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OPERATION AND MAINTENANCE MANUAL
BROADBAND SEISMOMETER
BB-13

Stock Number 990-57760-9800

TELEDYNE
GEOTECH

OPERATION AND MAINTENANCE MANUAL
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April 1988

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1. GENERAL DESCRIPTION

1.1 PURPOSE OF THE EQUIPMENT

The Broadband Seismometer, Model BB-13, is designed for use in field operations where a wide range of seismic frequencies and amplitudes is to be measured. The seismometer may be operated as a horizontal or vertical instrument. This manual describes the operation and maintenance and conversion from vertical to horizontal operation.

1.2 DESCRIPTION OF THE EQUIPMENT

The BB-13 Seismometer is an enhancement of the S-13 Short-Period Seismometer. A capacitance transducer that senses motion between the 5 kg mass and the BB-13 frame, and an electronic feedback loop that drives the main coil/magnet transducer of the S-13 has been added. The result is an instrument that senses seismic acceleration over a bandwidth of dc to 20 Hz and amplitudes to .1 m/sec^2. Controls consist of a mass position adjust (vertical) and a mass lock. The vertical and horizontal configurations are shown in figures 1-1 and 1-2. See paragraph 2.2 for a listing of items shipped with each seismometer.

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Figure 1-1. Vertical, BB-13 Seismometer

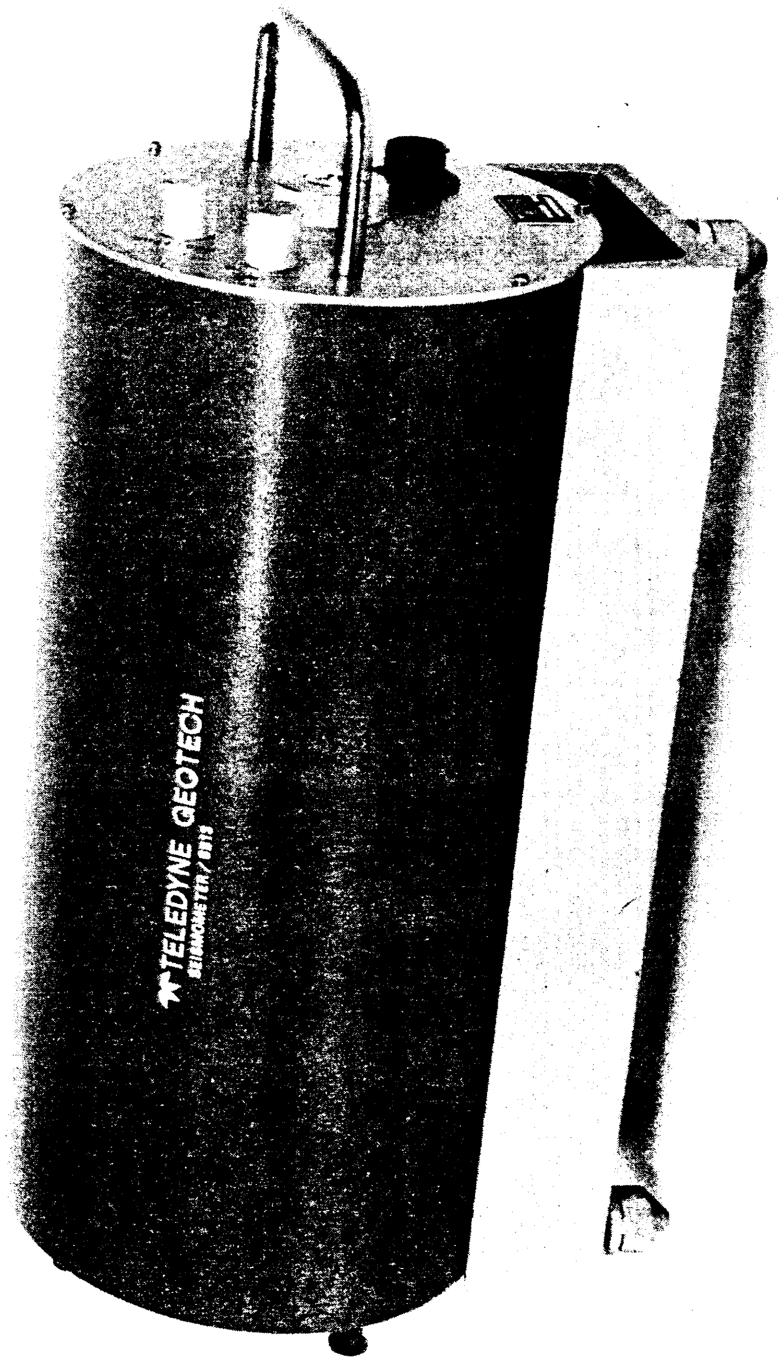

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Figure 1-2. Horizontal, BB-13 Seismometer

2. INSTALLATION

2.1 GENERAL

The Model BB-13 Seismometer is a stable instrument and, when properly installed, will operate without further adjustment for several years. Those unfamiliar with setting up seismic instruments for long-period and very long period measurements are urged to be patient and very thorough in installing the BB-13 instrument when it is to record long-period signals.

Normally, a seismometer is placed on bedrock, on a pier anchored to bedrock, or in a vault anchored to bedrock.

If the maximum possible magnification is to be realized, the location must be in a quiet zone away from cultural noise.

2.1.1 Thermally Stable Environment

The instrument must be placed in a thermally stable environment. This one condition cannot be emphasized enough. An underground vault or cave is preferable and the instrument should be insulated and protected from drafts and direct infrared radiation and other thermal sources. Power supplies and other heat producing equipment should be located near the ceiling of the vault or enclosure to cause stratification of the air within the vault. Diurnal temperature changes of as much as .5°C may cause problems. Temperature changes cause the mass position to change and even if the rate of change is outside the passband of interest, these changes can cause noise within the passband.

Even in an absolutely stable environment some creep of the mass is to be expected. This creep often takes the form of small discrete steps of mass position. Note that a spring length change as small as 1×10^{-12} meter is equivalent to a step in acceleration of approximately 1×10^{-9} g. Experience has shown that these discrete steps will be fairly frequent when the seismometer is initially installed (10 to 20 per 24 hrs) but will decrease significantly over a period of days or weeks depending on the stability of the environment.

Figure 2-1 describes a thermal insulation technique that was found to be very effective during the development of the BB-13 vertical seismometer. The important feature is the aluminum infrared shield.

The horizontal seismometer configuration is not as temperature sensitive as the verticals but for very long period measurements a similar insulation technique should be used.

2.1.2. Placement of the Instrument

The instrument must be placed on a solid surface for best results. Setting the instrument directly on a concrete pier or bedrock is acceptable for most applications. Good results have also been obtained in vertical installations by

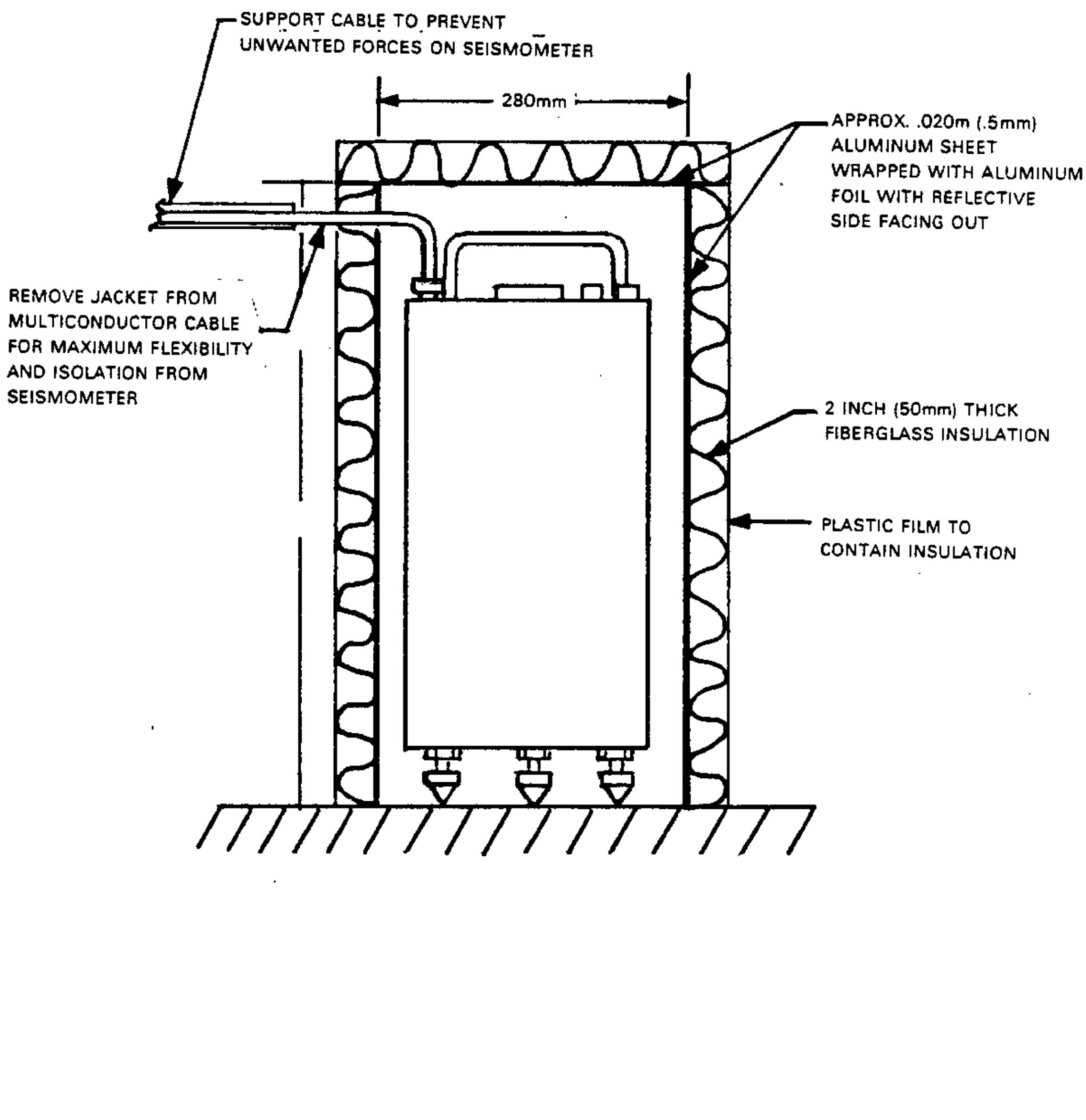

Figure 2-1. Insulation and Installation Techniques

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grouting a thick (3 inch/75mm) plate to a concrete pier. Special precaution should be taken to ensure that air is not trapped in the grout. These air pockets can expand and contract with temperature and/or barometeric pressure changes and cause noise.

The instrument must be well insulated as described in section 2.1.1 for very long period measurements (e.g. 50 to 300 seconds). If access to the instrument is difficult, the instrument should be left to stabilize with the environment for several days before final adjustments are made.

The instrument should not be placed near other equipment that generates changing magnetic fields. Changing magnetic fields can couple into the associated external power and signal cables and cause noise in the system.

2.2 UNPACKING

The seismometer is packed in a reusable container and is shipped in the vertical configuration with the mass locked. Visually inspect the outside of the seismometer for any visible signs of damage. If damage is apparent, contact the carrier and Teledyne Geotech.

NOTE

> When moving the instrument, always be sure that the mass is locked. See section 3.2.1 for locking and unlocking controls.

The seismometer is shipped with a shipping plug installed in the center of the top cover. See figure 2-2. This plug must be removed and replaced with Cap Assembly (item 37, figure 6-12) that is located in the Accessory Kit, Part Number 990-58098-0101 furnished with each instrument. To remove the shipping plug, turn counterclockwise until it is free, pull up on the plug and rotate it counterclockwise through the cover. If the plug is extremely tight at first, loosen the three 3/8 inch hex nuts (item 116, figure 6-12) at the bottom of the cover. Retighten the nuts after shipping plug is removed.

Save the O-ring and place it in the groove of the Cap Assembly before installing it in the cover. The BB-13 seismometer must be pressure tight for proper vertical operation.

If the seismometer is to be reshipped by commercial carrier, or equivalent, the shipping plug should be reinstalled. The seismometer should never be shipped on its side without the shipping plug in place. Ordinary handling or transporting short distances in the upright position may be done without the shipping plub.

It should not be necessary to remove the cover unless the instrument is being changed from ±15 Vdc power to ±12 Vdc power or from master to slave operation or from vertical to horizontal operation. See section 3.0 for instructions on these conversions.

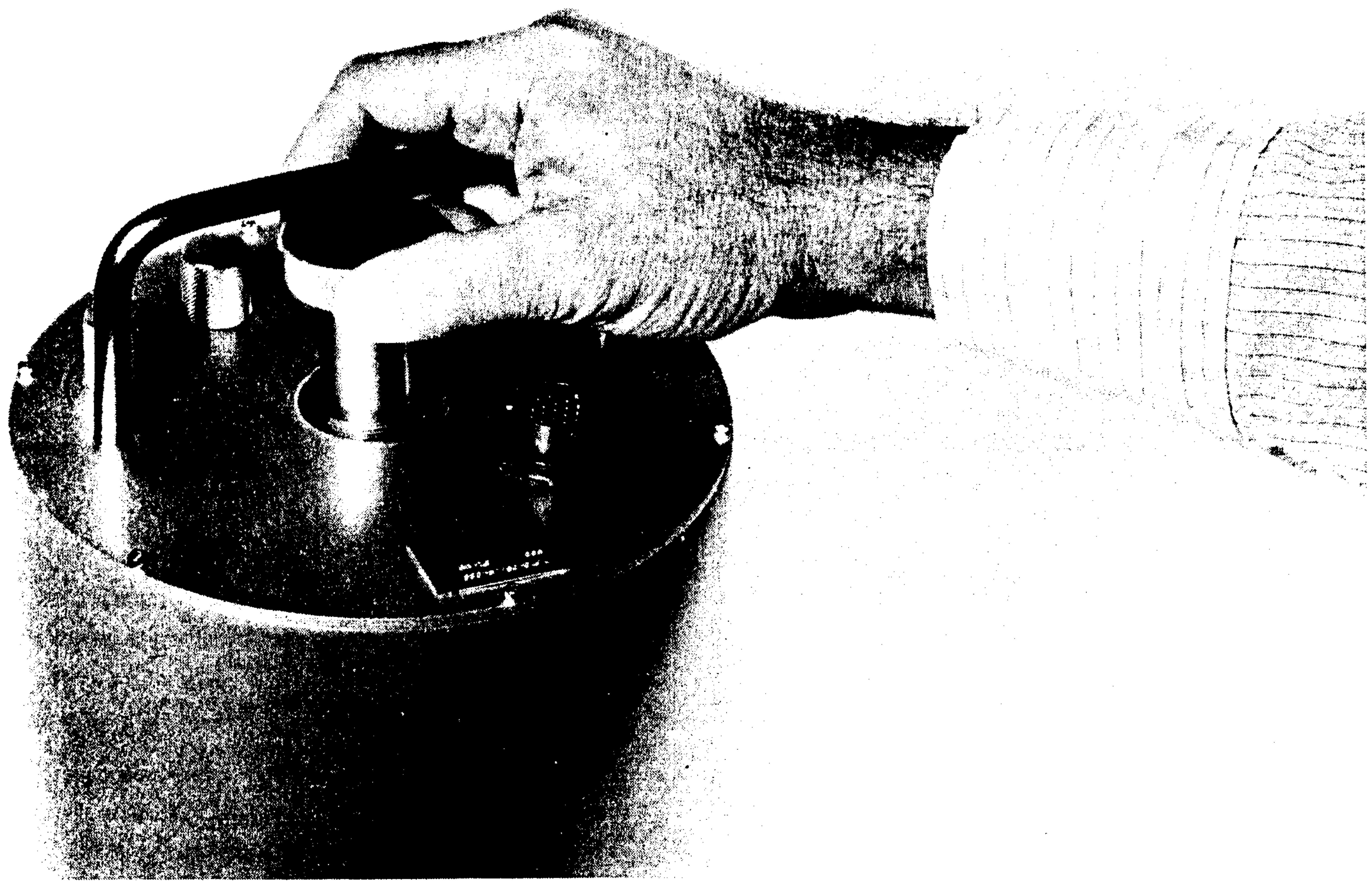

Figure 2-2. Removing the Shipping Plug

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Save the shipping container and packing for reshipment if necessary. Always ship the unit in the vertical configuration. See paragraph 3.3.2.1.

The following items are furnished with each shipment.

1	Broadband Seismometer, BB-13, 990-57760-0101
1	Operation and Maintenance Manual, 990-57760-9800
1	Accessory Kit, 990-58098-0101
1	Carton, shipping

Optional items such as horizontal cradle, pressure check kit, etc. may be included. See shipping documents for optional items.

2.3 SETTING UP THE INSTRUMENT

The following decisions must be made before setting up the instrument.

a. horizontal or vertical operation
b. master or slave operation
c. ±15 Vdc or ±12 Vdc power

Instruments are shipped in the vertical configuration. See section 3.5 for conversion to horizontal operation.

If more than one seismometer is to be operated at the same location (e.g. in the same vault) and connected to a common recording system, one and only one instrument must be designated the master and the other units must be configured as slave units. See section 3.3.4 for definition of master/slave operation and the instruction for conversion.

The unit is shipped for ±15 Vdc power. Internal regulators convert this to ±12 Vdc power. For external ±12 Vdc operation, internal jumpers must be reset. See section 3.3.3 for instructions on making these conversions. If external ±12 Vdc power is used, it must be well regulated as it will not be internally regulated.

All of the above options require removing the cover. See section 3.3.1 for instructions on removing and replacing the cover. Vertical units must be sealed for proper operation.

Appendix A describes the connection of the BB-13 Broadband Seismometer to a Teledyne Geotech DTS-100 Digital Telemetry System.

Figure 2-3 and 2-4 show suggested wiring diagrams for general applications. Figure 2-3 is for wiring when only one calibration input is desired. See section 4.3 for discussion of calibration options between acceleration or velocity calibration. Figure 2-3 shows wiring for acceleration calibration. If velocity calibration is desired, move wire from J to S and wire from K to T. Note that neither K nor T are calibration signal common. Calibration signal must be applied between J and N or S and N. Calibration control switch must be closed (R to N) before calibration circuit is active internally. Calibration control switch must be open for normal operation.

Figure 2-4 shows an acceptable wiring if both calibration lines are desired. Drive only one calibration circuit at a time.

Figure 2-5 is a typical wiring diagram when two or more seismometers are operated at one location. One and only one (usually the vertical) must be selected as the master unit to provide the 8.192 kHz carrier signal to itself and all other units. The remaining units must be configured as slave units to receive the 8.192 kHz carrier signal.

Read all of section 3.0 before applying power and attempting to operate the seismometer.

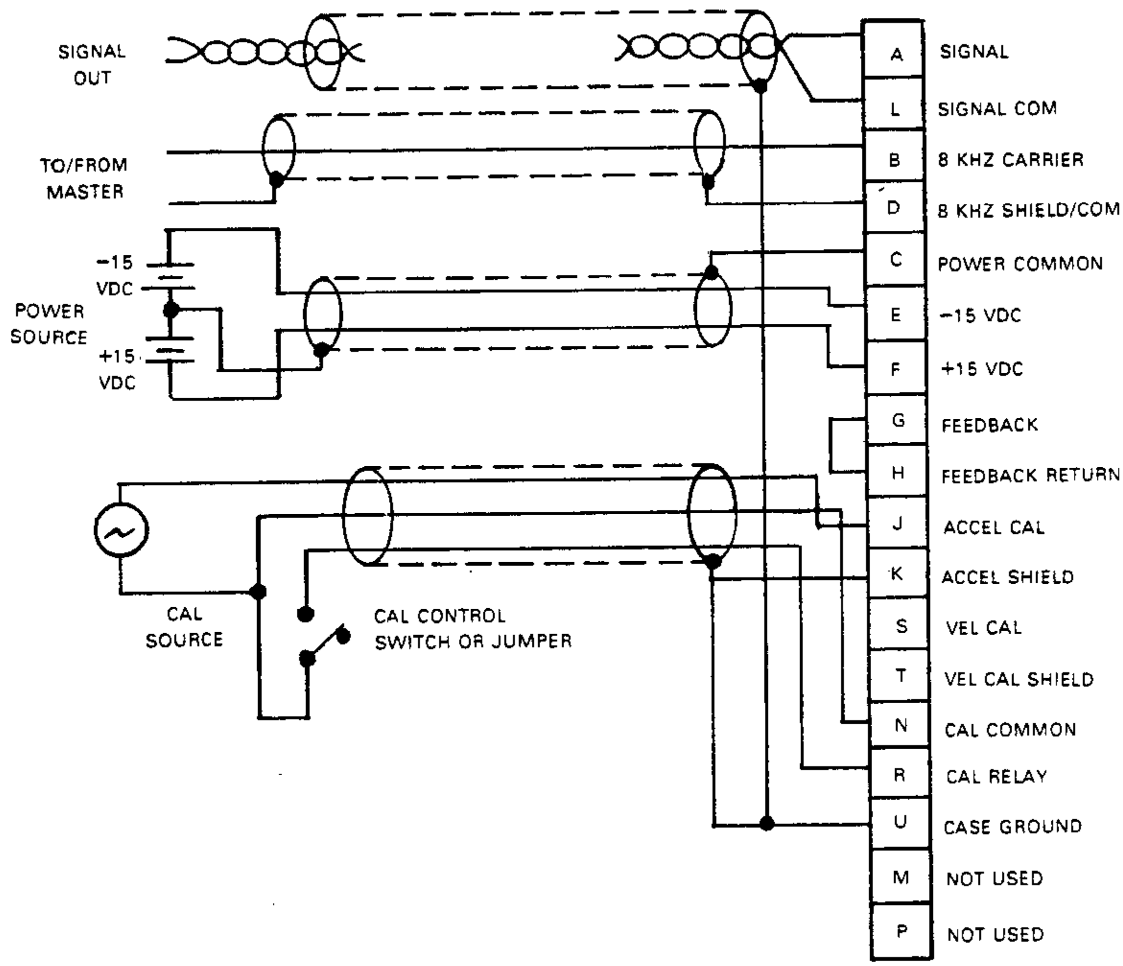

Figure 2-3. Wiring Diagram - Mating Connector P1, Single Calibration Circuit

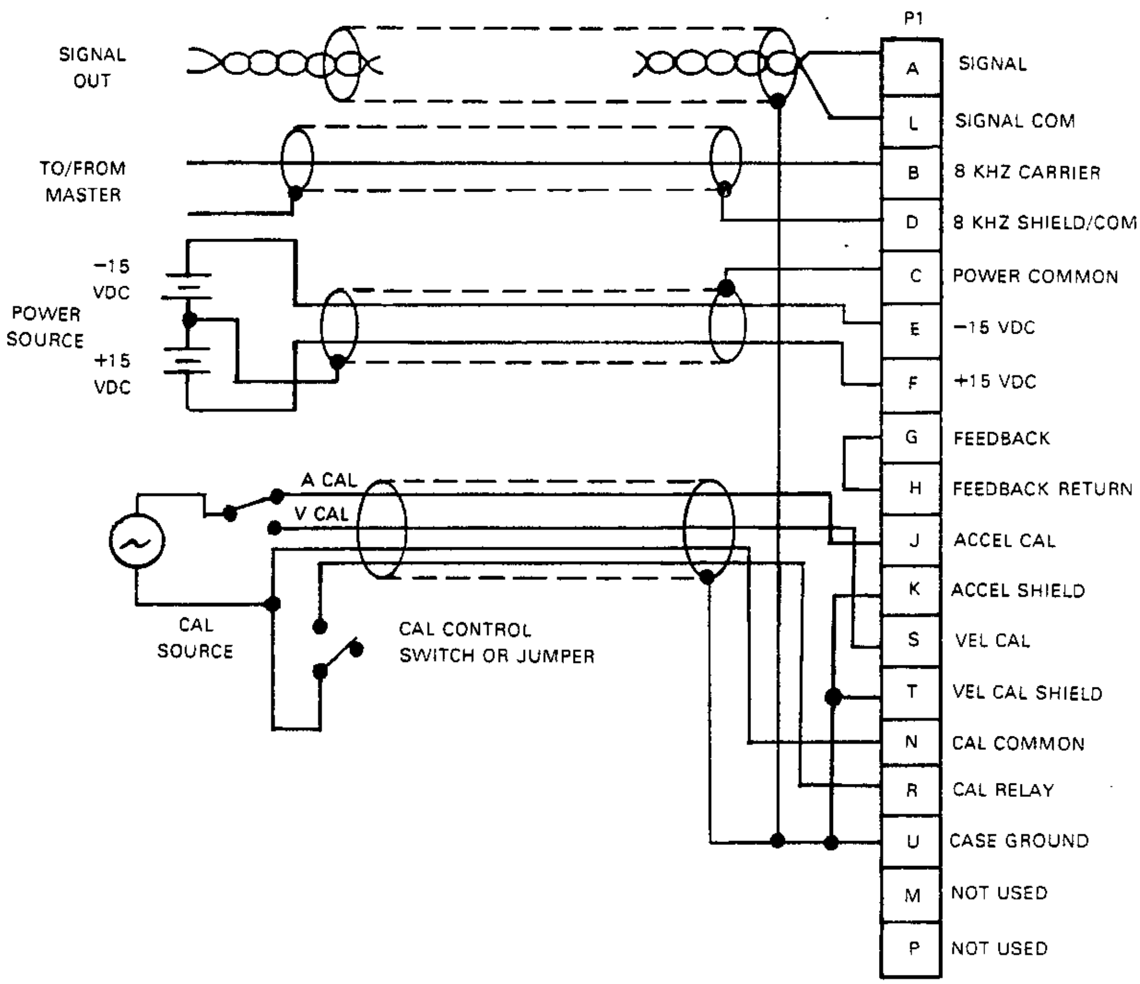

Figure 2-4. Wiring Diagram - Mating Connector P1, Dual Calibration Circuit

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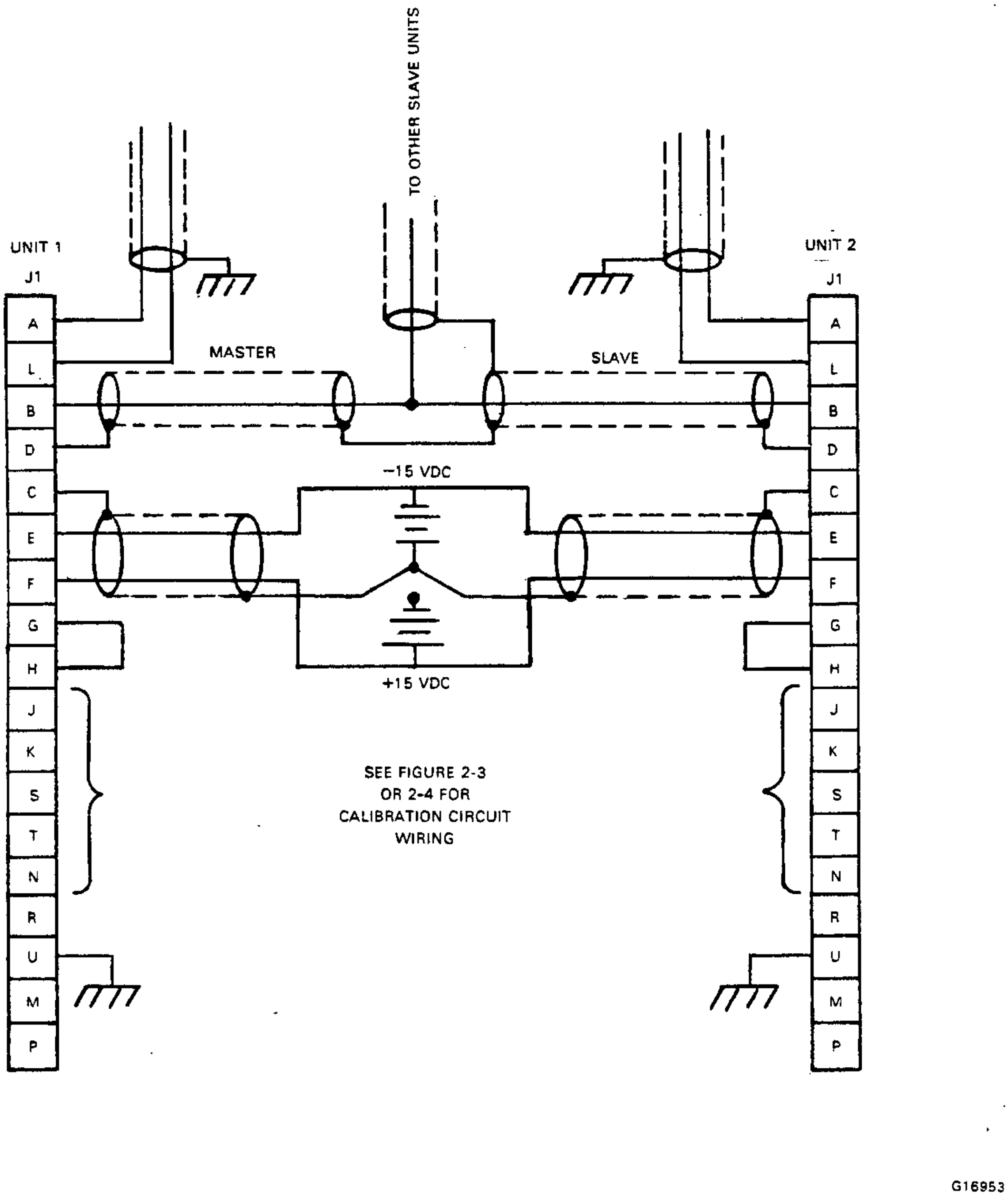

Figure 2-5. Typical Wiring Diagram - Two or More Seismometers

3. OPERATION

3.1 PRINCIPLES OF OPERATION

The Broadband Seismometer, Model BB-13, belongs to a class of instruments commonly referred to as a force feedback accelerometer. The operation of this instrument can be explained by referring to figure 3-1.

The FRAME of the instrument moves with earth motion. This FRAME is connected to the MASS by means of a SPRING. A "MASS" CAPACITOR PLATE is mechanically connected to the MASS, and the "FRAME" CAPACITOR PLATES are connected to the FRAME.

The inertia of the MASS will result in a relative displacement between it and the FRAME when the earth moves. This displacement is proportional to the FRAME acceleration. The relative displacement moves the MASS CAPACITOR PLATE with respect to the two "FRAME" CAPACITOR PLATES.

These "FRAME" PLATES are electrically driven in phase opposition at approximately 8 kHz, so that when the MOVING PLATE is exactly centered, the signal on it is zero.

When the "MASS" CAPICITOR PLATE is displaced from center, the resulting 8 kHz signal is amplified by the PREAMP, filtered by a bandpass FILTER and then demodulated by the DEMODULATOR CIRCUIT. This signal goes to the OUTPUT and to the FEEDBACK CIRCUIT.

The OUTPUT voltage, e_o, produces a current, i_f, through the FEEDBACK COIL that reacts with the magnetic flux in the MAGNET to produce a force on the MASS. This force is proportional to the OUTPUT voltage and the relative displacement which is in turn proportional to the FRAME acceleration. The phase of this feedback force is such that it opposes the relative displacement and therefore stiffens the system. For example, when the feedback is disconnected the natural frequency of the SPRING and MASS/MAGNET is approximately 1.0 Hz, but when feedback is connected the natural frequency is approximately 20 Hz.

Also shown in figure 3-1 is the calibration circuit. This circuit is active only when the CALIBRATION RELAY is activated. Signals proportional to acceleration or velocity can be used for calibration.

A simplified form of the transfer function where $s = j\omega$ is:

$$\frac{e_o}{\ddot{y}} = \frac{K}{s^2 + \left(\dfrac{KGC_dR_s}{M(R_s + R_c)}\right)s + \left(\dfrac{KG}{M(R_c + R_s)}\right)}$$

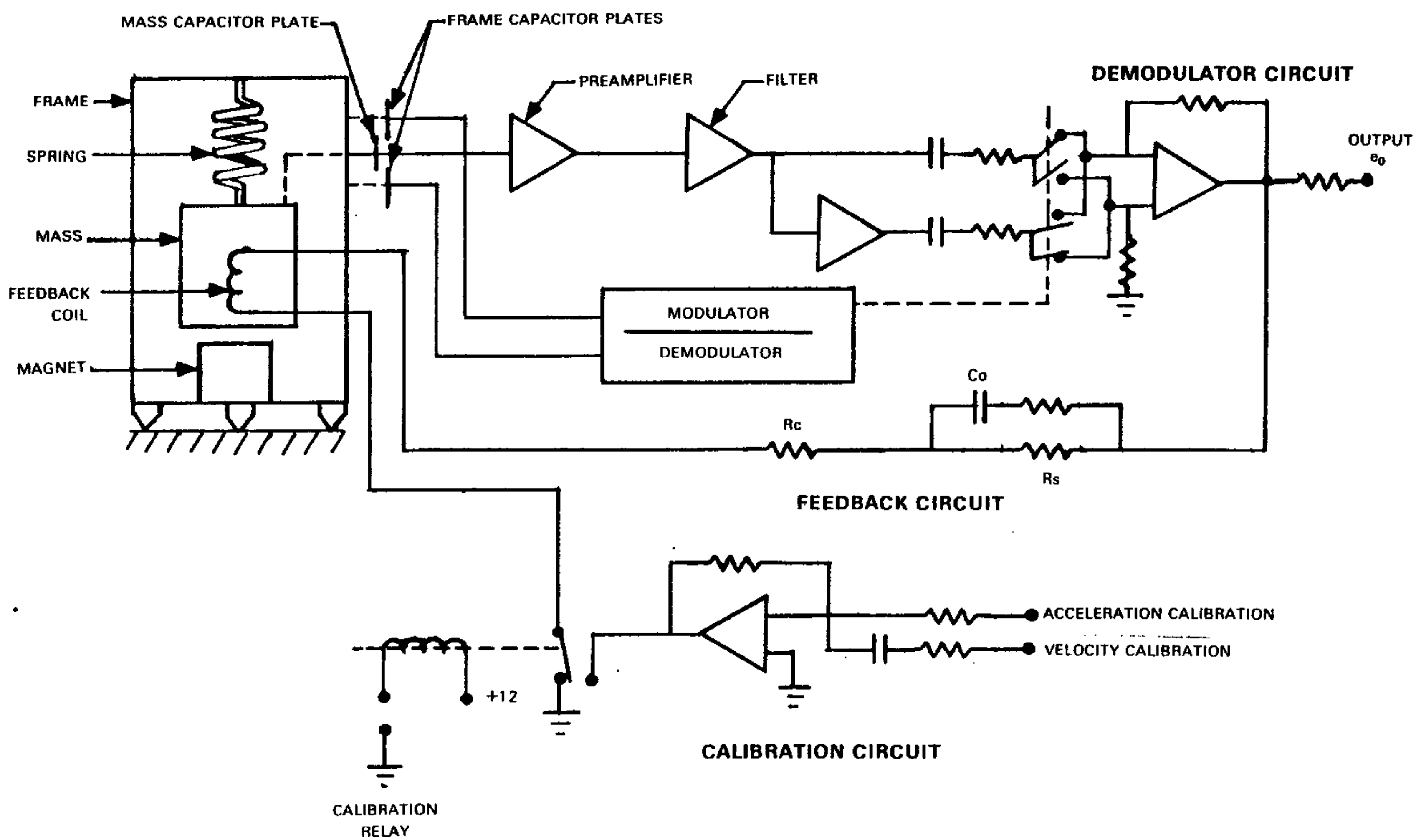

Figure 3-1. Principle of Operation - Vertical Seismometer

This is the transfer function of a second order low-pass system. K is the forward gain consisting of the bridge sensitivity, and preamp, filter, and demodulator gains. G is the motor constant of the coil magnet assembly, newtons/ampere, and M is the mass in kilograms. R_s and R_c are the feedback and coil resistances respectively.

From the transfer function, the closed loop natural frequency, ω_c, is:

$$\omega_c 2 = \frac{KG}{M(R_c + R_s)}$$

and damping λ_c is given by:

$$\lambda_c = \frac{C_d R_s}{2} \omega_c$$

and for frequencies less than ω_c the sensitivity is:

$$\frac{e_o}{\ddot{y}} = \frac{M(R_c + R_s)}{G}$$

The sensitivity and response are functions of very stable electronic and mechanical components.

Typical amplitude and phase response curves are shown in figure 6-1 through 6-6.

The operation of a vertical BB-13 has been described, but the horizontal BB-13 operates in a similar manner where the coil springs are removed, and the mass is supported by the delta rods that produce the mechanical natural frequency of approximately 1.0 Hz.

3.2 INSTRUMENT CONTROLS

Figure 3-2 and 3-3 locate the controls and indicators that are described in the following paragraphs. Do not operate controls until you have read section 3.3.

3.2.1 Mass Lock

To lock or unlock mass, remove plug marked LOCK in the top of the instrument. Reach through this hole with a flat blade screwdriver and rotate the lock shaft clockwise to lock and counterclockwise to unlock.

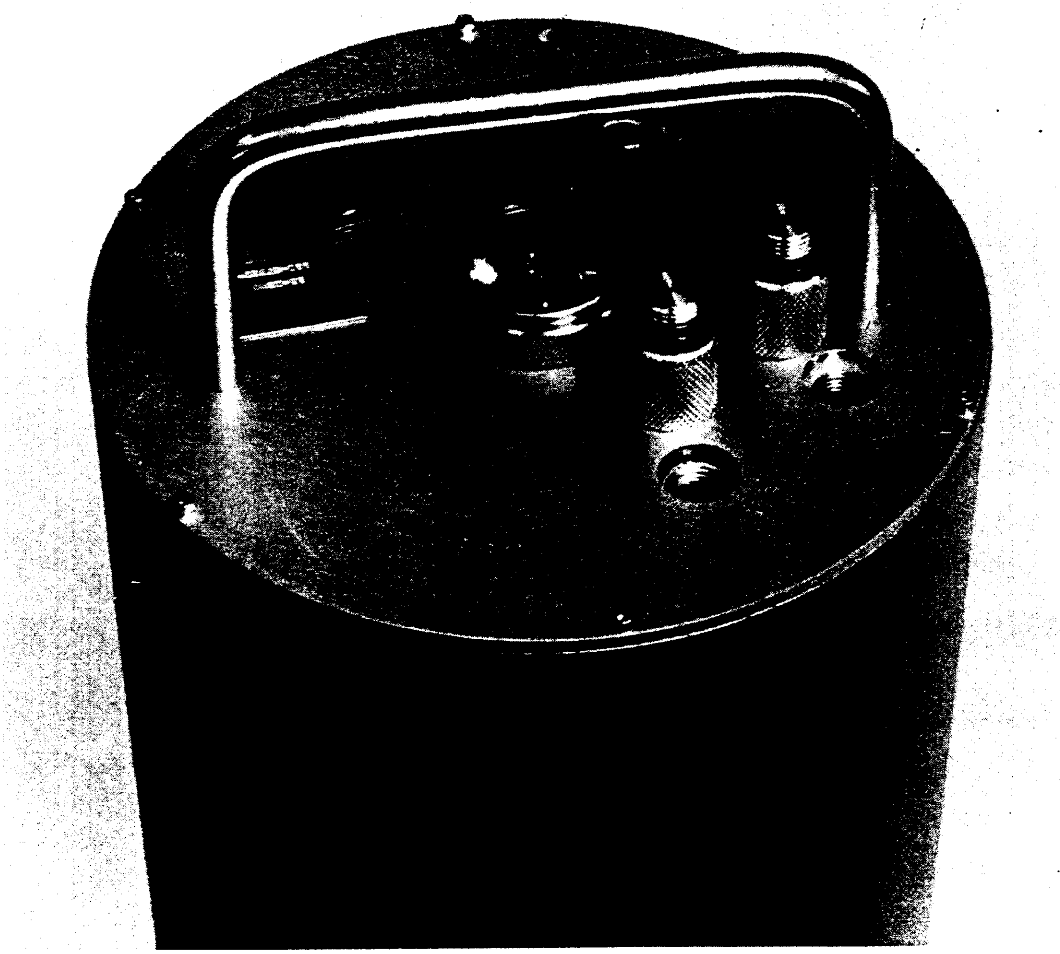

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Figure 3-2. Vertical Controls

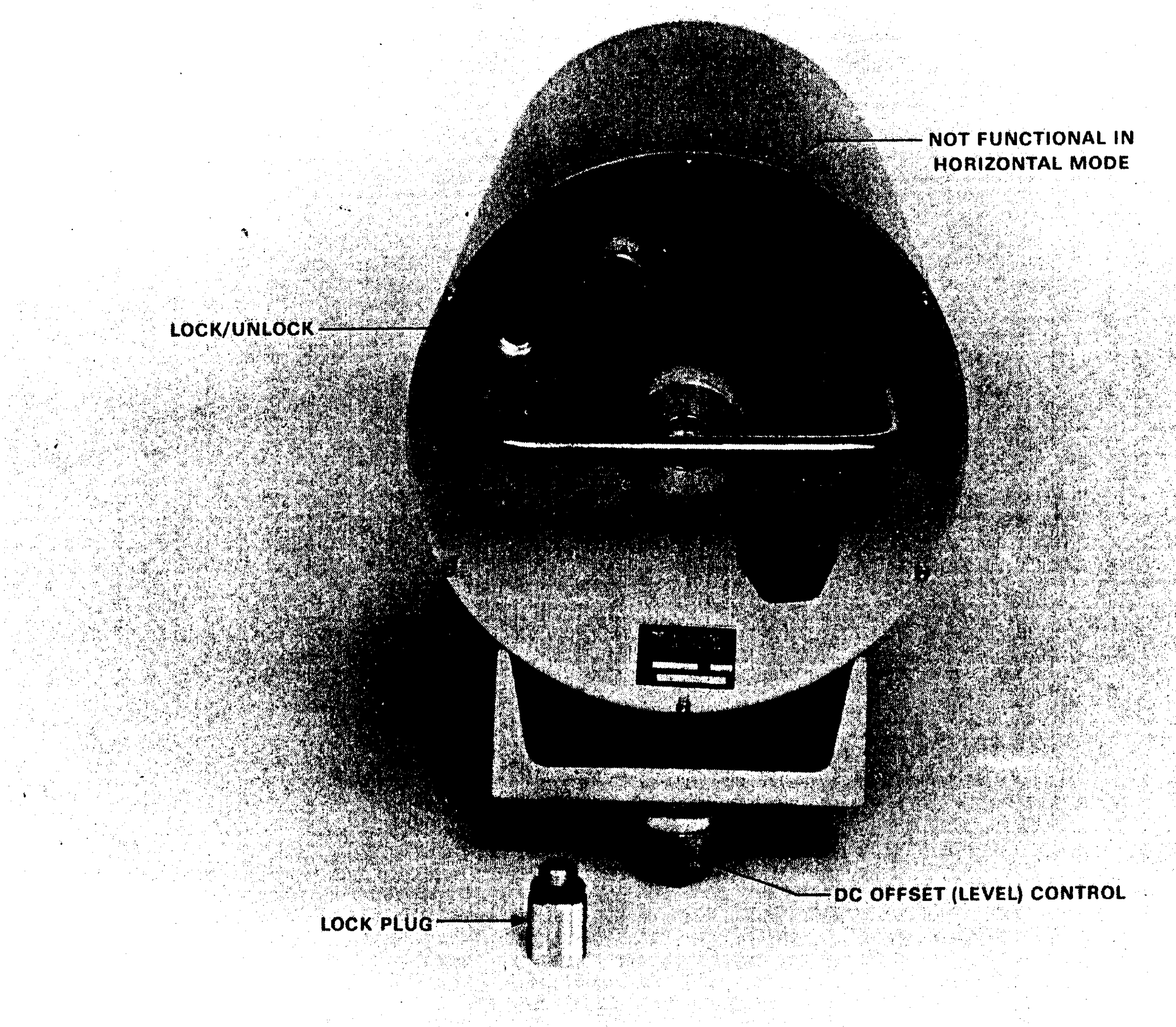

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Figure 3-3. Horizontal Controls

3.2.2 Dc Offset (Mass Position) Adjustment (Vertical Operation)

To adjust the dc offset remove the plug marked "position" in the top of the vertical instrument. Reach through this hole with a flat blade screwdriver and rotate the slotted spring adjust knob. Only very slight adjustments are ordinarily needed, and with experience and patience the dc offset can be adjusted to less than ± 10 mV. Clockwise rotation gives a negative offset at pin A of P1. This control is inactive when in the horizontal configuration. Dc offset must be less than ±30 mV to avoid very long period 1/f noise. See figure 6-7.

3.2.3 Dc Offset (Mass Position) Adjustment (Horizontal Operation)

Dc offset in the horizontal instrument is set by adjusting the tilt of the horizontal cradle with the knurled foot at the end of the cradle. Lowering the connector end of the instrument gives a negative offset at pin A of P1. (see section 3.3.2 k.) Dc offset must be less than ±30 mV to avoid very long period 1/f noise. See figure 6-7.

3.3 INSTRUMENT OPTIONS (INTERNAL ADJUSTMENTS)

The BB-13 Seismometer is a sturdy instrument, but it is also very sensitive and should be handled accordingly. The following procedures apply to both horizontal and vertical instruments.

a. The instrument should always be locked when the instrument is being moved or major internal adjustments are being made.
b. Cleanliness of the internal parts and O-rings is essential for proper operation.
c. The cover of the instrument should not be removed in a dirty or dusty atmosphere where small magnetic particles may be attracted to the magnet or where small particles can fall into the capacitor bridge assembly.
d. Covers need to be removed only if the internal adjustments described in 3.3.2, 3.3.3 or 3.3.4 are required.

3.3.1 Removing the Cover

a. The cover cannot be removed until the shipping plug is removed. See section 2.2. Lock the mass as described in section 3.2.1. Remove the 1 3/16" hex nut from the connector (J1) that is in the top of the top plate (figure 3-4a). Hold the connector with padded pliers or other suitable device, if necessary, to prevent it from turning. Ordinarily it can be held by hand to keep it from turning. Push the connector down into the hole below its threads to keep it from being caught in the cover when it is removed.
b. Remove the six 4-40 socket head screws (3/32 hex wrench) from the cover plate.
c. CAREFULLY pull up with a controlled pull on the handle to remove the top cover plate (figure 3-4b). There is an O-ring seal around the outer edge of the cover and the cover will suddenly pull loose if care is not taken. Caution should be taken to ensure that the connector does not catch in the cover and damage the internal wires

when the cover comes loose. Remove the O-ring from the connector and save it for reuse.

d. Invert the seismometer and set it on a suitable stand as shown in figure 3-5. A stand is available as an accessory item (Part Number 990-58103-0101) or a 6 inch (150mm) diameter by 2 inch (50mm) thick block of wood or metal may be used. If a block is used, support the seismometer on the three spring adjust screws being careful to not damage the connector or wires.
e. Remove the seismometer feet, locking rings hex nuts, seal retainers and seals from the three seismometer legs.
f. Remove the cover by lifting vertically off of the seismometer.
g. If the seimometer is to be turned upright, reinstall the feet on the legs to protect the threads. Remove the cap from the cover plate and screw it into the top of the seismometer to prevent foreign particles from falling into the capacitor assembly.
h. To install cover, reverse the above procedure. The connector O-ring may be installed without lubrication as this will help hold connector and keep it from turning. Make sure all other O-rings are clean, lubricated and in good shape. For successful long-period operation, the vertical instrument <u>must be sealed</u> to prevent barometric pressure (air density) variations from disturbing the mass position.
i. A Pressure Test Kit is available as an optional item from Teledyne Geotech (Part Number 990-58104-0101).

3.3.2 Converting to Horizontal Operation

As previously stated, the seismometer is assembled and shipped ready for vertical operation. If the instrument is to be used in the horizontal mode, convert it as follows:

a. Lock the mass and remove the instrument cover as directed in paragraph 3.3.1.
b. Set the seismometer in a vertical position.
c. Referring to figure 3-6, unfasten each of the three flexures (33) from the cantilever assembly (11) by removing the screw (86) and washer (88) and the flexure clamp (31). Press down on the mass end of the cantilever until all tension is removed from the flexure. Carefully work the flexure off the locating pin. Let each cantilever rise to rest against its cantilever stop (58). Store the flexure clamps and screws in the tapped hole provided in the top of each cantilever stop. The flexures, when free of the locating pin, should flex back, out of the way of the cantilevers. If any one of the three flexures touches any part of the cantilever assemblies, gently bend it back over a large radius until it will clear when released.
d. Replace the cover as described in section 3.3.1 except leave off the feet, lock rings, and the top cover plate.
e. Remove the plastic thread protectors from the feet of the Horizontal Cradle, Part Number 990-58082-0101. (Note: This cradle is ordered separately and is not furnished with each instrument.) Place these plastic thread protectors on the seismometer feet to protect their threads.

f. Install the three feet and lock rings on the Horizontal Cradle for use as support and adjustment of the cradle.
g. Place the seismometer upright and loosen the 1/4-20 socket head screw holding the top horizontal foot. See figure 3-7. Push the slotted foot out against the side of the cover with the slot oriented along a radial line. Tighten the 1/4-20 screw.
h. Replace the top cover, connector, etc. as described in 3.3.1.
i. Locate the horizontal cradle and place the seismometer in the cradle with the seismometer handle horizontal and the connector down. See figure 1-2. Loosen the 3/8-24 nut on the top vertical leg so that the seismometer will set down firmly on the top horizontal foot. See figure 3-8.
j. Note: The seismometer may be placed in the cradle with the connector end at the single foot end of the cradle as shown in figure 1-2 or reversed. For some installations it may be more convenient to use the reverse configuration as cabling and wires will not be in the way of adjusting the dc offset.
k. Always return the seismometer to the vertical configuration before shipping unit by commercial carrier. The horizontal units may be transported short distances with care, but the cantilever beams are loose and a sharp jolt could dislodge them and cause damage.

3.3.3 Power Supply Voltage

All instruments are shipped from the factory set for ±15 Vdc power voltage operation. The instruments can be set for ±12 Vdc operation by changing jumpers on the Oscillator Board, Part Number 990-57591-0101. Remove cover per paragraph 3.3.1. See figure 3-9 for location of these jumpers. Remove jumpers from E9 to E1 and E11 to E2. Install jumpers from E9 to E3 and E11 to E4. Reinstall cover per paragraph 3.3.1.

3.3.4 Master/Slave Operation

All instruments are shipped from the factory in the master configuration. If only one instrument is being operated at a site, no further adjustments are required. If more than one instrument is to be operated at a site, one must be selected as the master and the others set as slave units. This simply means that the master unit provides the 8.192 kHz carrier signal for all units. Synchronization of the 8.192 kHz signal between units is required to eliminate long-period noise that occurs if they are not synchronized.
To change from master to slave, remove the cover as described in paragraph 3.3.1. Remove the jumper on the oscillator board (figure 3-9) from E12 to E10. Install jumper from E22 to E23. Replace cover as described in paragraph 3.3.1.

3.4 VERTICAL OPERATION

Once power and master/slave options have been selected, the instrument is ready for operation. (In master/slave combinations, the slave must be connected to an operating master before it will function).

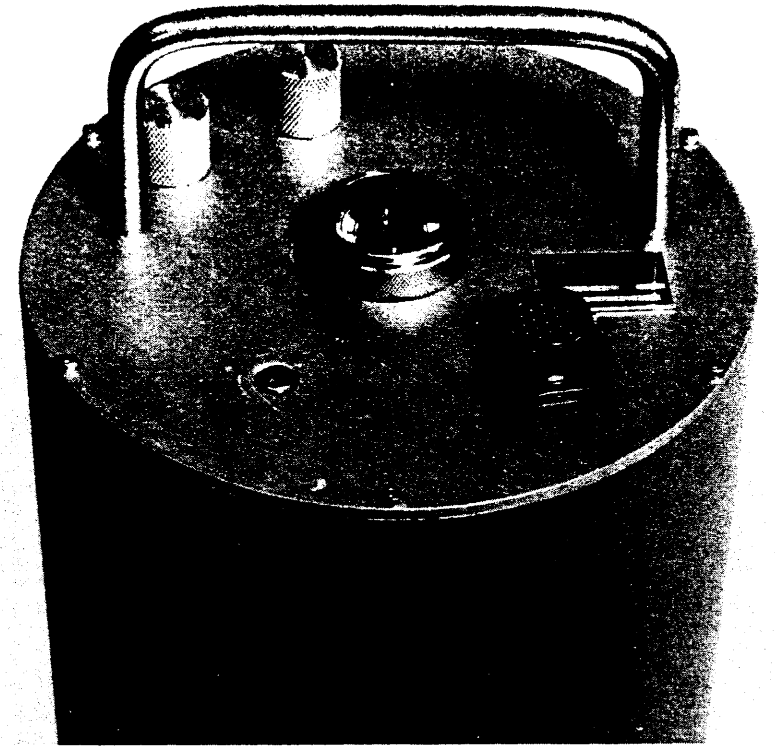

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Figure 3-4a. Cover Removal

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Figure 3-4b. Cover Removal

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Figure 3-5. Cover Removal

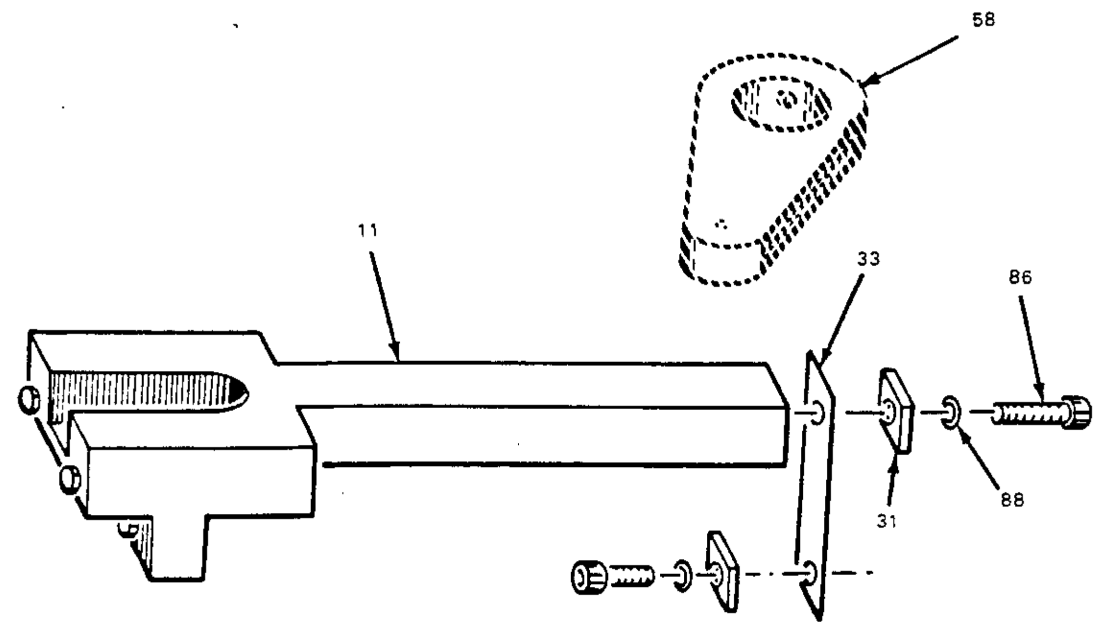

Figure 3-6. Flexure Detachment for Horizontal Operation

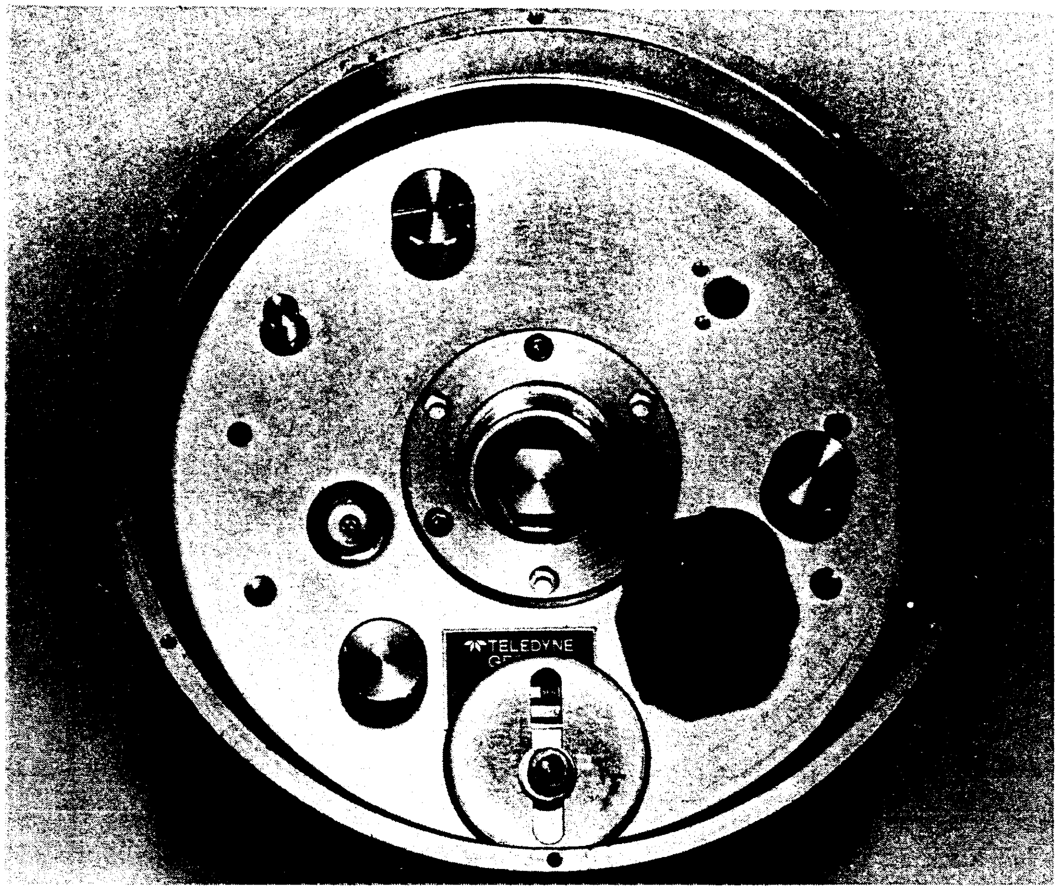

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Figure 3-7. Top Horizontal Foot Adjustment

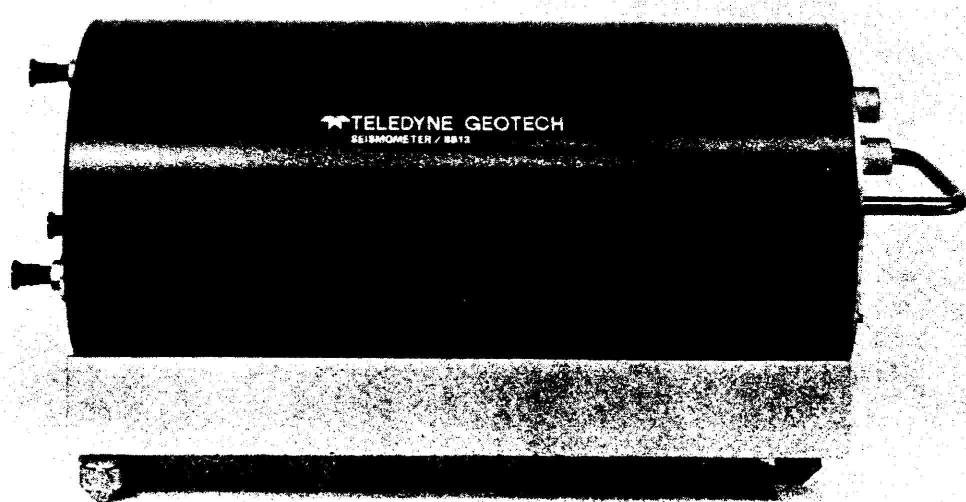

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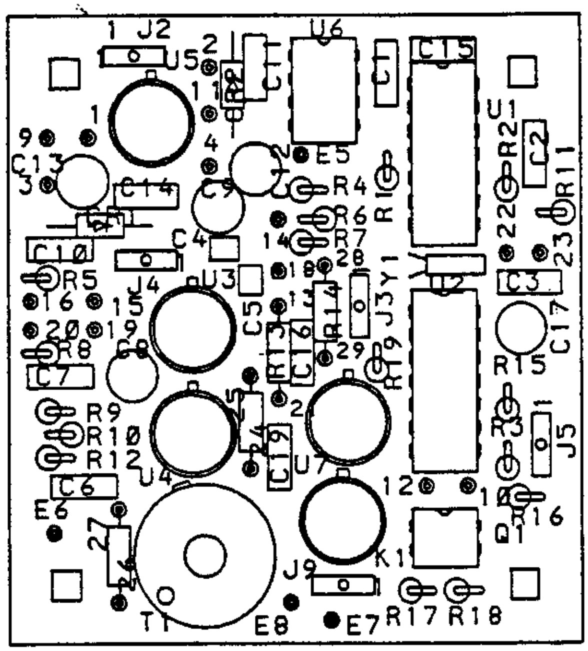
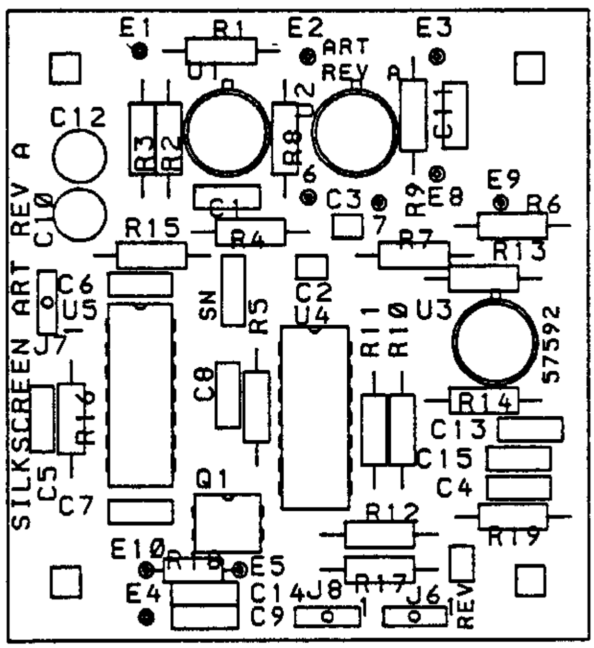
Figure 3-8. Horizontal BB-13 Installation in Cradle



CONNECTOR COLOR CODE	
J	COLOR
2	VIOLET
3	WHITE
4	BLUE
5	GREEN
9	YELLOW

Figure 3-9. Oscillator Board, Part Number 990-57591-0101

E1



E4

CONNECTOR COLOR CODE

J	COLOR
6	ORANGE
7	BLUE
8	GREEN

Figure 3-10. Amplifier Board, Part Number 990-57592-0101

When all power and signal connections have been made to the instrument (paragraph 2.3.2), proceed as follows:

a. With the masslock locked, turn on power.
b. Connect a dc voltmeter across seismometer output (pins A and L of P1 connector). The voltmeter should read between -11 and -12 Vdc.
c. Slowly unlock the instrument while observing the voltmeter. Ordinarily the instrument will capture somewhere within the ±10 V operating range. When this is the case, the instrument is operating normally. If it does not, see the following paragraph. See paragraph 3.2.2 or 3.2.3 for dc offset adjustment. After the first adjustment, it may take one to several more adjustments over a period of several days until the instrument settles into its environment. Vertical instruments usually take longer to stabilize. Dc offset should be less than ±30 mV to avoid very long period noise. See figure 6.7.
d. If the instrument does not capture in the ±10 V range, larger adjustments of the dc offset screw are required. If the voltage remains between -11 and -12 Vdc the mass is pulled to the top stop. Turn the dc adjust screw counterclockwise no more than three turns. If the adjustment cannot be made within these limits see paragraph 4.4. If the voltage changes from full negative to between +11 and +12 Vdc the mass is against the lower stop, and adjusting the dc adjust screw clockwise no more than three turns will ordinarily be sufficient. If it is not, remove cover per paragraph 3.3.1 and adjust each of the spring adjust screws (items 26 and 27, figure 6-12) to obtain dc offset. Make sure pin does not come off of item 34 as spring is adjusted. Replace cover per paragraph 3.3.1.

3.5 HORIZONTAL OPERATION

Once power and master/slave operations have been selected, the instrument is ready for operation. (In master/slave combinations, the slave must be connected to an operating master before it will function).

When all power and signal connections have been made to the instrument (paragraph 2.3.2) proceed as follows:

a. Place the seismometer in the horizontal cradle with handle horizontal and the connector down. See figure 3-8 and section 3.3.2.j. With the masslock locked, turn on the power.
b. Connect a dc voltmeter across the seismometer output (pins A and L P1 of the connector). The voltmeter should read between -11 and -12 Vdc.
c. Slowly unlock the instrument while observing the voltmeter. If the voltage remains negative, raise the connector end of the seismometer with the tilt adjusting screws on the horizontal cradle. If the voltage is positive, lower the connector end. With care and patience the instrument can ordinarily be set to zero within ±10 mV. Lock the leveling screws after final adjustment. Several additional adjustments may be required over a period of several days until the instrument adjusts to its environment. Dc offset

should be less than ±30 mV to avoid very long period noise. See figure 6-7.

3.6 CONNECTING TO RECORDING SYSTEM

It is beyond the scope of this manual to describe all of the possible system configurations that can be used with the BB-13 Broadband Seismometer. The instrument was basically designed to be used with a wide-range digitizer/telemetry system such as the Teledyne Geotech DTS-100 Digital Telemetry System. See Appendix A for connection of BB-13 to the DTS-100.

The unit can be used in analog recording systems with appropriate filters and amplifiers. The full scale output is ±10 V and the output impedance is 100 ohms. The output is single-ended. The output will have a dc offset that may change with time/temperature etc., therefore, ac coupling at the input amplifier is desirable.

Observing the output of the seismometer with an oscilloscope will show that there is a 16.2 kHz ripple about 500 mV peak-to-peak in the output signal. This is normal and should be filtered out in the input stages of the post amplifier/filter system.

For advice on specific system design problems contact Teledyne Geotech.

4. OPERATING TESTS AND CALIBRATION

This section describes the basic calibration of the seismometer and the use of the electronic calibration circuits.

4.1 VERTICAL CALIBRATION USING WEIGHT LIFT

a. Set up seismometer as described in section 3. Connect a voltmeter to the seismometer output (pins A and L of the P1 connector) and remove the top cap (figure 3-2).

CAUTION

Be careful when top cap is removed that particles do not fall inside. The clearances in the capacitor bridge are small and particles can cause shorting or jamming of the seismometer.

b. Tie a piece of thread to a 20 gram weight and lower the weight onto the weight lift platform as shown in figure 4-1.

c. Note the output voltage with the weight on and off. Repeat several times to obtain an average.

d. Compute the sensitivity of the seismometer from the following equation:

$$S_a = \frac{\Delta V \times M}{W \times 9.8} \quad \frac{\text{Volts sec}^2}{\text{meter}}$$

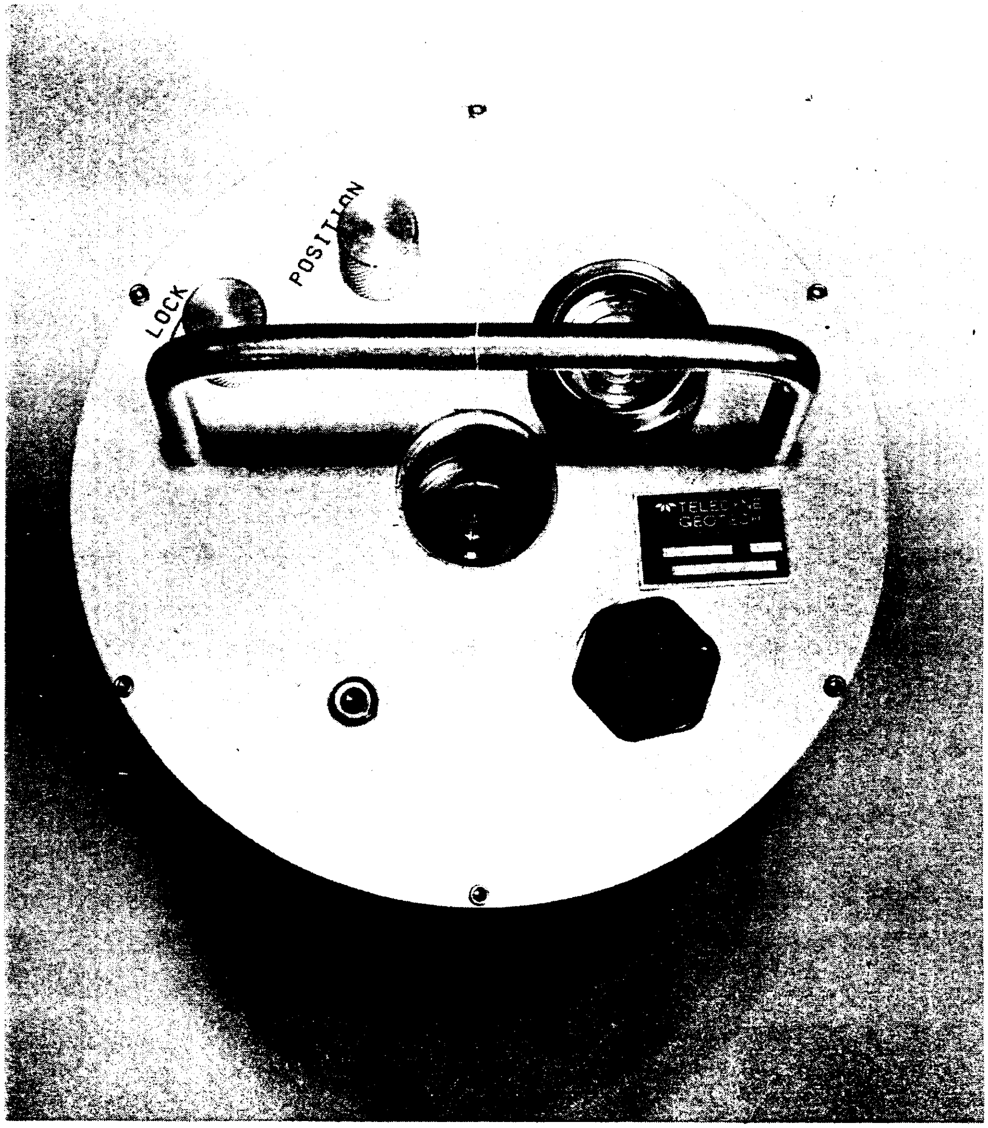
Where: ΔV = difference in voltage between weight-on and weight-off

M = seismometer suspended mass - 5 kilogram

W = mass of lift weight - .020 kilogram

EXAMPLE: For 20 gram weight lift and average ΔV equal to 4.05 volts

$$S_a = \frac{4.05\ (5)}{.020 \times 9.8} = 103.3 \quad \frac{\text{Volts sec}^2}{\text{meter}}$$



P23251

Figure 4-1. Vertical Calibration with Weight

4.2 HORIZONTAL CALIBRATION USING TILT

a. Set up seismometer as described in section 3.0. Connect a voltmeter to the seismometer output (pins A and L of the P1 connector).
b. Rotate the single leveling screw at the connector end of the cradle two turns, and note the change in output voltage. Repeat several times to obtain an average.
c. Compute the acceleration sensitivity from:

$$S_a = \frac{\Delta V}{9.8 \times N \times T} \quad \frac{\text{Volts sec}^2}{\text{meter}}$$

Where: ΔV = difference in voltage for N turns of screw - volts
N = number of turns of screw
T = tilt constant of cradle - .00273 radians/turn

Example: For two turns and an average ΔV of 5.4 volts

$$S_a = \frac{5.4}{9.8 \times 2 \times .00273} \quad \frac{\text{Volts sec}^2}{\text{meter}} = 100.9 \frac{\text{Volts sec}^2}{\text{meter}}$$

4.3 REMOTE CALIBRATION CIRCUIT - HORIZONTAL AND VERTICAL

The remote calibration circuit is connected in series with the feedback circuit by means of a relay as shown in figure 3-1. The calibration circuit is a source of long-period low-level noise, therefore it is switched out of the circuit by the relay when calibration is complete.

The calibration circuit has two inputs. The acceleration calibration input produces an equivalent earth acceleration that is proportional to the applied voltage. The velocity calibration input produces an equivalent earth velocity that is proportional to the applied voltage.

4.3.1 Remote Acceleration Calibration Constant

a. Determine the acceleration sensitivity S_a as described in paragraph 4.1 or 4.2.
b. Apply a 1 volt p-p 1 Hz sinusoidal signal to the A cal input (pin J to N of the connector).
c. Short pin R to N of connector to activate calibration relay.
d. Measure output voltage (pin A to L) with an oscilloscope or other suitable instrument. This voltage should be approximately 1.0 V p-p.

e. Compute the acceleration calibration constant from:

$$A_c = \frac{V_i}{S_a \times V_o} \quad \frac{\text{meter}}{\text{sec}^2 \text{ Volt}}$$

Where: V_i = input voltage 1 Volt p-p
S_a = acceleration sensitivity Volt sec^2/meter
V_o = output voltage Volt p-p

f. Note that any frequency other than 1 Hz can be used for this calibration as long as it is in the flat portion of the frequency response curve (see figure 6-1).

g. The acceleration frequency response of the seismometer can be measured by applying a constant amplitude signal to the A_{cal} input and measuring the output at various frequencies within the passband of the instrument.

h. Be sure to deactivate cal relay for normal operation.

4.3.2 Remote Velocity Calibration Constant

a. Determine the acceleration sensitivity as described in paragraph 4.1 or 4.2.

b. Apply a 1 volt 1 Hz sinusoidal signal to the V_{cal} input (pin S to N).

c. Short pin R to N to activate calibration relay.

d. Measure output voltage (pin A to L) with an oscilloscope or other suitable instrument. This voltage should be approximately ~~0.16~~ Volt p-p.

e. Compute the velocity calibration constant from:

$$V_c = \frac{V_o}{S_a \times V_i \times 2\pi f} \quad \frac{\text{meter}}{\text{sec Volt}}$$

Where: V_i = input voltage 1 Volt p-p
V_o = output voltage Volt p-p
S_a = acceleration sensitivity Volt sec^2/meter
f = frequency of signal 1 Hz

f. The velocity frequency response of the seismometer can be measured by applying a constant amplitude signal to the V_{cal} input and measuring the output at various frequencies. V_{cal} is accurate up to about 15 Hz.

g. Be sure to deactivate cal relay for normal operation.

4.3.3 Determining Equivalent Earth Motion

Often it is desired to know what the equivalent earth motion amplitude is for a given cal signal. For sinusoidal calibration signals the equivalent earth motion can be determined from either of the following formulas:

$$y = \frac{V_i \times A_c}{4\pi^2 \times f^2} \text{ meters}$$

Where: y = equivalent earth motion - meter p-p

V_i = input voltage to A_{cal} - Volts p-p

A_c = acceleration calibration constant - $\frac{\text{meter}}{\text{sec}^2 \text{ Volt}}$

f = frequency of input voltage - Hz

Or:

$$y = \frac{V_i \times V_c}{2\pi \times f} \text{ meters}$$

Where: y = equivalent earth motion - meter p-p
V_i = input voltage to V_{cal} - Volts p-p
V_c = velocity calibration constant $\frac{\text{meter}}{\text{sec Volt}}$
f = frequency of input voltage - Hz

4.4 OPERATING SEISMOMETER WITH COVER OFF

For various troubleshooting operations it may be desirable to operate the BB-13 Seismometer with its cover off.

For the horizontal configuration, the end opposite the connector must be supported on blocks or other suitable shims to relevel it when the cover is removed. The unit must be supported firmly or some oscillation may occur.

4.5 TROUBLESHOOTING DIAGNOSIS

Symptom	Possible Problem
No Output	1. Power not properly connected. Check that jumpers on Oscillator Board are properly set. See section 3.3.3 2. No oscillator signal. Check that jumpers are correctly set for master/slave operation. Slaves must be connected to a master for correct operation. See section 3.3.4 3. Amplifier or oscillator board inoperative. Return to factory for repair and recalibration. See section 5.3

Symptom	Possible Problem
Dc Output High + or -	1. Seismometer locked. See section 3.2.1. 2. Capacitor or coil interference causing mass to drag. Check for free motion of mass with power removed, and seismometer unlocked. See sections 5.7, 5.8 and/or 5.9.
Output too High	1. G to H connection in P1 broken. G to H must be shorted together for proper closed loop operation. See section 2.3.
Erratic Oscillation of Output	1. G to H connection in P1 intermittent. See section 2.3. 2. Frame capacitor shorting to mass capacitor. Check for proper clearance. Check for foreign matter in capacitor assembly. See paragraph 5.9.
Steady Oscillation at 15 to 20 Hz	1. Coil leads reversed or frame capacitor leads reversed. See wiring diagram, figure 6-9. 2. Check that seismometer is firmly setting on solid foundation. See section 2.1.2.
Approximately 500 mV 16 kHz Signal on Output	1. This is normal. See section 3.6.
Excessive Long-Period Noise	1. Poor or improper insulation and installation. See sections 2.1.1 and 2.1.2. 2. Two master units connected together. One and only one unit at an installation can be a master unit. See section 3.3.4. 3. Leaking pressure seal. See section 3.3.1.
Excessive High Frequency Noise	1. High cultural noise. Locate seismometer away from pedestrian and vehicle traffic.
Dc Offset Drifts Excessively on Vertical Unit	1. Leaking pressure seal. Vertical units must be sealed against atmospheric pressure changes. See section 3.3.1. 2. Improper insulation. See sections 2.1.1 and 2.1.2.
Dc Offset Drifts Excessively on Horizontal Unit	1. Pressure seal not critical on horizontal units. Check for improper insulation. See sections 2.1.1. and 2.1.2.
Vertical Units Oscillate or Try to Oscillate at Approx. 100 to 120 Hz	1. Check centering of capacitor transducer. Capacitor should have uniform spacing around circumference. See section 5.9. Check for loose delta rods. See section 5.4.
Frequency Response Exceeds 20 Hz.	1. Check centering of capacitor transducer. Capacitor should have uniform spacing around circumference. See section 5.9.

5. MAINTENANCE

5.1 GENERAL

The design of the BB-13 Seismometer is such that complete disassembly of the instrument should seldom be necessary and disassembly beyond the limits outlined in this section should be avoided. If it appears that further disassembly is needed, the instrument should be returned to the manufacturer for repair and adjustment. For best results, parts removed should be replaced in their original locations. Figure 6-12 is an exploded view of the vertical instrument which should be used as a reference for the item numbers ( ) which are given in the maintenance instructions.

The following precautions should be observed when disassembling the seismometer.

a. Assembly area should be clean and free of dirt and metal chips.
b. The O-rings and O-ring grooves should be kept free of dirt, chips, and other foreign matter. On installation, the O-rings should be lubricated with a suitable O-ring lubricant. Exception: Leaving connector O-ring dry will aid in keeping the connector from turning when nut is tightened.
c. Before attempting any maintenance on this seismometer, the operations section (section 3) should be read and thoroughly understood.

5.2 REMOVING AND REPLACING COVER

Instructions for removing and replacing the cover are given in paragraph 3.3.1.

5.3 REPLACING CIRCUIT BOARDS

To remove either circuit board, proceed as follows:

a. Lock mass and remove cover per paragraph 3.3.1.
b. Disconnect each connector by gently pulling it away from the board. Connectors are marked with colored paint on pin 1 end of each connector. If paint is missing, mark each connector to ensure that connectors are not interchanged or reversed.
c. Unsolder any wires that connect to the board at the board.
d. Remove the four screws (92), one at each corner, that holds the circuit board and carefully remove it.
e. To replace the circuit board reverse the above process making sure the connectors are properly placed and wires are correctly resoldered. (See wiring diagram, figure 6-9).
f. Replace cover per paragraph 3.3.1.

5.4 CHANGING DELTA RODS

Delta rods which are distorted or broken should be replaced. If only the small diameter wire is bent, it can be straightened and replaced in the seismometer. To remove damaged delta rods, proceed as follows:

a. Lock the mass.

b. Remove the cover per paragraph 3.3.1
c. Remove the damaged delta rods (3) by slackening the 4-40 x 1/4 socket head cap screws (90).

CAUTION

Do not remove all six delta rods at one time. At least 2 delta rods, 1 upper and 1 lower, should be left in place.

d. Fit the new delta rods so that:
   (1) The wires rest in their grooves in the clamping blocks.
   (2) The two ends of each delta rod lie in the same plane to form one straight line.
   (3) The stiffened section is centrally disposed (0.250 each end) between the clamping blocks.
e. Ensure that all clamps (30) are straight and that all screws (90) are tight.
f. Replace cover per paragraph 3.3.1

5.5 CHANGING SPRINGS ON VERTICAL SEISMOMETERS

To change the springs (6), proceed as follows:

a. Lock the mass.
b. Remove the cover per paragraph 3.3.1.
c. Release the springs until all tension is off the flexures (32, 33, and 34). To release the springs, turn the spring adjust nuts (26,27) counterclockwise. Hold the spring to keep it from rotating when pin comes out of the slot in item (47).
d. Remove the 2-56 x 3/8 socket head screws (86) and flexure clamp (31) at the upper end of the cantilever-to-spring flexure (34).
e. Work the flexure off the flexure pin in the spring connector.
f. Pull up on the spring adjust nut and turn it counterclockwise until the nut comes off the spring assembly.
g. Carefully remove the spring assembly from the seismometer.
h. Before replacing the spring assembly:
   (1) Clean the O-ring grooves.
   (2) Lubricate the O-rings (70) with light silicone oil or other suitable lubricant.
   (3) Place the O-ring in the groove.
i. Extend the threaded end of the spring assembly through the hole in the upper frame plate (21). The flexure pin in the spring connector should be pointing to the left of the observer. Place the teflon washers (51) over the stud and screw the spring adjust nut onto the stud. Three to five turns will be sufficient. Push the spring adjust nut into the O-ring.
j. Lower or raise the spring assembly until the flexure pin will pass through the hole in the upper end of flexure (34).
k. Clamp the flexure to the spring assembly with the flexure clamp (31) and a 2-56 x 3/8 socket-head screw (86). Do not tighten the screw at this time.

l. Turn the spring adjust nut clockwise until a small amount of tension is on all flexures. Caution: Too much tension will distort holes in flexure and damage it.

m. Make certain that the cantilever and flexures are straight. It may be necessary to slacken all screws holding the flexures. When the cantilevers and flexures are straight, tighten the screws making sure that the clamps are straight with their flexures. Take care not to misalign the cantilever and spring.

n. Tighten the spring adjust nuts until the springs will support the mass. Make sure that the springs line up with spring guides (47). Hold spring from rotating until pin enters spring guide (47). Turn spring adjust nut until the dowel pins are approximately 1/8-inch from the bottom of the groove in spring guides. Unlock the mass.

o. Center the mass between the stops, taking care to keep the elongation in all springs equal.

CAUTION

Make sure no part of the spring assembly is rubbing against the cantilevers, and that no wires are touching springs or cantilevers. The spring assembly should be centered in the yoke of the cantilever. Spring to cantilever flexure (34) must not be twisted.

p. If possible power the seismometer and connect a dc voltmeter across pins A and L of connector P1. Adjust spring adjust nuts approximately equal amounts to bring the voltmeter reading to approximately zero volts. If this step is not possible or feasible then centering the mass as in step o. above should be adequate.

q. Replace cover per paragraph 3.3.1.

5.6 REPLACING DAMAGED FLEXURES

To replace a cantilever-to-spring flexure (34), proceed as follows:

a. Lock the mass

b. Remove the cover per paragraph 3.3.1.

c. Remove all tension from the flexures (see step 5.5 c).

d. Remove the 2-56 x 1/4 socket-head cap screws (87) and flexure clamp (31) at the upper and lower end of the flexure.

e. Remove the damaged flexure and replace it with a new one.

f. Clamp the flexure to the spring assembly and cantilever with the flexure clamps and 2-56 x 1/4 socket-head screws. Do not tighten the screws at this time.

g. Repeat steps 5.5 i. through 5.5 q.

To replace a damaged cantilever-to-base flexure (32), proceed as follows:

a. Remove all tension from the flexures (see step 5.5. c.).

b. Remove the 2-56 x 1/4 socket-head cap screw (87) and flexure clamp (31) from the bottom of the flexure.

c. Remove the 2-56 x 3/8 socket-head cap screw (86) and flexure clamp (31) from the top of the flexure.

d. Remove the damaged flexure and replace it with a new one.
e. Clamp the flexure to the cantilever with a 2-56 x 3/8 socket-head screw and the flexure clamp. Clamp the flexure to the middle frame plate assembly (15) with the 2-56 x 1/4 socket-head screw and flexure clamp. Do not tighten the screws at this time.
f. Repeat steps 5.5 i. through 5.5 q.

To replace a damaged cantilever-to-mass flexure, proceed as follows:

a. Remove all tension from the flexures (see step 5.5 c).
b. Remove the 2-56 x 3/8 socket-head screw (86) from the top of the flexure (if the seismometer is in the vertical operation mode).
c. Remove the 2-56 x 1/4 socket-head screw (87) from the bottom of the flexure.
d. Remove the damaged flexure and replace it with a new one.

NOTE

The flexure should be installed with the bend away from the cantilever.

e. Clamp the flexure to the cantilever with a 2-56 x 3/8 socket-head screw and the flexure clamp. Clamp the flexure to the mass assembly (8) with a 2-56 x 1/4 socket-head screw. Do not tighten either screw at this time.
f. Repeat steps 5.5 i. through 5.5 q.

5.7 REPLACE THE MAIN COIL

To replace the main coil, proceed as follows:

a. Lock the mass
b. Remove the cover per paragraph 3.3.1.
c. Place the seismometer upside down on a level working surface. Be careful not to damage connector or wires.
d. Remove the three legs (24). CAREFULLY remove magnet support plate (12) and magnet assembly (4) as a unit. Be careful not to damage coil.
e. Unsolder the wires from the terminals on the coil.
f. Remove the three 6-32 x 5/16 socket head screws (98) and remove coil and mounting plate (10) as a unit.
g. Unscrew the three 10-32 x 1/2 flat-head screws (103) and remove the main coil (1) from the mounting plate (10).
h. Place the new coil assembly in position and secure it in place with the three 10-32 x 1/2 flat-head screws.
i. Reinstall the coil and mounting plate assembly onto the three support rods (28) with the 6-32 x 5/16 socket-head screws (98).
j. Solder the leads to the new coil terminals per the wiring diagram, figure 6-12.
k. Carefully replace the magnet and mounting plate assembly being very careful not to damage the coil.
l. Set the seismometer vertical right side up and unlock mass. If coil drags, loosen the 1/2-20 x 3/4 hex head screw (75) in the

center of the mounting plate and the six 4-40 x 3/4 socket head screws (94) in the magnet mounting plate. Move the magnet around until coil does not drag then tighten center screw (75) and then tighten the 4-40 x 3/4 socket head screws. If there is not enough clearance, see next step m.

m. In the event that there is not enough clearance to allow the magnet to be centered, loosen the 6-32 x 5/16 screws (98) holding the coil mounting plate to the support rod and move the coil and magnet until the mass does not drag then tighten all screws.
n. Lock the mass and replace the cover.

5.8 CLEANING THE GAP

To clean the air gap, remove the magnet (see paragraph 5.7, steps a. through d.). Clean out the dust, dirt, and nonmagnetic particles with a soft brush. Remove the magnetic particles with a nonmetallic rod tipped with masking tape. Take care at all times to avoid causing nicks or burrs in the gap or at its edges. When the gap is clean, replace the magnet (see paragraph 5.7, steps k. through n.).

5.9 REPLACING THE CAPACITOR ASSEMBLY

The capacitor assembly should be removed only if it is suspected that foreign matter is in the gap. To adjust gap only see paragraph k. below.

To replace the capacitor sensor assembly, proceed as follows:

a. Lock the mass.
b. Remove the cover per paragraph 3.3.1.
c. Remove the spring assembly (6) that is opposite both printed circuit boards per paragraph 5.5. Remove cantilever beam (11) and flexures (32 and 33) by removing screws (86, 87) and clamps (31). Be careful not to kink flexures. Remove the upper delta rod (3) per paragraph 5.4.
d. Disconnect the wire from the amplifier board (53) pin E1 to the terminal on the frame capacitor (16). Disconnect the three coiled magnet wire lead (38) from the terminals CC, CD and terminals 1 and 2 on the frame capacitor (16). Remove circuit board (53) and mounting plate (52).
e. Disconnect the two wires that go from the oscillator board (54) pins E9 and E7 to the two terminals on the frame capacitor (16). Remove circuit board (54) and mounting plate (52).
f. With a 5/8 socket wrench, remove the mass capacitor screw (17).
g Place a rod or other suitable tool in the hole at the top circumference of the frame capacitor (16) to prevent it from turning. Using a spanner wrench, loosen the frame capacitor support nut (36) and remove it. Hold frame capacitor support so that it does not fall and damage the terminals on the mass capacitor (13). Slide the mass capacitor (13) up into the frame capacitor (16) and remove from the seismometer.
h. Separate the capacitor halves from each other and examine for any foreign matter that may cause shorting or jamming of the brass rings. Inspect for burrs or other damage to the brass rings.

Small burrs may be smoothed down with a fine file or stone. Nominal radial clearance between the rings is .007 in. (.178 mm). Rings that have been severly damaged such that they are out-of-round or warped should be replaced.

i. To replace capacitor assembly, slide the two halves together and place them inside the seismometer while supporting the frame capacitor (16). Start the frame capacitor nut (36). Align the terminals on the frame capacitor with the oscillator board (54) and tighten the nut (36) securely with the spanner wrench while holding the capacitor with a rod in the hole at the top.

j. Align terminal on mass capacitor with amplifier board and install the frame capacitor screw (17) and tighten it lightly. By shining a light through the top of the seismometer and past the frame capacitor screw, you can see the gap between the brass rings of the capacitor sensor. Unlocking the mass and moving it up and down will highlight the gap. The mass capacitor can be centered in the frame capacitor by lightly tapping around the circumference of its base. Be careful not to damage terminals or magnet wire leads. How hard to tap depends on the tightness of the frame capacitor screw, and some patience and trial and error is required.

   When the capacitor spacing is properly adjusted, the gap will appear as a uniform dark line all around the inside circumference about the width of a pencil line. Unlocking the mass and moving it up and down while observing the gap will accentuate the dark line or shadow of the gap. When the gap is properly adjusted, lock the mass and tighten the mass capacitor screw securely (90 to 100 in-lbs/, 10 to 11 n-m).

   It is important to have the gap visibly uniform. If the capacitor spacing is off center visibly and even though mass movement is free, improper operation may occur. Off center capacitor alignment may result in an unstable frequency response and cause oscillation at 100 to 120 Hz.

k. Rotate the seismometer from vertical to horizontal , unlock the mass, and move it back and forth by hand. It should not drag. If it does, repeat the capacitor adjusting procedure described in paragraph k.

l. Reassemble the remaining parts in reverse order. Make sure that flexure clamps are aligned square and that all screws are tight.

m. Replace cover per paragraph 3.3.1.

6. SPECIFICATIONS AND CHARACTERISTICS

The Broadband Seismometer, BB-13, specifications and typical instrument characteristics are included in this section. Since each instrument will vary within these specifications, those wishing to make precision measurements are urged to calibrate their instruments to their requirements as described in section 4 of this manual.

6.1 SPECIFICATIONS

6.1.1 Operating Characteristics

Mode of Operation	Horizontal or Vertical, convertible
Bandwidth (Frequency Response)	dc to 20 Hz (See figure 6-1 to 6-6)
Sensitivity	1000 V/g (102 v-sec^2/m) Standard
Noise Spectra Referred to Ground Acceleration	2 x 10^{-18} (m/sec^2)^2/Hz (also see figure 6-7)
Clipping Level	
Amplitude	.01 g (.098 m/sec^2)
Tilt (Horizontal)	.01 radian (.57 degrees)
Dynamic Range	Greater than 160 dB @ frequencies <.5 Hz (rms noise in 1/2 octave bandwidth to rms clipping) See figure 6-8
Mass	5 kg
Calibration Sensitivity	
Acceleration	1 milli-g/volt STD
Velocity	4 (micrometer/sec)/volt STD
Harmonic Distortion	Less than .005 percent (two frequency test)

6.1.2 Power Requirements

Voltage	±15 V or 12± V Convertible with internal jumpers
Current	25 mA @ ±15 Vdc nominal

6.1.3 Output Characteristics

Clipping Voltage	10 V
Output Impedance	100 ohm

6.1.4 Physical Characteristics

Basic Dimensions

VERTICAL	
Height	.52 m (20.5 in.)
Diameter	.19 m (7.5 in.)
Net Weight	20.4 kg (45 lbs.)

6.1.5 Connectors

Input/Output	Bendix PT02A-14-18P

6.2 RESPONSE CURVES

Various response curves and noise level curves of a typical instrument are shown in figures 6-1 through 6-8.

6.3 WIRING DIAGRAMS, SCHEMATICS, DRAWINGS

Wiring diagrams, schematics, and mechanical details are described by figures 6-9 through 6-12. Also see figures 2-3 through 2-5.

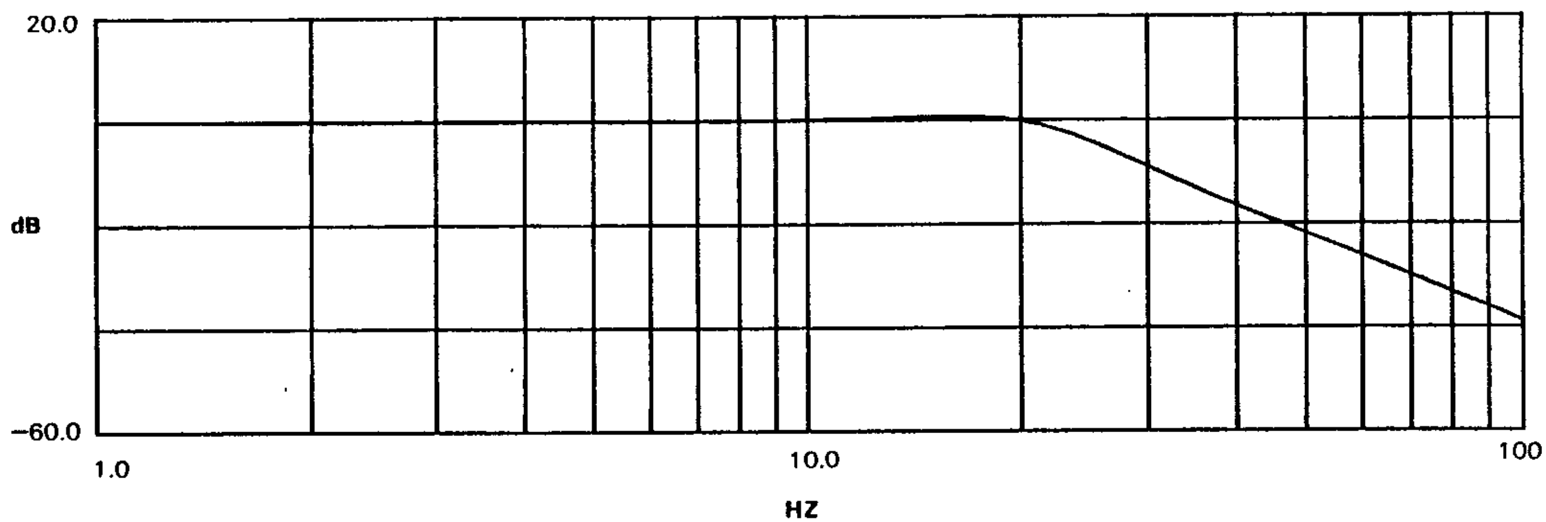


Figure 6-1. Acceleration Amplitude Response

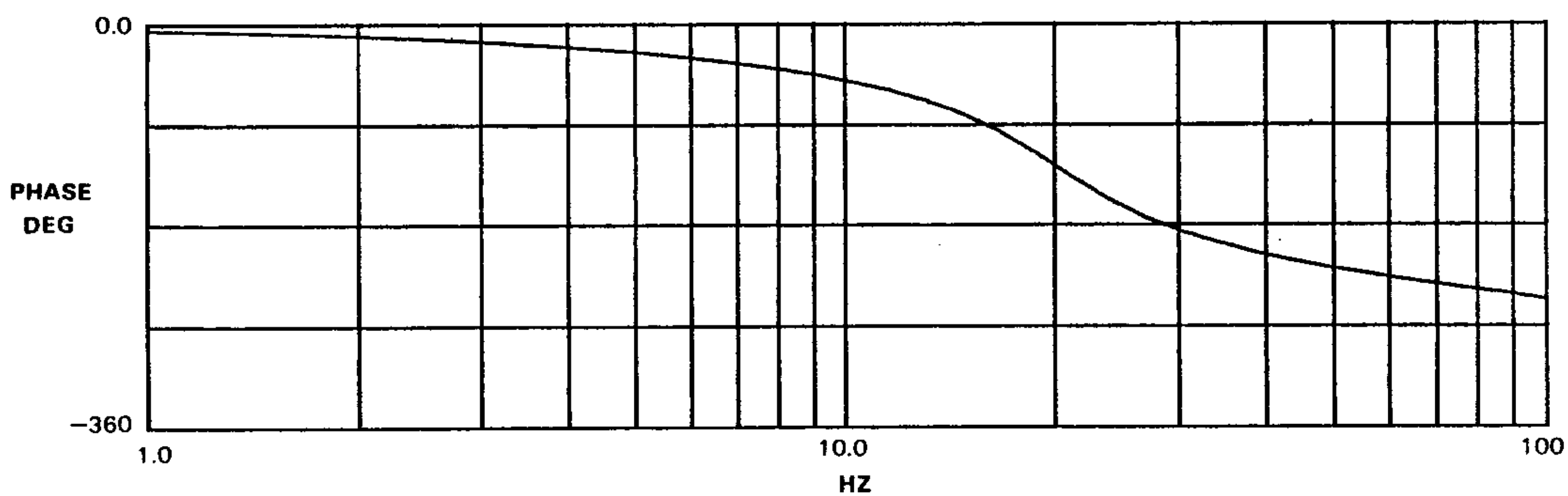


Figure 6-2. Acceleration Phase Response

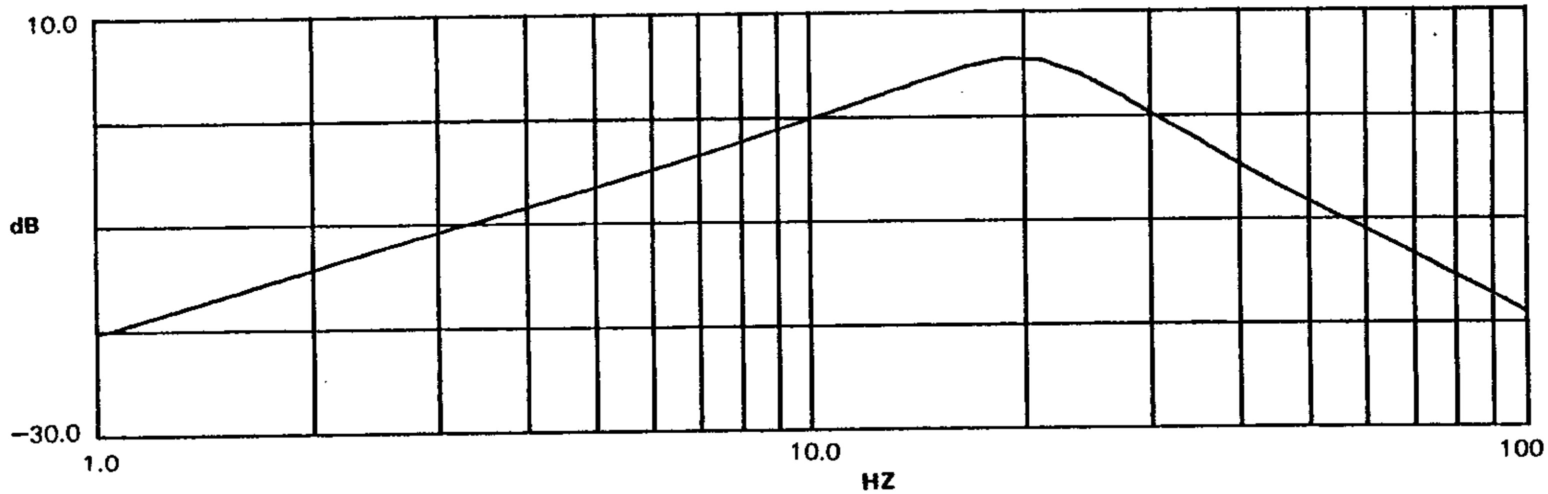


Figure 6-3. Velocity Amplitude Response

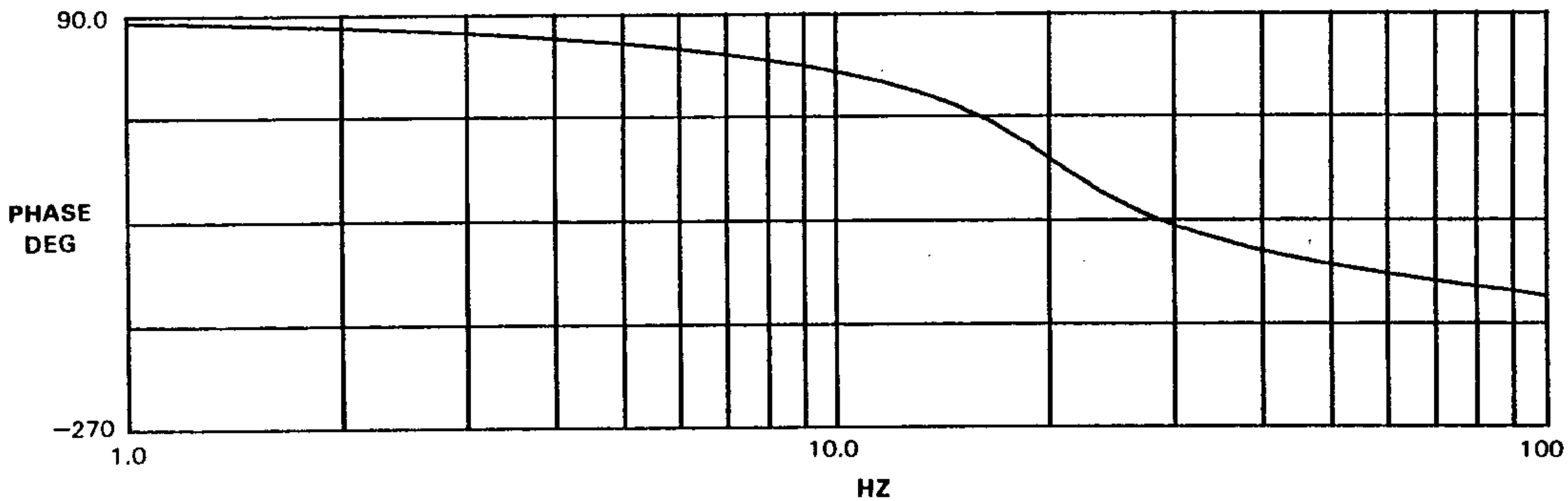


Figure 6-4. Velocity Phase Response

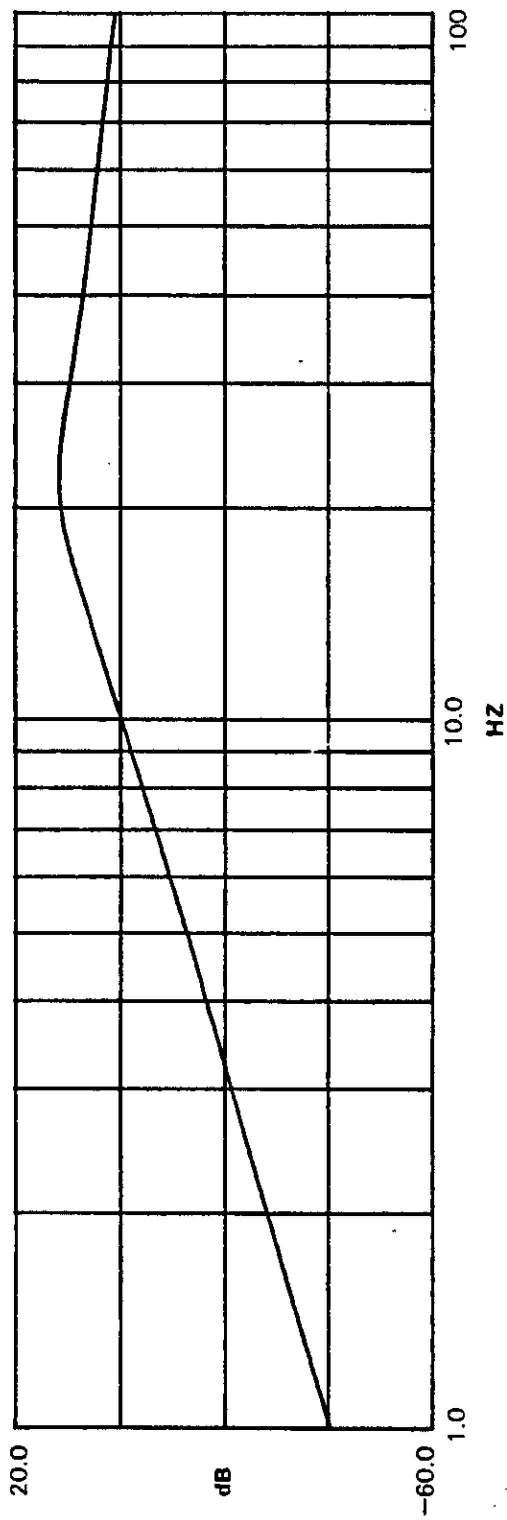


Figure 6-5. Displacement Amplitude Response

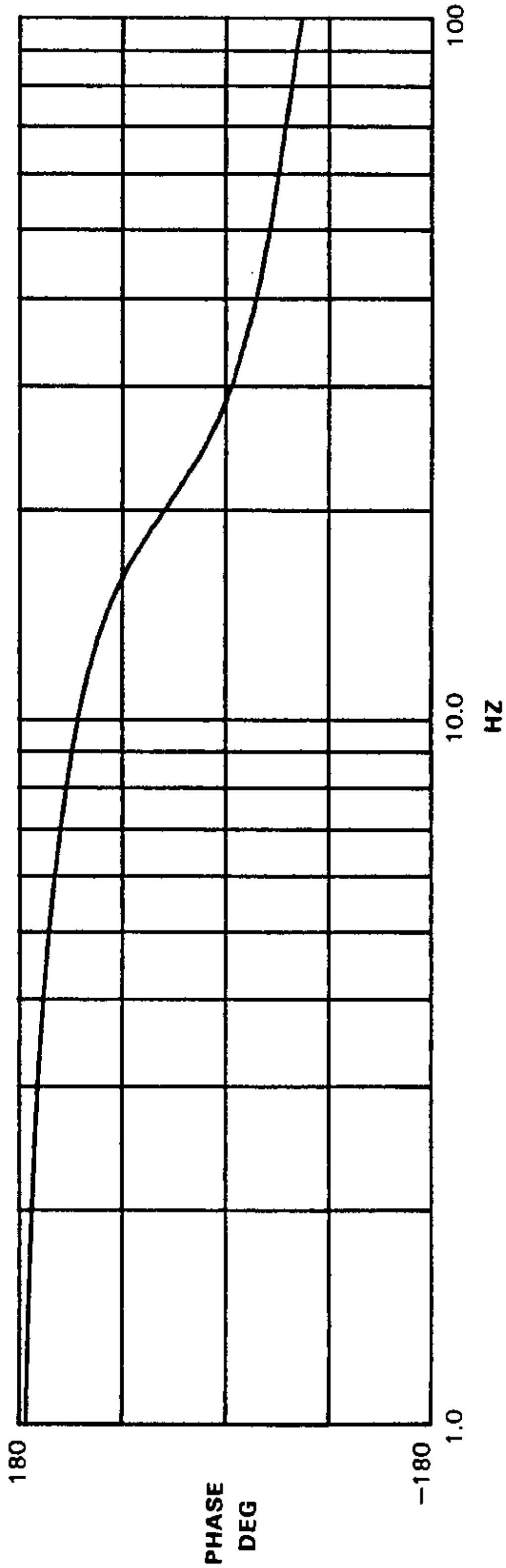


Figure 6-6. Displacement Phase Response

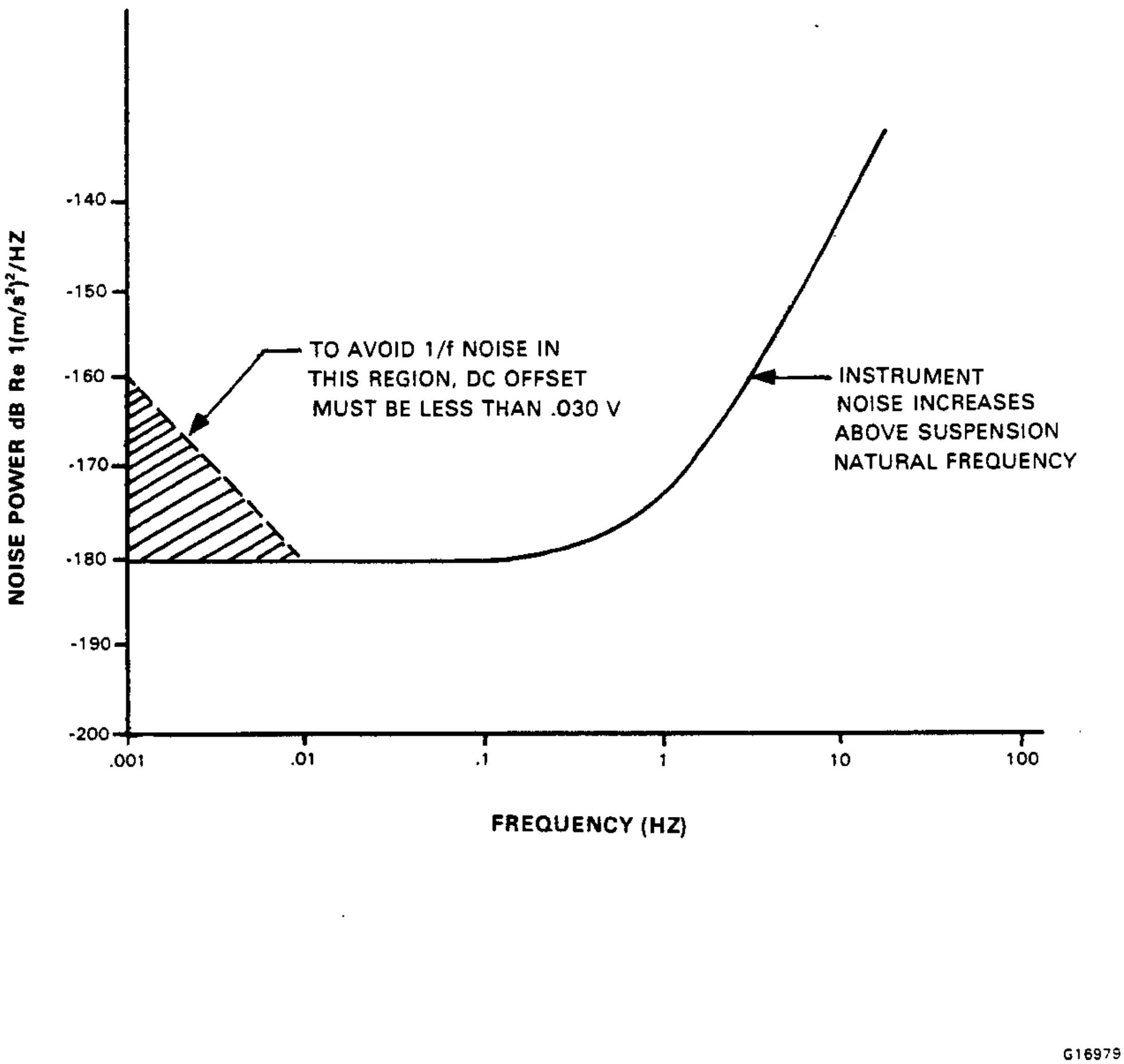


Figure 6-7. BB-13 Typical Instrument Noise

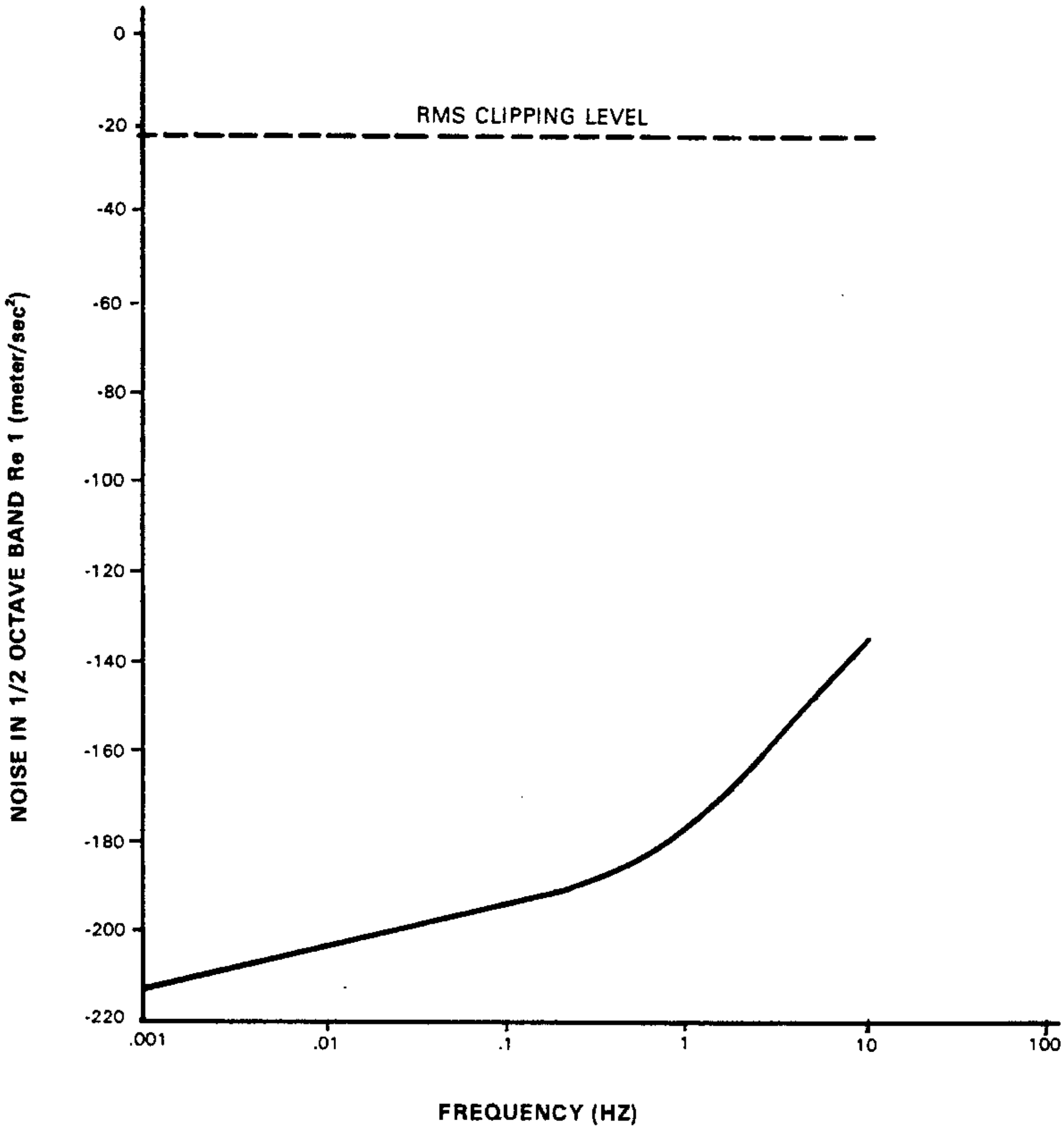


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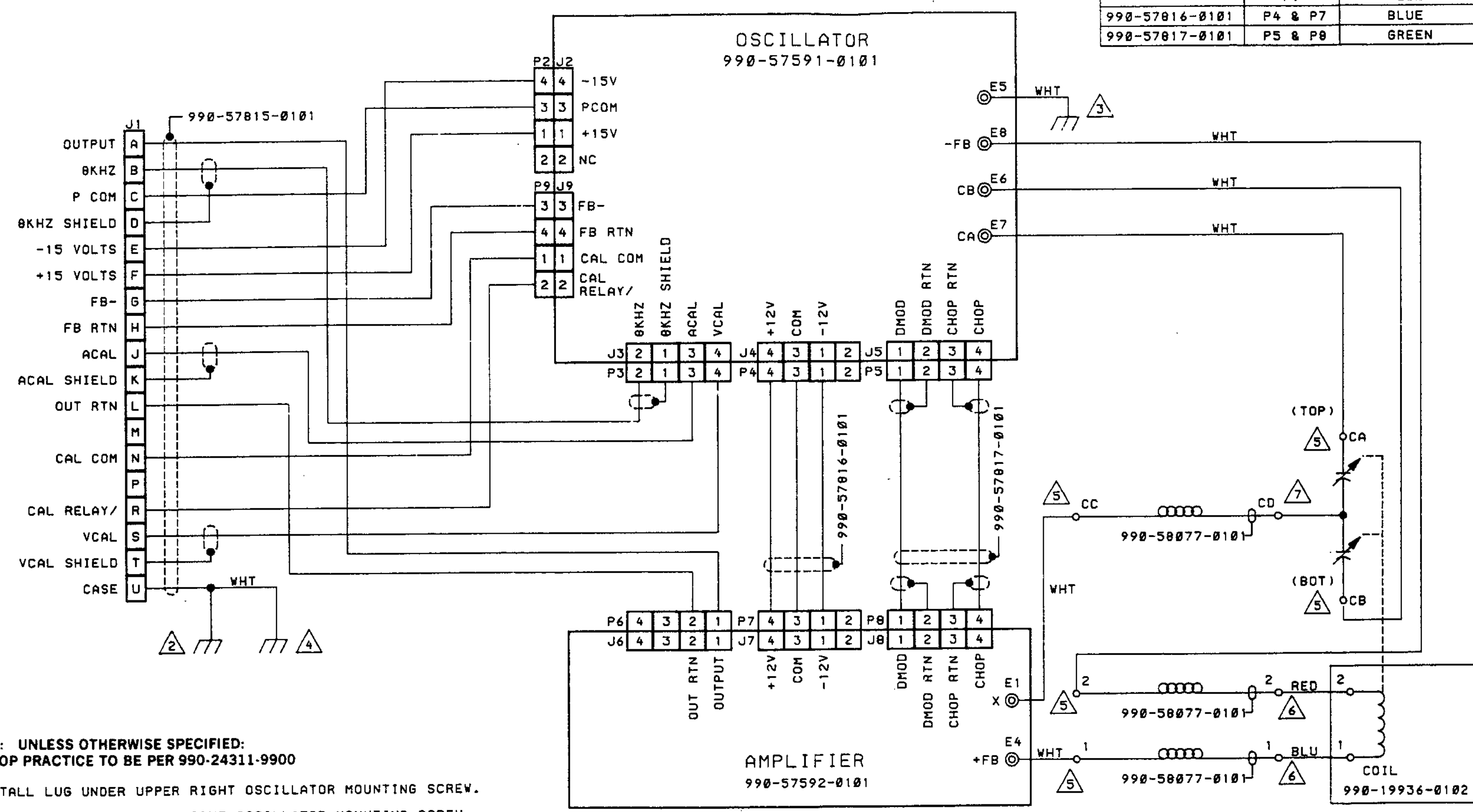
Figure 6-8. BB-13 Noise In One-Half Octave Frequency Band

CABLE IDENTIFIER		
PART NO.	CONNECTOR	PAINT DOT COLOR
990-57815-0101	P2	VIOLET
	P3	WHITE
	P6	ORANGE
	P9	YELLOW
990-57816-0101	P4 & P7	BLUE
990-57817-0101	P5 & P8	GREEN



NOTES: UNLESS OTHERWISE SPECIFIED:
1. SHOP PRACTICE TO BE PER 990-24311-9900

2. INSTALL LUG UNDER UPPER RIGHT OSCILLATOR MOUNTING SCREW.
3. SOLDER TO LUG AT UPPER RIGHT OSCILLATOR MOUNTING SCREW.
4. SOLDER TO LUG AT BOTTOM OF MAGNET MOUNTING PLATE.
5. TERMINALS ARE LOCATED ON 990-57840-0101 FRAME CAPACITOR.
6. TERMINALS ARE LOCATED ON 990-58073-0101 MASS.
7. TERMINAL IS LOCATED ON 990-57854-0101 CAPACITOR ASSEMBLY.

Figure 6-9. Wiring Diagram Internal, Drawing Number 990-57760-2101

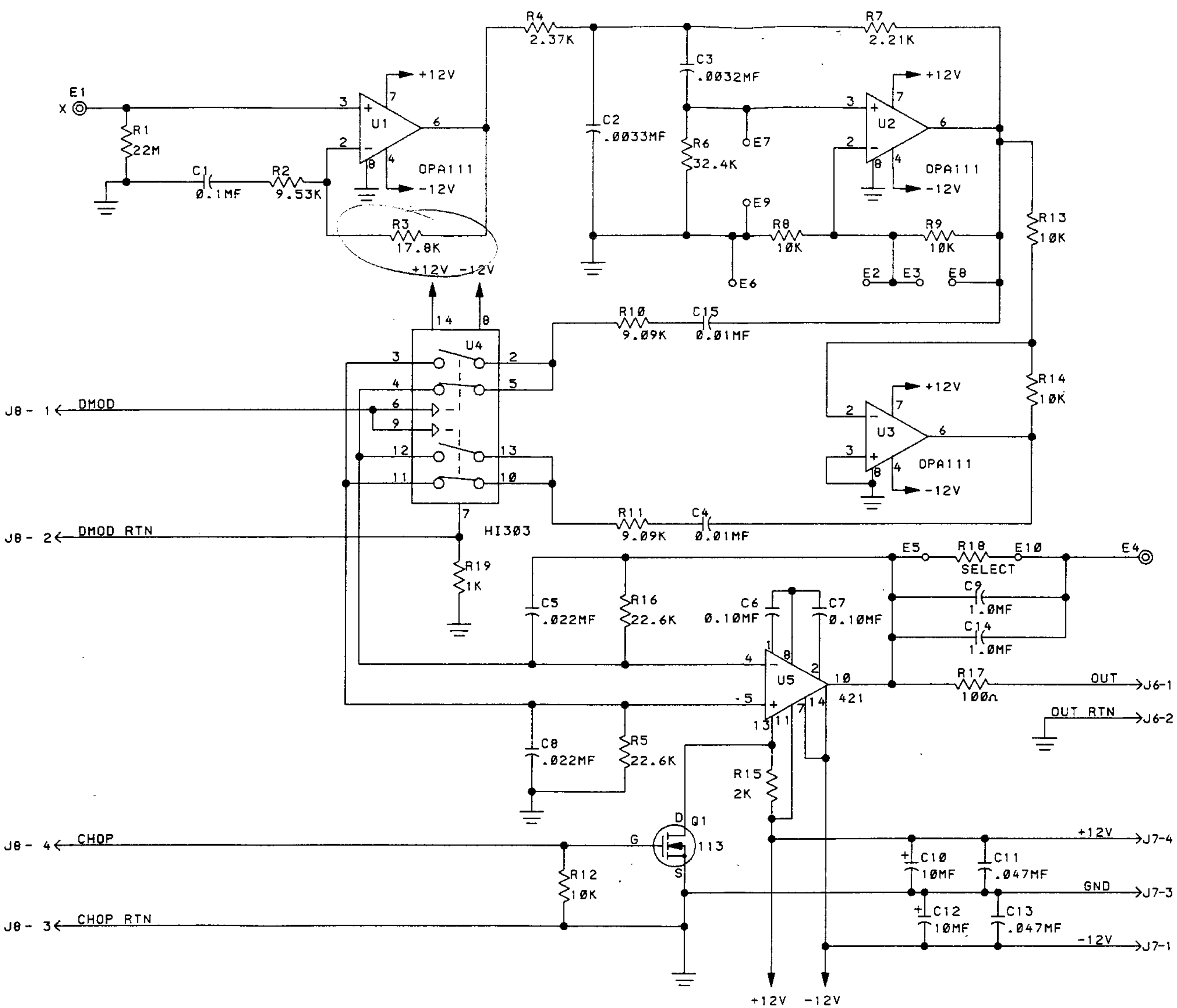


TABLE 2

HIGHEST REFERENCE DESIGNATOR USED	
C15	
E10	
Q1	
R18	
U5	

REFERENCE DESIGNATORS NOT USED	

Figure 6-10. Schematic - Amplifier, Drawing Number 990-57592-2101

M-57760

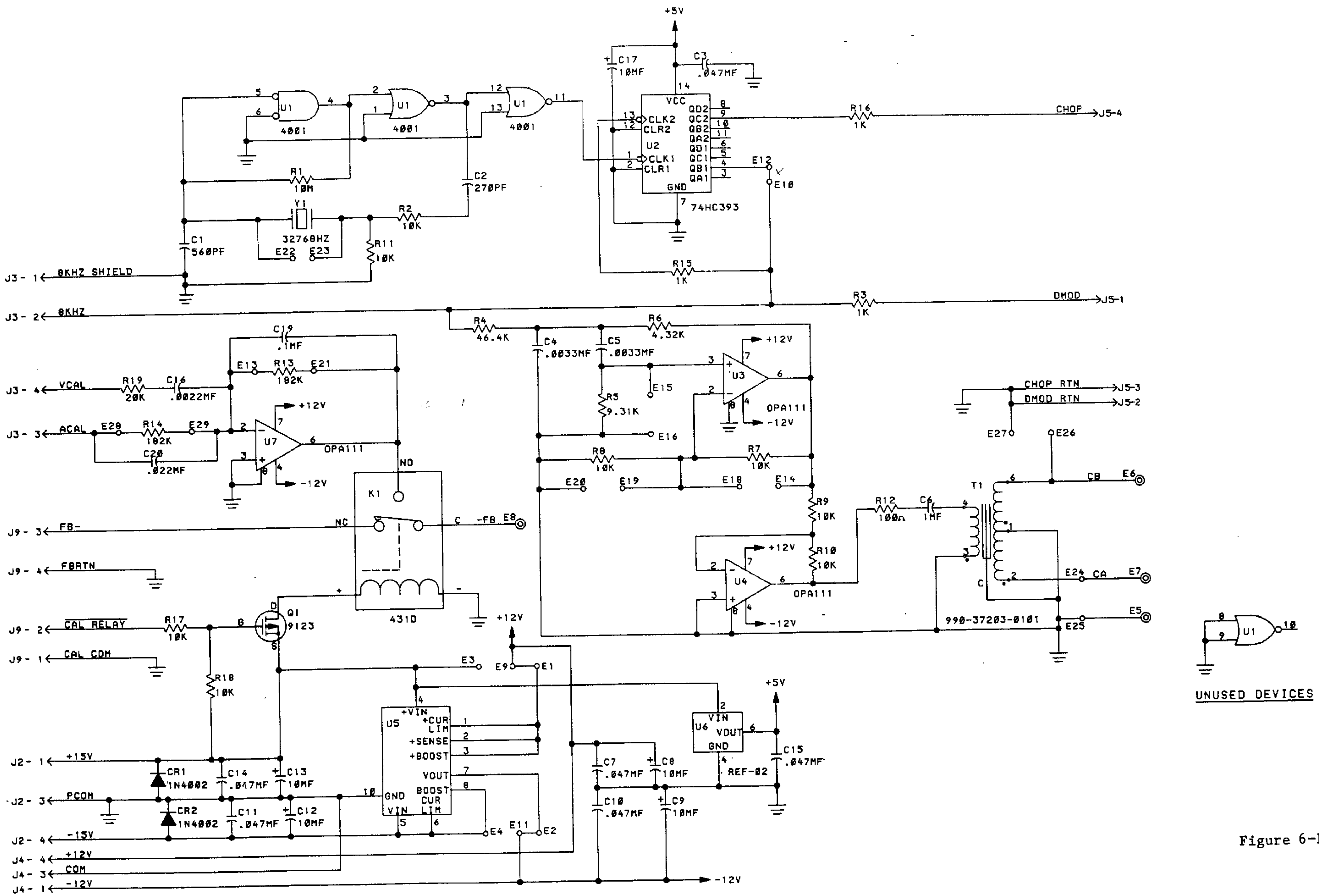


TABLE 2

HIGHEST REFERENCE DESIGNATOR USED	
C20	R19
CR2	T1
E29	U7
J9	Y1
K1	
Q1	

REFERENCE DESIGNATORS NOT USED	
J1,J6-J8	
E17	
C18	

PWR/GND TBL		
GND	DES	PWR
		+5V
7	U1	14

Figure 6-11. Schematic - Oscillator, Drawing Number 990-57591-2101

M-57760

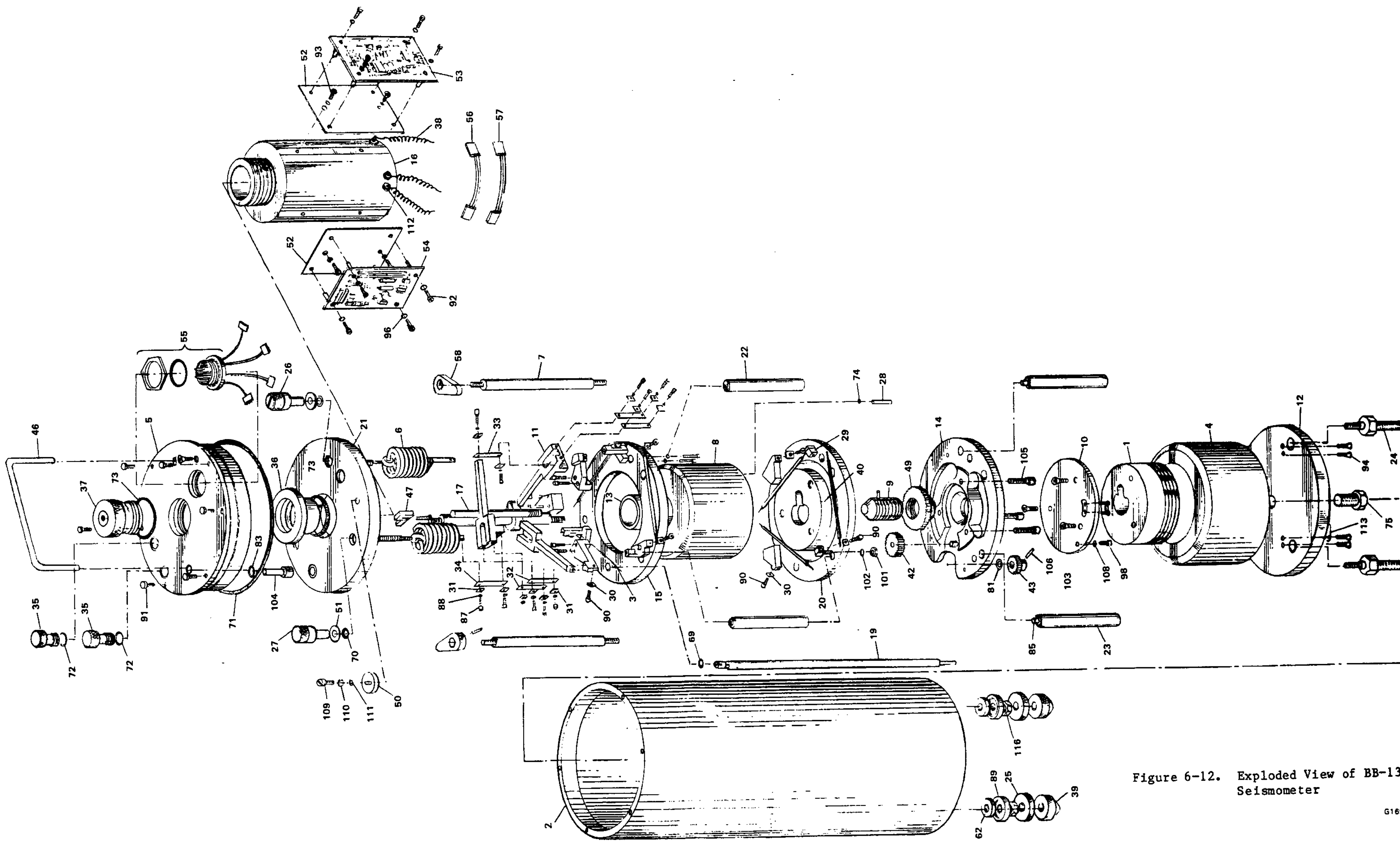


Figure 6-12. Exploded View of BB-13 Seismometer

G16996

6-15/16

M-57760

7. PARTS LIST

7.1 GENERAL

Listings in the Table of Replaceable Parts, Table 7-1, constitute a partial breakdown of the seismometer. Included are all electrical parts and those operative mechanical parts that are subject to loss or failure. Item numbers refer to figure 6-12.

Table 7-1. Table of Replaceable Parts

Item	Part Number	Description	Qty
1	990-19936-0102	Main Coil Assembly (3600 Ohm)	1
2	990-57866-0101	Case Assembly	1
3	990-19959-0101	Delta Rod Assembly	6
4	990-20346-0101	Magnet Assembly	1
5	990-57863-0101	Plate, Top Cover	1
6	990-20347-0101	Spring Assembly	3
7	990-19944-0101	Upper Frame Spacer Assembly	3
8	990-58073-0101	Mass - BB-13	1
9	990-20350-0101	Lock Assembly, Mass	1
10	990-58064-0101	Plate - Coil Support	1
11	990-20572-0102	Cantilever Assembly	3
12	990-58065-0101	Plate - Magnet Support	1
13	990-57854-0101	Capacitor Assembly - Mass	1
14	990-58067-0101	Base Assembly, Mass Lock	1
15	990-21085-0101	Middle Frame Plate Assembly	1
16	990-57848-0101	Frame Capacitor Assembly	1
17	990-57849-0101	Bolt - Mass Capacitor	1
18	990-04950-0102	Nameplate	1
19	990-57859-0101	Shaft - Mass Lock	1
20	990-19940-0101	Plate - Lower Frame	1
21	990-58074-0101	Plate - Upper Frame	1
22	990-58059-0101	Spacer - Lower Frame	3
23	990-58061-0101	Spacer - Magnet Support	3
24	990-19949-0101	Leg	3
25	990-19950-0101	Ring, Lock	3
26	990-58072-0101	Nut - Spring Tension Adjust	1
27	990-19952-0101	Nut, Spring Tension Adjust	2
28	990-58062-0101	Support Rod - Coil	3
29	990-19963-0101	Lower Delta Rod to Base Clamp	3
30	990-19964-0101	Clamp, Delta Rod	12
31	990-19965-0101	Clamp, Flexure	24
32	990-19971-0101	Vertical Flexure Cantilever to Base	6
33	990-19973-0101	Vertical Flexure Cantilever to Mass	3
34	990-19974-0101	Flexure, Vertical Cantilever to Spring	3
35	990-58066-0101	Plug, Mass Position	2
36	990-57844-0101	Nut - Frame Capacitor	1
37	990-58075-0101	Cap Assembly - BB-13	1
38	990-58077-0101	Pigtail	3
39	990-19989-0102	Stainless Steel Foot	3
40	990-58063-0101	Plate - Gear Retainer	1
42	990-20200-0101	Spur Gear - Idler	1
43	990-20201-0101	Gear, Drive	1
46	990-20515-0101	Handle	1
47	990-20571-0101	Guide, Spring	3
49	990-20349-0101	Support, Mass Lock	1
50	990-58078-0101	Foot - Upper Horizontal	1

Table 7-1. Table of Replaceable Parts, Continued

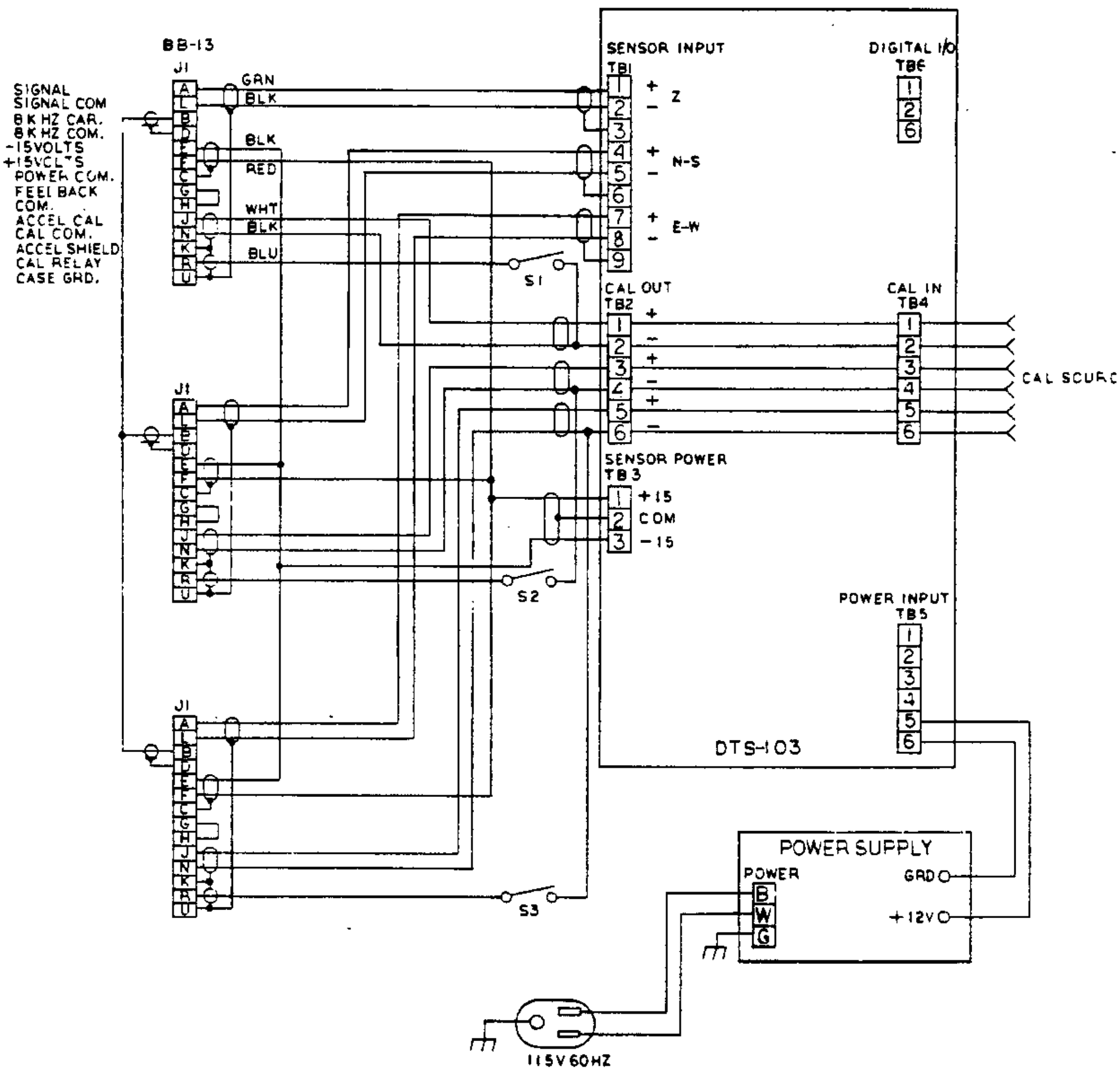
Item	Part Number	Description	Qty
51	990-20857-0101	Washer	3
52	990-57851-0101	Plate, PC Board Mount	2
53	990-57592-0101	Amplifier	1
54	990-57591-0101	Oscillator BB Seismometer	1
55	990-57815-0101	Cable Assembly, J1-P2-P3-P6-P9	1
56	990-57816-0101	Cable Assembly P4 and P7	1
57	990-57817-0101	Cable Assembly, P5 and P8	1
58	990-20659-0101	Cantilever Stop	3
62	990-19951-0101	Retainer, Seal	3
69	042-11227-0500	Packing, Preformed (O-Ring)	1
70	042-11227-0800	Packing, Preformed (O-Ring)	3
71	042-11166-6747	Packing, Preformed (O-Ring)	1
72	042-11205-6747	Packing, Preformed (O-Ring)	2
73	042-11227-2300	Packing, Preformed (O-Ring)	1
74	035-47018-0600	Setscrew, Socket Head, Cup PT, 18-8 SST, 6-32 x 3/8 Lg	3
5	035-07061-1200	Screw, Machine (Cap) Hex Head SST, 1/2-20 x 3/4 Lg	1
81	038-68968-7200	Washer, Nylon, Natural Color	1
83	038-61100-1000	Washer, Sealing, Static, No. 10	2
85	035-47041-1600	Setscrew, Socket Head, Cup Point, 18-8 SST, 1/4-20 x 1 Lg	3
86	035-01007-0600	Screw, Machine (Cap), Socket Head, 18-8 SST, 2-56 x 3/8 Lg	9
87	035-01007-0400	Screw, Machine (Cap), Socket Head, 18-8 SST, 2-56 x 1/4 Lg	15
88	038-56106-0000	Washer, Lock, Internal Tooth 430 SST, No. 2	24
89	990-21340-0101	Gasket, Leg	3
90	035-01013-0400	Screw, Machine (Cap), Socket Head, 18-8 SST, 4-40 x 1/4 Lg	12
91	035-01013-0600	Screw, Machine (Cap), Socket Head, 18-8 SST, 4-40 x 3/8 Lg	6
92	035-25013-0800	Screw, Machine, Pan Head, Slotted 18-8 SST, 4-40 x 1/2 Lg	8
		crew, Machine, Pan Head, Slotted 18-8 SST, 8-32 x 1/4 Lg	4
94	035-01013-1200	Screw, Machine (Cap), Socket Head 18-8 SST, 4-40 x 3/4 Lg	6
96	038-56108-0000	Washer, Lock, Internal Tooth 400 Ser SST, No. 4	15
97	035-01018-0800	Screw, Machine (Cap), Socket Head 18-8 SST, 6-32 x 1/2 Lg	3
98	035-01018-0500	Screw, Machine (Cap), Socket Head 18-8 SST, 6-32 x 5/16 Lg	3
101	035-02021-0000	Nut, Hex, Chamfered Corner 18-8 SST, 8-32 (11/32 AF x 1/8 THK)	3

Table 7-1. Table of Replaceable Parts, Continued

Item	Part Number	Description	Qty
102	038-56111-0000	Washer, Lock, Internal Tooth 430 SST, No. 8	7
103	035-17025-0800	Screw, Machine, Flat Head (82) Phillips, 18-8 SST, 10-32 x 1/2 Lg	3
104	035-25025-1600	Screw, Machine, Pan Head, Slotted 18-8 SST, 10-32 x 1 Lg	2
105	035-01025-1200	Screw, Machine (Cap), Socket Head 18-8 SST, 10-32 x 3/4 Lg	3
106	039-02606-1600	Pin, Roll (Spring) Beryllum Copper, 3/32 Dia x 1/2 Lg	1
108	038-56110-0000	Washer, Lock, Internal Tooth 400 Ser SST, No. 6	3
109	035-25041-0800	Screw, Machine, Socket Head, 18-8 SST, 1/4-20 x 1/2 Lg	1
110	038-56118-0000	Washer, Lock, Internal Tooth 430 SST, 1/4 Id	1
111	038-50018-0000	Washer, Flat, 18-8 SST, No. 1/4 (1/2 Od x .063 Thk)	1
112	008-20141-6400	Lug, Solder	1
113	008-22014-8037	Terminal, 4-40 Thd,	6
116	038-21053-0000	Nut, Jam, Hexagon, 18-8 SST, 3/8-24 (.218 Thk)	3
200	990-58098-0101	Accessory Kit, Model 57760	1
201		Connector	
202	990-57760-9800	Operation Manual	1
203	990-58094-0101	Shipping Crate 57760 Seis	1
900	990-58082-0101	Cradle Assembly - Horizontal	1

APPENDIX A

CONNECTING BB-13 TO DTS-100



Typical Connection BB-13 to DTS-100