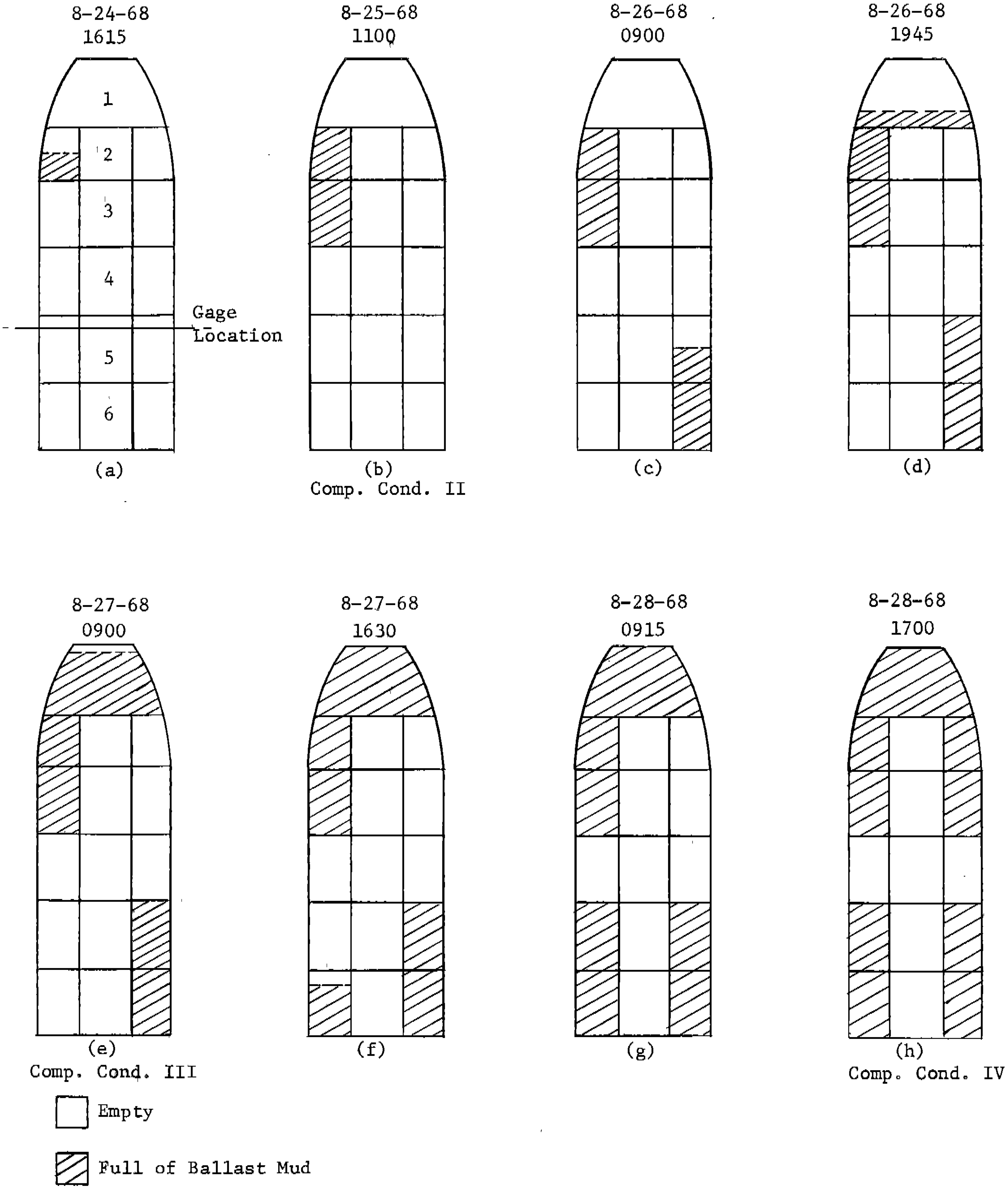


FIGURE 8

Dockside Calibration Conditions
Using Double-Bottom Tanks

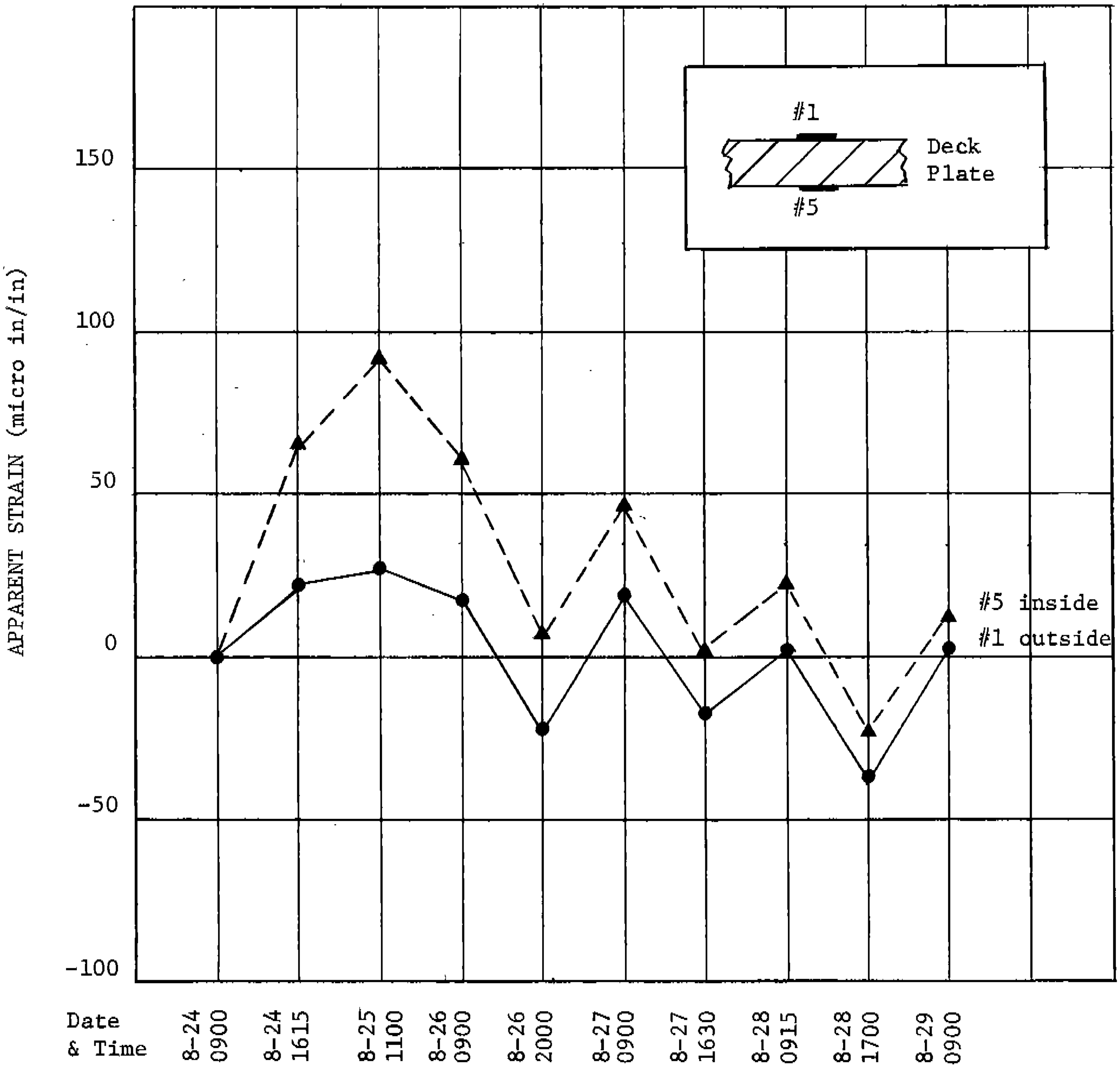


FIGURE 9

Starboard Deck Gages 1 & 5
An Example of Poor Inside-Outside Correlation

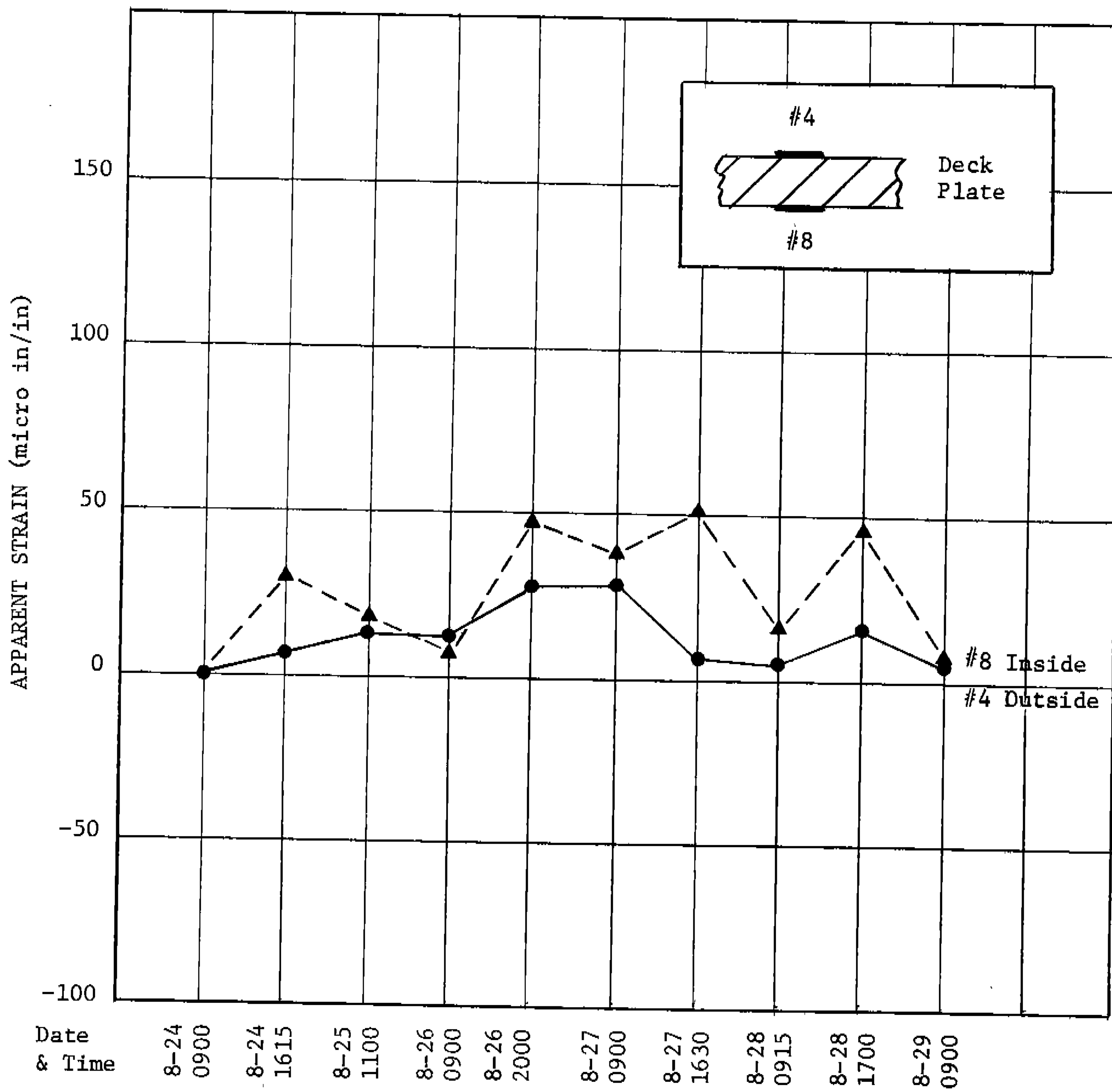


FIGURE 10

Port Deck Gages 4 & 8
Typical Inside-Outside Correlation

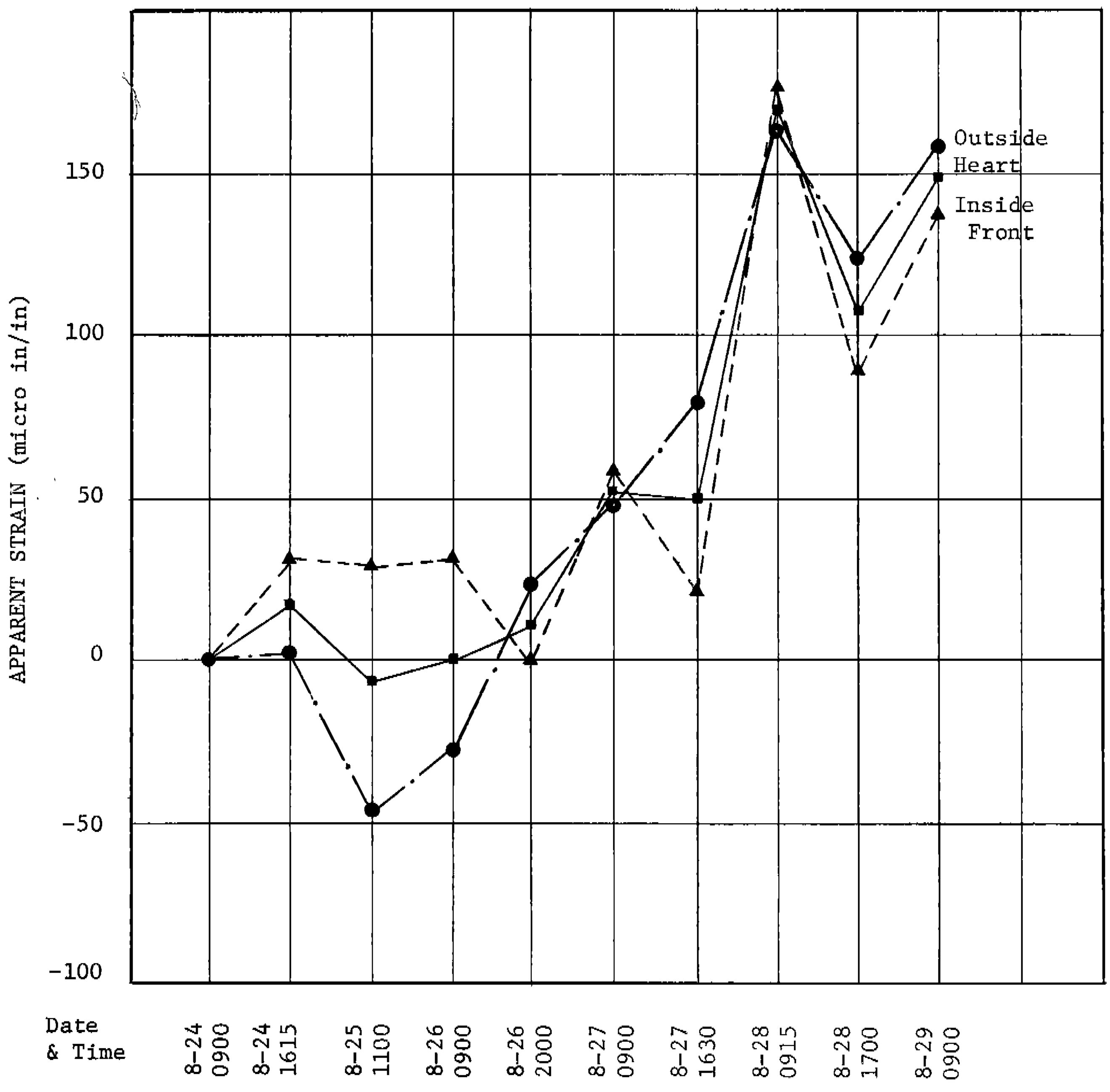


FIGURE 11

Port Shear Gages-Outside & Inside Front
Poor Inside-Outside Correlation

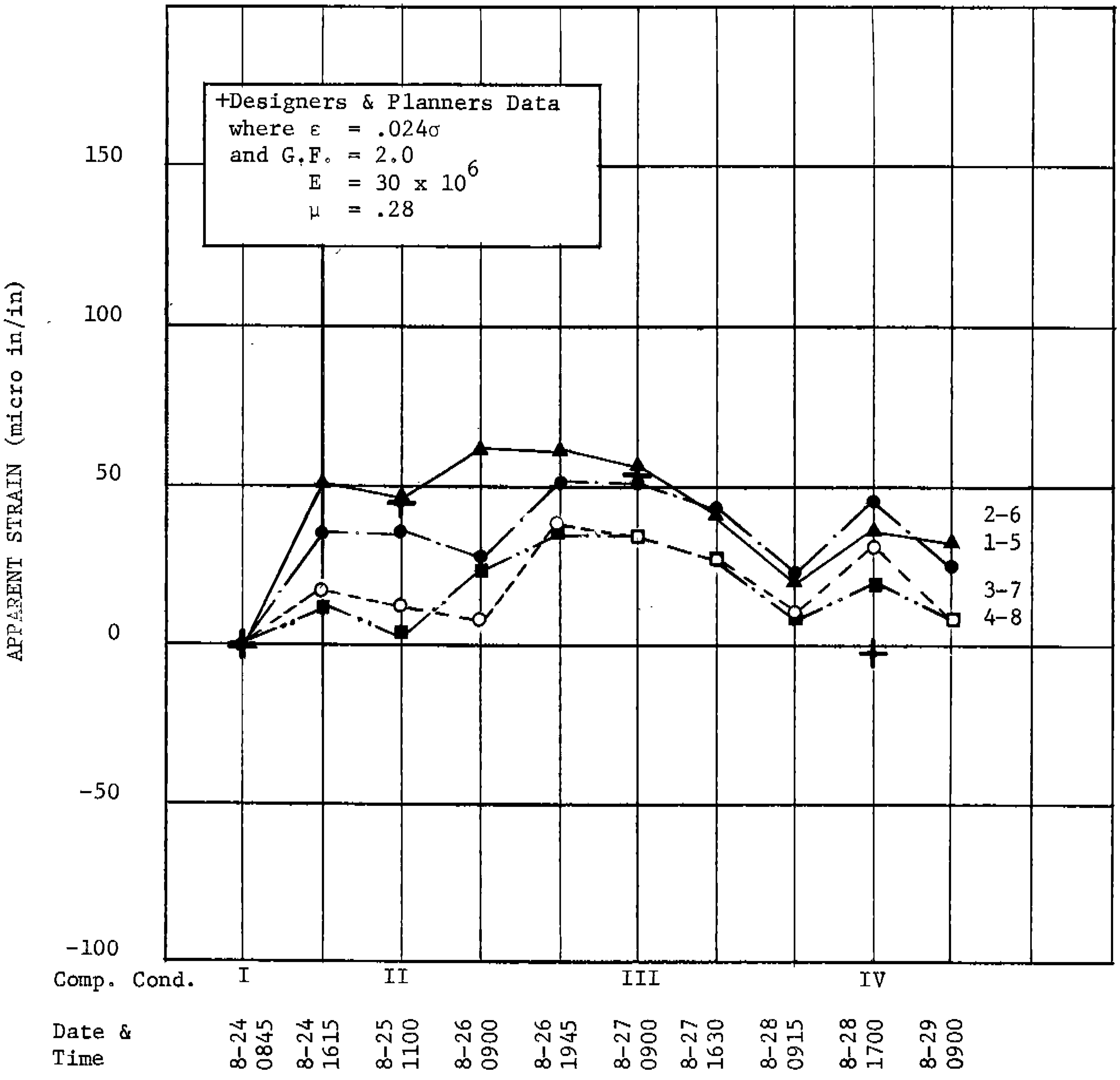


FIGURE 12

Heart of Plate Strains
Port Deck Gages

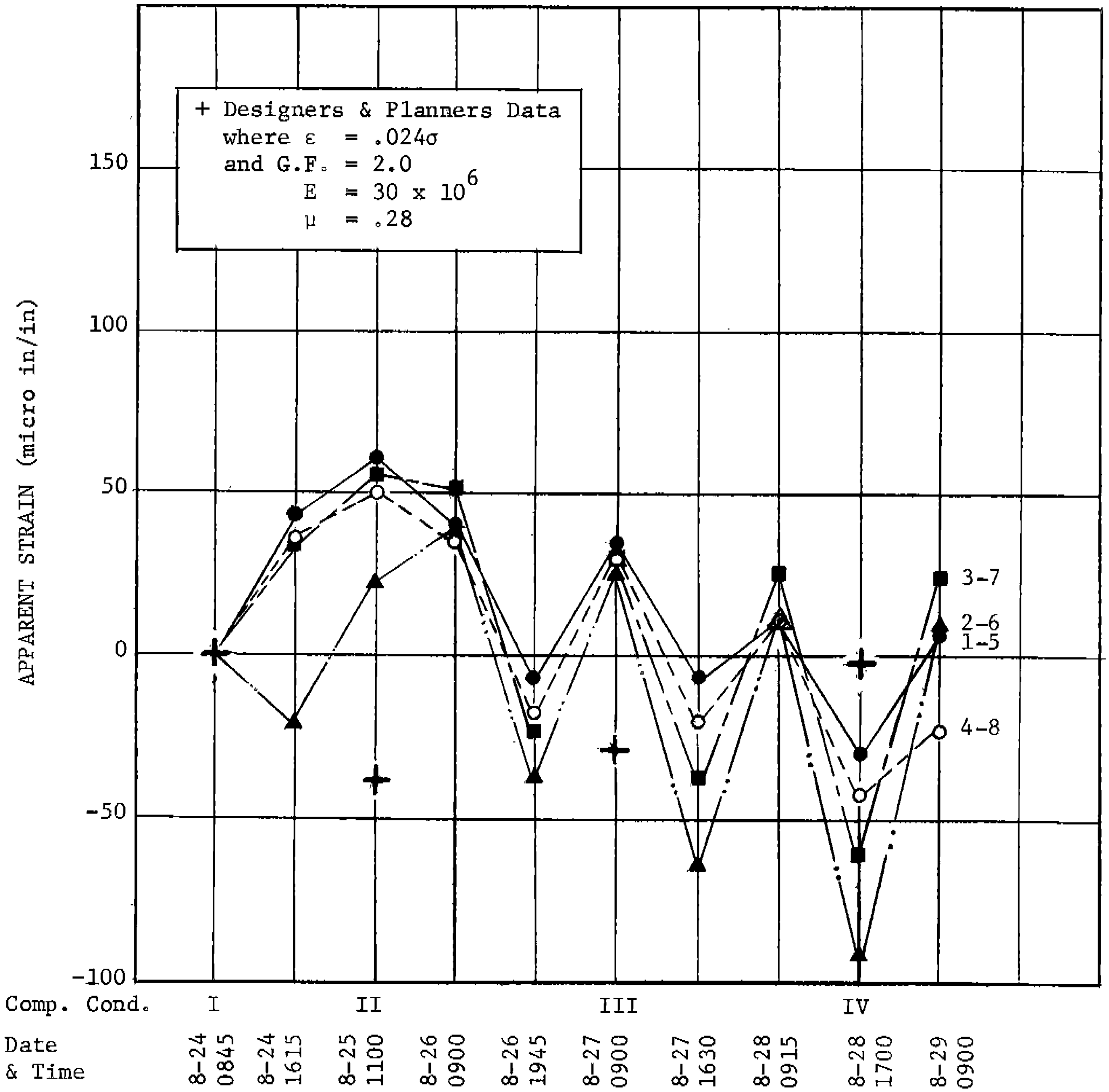


FIGURE 13

Heart of Plate Strains
Starboard Deck Gages

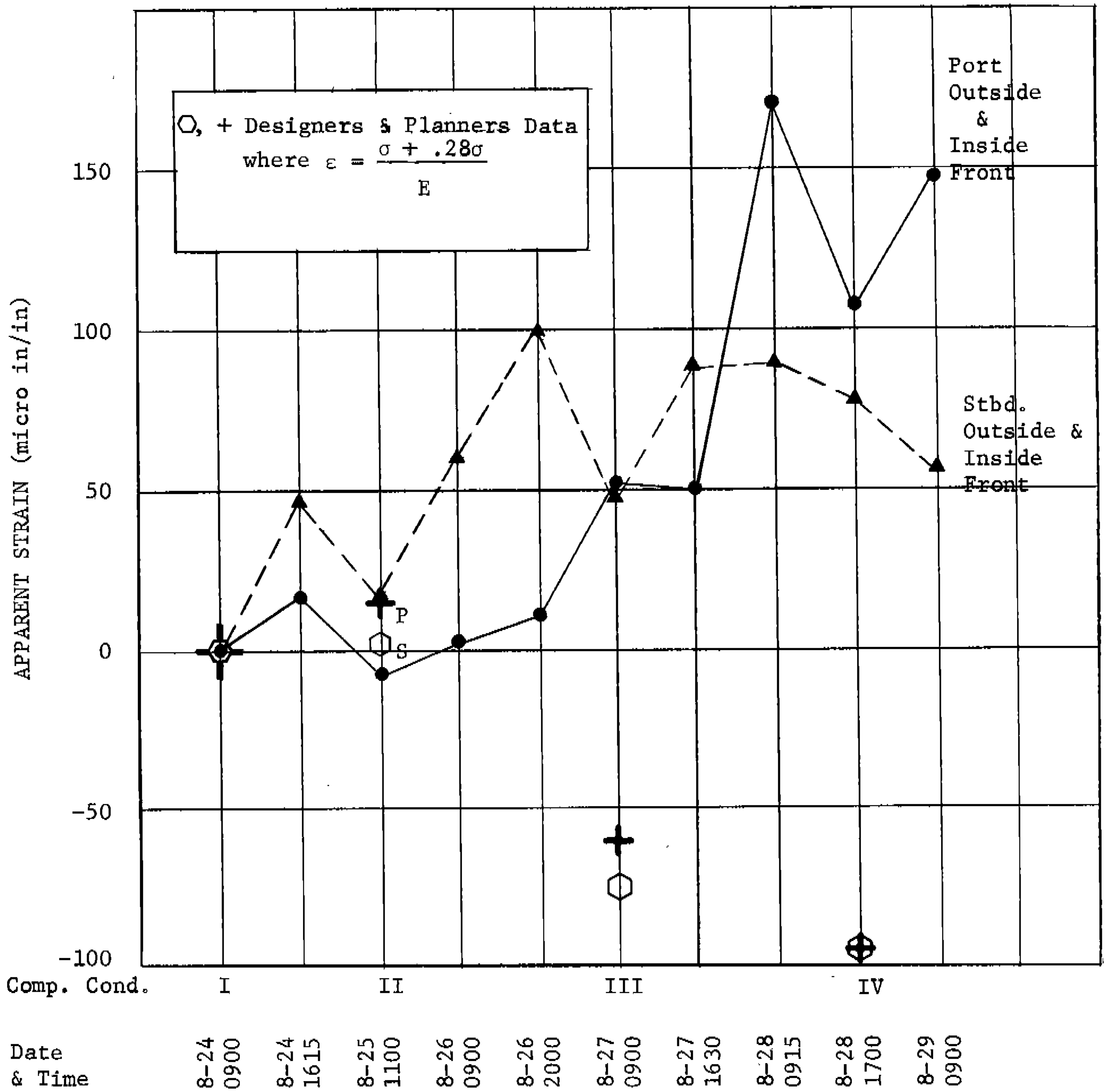


FIGURE 14

Heart of Plate Strains
Shear Gages

TABLE NO. 1

S.S. BOSTON CONTROL CONSOLE CABLING

Console Cable No.	From	To	Size/Function	Cable Type
1	24-Hr. Timer	Programmer	4 Cond. AWG #20 Timing Signals	Belden 8424
2	Programmer	Stress Monitoring Panel	8 Cond. AWG #20 Stress Signals	Belden 8418
3	Programmer	Tape Recorder	6 Cond. AWG #20 Control Signals	Belden 8426
4	Programmer	Signal Conditioning Equipment	6 Cond. AWG #20 Control Signals	Belden 8426
5	Power Supply #8	Programmer	4 Cond. AWG #20 DC Power	Belden 8424
6	Junction Box C-TM12	Programmer	20 Cond. AWG #20 Transducer Signals	MSV-20
7	Programmer	Junction Box C-TM 12	12 Cond. AWG #20 Calibration Commands	Alpha 1255/12
8 4 Req'd. 8.1, 8.2, 8.3, 8.4.	S.C. Xducer Output Jack	S.C. Amp. Input	2 Cond. AWG #20 Bridge Signals	Belden 8412
9 4 Req'd. 9.1, 9.2 9.3, 9.4.	S.C. Amp. Output Jack	Stress Monitoring Panel	2 Cond. AWG #20 Bridge Signals	Belden 8412
10	S.C. Monitoring Jack	Stress Monitoring Panel	2 Cond. AWG #20 Excitation Voltage	Belden 8412
11.1 11.2 11.3	Junction Box GTM11A&B	S.C. Equip. Xducer Input CH1, CH2, CH3.	8 Cond. AWG #20 Bridge Signals	Belden 8418

TABLE NO. 1

S.S. BOSTON CONTROL CONSOLE CABLING

(Continued)

Console Cable No.	From	To	Size/Function	Cable Type
11.4	Conditioning Channel Select Pane	S.C. Equip. Xducer Input CH. 4	8 Cond. AWG #20 Bridge Signals	Belden 8418
12	J.B. C-TM11B	Conditioning CH. Select Panel	6 Cond. AWG #20 Port Tunnel Signals	Belden 8426
13	J.B. C-TM11A	Conditioning CH. Select Panel	20 Cond. AWG #20 Stbd. Tunnel Signals	MSV-20
14	J.B. C-TM10	Conditioning CH. Select Panel	12 Cond. AWG #20 Bow Coaming Signals	Alpha 1255/12
15	Oscillograph Play-Back Panel	Oscillo-graph	12 Cond. AWG #20 Play-Back Signals	Alpha 1255/12
16	Junction Boxes C-TM11A & B	Displace-ment Trans-ducer Panel	4 Cond. AWG #20 Displacement Signals	Belden 8424
17	Power Supply #7	J.B. C-TM12	4 Cond. AWG #20 DC Power	Belden 8424
18	Power Supplies #1 to #4	J.B. C-TM12	20 Cond. AWG #20 DC Power	MSV-20
19	Power Supplies #5 & #6	J.B. C-TM11A & B	8 Cond. AWG #20 DC Power	Alpha 1255/8
20 2 Req'd.	Power Panel C-TM1	Console Power	4 Cond. AWG #10 AC Power	Types

NOTE: All cables are overall shielded with rubber or vinyl jacket.

TABLE NO. 2

S.S. BOSTON JUNCTION BOX SPECIFICATIONS

Junction Box Number	No. of Terminals	Physical Location
C-TM1	40	Stbd. Side FR 129
C-TM2	40	Stbd. Side FR 97
C-TM3	40	Stbd. Side FR 65
C-TM4	40	Stbd. Side FR 47
C-TM5	40	Amidships FR 13
C-TM6	40	Amidships FR 195
C-TM7	40	Amidships FR 112
C-TM8	Deleted Due to New Cable Routing	
C-TM9		
C-TM10	40	Aft Bulkhead TMR Room
C-TM11A	80	Aft Bulkhead TMR Room
C-TM11B	80	Aft Bulkhead TMR Room
C-TM12	80	Aft Bulkhead TMR Room
C-TM13	10	Aft Bulkhead TMR Room
C-TM14	80	Port Tunnel FR 105
C-TM15	80	Stbd. Tunnel FR 105
C-TM16	10	Bridge Deck

NOTE: Power Panel CTM-1 is in Instrument Room.

TABLE NO. 3

S.S. BOSTON SHIPBOARD CABLING

Cable No.	From Junction Box	To Junction Box	Size/Function	Cable Type
C-TM1	C-TM10	C-TM1	10 AWG #18 Power Containers	MSV-10
C-TM2	C-TM10	C-TM1	20 AWG #20 Container Measurements	MSV-20
C-TM3	C-TM1	C-TM2	10 AWG #18 Power Containers	MSV-10
C-TM4	C-TM1	C-TM2	20 AWG #20 Container Measurements	MSV-20
C-TM5	C-TM2	C-TM3	10 AWG #18 Power Containers	MSV-10
C-TM6	C-TM2	C-TM3	20 AWG #20 Container Measurements	MSV-20
C-TM7	C-TM3	C-TM4	10 AWG #18 Power Containers	MSV-10
C-TM8	C-TM3	C-TM4	20 AWG #20 Container Measurements	MSV-20
C-TM9	C-TM15	C-TM11A	70 AWG #20 Stbd. Signals	MSV-70
C-TM10	C-TM14	C-TM11B	70 AWG #20 Port Signals	MSV-70
C-TM11 C-TM12	Deleted due to cable rerouting.			———
C-TM13	C-TM5	C-TM12	20 AWG #20's FWD. Accel.	MSV-20
C-TM14	C-TM6	C-TM12	20 AWG #20's Stern Accel.	MSV-20
C-TM15	C-TM7	C-TM12	30 AWG #20's Midships Motions	MSV-30

NOTE: All cables overall shielded with rubber or vinyl jacket.

TABLE NO. 3

S.S. BOSTON SHIPBOARD CABLING

(Continued)

Cable No.	From Junction Box	Junction Box	Size/Function	Cable Type
C-TM16	C-TM16	C-TM13	6 Cond. & Shielded	TTRSA-6
C-TM17	Hotel Service	Power Panel CTM-1	PR Bridge Communications as Required	TSGA-23
C-TM18	Bow Acceleration Box	C-TM5	20 AWG #20 Bow Accelerations	MSV-20
C-TM19	Stern	C-TM6	20 AWG #20 Stern Accelerations	MSV-20
C-TM20	Midships Acceleration Box	C-TM7	12 AWG #20 Heave & Sway	Alpha 1255/12
C-TM21	Midships Pendulum Box	C-TM7	20 AWG #20 Pitch-Roll	MSV-20
C-TM22	Port Topside Housing	C-TM14	12 AWG #20 Port Topside Stress	Alpha 1255/12
C-TM23	Port Underside Housing	C-TM14	12 AWG #20 Port Underdeck Stress	Alpha 1255/12
C-TM24	Port Torsion Housing	C-TM14	8 AWG #20 Port Torsion	Belden #8418
C-TM25	Port Displacement Gage	C-TM14	4 AWG #20 Port Displacement	Belden #8424
C-TM26	Port Side Weld Gage	C-TM14	8 AWG #20 Side Weld Stress	Belden #8418
C-TM27	Stbd. Underdeck Housing	C-TM15	12 AWG #20 Stbd. Underdeck Stress	Alpha 1255/12
C-TM28	Stbd. Topside Housing	C-TM15	12 AWG #20 Stbd. Topside Stress	Alpha 1255/12
C-TM29	Stbd. Underdeck and Box Beam Gages	C-TM15	12 AWG #20 Stbd. Tunnel Stresses	Alpha 1255/12
C-TM30	Stbd. Disp. Gage	C-TM15	4 AWG #20 Stbd. Displacement	Belden #8424
C-TM31	Stbd. Side Plate Gage	C-TM15	8 AWG #20 Stbd. Side Stress	Belden #8418
C-TM32	Stbd. Torsion Gage	C-TM15	8 AWG #20 Stbd. Torsion	Belden #8418
C-TM33	Bow Coaming Gages	C-TM4	12 Cond. AWG #20 Bow Stresses	Alpha 1255/12

TABLE 4

CHARACTERISTICS OF SS BOSTON

Original Name:	GEN. M.M. PATRICK
Builder:	Kaiser Richmond (Hull #16)
Converter:	Todd Shipyards Corporation Galveston Division (Hull #87)
Type:	C4-SA1 converted to C4-X2 Container Ship
Official Number:	511585
Length Overall:	522' - 10 1/2"
Length Between Perpendiculars:	496' - 0"
Breadth, Molded:	71' - 6"
Depth, Molded to Upper Deck @Side:	45' - 6"
Depth, Molded to Second Deck:	35' - 0"
Depth Molded to Tank Top:	5' - 0"
Tonnage (U.S.) Gross:	11,521.77
Net:	7,607.00
Draft Scantling (Full Load):	30' - 6"
Full Load Displacement:	20,250 Tons S. Water
Draft Light Ship:	17' - 8"
Dead Weight:	9,317
Light Load Displacement:	10,933 Tons S. Water
Center of Gravity Full Load:	l.c.g. 1.35' aft amidships, v.c.g. 27.04' above base line
Light Ship:	l.c.g. 1.13' fwd amidships, v.c.g. 18.2' above base line
Machinery:	Steam Geared Turbine
Shaft Horsepower - Max. Cont.	9,900 S.H.P.
Propeller (1)	5 Bladed 21' - 8" Dia.
Container Capacity (No.)	360
Container Geometry:	L - 35' - 0"
	W - 8' - 0"
	H - 8' - 6 1/2"

APPENDIX A

TORSION TRANSDUCER INSTRUMENTATION

In the discussion below consideration is given to the location and electrical arrangement of the strain gage bridge installed for the measurement of the shear stress due to torsion about the longitudinal axis. The influence of the existing stresses is evaluated demonstrating the exclusion of the effect of other stresses on the torsional measurement.

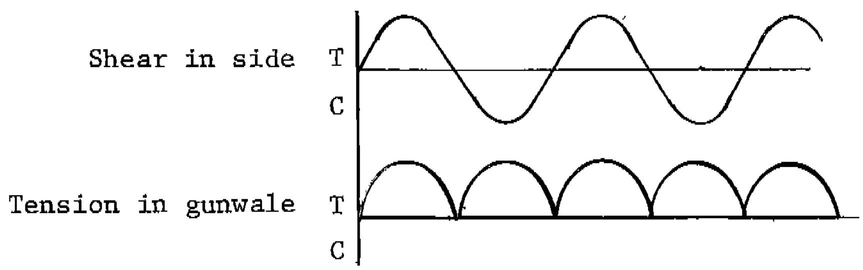
A. STRESSES PRESENT

1. Shear

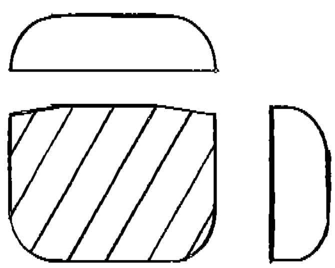
(a) Torsion around longitudinal axis

(1) Shear stresses present in main deck, sides and bottom; no shear in area of gunwales and turn of bilge.

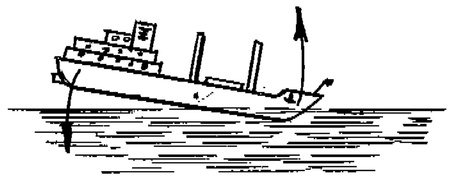
(2) Gunwale and turn-of-bilge stresses tensile at twice the frequency of torsion



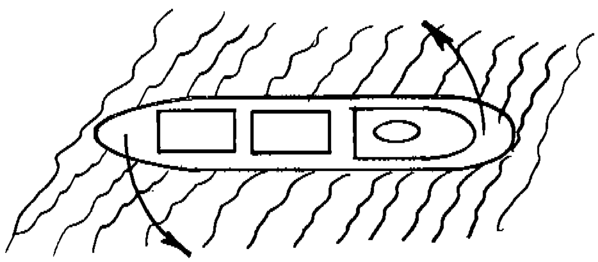
(3) Shear stresses fairly uniform, dropping sharply to zero at gunwales and turn-of-bilge.



(b) Pitching motion induces shear in sides, none in deck or bottom.



(c) Yawing induces shear in deck and bottom, none in sides.

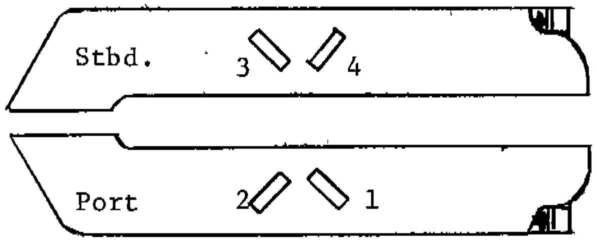


2. Bending

(a) Longitudinal in vertical plane - main deck and sides above neutral axis in compression while bottom and sides below neutral axis in tension.

(b) Longitudinal in horizontal plane - port side and portside of deck and bottom in compression while starboard side and starboard side of deck and bottom in tension.

B. GAGE PLACEMENT AND HOOKUP



Strain gages are mounted at midships close to neutral axis at 45° to longitudinal axis. Gages 1 and 2 are on port side, gages 3 and 4 are on starboard side. Gages mounted /\ or \/ to keep them same distance from neutral axis.

Table 1

SUMMARY OF STRESSES INDUCED IN EACH STRAIN GAGE OF THE TORSION BRIDGE

Induced Stress	STRAIN GAGE 1	2	3	4	Net Stress Measured
	Stress Direction				
Torsion-Long. Axis	C	T	C	T	Torsion
Shear-Pitching	C	T	T	C	None
Shear-Yawing	0	0	0	0	None
Bending-Horizontal	C	C	T	T	None
Bending-Vertical (neutral axis)	0	0	0	0	None
Bending Vertical (off neutral axis)	C	C	C	C	None

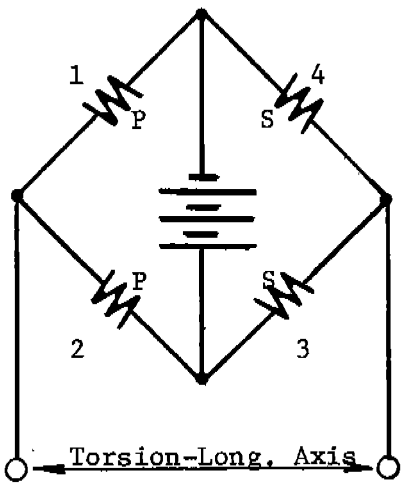
C = compression

T = tension

0 = none

Note 1: Values of T and C along horizontal rows are of equal magnitude.

Note 2: See Torsional Bridge arrangement on next page.



C. DISCUSSION

1. If gages are located on neutral axis, vertical bending stresses are zero.

2. If gages are off neutral axis, vertical bending is present, but in phase. The two portside gages cancel one another as do the starboard side gages.

3. In similar manner horizontal bending is self-canceling on each side.

4. Plating unfairness is thus not a factor with respect to bending, since gage connections will not measure bending. Hence, no requirement for gages on each side of plating.

5. Shear stresses due to yawing are not present in the sides.

6. Shear stresses due to pitching are out of phase in each side and thus additive; however, one side is subtractive from the other because of bridge hookup.

7. Shear stresses due to torsion around the longitudinal axis are additive on each side and from side to side giving an output four times that which could be obtained with one active gage.

8. The bridge is inherently temperature-compensated.

D. CONCLUSION

The instrumentation described in paragraph B will best accomplish the stated aim of monitoring torsional shear stress independent of other stress influences.

APPENDIX B

TRANSDUCER SPECIFICATIONS

1. Stress Gages

BLH Electronics, Inc., Type FAB-28-S6

Longitudinal Gage

Resistance: 350.0 ± 2.5 Ohms
Gage Factor: 2.06 ± 1%

Lateral Gage

Resistance: 98.0 ± 1.0 Ohms
Gage Factor: 2.05 ± 1%
Poisson Ratio: .28 + 1%
Stress Gage Factor: 1.48 ± 1%

2. Torsion Gages

BLH Electronics, Inc., FABD-25-12S6

Gage Factor: 2.02 ± 1%
Resistance: 120.0 ± .2 Ohms

3. Bow and Stern Accelerometers

Setra Inc., Model 100

Range: ± 5g
Maximum Static Acceleration: ± 100g
Approximate Natural Frequency: 490 Hz
Transverse Acceleration Response: <0.01g/g
Excitation: 6 VDC at 20 ma
Full Range Output: ± 1.5 VDC
Output Impedance: 400 Ohms

4. Midships Accelerometers

Statham Instruments, Inc., Model A3-2.5 - 350

Range: ± 2.5g
Nominal Bridge Resistance: 350 Ohms
Approximate Natural Frequency: 55 Hz
Transverse Acceleration Response: 0.02g/g
Excitation: 11 Volts DC or AC (RMS)
Full-Scale Output: ± 20 mv
Used with Statham Instruments
Model CA9-56 Strain Gage Signal Amplifier
with an output of ± 2.5 VDC.

5. Midships Pitch-and-Roll Signals

Humphrey Inc., Pendulum Transducers, Model CP17-0601-1

Range: $\pm$ 45° $\pm$ 0.5°
Resistance: 2000 Ohms $\pm$ 5%
Power Dissipation: 0.5 watt at 130°F
Accuracy: $\pm$ 1% with straight line approximation
Natural Frequency: 2 Hz

6. Displacement Transducers

Hewlett Packard, Model 7DCDT-050

Full-Scale Output: 1.5 VDC
Range: $\pm$ 0.050 inches
Scale Factor: 30 V/in
Maximum Nonlinearity: $\pm$ 0.5% FS
Excitation Voltage: 6 VDC Nominal
Output Impedance: 2.2 K Ohms
Frequency Response: 3 db down at 350 Hz

7. Wave Data Acquisition System

Eastech Limited, Windsor, Nova Scotia, Model 440

Used with Model 266 Wave Buoys.
Data recorded as positive pulses approximately 3 milliseconds in duration, approximately 1.5 volts peak at 30 pulses per second at zero acceleration.

APPENDIX C

AMPEX FR-1300

INSTRUMENTATION

RECORDER

AMPEX FR-1300 INSTRUMENTATION RECORDER

PERFORMANCE SPECIFICATIONS

General Description

The Ampex FR-1300 is a compact, lightweight portable recorder, available in 7 or 14-channel versions. It features an integral capstan servo system that assures speed accuracy under variable power conditions and provides electrical switching over a range of six speeds. For applications requiring precisely accurate speeds, or where it is desired to record and reproduce on different recorders under unpredictable voltage conditions, a control track generator/demodulator module can easily be added to the integral capstan servo system to provide a complete record/reproduce tape speed servo control system (Speedlock). Transport control circuitry is completely interlocked to prevent tape damage if the recorder is operated carelessly or accidentally. Interchangeability of electronics is possible with nine other Ampex recorders using ES-100 electronics. Signal compatibility with earlier recorders having 100 Kc direct or 10 Kc FM capability is also provided. A rack mounted version is available.

Tape Transport

Tape Speeds: 60, 30, 15, 7½, 3¾, 1⅞ ips standard. All six transport speeds are selected by a single front panel control. All speeds are synchronously controlled by a phase-locked servo system on capstan drive motor. Other fixed or variable speeds on special order.

Capstan Speed Accuracy: ±0.05% maximum, long term, when using the internal crystal reference. Frequency standard is accurate to ±0.01%, long term.

Tape Speed Deviation: ±0.25%.

Reels: The FR-1300 tape transport accommodates 10½-inch reels, Ampex Precision or NAB.

Tape Specifications: Available in versions for ½ or 1-inch tape of 1 mil or 1½ mil Polyester, or 1½ mil Acetate. Stated performance guaranteed only when using recommended Ampex Instrumentation Tape.

Controls: Illuminated pushbuttons for Record, Drive, Stop, Forward and Rewind. All functions may be remotely controlled. Control circuitry is completely interlocked so that recorder can be switched from any mode to any other mode without damaging the tape.

Fast Wind Time: For 10½-inch reel, with 3600 feet of tape, approximately 3.0 minutes at 60 cycles per second (3.5 min. at 50 cps).

Start Time: Time required from start command to meet flutter specifications is as follows:

Speed (ips)	Time
60	8 seconds
30	6 seconds
15 and lower speeds	4 seconds

Stop Time: Maximum of 1.5 seconds at 60 ips tape speed; shorter stop times with lower tape speeds.

Flutter: Maximum cumulative flutter (% peak-to-peak):

Tape Speed (ips)	Bandpass (cps)	Flutter (%)	Bandpass (cps)	Flutter (%)
60	0.2 to 10,000	0.6	0.2 to 312	0.20
30	0.2 to 5,000	0.6	0.2 to 312	0.25
15	0.2 to 2,500	0.6	0.2 to 312	0.4
7½	0.2 to 1,250	0.75	0.2 to 312	0.6
3¾	0.2 to 625	1.2	0.2 to 312	1.2
1⅞	0.2 to 312	1.5	0.2 to 312	1.5

Heads

Gap Scatter: Trailing edges for record heads (or gap centers for reproduce heads) within a band 100 microinches wide (0.0001 inch).

Gap Azimuth: All stacks within ±1 minute of arc perpendicular to head base plate.

Track Dimensions: Track width is 0.050 inch; tape track spacing 0.070 center (IRIG Standard). Other heads on special order.

Number of Tracks: 7 on ½ inch; 14 on 1 inch (IRIG Standard). Other heads on special order.

Interstack Spacing: 1.5 ±0.0005 inch, gap to gap.

Direct Record/Reproduce System

Frequency Response:

Tape Speed (ips)	Bandwidth	S/N* (db) Bandpass Filtered**	S/N* (db) Unfiltered
60	300 cps to 300 Kc ±3 db	35	31
30	150 cps to 150 Kc ±3 db	34	30
15	100 cps to 75 Kc ±3 db	32	27
7½	50 cps to 38 Kc ±3 db	30	22
3¾	50 cps to 19 Kc ±3 db	29	22
1⅞	50 cps to 10 Kc ±3 db	28	22

*For an all Direct system only. In a mixed Direct/FM system, Direct S/N and crosstalk may be affected.
**Measured at output of a bandpass filter having 18 db/octave attenuation beyond limits stated.

RMS Signal-to-Noise Ratio: See table.

Harmonic Distortion: Less than 1.2% total of a 1 Kc signal recorded at 60 ips.

Input Level: 1.0 volt rms nominal (0 dbv) to produce normal recording level; operable from 0.2 to 10 volts rms by adjustment of input potentiometer.

Input Impedance: Nominal 50 K ohms resistive, in parallel with 150 pF, unbalanced to ground.

Output Level: 1.0 volt rms nominal (0 dbv), across a 600 ohms or greater impedance.

Output Impedance: Less than 50 ohms, unbalanced to ground.

FM Record/Reproduce System

Frequency Response:

Tape Speed	Frequency Response (within 1.0 db)	S/N Ratio RMS	Total Harmonic Distortion
60 ips	0 to 20,000 cps	46 db	1.2%
30 ips	0 to 10,000 cps	46 db	1.2
15 ips	0 to 5,000 cps	45 db	1.2
7½ ips	0 to 2,500 cps	45 db	1.2
3¾ ips	0 to 1,250 cps	42 db	1.5
1⅞ ips	0 to 625 cps	40 db	1.8

RMS Signal-to-Noise Ratio (at center carrier): See table.

Harmonic Distortion: See table.

DC Drift: Less than ±0.5% of full deviation over a four-hour period after warmup (10 minutes). Less than 2% in 8 hours with temperature variations between +40°F and +125°F.

continued

FM Record/Reproduce System (con't)

Record/Reproduce Voltage Linearity: ±0.75% of full band, of a zero-based straight line.

Input Level: Input of 1 volt rms (0 dbv) to produce ±40% deviation; operable from 0.5 to 25 volts rms by adjustment of input potentiometer.

Input Impedance: Nominal 20,000 ohms resistive, in parallel with 150 pF, unbalanced to ground.

Output Level: 1.0 volt rms (nominal) into 10 K ohms or greater load impedance.

Output Impedance: 600 ohms, unbalanced to ground.

PDM Record/Reproduce System (IRIG Compatible)

System Pulse Characteristics:

Tape Speed (ips)	Pulse Duration in Microseconds Min.	Max.	Pulse Accuracy in Microseconds Over Specified Pulse Widths
60	20	10,000	±2.0 (30 to 900 μsec duration)
30	30	10,000	±2.0 (45 to 900 μsec duration)
15	60	10,000	±3.0 (60 to 2,000 μsec duration)
7½	120	10,000	±10.0 (120 to 3,000 μsec duration)

Input Level: 1 volt peak-to-peak rectangular wave 20 microseconds to 10,000 microseconds pulse duration, operable from 0.75 to 20 volts peak-to-peak.

Input Impedance: 20,000 ohms nominal paralleled by 150 pF maximum, unbalanced to ground.

Output Level: 20 to 24 volts peak-to-peak across 1000 ohms and 0.001 mfd.

Output Impedance: Less than 100 ohms, unbalanced to ground.

Output Rise and Fall Time: 2 microseconds maximum (from 10% to 90% amplitude level).

Servo Tape Speed Control System (Speedlock)

Frequency Standard Accuracy: ±0.01%, long term.

Speed Correction Range: ±2% of nominal.

Servo Tape Speed Control System (con't)

Time Displacement Error:

Tape Speed	Error
60 ips	100 microseconds
30 ips	150 microseconds
15 ips	200 microseconds

Synchronization Time: After 10-minute warmup.

Tape Speed	Time
60 ips	8 seconds
30 ips	6 seconds
15 ips	4 seconds

Power Requirements

Voltage: 105 to 125 volts, single phase, 48 to 62 cps AC (with Frequency Standard).

Power Consumption: Less than 325 watts steady state for a 14-track record/reproduce system. Starting surges up to 400 watts may be encountered.

Environment

Temperature: Operating: 5°C to 52°C (40°F to 125°F)
Storage/non-operating: −30°C to 66°C (−20° to 150°F)

Altitude: Operating: 15,000 feet (4600 m).
Non-operating: 50,000 feet (15,000 m).

Relative Humidity: 5 to 95%, non-condensing, both operating and non-operating.

Vibration: Normal handling and transportation only.

Physical Characteristics

Size: Portable case 24 inches (61 cm) high, by 18 inches (46 cm) wide, by 12½ inches (31 cm) deep, for complete 14-track record/reproduce system and capstan servo.

Vertical Rack Space Required: Rack mounted version: Transport 24½ inches (62.2 cm), electronics tray 5¼ inches. Each electronics tray accommodates up to 14 record or reproduce modules, plus 3 auxiliary modules.

Weight: Portable version: Approximately 110 lbs. (50 kg) for 7-track system.

METRIC CONVERSION TABLES

Applicable to all Ampex recorders—specific items may not apply to the unit described in this sheet.

TAPE SPEEDS

ips	1⅞	3¾	7½	15	30	60	120
cm/sec	4.76	9.52	19.05	38.1	76.2	152.4	304.8

TAPE DIMENSIONS

Reels:	inches	14	10½	7	5¾	5
	cm	35.56	26.67	17.78	14.62	12.70
Widths:	inches	¼	½	¾	1	2
	cm	0.635	1.27	1.905	2.54	5.08
Base Thicknesses:	inches	1 mil	1.5 mil			
	mm	0.0254	0.0381			

TAPE DIMENSIONS (Continued)

Length:	feet	600	1200	1800	2500	3600	5000	7200	9600
	meters	185	366	549	762	1097	1524	2195	2926

HEAD DIMENSIONS

Gap Scatter		Interstack Spacing*		Track Width & Spacing*		
microinches	100	inches	1.5 ±0.0005	inches	0.050	0.070
mm	0.00254	cm	3.81 ±0.00127	mm	1.27	1.778

*(IRIG)

STANDARD PANELS FOR 19-INCH (48.26 cm) RACK

in.	1¾	3½	5¼	7	8¾	12¼	14	15¾	17½	19¼	21	35
cm	4.45	8.89	13.34	17:78	22.23	31.12	35.56	40.01	44.45	48.9	53.34	88.9

AMPEX CORPORATION
401 Broadway • Redwood City • California • U.S.A. • 94063
Australia, Canada, England, France, Germany, Hong Kong, Mexico, Switzerland

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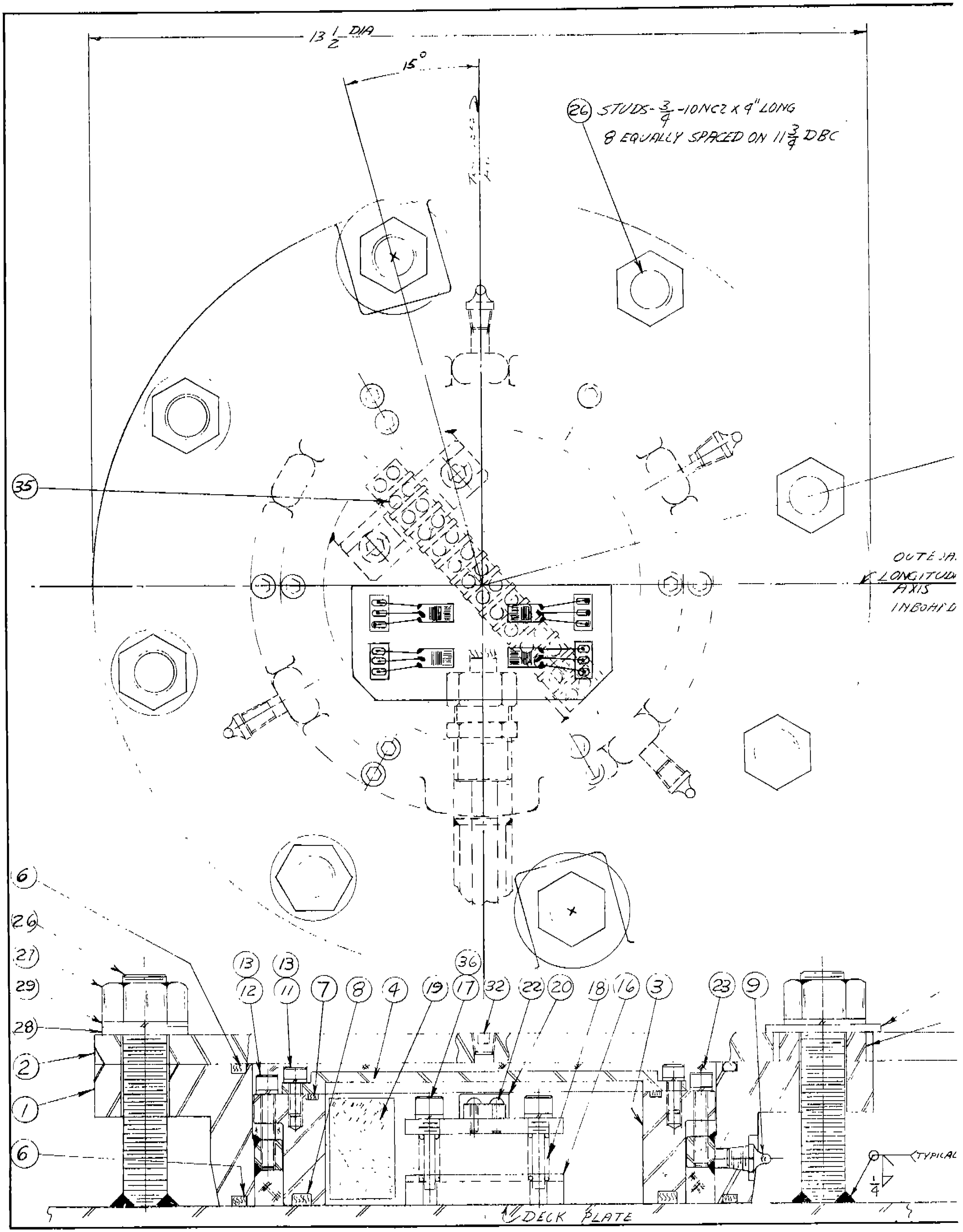

13 1/2 DIA
15°
(26) STUDS-3/4-10NC2 X 4" LONG
8 EQUALLY SPACED ON 11 3/4 DBC
(35)
OUTBOARD
LONGITUDINAL AXIS
INBOARD
(6)
(26)
(27)
(29)
(28)
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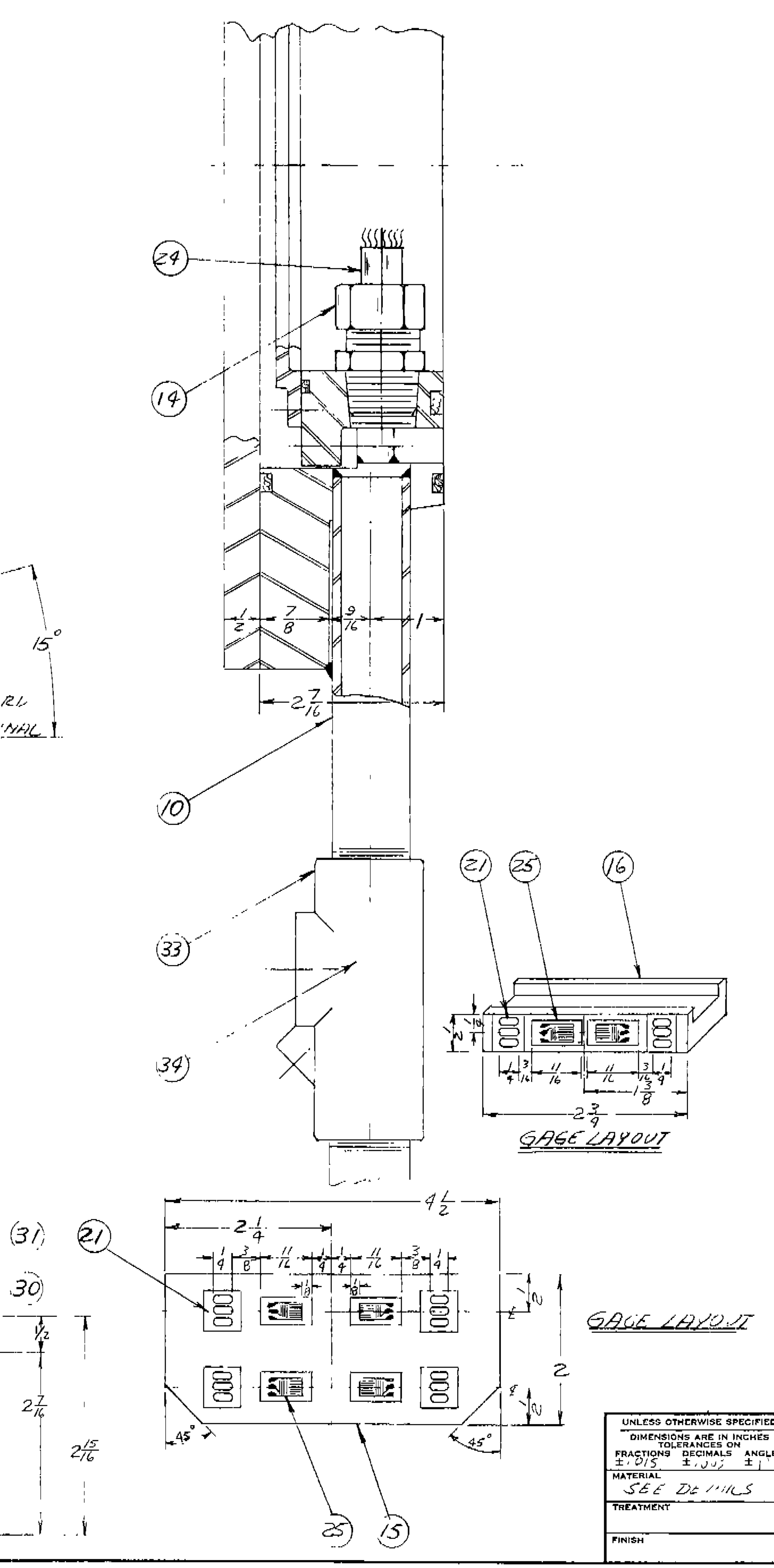
DECK PLATE



ITEM	DESCRIPTION	DRAWING NUMBER	QTY
1	OUTER HOUSING	D 2701	1
2	OUTER HOUSING COVER	C 2597	1
3	INNER HOUSING	D 2698	1
4	INNER HOUSING COVER	B 2598	1
5			
6	"O" RING-PARKER #2-370 NEOPRENE 60° SHORE A DUROMETER		2
7	"O" RING PARKER # 2-256 NEOPRENE 60° SHORE A DUROMETER		1
8	"O" RING PARKER # 2-437 NEOPRENE 60° SHORE A DUROMETER		1
9	ALEMITE GREASE FITTING 1/8-27 NPT M - STRAIGHT		4
10	NATIONAL ELECTRICAL RIGID STEEL CONDUIT - 3/4" x 6" LONG (THREADED ONE END)		2
11	SOCKET HEAD CAP SCREW 1/4-20 NC2 x 3/4 LONG		6
12	SOCKET HEAD CAP SCREW 1/4-20 NC2 x 1 1/4 LONG		6
13	SPLIT-TYPE LOCKWASHER 1/4 STANDARD		12
14	T & B STRAIN RELIEF CONNECTOR-NEOPRENE BUSHING - WATERTIGHT NO 2532 (.375 TO .500)		1
15	SHIM STOCK $4\frac{1}{2}$ x 2 x .006 THICKNESS STEEL		1
16	DUMMY GAGE BLOCK	A 2217	1
17	SPECIAL SOCKET HEAD CAP SCREW	A 2218	2
18	HARDWARE PRODUCTS CO BOSTON SPRING SC 1" x 3/8 O.D. x .062 WIRE		2
19	SILICA GEL PACKETS		2
20	TERMINAL STRIP CINCH-JONES # 12-140		1
21	STRAIN GAGE WIRING TERMINAL BLH TYPE T-25		6
22	RD HD SLOTTED MACHINE SCREW # 6-32 NC2 x 1/2 LONG		4
23	SILICONE GREASE DOW CORNING NO 3 COMPOUND		TO SUIT
24	CABLE ALPHA #1255-12 #20 SHIELDED RUBBER COVERED (.525 DIA)		**
25	BLH-SR 4 STRESS GAGE TYPE FAB-28-S6		6
26	THREADED STUD 3/4-10 NC2 x 4" LONG		8
27	HEX NUT - REGULAR 3/4-10 NC2 (1 1/8 ACROSS FLATS)		8
28	FLAT WASHER 13/16 I.D. x 1 7/16 O.D. x 1/8 THICK		6
29	SPLIT-TYPE LOCKWASHER 3/4 STANDARD		8
30	FLAT SPACER WASHER 13/16 I.D. x 1 7/16 O.D. x 1/2 THICK - C.R. STEEL	AT LOCATION "X"	2
31	FLAT WASHER 13/16 I.D. x 2" O.D. x 1/8 THICK		2
32	SOCKET HEAD PIPE PLUG 1/8-27 NPT STEEL		1
33	CROUSE HINDS TYPE EYS 216 CONDULET EXPLOSION PROOF 3/4 I.P.S.		1
34	SEALING COMPOUND CAT# SC 804 KILLARK ELECT MFG CO		1 CAN
35	T & B STA-KON SOLDERLESS CONNECTOR CAT# RB-14-6 NO6 SCREW		24
36	SPLIT-TYPE LOCKWASHER 3/8 STANDARD		2

UNLESS OTHERWISE SPECIFIED
DIMENSIONS ARE IN INCHES
TOLERANCES ON
FRACTIONS ±.015 DECIMALS ±.005 ANGLES ±1°

MATERIAL: SEE DETAILS

TREATMENT

FINISH

DRAFTSMAN: DJG | DATE: 7/15/68

CHECKER

ENGINEER

APPROVAL

SCALE: FULL

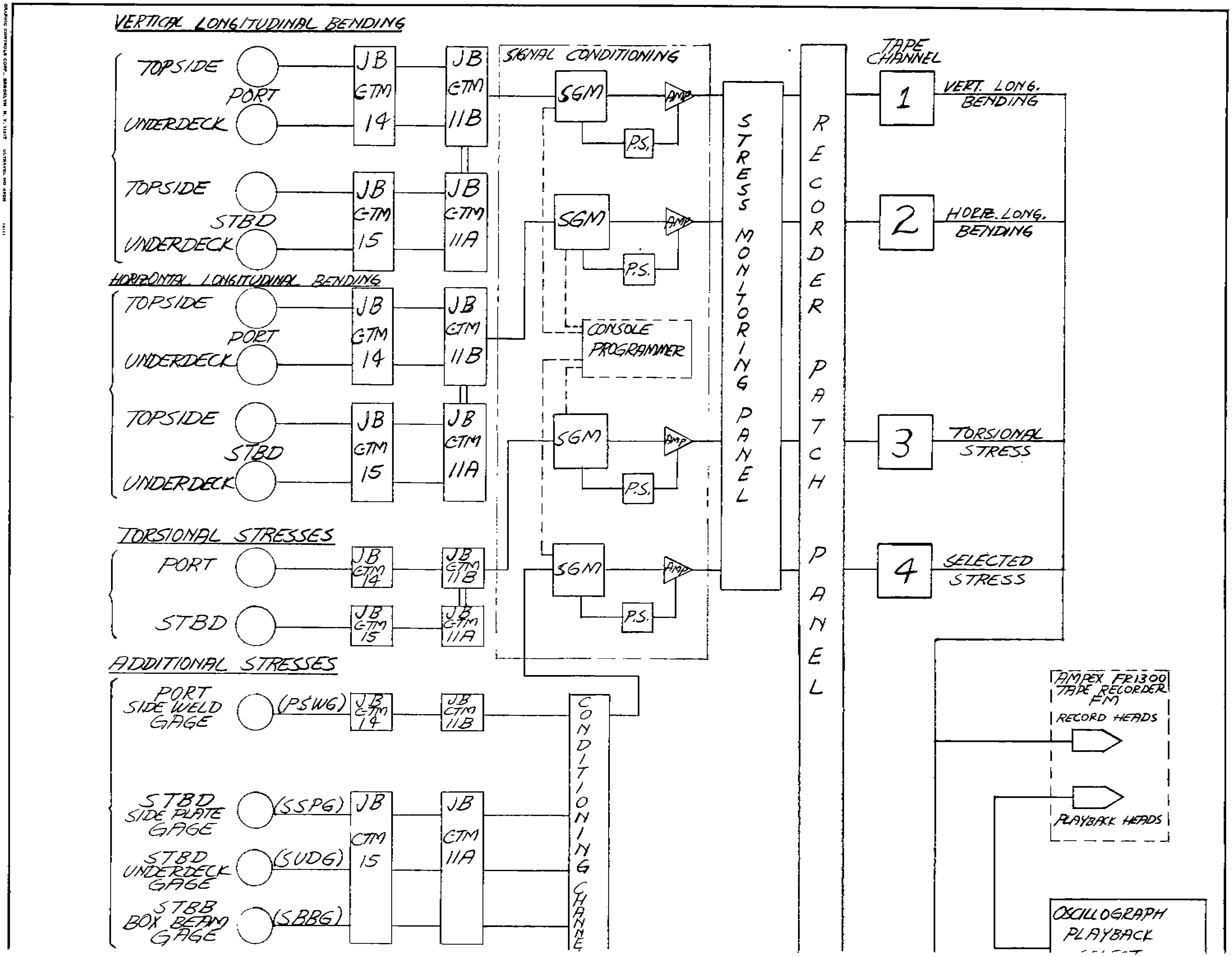
TELEDYNE MATERIALS RESEARCH

A TELEDYNE COMPANY

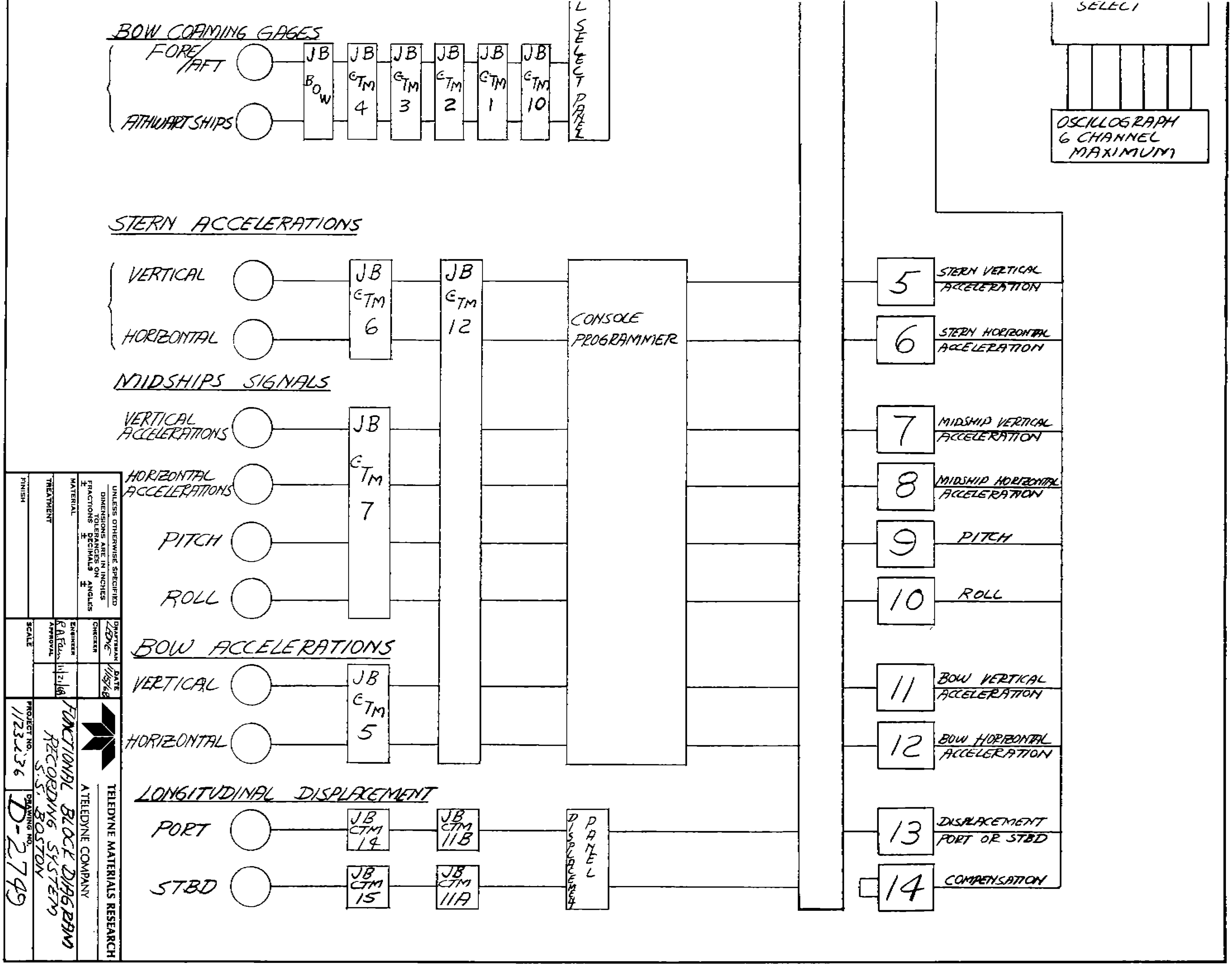
TRANSDUCER ASSY

PROJECT NO.: 1123-36

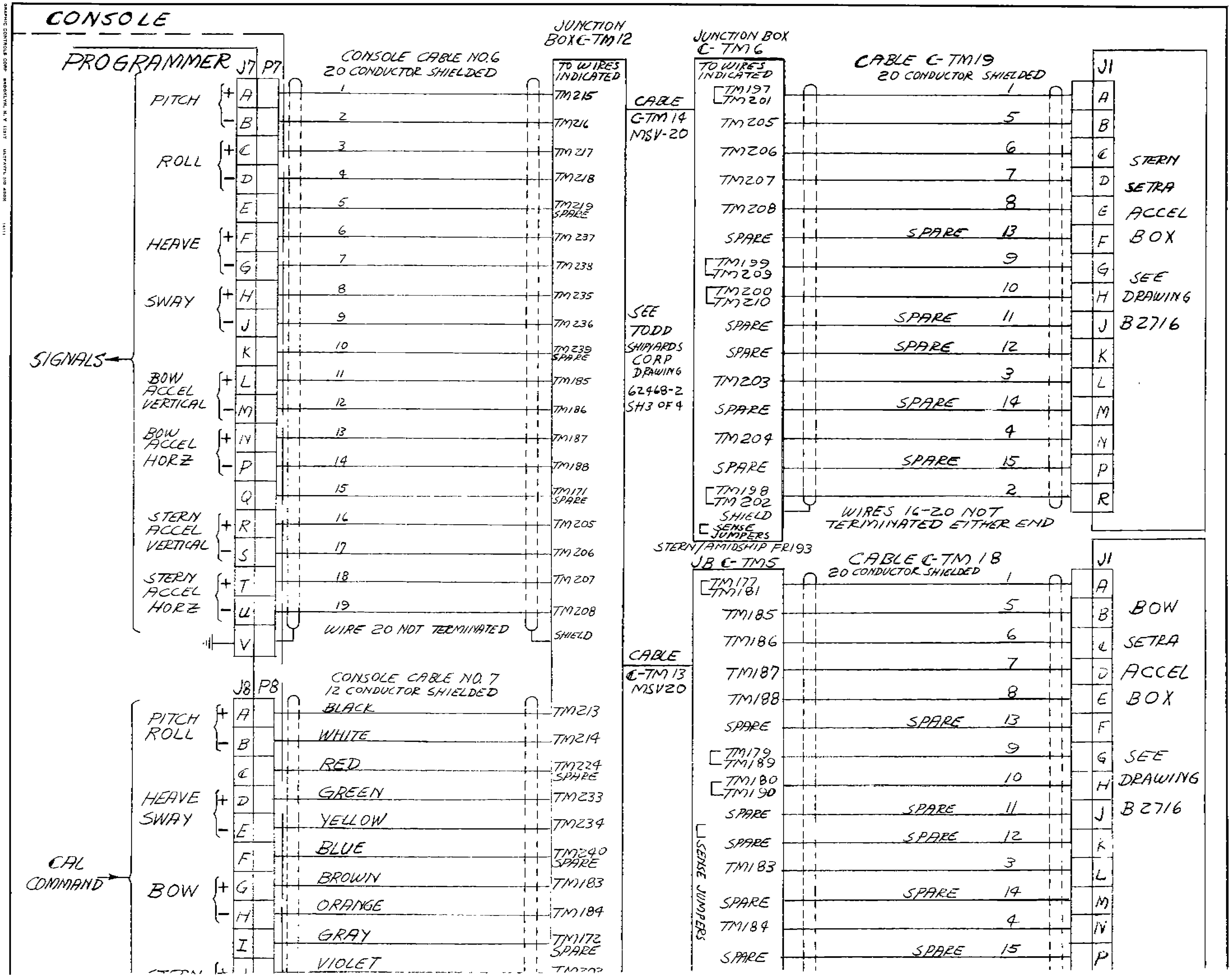
DRAWING NO.: D-2700



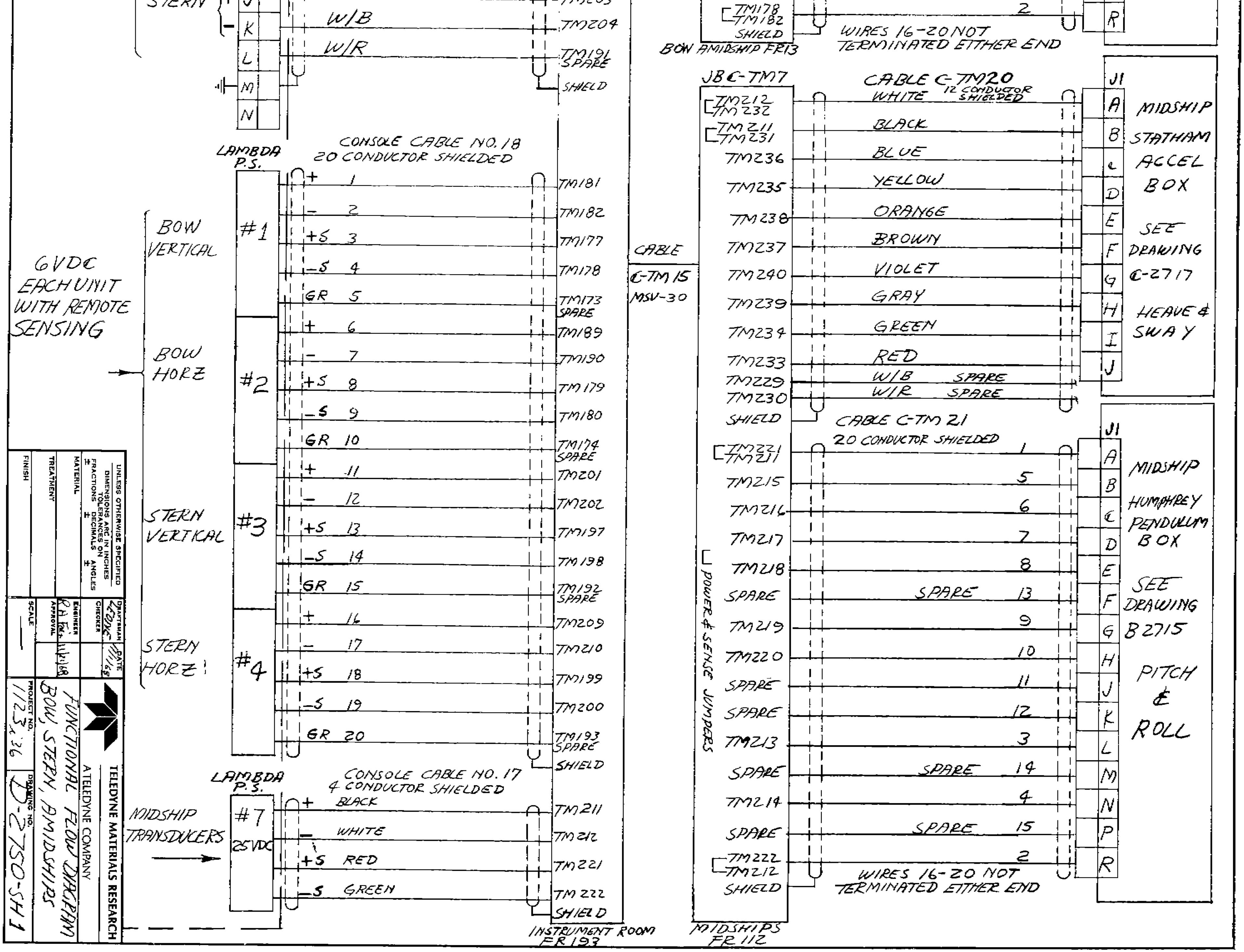
GRAPHIC CONTROLS CORP., BROOKLYN N. Y. 11X17 ULTRAVEL NO 490M



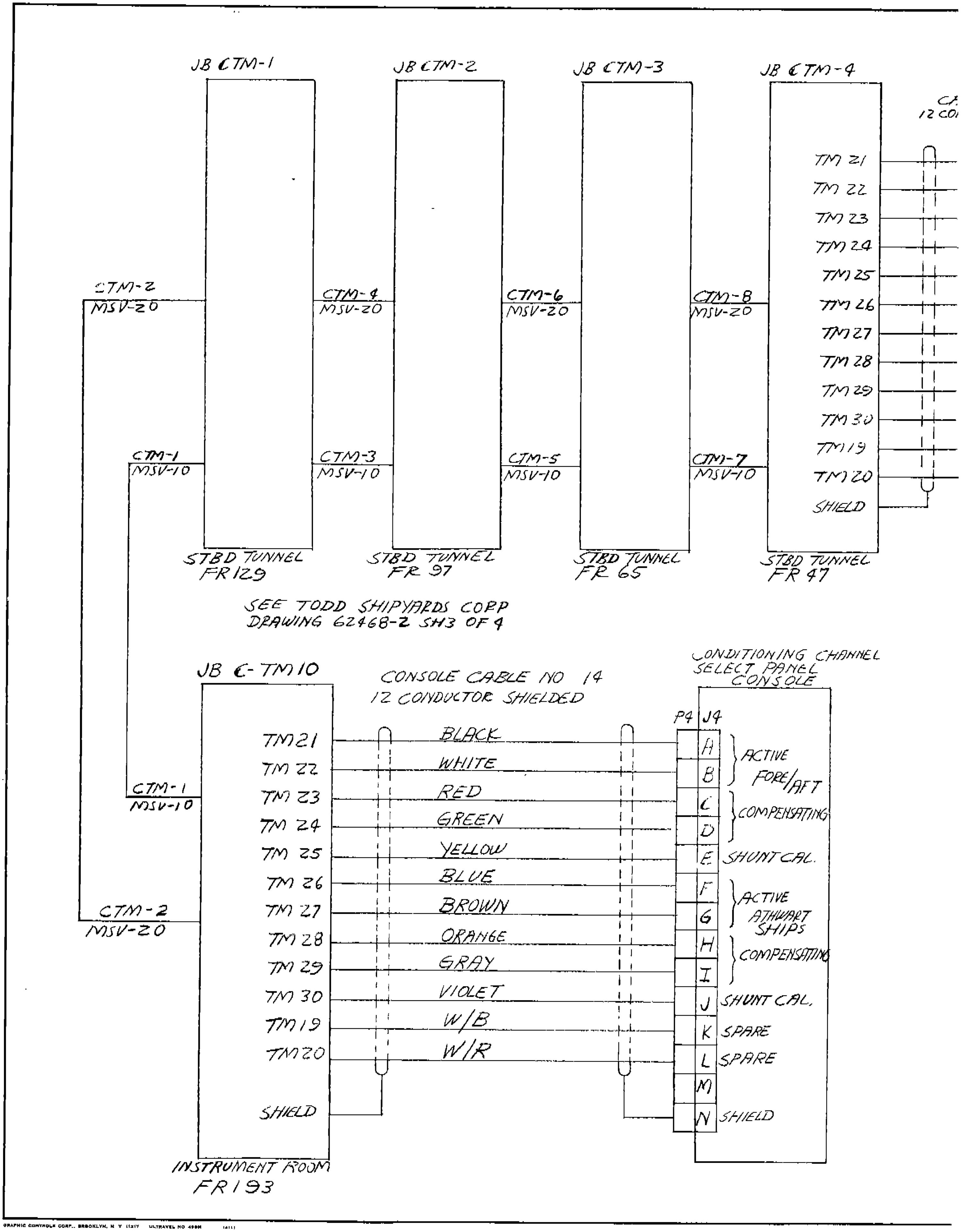
BOW COAMING GAGES
FORE/AFT
ATHWARTSHIPS
JB BOW
JB CTM 4
JB CTM 3
JB CTM 2
JB CTM 1
JB CTM 10
SELECT PANEL
SELECT
OSCILLOGRAPH 6 CHANNEL MAXIMUM
STERN ACCELERATIONS
VERTICAL
HORIZONTAL
JB CTM 6
JB CTM 12
CONSOLE PROGRAMMER
MIDSHIPS SIGNALS
VERTICAL ACCELERATIONS
HORIZONTAL ACCELERATIONS
PITCH
ROLL
JB CTM 7
BOW ACCELERATIONS
VERTICAL
HORIZONTAL
JB CTM 5
LONGITUDINAL DISPLACEMENT
PORT
STBD
JB CTM 14
JB CTM 11B
JB CTM 15
JB CTM 11A
DISPLACEMENT PANEL
5 STERN VERTICAL ACCELERATION
6 STERN HORIZONTAL ACCELERATION
7 MIDSHIP VERTICAL ACCELERATION
8 MIDSHIP HORIZONTAL ACCELERATION
9 PITCH
10 ROLL
11 BOW VERTICAL ACCELERATION
12 BOW HORIZONTAL ACCELERATION
13 DISPLACEMENT PORT OR STBD
14 COMPENSATION
UNLESS OTHERWISE SPECIFIED
DIMENSIONS ARE IN INCHES
TOLERANCES ON
FRACTIONS ± DECIMALS ± ANGLES ±
MATERIAL
TREATMENT
FINISH
DRAFTSMAN LEONE
DATE 11/15/68
CHECKER
ENGINEER R.A.Fau
11/21/68
APPROVAL
SCALE
TELEDYNE MATERIALS RESEARCH
A TELEDYNE COMPANY
FUNCTIONAL BLOCK DIAGRAM
RECORDING SYSTEM
S.S. BOSTON
PROJECT NO. 1123-236
DRAWING NO. D-2749

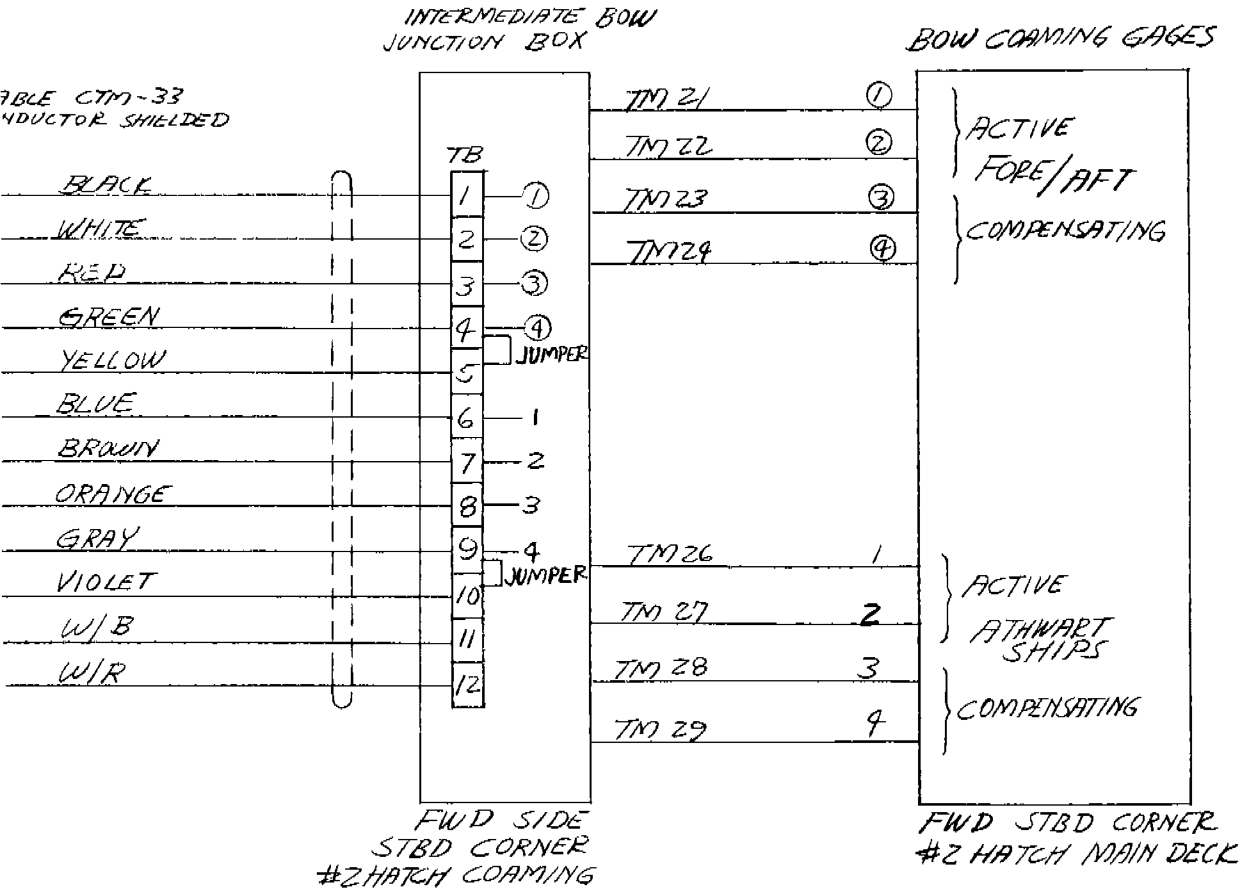


GRAPHIC CONTROLS CORP BROOKLYN, N.Y. 11217

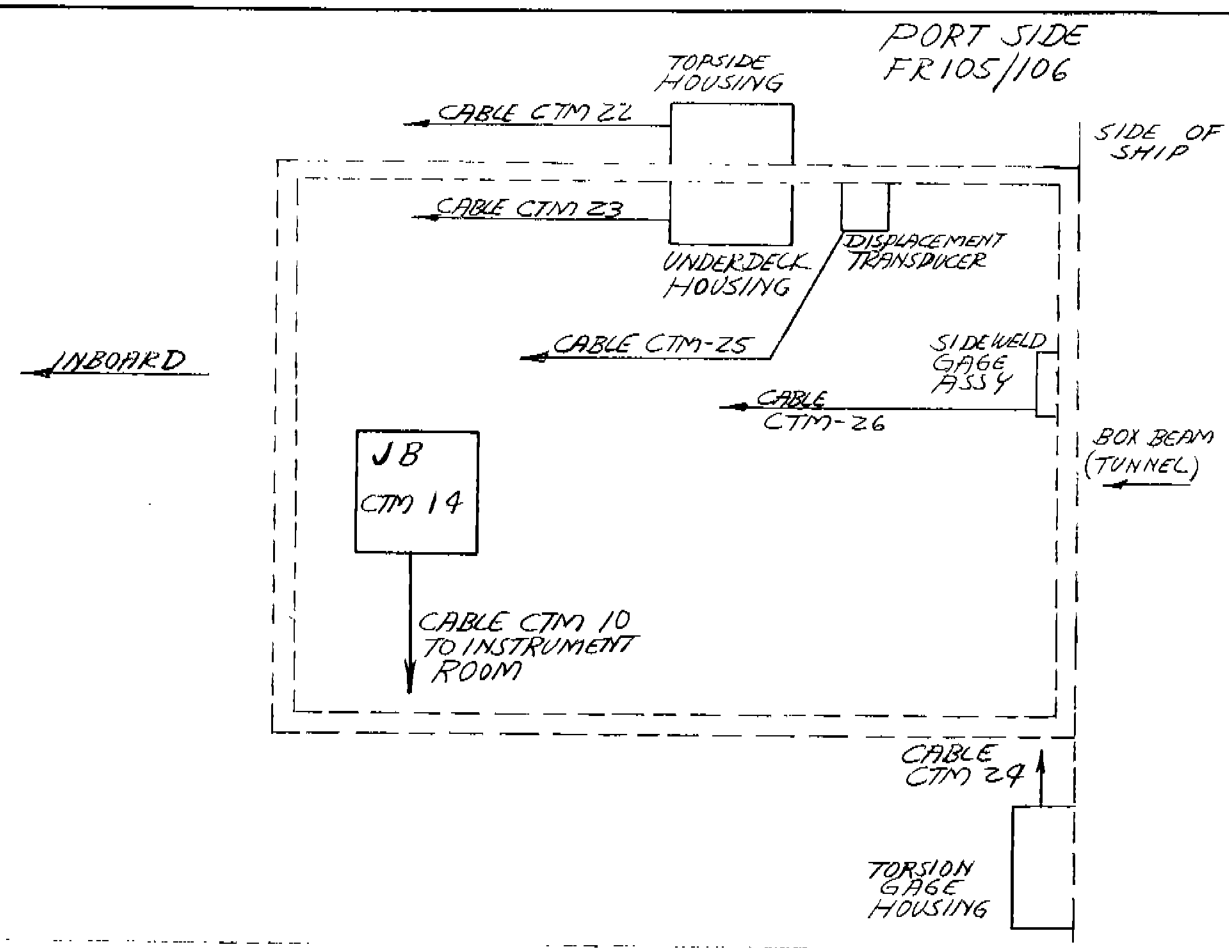


STERN
W/B
W/R
TM204
TM191 SPARE
SHIELD
TM178
TM182
SHIELD
BOW AMIDSHIP FR13
WIRES 16-20 NOT TERMINATED EITHER END
JBC-TM7
CABLE C-TM20 12 CONDUCTOR SHIELDED
WHITE
BLACK
BLUE
YELLOW
ORANGE
BROWN
VIOLET
GRAY
GREEN
RED
W/B SPARE
W/R SPARE
TM212
TM232
TM211
TM231
TM236
TM235
TM238
TM237
TM240
TM239
TM234
TM233
TM229
TM230
SHIELD
J1
MIDSHIP STATHAM ACCEL BOX
SEE DRAWING C-2717
HEAVE & SWAY
LAMBDA P.S.
CONSOLE CABLE NO. 18 20 CONDUCTOR SHIELDED
6VDC EACH UNIT WITH REMOTE SENSING
BOW VERTICAL
BOW HORZ
STERN VERTICAL
STERN HORZ
#1
#2
#3
#4
TM181
TM182
TM177
TM178
TM173 SPARE
TM189
TM190
TM179
TM180
TM174 SPARE
TM201
TM202
TM197
TM198
TM192 SPARE
TM209
TM210
TM199
TM200
TM193 SPARE
SHIELD
CABLE C-TM15 MSV-30
CABLE C-TM21 20 CONDUCTOR SHIELDED
TM221
TM211
TM215
TM216
TM217
TM218
SPARE
TM219
TM220
TM213
TM214
TM222
TM212
POWER & SENSE JUMPERS
MIDSHIP HUMPHREY PENDULUM BOX
SEE DRAWING B2715
PITCH & ROLL
WIRES 16-20 NOT TERMINATED EITHER END
LAMBDA P.S.
CONSOLE CABLE NO. 17 4 CONDUCTOR SHIELDED
MIDSHIP TRANSDUCERS
#7
25VDC
BLACK
WHITE
RED
GREEN
TM211
TM212
TM221
TM222
SHIELD
INSTRUMENT ROOM FR 193
MIDSHIPS FR 112
UNLESS OTHERWISE SPECIFIED DIMENSIONS ARE IN INCHES TOLERANCES ON FRACTIONS ± DECIMALS ± ANGLES ±
MATERIAL
TREATMENT
FINISH
DRAFTSMAN
CHECKER
ENGINEER
APPROVAL
DATE
SCALE
TELEDYNE MATERIALS RESEARCH
A TELEDYNE COMPANY
FUNCTIONAL FLOW DIAGRAM BOW, STERN, AMIDSHIPS
PROJECT NO. 1123.26
DRAWING NO. D-2750-SH1

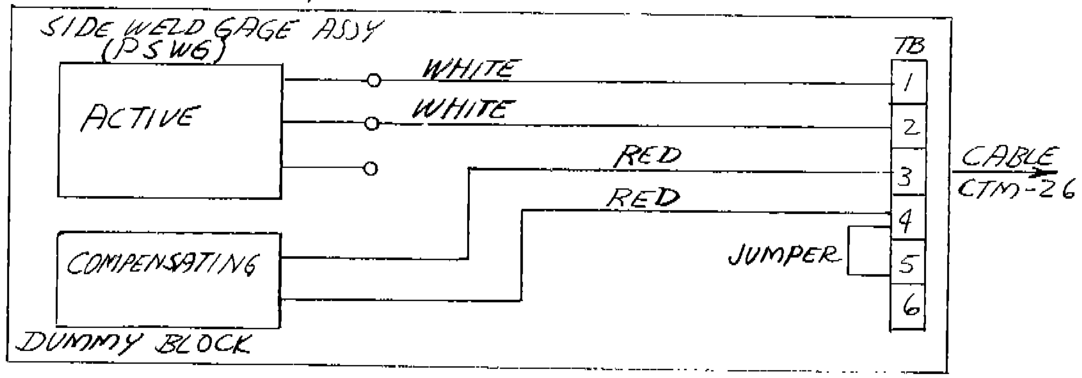

JB CTM-1
JB CTM-2
JB CTM-3
JB CTM-4
TM 21
TM 22
TM 23
TM 24
TM 25
TM 26
TM 27
TM 28
TM 29
TM 30
TM 19
TM 20
SHIELD
CTM-2
MSV-20
CTM-4
MSV-20
CTM-6
MSV-20
CTM-8
MSV-20
CTM-1
MSV-10
CTM-3
MSV-10
CTM-5
MSV-10
CTM-7
MSV-10
STBD TUNNEL
FR 129
STBD TUNNEL
FR 97
STBD TUNNEL
FR 65
STBD TUNNEL
FR 47
SEE TODD SHIPYARDS CORP
DRAWING 62468-2 SH3 OF 4
JB C-TM10
CONSOLE CABLE NO 14
12 CONDUCTOR SHIELDED
CONDITIONING CHANNEL
SELECT PANEL
CONSOLE
P4
J4
TM21
TM 22
TM 23
TM 24
TM 25
TM 26
TM 27
TM 28
TM 29
TM 30
TM19
TM20
SHIELD
BLACK
WHITE
RED
GREEN
YELLOW
BLUE
BROWN
ORANGE
GRAY
VIOLET
W/B
W/R
A
B
C
D
E
F
G
H
I
J
K
L
M
N
ACTIVE
FORE/AFT
COMPENSATING
SHUNT CAL.
ACTIVE
ATHWART
SHIPS
COMPENSATING
SHUNT CAL.
SPARE
SPARE
SHIELD
CTM-1
MSV-10
CTM-2
MSV-20
INSTRUMENT ROOM
FR 193



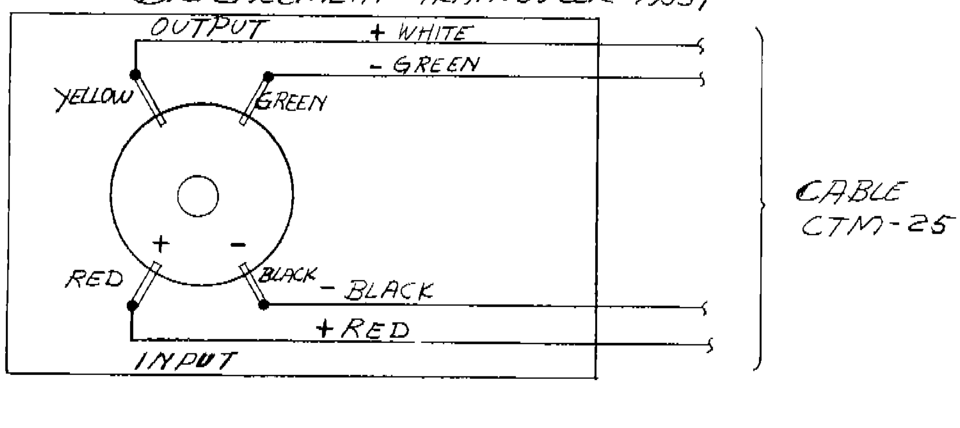
UNLESS OTHERWISE SPECIFIED DIMENSIONS ARE IN INCHES TOLERANCES ON FRACTIONS ± DECIMALS ± ANGLES ±	DRAFTSMAN LEONE	DATE 11/1/68	TELEDYNE MATERIALS RESEARCH A TELEDYNE COMPANY
	CHECKER		
MATERIAL	ENGINEER R.A. Fein	11/21/68	FUNCTIONAL FLOW DIAGRAM
TREATMENT	APPROVAL		BOW COAMING GAGES
FINISH	SCALE		PROJECT NO. 1123236 · DRAWING NO. D-2750-SH2

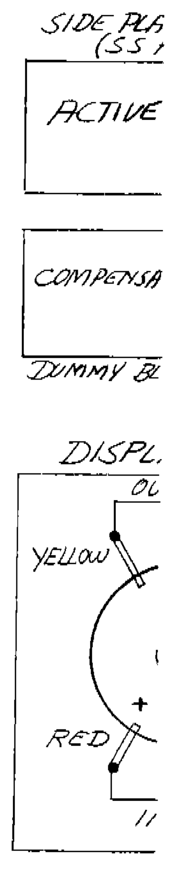


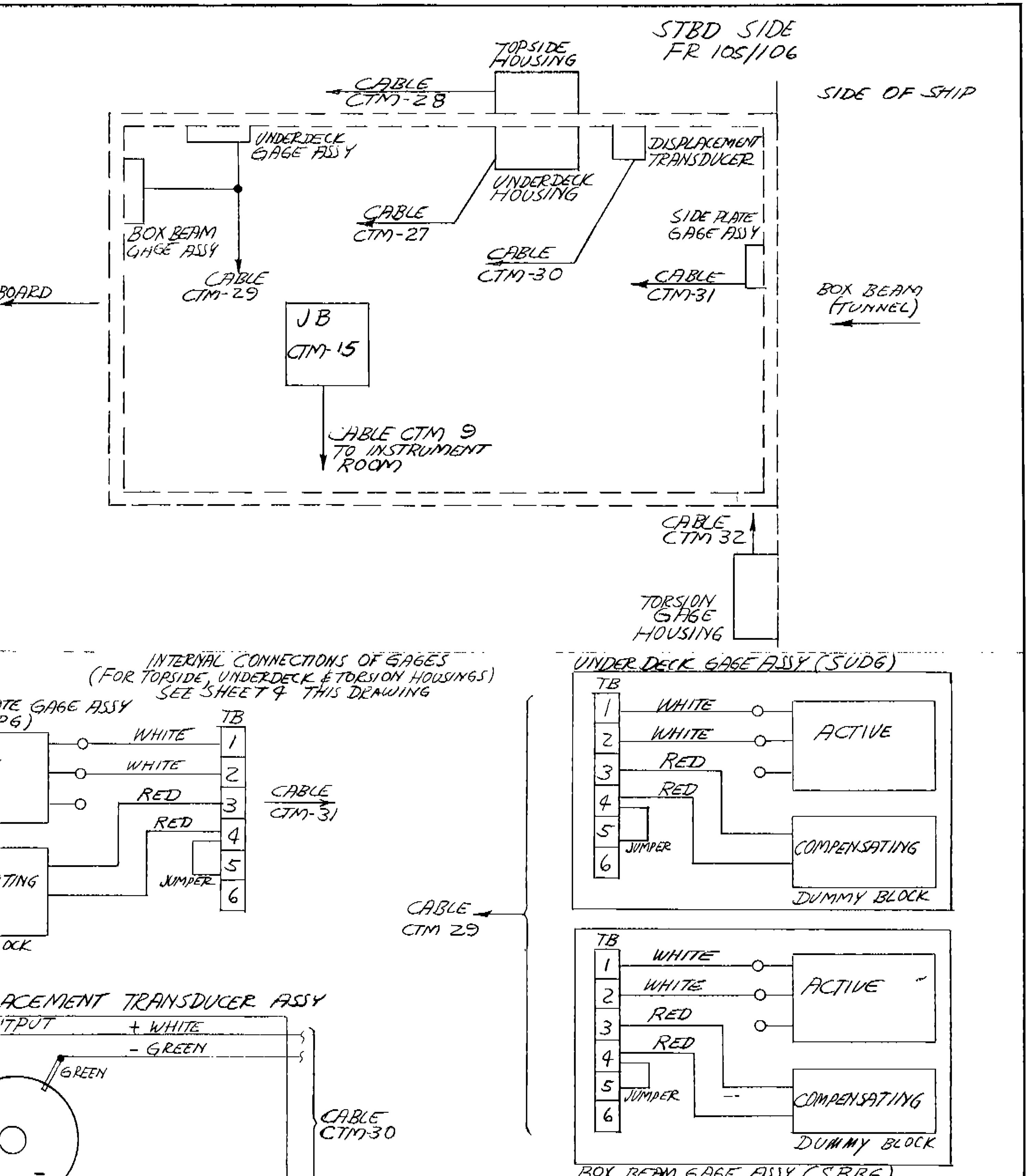
INTERNAL CONNECTIONS OF GAGES
(FOR TOPSIDE, UNDERDECK & TORSION HOUSING)
SEE SHEET 4 THIS DRAWING



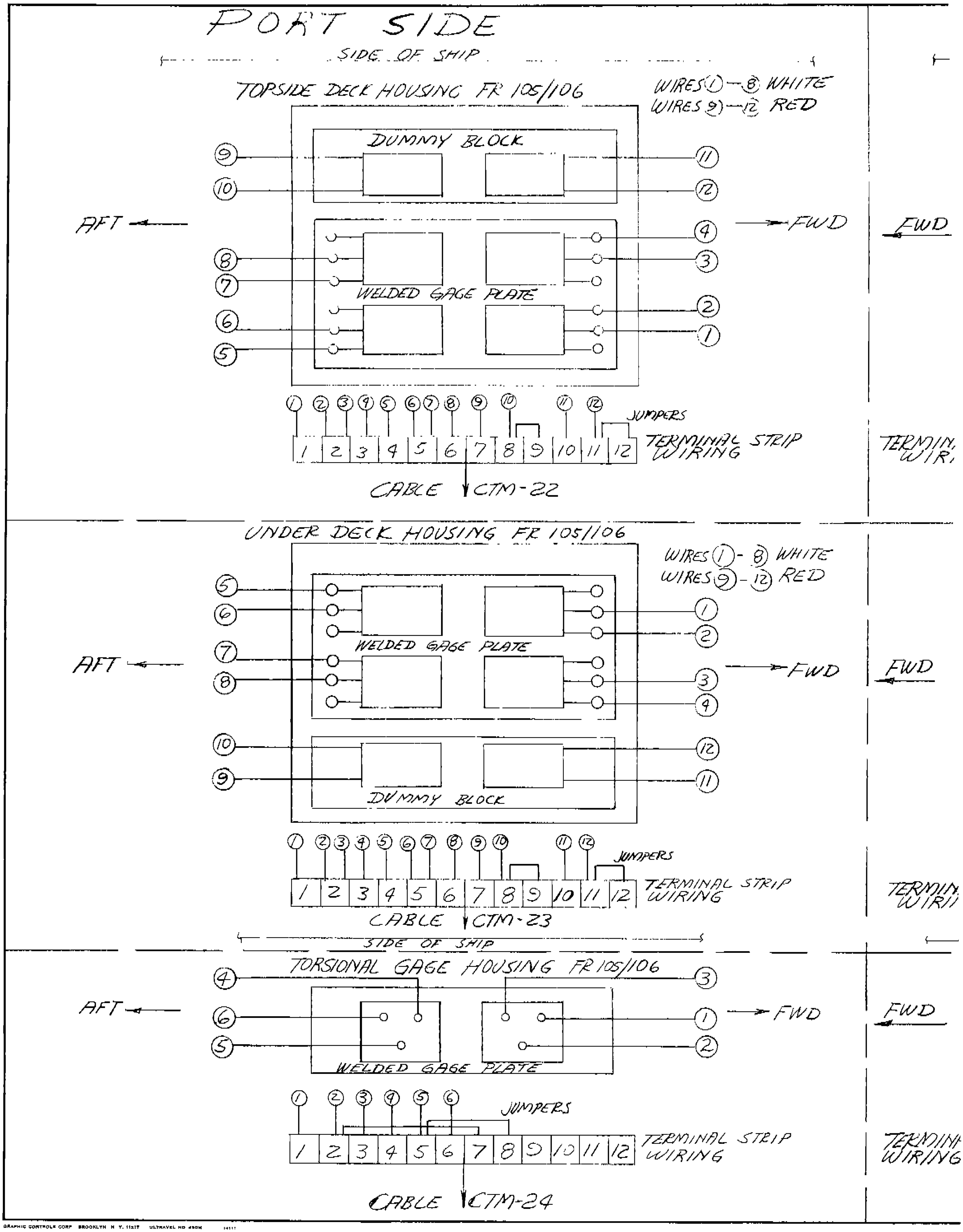
DISPLACEMENT TRANSDUCER ASSY

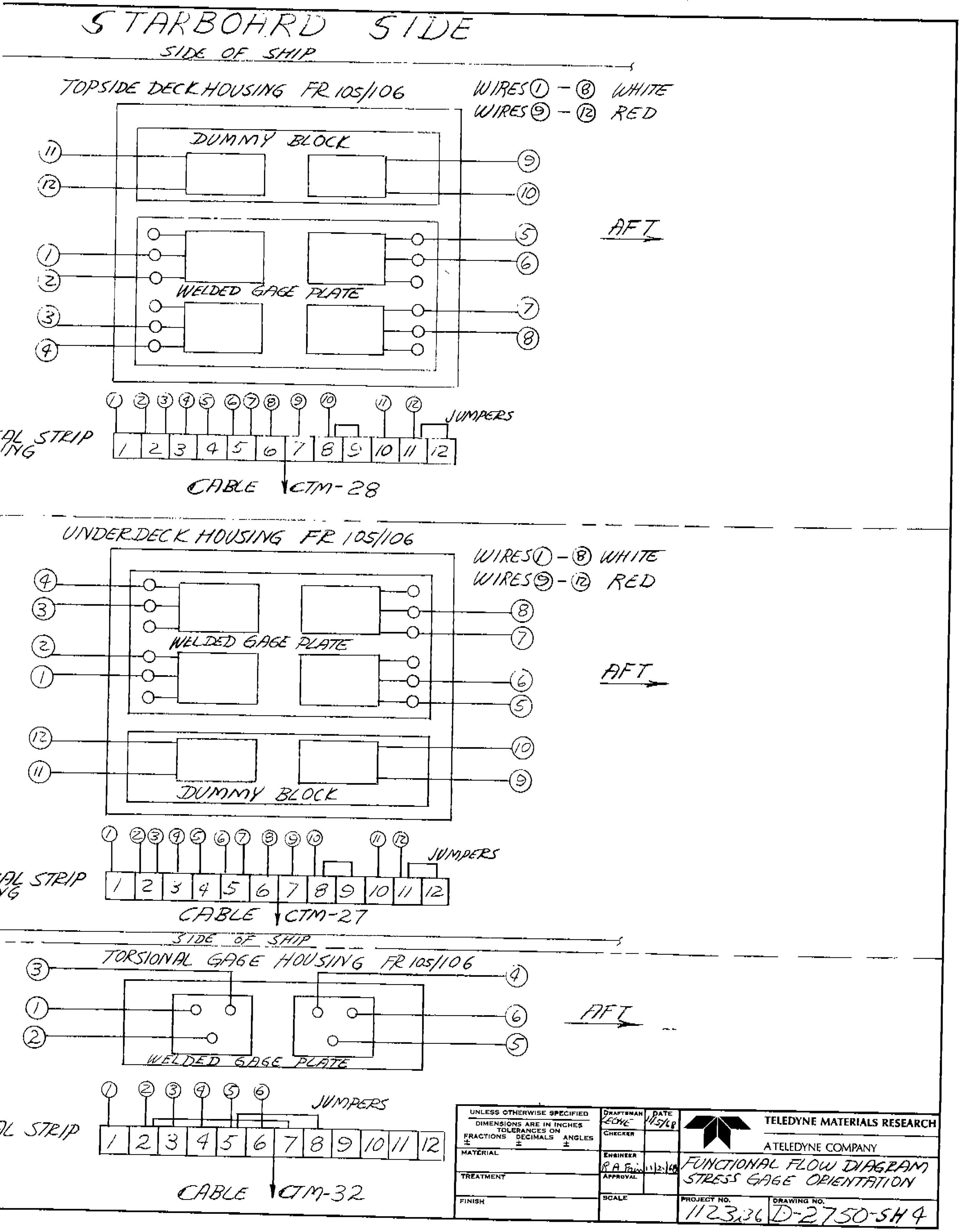




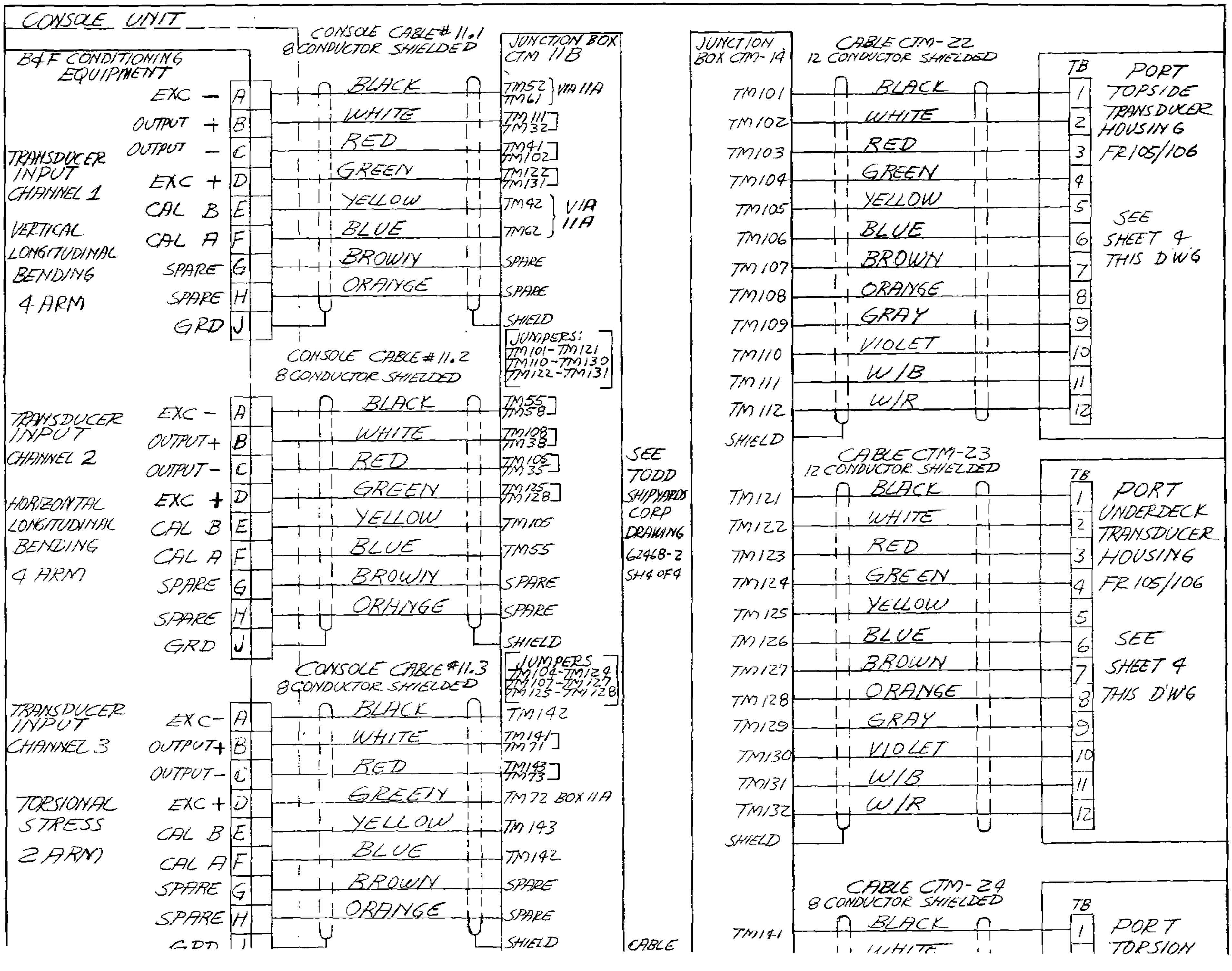


UNLESS OTHERWISE SPECIFIED DIMENSIONS ARE IN INCHES TOLERANCES ON FRACTIONS ± DECIMALS ± ANGLES ±	DRAFTSMAN LEONE	DATE 11/1/68	TELEDYNE MATERIALS RESEARCH — A TELEDYNE COMPANY
MATERIAL	CHECKER		
TREATMENT	ENGINEER R.A. Fay	11/21/68	FUNCTIONAL FLOW DIAGRAM GAGE LOCATIONS & TIE IN
	APPROVAL		
FINISH	SCALE		PROJECT NO. 1123,136 — DRAWING NO. D-2750-SH3

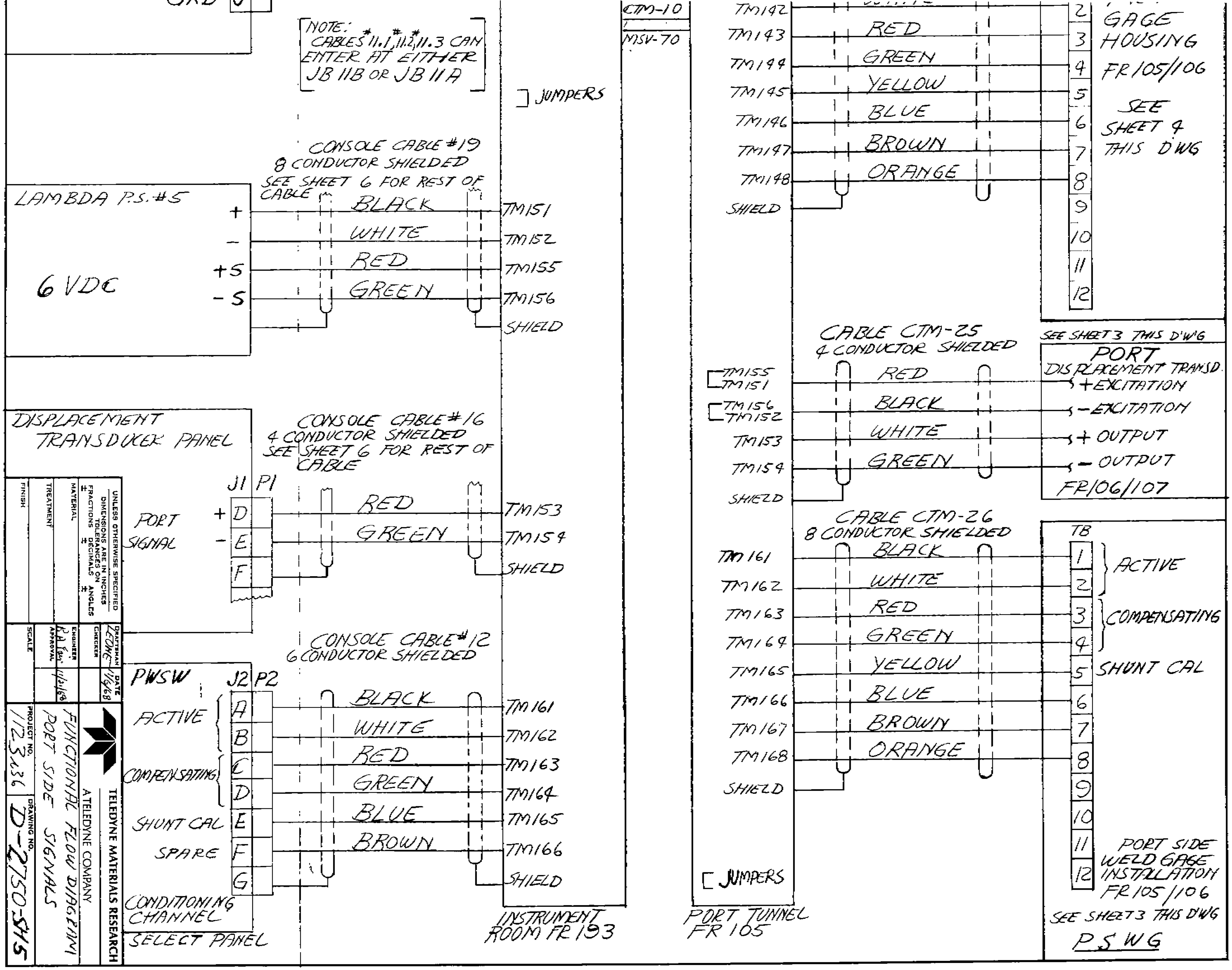

PORT SIDE
SIDE OF SHIP
TOPSIDE DECK HOUSING FR 105/106
WIRES 1 - 8 WHITE
WIRES 9 - 12 RED
DUMMY BLOCK
WELDED GAGE PLATE
AFT
FWD
JUMPERS
TERMINAL STRIP WIRING
CABLE CTM-22
UNDER DECK HOUSING FR 105/106
WIRES 1 - 8 WHITE
WIRES 9 - 12 RED
WELDED GAGE PLATE
DUMMY BLOCK
AFT
FWD
JUMPERS
TERMINAL STRIP WIRING
CABLE CTM-23
SIDE OF SHIP
TORSIONAL GAGE HOUSING FR 105/106
AFT
FWD
WELDED GAGE PLATE
JUMPERS
TERMINAL STRIP WIRING
CABLE CTM-24



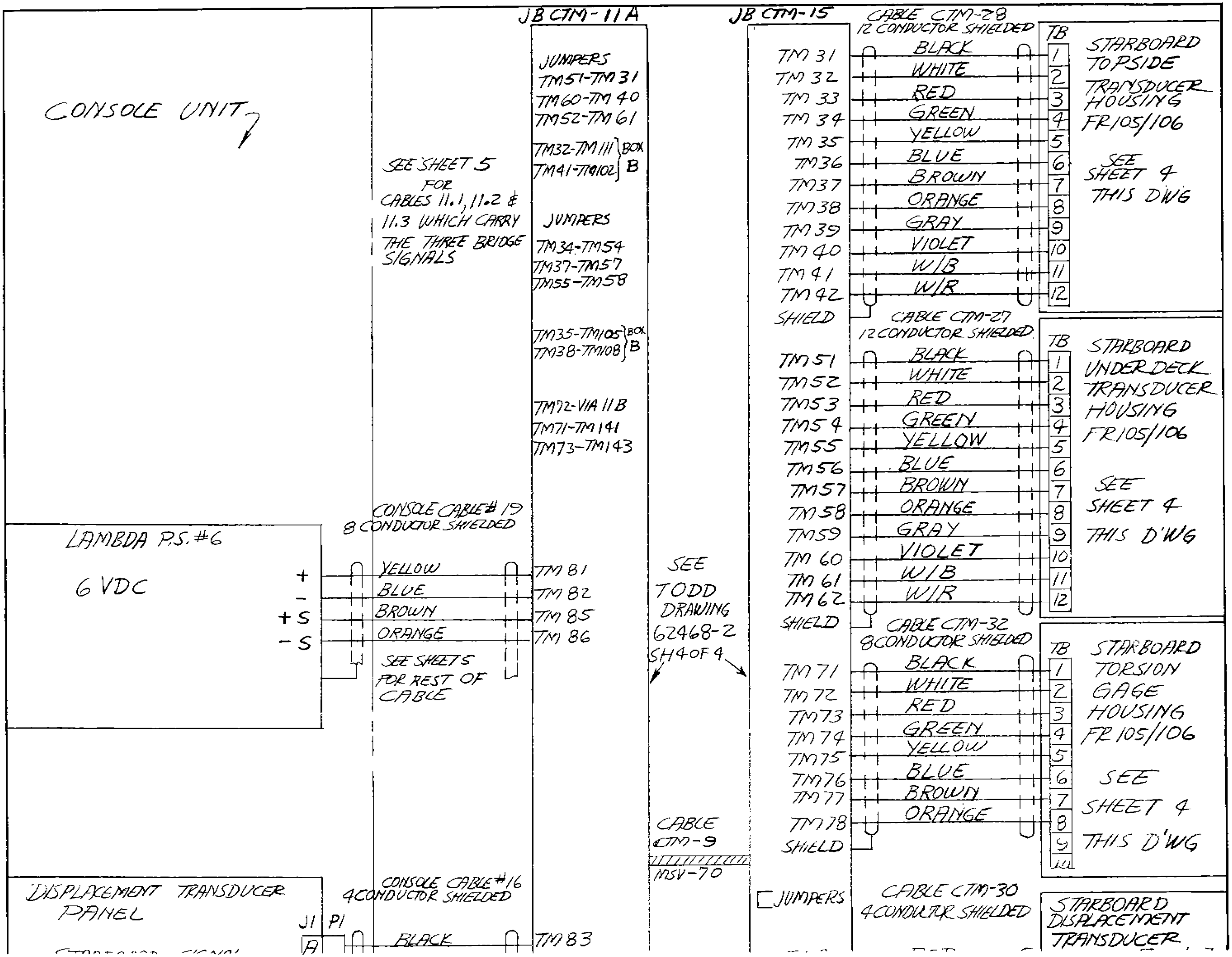
STARBOHRD SIDE
SIDE OF SHIP
TOPSIDE DECK HOUSING FR 105/106
WIRES ① - ⑧ WHITE
WIRES ⑨ - ⑫ RED
DUMMY BLOCK
WELDED GAGE PLATE
AFT
JUMPERS
CABLE CTM-28
UNDERDECK HOUSING FR 105/106
WIRES ① - ⑧ WHITE
WIRES ⑨ - ⑫ RED
WELDED GAGE PLATE
DUMMY BLOCK
AFT
JUMPERS
CABLE CTM-27
SIDE OF SHIP
TORSIONAL GAGE HOUSING FR 105/106
WELDED GAGE PLATE
AFT
JUMPERS
CABLE CTM-32
UNLESS OTHERWISE SPECIFIED
DIMENSIONS ARE IN INCHES
TOLERANCES ON
FRACTIONS DECIMALS ANGLES
MATERIAL
TREATMENT
FINISH
DRAFTSMAN
DATE
11/5/68
CHECKER
ENGINEER
R A Fair
APPROVAL
SCALE
TELEDYNE MATERIALS RESEARCH
A TELEDYNE COMPANY
FUNCTIONAL FLOW DIAGRAM
STRESS GAGE ORIENTATION
PROJECT NO.
1123.36
DRAWING NO.
D-2750-SH 4



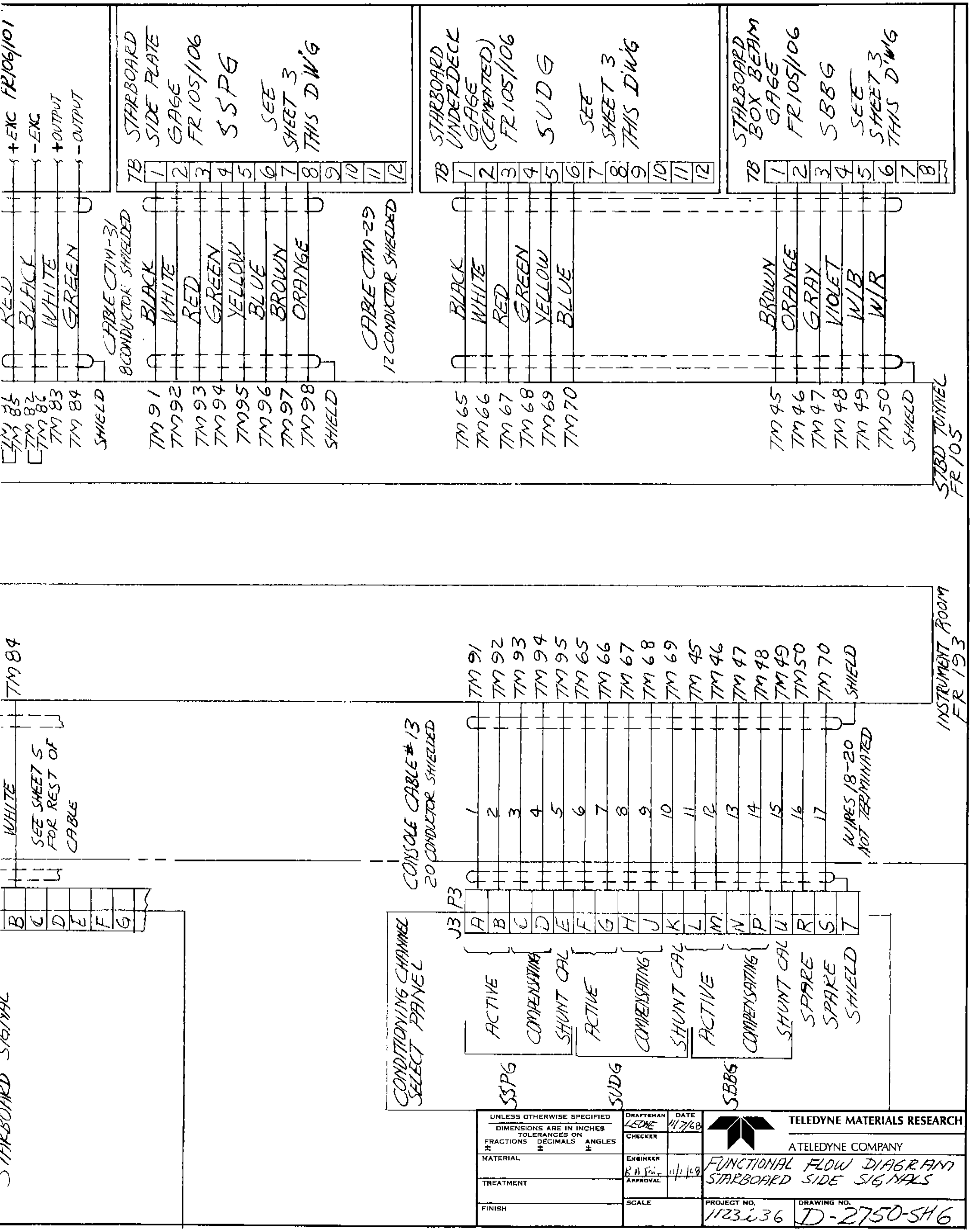
CONSOLE UNIT
B&F CONDITIONING EQUIPMENT
TRANSDUCER INPUT CHANNEL 1
VERTICAL LONGITUDINAL BENDING
4 ARM
EXC − A
OUTPUT + B
OUTPUT − C
EXC + D
CAL B E
CAL A F
SPARE G
SPARE H
GRD J
CONSOLE CABLE # 11.1
8 CONDUCTOR SHIELDED
BLACK
WHITE
RED
GREEN
YELLOW
BLUE
BROWN
ORANGE
JUNCTION BOX CTM 11B
TM52 TM61 VIA 11A
TM111 TM32
TM41 TM102
TM122 TM131
TM42 TM62 VIA 11A
SPARE
SPARE
SHIELD
JUMPERS: TM101-TM121 TM110-TM130 TM122-TM131
TRANSDUCER INPUT CHANNEL 2
HORIZONTAL LONGITUDINAL BENDING
4 ARM
EXC − A
OUTPUT + B
OUTPUT − C
EXC + D
CAL B E
CAL A F
SPARE G
SPARE H
GRD J
CONSOLE CABLE # 11.2
8 CONDUCTOR SHIELDED
BLACK
WHITE
RED
GREEN
YELLOW
BLUE
BROWN
ORANGE
TM55 TM58
TM108 TM38
TM105 TM35
TM125 TM128
TM106
TM55
SPARE
SPARE
SHIELD
JUMPERS TM104-TM124 TM107-TM127 TM125-TM128
TRANSDUCER INPUT CHANNEL 3
TORSIONAL STRESS
2 ARM
EXC − A
OUTPUT + B
OUTPUT − C
EXC + D
CAL B E
CAL A F
SPARE G
SPARE H
CONSOLE CABLE #11.3
8 CONDUCTOR SHIELDED
BLACK
WHITE
RED
GREEN
YELLOW
BLUE
BROWN
ORANGE
TM142
TM141 TM71
TM143 TM73
TM72 BOX 11A
TM143
TM142
SPARE
SPARE
SHIELD
SEE TODD SHIPYARDS CORP DRAWING 6246B-2 SH 4 OF 4
CABLE
JUNCTION BOX CTM-14
TM101
TM102
TM103
TM104
TM105
TM106
TM107
TM108
TM109
TM110
TM111
TM112
SHIELD
CABLE CTM-22
12 CONDUCTOR SHIELDED
BLACK
WHITE
RED
GREEN
YELLOW
BLUE
BROWN
ORANGE
GRAY
VIOLET
W/B
W/R
TB
1
2
3
4
5
6
7
8
9
10
11
12
PORT TOPSIDE TRANSDUCER HOUSING FR 105/106
SEE SHEET 4 THIS D'WG
TM121
TM122
TM123
TM124
TM125
TM126
TM127
TM128
TM129
TM130
TM131
TM132
SHIELD
CABLE CTM-23
12 CONDUCTOR SHIELDED
BLACK
WHITE
RED
GREEN
YELLOW
BLUE
BROWN
ORANGE
GRAY
VIOLET
W/B
W/R
TB
1
2
3
4
5
6
7
8
9
10
11
12
PORT UNDERDECK TRANSDUCER HOUSING FR 105/106
SEE SHEET 4 THIS D'WG
TM141
CABLE CTM-24
8 CONDUCTOR SHIELDED
BLACK
TB
1
PORT TORSION



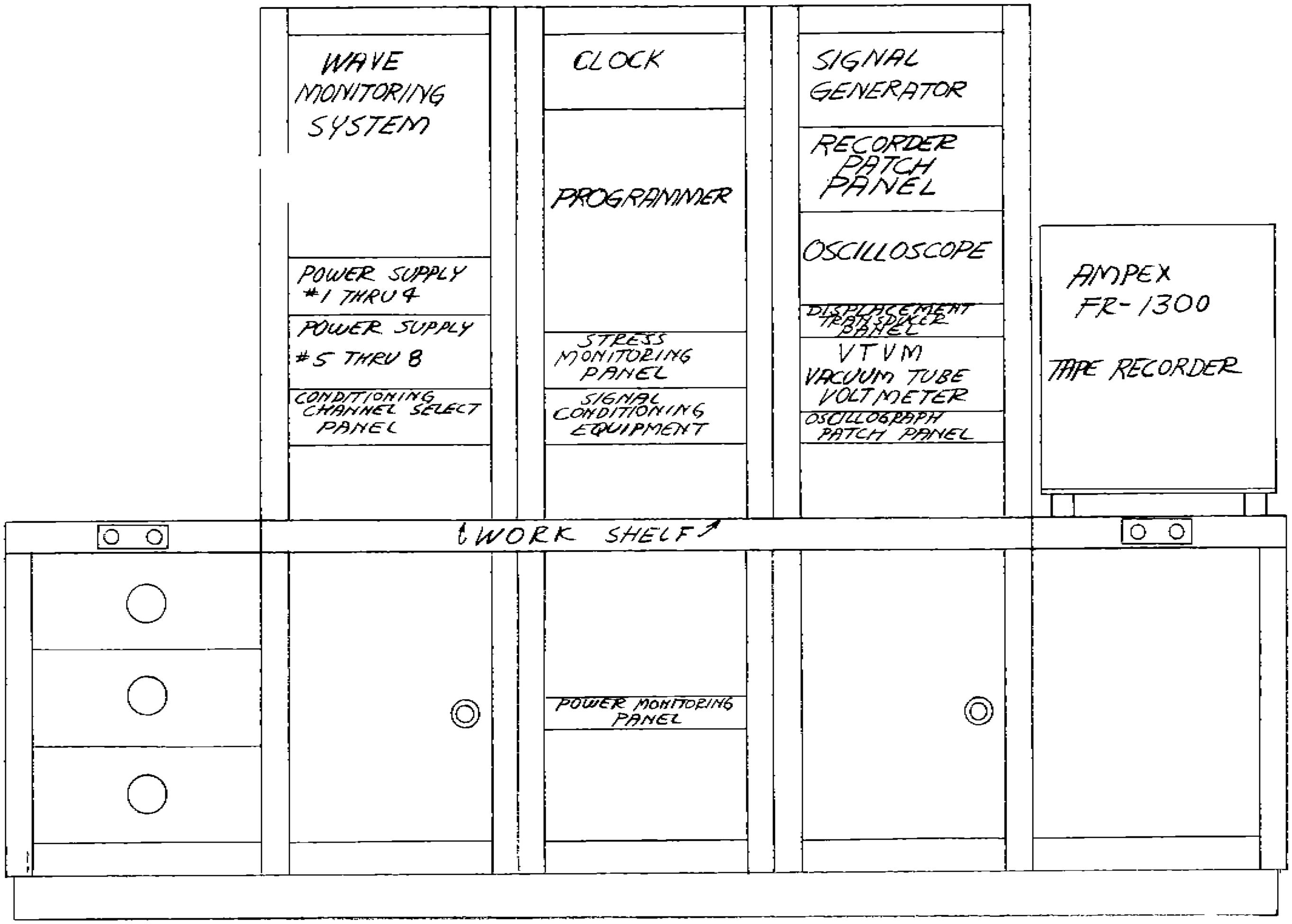
UNLESS OTHERWISE SPECIFIED DIMENSIONS ARE IN INCHES TOLERANCES ON FRACTIONS ± DECIMALS ± ANGLES ±	DRAFTSMAN LEONE	DATE 11/6/68	TELEDYNE MATERIALS RESEARCH A TELEDYNE COMPANY
MATERIAL	CHECKER		FUNCTIONAL FLOW DIAGRAM PORT SIDE SIGNALS
TREATMENT	ENGINEER R.A. Fair	11/21/68	
	APPROVAL		
FINISH	SCALE		PROJECT NO. 1123.36 DRAWING NO. D-2750-SH5



GRAPHIC CONTROLS CORP. BROOKLYN, N. Y. 11217 ULTRAVEL NO 490M

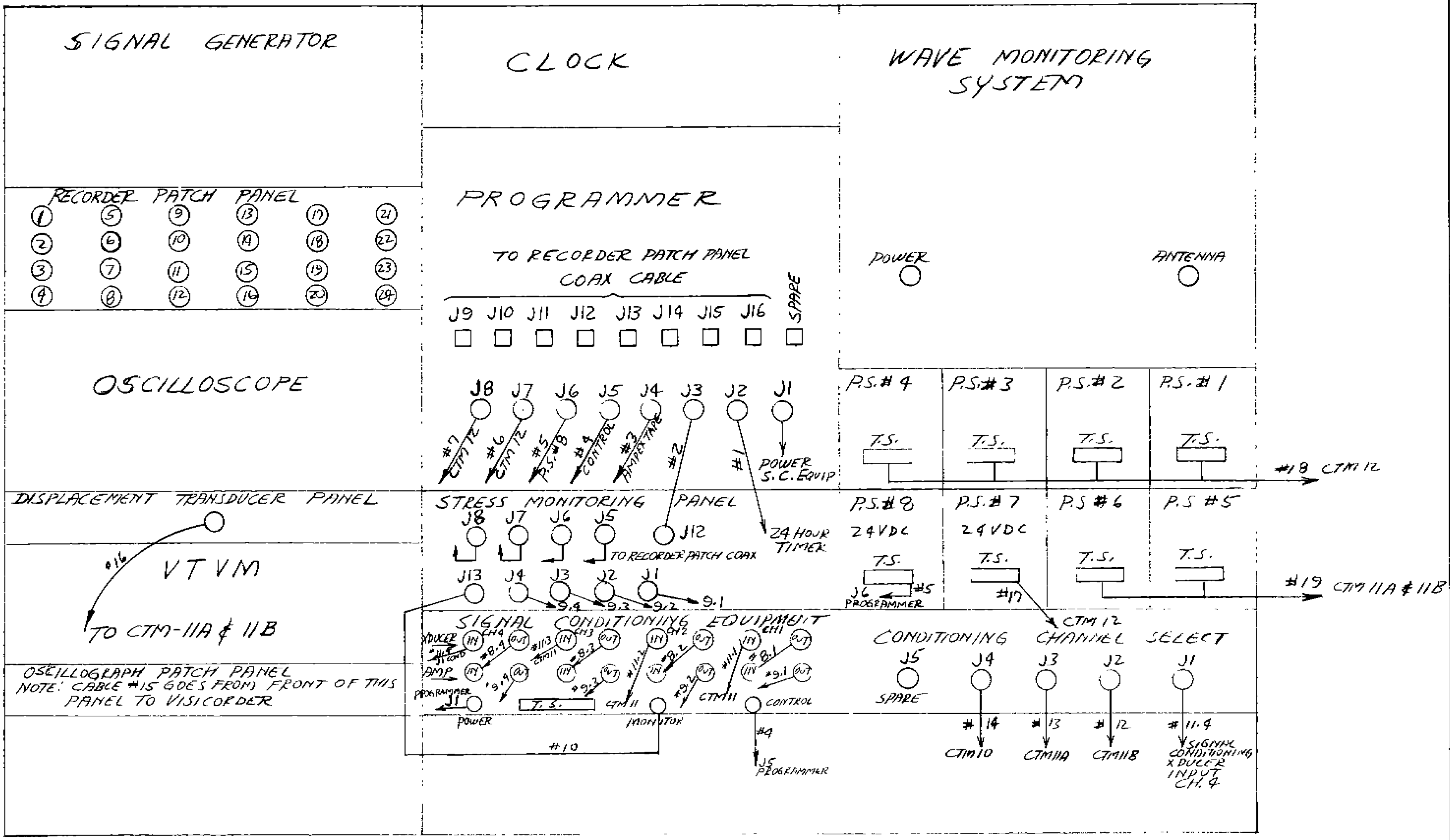


+EXC FR106/101
-EXC
+OUTPUT
-OUTPUT
RED
BLACK
WHITE
GREEN
TM 85
TM 82
TM 86
TM 83
TM 84
SHIELD
STARBOARD SIDE PLATE GAGE FR105/106
SSPG
SEE SHEET 3 THIS DWG
TB 1 2 3 4 5 6 7 8 9 10 11 12
CABLE CTM-31 8 CONDUCTOR SHIELDED
BLACK
WHITE
RED
GREEN
YELLOW
BLUE
BROWN
ORANGE
TM 91
TM 92
TM 93
TM 94
TM 95
TM 96
TM 97
TM 98
SHIELD
CABLE CTM-29 12 CONDUCTOR SHIELDED
STARBOARD UNDERDECK GAGE (CEMENTED) FR105/106
SUDG
SEE SHEET 3 THIS DWG
TB 1 2 3 4 5 6 7 8 9 10 11 12
BLACK
WHITE
RED
GREEN
YELLOW
BLUE
TM 65
TM 66
TM 67
TM 68
TM 69
TM 70
STARBOARD BOX BEAM GAGE FR105/106
SBBG
SEE SHEET 3 THIS DWG
TB 1 2 3 4 5 6 7 8
BROWN
ORANGE
GRAY
VIOLET
W/B
W/R
TM 45
TM 46
TM 47
TM 48
TM 49
TM 50
SHIELD
STBD TUNNEL FR105
TM 84
WHITE
SEE SHEET 5 FOR REST OF CABLE
B C D E F G
STARBOARD SIGNAL
TM 91
TM 92
TM 93
TM 94
TM 95
TM 65
TM 66
TM 67
TM 68
TM 69
TM 45
TM 46
TM 47
TM 48
TM 49
TM 50
TM 70
SHIELD
INSTRUMENT ROOM FR 193
CONSOLE CABLE #13 20 CONDUCTOR SHIELDED
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17
WIRES 18-20 NOT TERMINATED
P3
J3 A B C D E F G H J K L M N P U R S T
CONDITIONING CHANNEL SELECT PANEL
ACTIVE
COMPENSATING
SHUNT CAL
ACTIVE
COMPENSATING
SHUNT CAL
ACTIVE
COMPENSATING
SHUNT CAL
SPARE
SPARE
SHIELD
SSPG
SUDG
SBBG
UNLESS OTHERWISE SPECIFIED
DIMENSIONS ARE IN INCHES
TOLERANCES ON
FRACTIONS ± DECIMALS ± ANGLES ±
MATERIAL
TREATMENT
FINISH
DRAFTSMAN LEONE
DATE 11/7/68
CHECKER
ENGINEER
APPROVAL
SCALE
TELEDYNE MATERIALS RESEARCH
A TELEDYNE COMPANY
FUNCTIONAL FLOW DIAGRAM STARBOARD SIDE SIGNALS
PROJECT NO. 1123i36
DRAWING NO. D-2750-SH6

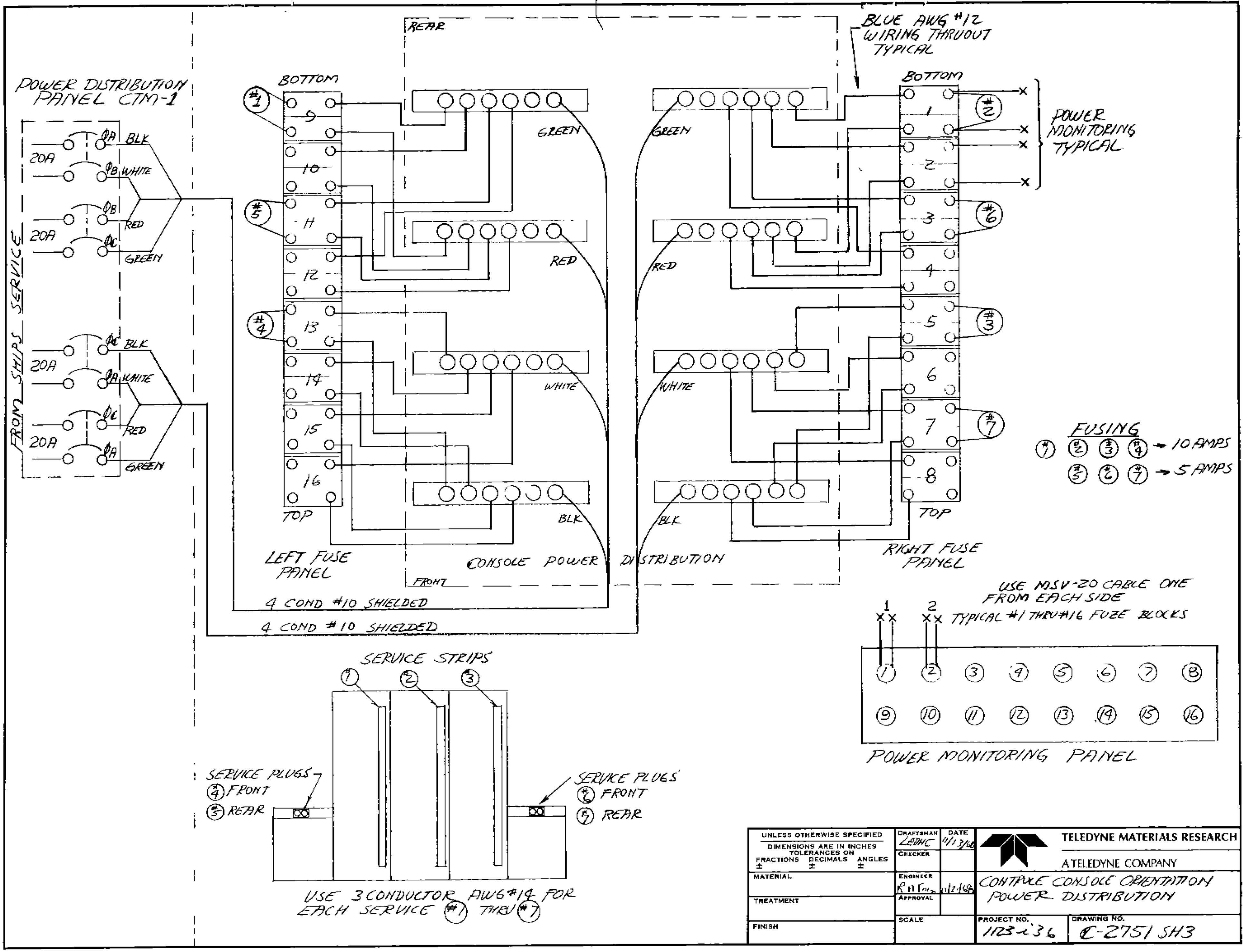


UNLESS OTHERWISE SPECIFIED DIMENSIONS ARE IN INCHES TOLERANCES ON FRACTIONS ± DECIMALS ± ANGLES ±	DRAFTSMAN Leone	DATE 11/14/63	TELEDYNE MATERIALS RESEARCH A TELEDYNE COMPANY
	CHECKER		
MATERIAL	ENGINEER R A Fan	11/21/63	CONTROL CONSOLE ORIENTATION
TREATMENT	APPROVAL		PANEL LOCATION (FRONT VIEW)
FINISH	SCALE —		PROJECT NO. 1123-36 / DRAWING NO. C-2751 SH1

GRAPHIC CONTROLS CORP., BROOKLYN, N. Y. 11217 ULTRAVEL NO. 480M 14110



UNLESS OTHERWISE SPECIFIED DIMENSIONS ARE IN INCHES TOLERANCES ON FRACTIONS ± DECIMALS ± ANGLES ±	DRAFTSMAN LEONE	DATE 11-13-68	TELEDYNE MATERIALS RESEARCH A TELEDYNE COMPANY
MATERIAL	CHECKER		
	ENGINEER C.A.Fa...	11/4/68	CONTROL CONSOLE ORIENTATION CONSOLE CABLING (REAR VIEW)
TREATMENT	APPROVAL		
FINISH	SCALE —		PROJECT NO. 1123-... DRAWING NO. C-2751 SH2


POWER DISTRIBUTION PANEL CTM-1
FROM SHIPS SERVICE
20A
ØA BLK
ØB WHITE
ØB RED
ØC GREEN
ØC BLK
ØA WHITE
ØC RED
ØA GREEN
BOTTOM
TOP
LEFT FUSE PANEL
RIGHT FUSE PANEL
#1
#5
#4
#2
#6
#3
#7
REAR
FRONT
GREEN
RED
WHITE
BLK
CONSOLE POWER DISTRIBUTION
BLUE AWG #12 WIRING THRUOUT TYPICAL
POWER MONITORING TYPICAL
4 COND #10 SHIELDED
4 COND #10 SHIELDED
FUSING
#1 #2 #3 #4 → 10 AMPS
#5 #6 #7 → 5 AMPS
USE MSV-20 CABLE ONE FROM EACH SIDE
TYPICAL #1 THRU #16 FUZE BLOCKS
POWER MONITORING PANEL
SERVICE STRIPS
SERVICE PLUGS #4 FRONT #5 REAR
SERVICE PLUGS #6 FRONT #7 REAR
USE 3 CONDUCTOR AWG #14 FOR EACH SERVICE #1 THRU #7
UNLESS OTHERWISE SPECIFIED
DIMENSIONS ARE IN INCHES
TOLERANCES ON
FRACTIONS ± DECIMALS ± ANGLES ±
MATERIAL
TREATMENT
FINISH
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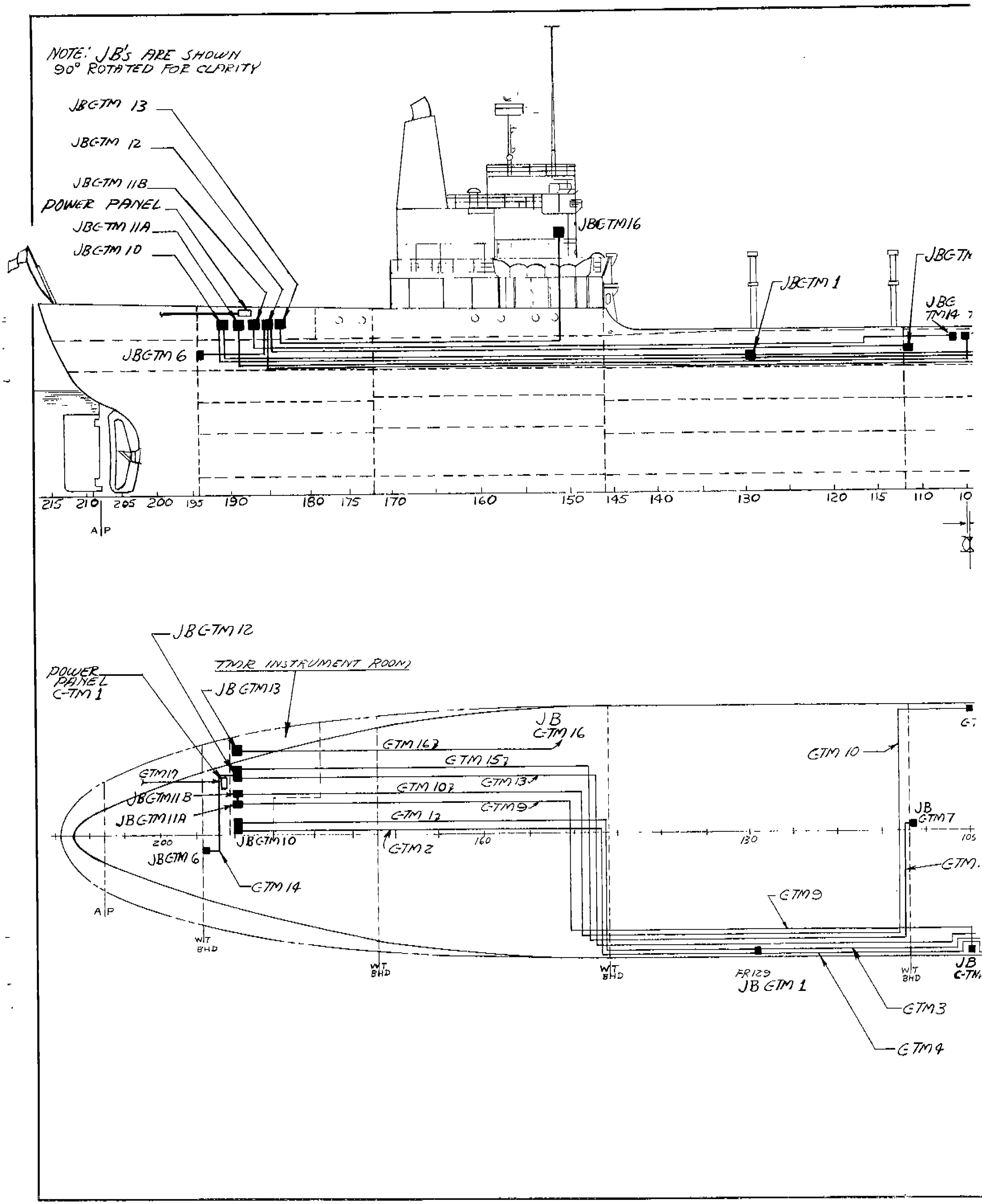
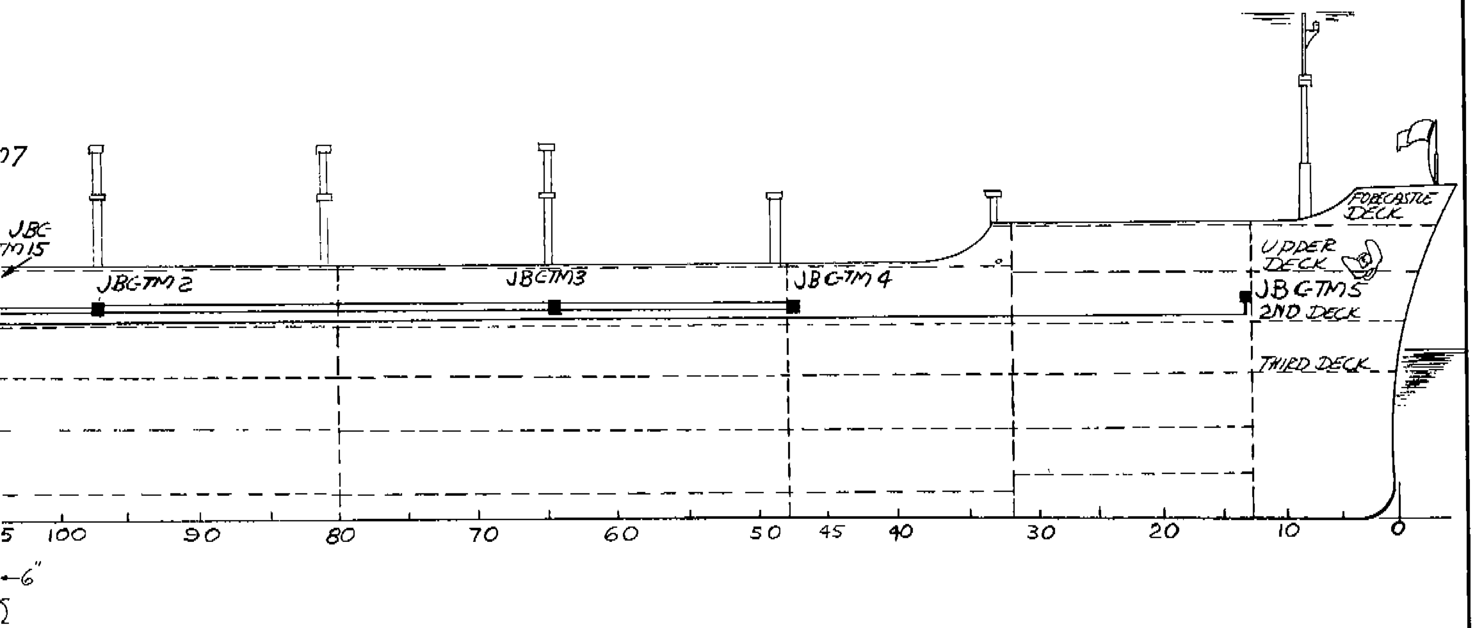
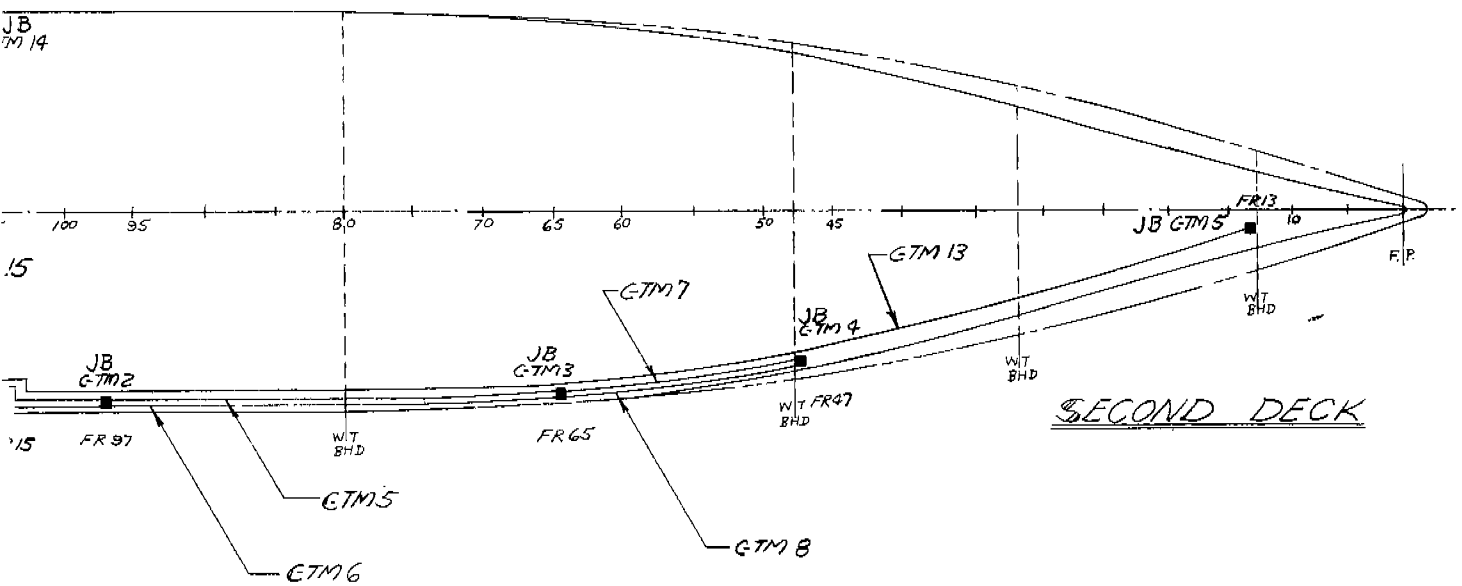


NOTE: JB's ARE SHOWN 90° ROTATED FOR CLARITY
JBGTM 13
JBGTM 12
JBGTM 11B
POWER PANEL
JBGTM 11A
JBGTM 10
JBGTM 16
JBGTM 1
JBGTM 6
JBG TM14
215 210 205 200 195 190 180 175 170 160 150 145 140 130 120 115 110
A P
JBGTM 12
TMR INSTRUMENT ROOM
POWER PANEL GTM 1
JB GTM13
JB GTM 16
GTM 16
GTM 15
GTM 10
GTM 13
GTM 9
GTM 12
GTM 11
JBGTM 11B
JBGTM 11A
JBGTM 10
GTM 2
JBGTM 6
GTM 14
200
160
130
GTM 10
JB GTM 7
GTM 9
W T BHD
FR 129
JB GTM 1
GTM 3
GTM 4





UNLESS OTHERWISE SPECIFIED DIMENSIONS ARE IN INCHES TOLERANCES ON FRACTIONS ± DECIMALS ± ANGLES ±	DRAFTSMAN LEONE	DATE 7/16/68	TELEDYNE MATERIALS RESEARCH A TELEDYNE COMPANY
MATERIAL	CHECKER		INSTRUMENTATION CABLING AND JUNCTION BOX LAYOUT S.S. BOSTON
TREATMENT	ENGINEER		
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13. ABSTRACT

SUMMARY

Progress during this reporting period consisted of design, procurement, and installation of a ship response instrumentation system aboard the container vessel S.S. BOSTON. Included in this report are the following: a detailed description of the system, consisting of the parameters to be measured; the type and location of the transducers installed; components and functional operation of the data acquisition and recording system; data analysis procedures; and equipment specifications.

In addition, a description of the procedure and the results of the first transducer calibration attempt are presented.