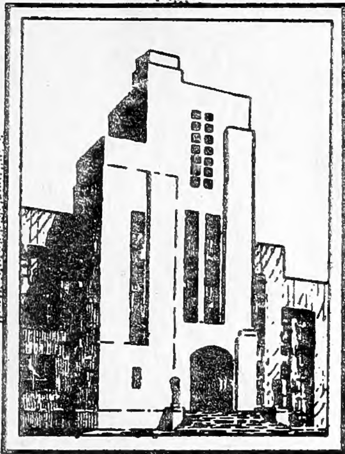

NAVY DEPARTMENT
DAVID TAYLOR MODEL BASIN

HYDROMECHANICS

○

AERODYNAMICS

○

STRUCTURAL
MECHANICS

○

APPLIED
MATHEMATICS

DYNAMIC WAVE-HEIGHT RECORDER
TYPE 286-1A

by

F.B. Miller

INSTRUMENTATION DIVISION

RESEARCH AND DEVELOPMENT REPORT

August 1957 Report 1123

DYNAMIC WAVE-HEIGHT RECORDER

TYPE 286-1A

by

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LIST OF ILLUSTRATIONS

ABSTRACT

This report describes a dynamic wave-height recording system which utilizes an insulated wire probe as a capacitance-type transducing element. The electronic portion of the system is designed as a plug-in component of a commercial direct-writing recorder console. The output of the system is in the form of a rectangular plot of wave height versus time. Schematic diagrams and operating instructions are included.

INTRODUCTION

In a facility engaged in ship hull design, the problems associated with the testing of the various models in waves dictate that some types of tests be made in waves of known and controlled dimensions. The waves desired for these tests may be produced by the various wavemakers available at the David Taylor Model Basin. It is desirable to be able to record these wave profiles and produce a permanent record for analysis and correlation with other data. Furthermore, such a record allows the wavemaker to be more easily adjusted to the desired condition.

In earlier work, some wave profile recording was done by photographing a grid marked on one wall of the basin. As the wall had an adverse effect on the wave shape, and as any imperfections in the wall surface further distorted the wave, the method left much to be desired. Also, the results were not available until after the film was developed.

During 1952, the TMB Type 145-A Dynamic Wave-Height Recorder[1] was designed and produced and has met with notable success in a number of tests since that time. This system exhibited excellent linearity characteristics, and the gage was easy to produce and simple to clean or replace when necessary. No photography was required, and the gage dimensions were small enough to cause little effect on the wave under investigation.

In order to meet the needs of the expanding test programs of the Hydromechanics Laboratory, more channels of wave-height recording instrumentation were desired. In the meantime, a commercial direct-writing recording system featuring semimodular construction became available. It was decided to redesign the circuits of the older Type 145-A recorder and package the electronic portion in a plug-in chassis which could be used with the new recording console. All the desirable features

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[1] References are listed on page 19

of the prototype were retained and several improvements contributing to simplicity of operation were incorporated in the new design. The calibration method has been simplified, as has the bridge balancing-null detection operation. The new units are known as TMB Type 286-1A and are used with the Sanborn driver amplifier[2], power supply[3], and recorder.

PART I

DESIGN

GENERAL

The wave-height recording system consists of a gage, the associated electronic system, and the recorder. The gage is essentially a capacitive transducer, the capacity varying linearily with the water height. This gage is used in a capacitive bridge energized with a 10-kc carrier signal. The signal recovered from this bridge is demodulated in a phase-sensitive detector and further amplified. This signal is then fed to the Sanborn driver amplifier and to the recording pens.

GAGE

The gage consists of a length of No. 28 enameled wire, stretched taut, insulated from the water, and positioned vertically through the water surface. The conductor forms one plate of the capacitor, the water forms the other plate of the capacitor, and the enamel is the dielectric. Since the plate area formed by the water varies linearily with the height of the water (if the thickness of the enamel dielectric is uniform), the capacity of the gage is a linear function of the water height. The gage gives a large ΔC of about 50 μμf per inch of water. For a more complete discussion of the gage, see TMB Report 859, "An Electronic Wave-Height Measuring Apparatus."[1]

CARRIER SYSTEM

Bridge drive is provided by a bootstrap oscillator and driver of fairly conventional design. This drive is link coupled into the bridge. Both the input and the output of the bridge are resonated at the carrier frequency. Thus, a high-drive voltage is obtained at a small outlay in power, and the bridge output is multiplied by the resonant output condition. Bridge output signal shifts 180 degrees in phase with change in direction of bridge unbalance.

The bridge output is fed through an attenuator to a pair of cascaded voltage amplifier stages. The output of this second voltage amplifier is transformer coupled in push-pull into the modulator grids. The carrier is injected into these grids in parallel. The phase sense is recovered by this action. The signal is then fed to a demodulator and voltage amplifier, then to the Sanborn driver amplifier.

The injected carrier is taken from the driver amplifier plate and fed to the injection point by means of a cathode follower.

In order to detect bridge balance, a device to indicate bridge signal voltage is necessary. In this unit, this function is accomplished by removing the injected carrier from the modulator and disabling one side of the demodulator, leaving the other side as a straight amplifier. This removes the phase-sensitivity of the demodulator, and any signal present drives the recorder in one direction. It is then possible to balance the bridge, using the minimum recorder deflection as an indication of bridge balance.

In order that the unit may be used with two or more gages by means of a multichannel balancing unit (for example, TMB Type 286-2A, shown in the circuit section of this manual), a switch is installed to disconnect the internal bridge balancing system. This allows the components in the multichannel balancing unit to complete the bridge and supply the balancing function; see PART I, BALANCING UNIT, page 4.

The front panel GAGE connector is paralleled by pins 6 and 9 of connector J-204 on the rear apron of the driver amplifier (9 is ground). Thus, it is possible to bring the gage cables into the rear of the unit rather than the front.

When two or more carrier systems are used close to one another, the carrier oscillators may beat with each other and produce a cyclic variation in the output signal at the difference frequency of the individual oscillators. Provision has been made in the Type 286-1A for synchronizing the oscillators to avoid this undesirable effect.

The positioning of the recording stylus is controllable from the front panel of the Type 286-1A.

ADJUSTMENT

The following adjustments are made as part of the construction and should remain fixed short of a major change in one of the associated components.

The oscillator frequency determining elements and the bridge driver tank circuits are fixed-tuned and should require no attention. Should the frequencies of a number of these units be very different, it may not be possible to synchronize the oscillators. Should this problem arise, each of the oscillators should be set reasonably close to a 10-kc secondary frequency standard.

Phasing of the unit is accomplished by a slight variation in the tuning of the bridge output. This is a broad adjustment and is not overly critical. The phasing adjustment should be made for maximum output with a slight capacitive unbalance in the bridge circuit.

The bridge DRIVE (and injected carrier) is adjustable by means of a deck-mounted potentiometer. This control is used as a rough sensitivity control, with the front panel FINE SENSITIVITY control being effective over a range of about 10 percent of full scale. With the FINE SENSITIVITY control at about midposition, the DRIVE control on the deck should be adjusted until the full-scale deflection of the recording stylus is satisfactory for the use intended. An approximate full-scale signal may be secured by balancing the bridge, setting the SENSITIVITY control to the 4-inch-full-scale step, then rotating the 0-0.001 ROUGH CAP. BALANCE control one step in either direction. This adds or subtracts 100 μμf in the gage arm, corresponding to approximately 2 inches change in the water level.

The CAL. ADJ. allows the calibration step to be adjusted over a narrow range. It is intended that the calibration step be full scale on the 4-inch full-scale SENSITIVITY step. The CAL. ADJ. control should be adjusted until the calibration step corresponds to a 2-inch change in submersion of the gage while on the 4-inch full-scale SENSITIVITY step.

In order to facilitate bench work on these units, the bridge components are chosen so that the unit may be balanced with no gage or cable connected. In operation, more than 100 feet of RG 62/U coaxial cable can be used, as the system will balance with more than 4000 μμf of external capacity.

BALANCING UNIT

When it is desired to record wave heights from two gages with the same wave-height recorder, a TMB Type 286-2A Balancing Unit may be used to couple the two gages to the single recording unit, and the recorder may then be switched to either of the gages. The internal bridge balancing system

of the recorder is then disconnected by means of the switch provided for this purpose, and the balancing function is taken over by two sets of similar components in the balancing unit. Two sets of the bridge-balancing components are necessary in order to achieve a balance on both gages simultaneously because of the different values of capacitance and dissipation associated with the individual gages. The balancing unit is pictured in Figure 3, with the corresponding schematic diagram in Figure 5.

PART II

INSTALLATION, OPERATION, AND MAINTENANCE

INSTALLATION

Installation of the Type 286-1A unit is similar to the Type 145-A. The gage is positioned through the resting surface of the water and clamped in this position. Approximately half of the gage should be immersed in the water. The gage is then connected to the wave-height recorder by means of any good quality coaxial cable. As the Type 286-1A is used in the Sanborn console, the connections to the unit are automatically made when the unit is placed in the rack. The connections between the driver amplifier, power supply, and recorder are already made by plug-in cables[4] inside the rack and should offer no problems.

Should it be desired to use two gages with a single Type 286-1A unit, a bridge balancing unit, Type 286-2A, may be used to properly couple to the two gages. The internal bridge balancing controls must be switched out of the system by means of the INT-EXT deck switch in the Type 286-1A. The GAGE connector and the two gage cables are then connected to the bridge balancing unit. The functions of the ROUGH CAP BALANCE, CAP. BALANCE, and RES. BALANCE on the Type 286-1A are then taken over by corresponding controls in the bridge balancing unit. The gages are each balanced in turn in the same manner as described in the next section. It is then possible to record from either gage as desired.

OPERATION

Before use, the system should be connected to the power line, turned on and allowed to come to operating temperature. The direct-coupled amplifiers in the system may be expected to drift during this period. A warm-up time of approximately 15 minutes should be allowed before measurements are made.

With the water still, the unit may be balanced by depressing the OPERATE-BALANCE switch and advancing the SENSITIVITY control as far as possible with the recording stylus remaining on the paper. Then the CAP. BALANCE and RES. BALANCE are alternately adjusted to obtain a minimum indication on the recorder. The SENSITIVITY is then advanced and the process repeated. This operation is repeated until a null indication is obtained on the 0.6-inch full-scale SENSITIVITY step. The OPERATE-BALANCE switch is then released. The SENSITIVITY control is then rotated back to OFF and the position to which the stylus shifts is noted. The SENSITIVITY control is then rotated back to the 0.6-inch full-scale step, and the CAP. BALANCE control (or controls, if necessary) rotated until the stylus shifts to the same position to which it moved when the SENSITIVITY control was placed in the OFF position. The stylus will then be found to stay in the same place when the SENSITIVITY control is rotated, provided that the bridge remains in balance. The SENSITIVITY control is then placed on the desired step and the stylus positioned to the center of the paper (or to the desired zero position) by means of the STYLUS POSITION control.

In calibrating the system, the SENSITIVITY control should be turned to the 4-inch full-scale step. This is because the calibration built into the unit represents a change in water depth of approximately 2 inches in each direction, or a total of 4 inches. After calibration, the SENSITIVITY control may be returned to the desired position. The system is then ready for use.

MAINTENANCE

The electrical components in the Type 286-1A Dynamic Wave-Height Recorder are all operated well within their ratings and should give very little trouble. The console has a blower for cooling.

Cables should not be walked upon nor permitted to stay in the water.

The gage should be cleaned occasionally with a soft cloth. This is necessary to remove the foreign matter that collects on the wire. Holes in the enamel have the effect of a leaky dielectric and prevent the proper balancing of the bridge. These holes will seldom be found in a new wire, but will sometimes develop after use. In the extreme case, they are evidenced by the inability to reach a resistance balance of the bridge.

In the event of a damaged wire, a new length of No. 28 enameled wire should be installed. It is of interest to note that ordinary Belden enameled wire has proven more satisfactory than the more expensive types now on the market. The new wire should be fitted with a bayonet-type fastening on the lower end and must be cleaned and soldered in place at the upper end. In preparing new wires, it is generally more economical to discard the old bayonet fitting and drill a new one from 1/4 inch diameter bakelite rod than to attempt to reuse the bayonet device. The wire itself is completely insulated from the water with automotive windshield sealing compound or the equivalent. With the gage properly positioned in the water, a d-c resistance measurement of less than 20 megohms indicates a questionable gage.

Because adjustment of the phasing of the unit is not normally expected to change, the phasing procedure is included under PART I, ADJUSTMENT.

PERSONNEL AND ACKNOWLEDGMENTS

The general design of the instrumentation described in this report was the work of Mr. R.G. Tuckerman of the Instrumentation Division. The detail design and final adjustment and testing of the equipment was the work of the author, also of the Instrumentation Division.

PARTS LIST FOR DYNAMIC WAVE HEIGHT RECORDER

DTMB TYPE 286-1A

C-1	0.10 µf	± 1 percent Sprague Vitamin-Q
C-2	0.01 µf	± 1 percent Sprague Vitamin-Q
C-3	140 µµf	Hammarlund MC-140S
C-4	0-0.011 µf	Cornell Dubilier CDA-5
C-5	0.005 µf	Silver Mica
C-6	3900 µµf approx.	Silver Mica
C-7	68 µµf	Silver Mica
C-8	50 µµf	Hammarlund MC-50S
C-9	0.11 µf	± 1 percent Sprague Vitamin-Q
C-10	0.01 µf	± 1 percent Sprague Vitamin-Q
C-11	7000 µµf approx.	Silver Mica
C-12	0.15 µf	400 v
C-13	0.15 µf	400 v
C-14	0.01 µf	400 v
C-15	0.15 µf	400 v
C-16	0.01 µf	400 v
C-17	470 µµf	Silver Mica
C-18	0.15 µf	400 v
C-19	0.01 µf	400 v
C-20	2400 µµf approx.	Silver Mica
C-21	0.001 µf	400 v
C-22	1200 µµf approx.	Silver Mica
C-23	0.15 µf	400 v
C-24	100 µµf	Silver Mica
C-25	0.01 µf	400 v
C-26	0.01 µf	400 v
C-27	0.01 µf	400 v
C-28	0.1 µf	400 v
C-29	125 µµf	Silver Mica
C-30	125 µµf	Silver Mica
C-31	700 µµf	Silver Mica
C-32	700 µµf	Silver Mica
C-33	.002 µf	Silver Mica
C-34	.002 µf	Silver Mica
C-35	0.25 µf	400 v
R-1	125 k	1/4 percent wire wound precision
R-2	100 k	1/4 percent wire wound precision
R-3	100 ohm	10 turn potentiometer
R-4	100 k	1/4 percent wire wound precision
R-5	100 k	1/4 percent wire wound precision
R-6	1.5 k	± 1/4 percent
R-7	0.9 k	± 1/4 percent
R-8	1.6 k	± 1/4 percent

R-9	2 k	± 1/4 percent
R-10	4 k	± 1/4 percent
R-11	5 k	± 1/4 percent
R-12	9 k	± 1/4 percent
R-13	16 k	± 1/4 percent
R-14	20 k	± 1/4 percent
R-15	40 k	± 1/4 percent
R-16	1 k	1/2 watt
R-17	22 k	1 watt
R-18	4.7 k	1/2 watt
R-19	1 meg	1/2 watt
R-20	680 ohms	1/2 watt
R-21	1000 ohms	2 watt potentiometer
R-22	4.7 k	1/2 watt
R-23	1 k	1/2 watt
R-24	1 k	1/2 watt
R-25	220 k	1/2 watt
R-26	220 k	1/2 watt
R-27	22 k	1/2 watt
R-28	3.9 k	1/2 watt
R-29	47 k	1/2 watt
R-30	47 k	1/2 watt
R-31	10 k	1/2 watt
R-32	220 k	1/2 watt
R-33	10 k	1/2 watt
R-34	47 k	1/2 watt
R-35	220 k	1/2 watt
R-36	4.7 k	1/2 watt
R-37	180 k	1/2 watt
R-38	1 meg	1/2 watt
R-39	100 k	2 watt potentiometer
R-40	47 k	1/2 watt
R-41	4.7 k	1/2 watt
R-42	2.2 k	1/2 watt
R-43	470 k	1/2 watt
R-44	470 k	1/2 watt
R-45	220 k	1/2 watt
R-46	220 k	1/2 watt
R-47	220 k	1/2 watt
R-48	220 k	1/2 watt
R-49	56 k	1/2 watt
R-50	15 k	1/2 watt
R-51	470 k	1/2 watt
R-52	470 k	1/2 watt
R-53	2.7 k	1/2 watt
R-54	2.7 k	1/2 watt
R-55	15 k	1/2 watt
R-56	27 k	1/2 watt
R-57	27 k	1/2 watt
R-58	47 k	1/2 watt

R-59	270 k		1/2 watt
R-60	1 meg		1/2 watt
R-61	1 meg		1/2 watt
R-62	270 k		1/2 watt
R-63	47 k		1/2 watt
R-64	120 k		1/2 watt
R-65	120 k		1/2 watt
R-66	10 k		2 watt potentiometer

L-1	5 mh	Toroid, Burnell Type TC-3, 27 Turn Link Added
L-2	10 mh	Toroid, Burnell Type TC-3
L-3	100 mh	Toroid, Burnell Type TC-3
L-4	100 mh	Toroid, Burnell Type TC-3, 31 Turn Link Added

T-1 4:1 Transformer Audio Dev. Co. Type A-5311

Resistors 5 percent except as noted

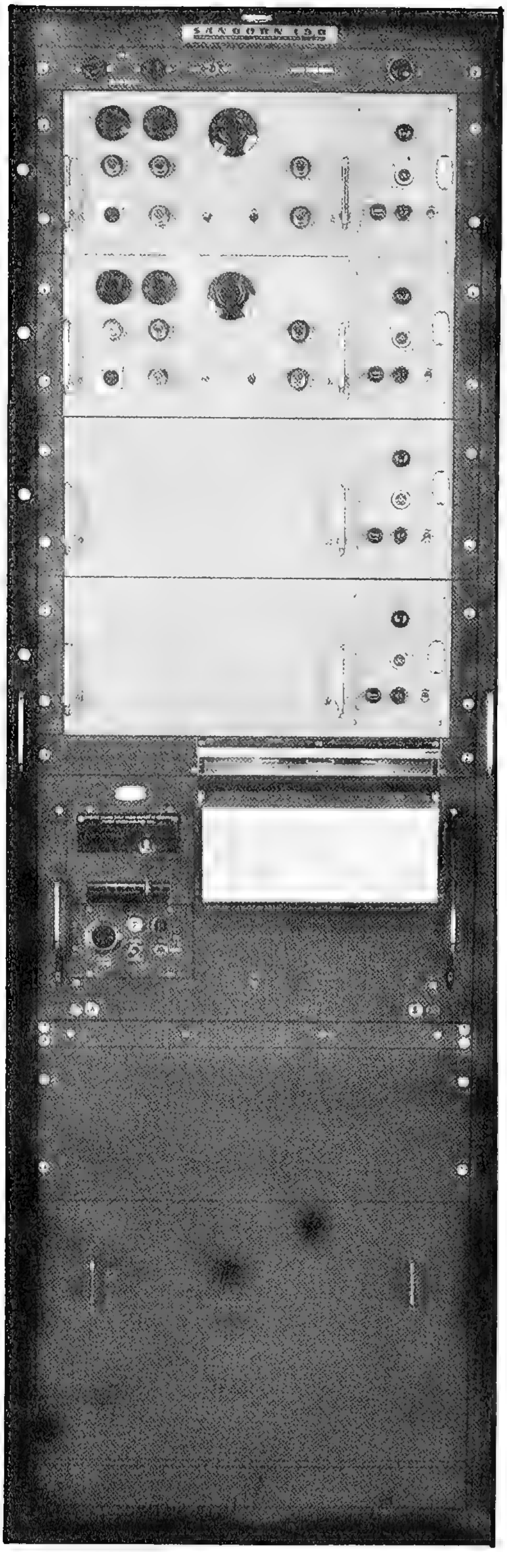


Figure 1 - Wave-Height Recording Console

Two TMB Type 286- 1A wave-height units are shown installed in the upper part of the Sanborn 4-Channel Recorder Console. The two blank panels are reserved for future units of the same type.

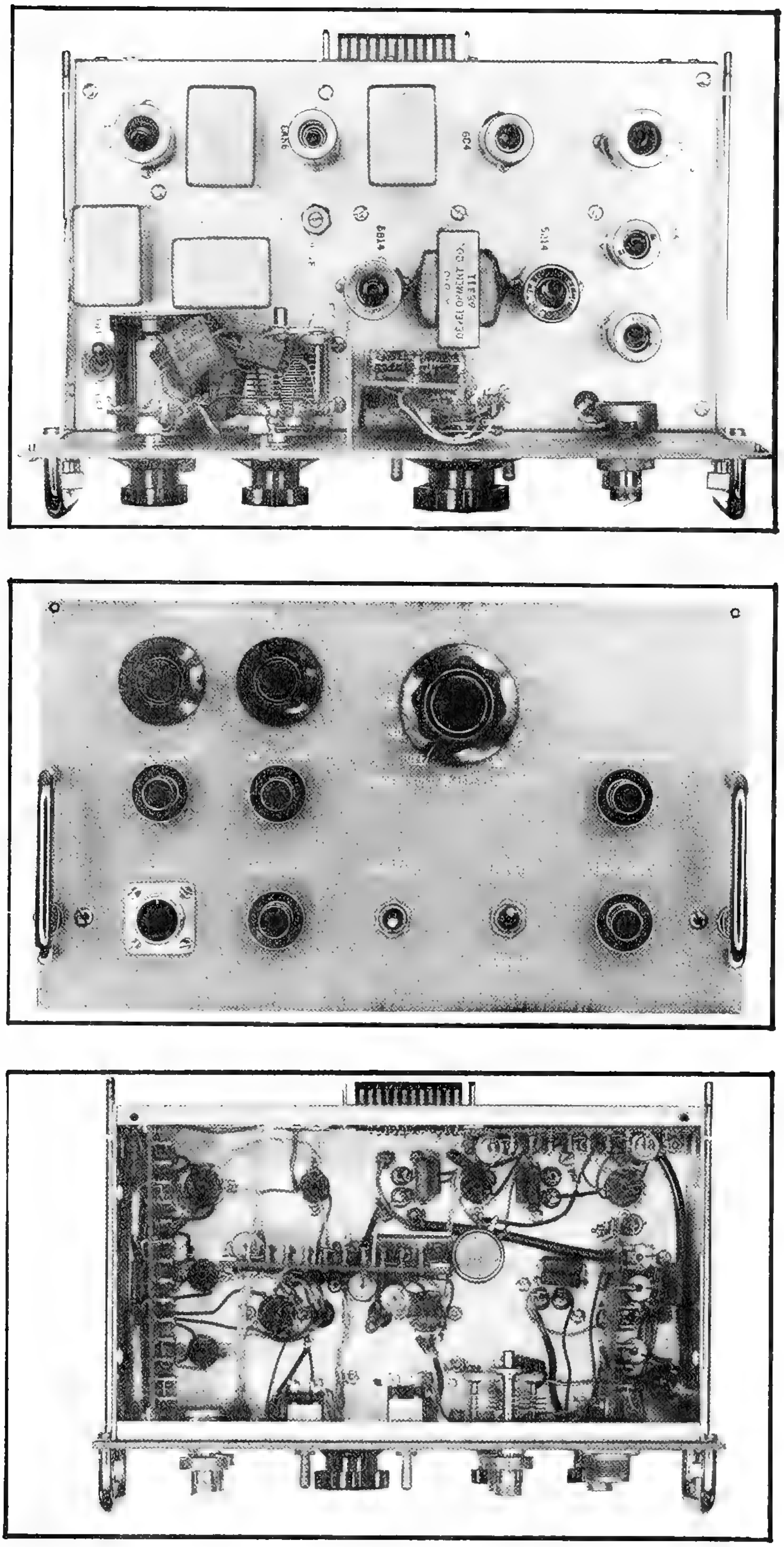


Figure 2 - Dynamic Wave-Height Recorder, TMB Type 286-1A Top, Front, and Bottom Views

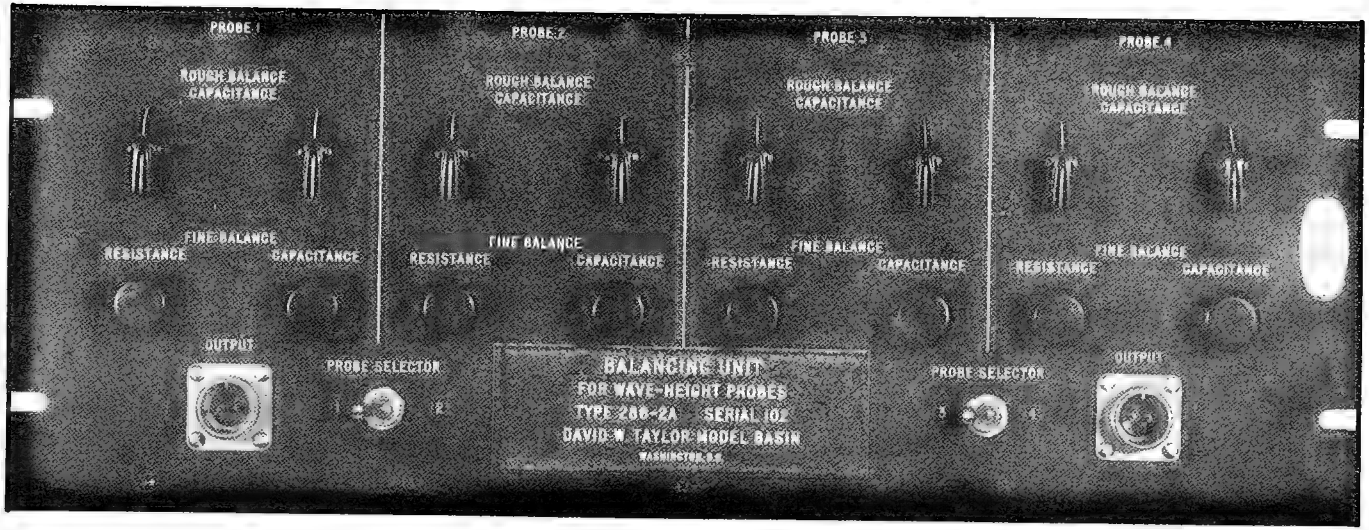


Figure 3 - Bridge Balancing Unit, TMB Type 286- 2A

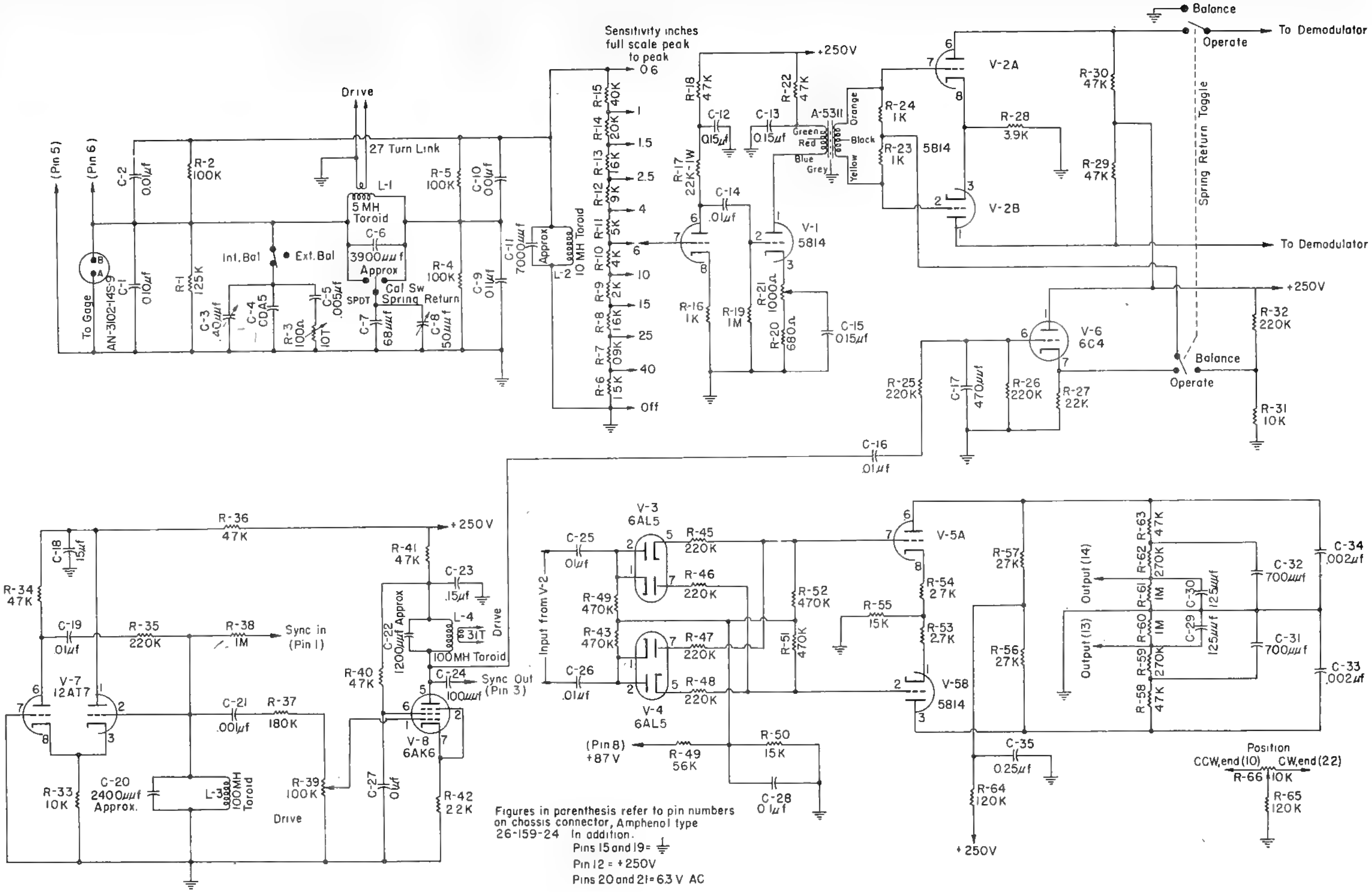


Figure 4 - Dynamic Wave-Height Recorder, TMB Type 286-1A, Schematic Diagram

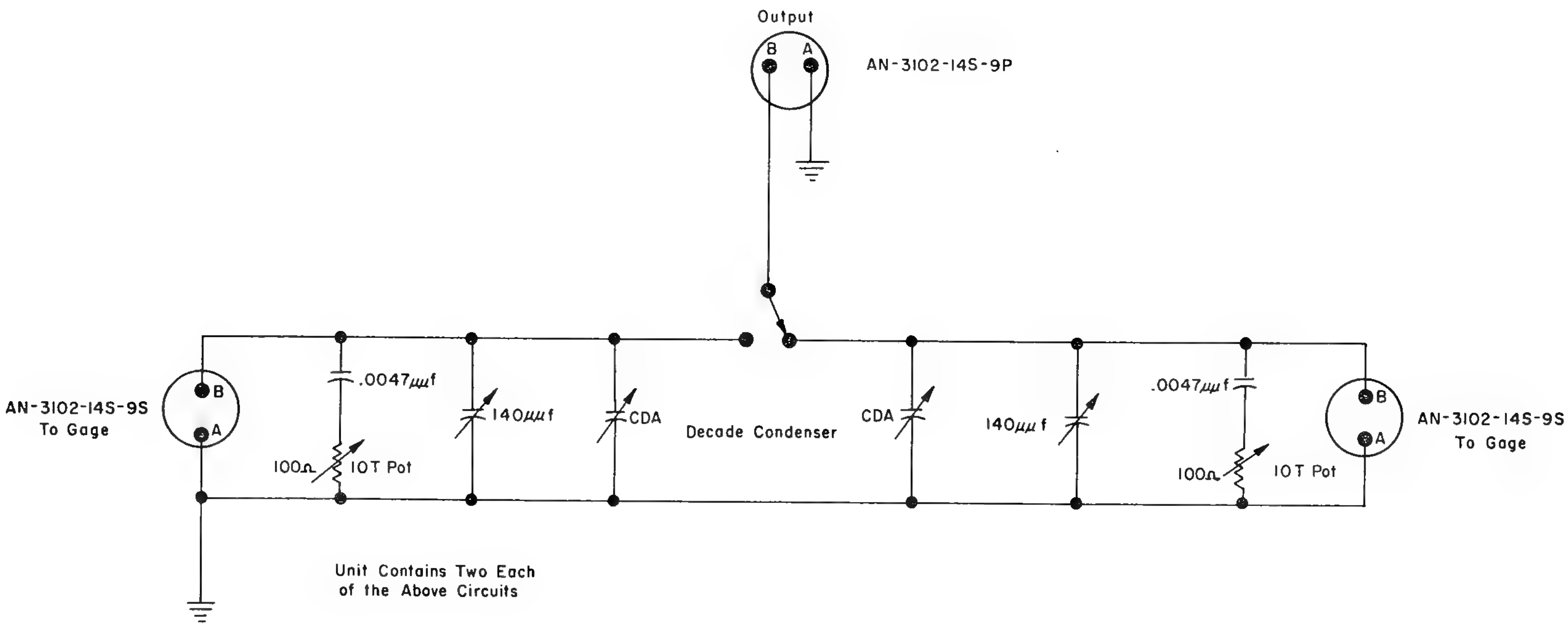
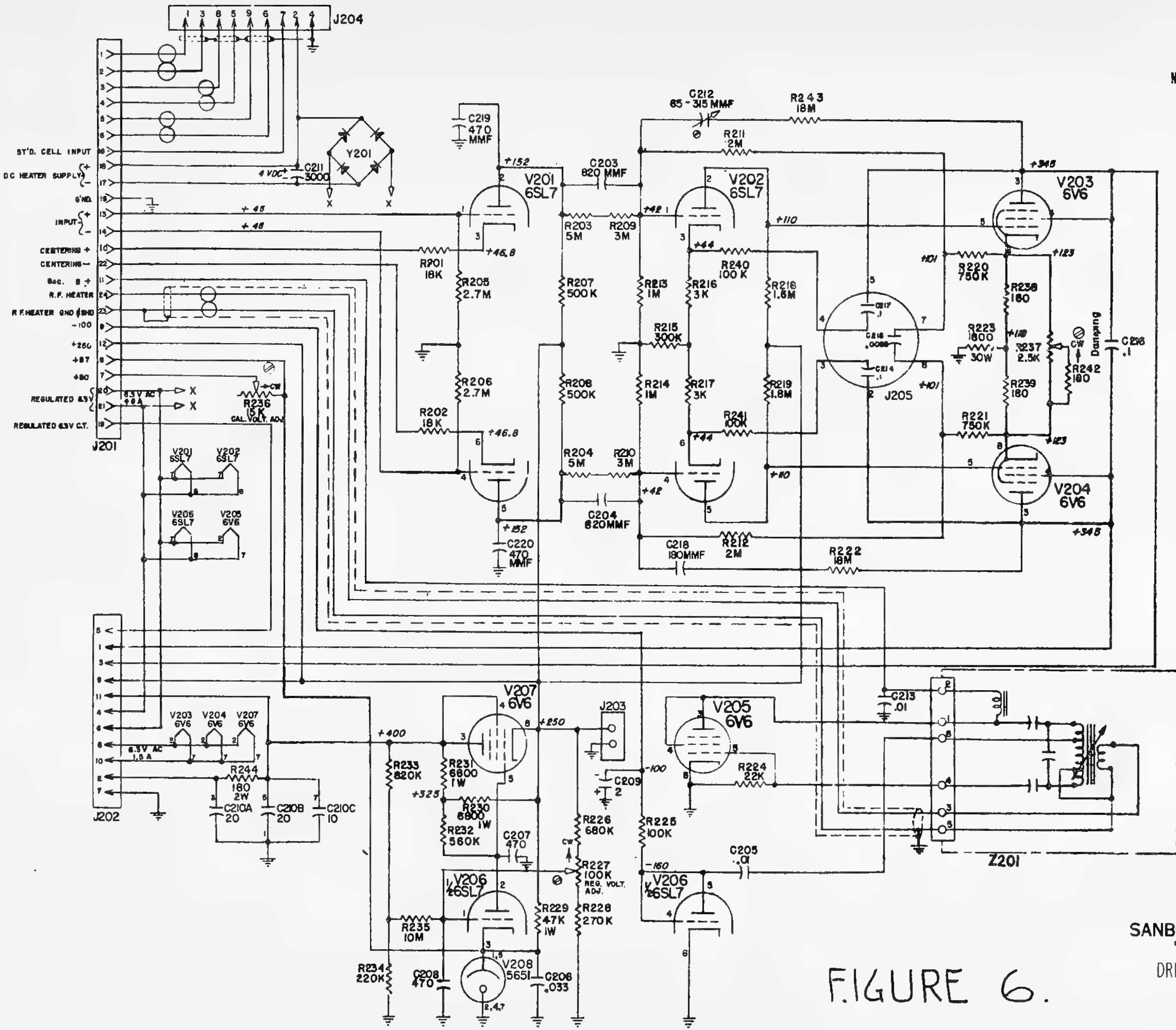


Figure 5 - Bridge Balancing Unit, TMB Type 286-2A, Schematic Diagram



NOTES:

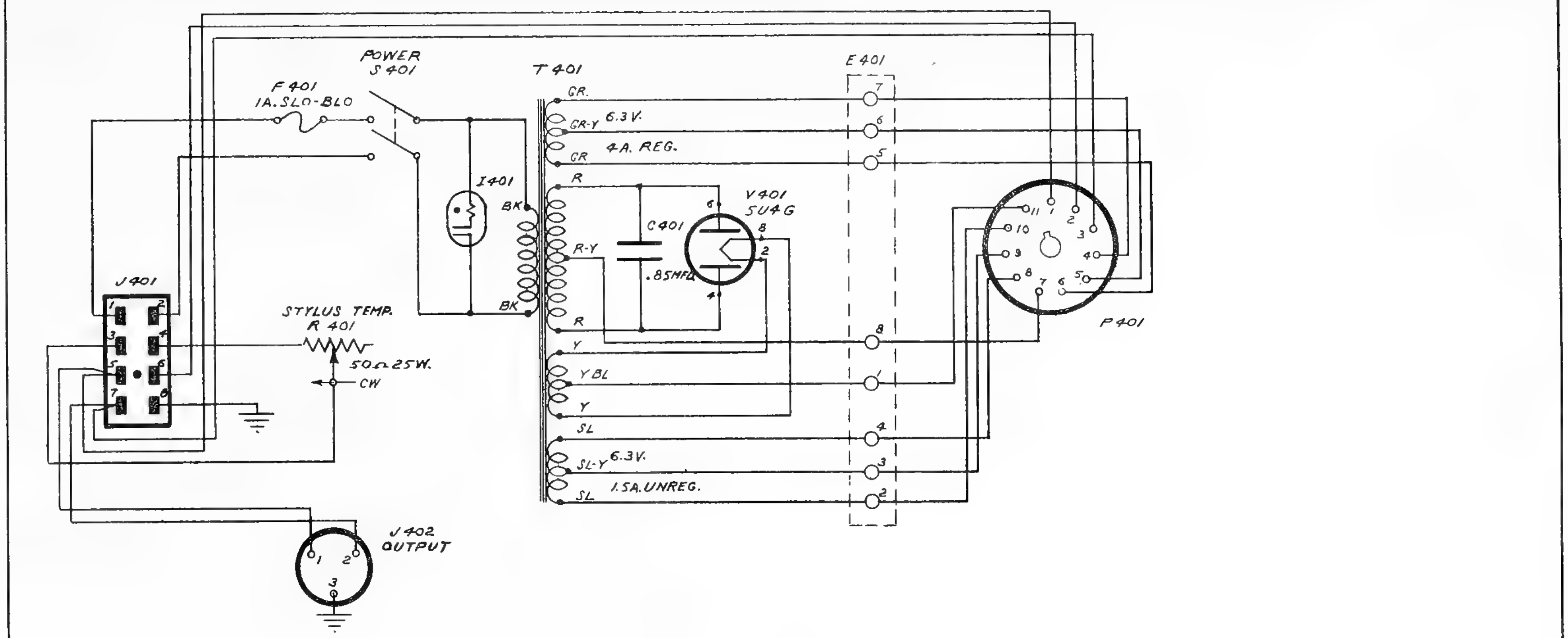
1. 5% Resistor Pairs matched within 2% of each other
   R201 - R202
   R205 - R206
   R218 - R219
2. The following are ±1% Comp. Resistors:
   R207, R208, R203, R204, R209, R210, R213, R214, R215, R216, R217, R240, R241, R220, R221, R211, R212
3. Capacitors matched within 3% of each other:
   C203 - C204
   C214 - C217
4. Capacitors matched within 10% of each other
   C219 - C220

FIGURE 6.

SANBORN COMPANY
CAMBRIDGE, MASS.

DRIVER AMPLIFIER
SCHEMATIC

DWG NO.
150-200B-C1



J401 Connections

Ter. 1. 110V. A.C.
2. A.C Common
3. Stylus Temp.
4. Stylus Temp Com.

Ter. 5. Galvy. +
6. Galvy. CT
7. Galvy −
8. Ground

FIGURE 7.

Schematic
Power Supply (Hi.) 60~

3/19/53 KN

150-400-C1

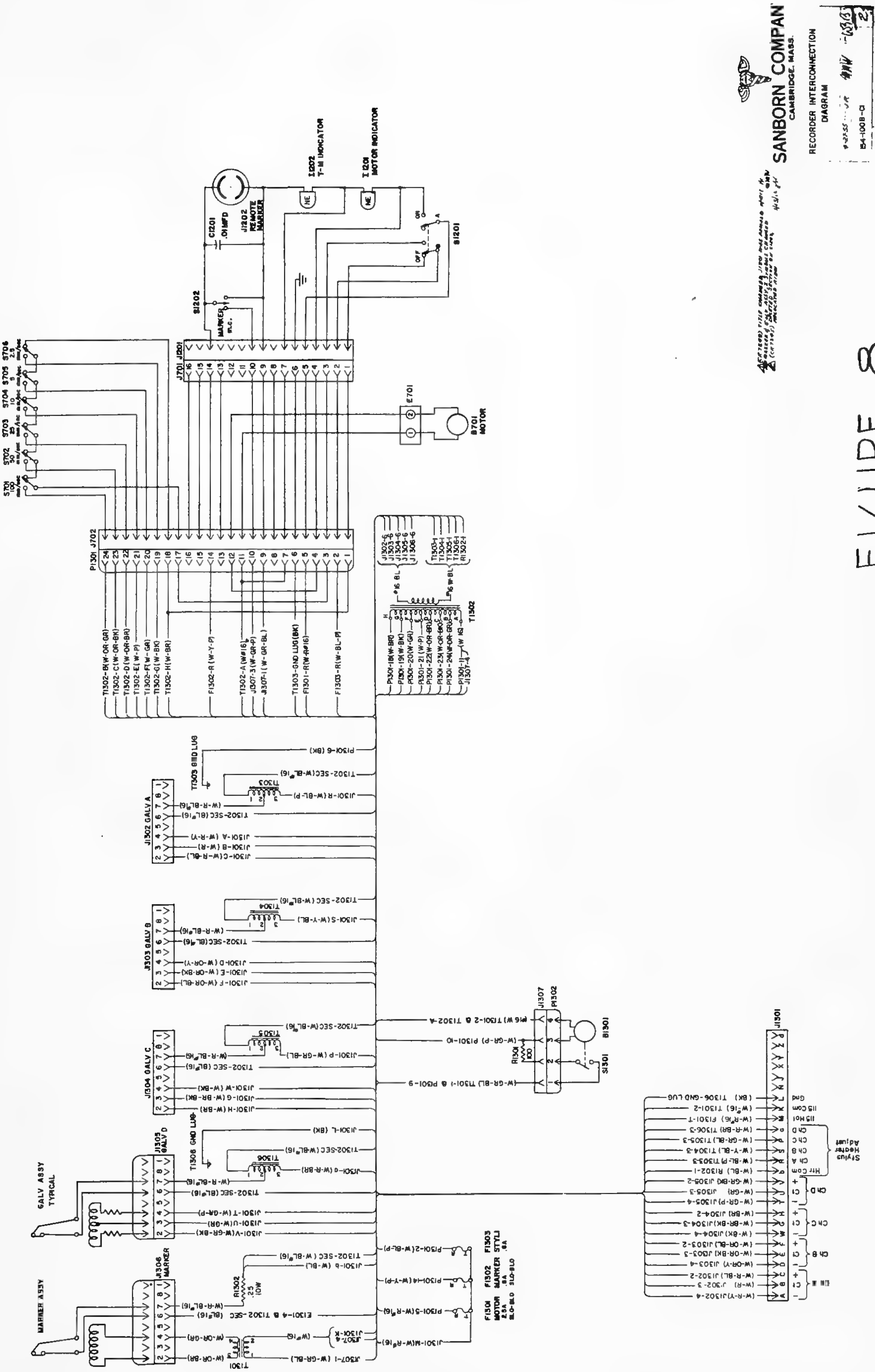

SANBORN COMPANY
CAMBRIDGE, MASS.
RECORDER INTERCONNECTION DIAGRAM
154-100B-C1

FIGURE 8.

REFERENCES

1. Campbell, W.S., "An Electronic Wave-Height Measuring Apparatus," TMB Report 859, October 1953.

2. Sanborn Driver Amplifier Schematic, from Driver Amplifier Model 150-200B Replacement Parts List, Sanborn Company, Cambridge, Mass. (Reproduced as Figure 6 of this report.)

3. Sanborn Power Supply Schematic, from 60 Cycle Power Supply Model 150-400 Replacement Parts List, Sanborn Company, Cambridge, Mass. (Reproduced as Figure 7 of this report.)

4. Sanborn Recorder Interconnection Diagram, from Four Channel Recorder Model 154-100B Replacement Parts List, Sanborn Company, Cambridge, Mass. (Reproduced as Figure 8 of this report.)

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1 Director, Woods Hole Oceanographic Institution, Woods Hole, Mass.

1 Director, St. Anthony Falls Hydraulic Laboratory, University of Minnesota, Minneapolis, Minn.

1 Dr. Per Bruun, College of Engr., Univ. of Florida, Gainesville, Fla.

David Taylor Model Basin. Report 1123.
DYNAMIC WAVE-HEIGHT RECORDER TYPE 286-1A, by F.B. Miller. August 1957. iii, 20p. diagrs., refs. (Research and development report) UNCLASSIFIED

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David Taylor Model Basin. Report 1123.
DYNAMIC WAVE-HEIGHT RECORDER TYPE 286-1A, by F.B. Miller. August 1957. iii, 20p. diagrs., refs. (Research and development report) UNCLASSIFIED

This report describes a dynamic wave-height recording system which utilizes an insulated wire probe as a capacitance-type transducing element. The electronic portion of the system is designed as a plug-in component of a commercial direct-writing recorder console. The output of the system is in the form of a rectangular plot of wave height versus time. Schematic diagrams and operating instructions are included.

1. Wavemeters – TMB 286-1A
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