PRELIMINARY
OPERATIONS MANUAL
WAVEMETER MODEL SW-1C

1 July 1975

(For U.S. Coast Guard use ONLY)

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INTRODUCTION

This manual describes the installation, operation and maintenance required for the Model SW-1C wavemeter developed by Oregon State University and in use at several Coast Guard stations along the coast of Oregon and Washington. The wavemeter infers the height and period of nearshore ocean waves from seismic motions and provides a panel meter readout for observers.

THEORY OF OPERATION

Ocean waves advancing on a sloping beach experience some reflection (less than 10% of incident energy). The reflected wave and incoming waves interact to produce a standing wave of pressure on the ocean bottom; this pressure wave has one-half the period of the ocean wave which causes it. The standing wave of pressure produces seismic motions which are transmitted on-shore through the sand and sediment layer on the ocean floor. The seismic motions can be detected easily by a seismometer, and the signals nearly all result from nearshore waves if the seismometer is located within a mile of the beach. The detected seismic signals are a function of wave height and period; electronic circuits remove the dependence on wave period, and an electrical signal is produced which can be read as wave height directly on a meter. Wave period can also be determined by timing zero-crossings of the meter needle and multiplying by 2.

SYSTEM COMPONENTS

The Model SW-1C system consists of three components:

1) Teledyne/Geotech Model SL-210 seismometer, Fig. 1

2) Linearizer, Fig. 2

3) Remote readout meter, Fig. 3

Only the linearizer requires electrical power (110V, 1Ø, 1 amp). All three components are precision units which will give years of uninterrupted operation if properly handled. DO NOT SHAKE, DROP OR HIT SYSTEM COMPONENTS.

INSTALLATION

Install the seismometer in a temperature-stable room having a concrete floor, preferably remote from foot traffic. The value of the temperature is not important, but it must be constant (±5°F.). At Coast Guard stations, the seismometer is usually installed in the radio beacon room and the readout meter is mounted on top of the communicator's console in the operations room, Fig. 4. Page 23 of Appendix A describes the seismometer leveling and balancing procedure; allow 2 days for temperature stabilization, and then rebalance if necessary. When cable connections are completed, plug linearizer into 110V AC power supply.

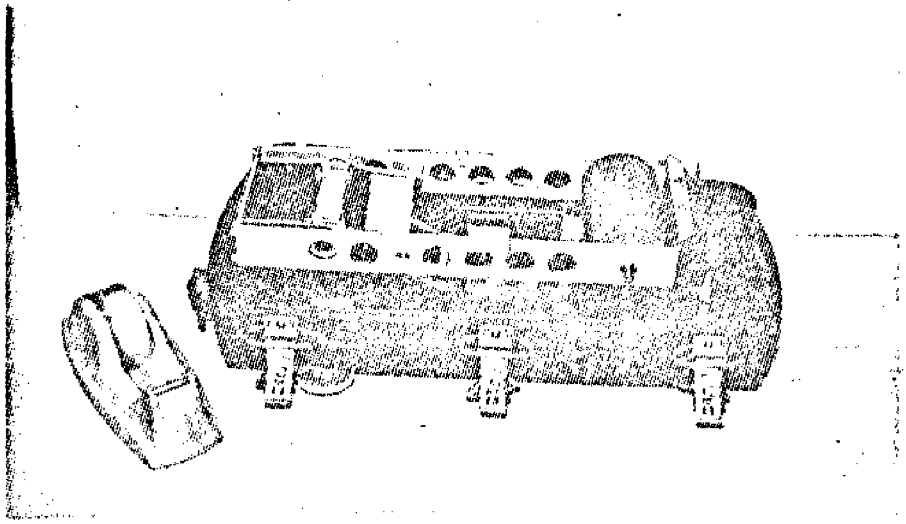


Fig. 1. Seismometer

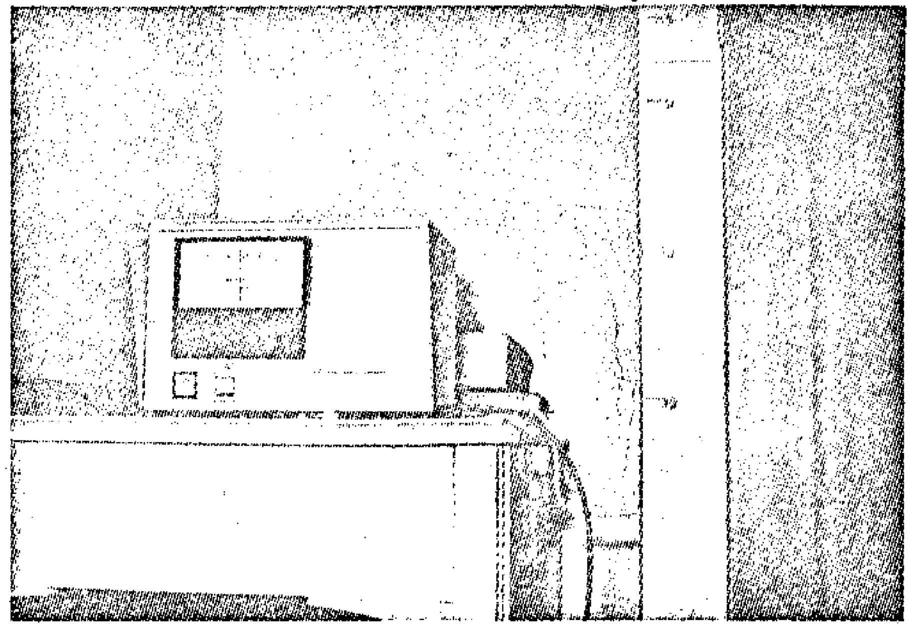


Fig. 2. Linearizer

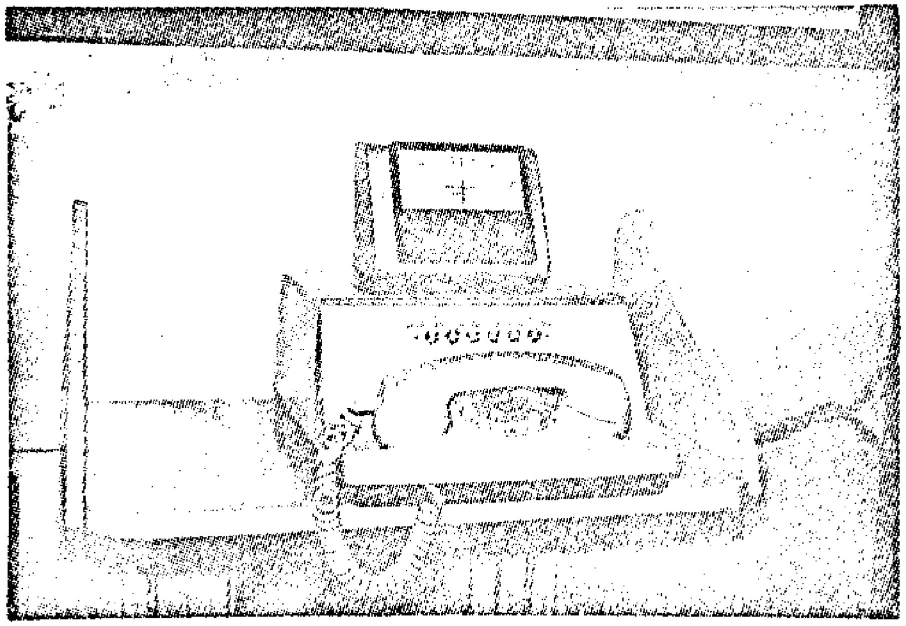


Fig. 3. Remote meter with telephone modem

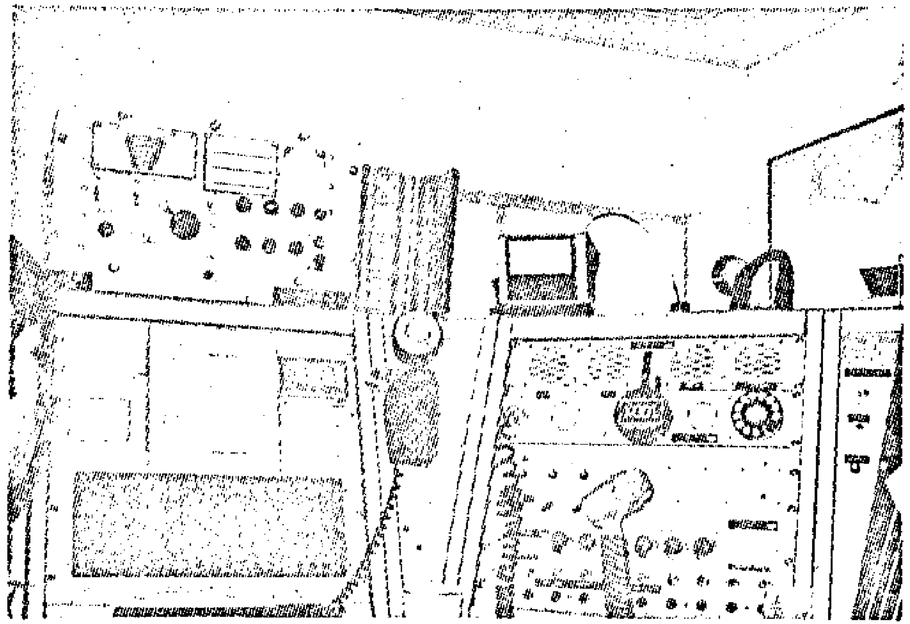


Fig. 4. Remote meter on communicator's console

There are 3 possible cable configurations depending upon the distance from the seismometer to the display unit, Fig. 5:

- 100 feet or less. If the distance to the display point is 100 feet or less, string RG-58/U coaxial cable from the seismometer connector to the input of the linearizer. The meter on the linearizer is now used as the wave height display.
- 100-6000 feet. If the distance to the display point is greater than 100 feet and up to 6000 feet maximum, mount the linearizer near the seismometer and make up a connecting coax cable as above. Connect a separate cable, or shielded telephone pair from the output of the linearizer to the input of the remote readout meter.
- 6000 feet or more. For distances greater than 6000 feet, a pair of Model 602C telephone datasets (modems) must be used. Connect a short piece of coax from the output of the linearizer to the back of the modem (25 pin cinch DB-19604-432 male with DB 51226-1 plastic hood). The modem is then connected to a commercial telephone line. The modem modulates the signal from the linearizer so that it can be transmitted almost unlimited distances over commercial telephone lines. The modem requires 110V,60Hz power; use same ground for 3rd prong as used with linearizer.

At the distant location, connect the remote meter to the receiving modem with a short coax.

Cinch Pin Connections

pin(s)	Transmitting Modem	pin(s)	Receiving Modem
1	shield	1	shield
2	center conductor	3	center conductor
4 & 9	shorted	19, 20 & 21	shorted
19 & 20	shorted		

Modem Keying Instructions

1. Lift handset
2. Push talk button
3. Push data button and hold 2 seconds
4. After red data light appears, hang up handset

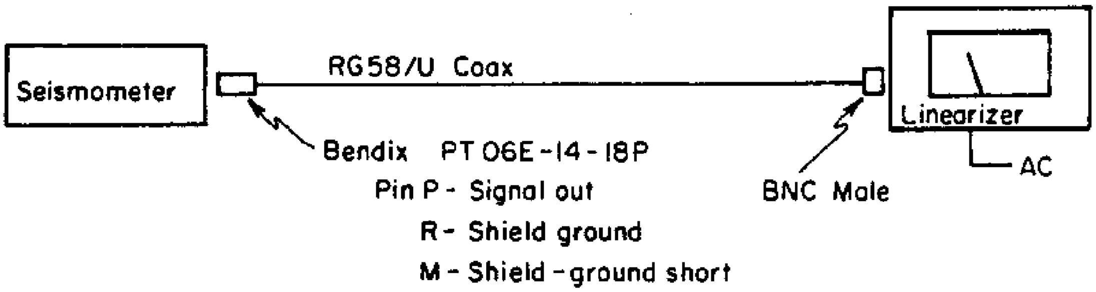
The modems must be re-keyed after power failures and line problems.

The pin connections provide for automatic keying from either location once the other location has been properly keyed.

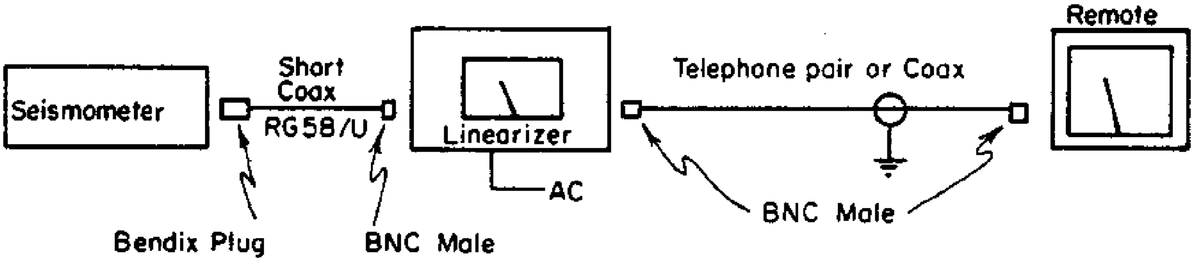
Fig. 5 Cable Configurations

Seismometer to Display Meter Distance:

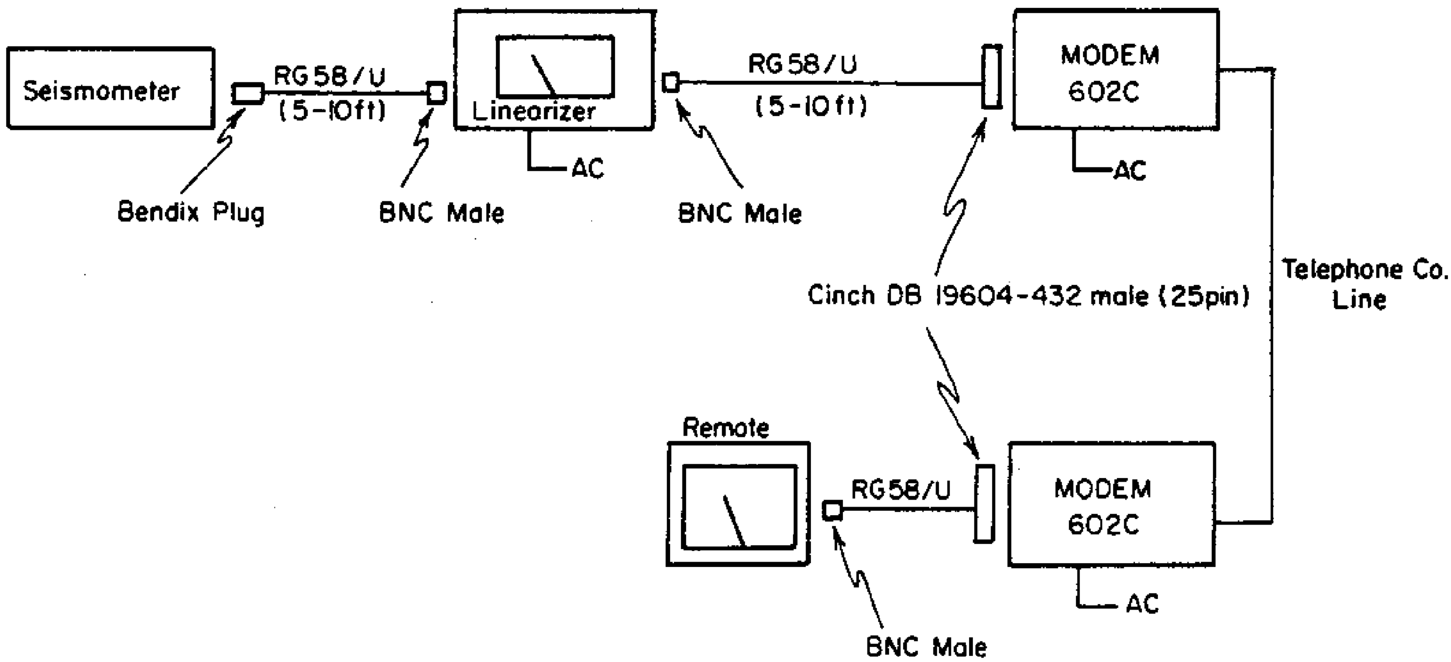
10-100 feet



100-6000 feet



6000 feet or more



CALIBRATION

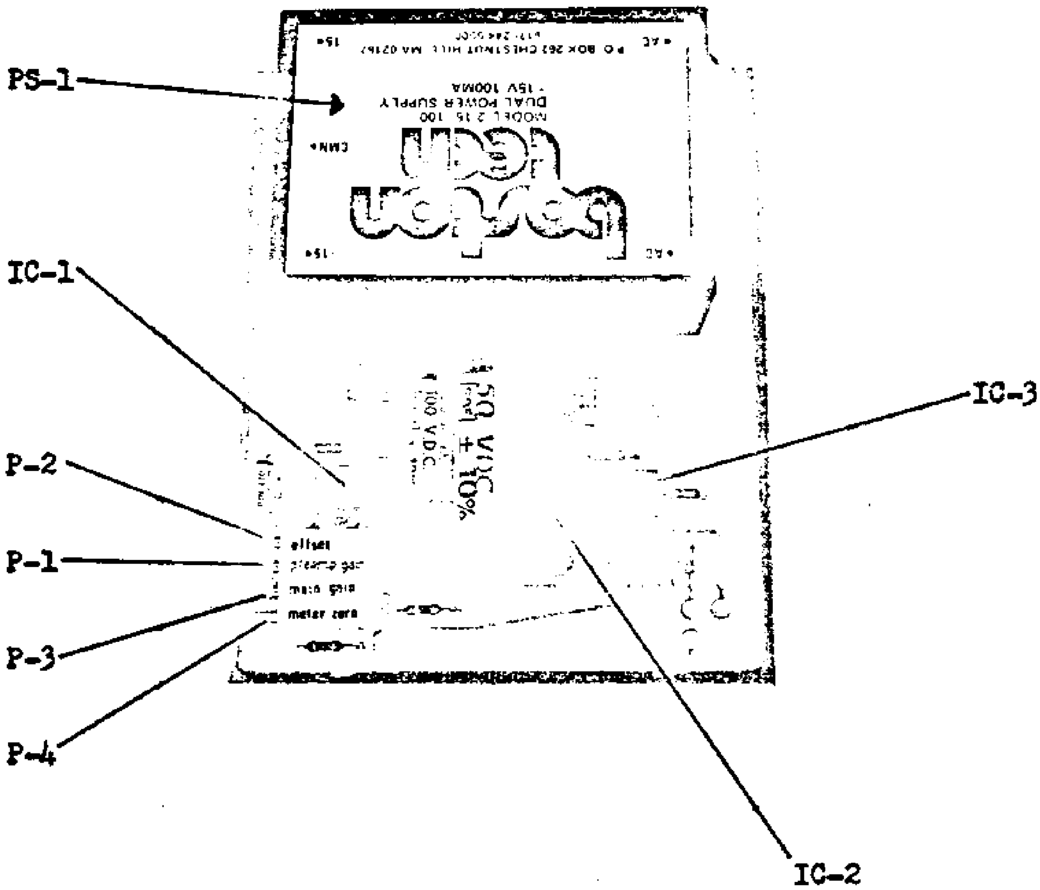
Remove linearizer electronics from enclosure (sheet metal screws).
Using a visual observation of present wave height at the desired reporting point, refer to Fig. 6 and set electronic gains as follows:

1) turn linearizer power switch ON; allow 1 minute for settling
2) turn P-3 and P-4 to about 1/2 full-up position - CAUTION, POTS ARE DELICATE, 20 TURNS ONLY - LISTEN FOR CLICK WHEN WIPER HITS THE STOP, THEN BACK OFF ~10 TURNS
3) turn P-1 until meter deflection left and right is near observed wave height as read on the meter. Then use P-2 to center meter needle swing around zero - CAUTION, POTS ARE DELICATE, 20 TURNS
4) use P-3 to adjust final gain (meter swing); use P-4 to adjust final center (meter zero) - CAUTION, POTS ARE DELICATE, 20 TURNS
5) turn power switch OFF; replace electronics in enclosure

Continue wavemeter calibration against visual observations under a variety of wave conditions for a week or so while circuits burn-in; adjust gains as before, but use P-3 & P-4 only, as required.
If the remote readout meter is used, set up linearizer gains as described above. Set final gain on remote meter with P-5 (back of remote meter enclosure). For small drift of the meter zero with time, the remote meter mechanical zero-set may be used for adjustment - CAUTION, METER ZERO-SET IS DELICATE, DO NOT TURN MORE THAN ± 1/8 TURN.

At some stations an ebb tide correction may be required if the bar of a large river's outfall to the ocean is being observed. The ebb correction is applied by using Table 1 and the ebb current value as obtained

Fig. 6 Circuit Board Wavemeter SW-1C



Abbreviation	Component
PS	Power supply
IC	Integrated circuit
P	Potentiometer

from the NOS Tidal Current Table for the particular location. If needed, the ebb correction is used within ±2 hours of maximum ebb current; its effect is to increase the wavemeter reading to the wave height that will be found on the bar in the presence of the ebb current's meeting the incoming ocean waves.

Table I

WAVE HEIGHT CORRECTION TABLE FOR COLUMBIA RIVER BAR

Wavemeter (feet)	Wave Height (feet)				
	Ebb Tidal Current (knots)				
	2	4	6	8	10
2	2	2	3	3	4
5	5	6	7	9	10
8	9	10	12	14	16
10	11	12	15	18	20
12	13	14	18	22	24
15	17	18	23	27	30
18	20	22	27	32	36
20	22	24	30	36	40

OPERATION

Turn linearizer power switch ON; allow 1 minute to settle. Observe left and right swings of meter needle (linearizer or remote meter) around zero for at least 2 minutes (use Table 2 instructions). Record the average of highest left and right swings observed. Using stop-watch, measure time for successive meter needle crossings of zero in the same direction; twice the time measured will be the predominant wave period - CAUTION - DO NOT TIME WAVE PERIODS WHEN WAVE HEIGHTS ARE 5 FT. OR LESS - RESULTS ARE NOT GENERALLY RELIABLE. Coast Guard stations should record wave height/period values on NOAA Form 72-5A and in teletype message according to station operating procedure.

MAINTENANCE

Routine maintenance and servicing of the Model SW-1C is not required. It is better to LEAVE THE EQUIPMENT ON AT ALL TIMES than to turn it on and off to take readings. Users may wish to adjust for small drifts in the meter display occasionally; this can be done with the meter zero-set, rather than readjusting the electronics. System calibration should be checked once a month against visual sitings when wave heights are greater than 5 feet.

TABLE 2

INSTRUCTIONS FOR WAVE METER OBSERVATIONS

(WAVE METER EQUIPMENT WILL ALWAYS BE "ON"; IT REQUIRES NO ADJUSTMENT OR MAINTENANCE).

1. Watch meter swings for 2 minutes. Look for a set of waves that give approximately the same left and right deflections.

2. Note maximum successive swings to right and left of zero wave height (meter center).

3. Mentally average maximum successive swing to right and left of zero wave height to the nearest foot.

   For instance:

   If max. successive right and left swings during 2 min. observation period were 10 ft.--enter 10 ft.

   If max. right swing was 10 ft. and left swing was 8 ft.--enter 9 ft.

   If max. right swing was 6 ft. and left swing was 10 ft.--enter 8 ft.

4. SWELL PERIOD = Time between successive zero crossing X 2

   For instance:

   If it takes 6 seconds for the needle to pass zero heading left to the next time it passes zero heading left--enter 12 sec.

5. The sensor for the wave meter is a seismometer. It measures vibrations of the earth caused by wave action. Because it is a seismometer, it will also feel the effects of an earthquake somewhere in the world. An earthquake will send the meter full scale for up to an hour. The needle will stay at 20 for a few seconds then move to the opposite 20 for a few seconds. The period is much longer than normal wave periods. Earthquakes cause abnormally high readings with a zero-crossing period of 16-20 seconds.

TROUBLE-SHOOTING

Fig. 7 is a block diagram of the system, Fig. 8 shows the circuit of the linearizer, and Table 3 gives a listing of replaceable parts. The seismometer is a precision mechanical unit, and repair should not be attempted in the field. The manufacturer is equipped to repair damaged units.

The remote readout meter is simply a meter in series with a potentiometer--either part can be replaced easily in the field if physically damaged.

The linearizer electronics consist of a pre-amplifier (IC-1), active filter (IC-2), output amplifier/buffer (IC-3), and regulated power supply module (PS-1) together with various passive components. Current loads throughout the circuit are small and failure of active and passive components has not occurred to date. Field replacement of active components can be done; however, passive components in the active filter should not be replaced. They are critical to proper operation of the wavemeter and special test equipment is required for checkout. Phone Oregon State University (Clayton Creech, (503) 867-3011) if failures occur.

Table 4 lists some problems which might occur that can be repaired in the field.

Fig. 7

BLOCK DIAGRAM

Model SW-1C Wavemeter

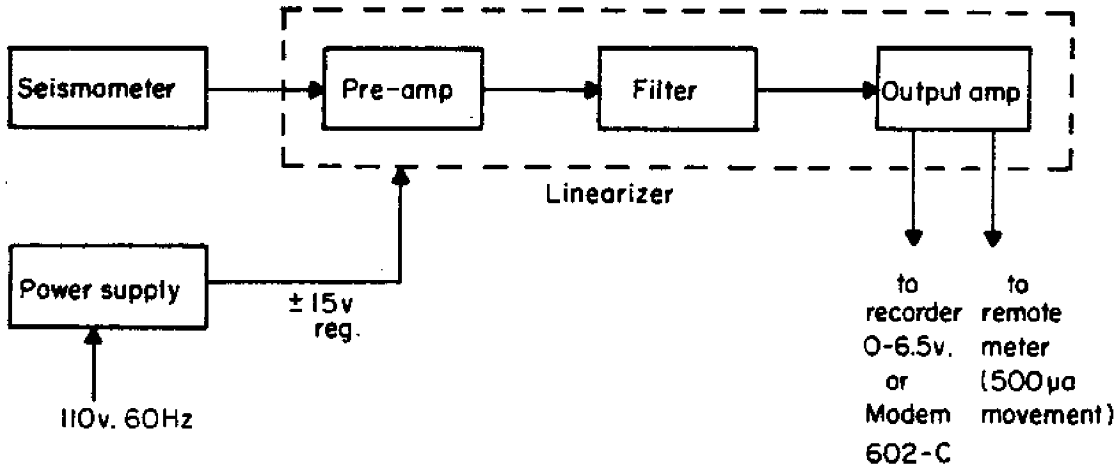
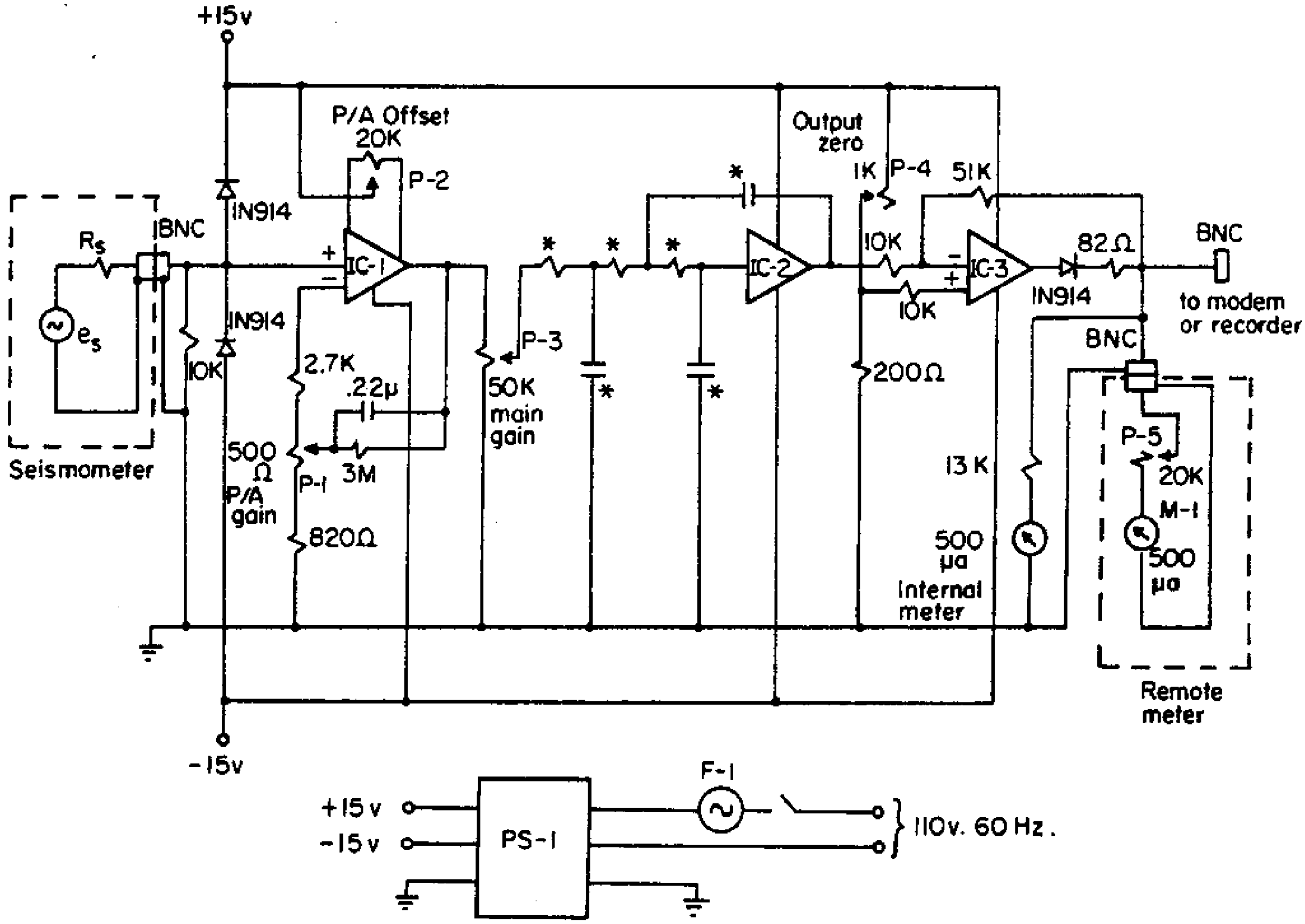


Fig. 8

LINEARIZER CIRCUIT DIAGRAM



* Do not replace in field

TABLE 3

SW-1C WAVEMETER REPLACEABLE PARTS

ITEM	DESCRIPTION	MANUFACTURER
IC 1	OP AMP OP-05-CJ	Precision Monolithics
IC 2	OP AMP LM 741	National Semiconductor
IC 3	OP AMP LM 741	National Semiconductor
PS-1	Power Supply	Boston Tech
M-1	Meter, 0-500 μA API 7045-5902-000	API
P-5	POT, 20K 1 turn, Linear Taper	Centralab, (Clarostat, Ohmite)
F-1	Fuse 3/4 A.	Littelfuse

TABLE 4

TROUBLE-SHOOTING GUIDE

SYMPTOM	PROBABLE CAUSE	REMEDY
Linearizer needle far left	power cord not connected	plug in
	power switch OFF	turn ON
	bad fuse	replace
	110v AC receptable off	flip station circuit breaker
	open input BNC connector	resolder
	seismometer connector	resolder/reconnect
	check PS-1 output (± 15v)	replace module
	check IC-1, IC-2 output (~0.65v with 20,000 ohms/volt multimeter)	if OK, replace IC-3
Linearizer operation OK, remote needle far left	open or shorted connecting cable	repair/replace
	open BNC connector	resolder
	P-5 open	replace
	open remote meter	resolder/replace
Linearizer operation OK, remote needle far left (using telephone MODEMS)	modem not plugged in either at receiving or transmitting site	plug in/re-key
	either modem data light not lit	re-key appropriate modem
	other causes (same as above)	
Linearizer/remote meter near zero center, no wave indication	actual waves (0-2 feet)	none
	seismometer pendulum on stops	stabilize temperature re-level after several hours (see page 5 of Appendix A)

SYMPTOM	PROBABLE CAUSE	REMEDY
inearizer/remote meter near zero center, no wave indication (cont.)	seismometer-linearizer cable open or shorted	clear as indicated
	linearizer-remote cable shorted	clear
	check IC-1, IC-2 output (~0.65v, with 20,000 ohm/ volt multimeter; should vary with significant wave motion	replace IC-1, IC-2 as indicated
inearizer/remote OK but deflections not centered at zero	electronic drift	carefully turn meter mechanical zero screw (MAXIMUM of 1/8 TURN!)

APPENDIX A

OPERATIONS MANUAL

TELEDYNE/GEOTECH MODEL SL-210

SEISMOMETER

OPERATION AND MAINTENANCE MANUAL
VERTICAL LONG-PERIOD SEISMOMETER, MODEL SL-210

TELEDYNE GEOTECH
3401 Shiloh Road
Garland, Texas

2 October 1969
Rev 15 February 1974

OPERATION AND MAINTENANCE MANUAL
VERTICAL LONG-PERIOD SEISMOMETER, MODEL SL-210

1. GENERAL DESCRIPTION

1.1 PURPOSE OF THE EQUIPMENT

The Long-Period Vertical Seismometer, Model SL-210 (figure 1), is an extremely sensitive electro-mechanical transducer that converts very low frequency vertical motion into an electrical output. Small size and rugged construction make it useful for remote field installation as well as laboratory use. The instrument's electrical characteristics are designed to be compatible with solid-state type amplifiers.

1.2 DESCRIPTION OF EQUIPMENT

The Seismometer, Model SL-210, is a moving-coil transducer with a 2-kilogram inertial mass. The natural period of the instrument is adjustable from 10 to 30 seconds. A calibration coil winding is an integral part of the coil structure.

The coil-magnet design of the seismometer is such that amplifiers with input impedances of a few thousand ohms and input noise levels of approximately one microvolt can be used with this instrument. Solid-state amplifiers with these characteristics are available.

The unit is light weight and compact. The suspension system is mounted on a rigid cast base and enclosed by a cast aluminum cover. The unit is sealed by an "O" ring against water and barometric pressure changes.

1.3 SPECIFICATIONS

Operating Characteristics

Natural Period	Adjustable from 10 to 30 seconds nominal period 20 seconds
Transducer	
Type	Single moving coil (velocity)
Effective generator constant	90 volt/meter/second
Damping	Electromagnetic
Signal Coil	
Terminal resistance	1200 ohms nominal at 20°C (68°F)

Calibration Coil	
Terminal resistance	1.7 ohms nominal at 20°C (68°F)
Motor constant	.025 newtons/amp min
Average flux density	0.160 webers/meter^2 (1600 gauss)
Weight of inertial mass	2 kilograms
Critical damping resistance	6440 ohms at 20 sec ±6%
Physical Characteristics	
Height	135 mm (5.31 in.)
Width	194 mm (7.64 in.)
Length	412 mm (16.22 in.)
Net weight	10.5 kg (23.2 lbs)
Shipping weight	15.5 kg (34.16 lbs)
Shipping volume	5.66 x $10^{-2}M^3$ (2 ft^3)

Environmental

Suitable for portable sheltered equipment operation.

Temperature	
Operating	±5°C about some temperature between 0°C and 60°C at which it is adjusted
Storage	-50° to 60°C (-60° to 140°F)
Mass position drift	2.7 mm/°C uncompensated
Relative humidity	10 to 95%
Shock and vibration	When properly packed will withstand shock and vibration normally encountered in shipment by commercial carrier including air.
Altitude	
Operating	Sea level to 4,572 m (15,000 ft)
Transit	Sea level to 15,240 m (50,000 ft)
Connectors	
Signal output	Bendix PT02A-14-18S mating to PT06E-14-18P (SR)

1.4 EQUIPMENT FURNISHED

1 Vertical Long-Period Seismometer, Model SL-210
1 Operation and Maintenance Manual
1 Mating connector, Bendix PT06E-14-18P (SR)
1 Spring Relief Tool, P/N 90-32215-01-01
1 Customer Data Sheet, P/N 90-28280-96-01
1 weight, 200 mg class C
1 Flexure Alignment Tool, 5/32", P/N 32202-01-01

1 spool thread, #60, cotton/dacron
1 Flexure Alignment Tool, 1/2", P/N 32203-01-01

2. INSTALLATION

2.1 UNPACKING

a. Carefully open the shipping container and remove the packing material from around the inner cardboard box.

b. Remove the inner box from the shipping container, open and remove the loose packing material.

c. Carefully remove the seismometer from the inner box. Do not destroy this box when removing the instrument for the box must be used for reshipment.

d. Replace the inner box and packing material in the shipping container and store for use in reshipment.

2.1.1 Inspection

After the equipment has been removed from its container, inspect it for shortages and damage. Paragraph 1.4 of this manual provides a list of equipment supplied. If shortages are discovered, notify Teledyne Geotech 3401 Shiloh Road, Garland, Texas, giving the missing parts; the model and serial numbers of the instruments; the date received; and the carrier involved. When damage in shipment is evident, file a claim with the carrier immediately.

2.2. LOCATION OF INSTRUMENT

2.2.1 Specific procedures and techniques for locating and protecting the instrument will vary with each installation to such an extent that complete details cannot be given in this manual. General consideration in the use and placement of the instrument are given and additional information about individual installations will be supplied on request.

2.2.2 If possible, the seismometer should be placed on bedrock or a pier anchored to bedrock or in a vault anchored to bedrock. The location should be in a quiet area away from cultural noise. The seismometer should be in a thermally stable atmosphere, protected from wind, moisture, and direct sunlight.

2.2.3 A typical field installation would be a hole dug down to bedrock, lined with plywood and insulation and covered with 2 feet of dirt. The location should be such that run-off water and ground seepage would not enter the hole.

2.3 SET UP PROCEDURES

a. Clean the instrument by wiping and brushing off all debris and dust.

b. Set the seismometer in the prepared location.

c. Screw out the two rear leveling feet six turns each.

d. Cross level the instrument by placing the bubble level on the boom directly over the main pivots and adjusting the rear leveling feet.

e. Make sure the mass limit nuts are tightened to prevent mass movement, then remove the two nuts holding the mass to the shipping brackets.

f. Remove the four bolts holding the shipping brackets to the base and remove the brackets.

g. Adjust the mass limit stop nuts until the mass can travel 10 mm above and below zero as indicated by the pointer and scale. Move the mass by hand (gently) to determine this motion.

h. Loosen the set screw holding the trim weight to the side rail of the boom. Position the trim weight until the mass is within ±2 mm of center.

i. Set the mass in motion at an amplitude of 2 to 3 mm and time one complete cycle with a stop watch or any watch with a sweep second hand.

j. Adjust the period to that desired by screwing out (lengthening) the front leg to increase the period and in (shortening) to decrease the period. Position the mass within 2 mm of center before checking the period.

k. Replace the cover but do not latch. Allow to temperature stabilize for several hours.

l. Make electrical connection to the seismometer using the mating connector supplied and the information in figure 2.

m. Reposition the mass to the center and make adjustments to the period to the desired accuracy.

n. Replace the lid and close the latches.