OPERATION AND MAINTENANCE MANUAL
HORIZONTAL LONG-PERIOD SEISMOMETER, MODEL SL-220

TELEDYNE GEOTECH
3401 Shiloh Road
Garland, Texas 75041

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ILLUSTRATIONS

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1. GENERAL DESCRIPTION

1.1 PURPOSE OF THE EQUIPMENT

The Long-Period Horizontal Seismometer, Model SL-220 (figure 1-1), is an extremely sensitive electro-mechanical transducer which converts very low frequency horizontal motion into an electrical output. The 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 amplifiers.

1.2 DESCRIPTION OF EQUIPMENT

The seismometer, Model SL-220, 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 intergral 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 a microvolt can be used with this instrument. Solid-state amplifiers with these characteristics are available.

The unit is lightweight and compact. The suspension system is mounted on a rigid cast base and enclosed by a cast aluminum cover. The unit is sealed against wind and insects but not against water and barometric pressure changes.

1.3 SPECIFICATIONS

1.3.1 Operating Characteristics

Natural Period	Adjustable from 10 to 30 seconds nominal period 20 seconds
Transducer	
Type	Single moving coil (velocity)
Effective generator constant	90 ± 4.5 volts/meter/second
Damping	Electromagnetic
Maximum mass travel	±10 mm
Signal Coil	
Terminal resistance	1200 ± 120 ohms at 20°C (68°F)
Calibration Coil	
Terminal resistance	5 ohm max at 20°C (68°F)
Motor constant	0.028 ±.003 newton/ampere
Average Flux Density	0.170 weber/meter^2 (1700 gauss)
Weight of Inertial Mass	2 kilograms
Critical Damping Resistance	6875 ohms at 20 sec ±10%

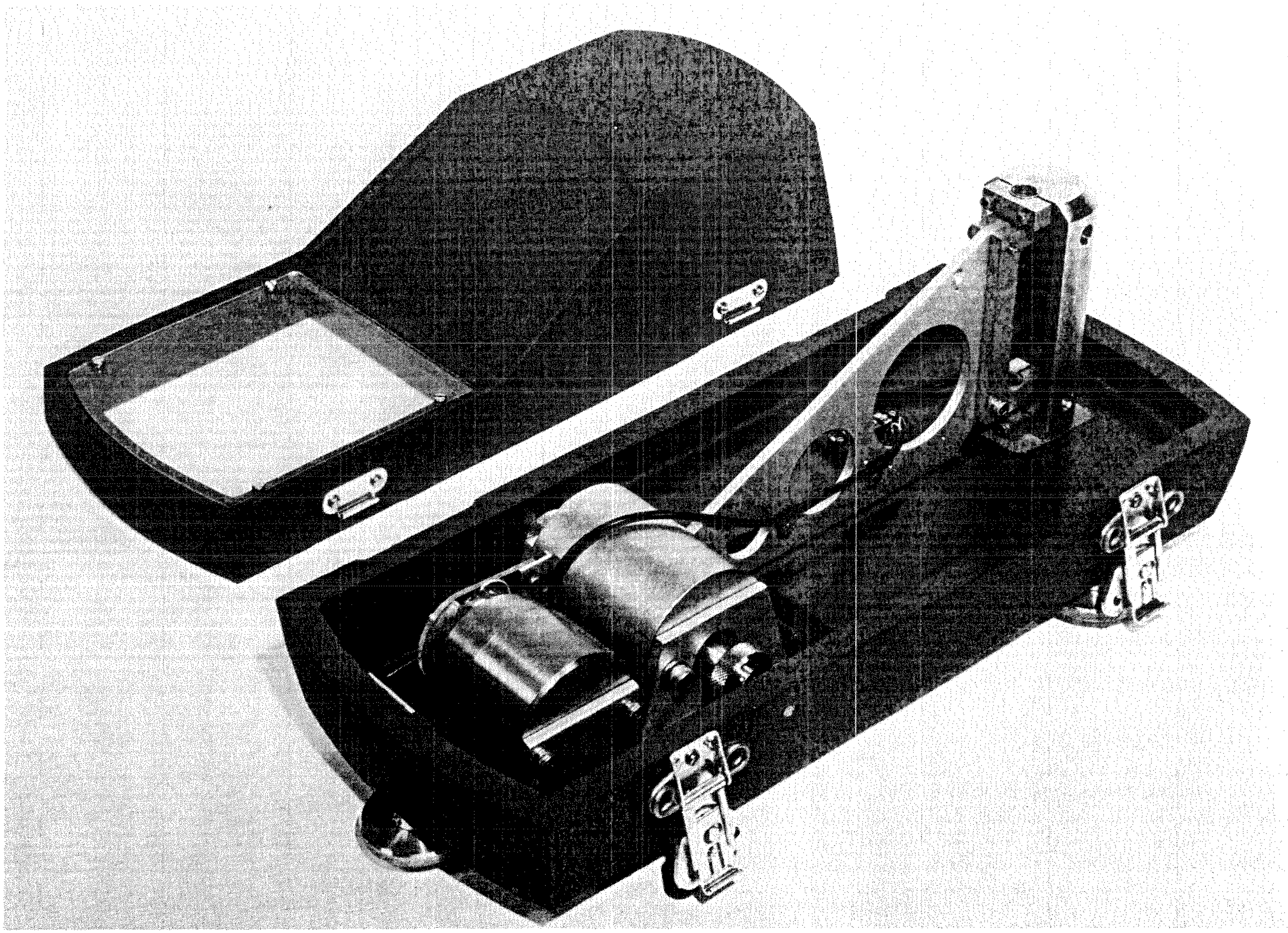

Figure 1-1. Long-Period Horizontal Seismometer, Model SL-220

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1.3.2 Physical Characteristics

Height	176 mm (6.93 in.)
Width	194 mm (7.64 in.)
Length	412 mm (16.22 in.)
Net weight	10 kg (22 lb.)
Shipping weight	15 kg (33 lb.) estimated
Shipping volume	5.66 x $10^{-2}m^3$ (a ft^3)

1.3.3 Environmental

Suitable for portable sheltered equipment operation.

Temperature	
Operating	-20°C to 60°C (-4°F to 140°F)
Storage	-50°C to 60°C (-60°F to 140°F)
Shock and Vibration	When properly packed will withstand shock and vibration normally encountered in shipment and 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.)

1.3.4 Connectors

Signal Output	Bendix PT02A-18S mating to PT06E-14-18P (SR)

1.4 EQUIPMENT FURNISHED

Horizontal Long-Period Seismometer, Model SL-220, Operation and Maintenance Manual

Mating Connector: Bendix PT06A-14-18P (SR)

Customer Data Sheet, Part Number 990-28700-96-01

Weight Lift Jig Assembly, Part Number 990-32914-01-01

One-Half Inch Flexure Alignment Tool, Part Number 990-32203-01-01

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 data received; and the carrier involved. When damage in shipment is evident, file a claim with the carrier immediately.

2.2 LOCATION OF INSTRUMENT

Specific procedures and techiques 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.

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.

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 loose debris and dust.

b. Screw out the three leveling feet four turns. The two rear legs are to be used to adjust the mass position and the front leg is used to adjust the period.

c. Set the seismometer in the prepared location.

d. Level the seismometer by removing the cover and placing a bubble level on the surface where the cover rested, then adjust the leveling feet until the surface is level in all directions.

e. Screw the front leveling foot in about three turns. Check to see that there is about one turn left to screw in for future period adjustment.

CAUTION

In performing step f, do not pull up on the mass or damage to the flexure may result.

f. Make sure the mass limit stops are tight against the mass, then remove the four shipping bolts from the mass.

g. Remove the four shipping bolts holding the two shipping brackets to the base of the seismometer, and remove the shipping brackets.

h. Replace the four shipping bolts in the base of the seismometer, to prevent debris, dust, and particularly insects from entering the seismometer.

i. Make electrical connections to the seismometer using the connector supplied and the information in figure 2-1.

j. Adjust the mass limit stops until the mass can travel 10 mm to the left and right of zero as indicated by the pointer and scale. Move the mass by hand (gently) to determine this setting.

k. Manually center the mass. Release and observe the direction of travel. Adjust either one of the back legs to counteract this motion.

l. Repeat step k until the mass drifts off center very slowly or remains stationary. This is a coarse adjustment and will be somewhat upset by the next step.

m. Replace the cover being careful not to strike any of the internal parts or move the instrument. Close the latches.

n. Connect a 1000 to 1500 ohm damping resistor across the main coil. Center the mass by carefully adjusting the height of either one of the back legs. Set the instrument to the desired center period by using the front leg to tilt the instrument back toward level.

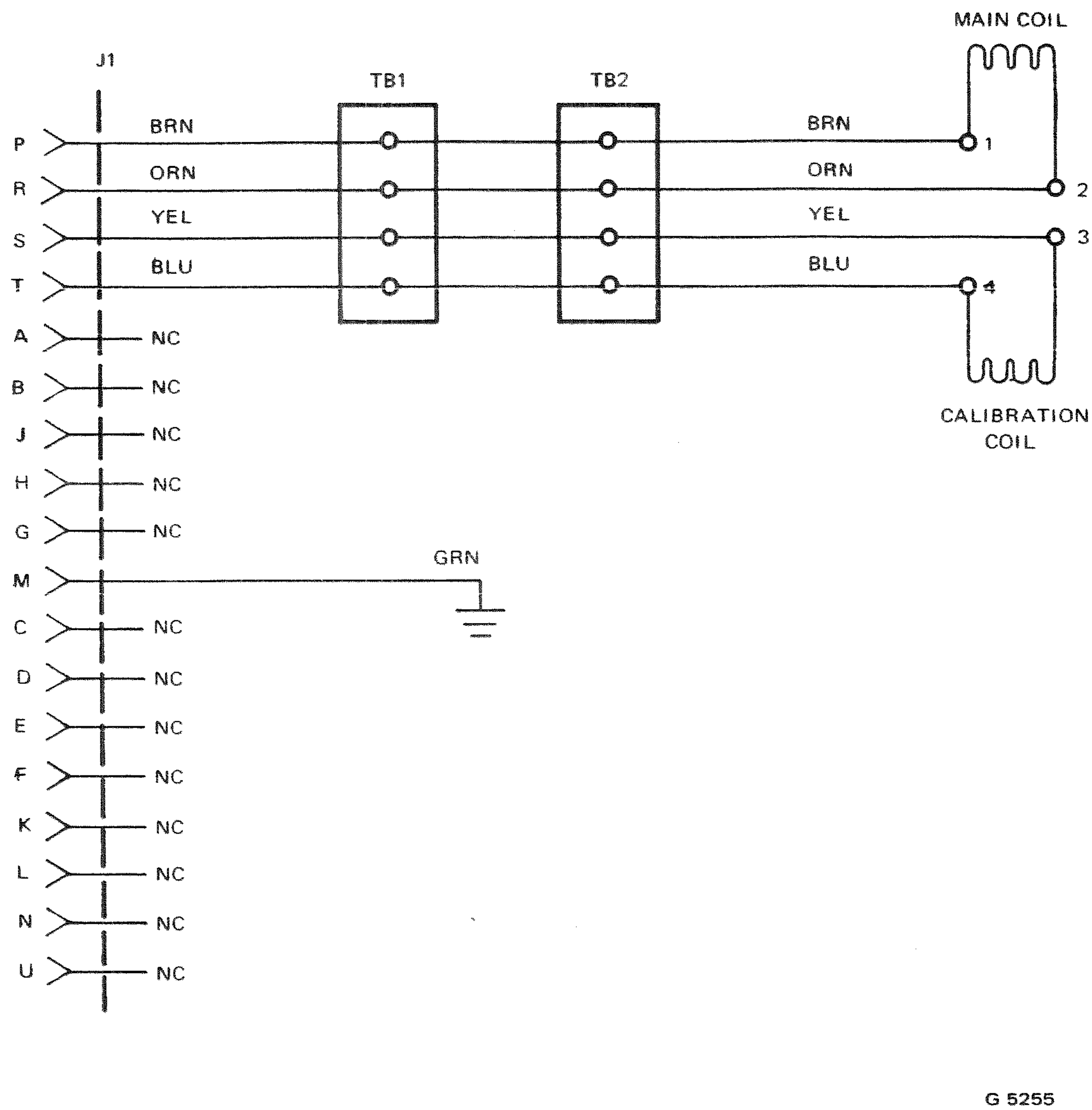

Figure 2-1. Wiring Diagram

3. TESTS

3.1 DETERMINING THE NATURAL PERIOD

a. Connect the test equipment to the seismometer as shown in figure 3-1.

CAUTION

The maximum current through the calibration coil should be limited to 50 mA and then for only a few seconds.

b. Pulse the calibration coil with just enough current to obtain about 20 mV peak out of the main coil, then turn off the current through the calibration coil.

c. As the meter crosses zero, start timing one complete cycle. This is the natural period in seconds.

d. Perform step c several times and average the results.

e. If the natural period is not the desired value, the period may be adjusted by screwing out (lengthening) the front leg to increase the period or screwing in (shortening) the front leg to decrease the period.

3.2 MECHANICAL DAMPING

a. Perform steps a and b of section 3.1

b. Measure the peak-to-peak amplitude of two consecutive cycles, such as the fourth and fifth.

c. The ratio of their amplitudes should not exceed 1.35; i.e., the amplitude of the fourth cycle divided by the amplitude of the fifth cycle should be about 1.2.

d. If the ratio is greater than 1.35, then the seismometer has too much mechanical damping probably caused by a dragging coil, shorted turns, etc.

3.3 DETERMINING THE CRITICAL DAMPING RESISTANCE (CDR)

a. Set the instrument on the desired natural period.

b. Use the test setup as shown in figure 3-1 with the addition of a variable resistance connected across the microvoltmeter. Set the value of the resistance to approximately 11,500 ohms. This is essentially the external damping resistance (R_X).

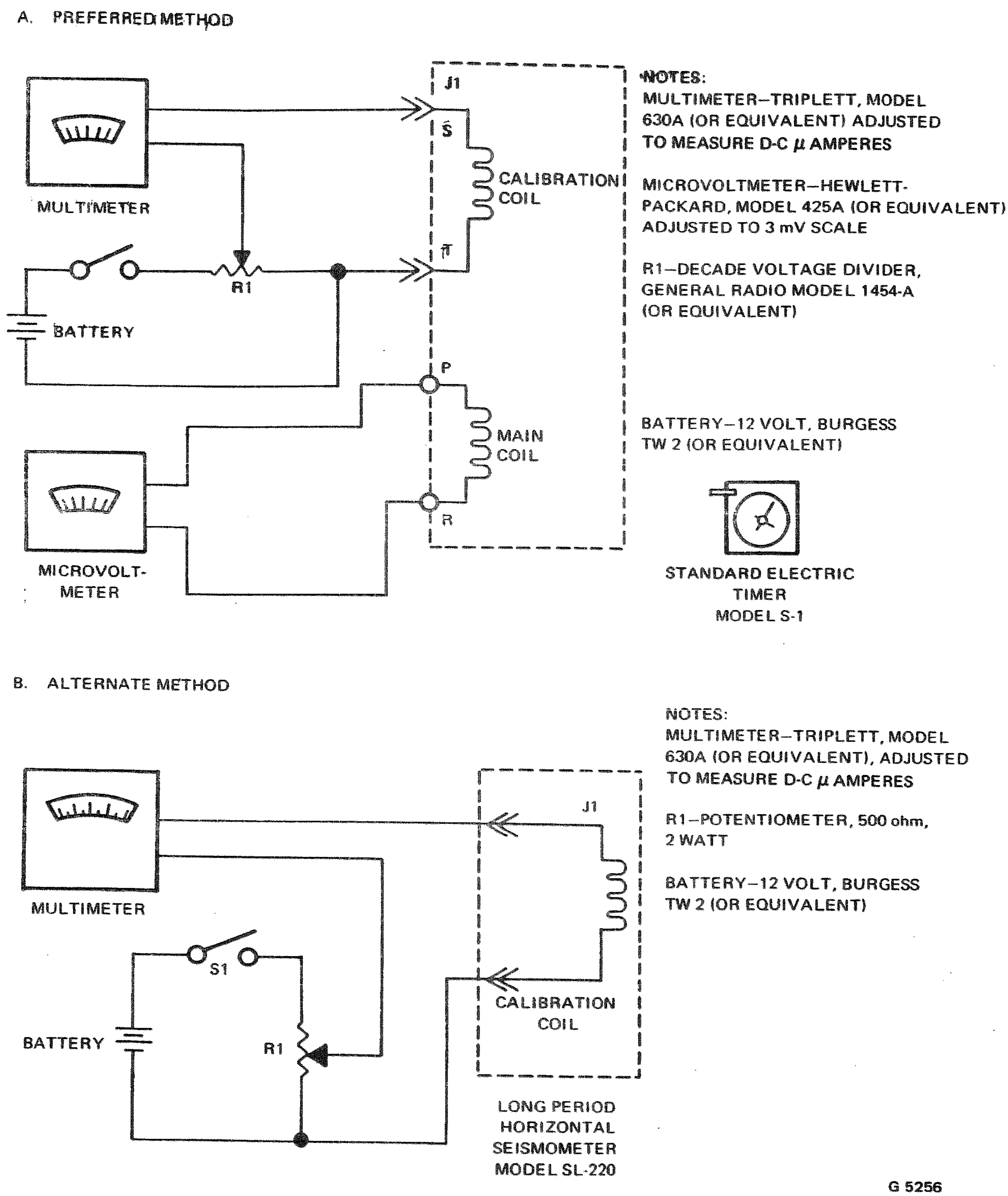

Figure 3-1. Test Setup for Natural Period and Damping

c. Adjust the current through the calibration coil until the initial peak output of the main coil is about 20 mV when the switch is closed.

d. Observe the voltmeter until it indicates the seismometer has ceased deflecting. Close the switch to the calibration coil and record the peak output voltage of the main coil in both the positive (initial) and negative (secondary) deflections. Adjust the external damping resistance until the ratio between the initial and secondary deflections is between 10 to 1 and 4 to 1. Repeat the test several times to ensure accuracy.

e. Calculate the percent overshoot by dividing the secondary deflection by the initial deflection and multiplying by 100. Enter table 3-1 with this percent to find λ, the ratio of actual damping to critical damping.

f. Determine the total resistance in the circuit, R_t, i.e., the resistance of the coil plus the external damping resistance, then:

$$CDR = R_t \times \lambda$$

NOTE

Within $\pm 10\%$, the CDR is ohms should be 344 times the natural period in seconds. If the CDR is not within the tolerance, check the magnet charge to be 1700 gauss and verify the coil resistance to be the value inscribed at the terminals.

3.4 DETERMINING THE MAIN GENERATOR CONSTANT

The main coil generator constant is determined by using the following equation:

$$G_{main\ coil} = \sqrt{\frac{(25.13)\ (CDR)}{T_o}}$$

where: G = generator constant in $\frac{\text{volt-sec}}{\text{meter}}$

CDR = critical damping resistance at T_o in ohms

T_o = natural period in seconds

Table 3-1. Ratio (λ) of Actual Damping to Critical Damping

% OVERSHOOT	λ	% OVERSHOOT	λ	% OVERSHOOT	λ
0.1	.910	5.0	.690	10.8	.578
0.2	.892	5.2	.685	11.0	.575
0.3	.880	5.4	.681	11.5	.567
0.4	.869	5.6	.676	12.0	.559
0.5	.860	5.8	.672	12.5	.552
0.6	.852	6.0	.667	13.0	.545
0.7	.845	6.2	.663	13.5	.537
0.8	.838	6.4	.658	14.0	.530
0.9	.832	6.6	.654	14.5	.524
1.0	.826	6.8	.650	15.0	.517
1.2	.815	7.0	.646	15.5	.510
1.4	.805	7.2	.642	16.0	.504
1.6	.796	7.4	.638	16.5	.497
1.8	.788	7.6	.634	17.0	.491
2.0	.780	7.8	.630	17.5	.485
2.2	.772	8.0	.627	18.0	.479
2.4	.765	8.2	.623	18.5	.473
2.6	.758	8.4	.619	19.0	.467
2.8	.751	8.6	.615	19.5	.462
3.0	.745	8.8	.612	20.0	.456
3.2	.739	9.0	.608	20.5	.450
3.4	.733	9.2	.605	21.0	.445
3.6	.727	9.4	.601	21.5	.439
3.8	.721	9.6	.598	22.0	.434
4.0	.716	9.8	.594	22.5	.429
4.2	.710	10.0	.591	23.0	.428
4.4	.705	10.2	.588	24.0	.414
4.6	.700	10.4	.584	25.0	.404
4.8	.695	10.6	.581		

3.5 DETERMINING THE CALIBRATION COIL MOTOR CONSTANT

a. Remove cover and attach weight lift test fixture as shown in figure 3-2, using a 400 mg weight.

b. Determine the external critical damping resistance (CDRX) by subtracting the resistance of the coil (R_{coil}) from the CDR. (CDRX = CDR-R_{coil}).

c. Use the test setup as shown in figure 3-1 with the addition of a resistance equal to the CDRX connected across the microvoltmeter. Deflect the boom by lifting the weight quickly to the height of the test fixture. Make several weight lifts and record the amplitude of initial deflections of the microvoltmeter.

NOTE

The tests should be accomplished with the mass position at zero ±2 mm and a period of 18 to 25 seconds.

Close the switch on the calibration coil circuit. When the mass has stopped swinging, open the switch and observe the initial deflection on the voltmeter. Repeat, adjusting the current in the calibration coil until the deflection of the seismometer is within at least 10 percent of the deflection observed by lifting the 400 mg weight. Record the current required to produce this deflection.

NOTE

> Use only dc pulse deflections in the same direction as the weight lift deflection. Reverse leads to calibration coil if necessary.

Calculate the motor constant (G) of the calibration coil using the average of three or more weight lifts.

$$G_{cal\ coil} = 0.392\ (X_i/X_w)/i \quad \text{(For 400 mg test weight)}$$

Where: G = Motor constant of the cal coil in newton/ampere,

X_w = Initial deflection of the seismometer caused by weight lift as determined by observation of voltmeter,

X_i = Initial deflection of the seismometer cause by current in the calibration coil being turned off, as determined by observation of voltmeter,

i = Current in calibration coil in mA used to obtain deflection X_i above.

The motor constant should be 0.028 newton/ampere, within ± 0.003 newton/ampere. If the test results do not fall within these limits, check the magnet charge. Look for worn spots on the coil and check clearance of coils in magnets. Inspect the calibration coil winding. It should be centrally located and on a plane perpendicular to the coil axis. Replace coil if necessary.

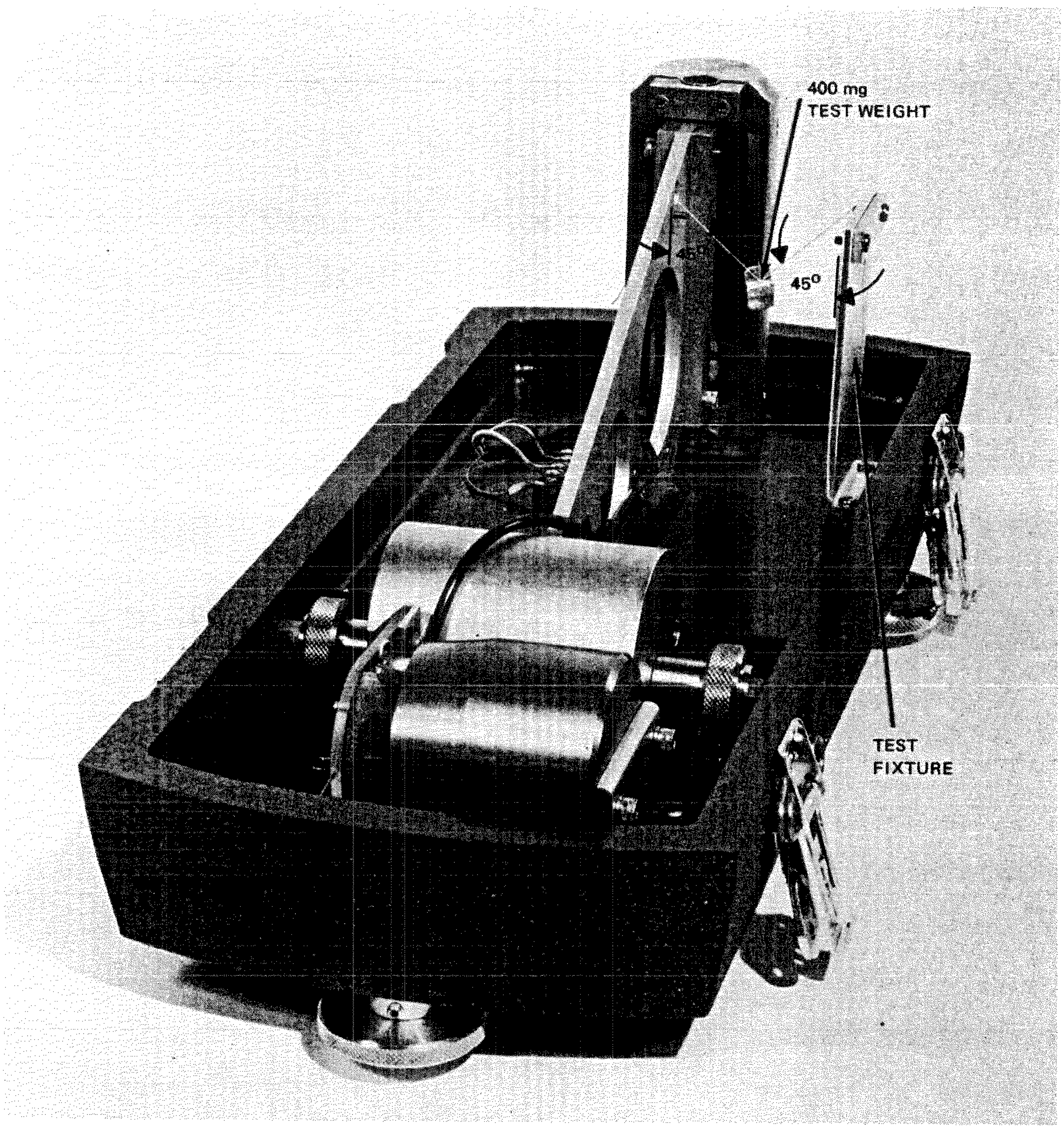

Figure 3-2. Weight Lift Test Fixture Setup

3.6 DETERMINING EQUIVALENT EARTH MOTION OF CALIBRATION COIL DRIVE

When the motor constant of the calibration coil has been determined, the equivalent sinusoidal earth motion produced by a sinusoidal signal in the calibration coil can be determined by the following relation:

$$y = \frac{Gi \times 10^6}{4\pi^2 f_1^2 M}$$

Where:

- Y = equivalent earth motion in microns, peak-to-peak
- G = calibration coil motor constant, newtons/ampere
- i = current through the calibration coil, amperes, peak-to-peak
- f_1 = frequency of calibration signal in Hz
- M = weight of mass in kilograms

3.7 DETERMINING THE SEISMOMETER SYSTEM MAGNIFICATION

The seismometer system, or seismograph, includes the seismometer, amplifier, and recorder. The record made by this system is called a seismogram. The seismometer system magnification ( ) is the ratio of the recorded signal divided by the earth motion amplitude.

$$m = \frac{A \text{ (peak-to-peak recorded amplitude) meters}}{y \text{ (peak-to-peak equivalent earth motion) meters}}$$

for convenience

$$m = \frac{A \text{ (millimeters)} \times 10^3}{y \text{ in microns}}$$

The magnification of the system at any frequency may be determined by driving the calibration coil with a sinusoidal signal of known frequency and amplitude. The equivalent earth motion of the driving signal is calculated by the formula given in section 3.6.

A more useful form of the magnification formula is as follows:

$$m = \frac{4\pi^2 \times AMf_1^2 \times 10^3}{G\ i \times 10^6}$$

Since, for this seismometer, the inertial mass (m) is always 2 kilograms then:

$$m = \frac{4\pi^2 \times 2 \times 10^3 \, A \, f_1^2}{G \, i \times 10^6}$$

$$m = \frac{.079 \, A \, f_1^2}{G \, i} \quad \text{or} \quad \frac{.079 \, A}{G \, T_1^2 i}$$

Where: m = system magnification

A = peak-to-peak recorded amplitude in millimeters

f_1 = frequency of calibration signal in Hz

G = calibration coil motor constant, newtons/ampere

i = current through the calibration coil, amperes, peak-to-peak

T_i = period of calibration signal in seconds

Example:

A = 50.8 millimeters

G = 0.030 newton/ampere

T_i = 25 seconds

i = 20×10^{-6} amperes

$$m = \frac{.079 \times 50.8}{0.030 \times 25^2 \times 20 \times 10^{-6}}$$

m = 10,700

3.8 PERIOD VERSUS MASS POSITION

Perform section 3.1, setting the natural period to 20 seconds. Time the natural period at 9 points along the scale. Plot period versus mass position on Form 281 (figure 3-3). One test point should fall under each bracket at top of graph.

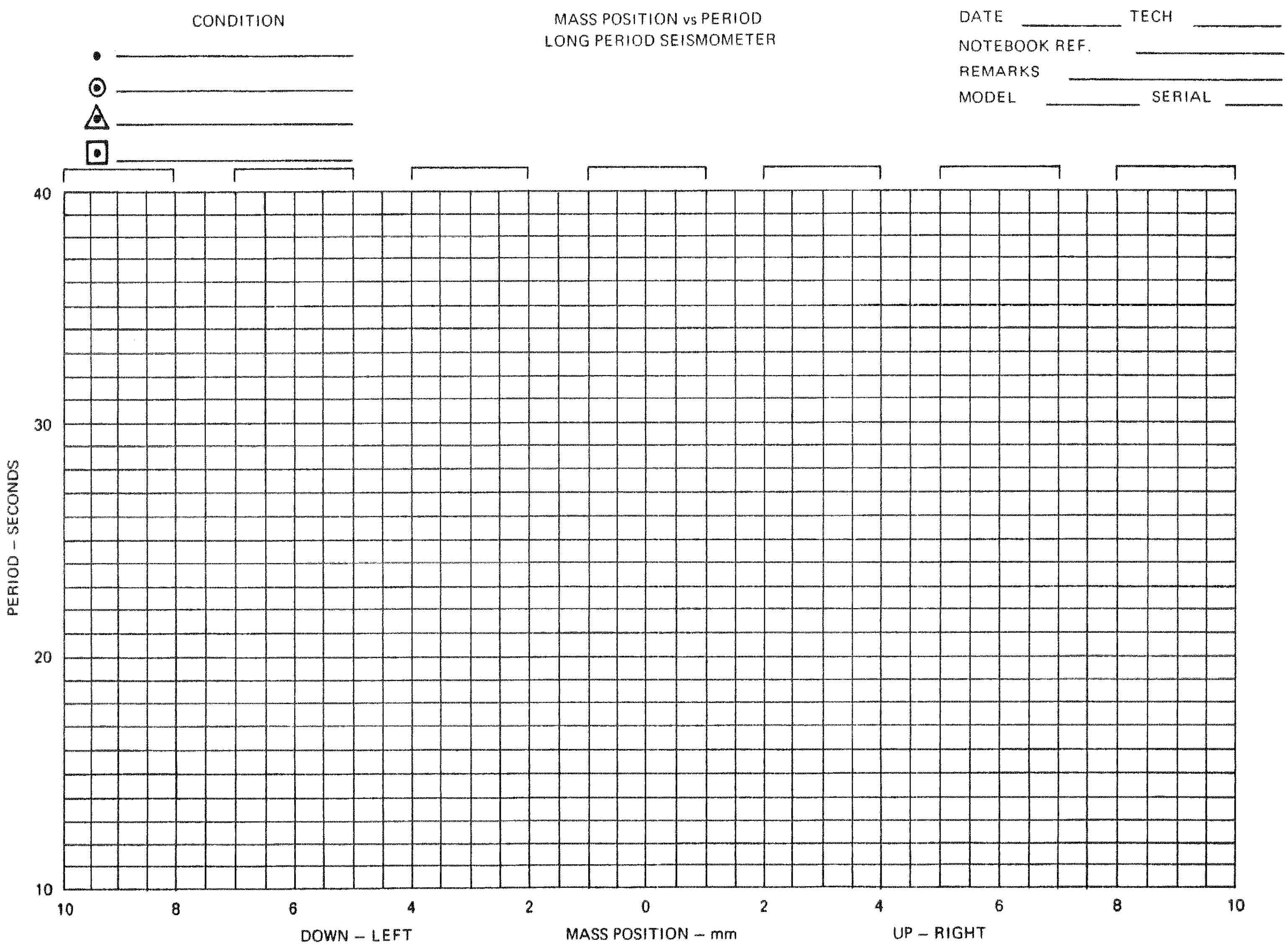

Figure 3-3. Mass Position vs. Period Form

Compute the average period. No test point should vary more than ± 10 percent from the average. At no point should the seismometer be unstable. Aim for a curve symmetrical about the scale zero. The maximum period should be within ± 2 mm of zero.

If the mass position response does not meet the above requirements, the flexures may be adjusted in the following manner until a "flat" response is obtained.

Flexure Adjustment: The symmetry of the period versus mass position curve may be improved by repositioning the upper flexure pivot. Accordingly, the periods on the left will become longer as the flexure is rotated clockwise (viewed from the top - figure 3.4).

To rotate the upper flexure, both ends must be unrestrained. Center the mass using the lock screws and secure the mass using the shipping brackets or a block under the mass to relieve the load on the upper flexure. Through the access hole in the hinge post, loosen the upper clamp screw. Loosen the upper clamp block on the hinge post and rotate the flexure using 1/2 inch flexure alignment tool. Observe the two elements of the flexure pivot and ensure that retightening of the clamp screws does not rotate either element.

CAUTION

Excessive clamping action will collapse the flexure housing.

Release the boom and proceed with the Period Versus Mass Position Test. In attempting to obtain a "flat" response, the amount of rotation should be limited to 2 to 5 degrees per trial. A period versus mass position curve that is significantly out of specification may be corrected by rotating both flexures.

The lower flexure is repositioned in the same way as the upper flexure. Make sure that both the upper and lower flexures are securely clamped before unlocking the mass.

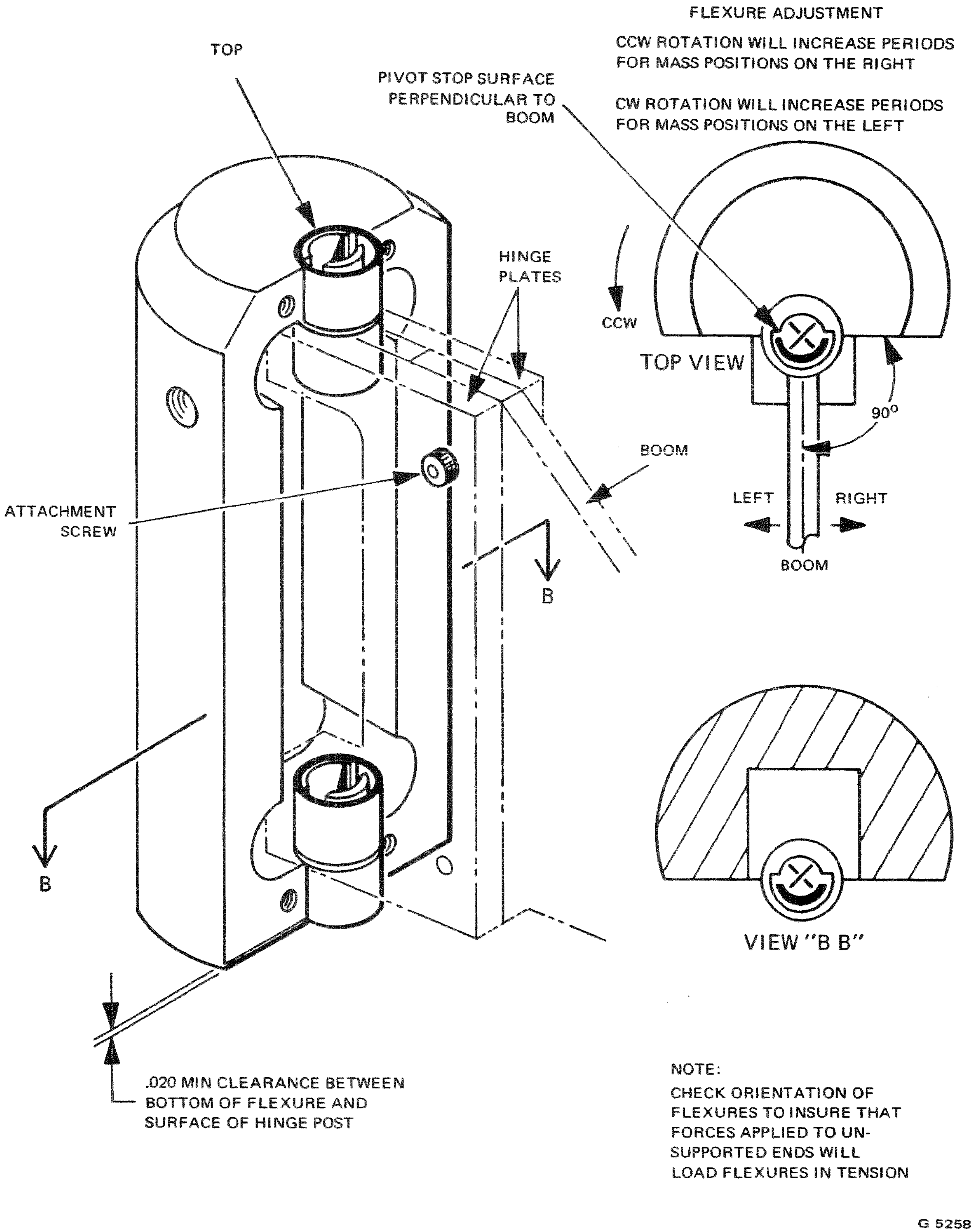

Figure 3-4. Flexure Adjustment

4. MAINTENANCE

4.1 GENERAL

The magnet gap should be inspected for debris and metallic particles and be kept clean at all times. Cleaning the gap may be accomplished in the following steps.

a. Secure the mass with the lock screws.

b. Loosen the screws attaching the coil support to the mass and slip the coil out of the magnet.

c. Wipe the gap with a lint-free cloth or brush (compressed air may also be used) until all foreign particles are removed.

d. Replace and center the coil.

Broken flexible wire leads from TB1 to TB2 (figure 2-1) may be replaced with #44 AWG enameled copper wire 2 1/2 inches long with enamel stripped 3/8 inch from the ends. The stripped end of the flexible wire may be wrapped around the ends of the large wire and inserted beneath the copper strips on the terminal block. Ensure that the flexible lead wires are not tangled and will not interfere with each other for the full ± 10 mm excursion of the mass.

4.2 REMOVING AND REPLACING FLEXURES (Refer to figure 3-4)

a. Center the mass using the lock screws and secure the mass using the shipping brackets or a block under the mass to relieve the load on the flexures.

CAUTION

Do not loosen or remove the hinge plate attachment screw.

b. Through the access hole in the hinge post, loosen the upper boom clamp screws. Loosen the upper clamp block on the hinge post and carefully remove the upper flexure.

c. Install the new upper flexure in the way to ensure that forces applied to unsupported end will load flexure in tension. Visually orient the flexure so that the pivot stop surface is perpendicular to the center line of the boom and the top surface of the flexure is flush with the top surface of the hinge post. Clamp securely in place.

CAUTION

Excessive clamping pressures will collapse the flexure housing.

d. Through the access hole in the hinge post, loosen the lower boom clamp screw. Loosen the lower clamp block on the hinge post and carefully remove the lower flexure.

NOTE

A pair of tweezers or bent long-nose pliers are useful to remove the lower flexure.

e. Install the new lower flexure in the way to ensure that forces applied to unsupported end will load flexure in tension. Visually, orient the flexure so that the pivot stop surface is perpendicular to the center line of the boom, and the top surface of the flexure is flush with the top.

f. Check that the bottom of the flexure clears the base by 0.015 to 0.030 inch.

g. Clamp securely in place.

h. Perform the period versus mass position test as described in section 3.8

5. PARTS LIST

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Item	Part No.	Mfr. Code No.	Description	Quantity
1	33905-01-01	99019	Coil assembly	1
2	32203-01-01	99019	1/2 flexure alignment tool	1
3	30927-01-01	99019	Level adjust assembly	3
TB1 TB2	4-171		Terminal strip	2
5	30931-01-01	99019	Magnet assembly	1
6	30937-01-01	99019	Cable assembly	1
7	32914-01-01	99019	Weight lift jig assembly	1
8	04950-01-02	99019	Name plate	1
9	35485-01-01	99019	Scale	1
10	32769-01-01	99019	Horizontal 2 Kgram mass	1
12	29731-01-01	99019	Bushing	3
13	30526-01-02	99019	Instrument base	1
14	32771-01-01	99019	Boom	1
15	30545-01-01	99019	Hinge plate	2
16	30546-01-01	99019	Hinge post	1
17	33906-01-01	99019	Holding plate	1
18	30551-01-01	99019	Stud	2
19	30552-01-01	99019	Lock screw	2
20	30558-01-01	99019	Clamp block	2
21	30675-01-01	99019	Instrument cover	1
22	32768-01-01	99019	Shipping bracket	2
23	30683-01-01	99019	Cover plate	1
24	32772-01-01	99019	Pointer	1

Item	Part No.	Mfr. Code No.	Description	Quantity
25	30685-01-01	99019	Coil mtg. bracket	1
26	30779-01-01	99019	Magnet mount	1
27	32779-01-01	99019	Set screw mod.	1
28	#3	82240	Spring-loaded link lock	4
30	3/16-2	95987	Cable clamp, Nylon (NY-Grip) Type 2	3
31	5016-800	77820	Flexure pivot	2
32		Any	#26 ga. wire, standard	4
33		Any	#10 sleeving	1
34		Any	Wire, enameled #44 ga. solid copper	4
35	10-101960-14	77820	Receptacle - protection cap	1
36	PT06E-14-18P(SR)	77820	Connector	1
37		Any	Pan head screw, #2-56 x 1/8 lg. SST	2
38		Any	Pan head screw, #2-56 x 3/8 lg. SST	3
40		Any	Pan head screw, #4-40 x 5/16 lg. brass	1
41		Any	Pan head screw, #4-40 x 3/16 lg. SST	18
42		Any	Pan head screw, #6-32 x 1/4 lg. SST	4
43		Any	Soc. hd. cap screw, #6-32 x 5/16 lg. SST	2
44		Any	Soc. hd. cap screw, #6-32 x 5/8 lg. SST	4
45		Any	Soc. hd. cap screw, 1/4-20 x 1/2 lg. SST	8

Item	Part No.	Mfr. Code No.	Description	Quantity
46		Any	Soc. hd. cap screw, #8-32 x 3/4 lg. SST	4
47		Any	Screw-pan head	1
48		Any	Nut-Hex	1
49		Any	Soc. hd. cap screw, #1/4-20 x 7/8 lg. SST	3
50		Any	Soc. hd. set screw, #5/16-24 cup point x 1/2 SST	1
51		Any	Washer, flat, #4 brass	2
52		Any	Washer, lock, #8 split SST	2
53		Any	Washer, lock, #1/4 split SST	13
54	CS-11	77820	Soc. hd. set screw, nylon tip 8-32 x 15/64 long	3
55	10-101949-14	77820	Gasket	1
56		Any	Pan head screw, #4-40 x 1/4 lg. SST	4
57		Any	Washer, lock, #4 split SST	4
58		Any	Pan head, screw, #2-56 x 3/8 lg. brass	1
59		Any	Washer, flat, #2 brass	1
60		Any	Soc. hd. cap screw, #8-32 x 1/2 lg. SST	2
61		Any	Washer, lock #4, Internal Star	16

MANUFACTURERS' CODE LIST

Code No.	Name and Address
02697	Parker Seal Co. Lexington, KY 40509
26233	USM Corp., Nylok Fastener Div. Torrance, CA 90510
71785	TRW Electronic Components Elk Grove Village, IL 60007
77820	Bendix Corp. Electrical Components Div. Sidney, NY 13838
82240	Simmons Fastener Corp. Albany, NY 12204
95987	Weckesser Co., Inc. Chicago, IL 60641
99019	Teledyne Geotech Garland, TX 75041

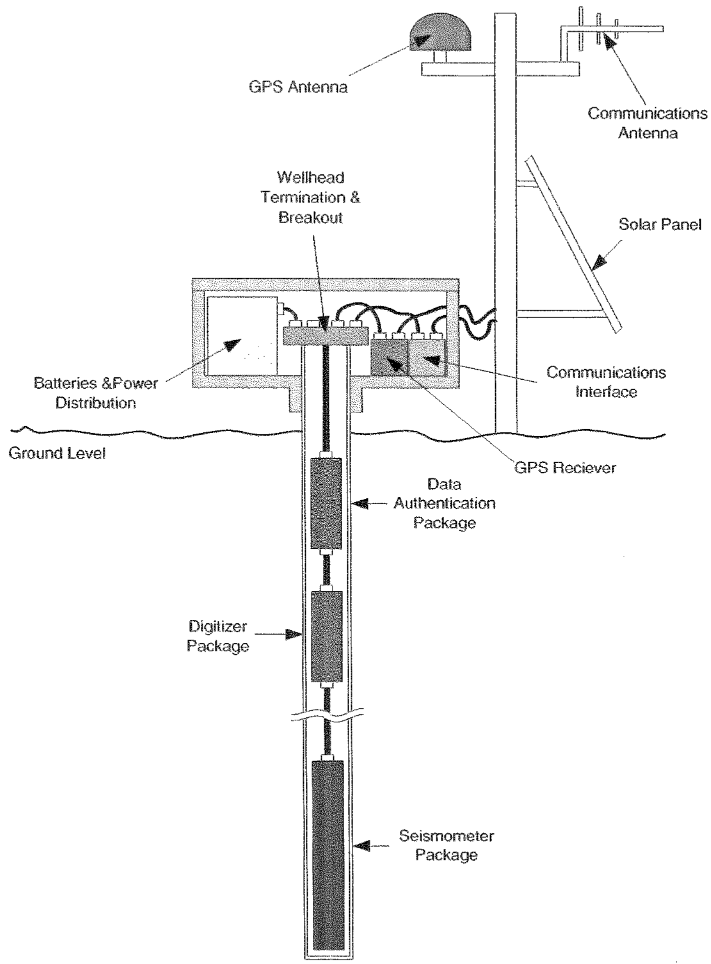

Figure 1. Typical Borehole Seismic Station

High power consumption of the equipment has also been a major problem. Early seismic stations consumed a great deal of power. Present systems have pushed power down to more reasonable levels but they still consume many watts. This presents a difficult challenge to the system designer to create a robust power subsystem that can operate reliably in remote locations. Batteries, solar panels, thermoelectric generators and more conventional generators along with local power have been used with varying degrees of success. However, these power sources have large on going maintenance costs and some require large amounts of fuel to be delivered to these remote sites. Ideally the station would be isolated from a local power grid and have its own integrated power system or automatic backup system. This would allow data to continue flowing even in the event of a general local power outage or bad weather conditions that may cut power lines. With power consumption decreasing, the power source should be as small as possible, require little maintenance and run for long periods of time between refueling or replacement.

1.1.2 Background

Geotech Instruments, LLC (Geotech) has a long and extensive history in the design, development and installation of remote seismic data acquisition stations as well as portable seismic data recorders and seismic sensors.

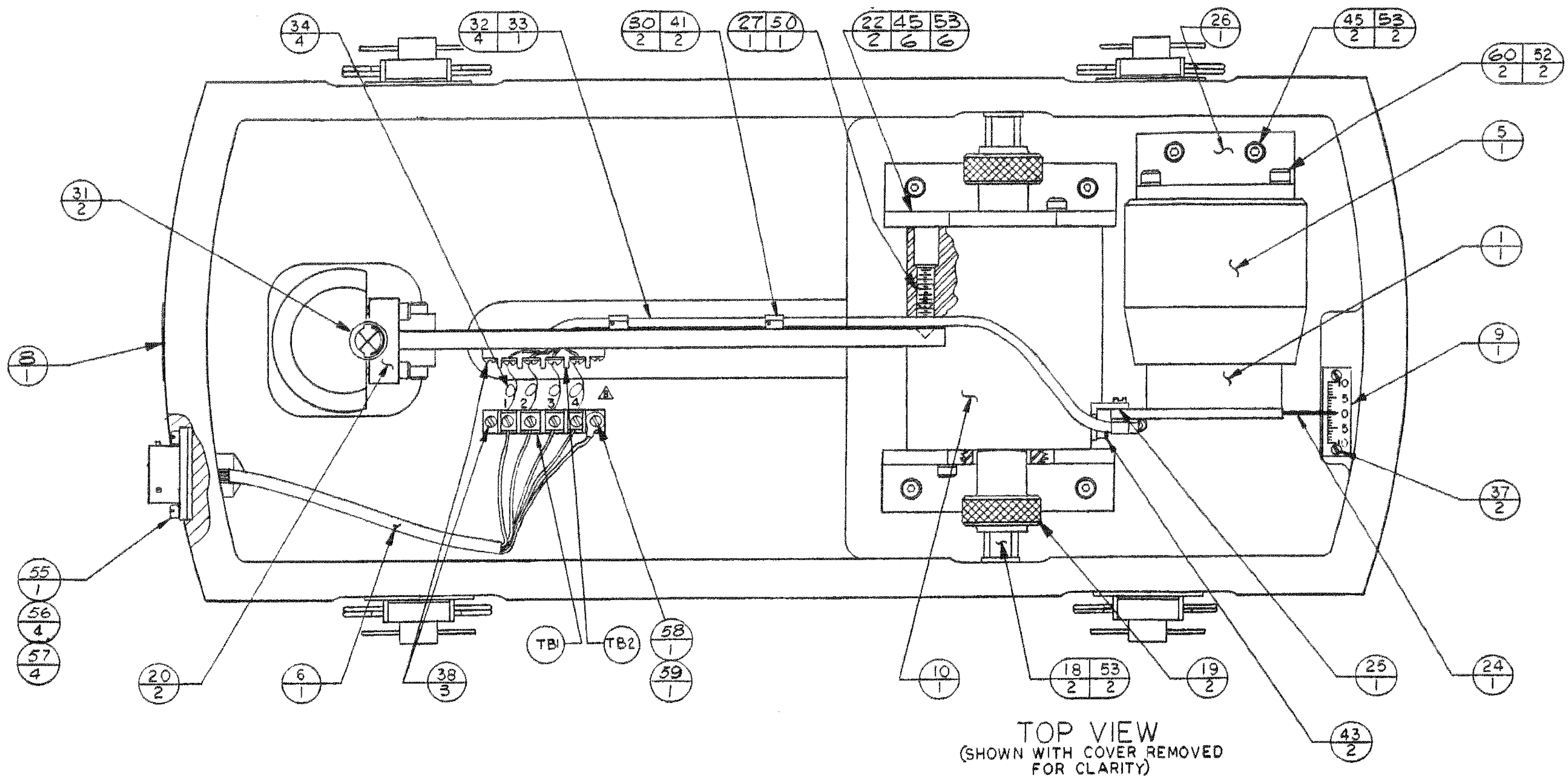

Figure 5-1. Parts Identification Drawing, Model SL-220 Seismometer, Top View

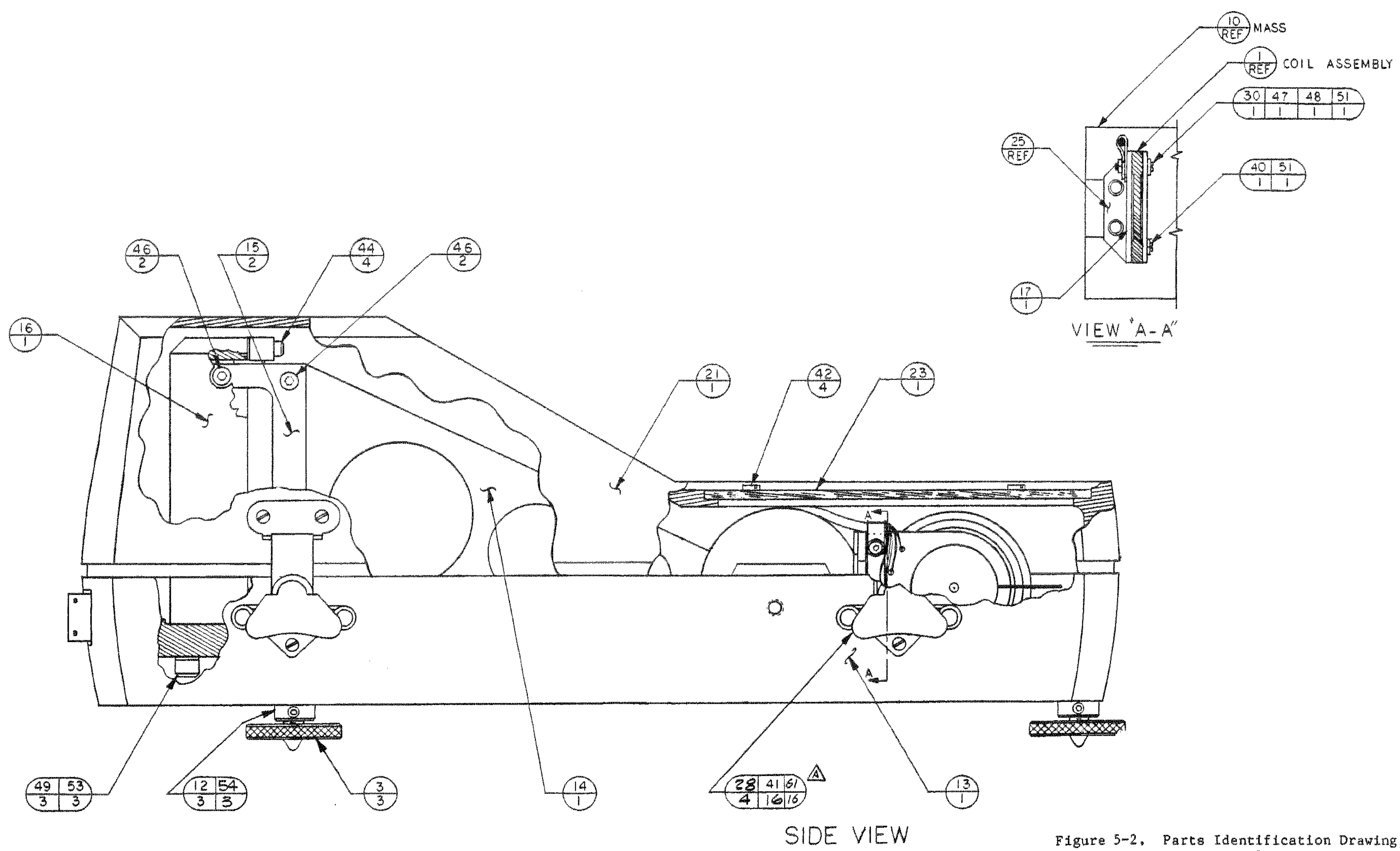

Figure 5-2. Parts Identification Drawing, Model SL-220 Seismometer, Side View