UNITED STATES DEPARTMENT OF THE INTERIOR

GEOLOGICAL SURVEY

NEAR-SURFACE STRAINMETERS AT SITES ALONG THE SAN ANDREAS FAULT, CALIFORNIA: INSTALLATION, OPERATION AND MAINTENANCE.

by
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Open-File Report 95-487

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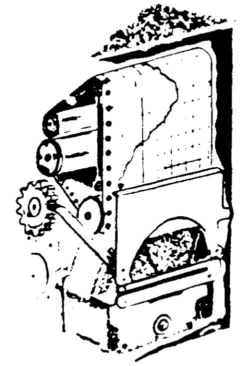
CONTENTS

TABLE OF CONTENTS

LIST OF TABLES

LIST OF ILLUSTRATIONS

Description



The Rustrak DC* recorder prints through the impinging action of its stylus driven by the chopper bar against pressure-sensitive chart paper. Its presentation is a series of dots appearing as a continuous line.

Recording on the chord of the stylus arc by the edge of the chopper bar is possible with a stylus able to write along its length rather than its point. This results in chart paper printed with straight lines and rectilinear recordings.

Writing speed varies with motor speed. Chart speed and trace density depend on the ratio of the interchangeable gear box which couples the paper drive to the motor.

*DC Recorders are intended to record DC parameters such as voltage or current. The chart drive motor may operate from AC lines or be battery-operated without changing the DC designation.

Summary

Installation

MODELS 288, 291, 2146 & 2194:

These recorders can be panel-mounted or used as table-top portable instruments. Hardware is furnished for both purposes.

Portable:

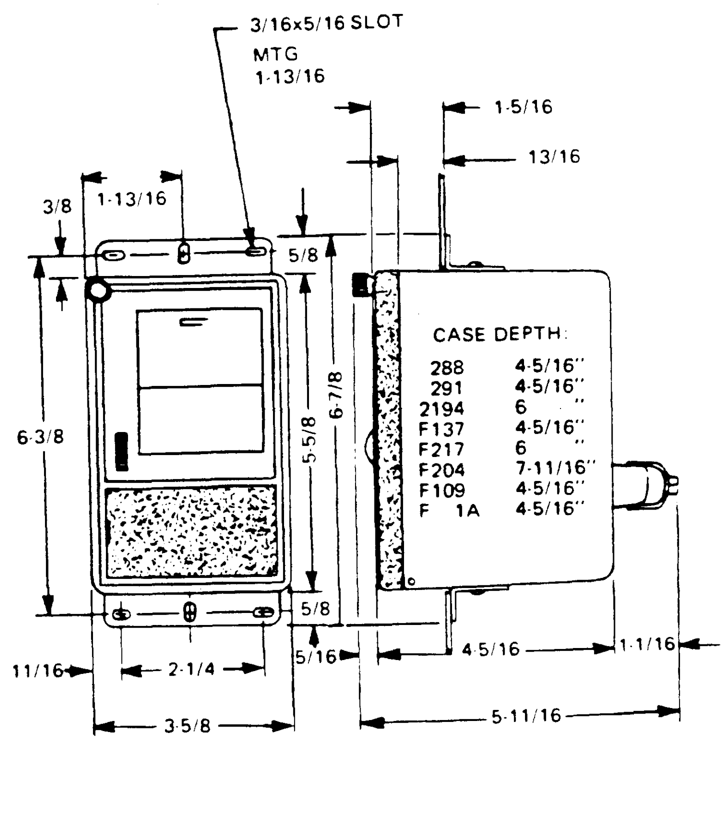
Install four (4) rubber feet in tapped holes at bottom of case using four (4) 4-40 x 1/4" screws provided. Snap white plastic cardholder into holes at top of case.

Panel-Mounting:

Follow instructions on drawing included with hardware kit. Mount both brackets to recorder and make panel cutout to size required or use Model 2176 precut panels. See recorder outline. For custom mounting, see template on back cover. If mounting with Model 2196 escutcheon, do not drill holes in panel and follow special instructions furnished with bezel.

300 SERIES MODELS:

Normally the 300 series recorder is shipped with rubber feet and handle mounted at the factory. It is ready to use as received. However, a modification kit is available for panel-mounting without drilling holes in the case.

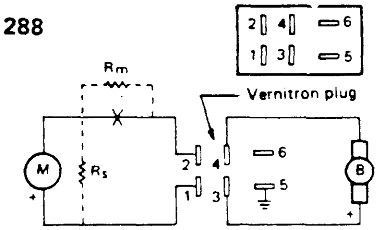


Wiring

Plug connections and terminals are identified on a label inside your recorder. Refer to this d^ta for correct wiring.

SCHEMATICS

Model 288



Terminal Connections

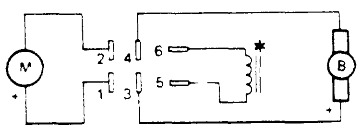
PIN #	MODEL 288	MODEL 291	MODEL 2146
1	Galvo +	Galvo 1 +	Galvo +
2	Galvo –	Galvo 1 –	Galvo –
3	Motor (DC+)	Motor (DC+)	Motor (DC+)
4	Motor (1)	Motor (1)	Motor (1)
5	Ground (2) (3)	Galvo 2 +	Actuator
6	(2)	Galvo 2 –	Actuator

(1) DC Motors are polarized Positive terminal is *always* pin 3

(2) Pins 5 & 6 are additional ranges in multi range recorders

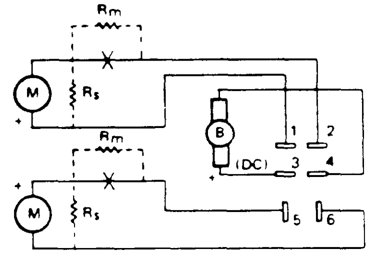
(3) If all pins are used, ground to chassis plug screw

Model 2146



* Actuator Solenoid, 24 VDC @ 70 MA Standard

Model 291



R_s = 100 n 1 where
R_s = shunt resistor
n = factor

Rm = (1000 V_{fs}) 100 where
V_{fs} = Volts full scale
100 = Internal R of meter

300 SERIES:

Since a "300 Series" recorder is a tandem unit enclosing two basic "200 Series" instruments, the inner wiring parallels the preceding schematics. Terminals are barrier strips with connections as follows:

TERM #	8	7	6	5	4	3	2	1
Model 388	NOT USED				– + Galvo 2		– + Galvo 1	
Model 391	– + Galvo 4		– + Galvo 3		– + Galvo 2		– + Galvo 1	
Model 3146	Event Actuator 2		– + Galvo 2		Event Actuator 1		– + Galvo 1	
Other Models	See right Scale		Right center Scale Factor		Left Center Scale Factor		See left Scale	

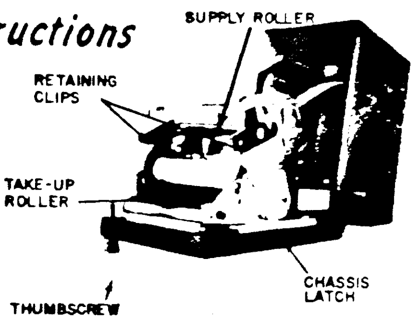
AC line cords terminate in three-prong plugs for 117 VAC. Use grounded outlet. Do not defeat purpose of grounding plug.

DC line cords terminate in a red (+) wire, a black (-) wire and a green lead connected to case ground. Ground this wire when using recorder.

Loading Instructions

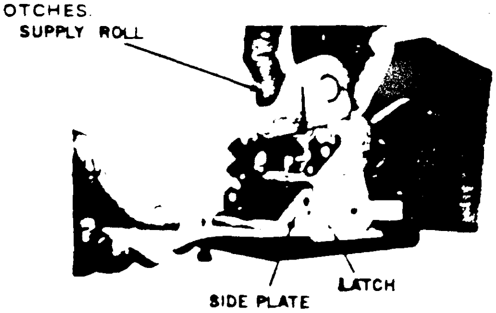
REROLL MODE

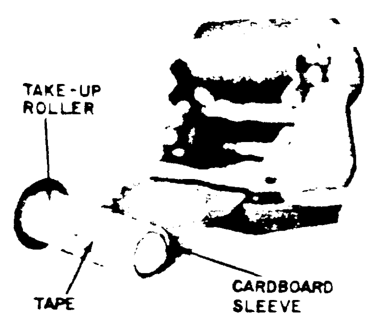
(USE FRESH ROLL OF CHART PAPER AT EACH LOADING)



1. OPEN RECORDER. UNLATCH RETAINING CLIPS. OPEN CHASSIS LATCH. REMOVE SUPPLY AND TAKE-UP ROLLERS.

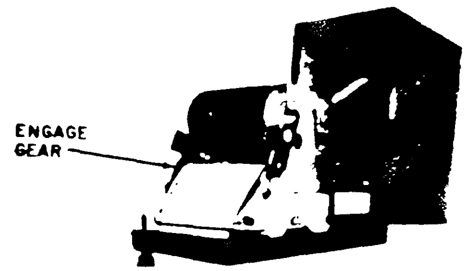
2. SLIDE SUPPLY ROLLER INTO FULL ROLL OF CHART PAPER, ROLLER SHOULDER NEAREST PAPER PERFORATIONS. UNROLL ABOUT A FOOT AND SLIDE PAPER (BACK SIDE UP) BETWEEN SIDE PLATE AND LATCH. *STEER PAPER AGAINST DRUM TO CLEAR POINTER.* ENGAGE PAPER PERFORATIONS INTO DRUM SPROCKETS AND DROP ROLL INTO SEATING NOTCHES.





3. SLIDE CARDBOARD SLEEVE ONTO TAKE-UP ROLLER. BUTT PAPER AGAINST DISC AND TAPE END OF CHART PAPER TO SLEEVE. TURN ONE REVOLUTION FOR PROPER PAPER ALIGNMENT.

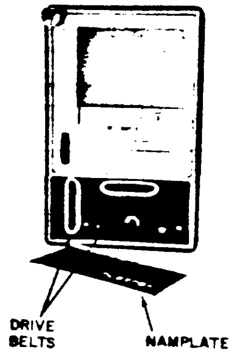
4. ROLL PAPER TIGHTLY AND STRAIGHT ON TAKE-UP ROLLER. KEEP PAPER TAUT. DROP INTO DEEPER N O T C H, ENGAGING GEAR. CLOSE RETAINING CLIPS. SNAP UP CHASSIS LATCH. CLOSE RECORDER. ADVANCE PAPER BY DEPRESSING AND TURNING CHART ADVANCE WHEEL ON FRONT PANEL.

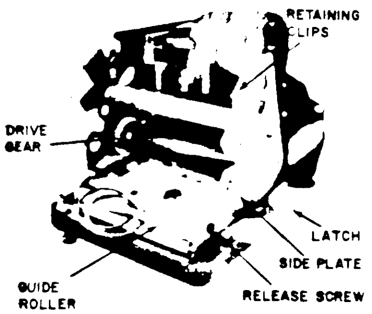


TEAR–OFF MODE

(USE PARTIAL OR FULL ROLLS OF CHART PAPER)

1. SNAP OUT NAMEPLATE USING SCREWDRIVER. REMOVE 2 BELTS. REPLACE NAMEPLATE.





2. OPEN RECORDER. UNLATCH RETAINING CLIPS. OPEN CHASSIS LATCH. REMOVE SUPPLY AND TAKE-UP ROLLERS. UNSCREW RELEASE SCREW 2 OR 3 TURNS. SPRING SIDE PLATE. REMOVE GUIDE ROLLER. SLIP ROLLER THROUGH 2 BELTS. RESEAT ROLLER TIGHTEN RELEASE SCREW.

CONVERSION INFORMATION

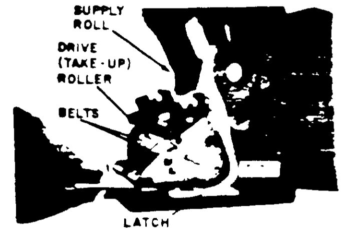
REROLL TO TEAR–OFF (uses drive belts)

Remove cardboard sleeve from take-up roller. Proceed with tear-off loading instructions.

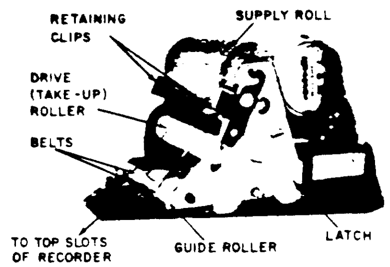
TEAR–OFF TO REROLL (Uses cardboard sleeve)

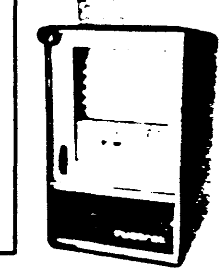
Store drive belts under front nameplate. Replace guide roller and finger tighten knurled release screw. Continue with reroll loading instructions.

3. PASS TAKE-UP ROLLER THROUGH BELTS. SEAT ROLLER TO ENGAGE DRIVE GEAR. PULL BELTS INTO CHAMFERED CENTER GROOVE OF GUIDE ROLLER AND ALIGN INTO V-SLOTS ON TAKE-UP ROLLER. INSERT SUPPLY ROLLER INTO SPOOL OF CHART PAPER (MAY BE PARTIAL ROLL) SO ROLLER SHOULDER IS NEAREST PERFORATIONS. UNROLL CHART PAPER AND SLIDE (BACK SIDE UP) BETWEEN SIDE PLATE AND LATCH. ENGAGE PAPER PERFORATIONS INTO DRUM SPROCKETS AND DROP ROLL INTO SEATING NOTCHES.



4. CLOSE RETAINING CLIPS. SNAP UP CHASSIS LATCH. PULL DRIVE BELTS INTO V SLOTS ON GUIDE ROLLER. CLOSE RECORDER.





5. ADVANCE PAPER AND SET TIME BY DEPRESSING AND TURNING CHART ADVANCE WHEEL. TEAR-OFF PAPER AS NEEDED.

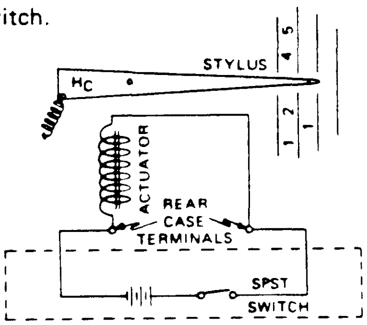
Operating Instructions

MODELS 288, 291, 2146, 300 SERIES

1. Install recorder and wire as detailed on page 3.
2. Load chart paper as shown on pages 4 & 5.
3. Apply power to motor and zero trace if needed.
4. Feed in signal to be recorded.
5. Recorder can operate unattended until chart paper supply is depleted.

(Event Marker), Model 2146

1. Wire actuator in series with contact switch and DC power source (Check voltage rating of actuator). See schematic.
2. Chart paper speed depends on gear train and motor combination selected for analog channel.
3. Recorder will print pulse for every change in state of contact switch.



Wiring to actuator of model 2146. Actuator responds to state of SPST switch.

Calibration: (All Models Except 2194)

No calibration except for periodic adjustment of the mechanical zero is needed on Rustrak DC recorders.

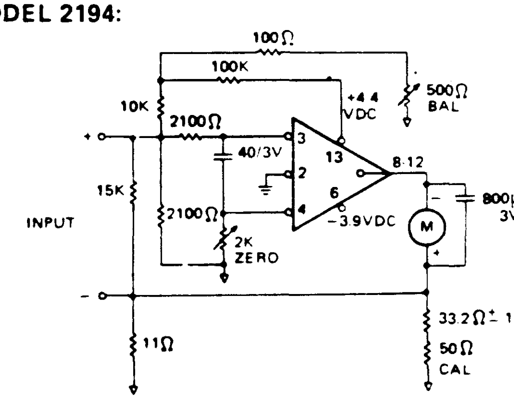
Mechanical Zero:

If trace on chart paper is above or below zero with galvanometer terminals shorted and motor running, snap out front nameplate (using fine screwdriver in slot at left) and vary zero adjust screw.

The stylus also may be adjusted mechanically at any point upscale if the recorder is used over a narrow span of the calibrated scale. Calibrate against a standard meter across the galvo terminals and a source.

See page 7 for special instructions on Model 2194.

MODEL 2194:



The full-scale sensitivity of 1 microampere (range 0-10 mV) is achieved with a medium gain amplifier driving a 100 mV meter. Input impedance is 10,000 ohms and the recorder is intended for a maximum source impedance of 100 ohms. Error due to amplifier loading with a 100 ohm source is less than 1% but rises to about 10% with a 1K ohm source. Temperature drift is also proportionately higher.

Electrical Zero:

1. With power off, adjust mechanical zero (behind front nameplate) until stylus (at chopper bar level) is at zero on chart paper.
2. Allow ½ hour warmup with power on.
3. Short input terminals and adjust ZERO (on case rear) for zero on chart paper.
4. Remove short and adjust BALance (on case rear) for zero trace. Short terminals again. Reading should not change from open to shorted condition.
5. If any change occurs, repeat steps 3 and 4.

Calibration:

1. Zero the recorder as shown in Electrical Zero instructions.
2. Apply 10 mV signal to binding posts from generator whose output resistance is less than 100 ohms.
3. Adjust CAL control (case rear) for full-scale printout.

Increasing Current Range:

To increase range (reduce current sensitivity), a shunt at the input terminals equal to 10,000/n-1 may be used. For example, a full-scale sensitivity of 100 uA is achieved with a 101 ohm resistor while a 0.01 ohm resistor results in 1 Amp full-scale readings.

Expanding Voltage Range:

The 2194 can be made into a solid-state voltmeter with 100,000 ohms/volt sensitivity by using a series multiplier whose value in ohms equals 100,000 Vfs - 1000 (where Vfs equals volts full-scale) providing a 1K ohm resistor shunts the input of the recorder. Representative values are 1K ohm for a 10 mV range, 99K ohms for 1 volt full-scale and 1 Megohm for a 10 V. scale. The 1K resistor should be wired to the recorder directly at the binding posts before connecting the multiplier.

Caution:

Voltages in excess of 1 VDC at the input may damage the amplifier.

TEAR-OFF or REROLL. Operating mode is quickly changed from one to the other in the field. Reroll generally used for long runs—tear-off feature allows sections of chart to be removed for immediate analysis and filing.

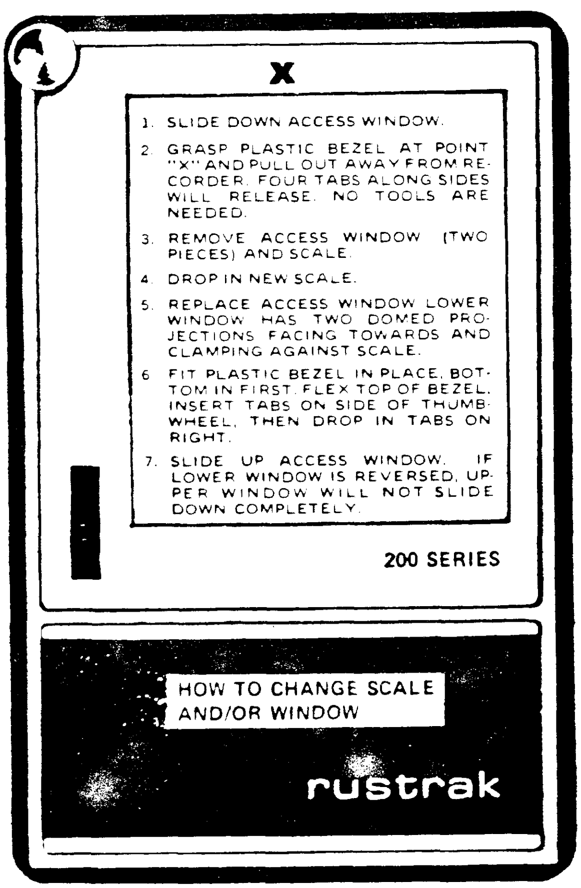
ACCESS WINDOW. Slides down for notes.

NAMEPLATE. Conceals mechanical meter zero adjustment and storage for tear-off feature drive belts. Snap out with fine screwdriver.

CHART ADVANCE FEATURE. Push in and roll down thumbwheel to advance chart for tear-off or to set time on chart.

QUICK REVIEW FEATURE. Recorded chart can be unrolled for analysis. Lift left retaining clip and set roll into closer notch. Unroll as needed. Rewind chart with thumbwheel then reseat roller into deeper notch. Lock retaining clip.

INTERCHANGEABLE GEAR TRAINS. Provide easy change of chart speed.



300 SERIES

HOW TO CHANGE SCALE AND/OR ACCESS WINDOW

1. Slide down top access window and bow it towards you until it releases.
2. Open recorder and remove 4-40 Pan Head screw holding Quick Review Thumbwheel arm to panel.
3. Remove two 4-40 Pan Head screws from rear of bezel. Lefthand screw is accessible after removing Quick Review Thumbwheel while right hand screw is unobstructed.
4. Lift out white bezel and anodized spacer.
5. Remove lower access window and change scale. Scale may be affixed with double-gummed tape so remove with care.
6. Replace lower access window in cutout.
7. Drop anodized spacer into panel then white bezel, inserting lower tabs first. Replace two 4-40 Pan Head screws and tighten securely.
8. Close recorder.
9. Bow out top access window towards you and insert both ends into bezel slot. Slide window into place.

Cleaning Your Recorder

The coating used on Rustrak recorders is Nextel Brand Suede Coating by 3M. It was chosen because of its toughness and visual qualities.

It can be cleaned with a damp sponge. The usual household spray and liquid cleaners can be used on tough stains without damage to the coating.

Formulas

$$\text{WRITING SPEED (strikes/sec.)} = \frac{\text{motor speed (rpm)}}{4}$$

$$\text{CHART SPEED (in./hr.)} = \frac{\text{motor speed (rpm)} \times \text{gear train assembly number}}{2}$$

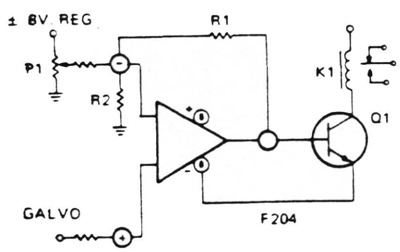
$$\text{TRACE DENSITY (strikes/in.)} = \frac{1800}{\text{gear train assembly number}}$$

$$\text{DURATION OF ROLL (in hrs.)} = \frac{756}{\text{chart speed (in./hr.)}}$$

Gear Train Ratios, Chart Speed, Writing Speed and Trace Density Table

DRIVE MOTOR (rpm)	WRITING SPEED	1/8 480:1	1/4 240:1	1/2 120:1	1 60:1	2 30:1	3 20:1	4 15:1	6 10:1	10 6:1	12 5:1	15 4:1	30 2:1	45 1.5:1	60 1:1	GEAR TRAIN NO GEAR TRAIN RATIO
1/2	1 strike/ 8 seconds	1/32 inch .8 mm 144 weeks	1/16 inch 1.6 mm 72 weeks	1/8 inch 3.2 mm 9 months	1/4 inch 6.35 mm 18 weeks	1/2 inch 12.7 mm 9 weeks	3/4 inch 19 mm 6 weeks	1 inch 25.4 mm 1 month	1½ inches 38 mm 21 days	2½ inches 63.5 mm 302½ hrs.	3 inches 76.2 mm 252 hrs.	3.75 inches 95.3 mm 201.6 hrs.	7½ inches 19 cm 100.8 hrs.	11¼ inches 28.6 cm 67.2 hrs.	15 inches 38 cm 50.4 hrs.	English Units/Hour, Metric Units/Hour: Chart Speed Duration of Chart Paper Spool
1	1 strike/ 4 seconds	1/16 inch 1.6 mm 72 weeks	1/8 inch 3.2 mm 9 months	1/4 inch 6.35 mm 18 weeks	1/2 inch 12.7 mm 9 weeks	1 inch 25.4 mm 1 month	1½ inches 38 mm 21 days	2 inches 50.8 mm 378 hrs.	3 inches 76.2 mm 252 hrs.	5 inches 12.7 cm 151.2 hrs.	6 inches 15.2 cm 126 hrs.	7½ inches 19 cm 100.8 hrs.	15 inches 38 cm 50.4 hrs.	22½ inches 57.2 cm 33.6 hrs.	2½ feet 76.2 cm 25.2 hrs.	English Units/Hour, Metric Units/Hour: Chart Speed Duration of Chart Paper Spool
2	1 strike/ 2 seconds	1/8 inch 3.2 mm 9 months	1/4 inch 6.35 mm 18 weeks	1/2 inch 12.7 mm 9 weeks	1 inch 25.4 mm 1 month	2 inches 50.8 mm 378 hrs.	3 inches 76.2 mm 252 hrs.	4 inches 10.2 cm 189 hrs.	6 inches 15.2 cm 126 hrs.	10 inches 25.4 cm 75.6 hrs.	1 foot 30.5 cm 63 hrs.	15 inches 38 cm 50.4 hrs.	2½ feet 76.2 cm 25.2 hrs.	45 inches 1.14 mtrs 16.8 hrs.	5 feet 1.52 mtrs 12.6 hrs.	English Units/Hour, Metric Units/Hour: Chart Speed Duration of Chart Paper Spool
4	1 strike/ second	1/4 inch 6.35 mm 18 weeks	1/2 inch 12.7 mm 9 weeks	1 inch 25.4 mm 1 month	2 inches 50.8 mm 378 hrs.	4 inches 10.2 cm 189 hrs.	6 inches 15.2 cm 126 hrs.	8 inches 20.3 cm 94½ hrs.	1 foot 30.5 cm 63 hrs.	20 inches 50.8 cm 37.8 hrs.	2 feet 61 cm 31½ hrs.	2½ feet 76.2 cm 25.2 hrs.	5 feet 1.52 mtrs 12.6 hrs.	7½ feet 2.29 mtrs 8.4 hrs.	10 feet 3.05 mtrs 6.3 hrs.	English Units/Hour, Metric Units/Hour: Chart Speed Duration of Chart Paper Spool
6	3 strikes/ 2 seconds	3/8 inch 9.53 mm 3 months	3/4 inch 19 mm 6 weeks	1½ inches 38 mm 21 days	3 inches 76.2 mm 252 hrs.	6 inches 15.2 cm 126 hrs.	9 inches 22.9 cm 84 hrs.	1 foot 30.5 cm 63 hrs.	18 inches 45.7 cm 42 hrs.	2½ feet 76.2 cm 25.2 hrs.	3 feet 91.4 cm 21 hrs.	45 inches 1.14 mtrs 16.8 hrs.	7½ feet 2.29 mtrs 8.4 hrs.	135 inches 3.43 mtrs 5.6 hrs.	15 feet 4.57 mtrs 4.2 hrs.	English Units/Hour, Metric Units/Hour: Chart Speed Duration of Chart Paper Spool
8	2 strikes/ second	1/2 inch 12.7 mm 9 weeks	1 inch 25.4 mm 1 month	2 inches 50.8 mm 378 hrs.	4 inches 10.2 cm 189 hrs.	8 inches 20.3 cm 94.5 hrs.	1 foot 30.5 cm 63 hrs.	16 inches 40.6 cm 47¼ hrs.	2 feet 61 cm 31½ hrs.	40 inches 1.02 mtrs 18.9 hrs.	4 feet 1.22 mtrs 15.75 hrs.	5 feet 1.52 mtrs 12.6 hrs.	10 feet 3.05 mtrs 6.3 hrs.	15 feet 4.57 mtrs 4.2 hrs.	20 feet 6.1 mtrs 3.15 hrs.	English Units/Hour, Metric Units/Hour: Chart Speed Duration of Chart Paper Spool
10	5 strikes/ 2 seconds	5/8 inch 15.9 mm 50 days	1¼ inches 31.8 mm 604 hrs.	2½ inches 63.5 mm 302 hrs.	5 inches 12.7 cm 151 hrs.	10 inches 25.4 cm 75½ hrs.	15 inches 38 cm 50⅓ hrs.	20 inches 50.8 cm 38 hrs.	2½ feet 76.2 cm 25.2 hrs.	50 inches 1.27 mtrs 15 hrs.	5 feet 1.52 mtrs 12.6 hrs.	75 inches 1.91 mtrs 10 hrs.	12.5 feet 3.8 mtrs 5 hrs.	225 inches 5.72 mtrs 3.4 hrs.	25 feet 7.62 mtrs 2.5 hrs.	English Units/Hour, Metric Units/Hour: Chart Speed Duration of Chart Paper Spool
12	3 strikes/ second	3/4 inch 19 mm 6 weeks	1½ inches 38 mm 21 days	3 inches 76.2 mm 252 hrs.	6 inches 15.2 cm 126 hrs.	1 foot 30.5 cm 63 hrs.	1½ feet 45.7 cm 42 hrs.	2 feet 61 cm 31½ hrs.	3 feet 91.4 cm 21 hrs.	5 feet 1.52 mtrs 12.6 hrs.	6 feet 1.83 mtrs 11½ hrs.	7½ feet 2.3 mtrs 8.4 hrs.	15 feet 4.57 mtrs 4.2 hrs.	22½ feet 6.86 mtrs 2.8 hrs.	30 feet 9.14 mtrs 2.1 hrs.	English Units/Hour, Metric Units/Hour: Chart Speed Duration of Chart Paper Spool
16	4 strikes/ second	1 inch 25.4 mm 1 month	2 inches 50.8 mm 378 hrs.	4 inches 10.2 cm 189 hrs.	8 inches 20.3 cm 94½ hrs.	16 inches 40.6 cm 47¼ hrs.	2 feet 61 cm 31½ hrs.	32 inches 81.3 cm 23.7 hrs.	4 feet 1.22 mtrs 15.75 hrs.	80 inches 2 mtrs 9.45 hrs.	8 feet 2.44 mtrs 7.8 hrs.	10 feet 3.05 mtrs 6.3 hrs.	20 feet 6.1 mtrs 3.15 hrs.	30 feet 9.14 mtrs 2.1 hrs.	40 feet 12.2 mtrs 95 mins.	English Units/Hour, Metric Units/Hour: Chart Speed Duration of Chart Paper Spool
TRACE DENSITY		14400	7200	3600	1800	900	600	450	300	180	150	120	60	40	30	STRIKES PER INCH (DENSITY)

F204 Controller



Milliameters and microammeters are basically low-range volt meters which register voltage excursions at their terminals. These minute fluctuations represent a real change in the monitored circuit and can be used to control circuit quantities. That's the function of the F204 On-Off Controller Feature.

The F204 is a comparator amplifier driving a power transistor in series with a relay. SPDT contacts enable on-off control of parameters being recorded or the external wiring may be adapted to open or close any circuit to follow voltage excursions at the galvanometer terminals. By comparing voltage levels of the meter terminals with a stable reference voltage adjustable from the front panel, limits can be set for the relay switching function.

Both the reference voltage and the voltage impressed across the meter terminals are applied to the inputs of an operational amplifier.

The operational amplifier in the F204 is operated open-loop, that is, with no feedback. Its voltage gain, including the power stage driving relay K1, is about 125,000 or 0.2 millivolts at the input give 24 volts out.

Voltage across the galvo is applied to the positive input. P1 is the front panel setpoint adjustment that varies the reference voltage applied to the negative input.

When the voltage of the positive input terminal (the galvo input) is below or equal to the voltage at the negative terminal (the reference), Q1 is cut-off and K1 de-energized. If the positive terminal becomes more positive than the – terminal by more than about 0.2 millivolts (resolution), Q1 conducts and energizes K1.

Loading on the galvanometer, because the input impedance of the op amp is about 30 megohms, is limited to about 0.2 microamperes.

Relay contacts are rated 5 amps, resistive load, at 30 VDC or 115 VAC. The "normally-open" and "normally-closed" contacts can be adapted to almost any application whose functions lend themselves to on-off control.

Configurations (A or B) represent control direction. The A style closes the normally-open contact below the setpoint and opens it above.

Style B configuration closes relay contacts above the setpoint and opens them below.

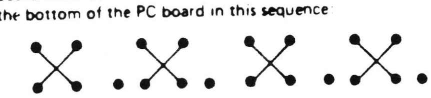
Besides these simple styles, two setpoint controllers are available. Style AA, featuring two control amplifiers both actuating the relay below the setpoint, are useful for control at one point and shut-down or alarming at the other.

Style AB is useful in "go-no-go" applications, or, "low-in-high" type of information needs. Similar applications as with style AA are possible with the BB configuration but with control above the setpoint.

No controller is limited to its initial configuration since styles can be changed by the user.

The type of setpoint, whether low (A) or high (B), depends on galvanometer connections relative to the reference voltage. Since the relay energizes only when the positive terminal of the op amp is more positive than the -terminal, it is possible to change setpoint types by reversing connections to the galvo.

These connections are jumpers on the controller circuit board mounted on the case rear. The jumpers are located at the bottom of the PC board in this sequence:



Criss-cross or "X" jumpers denote an "A" type configuration while parallel (||) jumpers result in a "B" configuration.

To change setpoint types, remove four screws holding case rear to recorder housing. Then unscrew PC board from the rear panel. When soldering, be careful not to destroy the printed circuit board.

ADJUSTING PANEL KNOBS

1. Apply signal to galvanometer for center scale reading.
2. Adjust controller setpoint knob until relay (de) actuates. Swing knob back and forth. Only slight movement of knob should be possible between on and off.
3. With galvo at center scale and reference pot at the control point the knob should be at the center mark on its dial. If not, loosen set screw and move pointer to center mark.
4. Check knob pointer against scale at 0, 20, 40, 60 and 100 percent points. A deviation of one division at any point is acceptable.

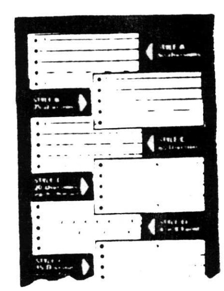


Chart Paper

Rustrak recorders use pressure-sensitive chart paper in 63-foot rolls (one month's recording at 1 inch/hour).

MODELS 288 and 2194:

Usually Style A, 50 divisions, 2-9/16" wide, useable width, 2-5/16". (Also styles B, C, G, H, I, K and L.)

MODEL 291:

Style D, 20 divisions or Style F, 15 divisions per channel. Each 2-9/16" wide, useable width, 1" per channel.

MODEL 2146:

Uses Style N paper, 2-9/16" wide, useable 2" (Analog) & 1/2" (Event).

300 Series:

See 300 Series catalog for many available styles.

F109A, SELECTIVE COMMAND PRINT:

Recorders with this feature have a solenoid-actuated striker rather than one which operates from the motor cam. (There is no cam). No recording occurs until the solenoid is en rgized and the striker presses the stylus against the paper until released by the solenoid. Average duty cycle must not exceed 25 percent.

Connections are made through two binding posts on the case rear. They are labeled for correct voltages.

F109B, AUTOMATIC COMMAND PRINT:

This feature retains the cam-operated striker but the motor cam doesn't engage until the solenoid is energized. Recorder operates normally as long as solenoid is actuated. Duty cycle can be up to 100%.

Connections to solenoid are made through binding posts labeled for correct voltages.

F1A, QUIET FEATURE:

The Quiet Feature reduces impact noise of the striker by changing the writing method to a pressing action. This is a mechanical feature only. The F1A is functional with all motors and gear trains available.

But since the cam arrangement differs from that of a regular recorder, the writing speed is based on strikes-per-15 seconds rather than strikes-per-second. Writing speed is about half as fast as that of a recorder without the F1A.

Strikes/15 sec.	1	2	4	8	12	16	20	24	32
Motor (rpm)	½	1	2	4	6	8	10	12	16

Recorders with this feature print two traces on the chart with only one galvanometer. Inputs are switched through a motor cam to produce two independent traces identified by a regular break in one recording. A Model 288/F137 can monitor two signals while a 291-F137 is a four-channel recorder.

WIRING; MODEL 288:

The second channel input is wired to pins 5 & 6 of the chassis plug. Other models use binding posts on the case rear. Check the label inside your recorder for correct wiring.

SPEED LIMITATIONS:

Because of the extra cam, limitations in chart and writing speed are inherent with the F137. Maximum motor speed is 1 rpm and only gear boxes #1/8 to #12 can be used in the recorder.

111 & 881:

Switchable shunts and multipliers as also hi-current shunts are available for Models 288 and 291. Separate instructions accompany these accessories.

Changing Gear Boxes

Open recorder. Remove gear box spring. More gear box in direction of arrow on its case. Life out from top. Don't force or lift from bottom.

Insert new gear box bottom in first. Slide into position against arrow direction. Replace gear box spring.

F217 AMPLIFIER FEATURE:

Input terminals for recorders with the F217 feature are binding posts on the case rear. The slide switch controls both amplifier and motor power.

Mechanical Zero:

With power off and striker bar allowing free swing of meter stylus (shut off recorder when striker bar does not impinge on stylus), adjust mechanical zero located behind front nameplate.

Electrical Zero & Calibration:

With power on and input binding posts shorted together, adjust Zero control accessible through case rear for zero trace on chart.

Remove short. Feed in an accurate signal equal to full-scale marking and adjust "Calibrate" control for full-scale trace. This control allows a variation of ±10% from full-scale design point.

Troubleshooting and Repair

Your Rustrak recorder is engineered for long and dependable service. It needs no maintenance schedule or lubrication.

But as a precision instrument, it should be given the best of care.

Many problems during use are due to improper chart loading, incorrect wiring or mishandling.

Typical problems are shown in the accompanying chart.

SYMPTOM	POSSIBLE CAUSE	SERVICE HINT
Meter records above or below zero with no signal applied	Meter zero out of adjustment	Remove front nameplate. Adjust mechanical zero
Meter can't be zeroed	Stylus bent; cross arm bent.	Return instrument to factory
Meter reads zero with signal applied.	Meter open. Connections to meter open, multiplier resistor open.	Check meter (Do not use VOM) Check wiring to galvo Check plug and terminal wiring Read out multiplier resistor with VOM
Meter hangs above zero	Dust in meter pivots.	Return recorder to factory
Offset stylus visibly bent	Meter has been overloaded.	Return recorder to factory.
Recorder has continuous trace	Stylus bent, rubs on chart paper.	Return to factory.
Meter reads consistently below zero.	Polarity to meter reversed.	Check wiring to mating socket Check polarity of signal being recorded
Reroll mode. Paper crinkles at view window	Take-up spool not seated to engage drive gear.	Unlatch retaining clip, reseat take-up spool in further notch
Reroll. Paper doesn't drive through recorder.	Perforations not engaged in drive drum. Gear train doesn't engage drive drum.	Reload following loading instructions. Bend tabs on gear train slightly for end play. Bend gear train spring for more tension
Tear-off. Paper doesn't drive through tear-off slot	Drive belts not seated on take-up roller. Also riding in large center groove of drive belt roller.	Seat drive belts as shown in loading instructions.
Paper tears on drive drum	Roll of chart paper is spiraled	Reload taking care chart paper is perfectly aligned
Chart advance thumbwheel is locked	Tab that disengages gear train is bent	Remove gear train and straighten tab

When testing, refer to Exploded View.

Other than service hints outlined on this page, we recommend factory service by technicians trained and equipped to troubleshoot and repair your recorder. Should you wish factory repair assistance, pack your recorder in a carton equal to the original packaging. Insure to full value and ship prepaid. Include a letter giving full details with your packing list.

Send to:

Customer Service Department
Rustrak Instrument Div., Gulton Industries, Inc.
Municipal Airport, Manchester, N. H. 03103

1. INTRODUCTION

In 1973 the U.S. Geological Survey (USGS) decided to build inexpensive horizontal strainmeters that could be used to study small tectonic stress changes in the earth's crust, caused by slip at depth along the San Andres Fault. The object of this experiment was to determine if it is possible to observe changes in the crustal strain field before the occurrence of nearby moderate-to-large earthquakes.

This paper describes in detail, design of the horizontal Invar wire strainmeters at the USGS in Menlo Park, field installation of these strainmeters in areas near Parkfield, Bear Valley, San Juan Bautista, and San Francisco, California (Figure 1), and maintenence practices required to allow meaningful data to be collected. Problems encountered during the development and installation, along with our solutions to these problems will be discussed.

1.1 HISTORICAL BACKGROUND

The first strainmeter we investigated used a commercial transducer developed by Diax Corp., in La Jolla, California (see Appendix 9.3). This instrument was assembled in the U.S. Geological Survey's Presidio vault in San Francisco, California (Figure 2). This vault was originally an old ammunition bunker dating back to the Spanish American war. The transducer was bolted to a steel support resting on the floor and the sensing element was attached to one end of a 10 meter length of invar wire. The other end of the wire was attached to a second steel support also resting on the floor of the bunker. The voltage output of the transducer was amplified with a PAR Lock-in Amplifier. This instrument proved to be noisy (due apparently to mechanical instability of the coupling) and thermally sensitive, but provided valuable experience on strainmeter and coupling design.

Our next attempt coupled the same transducer, and the anchor end of the invar wire directly into the sandstone below the tunnel floor. Thermal jostling of the blocks of concrete forming the floor apparently generated a noisy record. Two existing bore holes, about three meters apart, in one of the outer tunnels (Figure 2) were dug deeper, and granite piers lowered into them, with great difficulty. This installation was a little better, but we were unable to record earth tides with it.

A third installation was made back in a cross tunnel with the invar wire anchored into the wall at the end of the tunnel with an expanding bolt and the transducer bolted to one rail of an old railroad track embedded in the floor of the tunnel. We enclosed the invar wire in a PVC pipe to discourage spiders, sow bugs, and crickets. In spite of very good temperature stability in this tunnel, the transducer proved still to be sensitive to the small changes in temperature in the order of one hundredth of a degree C. This instrument, called PD1S was installed in August 1973, and is still running today, with small modifications over the years.

The cost of the components increased, and the company that manufactured the transducer went out of business. The PAR amplifier requires a reliable source of 115 volt AC power. In spite of these drawbacks, we installed one field strainmeter using these components, in Bear Valley, just north of Pinnacles National Monument in 1974. At about this same time, a strainmeter transducer using completely USGS built components was developed.

We installed the prototype of the USGS strainmeter transducer on the parallel rail next to PD1S. This installation appeared to have good prospects for success. A few months later an improved version of the transducer was installed, along with an electronics package developed at the USGS. This installation was named PD2S, and still produces some of our best near-surface strain records. Two single-component versions of this strainmeter were installed near the San Andreas fault at Parkfield and 3-component versions were installed at Bear Valley, and San Juan Bautista (Figure 1).

2. INSTRUMENT DESCRIPTION

Figure 3 shows the basics of the USGS strainmeter transducer. Three parallel capacitor plates are mounted horizontally on a base plate (Figures 4, 6 and 7). The two outer plates are mounted rigidly. The center plate (Figures 5 and 6) is attached to a ten-meter length of invar wire via a lever arm supported by a cardon hinge (Figures 8 and 10). The transducer is enclosed in a cast iron box (Figure 9). Movement of the wire translates into movement of the central plate between the two fixed plates (Figure 7). Fixed amplitude eight kHz sine waves are applied to these two outer plates. The two sine waves are 180 degrees out of phase with each other. The plate system thus forms a differential capacitance system that is part of an LC bridge. As the center plate moves, it unbalances the bridge. A preamplifier (Figure 22) located on the center moving capacitor plate amplifies the small out-of-balance AC signal. The high impedance signal of the capacitor plate is converted to a low impedance signal that is driven back through cables to the main electronics box. This signal, and the power for the center plate preamplifier are transmitted via a very thin piece of wire across the cardon hinge to a small cable driver amplifier located just outside the cast iron box (Figure 22).

In the main electronics box, the AC signals are converted to plus and minus DC signals in the electronics package, or box. The plus and minus DC signals represent expansion and contraction of the ground between the endpoints. The first instrument of this type was installed parallel to the PD1S strainmeter in the Presidio, and called PD2S. This instrument proved to have good temperature characteristics, and very good long-term stability, producing clean earth tides. The small temperature changes in the Presidio had little, or no effect on this strainmeter.

Our present near-surface strainmeter installations consist of three components, one measuring horizontal strain at right angles to the San Andres fault, and the others at 120 degrees angles to this component (Figure 1). The main electronics package, batteries, and a Sutron satellite platform are located in the electronics pit. This pit is buried about twenty meters horizontal from the transducer pits.

These sites were chosen to be in areas of high seismicity, and close proximity to other geophysical instruments, including tiltmeters, creepmeters, and magnetometers. The reason for picking active sections of the fault, as opposed to locked sections was to have an opportunity to look for evidence of precursors in the data related to frequent seismic events. Other deciding factors were permission to use the land from it's owners, and symmetrical topography to minimize rain loading effects of the ground. As of 1994, only SJS, CLS1, PD1S, PD2S, and PD3S are still in operation (Figure 1 and Table 1). The other stations were mostly shut down because of budget constraints.

2.1 Transducers

Metal parts for the transducers have mostly been manufactured in the USGS Menlo Park machine shop (Figures 5 through 17, and 19). The prototype original was made from components that were easy to machine, but were troublesome to assemble correctly. The cardon hinge (Figures 8 and 10) was easily damaged. The present design has a redesigned cardon hinge to overcome assembly problems, and allows the Invar wire to be clamped directly above the cardon hinge. These hinges are difficult to machine. The capacitor plates have to be lapped to insure parallel surfaces. All the pieces are heat treated to relieve stresses before assembly. These are assembled inside the cast iron box (Figure 9) that holds the silicon oil.

2.2 Instrument Assembly

2.2.1 Assemble the cardon hinge (Figure 8 and 10) and lever arm (Figure 5). Stress relieve this as a unit in an oven. This unit, and all the other small pieces should be brought up to 500 to 600 degrees F for two hours. Then bring the temperature down slowly.

2.2.2 Attach a signal lead to the round center capacitor plate (Figure 6). Use a piece of small, solid copper wire. File the head of the mounting screw down to clear the large hole in the lever arm.

2.2.3 Mount the center capacitor plate using three glass beads, and epoxy glue. Use a piece of optically flat glass with a little mold release to assemble the center plate and glass beads.

2.2.4 Mount the FET preamplifier, ground screw, and output leads.

2.2.5 Set lower fixed plate in position with spacers.

2.2.6 Loosely attach the cross brace to the hinge assembly. Mount this unit in the cast iron box, above the lower, fixed plate.

2.2.7 Add the optical glass spacers and the top, fixed plate. Bolt these in place.

2.2.8 Carefully tighten the screw holding the cross brace axle. A dental mirror is useful at this stage, to observe the three capacitor plates. Adjust for maximum up and down movement of the center arm. A few strands of very fine wire are used to carry the signal, power, and ground across the cardon hinge. Epoxy heavier wires to the cross brace axle.

3. SITE SELECTION AND PREPARATION

Locations of sites selected for installation along the San Andreas fault are listed in Table 1.

Table 1. Surface Strainmeter Locations in California

Site	Latitude	Longitude	Date installed
PDO	37.795	122.474	1974
SJS	36.830	121.540	1975
TRS	36.830	121.5343	1975
BVS	36.570	121.186	1975
BV1	36.571	121.188	1974
SMS	35.916	120.506	1979
CLS	35.941	120.511	1979
FFS	35.929	120.514	1979

Each site consists of three to five fiberglass pits (Figure 18), 3-feet in diameter, and buried 5-feet deep. These pits are connected with trenches that are 2-feet wide (Figure 2 and print next page). Before drilling and trenching takes place, the site should be laid out using a compass, stakes, and a sack of baking flour. A trail of flour helps the trencher operator dig a straight trench. Drill the five bore holes first, using a drill rig with a 42-inch auger. Then bore the smaller holes for the piers in the center of the 42-inch diameter holes. Bore 8-inch diameter holes in the three outer pit holes, and a 10-inch diameter hole in the center of the anchor pit hole. The fibreglass pits, or steel culverts we used originally were manufactured by various companies in California (Figure 18). One type has a bolt on fiberglass lid, and the other has a metal lid. The metal lid stands up to weather, cows, horses etc. and is more secure. Insects and occasionally rodents have an easier time intruding. The fiberglass bolt- on used later to pull the dams out of the ground.

The next step is to lower aged, steel pipes into holes bored below the three outer pits. A simple tripod made from three pipes, with block and tackle can be used to put the steel piers in place. These steel piers are grouted in place with expanding concrete (Appendix 9.5). Ordinary concrete cannot be used for this purpose.

The material we used for the steel piers was purchased from a local used metal dealer. The 1/4-inch wall, 5-inch ID pipe should be aged. New pipe may have undesirable internal stresses. The pipe was sawed into six foot lengths at a machine shop to avoid thermal stress produced by using a cutting torch. Mounting holes for 3/8-inch bolts, were drilled, 180 degrees from each other, and about 1-inch from the top end of each pipe. The anchor pier was made from 8-inch ID aged steel pipe. Three holes for 3/8-inch bolts were drilled 120 degrees from each other, and about one inch from the eventual top of the pipe.

Line up the 3/8-inch mounting holes with the horizontal PVC pipes, using a level to make the piers parallel and vertical. Wedge the piers in place with rocks, and pour in expanding grout around the pipes. Some of the piers had to be hung from 2 x 4 planks laid across the top of the pits. Recheck the alignment before the grout sets. The PVC pipes have to be sealed into the fiberglass pits with silicon rubber. Dig a shallow trench, about 18-inches deep, between the center anchor pit and the electronics pit. Install a 2-inch PVC pipe in this trench. It is used to carry all the electronics cables. Everything should be left at this point until the grout has set.

The anchor pier is the most complex of all the piers. It requires care in installing. As the strainmeters are only 5-feet deep, they are subjected to much higher temperature changes than the Presidio installations. The coefficient of expansion of Invar wire changes sign at about 68 degrees F. The coefficient of expansion for aluminum is much higher than for Invar wire. The clamp that holds the end of the invar wire (Figure 11 and 15) is back-loaded with a 12-inch length of aluminum tubing (Figure 11). One method of mounting the temperature compensating clamps tried was to bore 1-inch clearance holes in the anchor pier. It was found to be very difficult to assemble, and resulted in a lot of heavy, time consuming metal filing. The clamp mounts (Figure 15 and 14) had to be machined to the curve of the anchor pier. A much easier method was developed after the first field metal filing job. We sank the anchor pier down below the bottom of the horizontal PVC pipes. Adjustable steel pieces (Figure 16) were then bolted to the pier, and the aluminum pipe clamps mounted on these flat steel extensions.

The electronics pit has a solid bottom. We had trouble with two of these floating out when the water table came up during periods of heavy rain. We mounted 1/2-inch bolts around the diameter of the pit, and then poured in about 500 or more pounds of ready mix concrete.

Attach one side of the metal lid to the fiberglass culvert with a short piece of chain. The other side is held down with a chain and padlock. Pour a mixture of gravel and sand in around the pits. Pour roofing tar in, and allow it to settle into the sand and gravel. If the silicon rubber is not allowed to cure, the roofing tar and sand will enter the culvert, making a big mess. The trenches should be filled with soil, using the backhoe. Fill in with the top soil that was first removed when the trenches were dug. This is to aid in reseeding the disturbed area. Pull out the plywood dam, using the winch on the field truck, or use the " A" frame. Cover the trenches with plastic, and dig drainage ditches to lead off rain water. This is not necessary when installation takes place in the middle of a hot summer. Leave the sites to settle for about three months, before installing the transducers, invar wire, and electronics.

3.1 Field Assembly

3.1.1 Attach a rag to the cord that was left in the 6-inch PVC pipe. Pull this through the pipe with another cord attached. This is to clean out any wild life, dirt etc.. that may be in the pipe.

3.1.2 Mount vertical extension pieces (Figure 16) inside the pier pipes, if not already done. Mount the angled support pieces (Figure 17) to support the strainmeter box, on the outside of the pipe.

3.1.3 Stretch a length of Invar wire, about one meter longer than needed. Tie one end to something solid, and walk away stretching as the wire comes off the spool. Carefully pull this wire through the PVC pipe with the cord that has been left inside.

3.1.4 Join a short section of bellows to the vertical extension piece with silicon rubber. Set hinged NEMA electrical box down on the two supports, with the vertical extension of the pier coming up through the hole in the bottom of the metal box. The NEMA electrical box is a sheet metal box with a lid, and gasket. It is large enough to hold the strainmeter transducer, and dryer (dessicant) bags. The vertical extension should protrude about half an inch into the box. Pull the bellows through this same hole, and seal with silicon rubber. This decouples the box from the transducer.

3.1.5 Use a single screw, and an "O" ring to mount the transducer to the vertical extension of the pier. Starting at the transducer end, attach the invar wire to the transducer with the invar wire clamp (Figures 11 and 13). The other end of the invar wire is fed through the temperature compensator. Adjust the height of the transducer support to allow the Invar wire to hang free in the pipe with about a 3-inch catenary in the center. The height of the anchor mounting will have to be adjusted also. Adjust heights so everything lines up, and

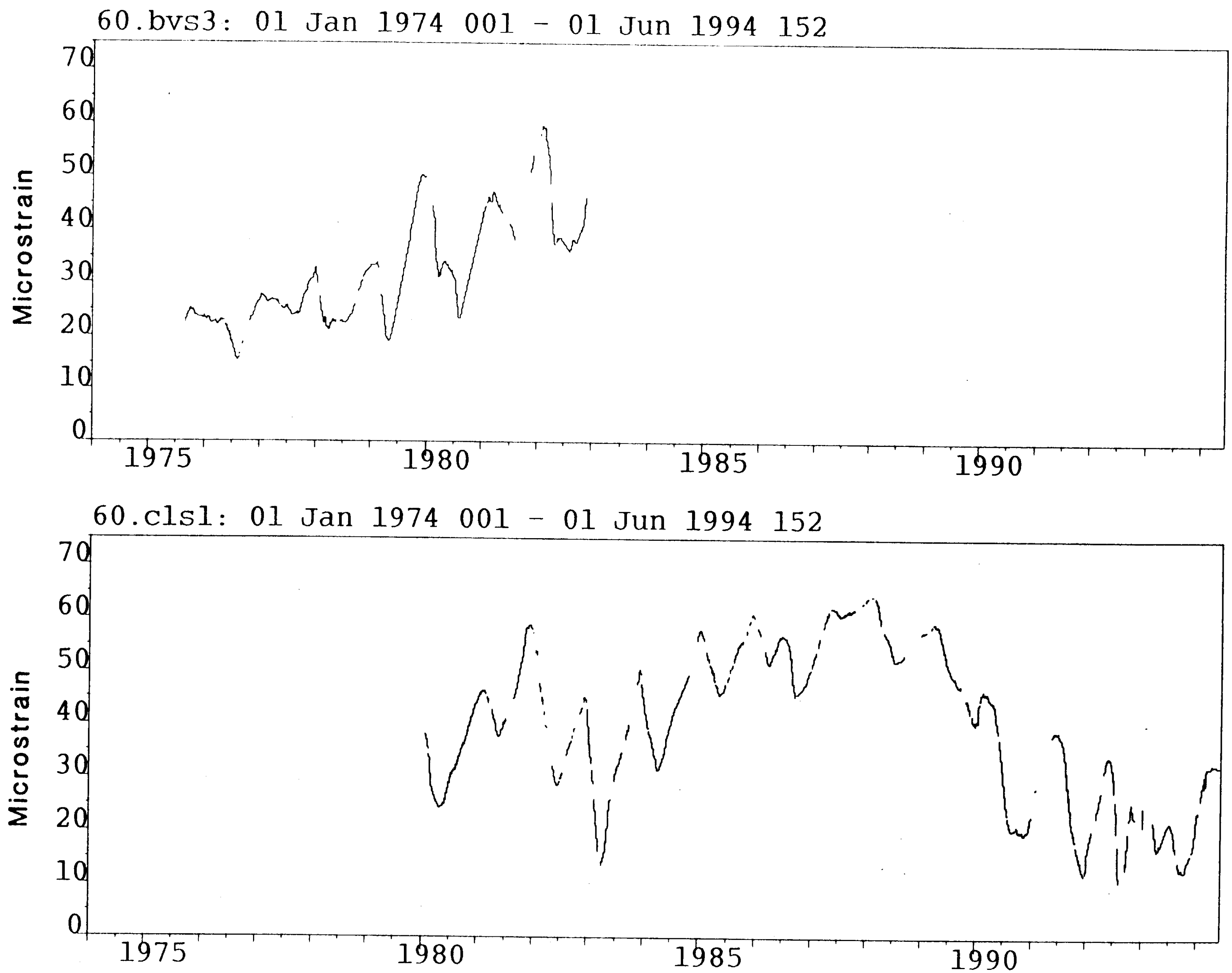


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Figure 10.5

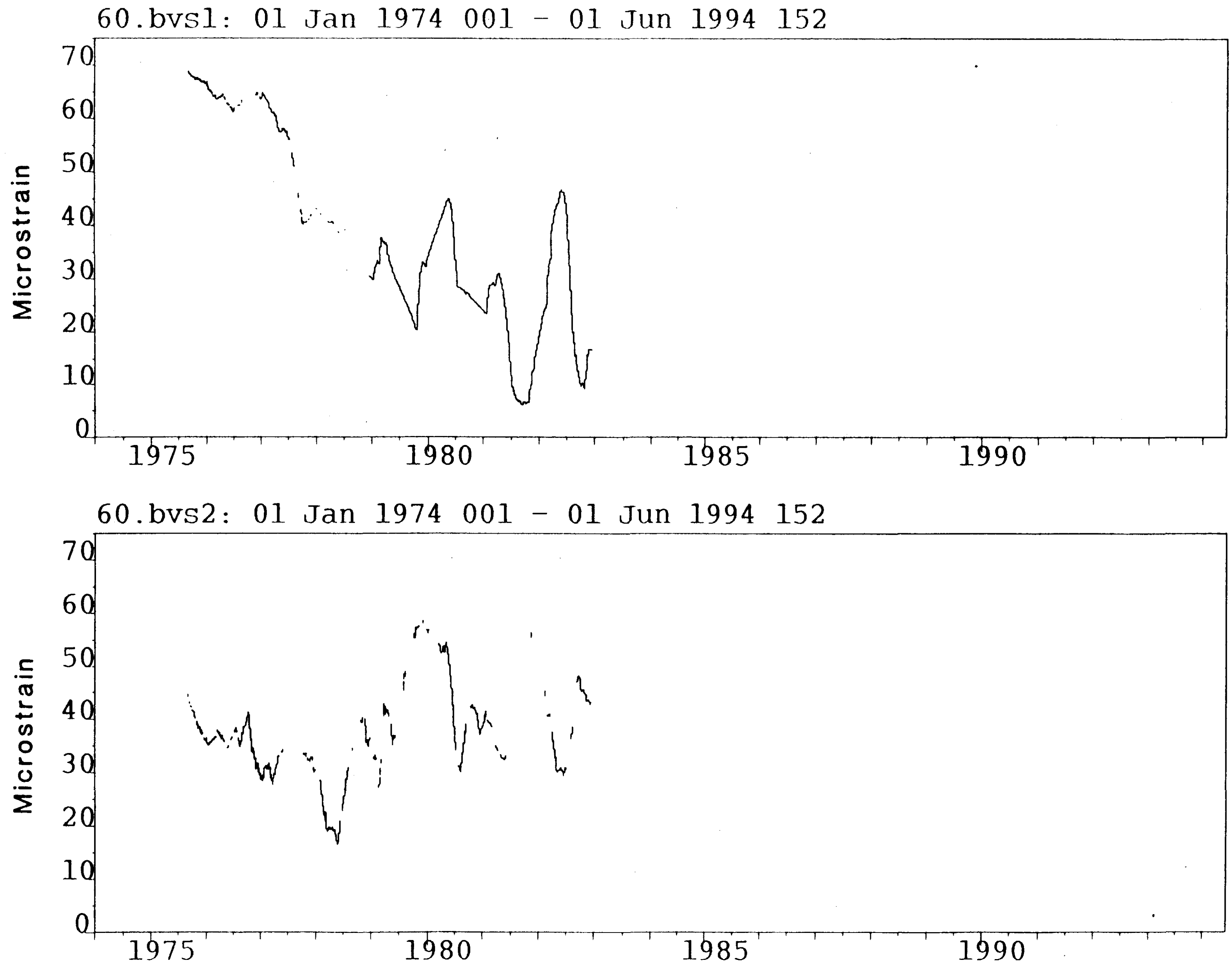

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Figure 10.4

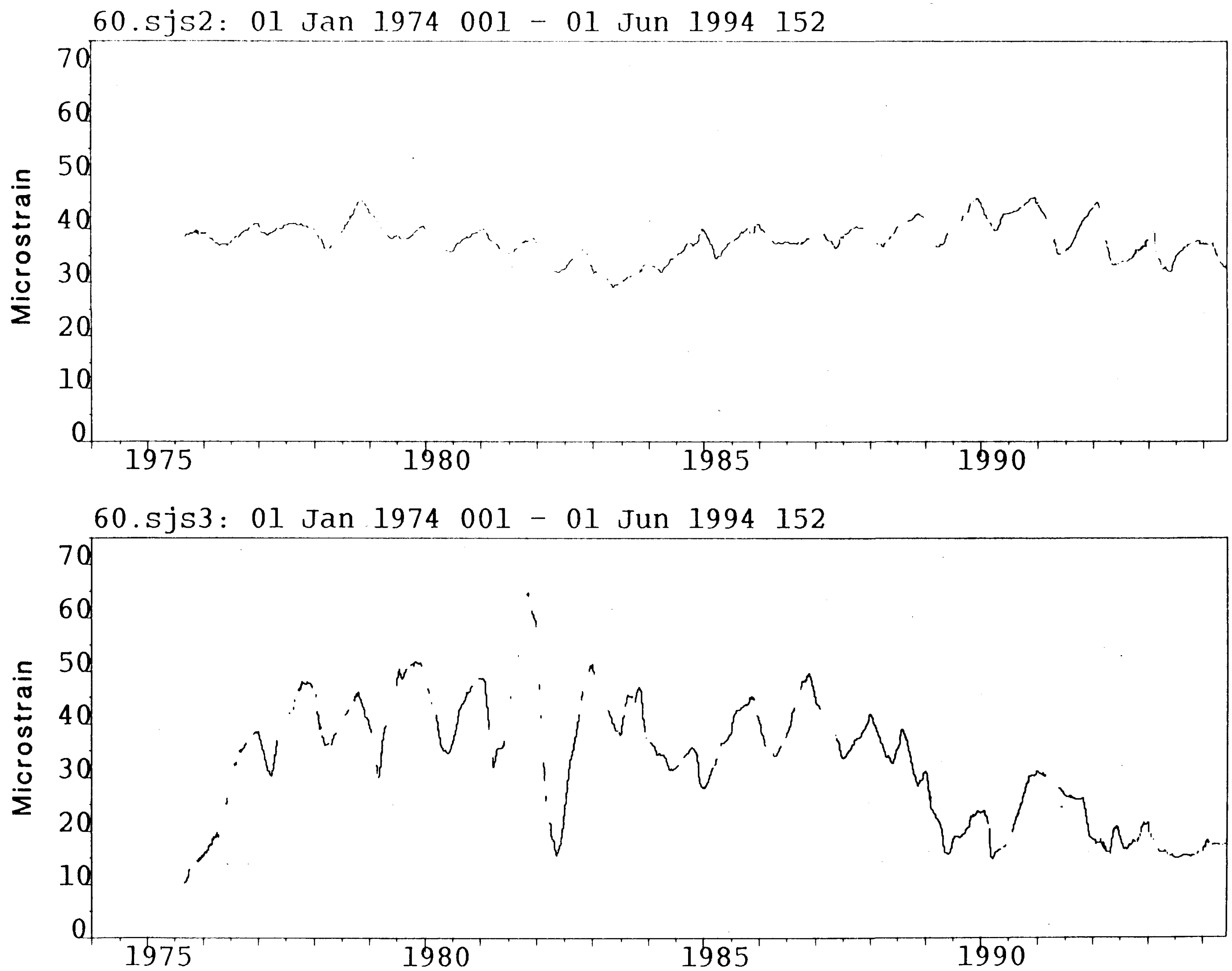

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Figure 10.3

grounded with one position of this switch, and the other position sends the signal on to the comparator, IC7. Use the "zero" position of this switch when adjusting the zero controls on the output amplifiers, and the comparator. The output of the comparator will be zero until one phase or the other AC signal comes through C10, a .02 mfd capacitor. With a signal, the output goes + or -. C11, C12, and C13 are time constant capacitors. R40 controls the voltage out to the digital telemetry system. R39 controls the deflection on the Rustrak strip chart recorder (see Appendix 9.7 for information on the recorder).

4.1.7 The 8-kHz sine wave is generated with a KTI FS-60 chip, IC3. IC4 amplifies this sine wave. A UTC 0-30 transformer splits the 8-kHz sine wave into two phases. These two sine waves are connected to the Ratio Transformer and to the two fixed transducer plates. The ratio transformer controls the relative amplitude of the two sine waves. The output of the oscillator is also fed to the inputs of two, number 710 ICs, IC5 and IC6. One IC acts as an inverting amplifier, and the other as a non-inverting amplifier. Transistors Tr4 and Tr5 amplify the square waves. The square waves then run through the chopper, consisting of two 3N138 transistors, Tr6 and Tr7, and then on to the inputs of the comparator IC7.

4.1.8 The AC signal is applied to the input of the comparator. Depending on which phase of the original oscillator signal is stronger on the center plate of the transducer, the output of the comparator will be plus, or minus compared to ground. IC8 amplifies the DC signal for the strip chart recorder, panel meter, and digital output. IC9 amplifiers the DC signal for the digital telemetry system.

4.1.9 Precise ratios of oscillator voltage can be controlled with the ratio transformer (see Appendix 9.4 for Singer Ratio Transformer data). This allows the electronics to be zeroed, even if the center plate of the transducer is not in the center between the two fixed outer plates.

It also allows fixed strain steps to be applied to each strainmeter. This gives a check of the operation of the strainmeter.

4.2 Power Supply

Figures 25, and 26 show the power supply diagrams. If the power source consists of air cells, the five volts is converted to plus and minus 12 volts, using a 5 volt to + and -12 volt converter. If a solar system is used, a twelve volt converter is used to obtain the plus and minus 12 volts. Almost any commercially available converter, can be used to obtain plus and minus 12 volts. The 12 volts is regulated down to plus and minus nine volts by IC10. IC5 and IC6 need a small minus voltage on Pin 6. R71 and C35 furnish this voltage.

5. STRAINMETER FIELD MAINTENANCE

5.1 Field visit

5.1.1 The time to make a field visit to a strainmeter site is usually determined by the looks of the data arriving in Menlo Park. Several inches of rain will saturate the ground, and the associated dilational strain will usually run the strainmeters off scale. Or, worse, water will get into the transducer pits.

5.1.2 Make sure permission is granted to drive onto the strainmeter site. This may involve a phone call to the landowner. Be sure to close all gates that are found closed on arrival. Be extremely careful about driving over dry grass. Do not park over the strainmeter wires.

5.1.3 Open the electronics culvert first. Carefully remove the large bag of pellets. If it is very hot, use a beach umbrella to shield the contents of the culvert. Usually a field visit will only involve electronic rezeroing, changing Rustrak paper, and perhaps resetting the Sutron data platform. The deep temperature bridge may need resetting also.

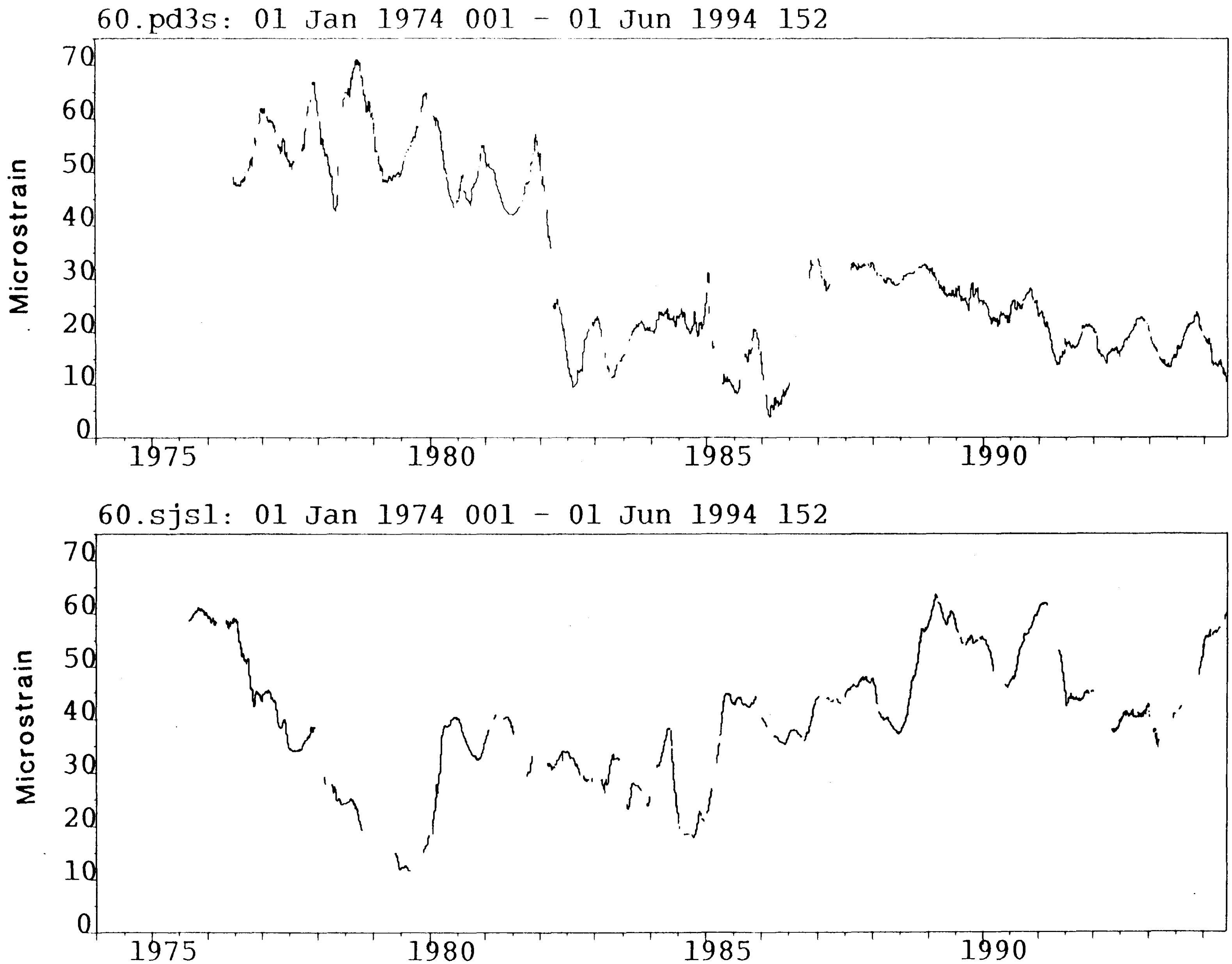

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Figure 10.2

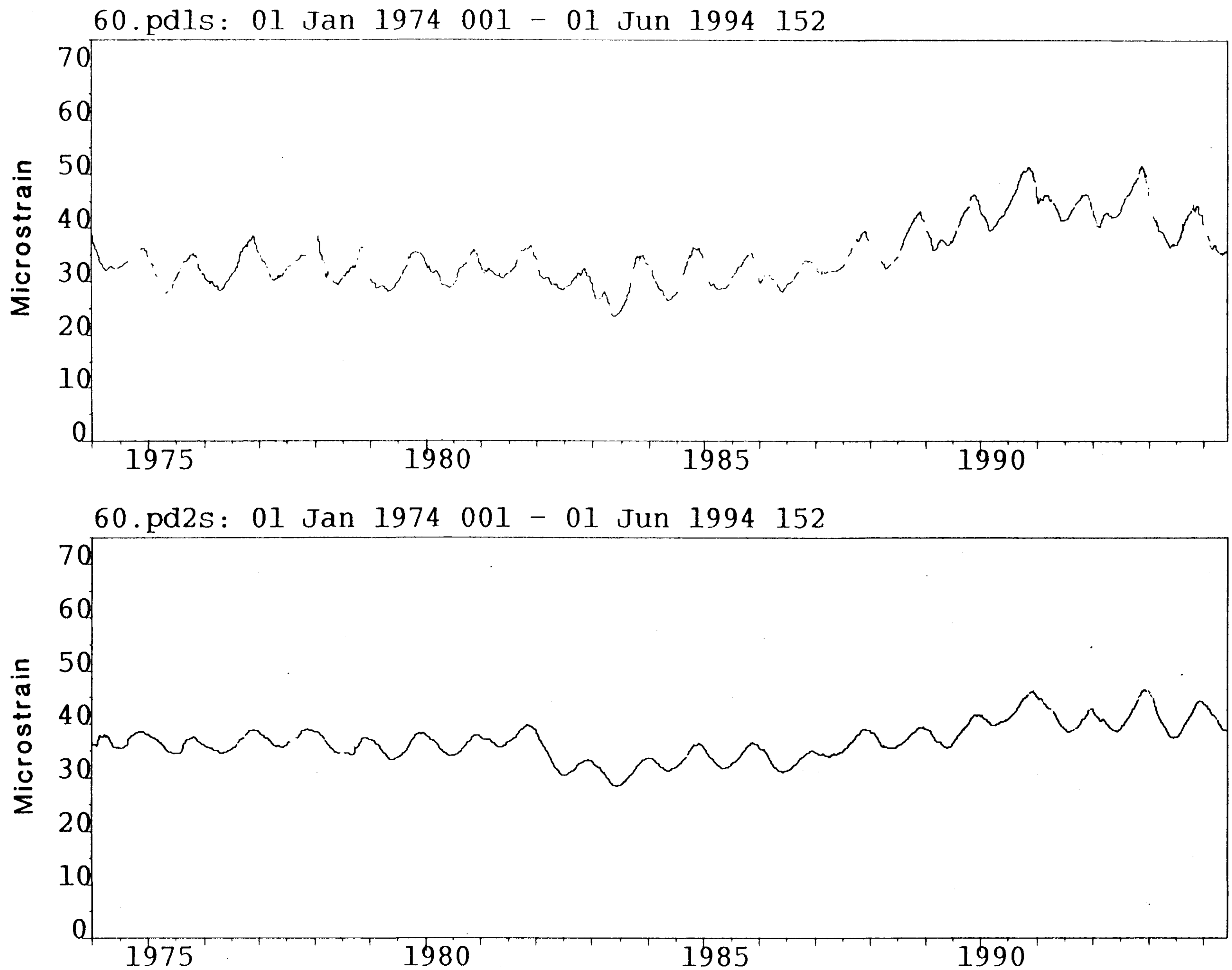
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Figure 10.1

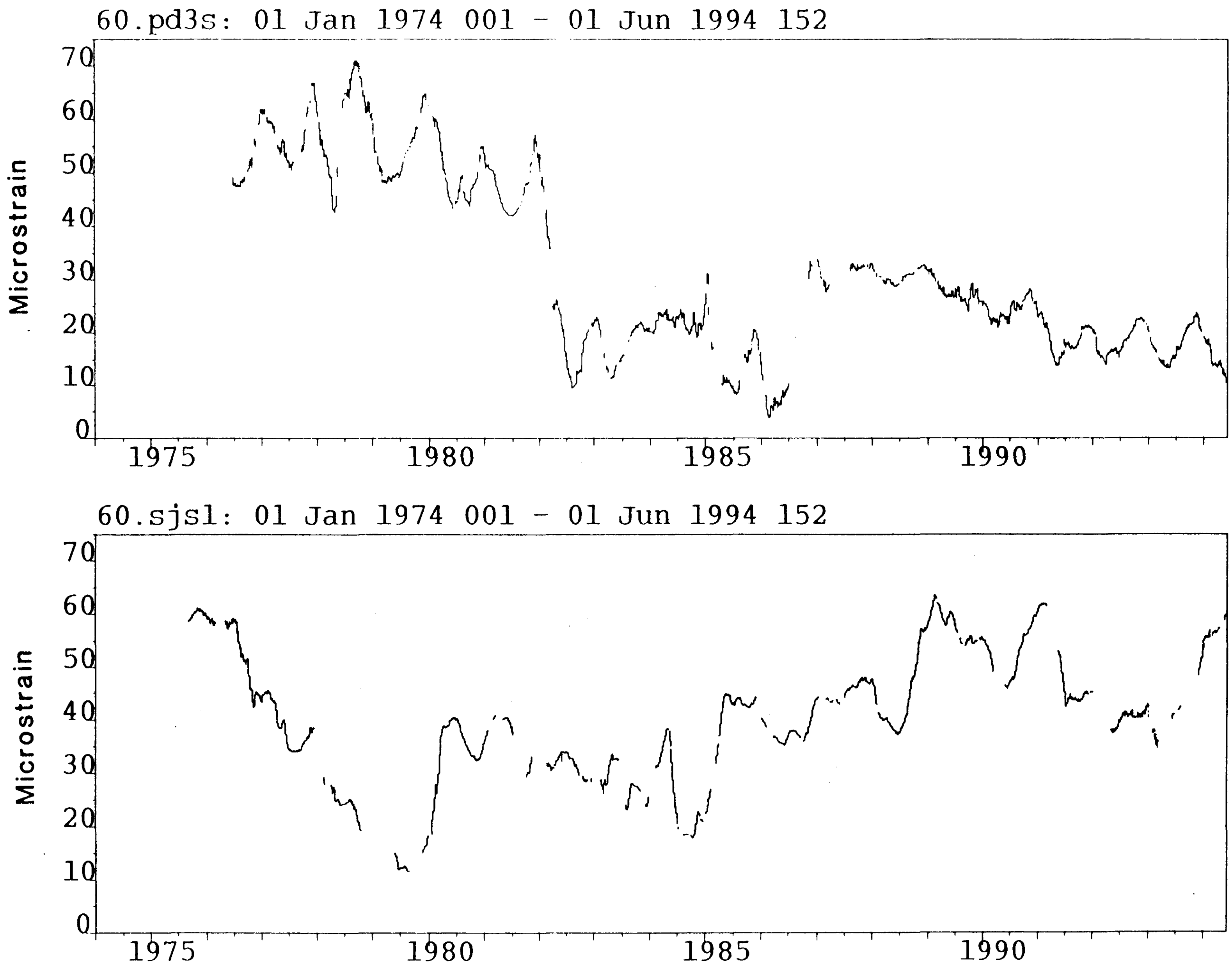
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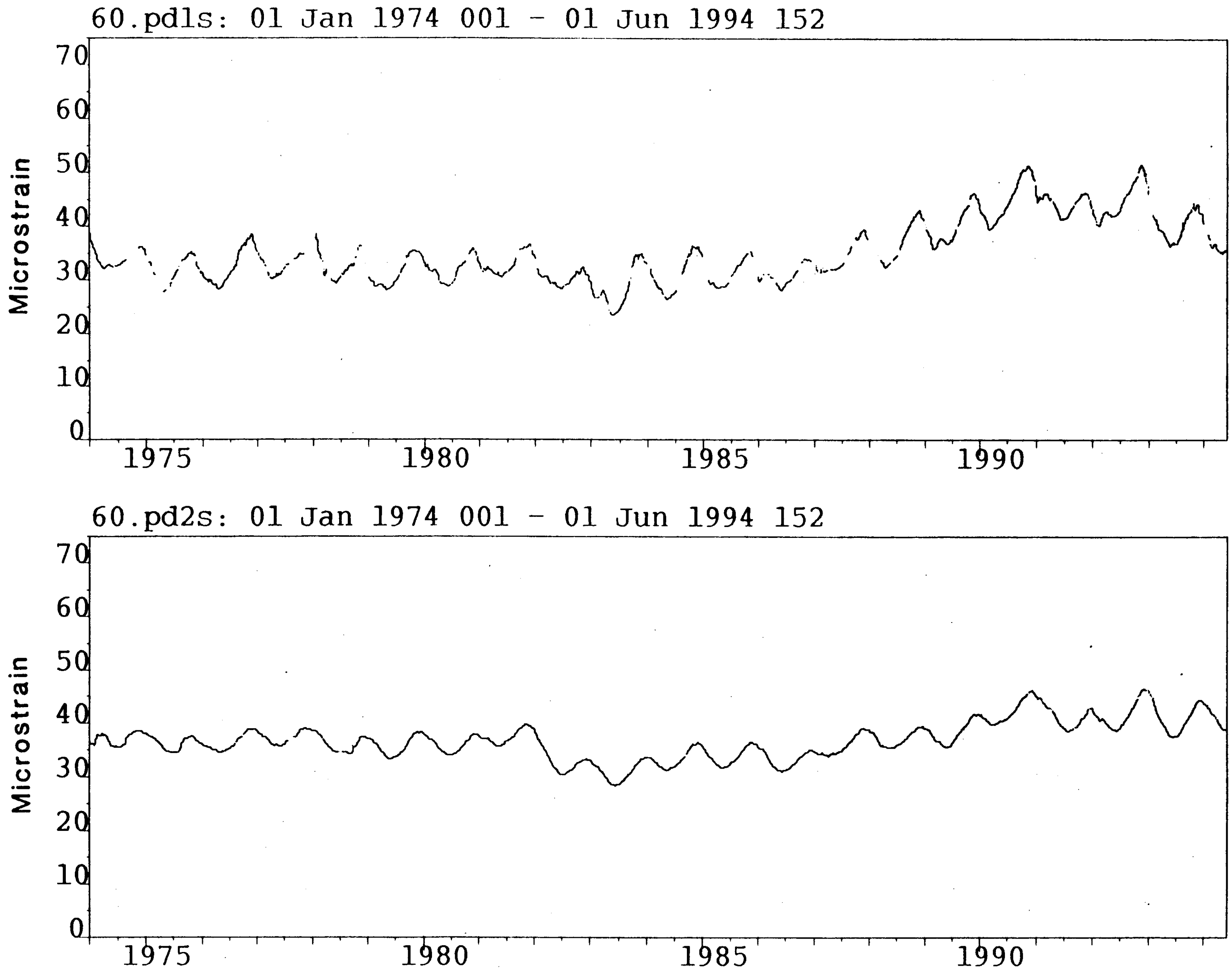
Figure 10.2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60.pd2s: 01 Jan 1974 001 - 01 Jun 1994 152
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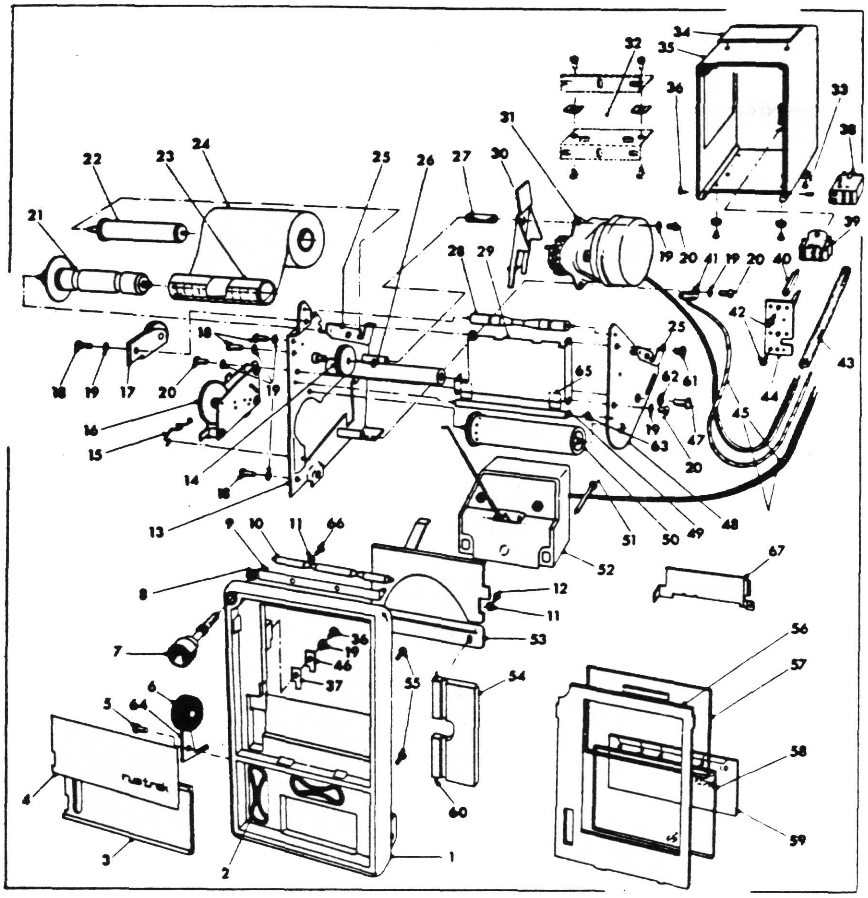
Figure 10.1

Exploded View of a Typical Model 288 Recorder

EXTRA COPIES OF EXPLODED VIEW ARE GRATIS FROM RUSTRAK BY SPECIFYING # 17102



Note	ITEM	PART NO.	DESCRIPTION
	1	C-4711-G1	Front Panel Ass'y
	2	A-4653-P1	Belt Drive
	3	B-4131-P1	B... Lower
	4	A-4728-P1	Nameplate
	5	A-4718-P1	Screw, Special
	6	A 3280	Thumbwheel, Chart Advance
	7	A-4477-P1	Thumbscrew
	8	A-4667-P1	Ring, ...ning
	9	B-4119-P1	Bracket, Friction Roller
A	10	A 5366-P1	Friction Roller
	11	LI 2	Lock Washer, Internal Tooth No. 2
	12	2-56x1/8LG	Mach Screw, Pan HD SST
	13	B-4664-G1	Left Hand Plate Ass'y
	14	A-2232	Gear, Idler
	15	A 2384	Spring, Gear Train
(1)	16	As Req'd	Gear Train Ass'y
	17	A-4479-G1	Arm and Gear Ass'y
	18	4-40x5/16LG	Mach Screw, Pan HD SST
	19	LI-4	Lock Washer, Internal Tooth No. 4
	20	4-40x1/4LG	Mach Screw, Pan HD SST
	21	B-4488-G1	Take-up Roller Ass'y
	22	B-2316-P1	Roller, Supply
	23	A 7754-P1	Sleeve, Cardboard
(2)	24	As Req'd	Paper, Strip Chart
	25	A-5151-P1	Clip, Retaining
	26	5100-18-C-MF	Ring, Retaining
	27	A-4185-P1	Spring, Brake
	28	B-4720-P1	Roller
	29	B 2474	Plate, Front Support
	30	A 2313-P2	Brake
(3)	31	As Req'd	Motor Ass'y & Cam (115V, 60HZ, 2RPM)
	32	B-4497-G1	Hardware Kit, Panel Mtg
	33	B-4649-G1	Rubber Feet, (4) With Screws
	34	B-4313-P1	Cardholder
	35	D-7744-2G	Case, Back
	36	4-40x3/16LG	Mach Screw, Fil HD SST
	37	A-4752-P1	Ratchet, Chart Advance
	38	A-4658-P1	Socket, Cable
	39	A-4659-P1	Plug, Chassis
	40	A-7779-P1	Spacer
	41	A-4303-P1	Lug, Dual
	42	6-32x1/4LG	Mach Screw, Pan HD SST
	43	A-4646-P1	Tubing, No. 3, .234 I.D.
	44	B 7466-P1	Board
	45	A-4555	Wire
	46	A-4751-P1	Stiffener, Ratchet
	47	6-32x5/16LG	Mach Screw, Pan HD SST
	48	C-4307-P1	Plate, Right Hand
	49	A 2703	Roller, Center
	50	B-4550-G1	Time Drum Ass'y
	51	6-32x1-5/16LG	Mach Screw, Pan HD SST
(4)	52	As Req'd	Meter Ass'y (1 MA)
	53	B-4497-G1	Striker and Arm Ass'y
	54	C-4214-P2	Latch, Chassis
	55	4-40x3/16LG	Mach Screw, Pan HD SST
	56	B-4117-P1	Bezel, Front Panel
	57	B-4178-P1	Window, Access
	58	B-4179-P1	Window, Bottom
(5)	59	As Req'd	Scale (Std) Only
	60	A-4551-P1	Pin, Latch
	61	A-4562-P1	Machine Screw, Special
	62	LI-8	Lock Washer, Internal Tooth No. 8
	63	A-4157-P1	Washer, Nylon
	64	A-4219-G1	Hinge Bracket Ass'y
	65	A-4089	Spring, Leaf
	66	2-56x3/16	Machine Screw, Pan Head
	67	A-4870-P1	Guard, Pointer

(1) SPECIFY GEAR TRAIN NO. REQUIRED. INTERCHANGEABLE GEAR TRAIN AFFECTS SPEED. SEE CATALOG

(2) SPECIFY CHART PAPER STYLE

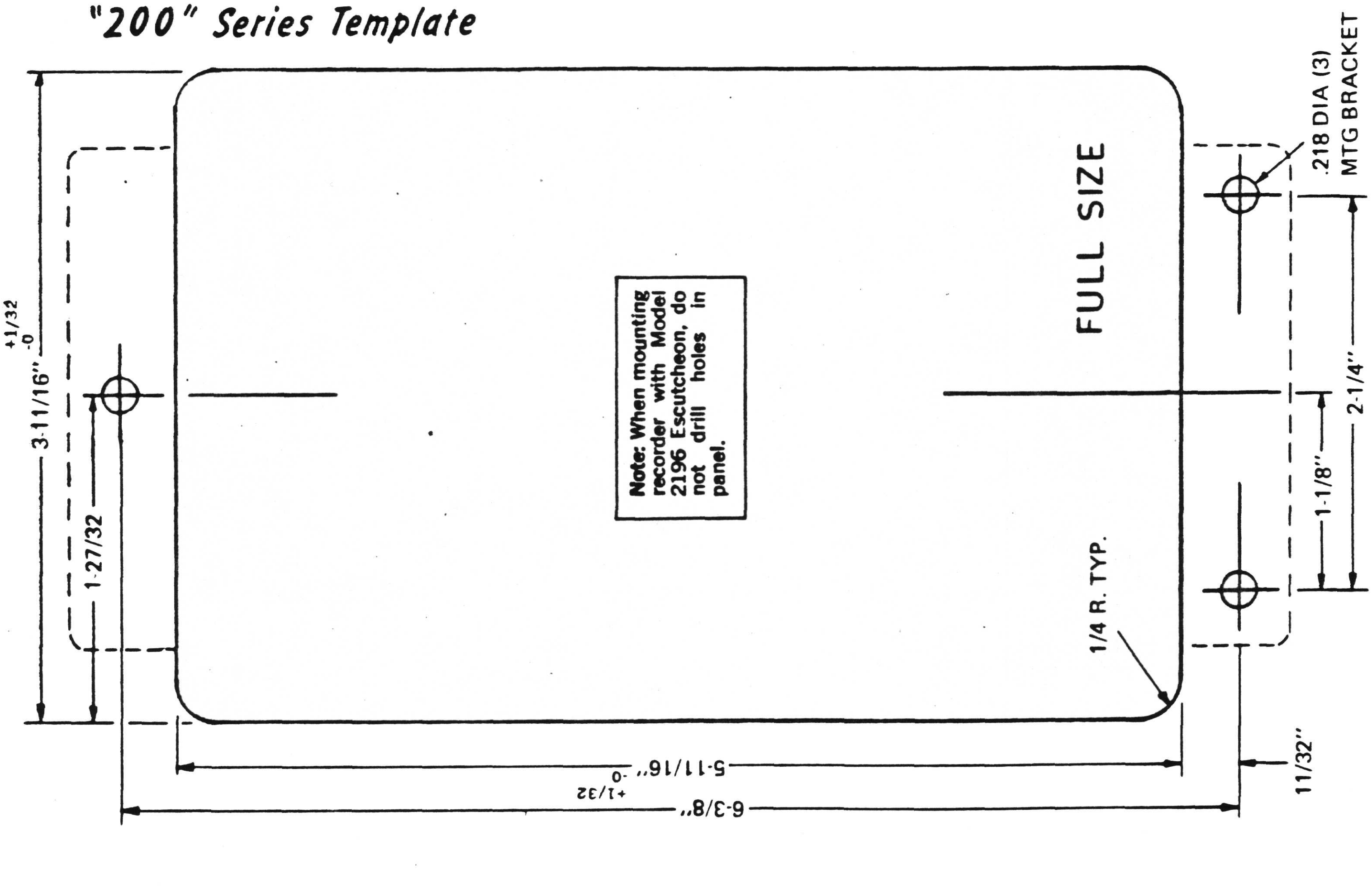
(3) WHEN ORDERING INCLUDE MOTOR SPEED, VOLTAGE AND FREQUENCY. SEE CATALOG

(4) SPECIFY METER PART NO. WRITE FOR PRICES

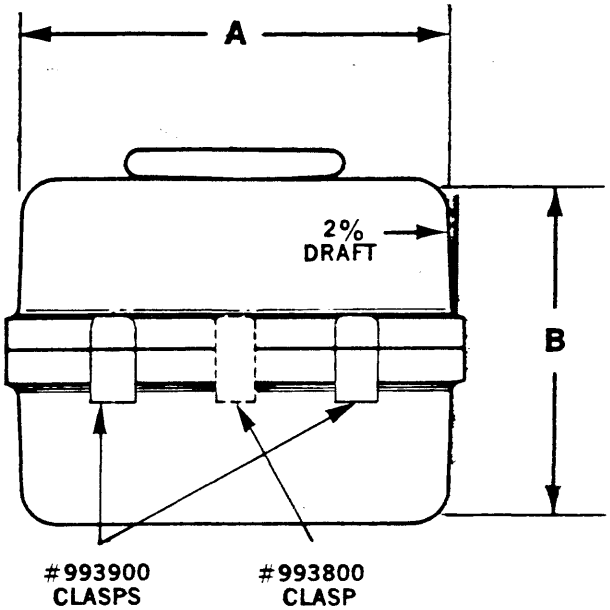
(5) SPECIFY SENSITIVITY, RANGE, PARAMETER AND SPECIAL MARKINGS IF ANY

(A) A 5366 P1 IS METAL ROLLER. FOR RUBBER ROLLER SPECIFY A-SA 1336-G1

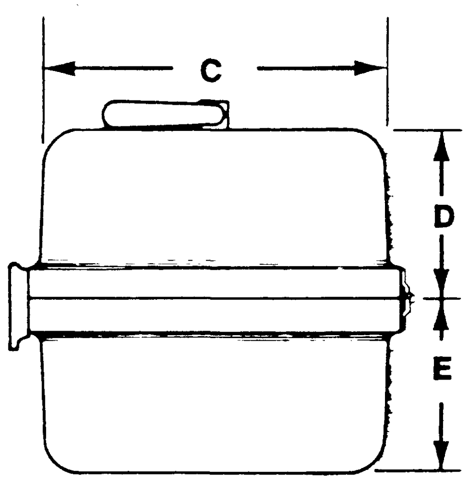
"200" Series Template

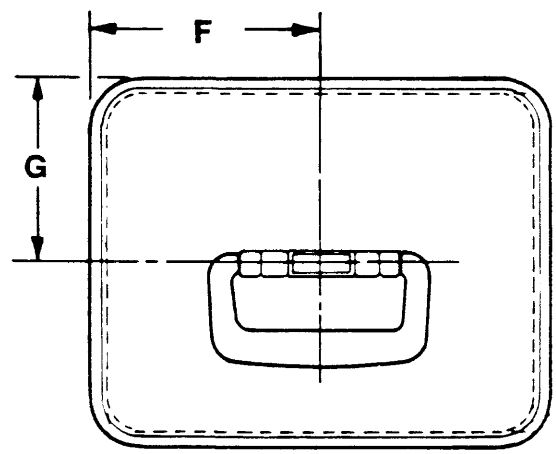


PORT-A-GLASS CASE SPECIFICATIONS



	CASE MODEL NO. & DIMENSIONS (INCHES)	
	993800	993900
A (INSIDE)	10.00	14.00
B (INSIDE)	8.00	9.50
C (INSIDE)	8.00	9.25
D (INSIDE)	4.00	2.50
E (INSIDE)	4.00	7.00
F	5.38	7.38
G	4.38	5.00





Represented by:

Skydyne®

River Road, Port Jervis, New York 12771

A b+p Brooks & Perkins Company

(914) 856-6655

TWX 510-260-1249

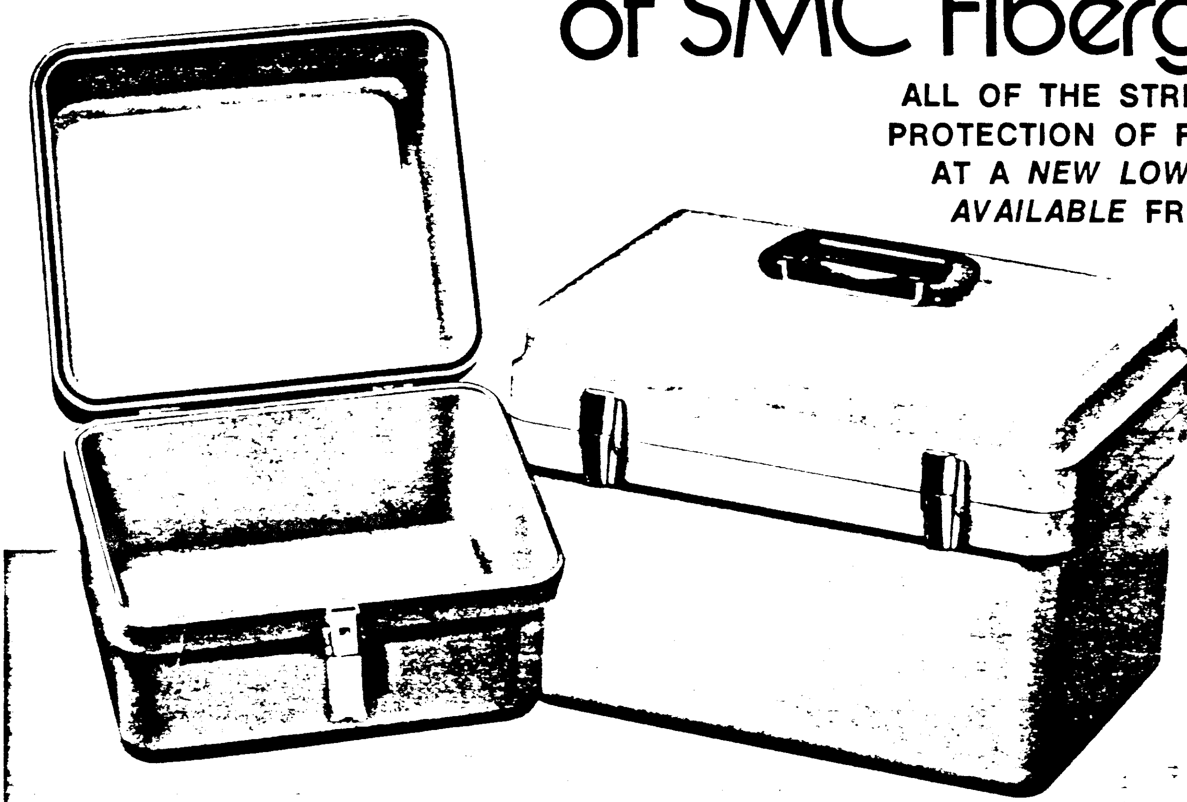
1-800-425-CASE

10M/9-74

LITHO IN U.S.A.

New Low Cost PORT-A-GLASS™ CASE of SMC Fiberglass

ALL OF THE STRENGTH AND PROTECTION OF FIBERGLASS AT A *NEW LOW COST . . . AVAILABLE* FROM *STOCK!*



TWO STANDARD SIZES

Skydyne's low cost fiberglass SMC (sheet molding compound) Port-a-glass cases provide a new standard in economy while offering all of the well known protective and structural qualities of fiberglass. These new cases have been specifically designed for application in the protection of portable sensitive instruments, optical equipment, field service equipment, models and medical supplies, and can be supplied with custom protective foam inserts if required. Standard case color is grey.

Some of the outstanding features of these new cases are listed below.

- **High Resistance to Impact**
- **High Resistance to Moisture, Corrosion and Weather**
- **Steel Reinforced Handle**
- **Extremely High Strength to Weight Ratio**
- **Polished Nickel Latches**
- **High Thermal Shock Resistance**
- **Inert to Most Chemicals**

Complete dimensional information on the new Skydyne Port-a-glass case is included on the reverse side of this sheet. Special, custom designed units are also available to meet specific application requirements. Typical physical properties for these new cases include:

Tensile Strength	15-17,000 psi
Izod Notched Impact Strength	5-15 ft. lbs./in.
Compression Strength	22-36,000 psi
Flexural Strength	26-32,000 psi

In addition to this new SMC Port-a-glass case, Skydyne manufactures a complete line of fiberglass, ABS and sandwich panel cases to MIL Specifications as well as all types of custom designed structural containers for every conceivable application.

Procedure for proper use
) Set Nonshrink Grout

Description
Set Nonshrink Grout requires only the addition of water to provide nonshrink grouting and anchoring of structural steel and precast concrete members. It is a high quality grout and must be treated accordingly. Formulated to meet the current Corps of Engineers Specification for Nonshrink Grout, CRD-C 621, it can be packed, flowed or pumped for a variety of applications.

Preparation of Area
Roughen and clean the concrete foundation, pedestal or surface, including anchor bolt holes, of all grease, oil, dirt and particles. Remove all curing compounds or protective membranes. The concrete should be sound and the area in contact with the grout must be thoroughly saturated with water prior to placing the grout. Remove all free-standing water. Forms must be installed and caulked to contain the grout after placement.

Mixing
By using the minimum water content that will provide the desired workability, maximum strength is achieved. Mix grout with a mechanical mixer. Either a mortar mixer or an electric drill with a paddle device is acceptable. Put measured amount of water into mixer, add grout and mix until a uniform consistency is obtained.

Flowable mix: 1.1 U.S. gal. of water to one 50-lb. bag of grout.
Plastic mix: 0.95 U.S. gal. of water to one 50-lb. bag of grout.
Stiff mix: must be mechanically mixed with a minimum of 0.75 U.S. gal. of water to one 50-lb. bag of grout.

For pumping or special flow requirements: check with your field representative or dealer for further information.

Applications
Shim Plate Grouting: Use a plastic mix and tap shim plate to proper elevation.
Structural Steel Plates and Precast Concrete Members: Use a flowable mix and continuously flow the grout from one side, forcing out all air pockets to provide a void-free, bearing surface. Do not place grout at a flow or consistency which exhibits bleeding.
Anchoring: Use a flowable mix to completely fill the voids around the bolt, rebar or item to be anchored. Fill hole to top and cure with damp rags.
Nonshrink Repairs: Use a plastic mix and pack into holes or voids to be repaired such as snap tie holes.
Dry Packing: Use a stiff cohesive mix. Allow to set for approximately 10 minutes and ram into place. Do not mix more material than can be placed in 30 minutes.

NOTE: Have all grout in place before any of the grout becomes unworkable. *Do not retemper.* Do not vibrate grout.

Curing
Thoroughly curing Set Nonshrink Grout immediately after placement is critical. The grout should be protected from wind, low humidity, high temperature and fast drying conditions that will cause the grout to dry out. Wet cure all exposed grout for a period of 3 to 6 hours using wet rags, wet burlap, or by ponding. Apply a membrane curing compound meeting the moisture retention requirements of ASTM C 309 upon completion of the wet-cure period.

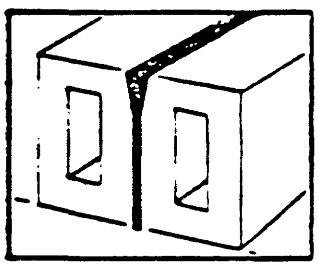
Cold Weather
Special precautions are required for grouting if ambient temperature is below 50°F. At low temperatures use warm water and allow extra time for strength buildup. Warm base to a minimum of 50°F. Protect grout from freezing with insulation blankets until 4000 psi compressive strength is achieved. Induce indirect heat for faster strength development. Reduce water content if bleeding occurs.

Hot Weather
At temperatures above 80°F, use ice water to prevent premature stiffening of grout. Place grout immediately after mixing. Dampen base prior to grouting and apply cure immediately to prevent rapid drying.

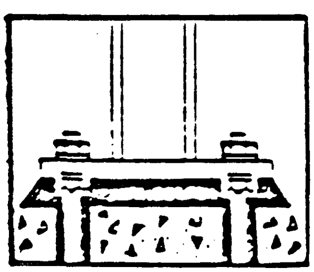
SET
Nonshrink Grout

Nonshrink Performance
Set Nonshrink Grout is a portland cement-based, natural aggregate grout designed for use at a flowable consistency. Mixing requires only the addition of water to produce a nonshrink, nonbleeding grout which meets the performance requirements of the Corps of Engineers Specification for Nonshrink Grouts, CRD-C 621.

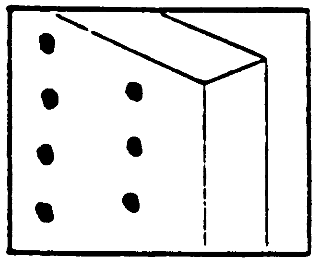
Multi-Use
Designed with field application in mind, Set Nonshrink Grout is the grout for structural grouting applications.



Precast, Prestressed Concrete Elements
Set Nonshrink Grout contains no chlorides or corrosive chemicals. It is non-staining and is approximately the color of concrete.

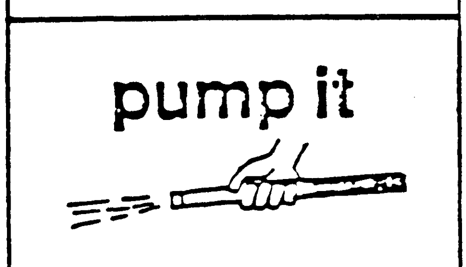


Structural Steel Baseplates and Members
Set Nonshrink Grout develops ample bearing strength and can be used above or below grade.



Nonshrink Repairs
Set Nonshrink Grout is perfect for plugging snap tie holes and filling pipe sleeves.

Versatility
Set Nonshrink Grout's water content can be controlled from a stiff mix for dry pack, to a nonbleeding flowable mix for gravity grouting or pumping.



Strength
Strict quality control, precise formulation and superior raw materials ensure the strength performance of Set Nonshrink Grout.

Compressive Strength-psi
Water Content per 50-Pound Bag

age	1.1 U.S. gal. flowable
1 Day	2500
3 Day	5000
7 Day	6000
28 Day	8000
*approx. flow @ 70°F	135%

*per ASTM C 109, 5 drops in 3 seconds

Approx. Setting Time at Flowable Consistency

initial	2 hrs., 15 min.
final	3 hrs., 45 min.

CRD-C 614

NOTE: Set Nonshrink Grout must be treated the same as any other high quality portland cement-based material. The water/grout ratio is important to obtain the required strength and nonshrink performance. The product is designed to simplify field applications and permit alternate methods of placement. Set Nonshrink Grout must be properly cured to achieve the desired performance.

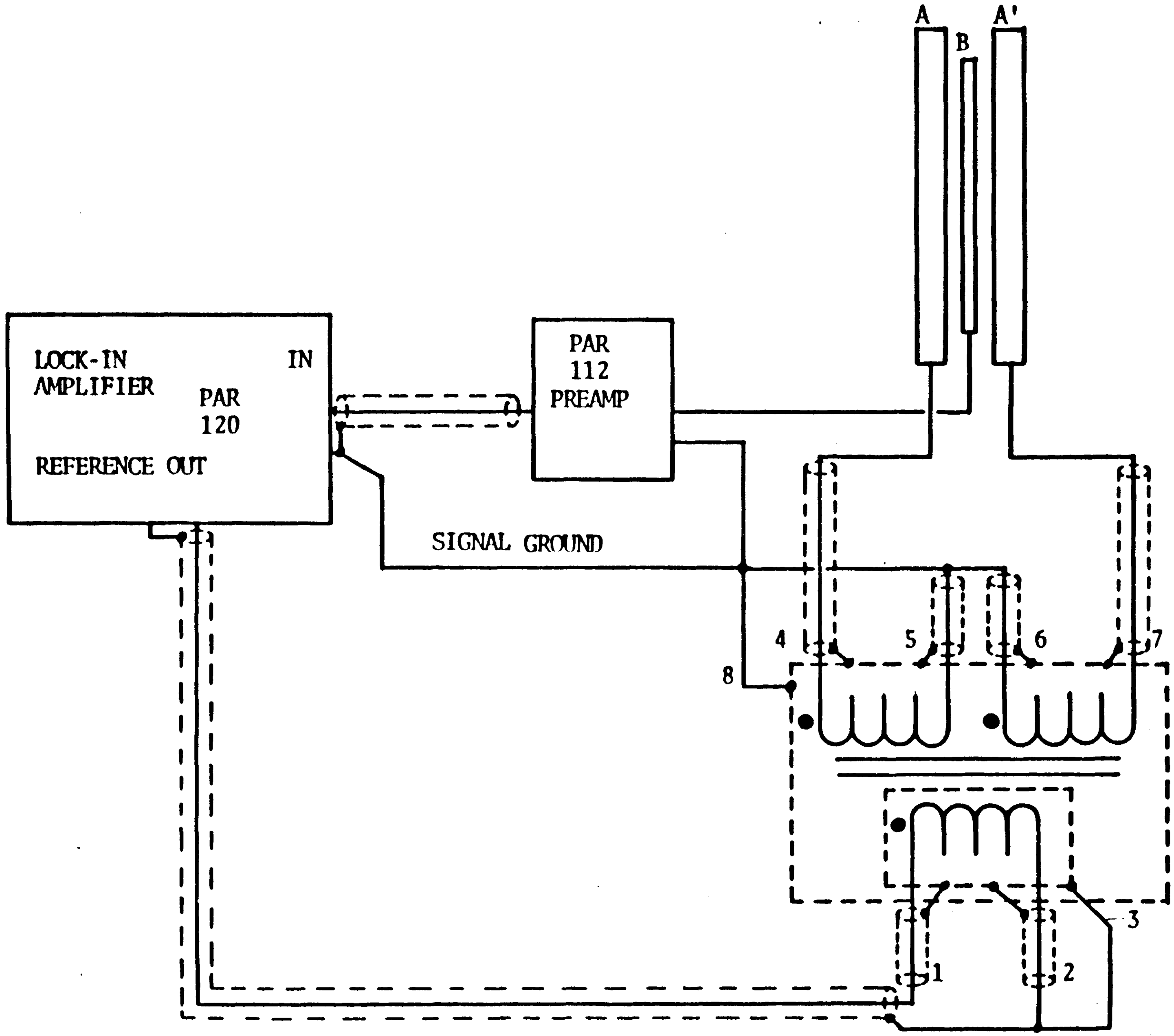

A
A'
B
LOCK-IN
AMPLIFIER
IN
PAR
120
REFERENCE OUT
PAR
112
PREAMP
SIGNAL GROUND
4
5
6
7
8
1
2
3

Fig. 2

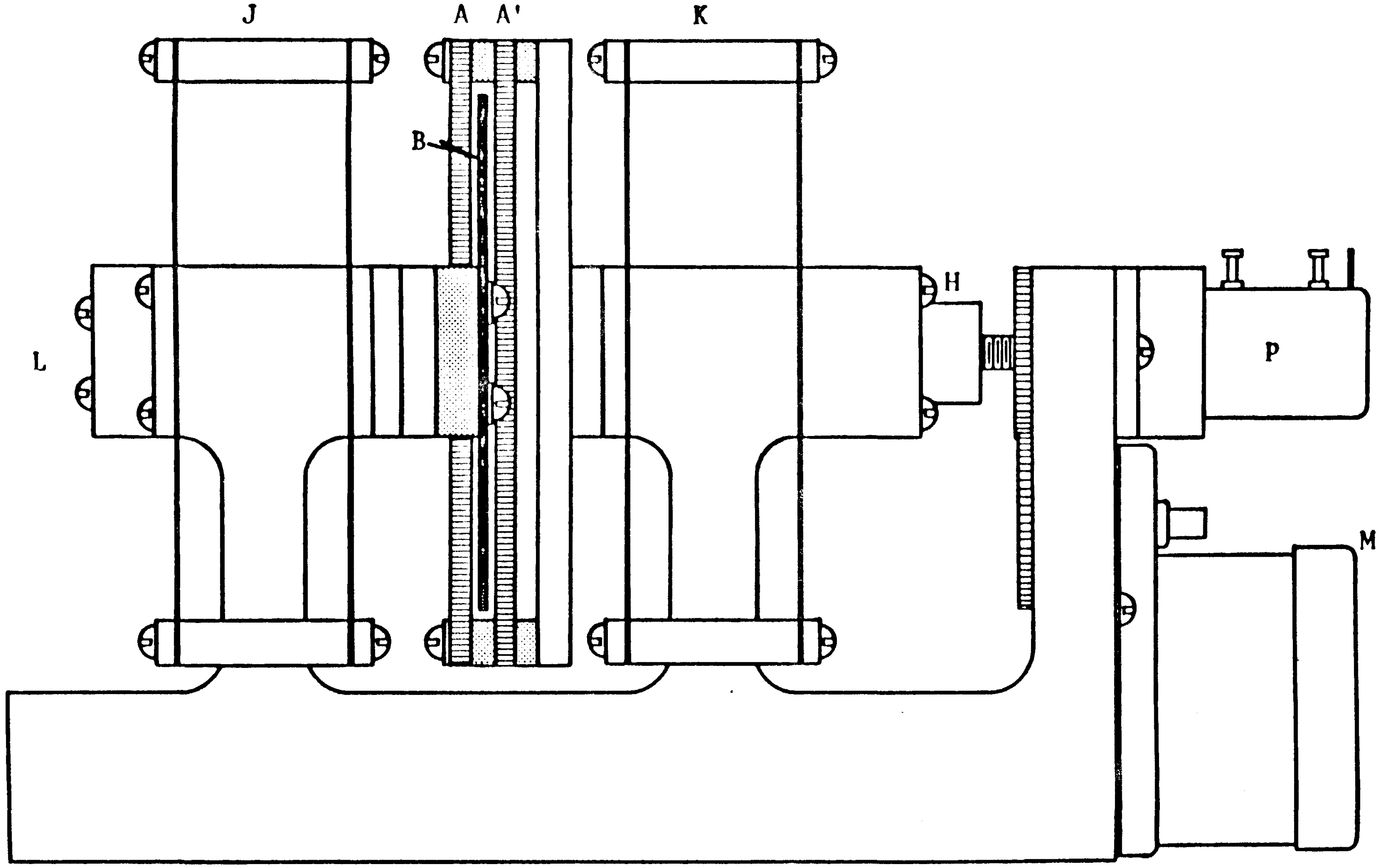


Fig. 1

meter head. The inevitable backlash of the gear train is thus used to advantage.

NOTE: The transformer windings should never be subjected to DC current as this results in damage to the core. A common mistake of this sort is to measure the DC resistance of the windings with a multimeter. Such rash impulses should be resisted.

phase of the detector is set as described in the manual to obtain an extremal output signal.

5) The phase-sensitive detector output is then measured as a function of the potentiometer resistance. This yields the gain of the system. One turn of the potentiometer gives a 2 kΩ resistance change and corresponds to 0.025 inch displacement of the center plate B relative to the outer plates A and A'. The measurements must be made with the motor and gear train driven in one direction so as not to incur errors from backlash. The phase-sensitive detector readings should be made for both signs of the output signal.

6) The motor is used to adjust the mechanical system to the electrical null at low electronic gain.

7) The electronic gain is increased to the required level, making minor adjustments to the mechanical position as required to keep the output on scale. It should be noted that the total system gain is directly proportional to the drive amplitude V_D and the lock-in amplifier gain. Both of these parameters may be adjusted during set-up and calibration procedures, and both should be recorded. The gain obtained in step 5 is scaled accordingly. It should be noted that the 1/10 RPM motor is capable of driving the micrometer head to a zero position with a resolution of several microinches.

8) The motor is then reversed to disengage the gear train from the micrometer head. This is electrically signaled by a low voltage signal light connected between the LINX base and the motor casing. The motor casing is insulated from the base and the contact is completed through the gear train connecting the motor with the micro-

(Fig. 1, K). The spring system K carries the drive plates (Fig. 1, A, A') which are insulated from each other and the LINX frame. This spring system provides accurate parallel motion over the range of adjustment of the micrometer head H.

A similar cantilever spring system (Fig. 1, J) provides parallel motion of the moving plate (Fig. 1, B) for a force supplied to (Fig. 1, L). The motor (Fig. 1, M) is a 1/10 RPM 110 VAC reversible motor Haydon #L81373-P4-F2 with an internal slip clutch. The potentiometer is a 5 turn, 10K ohm model with linearity 1/2%.

The calibration procedure is the following:

1) The system is wired as shown in Fig. 2.

2) The center plate B is offset visibly by the use of the motor (Fig. 1, M).

3) The reference drive voltage V_D is set to the desired voltage (about 1 - 10 volts) using an oscilloscope or RMS voltmeter. The specially balanced transformer supplied provides a 4 to 1 voltage increase from primary to each secondary. The PAR Model 112 preamplifier output is observed with an oscilloscope. It should appear as a clean sine wave at the driving frequency, and its amplitude should vary smoothly as the relative displacement of the center and outer plates is changed (e.g., by use of the calibrator motor, Fig. 1, M).

4) The phase-sensitive detector set-up procedure (see PAR Model 120 Lock-in Amplifier Operations Manual) is carried out and an output signal obtained at a gain setting low enough to avoid saturation. The

plished by a phase-sensitive detector or lock-in amplifier (Fig. 2).

The detector contains an internal oscillator which provides a reference voltage at the carrier frequency. This voltage is fed into the primary of a precision transformer with balanced split secondary windings (Fig. 2). The balanced secondaries provide the two out-of-phase drive voltages $\pm V_D$ which are applied to the drive plates A, A'.

Fig. 2 summarizes the electrical connections for the capacitive position sensor using a Princeton Applied Research Model 120 lock-in amplifier and a Princeton Applied Research Model 112 preamplifier. The transformer primary is electrostatically shielded. The primary electrostatic shield (Fig. 2, pin 3) is connected to the outer conductor of the coaxial drive cable. A second electrostatic shield surrounds both the primary and secondary coils. This shield is connected to the shields of the secondary leads and to signal ground as shown in Fig. 2. The secondary ground connection is separate from the primary ground connection. The secondary ground connection is the signal ground for the input to the phase-sensitive detector.

Secondary transformer leads (Fig. 2, pins 4, 7) are connected to the drive plates A and A', respectively and the signal lead is connected to the movable plate (Fig. 1, B). The shields for the secondary leads are connected to signal ground at only one end as shown in Fig. 2.

The motor (Fig. 1, M) is insulated from the LINX frame. The motor is used only to drive the micrometer head (Fig. 1, H) which in turn adjusts the position of the folded cantilever spring system

LINEAR EXTENSOMETER

The linear extensometer (LINX) is a relative position measuring device capable of extreme position resolution. The electronic limit of the position resolution attainable with the LINX is 0.05 Å (angstrom) or 5×10^{-10} centimeters in a one second measurement time. The mechanical full scale measurement distance is ± 0.077 cm (± 0.031 inch).

The LINX consists of two basic components:

- A differential capacitance position sensor
- A position calibrator and null adjustor

The capacitance position sensor consists of three plane parallel plates (Fig. 1: A, A', B). The outer two drive plates (Fig. 1: A, A') are driven by voltages at a fixed carrier frequency (10-20 kHz). 16 KHz The drive voltages have the same magnitude but are 180° out of phase. The moving center plate (Fig. 1: B) located between the two drive plates carries the signal voltage V_s. Neglecting fringing fields and assuming plane parallel configuration of the plates, V_s is

$$V_s = V_D \frac{\delta}{d} e^{j\omega t}$$

V_D is the drive voltage magnitude; d is the gap between the centered plate B and either fixed plate: δ is the algebraic displacement of the movable plate relative to the fixed plates; ω is the angular frequency of the carrier voltage. The voltage V_s is at the carrier frequency and must be demodulated to remove the carrier. The demodulation is accom-

DIAX

LINEAR EXTENSOMETER

DIAX CORPORATION

7825 Ivanhoe Avenue, # 202

La Jolla, California 92037

POWER SUPPLY CARD

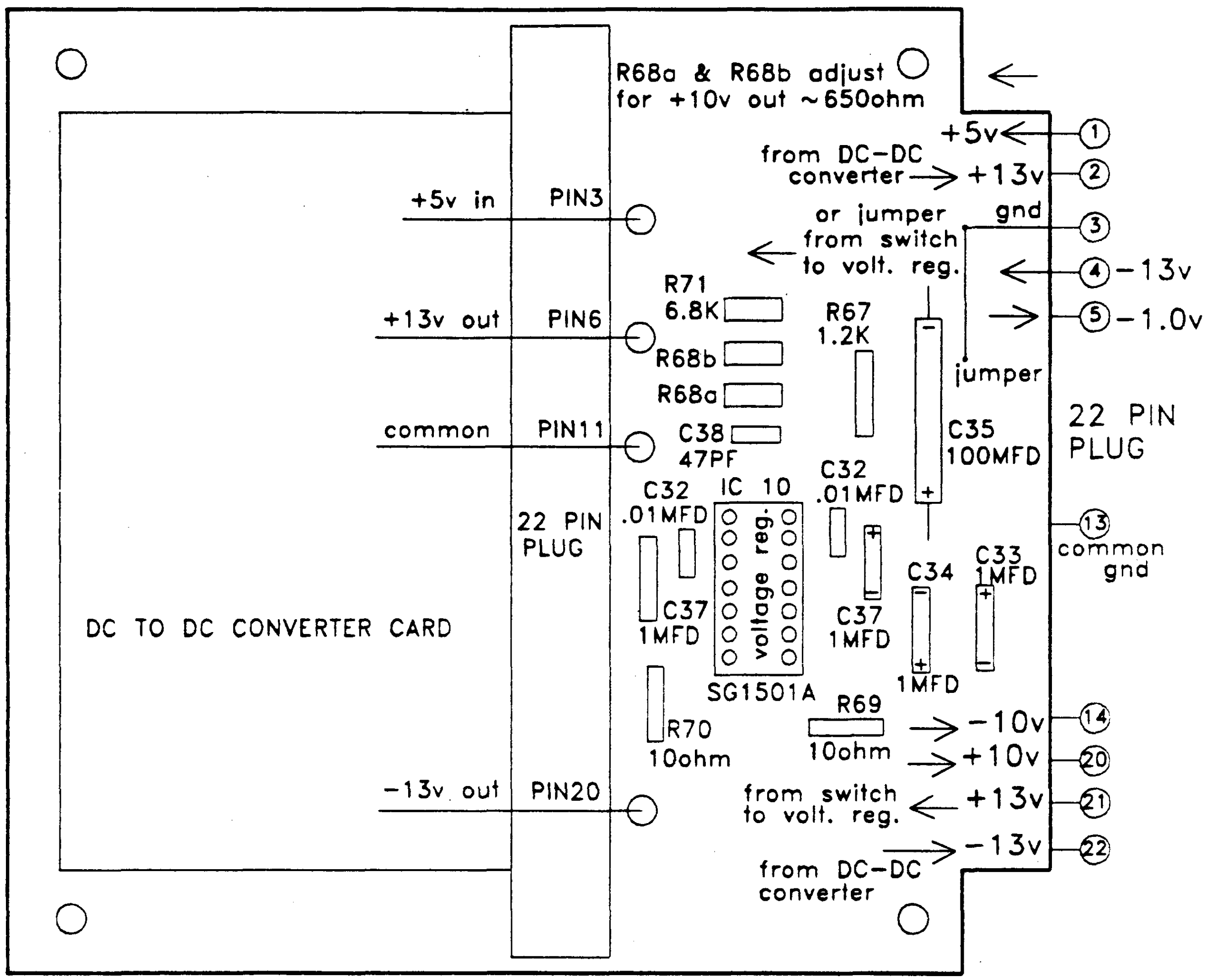
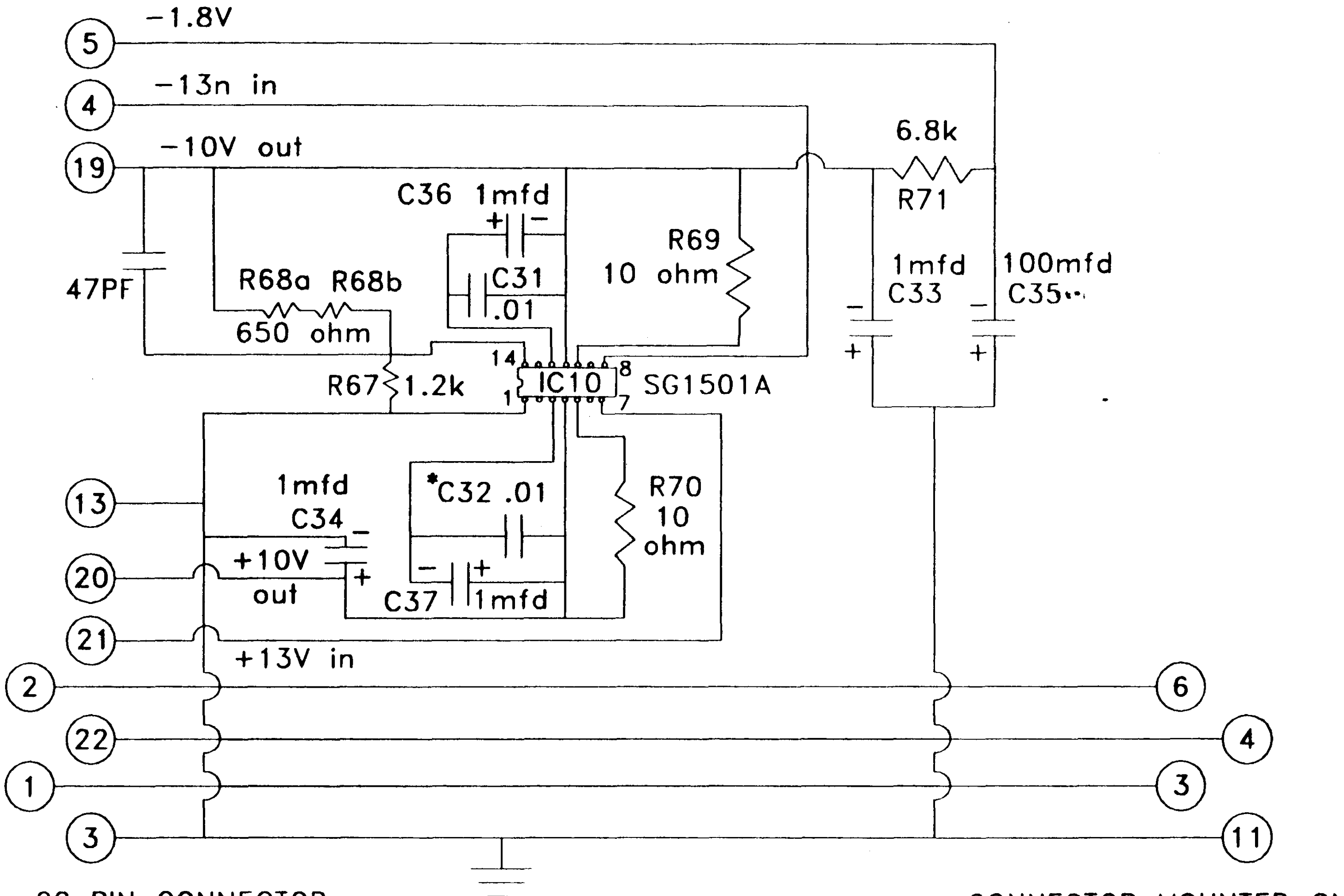


Figure **26**

STRAINMETER POWER SUPPLY



22 PIN CONNECTOR
ON BOTTOM OF
CIRCUIT BOARD

*MOUNT .01CAPS NEAR
IC10, PINS 3 & 12.

CONNECTOR MOUNTED ON
POWER SUPPLY BOARD
FOR DC-DC CONVERTER

Figure **25**

STRAINMETER ELECTRONICS PARTS LAYOUT

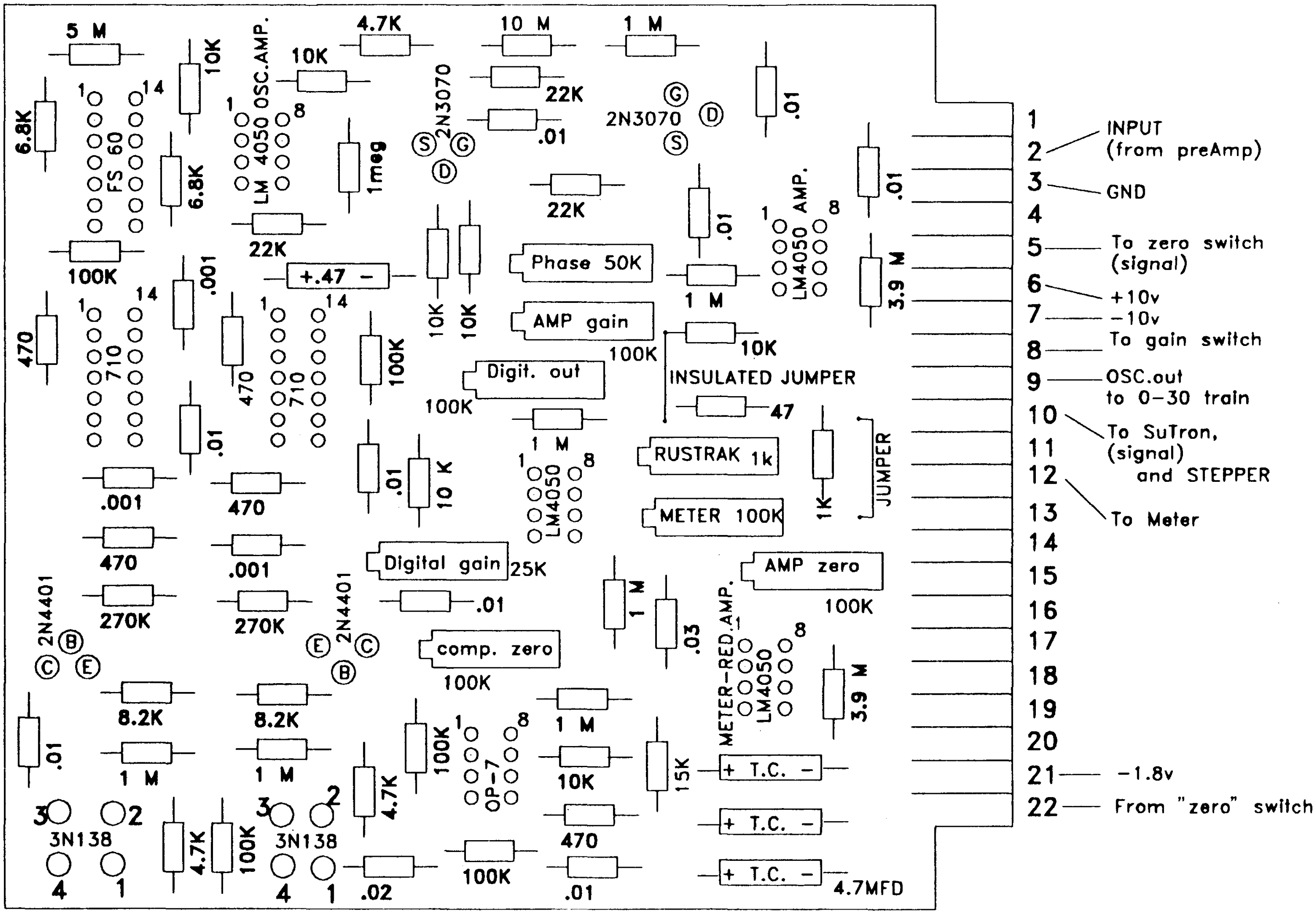


Figure 24

STRAINMETER ELECTRONICS

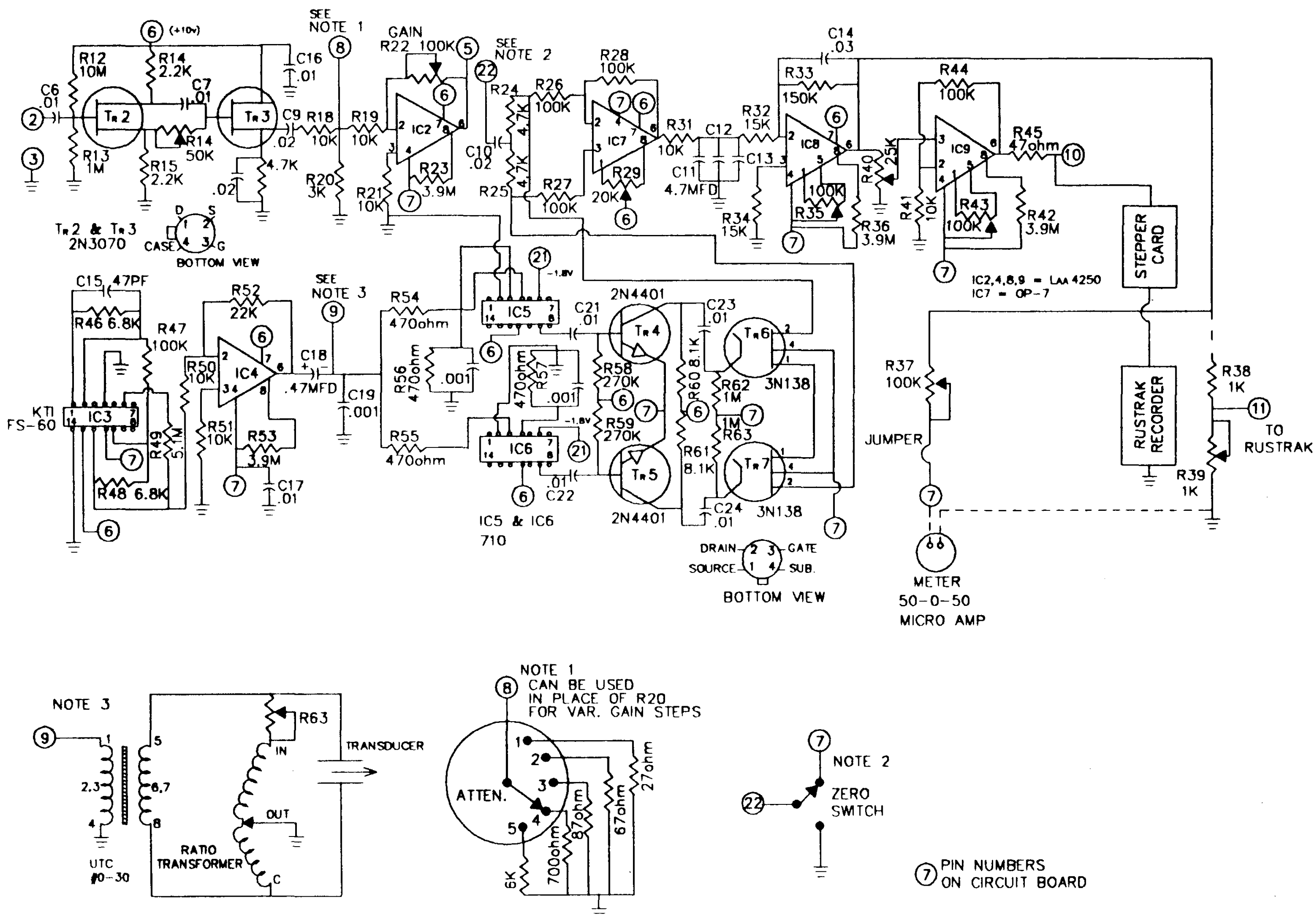


Figure 23

STRAINMETER PREAMPLIFIERS

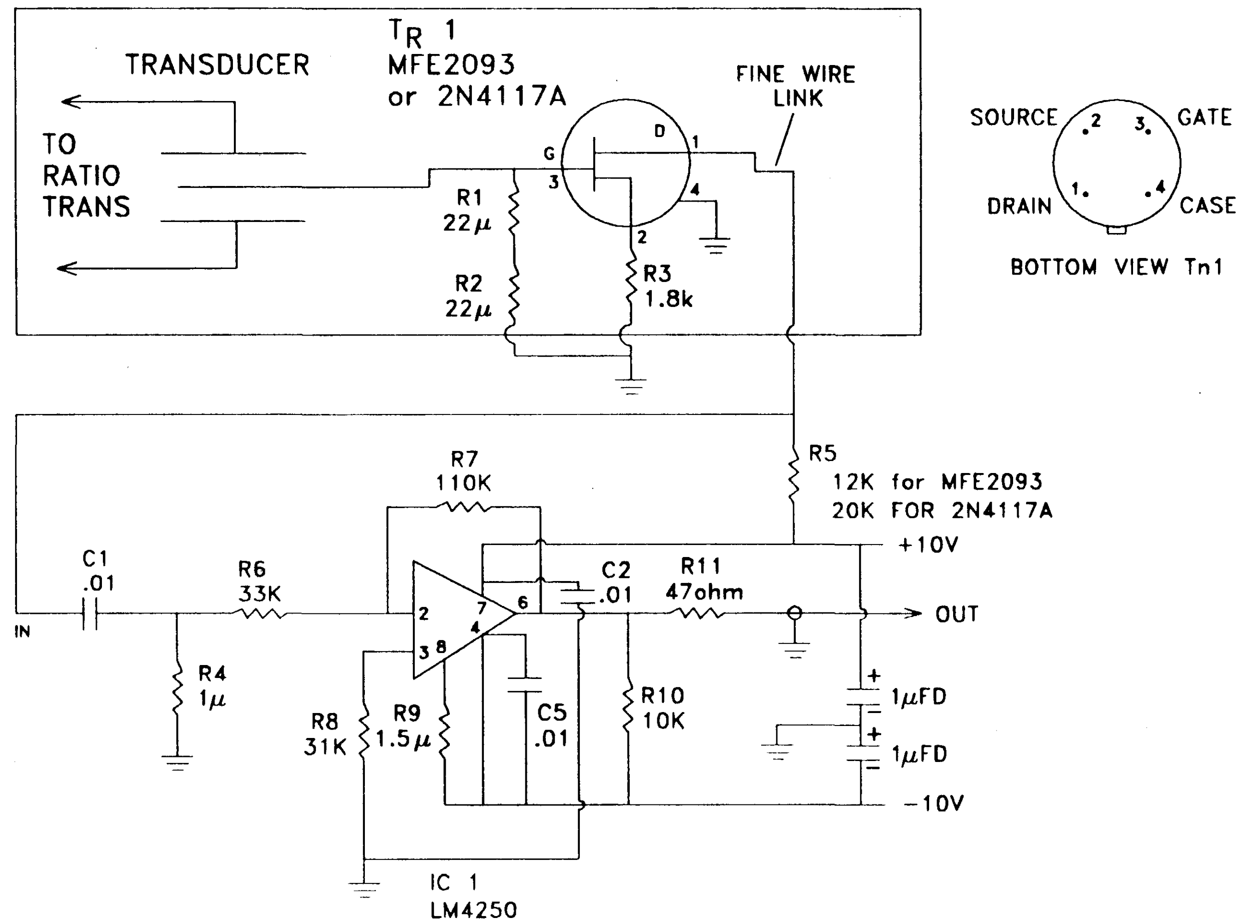


Figure 22

STRAINMETER PLUG CONNECTOR

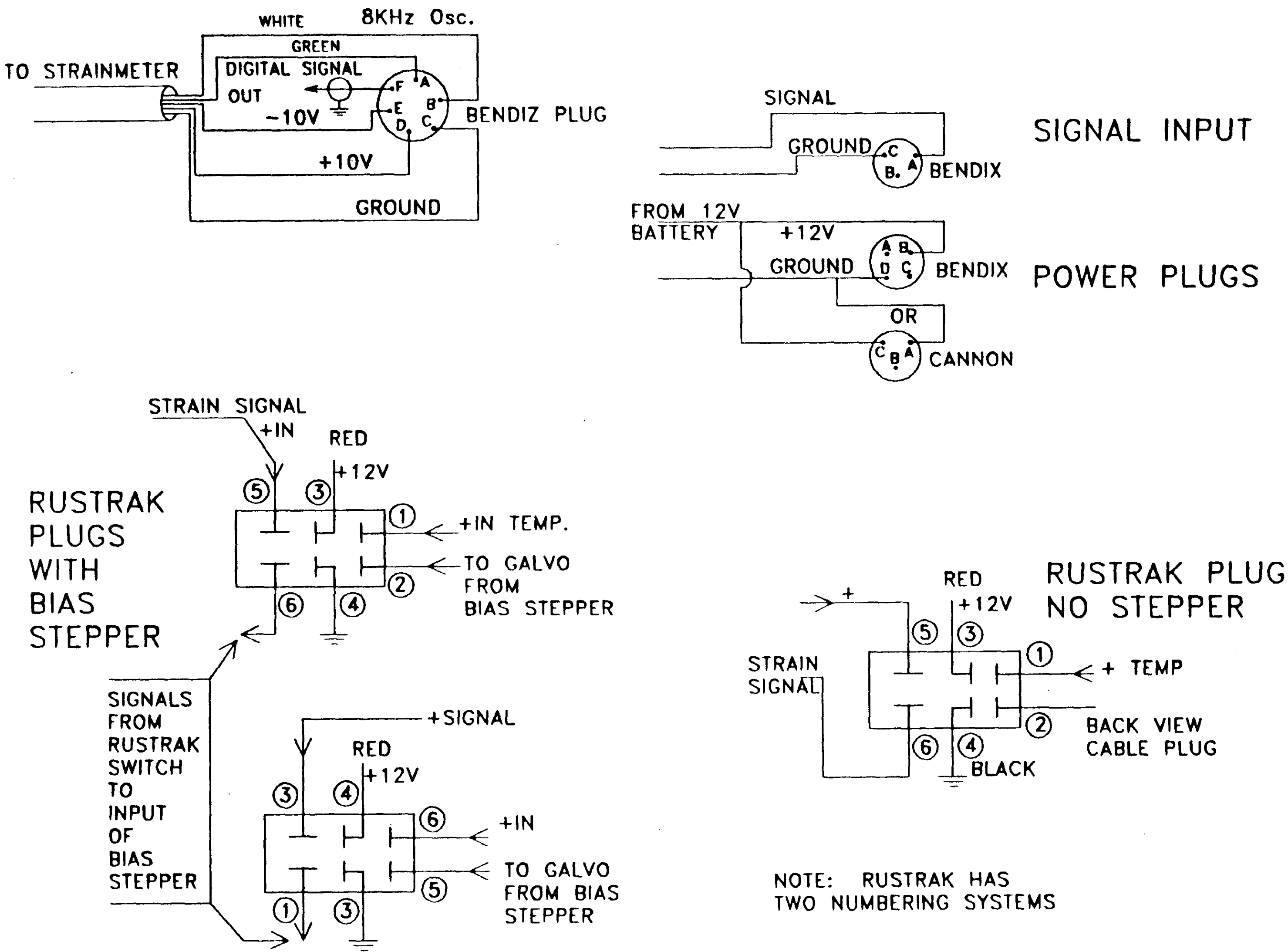


Figure 21

BLOCK DIAGRAM OF STRAINMETER

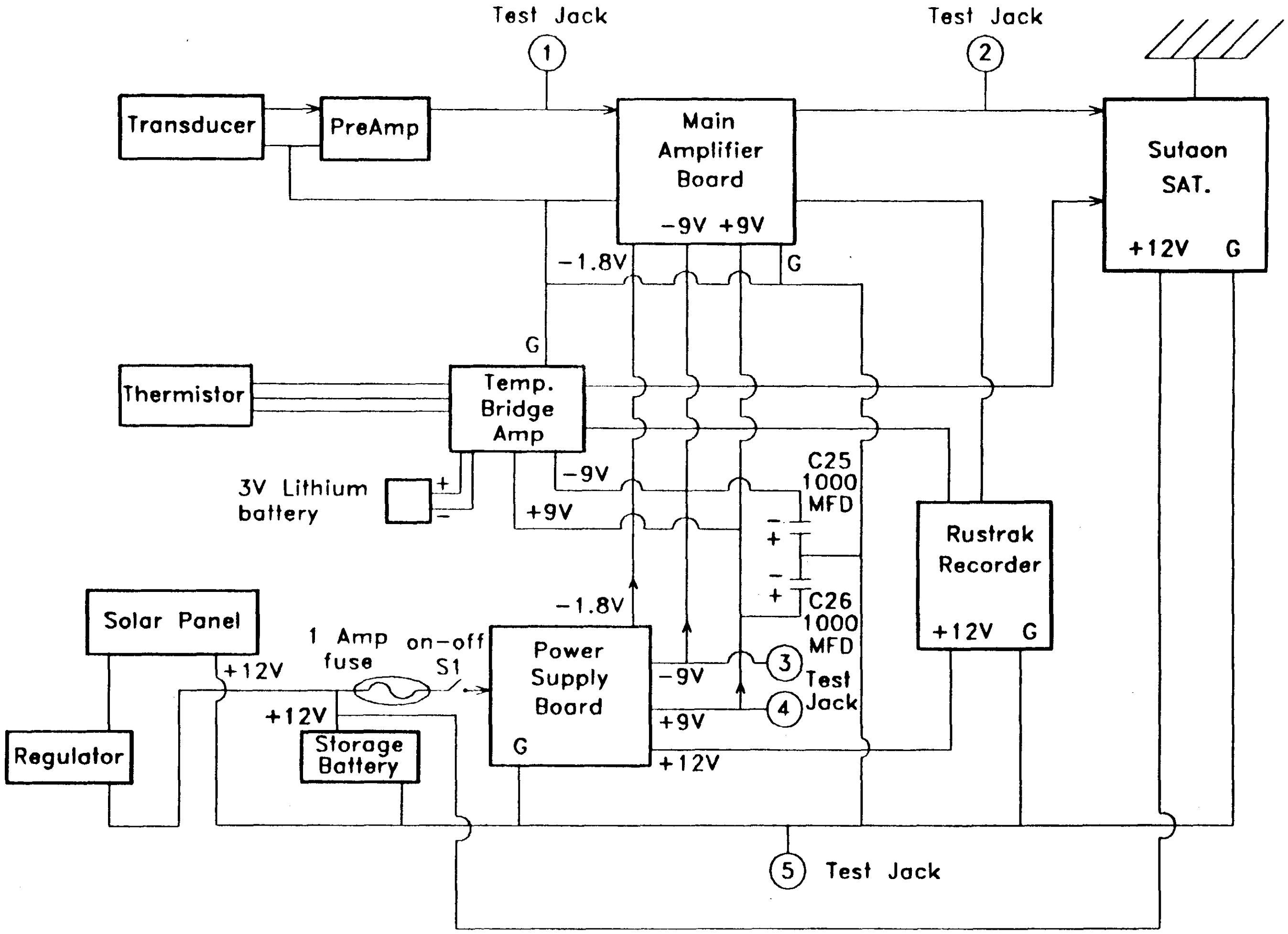
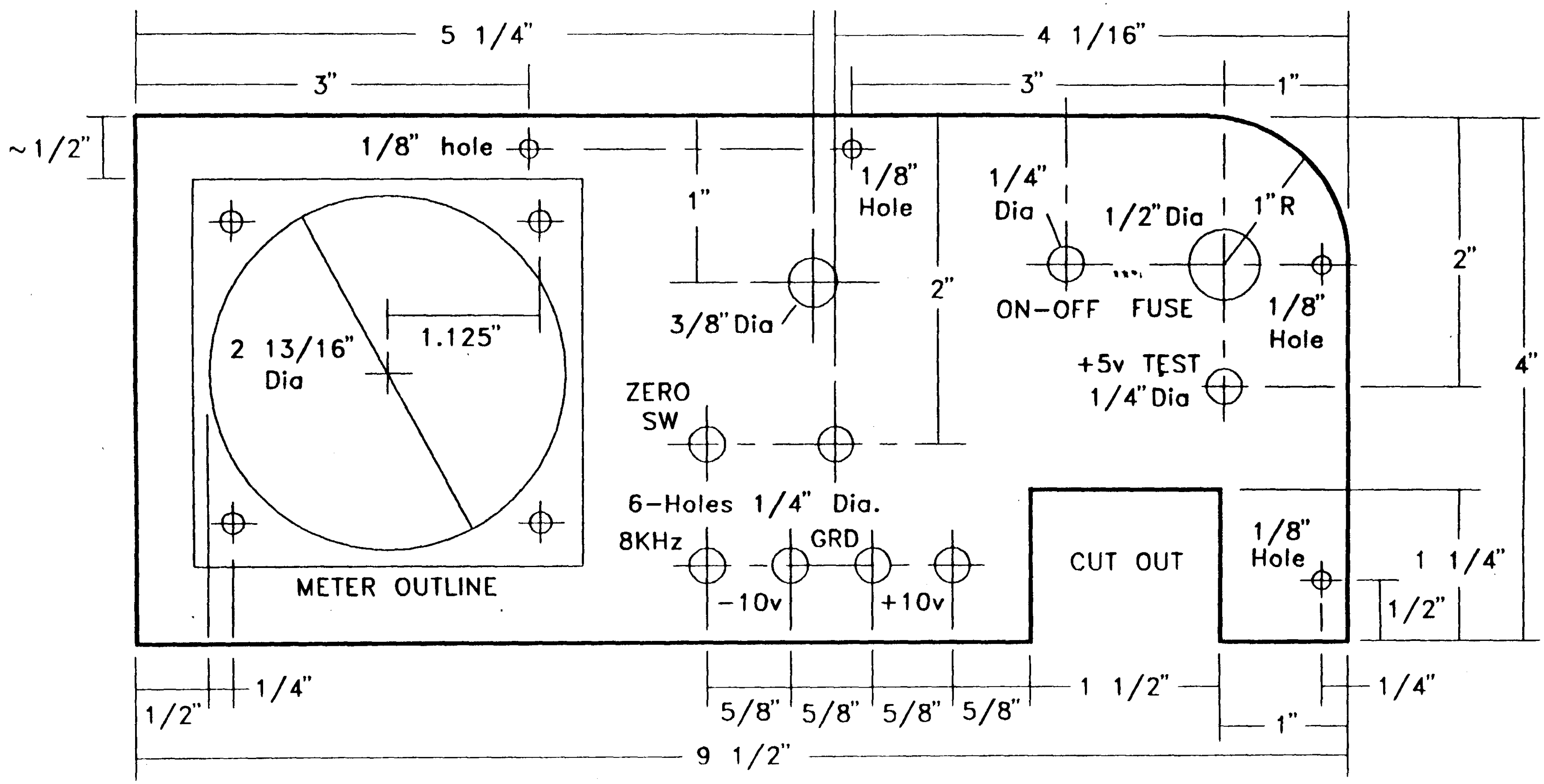


Figure 20

ELECTRONICS INSTRUMENT CASE PANEL



NOTE: No dimensions are critical
except meter holes.
Make 15 panels all 1/16"

Figure **19**

FIBERGLASS CULVERT

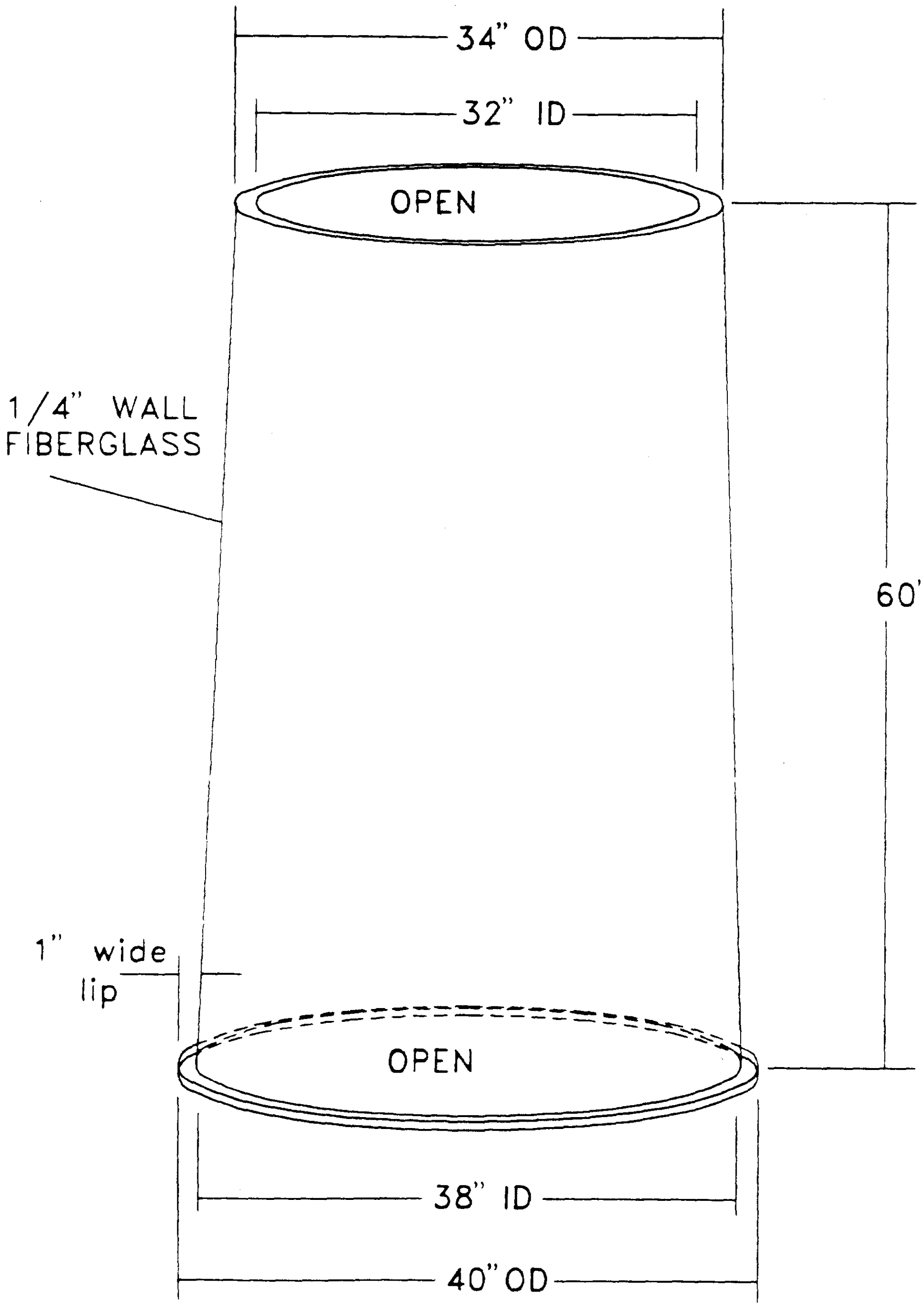


Figure **18**

TRANSDUCER BOX SUPPORT

2 FOR EACH BOX   MATERIAL: COLD ROLLED STEEL

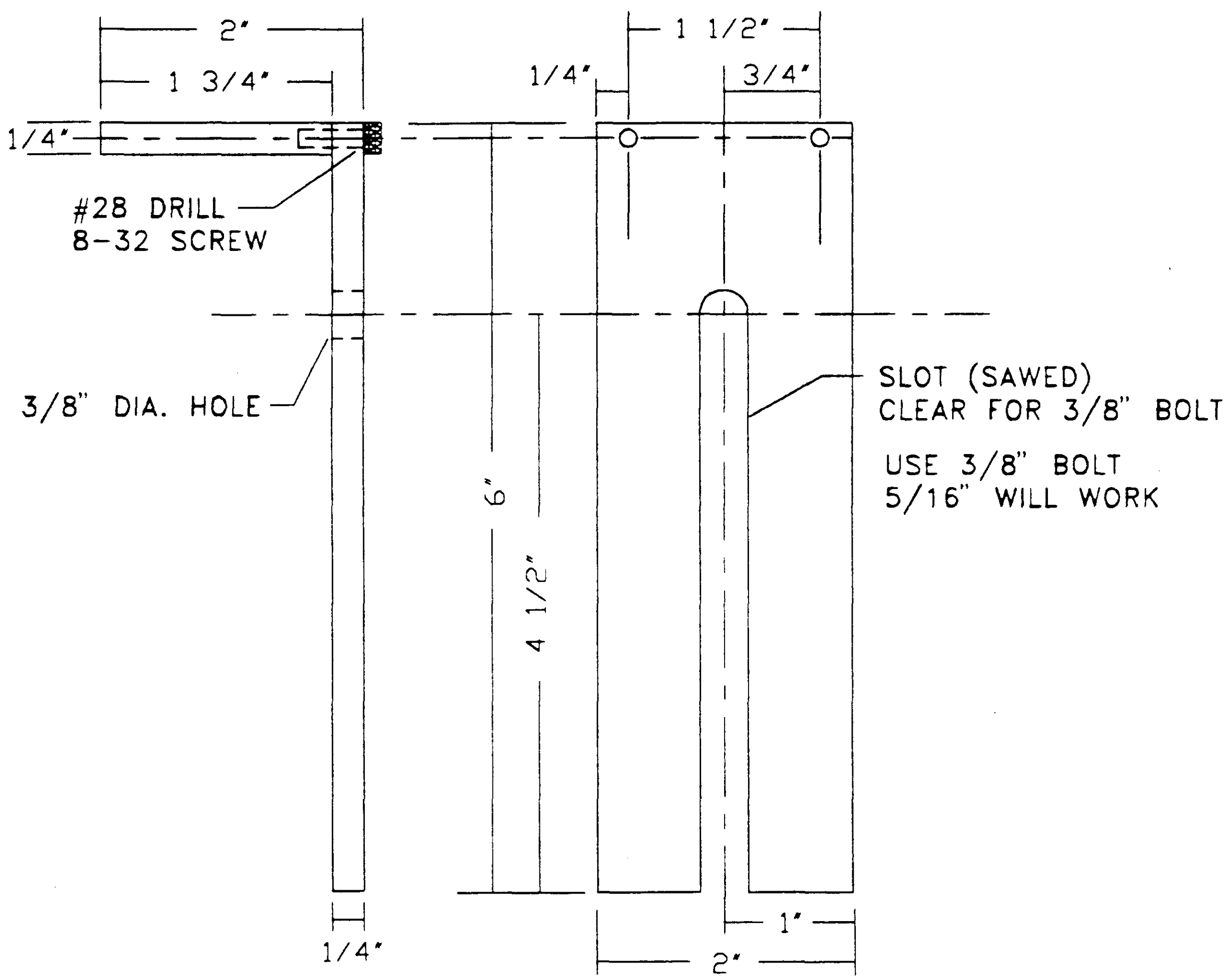


Figure **17**

ANCHOR MOUNT

MATERIAL: STAINLESS STEEL 303

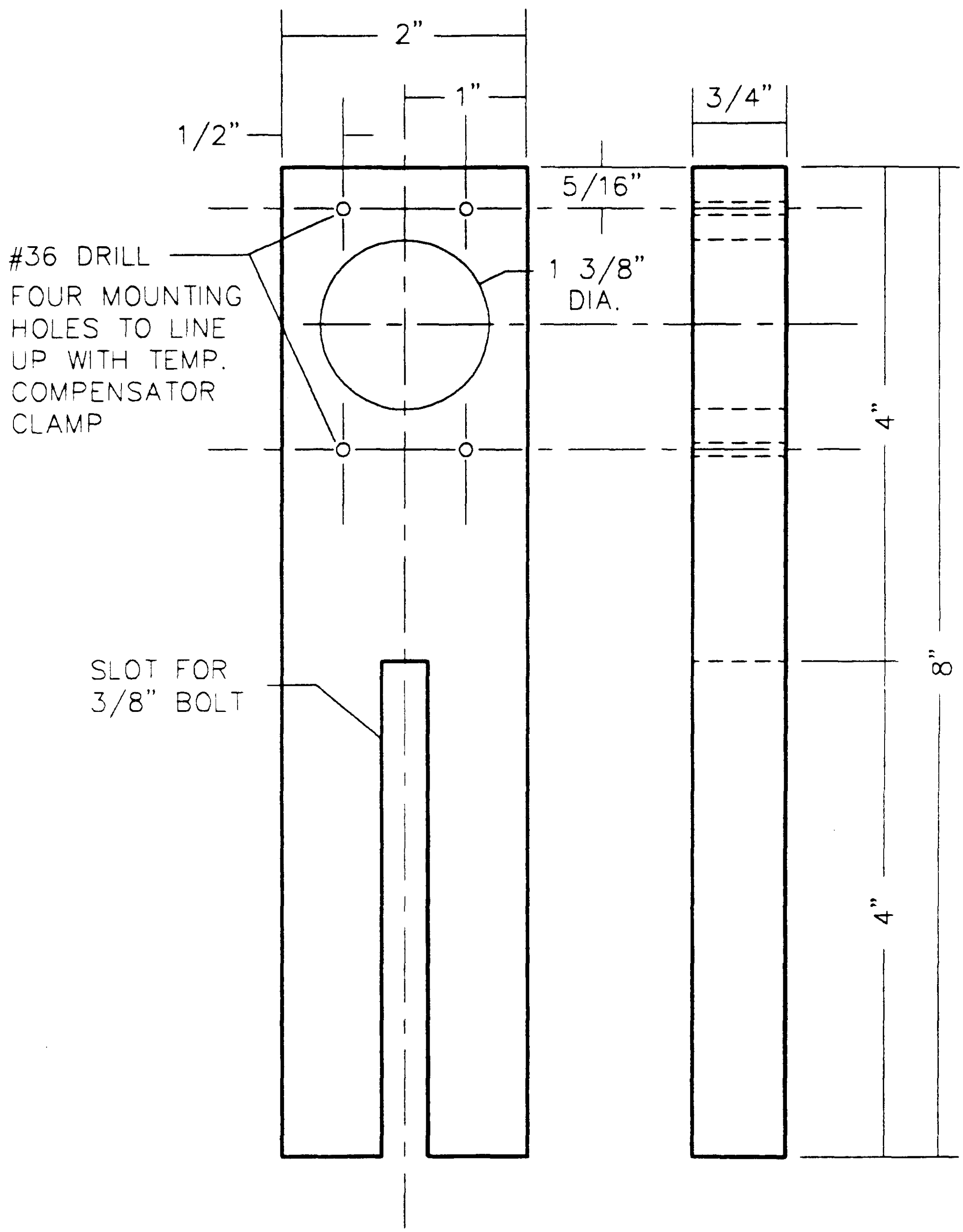


Figure **16**

TEMPERATURE COMPONENT CLAMP

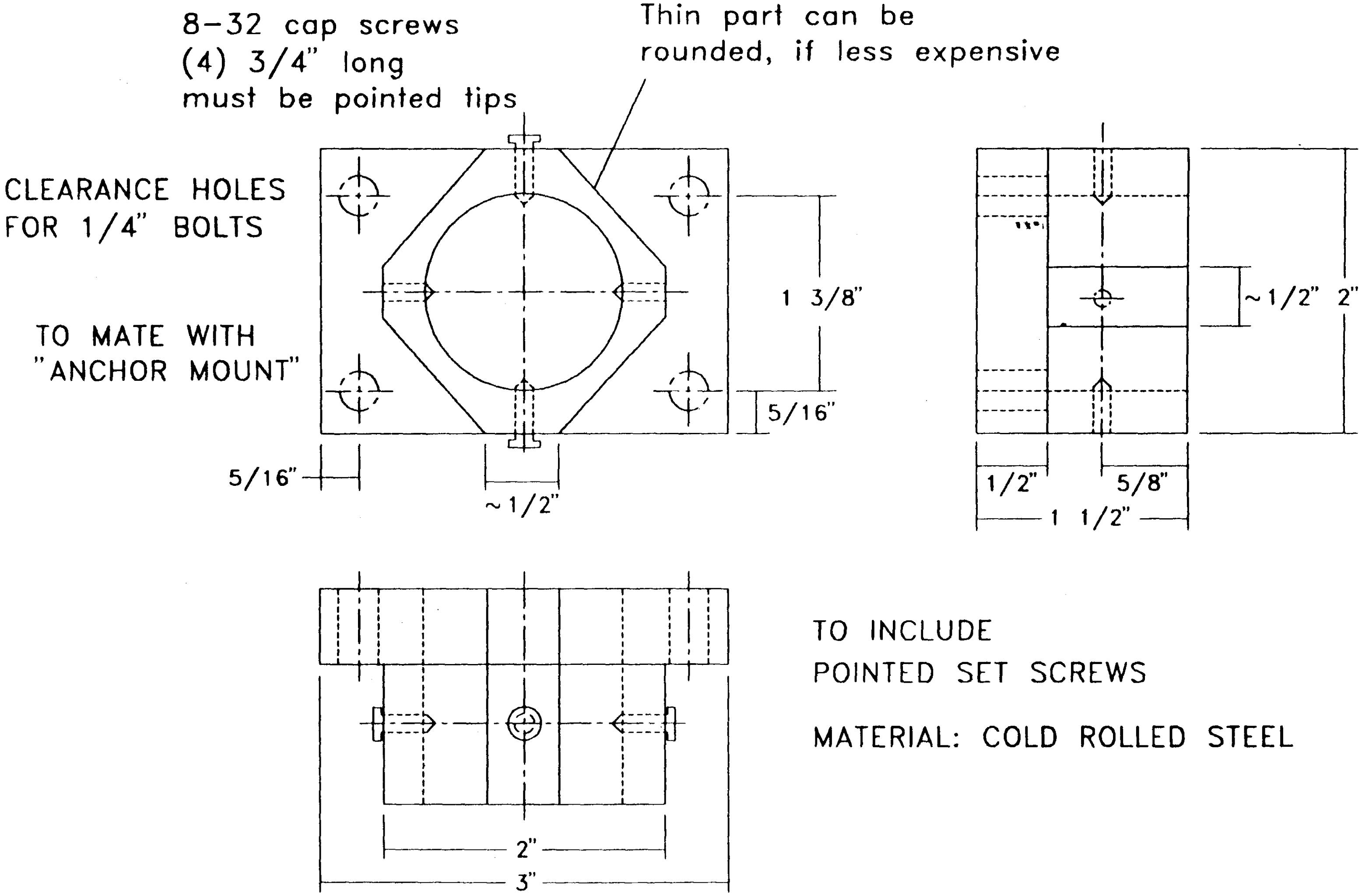
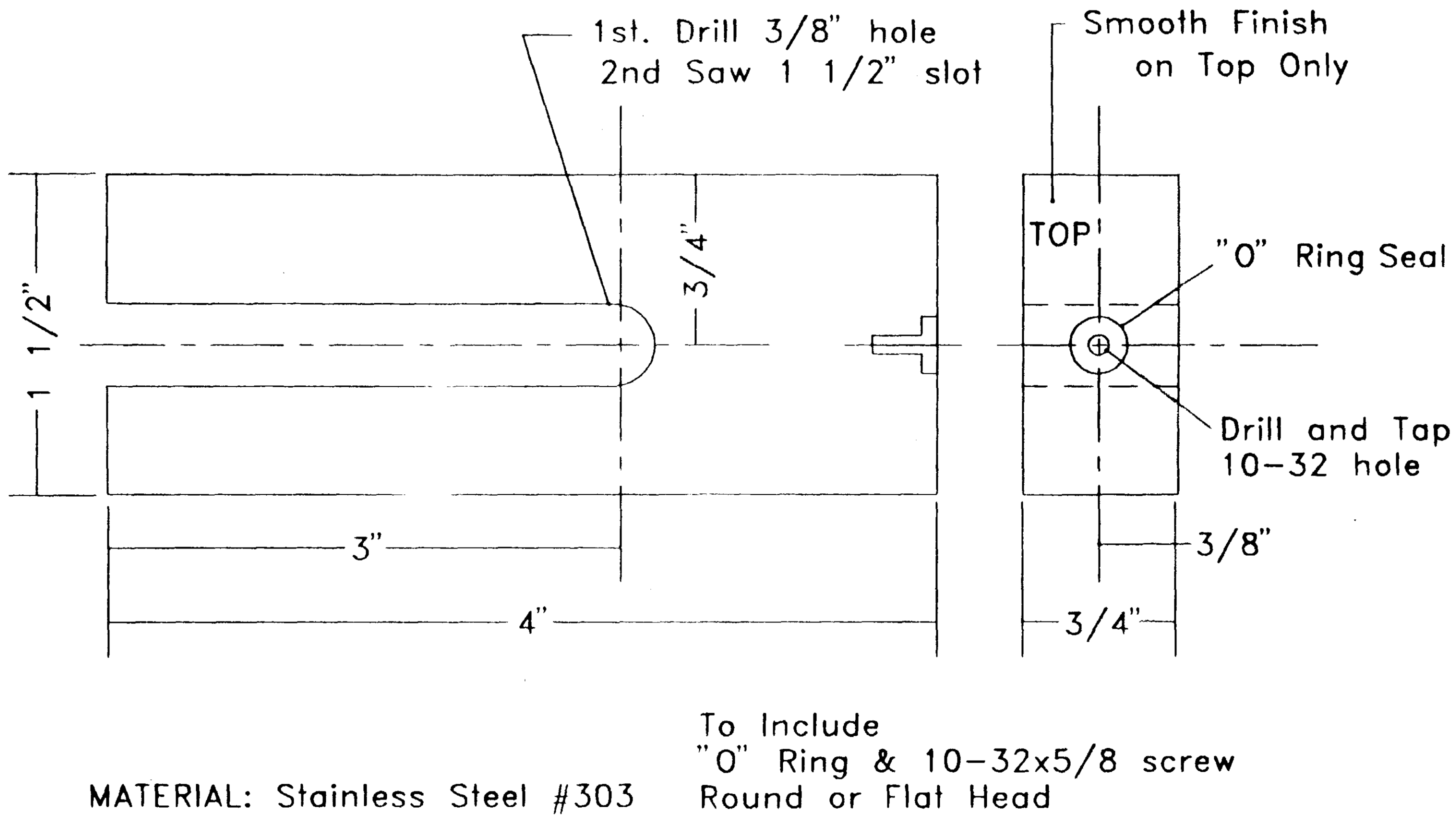


Figure 15

TRANSDUCER SUPPORT



MATERIAL: Stainless Steel #303

Figure **14**

CLAMP

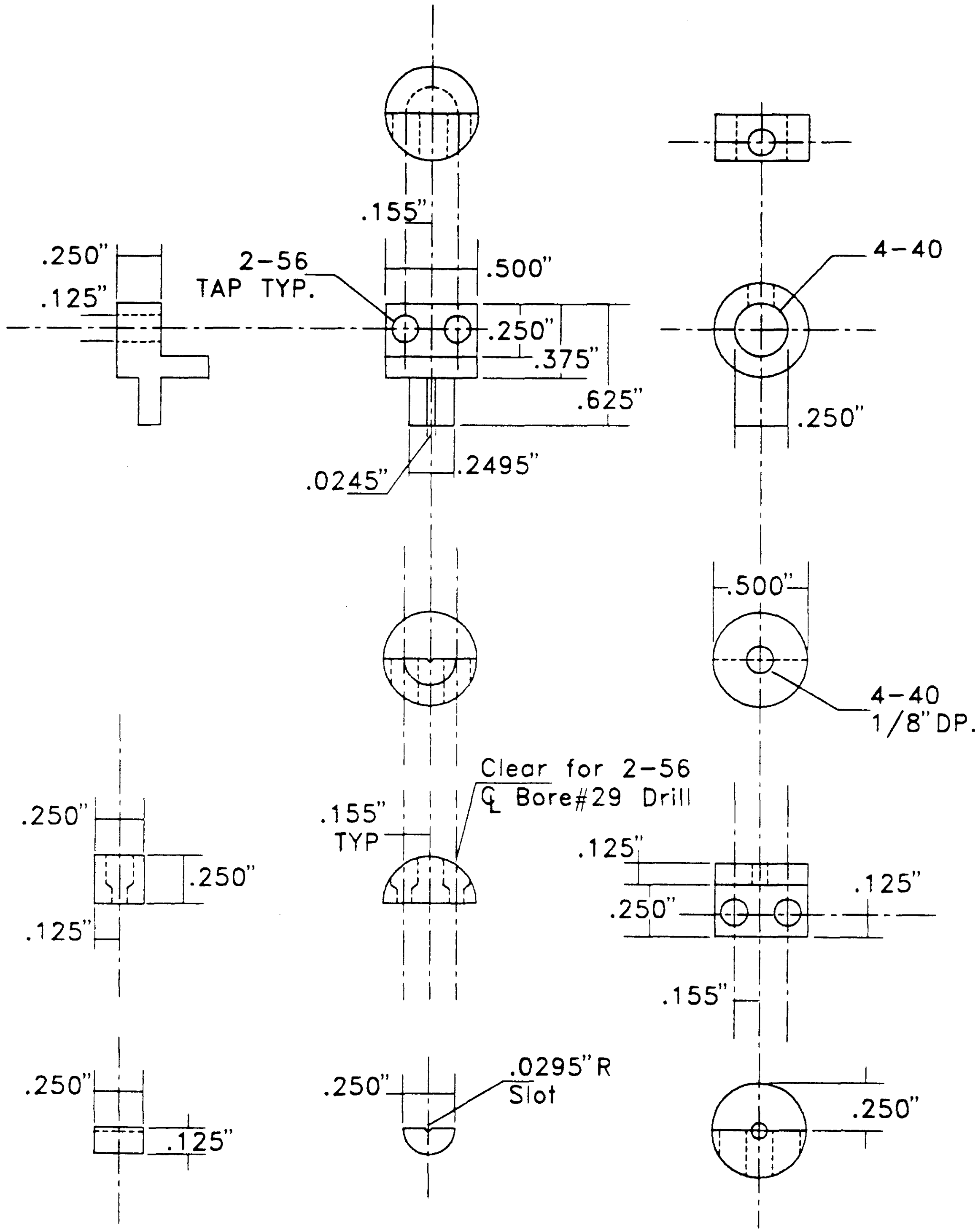


Figure **13**

INVAR WIRE CLAMP

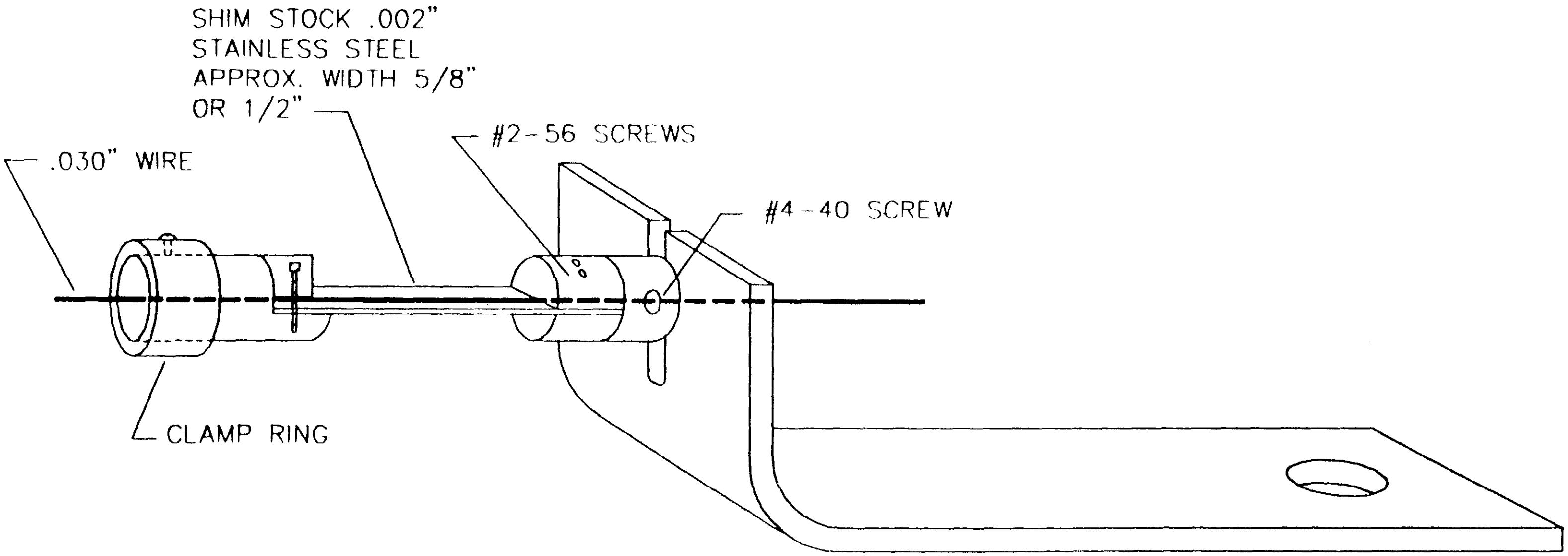
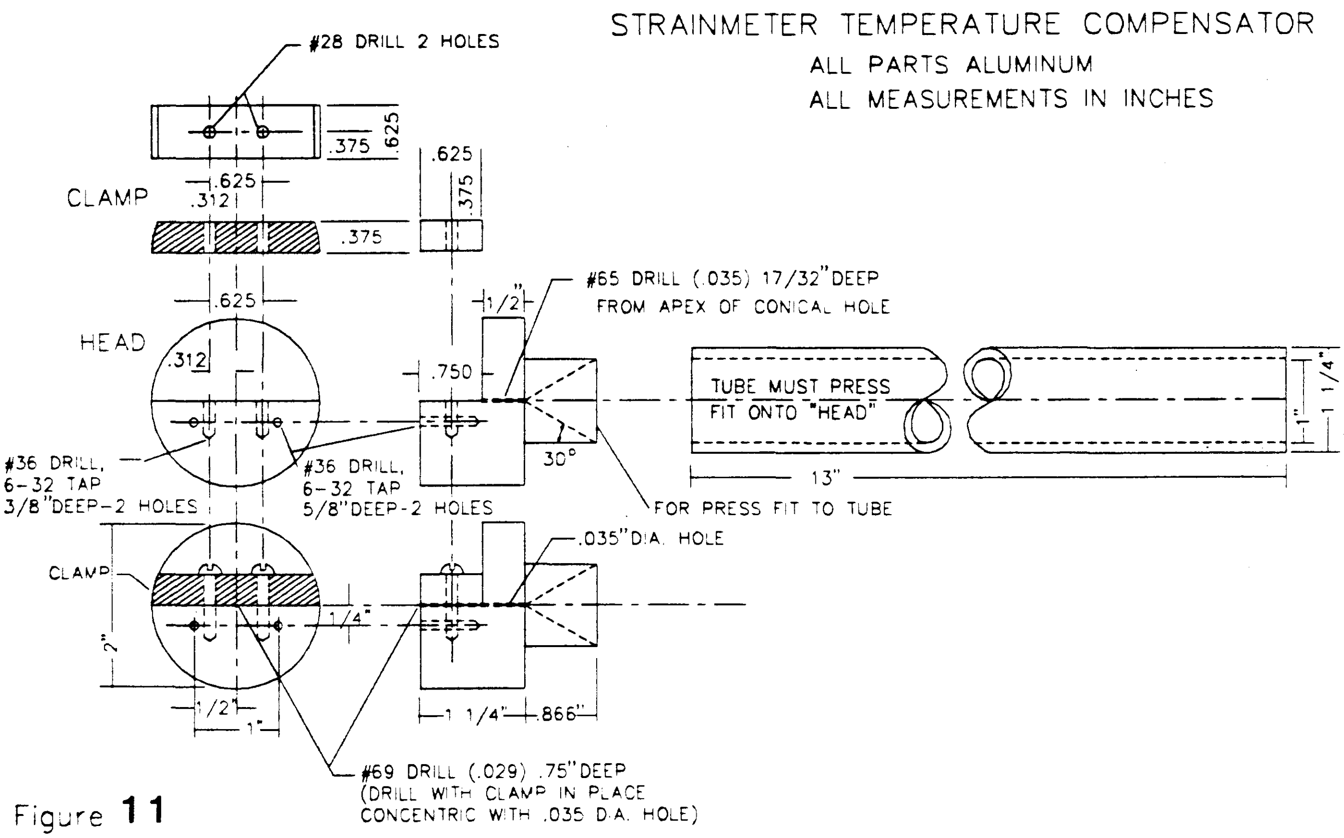


Figure **12**



STRAINMETER TEMPERATURE COMPENSATOR
ALL PARTS ALUMINUM
ALL MEASUREMENTS IN INCHES
#28 DRILL 2 HOLES
CLAMP
HEAD
#65 DRILL (.035) 17/32"DEEP
FROM APEX OF CONICAL HOLE
TUBE MUST PRESS
FIT ONTO "HEAD"
#36 DRILL,
6-32 TAP
3/8"DEEP-2 HOLES
#36 DRILL,
6-32 TAP
5/8"DEEP-2 HOLES
FOR PRESS FIT TO TUBE
.035"DIA. HOLE
CLAMP
#69 DRILL (.029) .75"DEEP
(DRILL WITH CLAMP IN PLACE
CONCENTRIC WITH .035 DIA. HOLE)

Figure **11**

STRAINMETER CARDON HINGE

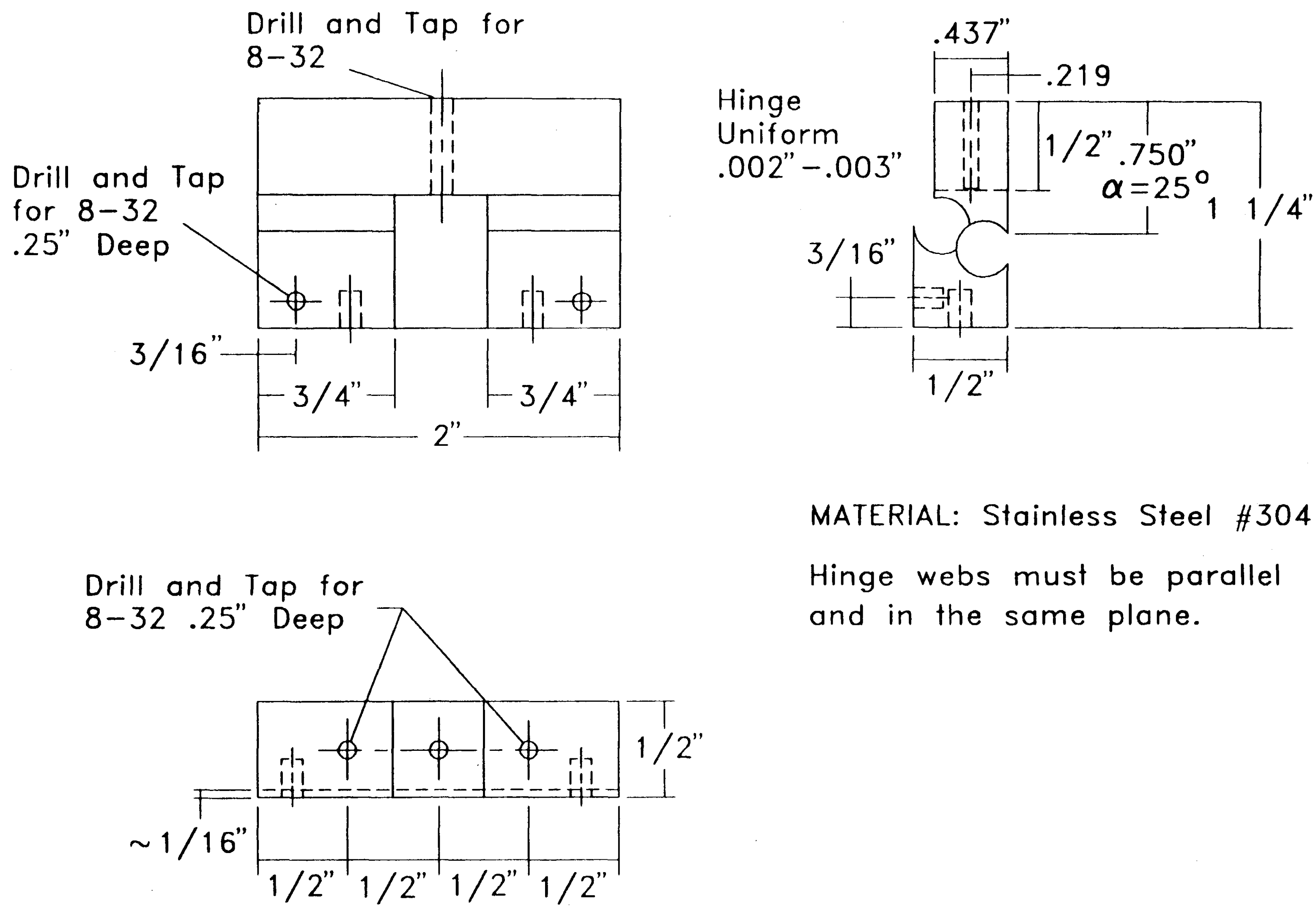


Figure 10

STRAINMETER CASTING

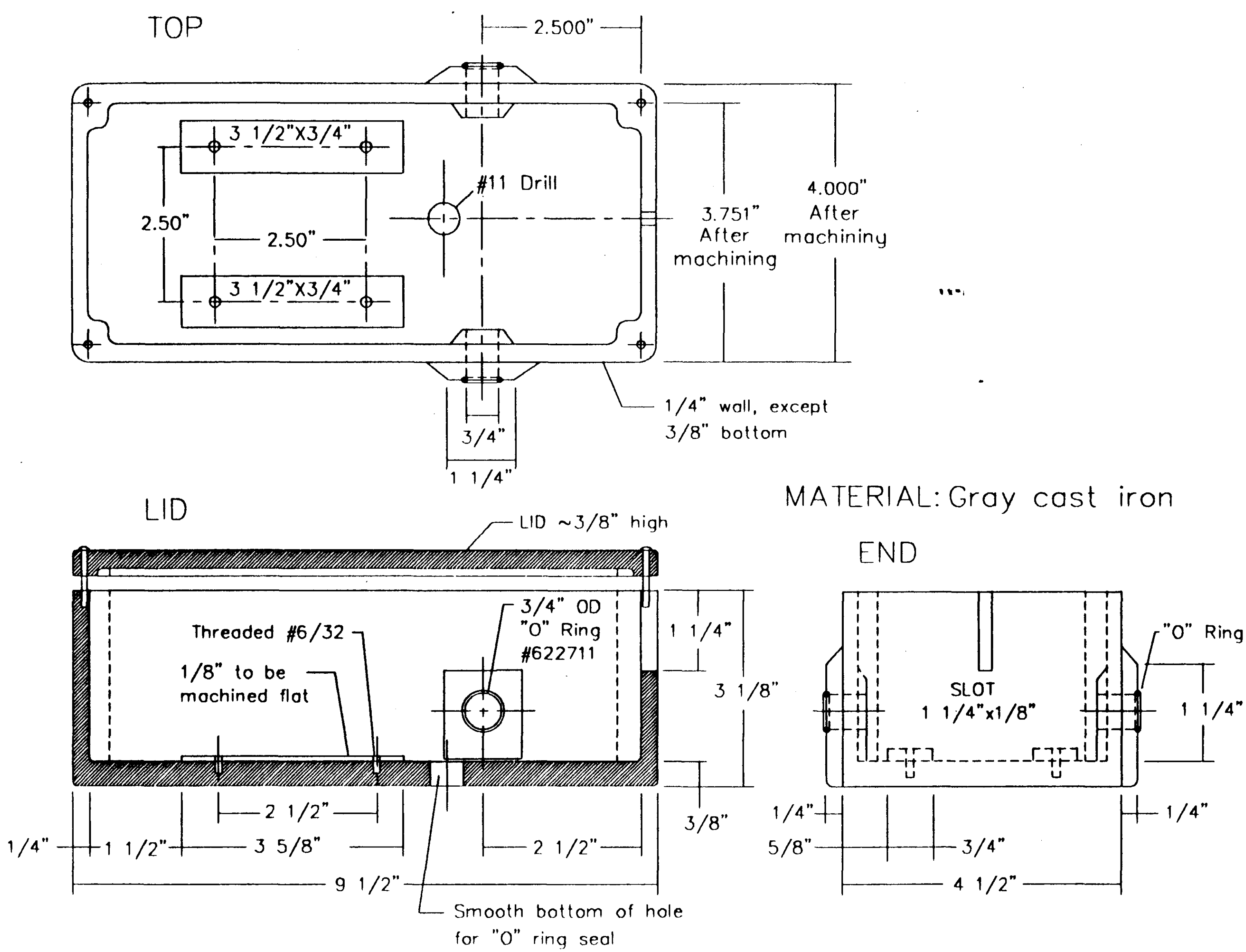
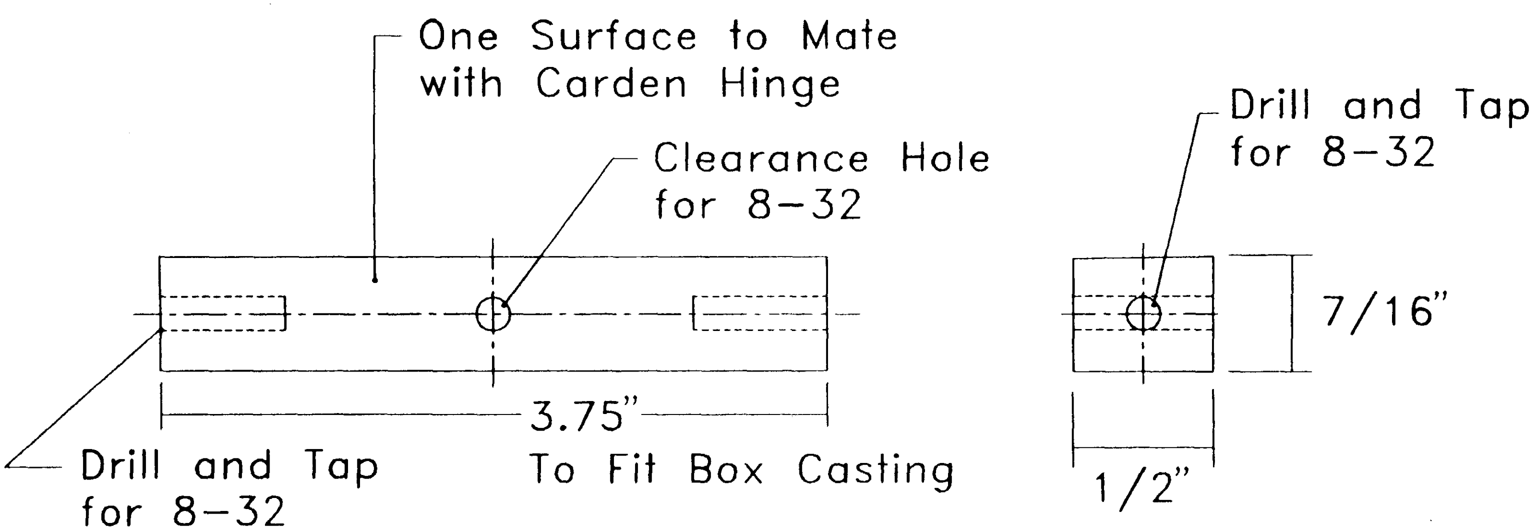


Figure **9**

CARDON HINGE AXLE



MATERIAL: Stainless Steel #304

Figure **8**

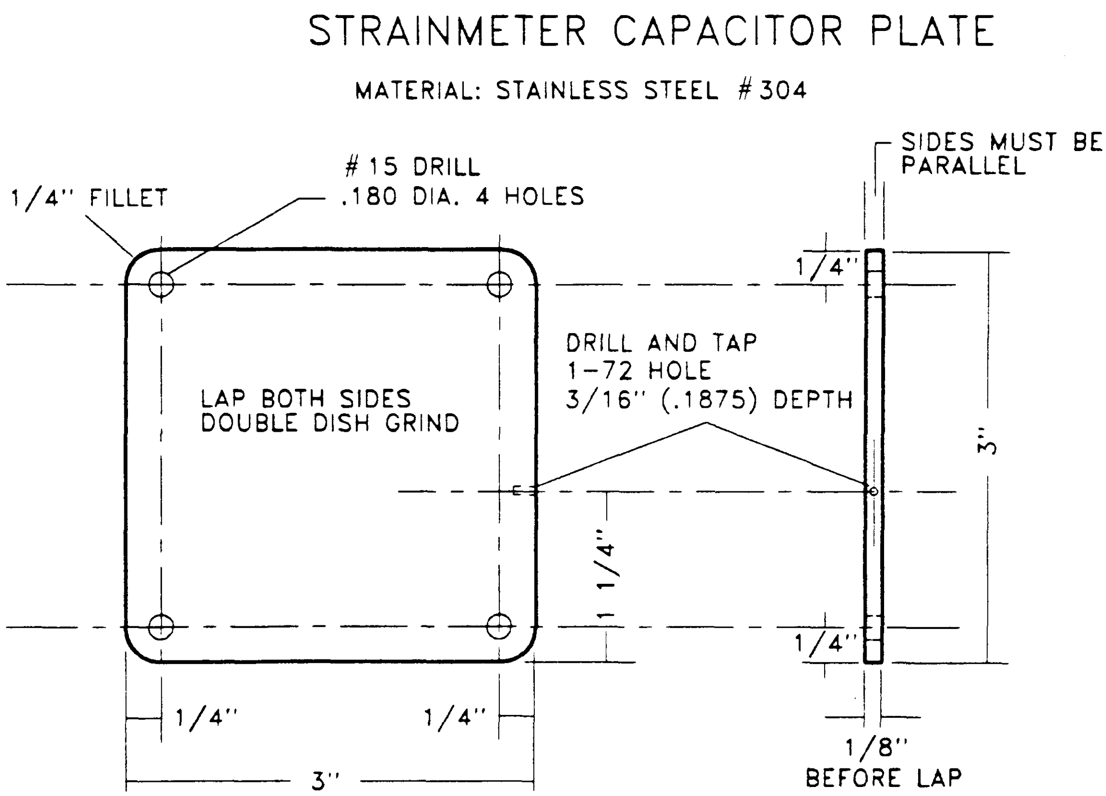

STRAINMETER CAPACITOR PLATE
MATERIAL: STAINLESS STEEL #304
SIDES MUST BE PARALLEL
15 DRILL
.180 DIA. 4 HOLES
1/4" FILLET
1/4"
DRILL AND TAP
1-72 HOLE
3/16" (.1875) DEPTH
LAP BOTH SIDES
DOUBLE DISH GRIND
3"
1 1/4"
1/4"
1/4"
1/4"
3"
1/8"
BEFORE LAP

Figure **7**

STRAINMETER LEVER ARM

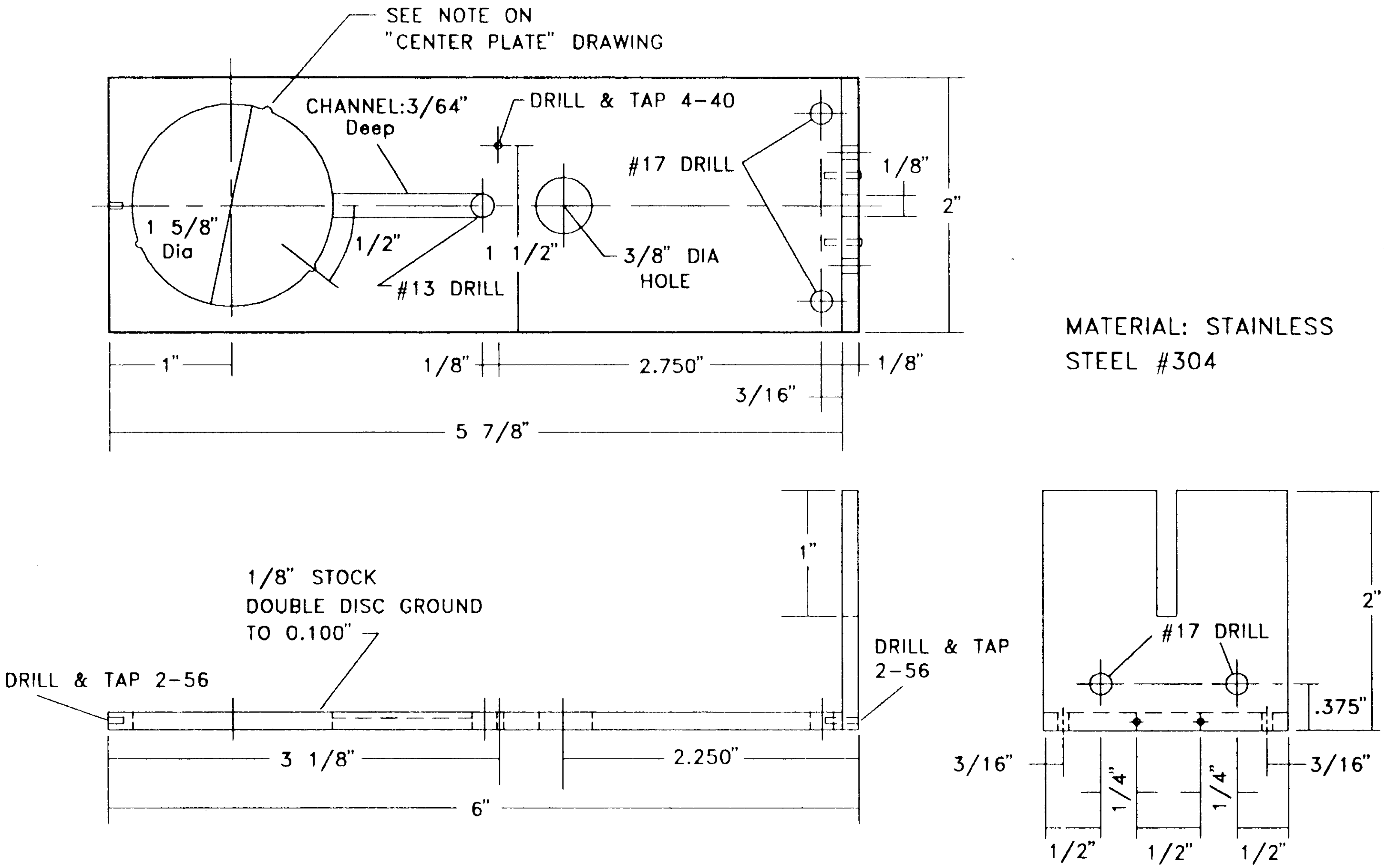
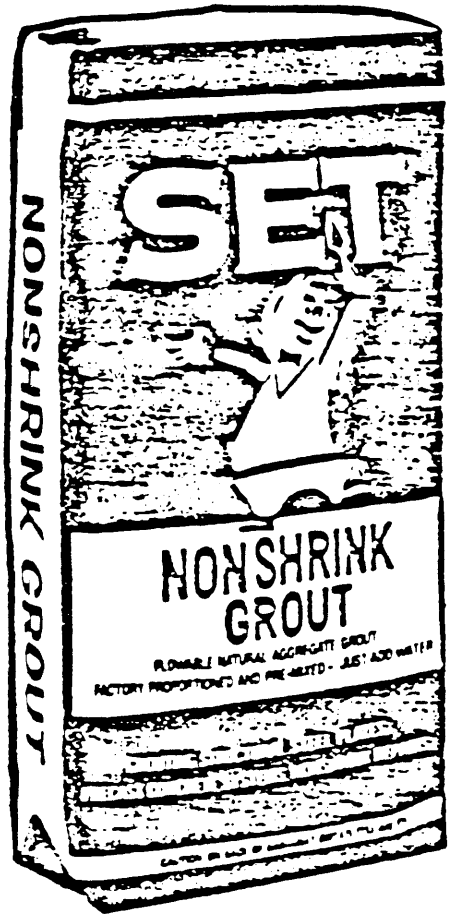


Figure 6

Color
Set Nonshrink Grout cures and dries to the color of plain portland cement concrete.

Packaging
Set Nonshrink Grout is packaged in 50-pound, polyethylene-lined bags with suggestions for usage.

Yield
One 50-lb. bag mixed with 1.1 U.S. gal. of water yields approximately 0.44 cu. ft. of grout.



Caution
Cementitious material may cause irritation: avoid contac with eyes and prolonged conta with skin. In case of contact with eyes, immediately flush with water for at least 15 minutes. Call a physician. Was skin thoroughly after handlinc Keep product out of reach of children.

Warranty
Master Builders stands behin its products when used by competent persons in accordance with current published recommendations, but canno be responsible for difficulty caused by other materials anc conditions, or by inferior wor manship. Master Builders reserves the right to have the true cause of any difficulty determined by accepted test methods.

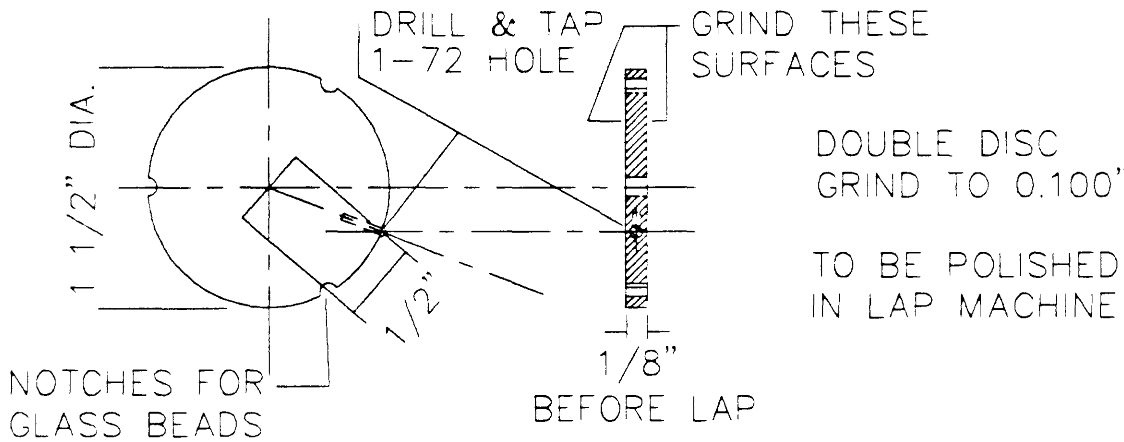
Special Notes
Contact your field representative or dealer for any special information or application assistance on Set Nonshrink Grout.

MASTER BUILDERS
IMPROVING CONCRETE WORLDWIDE

CLEVELAND, OHIO
TORONTO, ONTARIO

CENTER PLATE

MATERIAL: STAINLESS STEEL #304

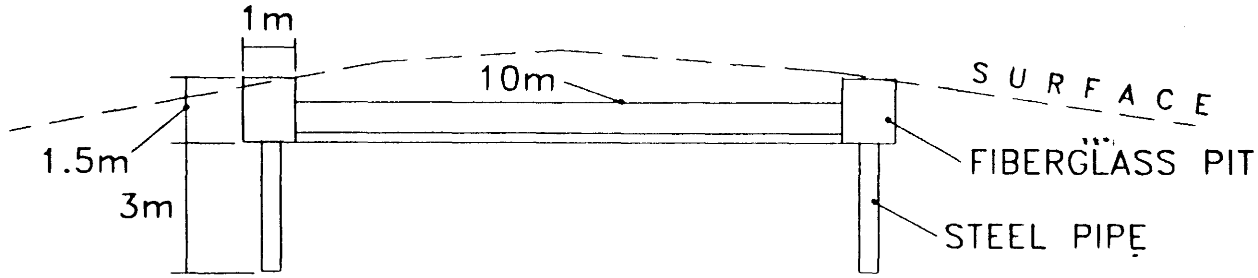


DO NOT PUNCH PRESS BLANK

NOTE: THE USGS MACH. SHOP HAS A JIG TO DRILL THE NOTCHES FOR GLASS BEADS, USING A #32 DRILL

Figure **5**

STRAINMETER INSTALLATION



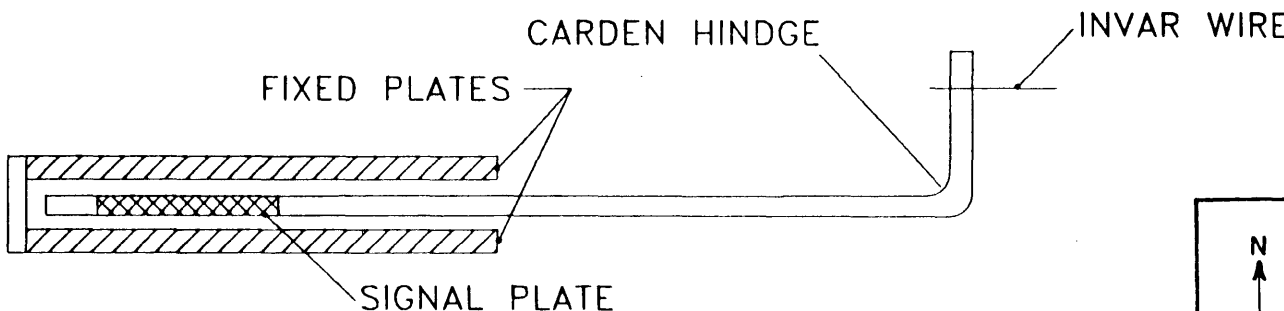
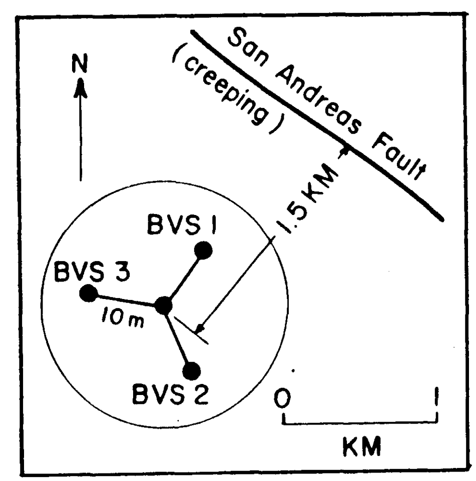


Figure 3



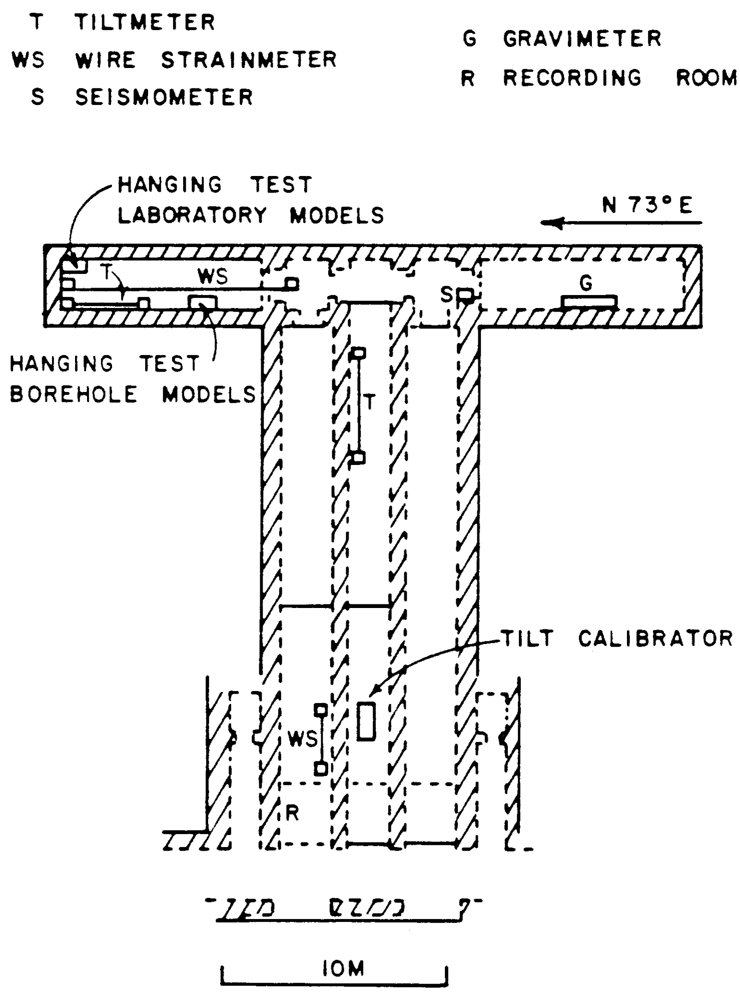


Figure 2. Layout of the Presidio Vault Test Facility.

9. APPENDIX

9.0 Figures - Construction

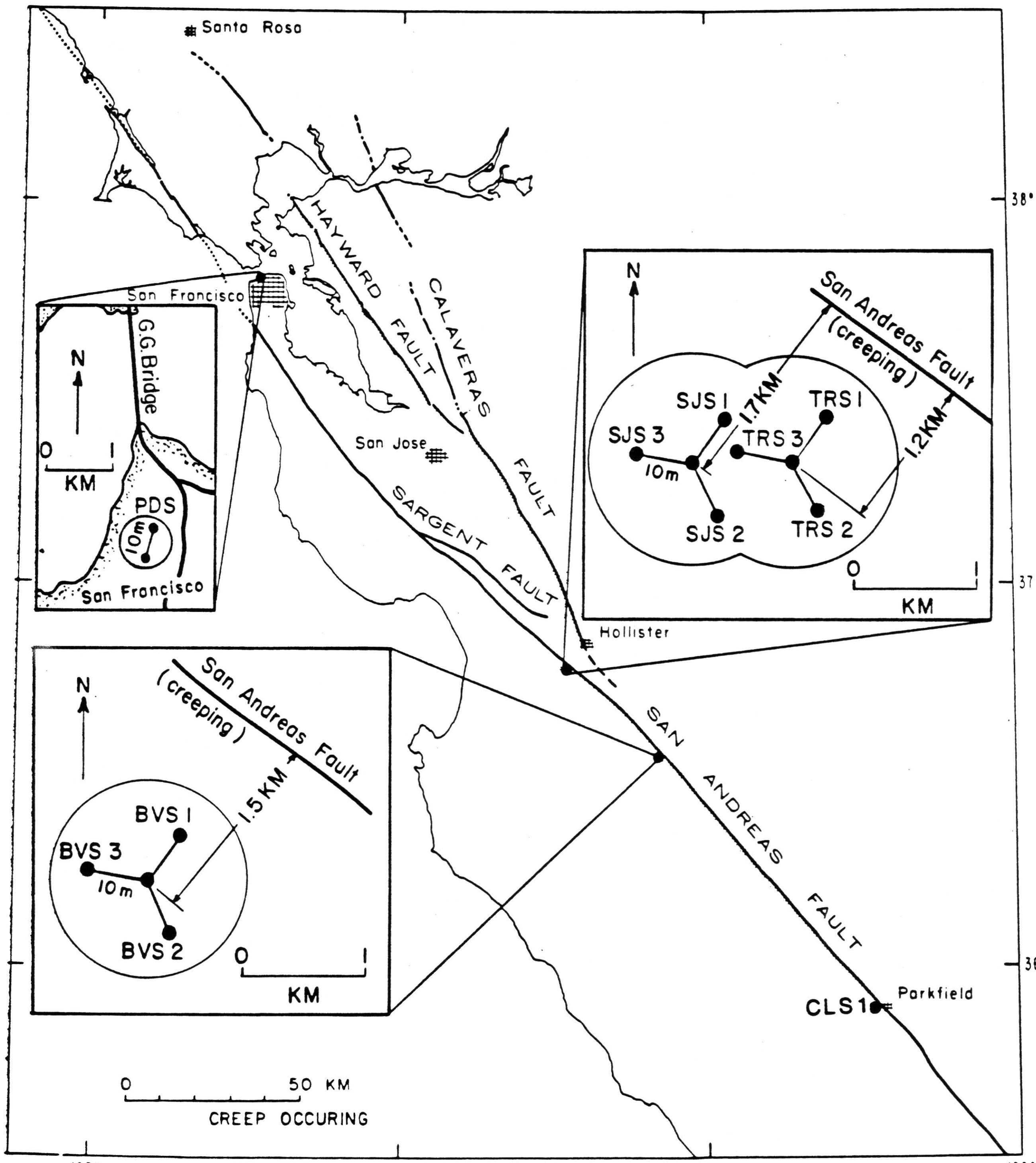


Figure 1 Strain Sites along the San Andreas

9.7 Rustrak Recorder

DC
RECORDER MANUAL

Models 288, 291, 2146,
2194 & 300 Series

#16906
4th Edition, 3-72

RECORDER SYSTEMS DIVISION
Gulton Industries Inc.
Gulton Industrial Park, East Greenwich, R.I. 02818
(401) 884-6800 TWX 710-387-1500

simply unplug the RS-232 connector, and remove the jumper.

Using the TRS-80/100, push F8, TRS-80/100 says Disconnect?, you say Y, and ENTER key, Then F8, (the TRS-80/100 will go into Menu), shut off power and disconnect the RS-232 connector.

Following these commands and using Table 3 for instrument names, ID's, transmit times, etc., the DCP can be programmed.

Table 3. Strainmeter DCP Coding Table.

Satellite Telemetry Coding			
Instrument	ID	Transmit Time*	Sensor Parameters
PDO	1613B156	2hr 5min (3hr)	pdst,pdoe,pdon,pd1s,pd2s,pd3s,pd2e,pd2n,pdvt
SJS	1613D4BO	2hr 7min (3hr)	sjs1,sjs2,sjs3,sjst,sjbv
CLS	16151160	5hr 48min (10min)	cls1,clst,clt2,clbv
BRK	1613E12A	2hr 8min (3hr)	brke,brkn

*The transmit time is set to be the time of reception in Menlo Park. Set Transmit Time 3 seconds early for 16 bit DCP's.

7. ACKNOWLEDGEMENTS

We thank Rich Liechti and Vince Keller for field support and Carl Mortensen for review comments.

8. REFERENCES

Johnston, M. J. S., and R. D. Borcherdt, Earth strain in the period range 0.1 - 10,000 seconds at six borehole sites within the San Andreas Fault System, *EOS Trans. Am. Geophys. Un.*, **65**, 1015, 1984.

Silverman, S., C. E. Mortensen, and M. J. S. Johnston, 1989. A Satellite based Digital Data System for Low-frequency Geophysical Data. *Bull. Seis. Soc. Am.*, **79**, 189-198.

Table 2.
Access order for DCP programming commands.

16 Bit 8004 DCP Programming		
prompt	response	meaning
GMT	00:00:00	universal time
TNC	00:00:00	time of next collection
UI	10	update interval
WT	5	warm-up time
NS	18	number of stored values
TNT	00:00:00	time of next transmission
TI	10	transmit interval
ID	12345678	platform identification
CHAN	134	transmit channel(frequency)
FMT	0	format in engineering units
INC	17	increment 17 samples with each transmission
CAR	150	baud rate of data transmission
PAR 1	Y/N	parameter(data) input location #1, Y(es)
PT	2	parameter type 2 = raw analog
CO	0	conversion option 0 = none
C1	0	
C2	0	
PAR 2	Y/N	The same as PAR1. Each site may have a different number of parameter (data) inputs, up to 8. Each will have PT,CO,C1,C2 responded to in the same fashion as PAR1.
CAL	N	
WND SPD	N	

All responses to DCP prompts are followed by a Carriage Return/enter.

A response of E after one of the PAR 1 Y/N commands will loop you to CAL N . A CR/Enter will put you to WND SPD N. A CR/Enter will loop you out of the program. At the end of this loop, push E, and then Carriage Return. The DCP will respond with; 0, DISABLE ; 1, ENABLE.

Pushing a 1 will enable the DCP to operate on the commands entered and it will start to collect and transmit at the times just programmed. To disconnect from the DCP: using the hand-held terminal, connector to the terminal location. To get into the DCP, the model 100 must be in TEL-COM mode, by using the arrow keys (STAT, 37I1E,10 pps), than F4. The DCP's first response will be 16 bit-V1.1 (with the hand-held terminal only), and then CMD:. For the TRS-80/100 to get responses from the DCP, the 80/100 must be in caps-lock mode. (lower left hand corner key) When carriage return/enter is pushed the DCP will respond with the universal time. When S is pushed, the setup/programming mode for the DCP is entered. The DCP will respond with GMT: . A correction of the time can be made by entering the hours, minutes, and seconds in this format, 24:24:24, (24 hour) then carriage return (CR)/enter at the correct time. A response by the operator of just (CR)/enter to each of the DCP commands will eventually loop out of the program mode and back to CMD: . The time of day is now reset. In order to change any of the other constants the operator must go through the following.

5.2.3 On the newer, open back motors, there are two small loops on the pc board. Attach a Lapse Time Counter here. Adjust pot for 66666 if 1 RPM motor. Adjust pot for 33333 if 2 RPM motor.

5.2.4 Some of the Rustrak recorders have been modified to use with a bias stepper. This gives a range of 15 chart widths. Occasionally the bias stepper boards fail and this can destroy the recorder galvanometer.

6. DATA TELEMETRY SYSTEM

The data telemetry system consists of a 12 bit or 16 bit analog to digital programmable data collection platform. It is set up to collect information from three components of the strainmeter, temperature, and Aattery voltage. It samples at 9 minutes past the ten minute mark, and transmits at an assigned time every ten minutes, if it is a 12 bit unit. The 16 bit platforms are set to transmit every three hours. This sample and transmit time are controlled by an internal crystal clock. The maintenance required of this unit is the resetting of the clock to universal time at infrequent intervals that are controlled by the temperature environment and aging of the crystal. This involves the opening of the enclosure, the careful removal of the insulation, the grey steel box housing the DCP, and the connection of a hand-held terminal or TRS-80 model 100 portable computer. Either one of these can program universal time, the transmit interval, time of transmission, and other programming constants into the DCP. We currently use Sutron Corporation model 8004 (16 bit) DCP's (see accompanying Table 2 for programming the assigned times of transmission, I.D., parameter inputs, and instrument name and code)

6.1 Data Collection Platform (DCP) Programming (16-bit Sutron 8004)

6.1.1 After attaching an RS-232 connector to the DCP at the location marked terminal, and putting a jumper between tr and gnd (hand-held terminal), the DCP can be programmed. The TRS-80, model 100, or other portable computers, can also be used by attaching a RS-232 volts to run the rezero motor in one direction or the other. A cable leads back into the back vault to the rezeroing motor. Watch the panel meter, and try one or the other, with respect to ground. If the strainmeter is trending in a negative direction, apply voltage to the rezeroing motor until the meter reads positive. Then reverse the polarity of the + or - voltage source to disengage the gears from the strainmeter. The ohmmeter will go from a low reading to a very high reading when the gears disengage. Switch the time constants back in, and shut off the 12 volt power supply.

5.1.7 PD2S is rezeroed by attaching an oscilloscope to the input leads coming out of the back vault from the strainmeter. An 8 kHz sine wave will be observed. Use the ratio transformer to bring down the amplitude of the sine wave. PD2S still has the prototype electronics that include an old design, four-step "stepper" for the Rustrak recorder, and the front panel meter.

5.1.8 PD3S is rezeroed by observing the panel meter, and using the ratio transformer dials. There is no stepper.

5.2 Rustrak Recorders

5.2.1 See Appendix 9.7 for directions on changing the roll of paper etc. If the whole recorder is changed, be sure the proper gear train is installed to give a chart speed of 1/4-inch per hour. Always use a full roll. Chart speed will be off if a partial roll is installed.

5.2.2 The chart speed of the recorder can be set in the lab as follows. The older model recorders have a black cover on the back of the chart motor. To set the speed on these, install a 1 ohm resistor in series with the power lead. This will be pin 3 of 4 of the input plug. Use an oscilloscope across this resistor, and set the sync. to int. sync on 60 Hz. Set the observed pulse train for a multiple of 60 Hz.

5.1.4 If the panel meter is found to be near the left or right end of its range, use the switch dials on the ratio transformer to rezero. The meter needle should go in the same direction as the switch is turned. Start with the second switch from the left. If the needle goes in the opposite direction as the switch, it will be necessary to mechanically rezero the instrument. The center plate of the transducer will be found to be touching one of the outside plates.

5.1.5 To mechanically rezero a strainmeter, first set the ratio transducer to read 49000. Then open the transducer pit, remove the bag of pellets, and the wooden table over the transducer box. A small boat ladder is useful to climb in and out of these pits, or culverts. Loosen the two screws on the metal box. If removed, they will probably get lost. Slide the lock pieces over, and off the top. Do not leave this top open while you go get the oscilloscope out of the field truck. Grass and insects will fall in if open. If an oscilloscope is not available, move the weights until the center plate is free of the top or bottom plate. The oscilloscope should be attached to the output of the small pre-amplifier board, and ground. Adjust the weights for minimum amplitude of the observed sine wave. Change the dryer bags, and close up. The second batch of strainmeters were built into a cast iron box, and covered with silicon oil. The cast iron box was then mounted inside the sheet metal box. It is possible to partially disassemble the transducer in the field, if water is found, but not advised. Removing the wire clamp will completely change the calibration of the strainmeter. Try blowing dry air between the plates, and changing the FET transistor on the moving plate first.

5.1.6 The three strainmeters located in the San Francisco Presidio, PD1S, PD2S and PD3S strainmeters require a different field procedure. To rezero PD1S, first attach an ohmmeter onto the leads labeled "gears". Next switch out all the time constants. Use either + or - 12

4.1.3 The circuit diagrams of the strainmeter preamplifiers are shown in Figure 22. Transistor Tn1, and resistors R1, R2, and R3 are mounted right on the center arm of the strainmeter transducer. One very fine wire carries both the signal and the power for Tn1 across the cardon hinge. C1 blocks the DC, and allows the AC signal to pass to IC1. IC1 drives the cable from the transducer pit to the electronics pit. Figure 22 shows the circuit diagram for this.

4.1.4 Two fixed amplitude, 8 kHz sine waves, 180 degrees out of phase with each other originate from the main amplifier electronics, to the two fixed capacitor plates of the transducer. The amplitude of these sine waves varies by fixed amounts controlled by the ratio transformer. As the strainmeter transducer center plate moves away from it's center position, a small 8 kHz signal moves to the FET preamplifier mounted on the strainmeter lever arm. A cable carries this signal to the Electronics Pit.

4.1.5 Figure 23 shows the circuit diagram of the main amplifier. Figure 24 shows the parts layout on the printed circuit board. The 8 kHz signal from the transducer pit is run through a phase shifting circuit consisting of T2 and T3. The signal coming from the center plate of the transducer, and the signal at C10, a .02 mfd cap, must be exactly in phase with each other. The phase is matched by observing a dual trace oscilloscope, while adjusting the 50 Kohm potentiometer, R16. The two wave forms can be super-imposed on each other.

4.1.6 IC2 amplifies the incoming AC signal. A variable feedback resistor, R22 controls the gain of the system. A variable attenuator (see note 1 on Figure 23) can be added. It was found that a single fixed gain resistor causes fewer data headaches. It is much harder to change gains in the field, so the calibration of the strainmeter is more likely to be preserved. The output of IC2 goes to a small switch on the control panel, labeled "zero." The signal is

3.1.12 Repeat the above steps for the other two strainmeter components. Fill in the anchor pit with insulation. Close all the lids.

4. ELECTRONICS

4.1 Description

4.1.1 Originally all the strainmeter sites, except BV1S, were powered by air cell batteries. For BV1S, AC power was provided from Bear Valley Fire station, via a buried cable. Four air cells were used to power the strainmeter, and two to power the telephone telemetry system. All the sites eventually were changed to rechargeable batteries, with solar cells mounted up on a strong post. The telephone system of telemetry proved to be very troublesome. A large percentage of troubles occurred within the telephone company, or telephone lines. The telemetry receiver electronics were difficult to maintain, especially the relay racks full of obsolete electronics. It was decided to convert to a satellite-based system (Silverman et al., 1989). The electronics for the new system is mostly purchased from Sutron Co. Data from each site is transmitted back to Menlo Park, via a GOES satellite. This system has proven much more reliable. Figure 20 shows the block diagram of the strainmeter electronics.

4.1.2 The electronics culvert, or pit contains the batteries, three electronic boxes, and the telemetry system. The main electronics for each strainmeter is installed in a water resistant Skydyne instrument box (Appendix 9.6). Water resistant plugs have been installed in the boxes for signal and power leads (Figure 21). These boxes contain a Ratio Transformer, a power supply board, and the main electronics board. The box also contains a Rustrak chart recorder. Preamplifiers and cable driver amplifiers are located with each transducer in the central pit.

tighten the bolts.

3.1.6 Make all the electrical connections. Pour in Dow Corning 200, 100 C.S. viscosity fluid to cover the transducer, inside the transducer cast iron box (Figure 4).

3.1.7 Attach the large bellows on the PVC pipe, and the horizontal extension of the NEMA box.

3.1.8 The final tensioning of the anchor clamp should be done after the electronics have been installed. Attach an oscilloscope to the signal output cable from the preamplifier. Pull, or release the invar wire, using a pair of long nose pliers as a lever arm on the anchor pier clamp. An extension wire can be plugged into the electronics box, and extended to the anchor pit. When a minimum output is observed on the oscilloscope, carefully clamp the wire clamp. This is a trial and error exercise that will have to be repeated several times, as the wire length will change slightly as the clamp is tightened.

3.1.9 It probably will be necessary to add some weight to the center arm of the strainmeter. Do this with the ratio transformer set to 49555. Make sure that the invar wire is not touching the PVC pipe anywhere. Move the weights until minimum amplitude of the output sine wave is observed on an oscilloscope.

3.1.10 Install the cast iron lid to the top of the strainmeter cast iron box (Figure 4). Put about 10 desiccant bags in the NEMA metal box. Put silicone grease on the gasket of the sheet-metal box, and close it.

3.1.11 Fill the transducer pit with insulation. We have tried various sizes of Styrofoam pellets, and various size bags to hold them. The best seems to be to use small bags around the strainmeter box, and a small wooden platform over this layer. Then a large nylon bag of pellets to fill up the rest of the space to the top.

9.4 Singer Ratio Transformer

INSTRUCTION MANUAL
FOR
RATIOTRANS
RT-60 SERIES

MANUAL NO. 1–500783–094

Serial No. ______

Reprinted 10/75 Lib

SINGER
INSTRUMENTATION

The Singer Company, Los Angeles Operation • 5340 Alla Road, Los Angeles, Ca. 90066

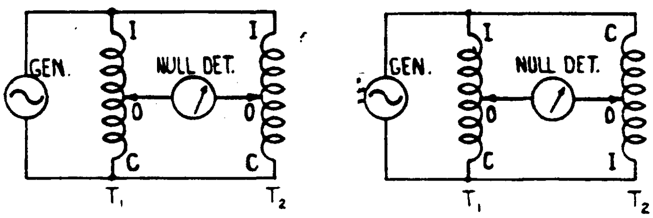
INDEX TO RatioTran* ENGINEERING BULLETINS

The following Engineering Bulletins cover the theory and applications of Gertsch RatioTrans. Additional bulletins are being prepared and will be made available as soon as possible.*

* *Trademark*

quoted above. The units are ageless, requiring no calibration tests and should perform indefinitely with no loss in accuracy barring some switch failure or actual damage to the transformer.

Tests have been performed on a basis of comparison between several units. While it is not possible to get complete absolute data in this manner, certain facts can be deduced. Referring to the diagram T_1 and T_2 represent the two transformers under test.



TEST 1 TEST 2

Let R_1 be indicated ratio of T_1
R_2 be indicated ratio of T_2

Let E_1 be error in indicated Ratio of T_1
E_2 be error in indicated Ratio of T_2

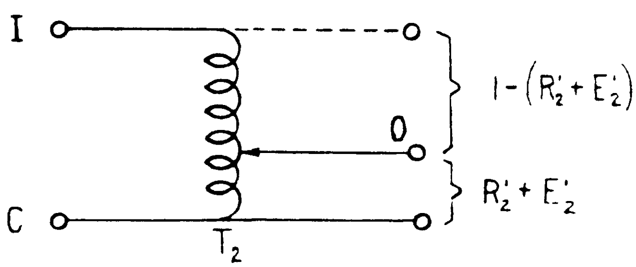
then at balance in Test 1

$R_1 + E_1 = R_2 + E_2$

at Balance in Test 2

$R_1 + E_1 = 1 - (R_2' + E_2')$

where $1 - (R_2' + E_2')$ is the complement of $R_2' + E_2'$ as shown below



Now suppose that in both tests

$R_1 = R_2$
$R_1 = 1 - R_2'$

then $E_1 = E_2$

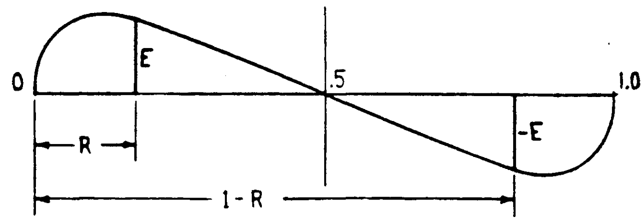
$E_2' = -E_1$

or $E_2' = -E_2$

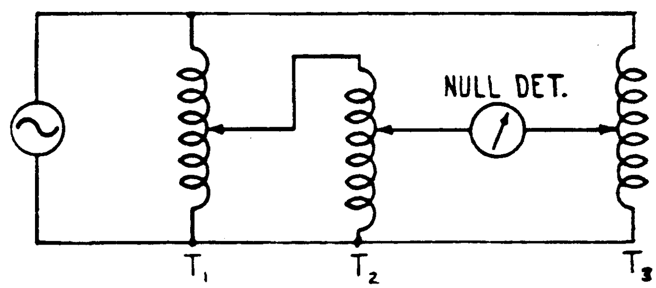
This shows that if at balance in both tests the indicated are exactly equal or complementary there can exist an error of a special nature which cannot be detected.

E at R = -E at (1-R)

E must be zero at R = .5 and show odd symmetry about R = .5



In general, any two transformers so tested will meet the conditions for the tests within 1 or 2 parts in 10^6 so that any components of error which do not show the above symmetry must be at least this small. To obtain some idea of the absolute errors two transformers were cascaded and compared against a third as shown below.



$(R_1 + E_1)\ (R_2 + E_2) = (R_3 + E_3)$ at Balance

if we choose $R_1 = R_2 = .5$

from the foregoing analysis $E_1 = E_2 = 0$

If proper care is taken to compensate for loading effects the magnitude of E_3 can be determined at $R_3 = .25$. This error in general is less than .001%.

This process can be continued by cascading more transformers and measuring the error at points $R = (.5)^N$

It is easy to show that the same analysis applies to quadrature voltage. The same tests can be made and values of θ at points $R = (.5)^N$ determined. The phase angle data given earlier in this article was derived in this manner.

All of the foregoing discussions apply to completely unloaded conditions on the transformers. Effects of loading are discussed in Engineering Bulletin No. 3 entitled "Accuracy Calculations for Gertsch Standard Ratio Transformers."

Accuracy formulas given above apply only to those units shipped after January 1, 1956. Previous units have accuracies of $\pm\left(.004\% + \frac{.0006\%}{R}\right)$ and

$\pm\left(.004\% + \frac{.0001\%}{R}\right)$ respectively.

USE OF GERTSCH STANDARD RATIO TRANSFORMERS (RatioTran*) FOR LOW IMPEDANCE VOLTMETER CALIBRATION

The RT Series Standard Ratio Transformers are very useful for AC voltmeter calibrations. Basically, the system consists of a standard voltage source driving the RatioTran* which in turn drives the meter to be calibrated.

Several things must be taken into consideration in this system. The source voltage must be known at least as accurately as the calibration to be made. The distortion of the source must be low, particularly in a case where the meter which is monitoring the source measures on a different basis from the meter to be calibrated. For example, the monitoring meter might read RMS voltage and the meter to be calibrated might read average voltage.

The loading effects of the meter to be calibrated on the RatioTran* should be taken into consideration. These loading effects can be easily determined from the ratio of meter impedance to ratio transformer impedance. For all practical purposes the ratio transformer impedance is resistive and forms, with the meter to be calibrated, a voltage divider. Therefore, if the voltmeter is resistive, the voltage appearing across it will be low by an amount equal to the ratio between the RatioTran* resistance and the meter resistance. For example, if the RatioTran* has an internal impedance of 5 ohms and the meter has a resistance of 5,000 ohms, the voltage appearing across the meter will be 5/5000 or .1% lower than it would be if the meter had infinite impedance.

The foregoing analysis can be generalized. The fractional error that will exist with the RatioTran* resistance R and meter resistance M is approximately equal to $\frac{R}{M}$, or stating it a different way, for a maximum error E the meter resistance M must be greater than $\frac{R}{E}$, where R is again the series impedance of the RatioTran.*

The maximum series impedance in any of the ratio transformers for nominal frequencies is less than 5 ohms with the exception of the RT-1 and RT-10 where the maximum is 12 ohms. Consequently, for meter impedance of 5,000 ohms or greater the error introduced by loading effects on the ratio transformers will not be greater than .1% for all ratio transformers except the RT-1 and RT-10, in which case for the same accuracy the meter resistance must not be less than 12,000 ohms.

If greater accuracies are desired or the meter impedance is lower than the values given above, power must be supplied to the meter in a bridge arrangement shown in Figure 1. With this circuit it is possible to adjust the variable series impedance so that all the power supplied to the meter comes from this branch. This, of course, occurs when the bridge is balanced, that is, the ratio of the meter impedance to the total impedance (meter impedance plus variable impedance) is equal to the ratio of the Standard Ratio Transformer. Obviously, when the bridge is balanced there is no current flow through the ratio arm of the transformer and the junction between the series impedance and the meter so there is effectively no load on the ratio transformer.

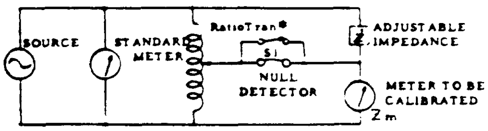


FIG. 1

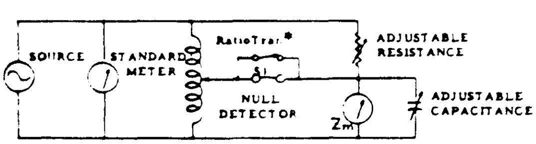


FIG. 1A
Modification of Fig. 1
CONVENIENT WHEN Z_m CONTAINS INDUCTIVE REACTANCE

Since we can make the ratio transformer operate essentially unloaded by this method, meters with impedance as low as desired can be calibrated with no loss in accuracy.

One other restriction must be placed on the variable impedance in series with the meter. It must have the same phase angle as the meter. The total requirement can be stated generally as follows: the ratio of the complex impedances of a meter and series impedance must be real and equal to $\frac{N}{1-N}$ where N is the ratio on the ratio transformer. Here we have assumed that the Ratio Transformer has zero phase shift.

This last statement is merely another way of saying that the bridge formed must be balanced.

The degree of unbalance which can be tolerated in the bridge circuit can best be expressed in terms of the unbalanced current flowing in the ratio arm of the transformer. Since the product of the unbalanced current times the effective impedance in the ratio arm gives the magnitude of the error voltage, the maximum value of this current can be easily determined. It would be simply E Max. divided by R Max. where E is the maximum allowable error voltage and R is the maximum series impedance in the ratio arm of the transformer.

The unbalanced current itself may be measured directly with a high sensitivity AC current meter, or the bridge may be brought to balance with standard null detector techniques. The null detector should be shorted out with switch, S1, after balance has been reached. This last step is recommended since the voltage at the junction between the series impedance and the meter will always be closer to the true voltage for small errors if the null detector is shorted out.

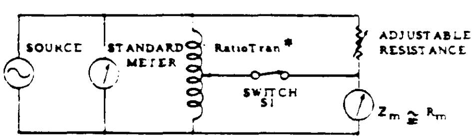


FIG. 2

SUITABLE ONLY WHEN Z_m IS RESISTIVE OR NEARLY RESISTIVE

If the phase angle of the meter is known to be small this series impedance may be resistive and balance of the bridge can be detected with a circuit shown in Figure 2. The switch, S_1, is alternately opened and closed and the series impedance adjusted so that the meter reads the same whether the switch is opened or closed. When this occurs the bridge is balanced provided the phase angle of the meter is small. The phase angle requirement must be met because it is possible, in this test, for the meter to read the same whether the switch is opened or closed and still not have the voltage across it equal to the open circuit voltage of the ratio transformer, when the phase angle of the meter in the series impedance are not equal. The allowable phase angle can be determined from the circuit constants and the accuracy desired, or a direct measurement of the unbalanced current may be made.

For maximum accuracy of calibration the RatioTran* should not be used to divide the standard source too far. The reason for this is, the accuracy of the ratio decreases for small ratios between output and input of the RatioTran.* To guarantee accuracies better than .02% it would be necessary to operate with ratios larger than .01. To extend the system range below .01 a new standard voltage one 100th the original standard voltage could be derived with the RatioTran* and this used to extend the system on down by another factor of 100. In this manner a total range of 10,000 to 1 can be covered with less than .04% error. One method of doing this is to connect two ratio transformers in cascade. The percentage errors of the two transformers can be added in this case.

* *Trademark*

ACCURACY CALCULATIONS FOR GERTSCH STANDARD RATIO TRANSFORMERS (RatioTran*)

1. DEFINITION

The accuracy of Gertsch Standard Ratio Transformers is specified by a formula which gives the maximum error which could be expected in the indicated ratio. This would give the error as a percentage of the output if the input is perfectly known. This accuracy is applicable to a bridge circuit, since the source voltage is common to both branches of the bridge circuit and variations of source voltage cause no error. The accuracy specification is given as a formula similar to $\pm\ (.004\% + \frac{.0001\%}{R})$ where R is the indicated ratio in the decimal fraction form with which the RatioTran* switches are calibrated. This formula gives a more accurate description of the maximum error which could be expected from a Gertsch RatioTran* than would be obtained by the standard definition of terminal linearity. In a potentiometer terminal linearity rating, the error component which is to be expected at the output is quoted as a percentage of the input voltage. A comparison of the specified maximum error in a RatioTran* and a potentiometer of .005% terminal linearity is given in the following table.

ERROR EXPRESSED AS PERCENTAGE OF OUTPUT			
Ratio	Ratio Transformer Units Shipped Prior to 1/1/56 $\pm(.004\% + \frac{.0001\%}{R})$	Ratio Transformer Units Shipped After 1/1/56 $\pm(.001\% + \frac{.0001\%}{R})$	Potentiometer .005% Terminal Linearity
1.0	± .0041%*	± .0011%*	± .005%
.1	± .005%	± .002%	± .05%
.01	± .014%	± .011%*	± .5%
.001	± .104%*	± .101%*	± 5%

*This is the exact solution of the formula. Since "error" is only roughly specified, all digits beyond the first significant figure are meaningless.

2. ACCURACY vs AGE

A careful study of the distribution of resistance and reactance in RatioTrans* leads us to believe that it is extremely improbable that the specified values of error will ever be exceeded. The accuracy of Gertsch RatioTrans* does not change appreciably with age and periodic calibration checks are unnecessary. Any periodic checks should be directed chiefly at detecting malfunctioning switches or potentiometers.

3. ACCURACY UNDER LOAD

Gertsch Standard Ratio Transformers have an internal impedance which can be considered to be in series with the output (see Fig. 1).

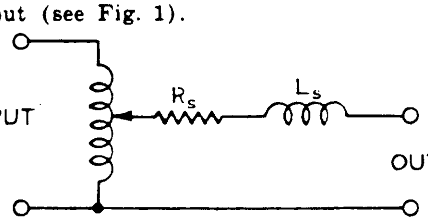


FIG. 1

The value of this impedance varies with ratio in a manner which makes it impractical to define it as a function of ratio. Instead, maximum values of resistance and reactance that can be expected at the worst possible setting of the instrument are given. Voltage drop in the RatioTran* will always be less than the value found by multiplying the load current by the specified maximum series impedance. If the impedance of the load is known, the error introduced by this impedance will always be less than the ratio of the specified maximum impedance to the load. As a numerical example, suppose that a 10,000 ohm resistive load is to be driven from a Model RT-5 operating at 400 cycles. The RT-5 has a maximum effective series inductance of 75 uh. At 400 cycles this is an inductive reactance of .2 ohms, and, for the purposes of this problem, it may be neglected since it is much less than the 3 ohms maximum effective series resistance. The RT-5 may be assumed to have a series impedance of 3 ohms or less resistive. When loaded by 10,000 ohms, the fraction of output voltage dropped across the internal impedance of the RT-5 is given by:

$$\frac{Edrop}{Eout} = \frac{Rseries}{Rload + Rseries} = \frac{3}{10{,}000 + 3} \simeq \frac{3}{10{,}000} = .0003 = .03\%$$

In this case the percentage error contributed from this source is .03%. If this error is acceptable, the circuit may be used. Otherwise a bridge circuit must be devised which will drive the required load impedance without loading the Ratio Transformer beyond the acceptable current level. Circuits for this purpose are discussed in another paper distributed by Gertsch Products, Inc. The title of this paper is Engineering Bulletin No. 2 (RatioTran*) "Use of Gertsch Standard Ratio Transformers For Low Impedance Voltmeter Calibration."

* *Trademark*

USE OF RatioTran* IN BRIDGE CIRCUITS

Since any bridge circuit has four terminals, only one of which may be grounded, it is recommended that a shielded bridge transformer such as the Gertsch Model ST100 or ST100A be used to isolate either the generator or detector. Typical circuits are shown below.

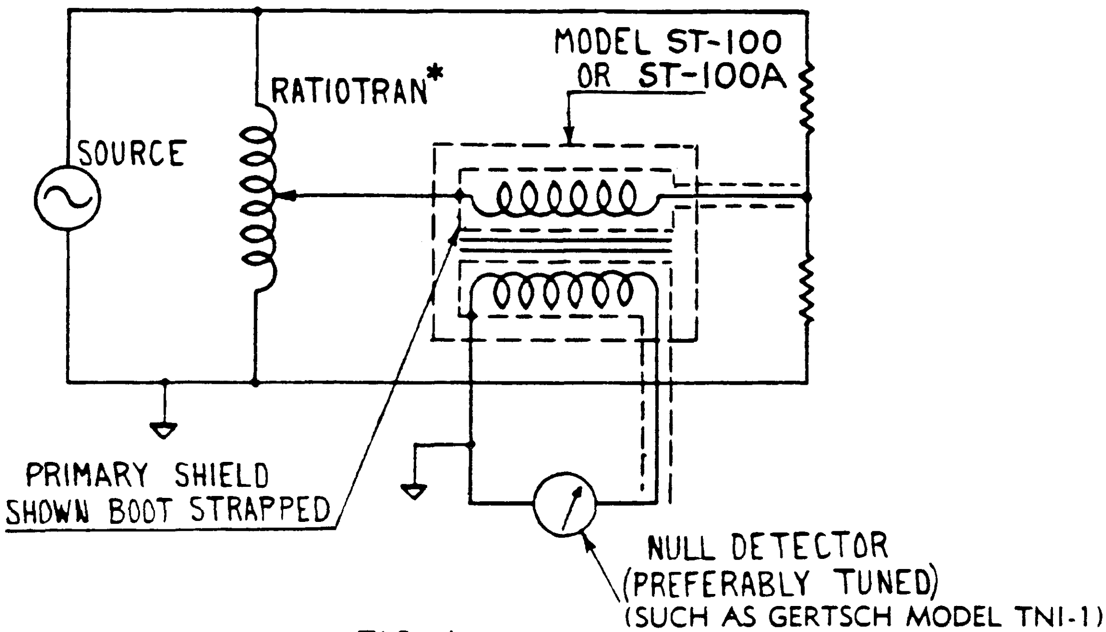


FIG. 1

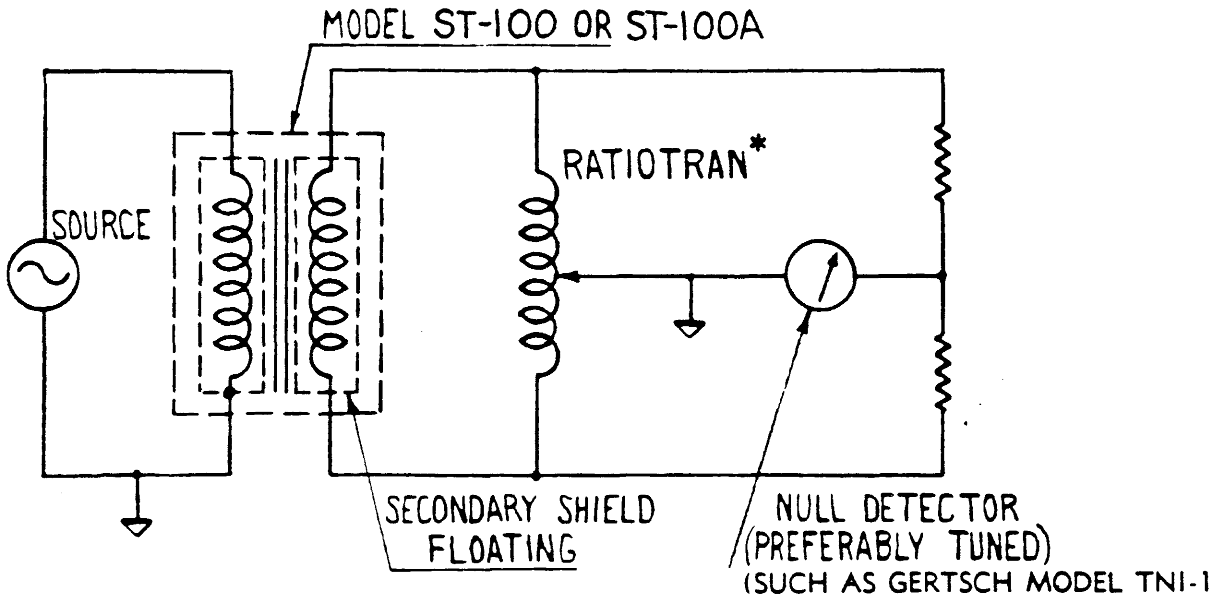


FIG. 2

The degree of shielding of the various bridge elements used depends on impedances and accuracy desired. For a good treatment on AC Bridge technique the reader is referred to "Electronic Measurements" - Terman & Pettit.

* *Trademark*

The following article originally appeared in the January 1956 issue of Control Engineering and is reprinted here with the permission of Control Engineering and the author, Mr. Jack Gilbert.

Measuring Small Phase Angles

JACK GILBERT, Norden Laboratories

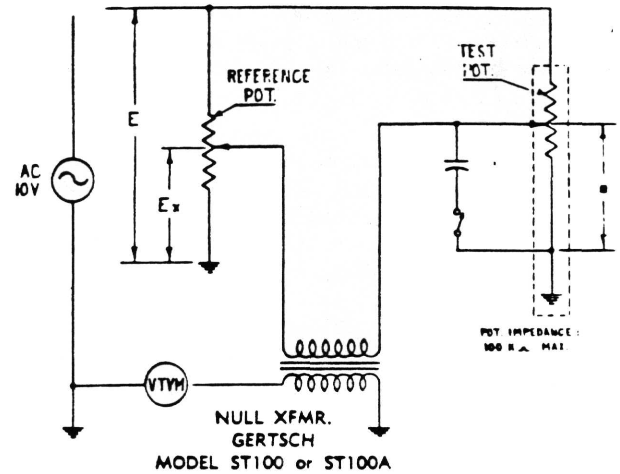


FIG. 1

Phase shift due to potentiometers, precision resistors, computer amplifiers, ac tachometers, and transformer windings can be found by a relatively simple technique that can measure phase angles as small as 0.005 deg and as large as 30 deg. With some loss of accuracy, angles up to 90 deg can also be detected by the method. The detection circuit, with elements of only conventional accuracy, obtains phase shift and quadrature voltage from a reference voltage varying from 50 to 5,000 cps. And the result is accurate to plus or minus 0.01 deg plus or minus 5 per cent at midband (350—1000 cps).

The reference voltage, E, is divided by the reference pot slider until a minimum or null reading is observed on the vacuum tube voltmeter. This voltmeter reading will be the quadrature voltage. The phase shift created by the reference pot is insignificant because of its relatively low impedance and internal construction. Figure 1 illustrates the circuit and Figure 2 its theory of operation.

The voltage ratio X is read directly from the dial of the reference pot, and the null voltage from the meter. An infinite resolution slide-wire type pot is desirable for the reference voltage divider. The phase shift is an angle whose tangent is equal to Mo/EX. For angles less than 6 deg, multiply the ratio Mo/EX by 57.3 deg to calculate a phase angle within the accuracy of the measurement technique. If a constant reference source is used, the dial of the voltmeter can be calibrated in phase shift directly.

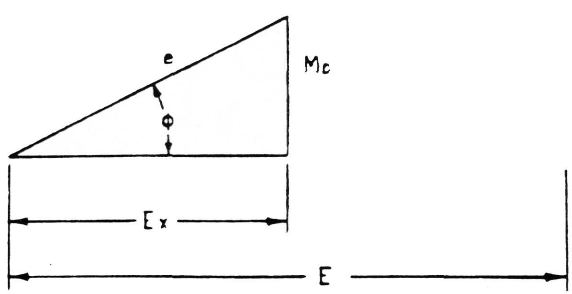
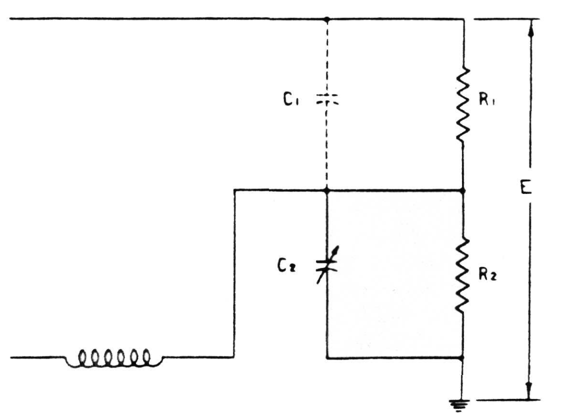


FIG. 2

It will be noted that as the phase angle becomes smaller, variations in EX produce an increasingly greater role in the variations of Mo. Hence, the accuracy of the technique for small angles is exceeded by its sensitivity. To achieve the indicated accuracy of 5 per cent, the reference pot should be accurate to ¼ per cent for angles less than 1 deg and the meter calibrated within 3 per cent.

For potentiometers, a small capacitor may be switched across the test component to determine the polarity (lead or lag) of the shift. The change in meter reading is then indicative of the polarity of the phase angle. For instance, if the shift is caused by capacitative reactance of the tested part, the condenser will augment them, increasing the negative phase shift and hence the null voltage. Similar techniques may be used for other components.

A plot of the phase shift of an unloaded ten-turn potentiometer can be easily calculated once its time con-



AT NULL
$R_1 C_1 = R_2 C_2$ = POT TIME CONSTANT

FIG. 3

* *Trademark*

:ant is known. The time constant could be found by suit-ble calculation involving the phase shift measurements obtainable by the balancing technique), but here is a irect way of finding it.

Figure 3 shows the setup R_1 is the entire ten-turn ɔt. R_1C_1 is the time constant produced by the distributed ıpacity of the pot. C_2 is a variable capacitor, and R_2 a nall fixed resistor of approximately the same resistance s the pot. The phase shift through this resistor is too nall to be significant. Only when the adjustable capaci-ır, C_2 is such that R_2C_2 equals R_1C_1 is the output voltage phase with the input voltage. With the reference pot :t near its halfway point, the in-phase component of the ɔltage will equal the voltage EX, but will be out of phase ith EX depending on the time constant of R_1C_1.

This time constant can now be used in the following ıuation to find the quadrature voltage of any of the n-turn pot's shaft settings.

$'o = EwRC\ (1-2S)\ (1-S)\ (S)$

E = input voltage

w = radian frequency

R = potentiometer overall resistance

C = equivalent lumped capacity measured across end terminals

S = shaft position, in per cent of maximum rotation.

Similarly, one can calculate phase shift (in radians) by

$\emptyset = wRC\ (1-2S)\ (1-S)$

Since similar expressions can be derived for other pot types, one reading provides all the information needed to plot a pot's phase shift characteristics.

Rather than a slide-wire pot, an ideal standard voltage divider is a Gertsch Ratio Standard, Model RT-5. Resolution better than 0.0001 per cent is available together with a voltage ratio accurate to within 0.004 per cent. The advantage of this item is accurate output with very low internal impedance and extremely low phase shift.

ıe following additional information is supplied by the Engineering Department of Gertsch Products, Inc.

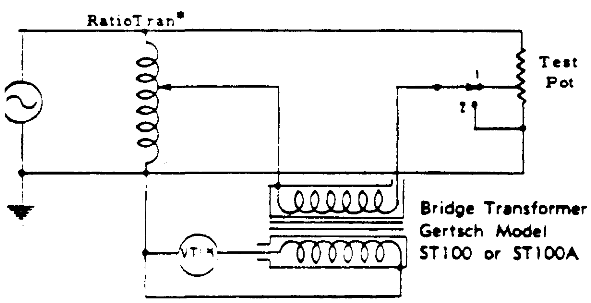


FIG. A

The circuit shown in Fig. A is a variation on the ɛthod described in the preceding article. Leads may be anged instead of using a switch.

In operation, the RatioTran* is adjusted to the best ll with the switch in position 1. The RatioTran* then ads the inphase component of voltage ratio. The VTVM read and the switch thrown to position 2. The RatioTran* then adjusted to bring the VTVM back to the same ading. The RatioTran* then reads the quadrature com-nent of the unknown ratio. This method has the ad-ntage of eliminating errors from the null transformer voltage ratio. Also, the source voltage need not be accurately known.

A possible source of error when measuring phase angles by this method is the loading on the bridge caused by the null transformer and null detector. The method depends on measuring the remaining voltage at the best null. This voltage will be reduced because of current through the primary of the null transformer. Unless the impedance of the device under test is low compared to the impedance of the null transformer primary, the error will be serious. The circuit of Fig. B can be used to reduce this effect since a high impedance VTVM may be used directly as a null detector.

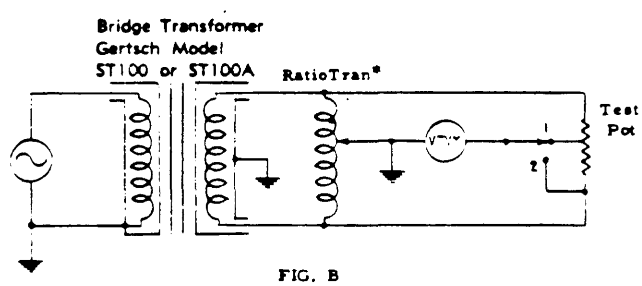


FIG. B

The bridge transformer may be omitted in this circuit if the source is capable of satisfactory operation as a floating source.

*Trademark

SECTION I
GENERAL DESCRIPTION

1-1. PURPOSE.

1-2. The RatioTrans are inductive voltage dividers providing an output voltage which is in a precise ratio to an input voltage. The RatioTran can be used to generate an output ratio, to measure the output voltage of a unit under test, or to duplicate the voltage ratio output required of a unit under test.

1-3. DESCRIPTION.

1-4. The units are completely self-contained test units which only require connection to an input voltage for operation. The units are designed as bench models, and are easily adapted to standard half-rack mounting, for which brackets are supplied.

1-5. Models RT-60 and RT-61 are similar except for frequency range and the related specifications (see Table 1-1).

1-6. Controls and a set of binding posts are mounted on the front panel. A parallel set of connection points are mounted on the rear panel.

1-7. The ratio accuracy of the unit is based upon the use of a toroidal autotransformer which is not affected by age or environmental conditions. Accuracy is traceable to National Bureau of Standards.

1-8. PREPARATION FOR USE.

1-9. No special precautions for unpacking are required other than that reasonable care must be taken when removing the unit from the shipping container. Installation consists only of mounting the unit in a rack.

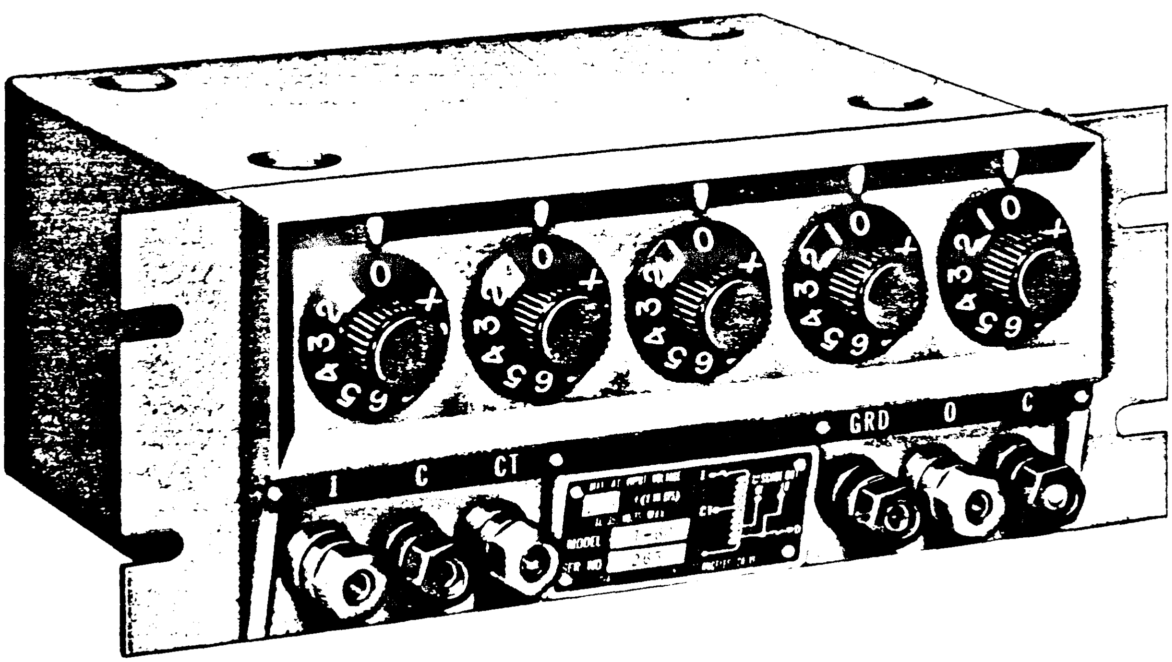


Figure 1-1. Model RT-60 RatioTran

TABLE 1-1. SPECIFICATIONS

RT-60

Accuracy of indicated ratio	50-3000 Hz $\pm (.001\% + \frac{.0001\%}{Ratio})$ 3000-10,000 Hz $\pm (.01\% + \frac{.001\%}{Ratio})$
Resolution	.001% steps
Ratio range	0 to 1.1111
Maximum effective series impedance	Rs - 2.5 ohms Ls - 75 μh
Input impedance	400,000 ohms, min., at 20 V and 400 Hz
Maximum input voltage	.35f (f in Hz) or 350 volts, whichever is less
Terminal linearity	.001%
Weight	approx. 6 lbs.

RT-61

Accuracy of indicated ratio	30-400 Hz $\pm (.001\% + \frac{.0005\%}{Ratio})$
Resolution	.001% steps
Ratio range	0 to 1.1111
Maximum effective series impedance	Rs - 20 ohms Ls - 2.5 mh
Input impedance	400,000 ohms, min., at 20 V and 60 Hz
Maximum input voltage	2.1f (f in Hz) or 350 volts, whichever is less
Terminal linearity	.001%
Weight	approx. 8 lbs.

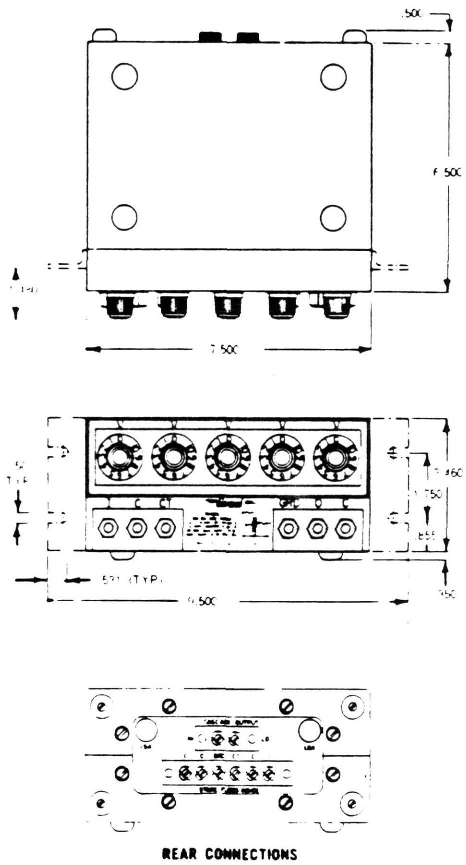


Figure 1-2. Dimensions

SECTION II
OPERATING INSTRUCTIONS

2-1. GENERAL.

2-2. A typical application of a RatioTran is shown in figure 2-1. The output of the RatioTran is compared to the output of the unit under test using a null indicator such as Gertsch Model N1-3 or a phase angle voltmeter such as Gertsch Model PAV-2. When the two outputs are exactly equal, the null indicator or phase angle voltmeter indicates a null. The input-to-output voltage ratio of the unit under test may then be read from the settings of the RatioTran.

2-3. Additional applications are included in the Engineering Bulletins which are appended to this instruction book.

2-4. OPERATION.

2-5. To operate the RatioTran, proceed as follows:

a. Connect input or reference voltage source to the I and C terminals. Make certain input voltage is within the input voltage limits listed in the specifications.

b. Make certain that the input voltage does not contain a dc component. DC currents of more than a few microamperes will cause saturation of the input winding. If dc voltage is accidentally applied to the unit, degauss the unit as outlined in the maintenance section.

c. Make necessary connections to the O and C output terminals.

CAUTION

Do not apply voltage across the output terminals.

d. Turn the input voltage source ON.

e. Set the RatioTran controls to the desired ratio or to the setting required to obtain a null.

2-6. CENTER TAP (CT) CONNECTION. The center tap connection (CT) provides the following:

a. A means for applying a balanced input with a center tap ground.

b. A means for measuring + and - ratios from the center tap position.

c. An output voltage which is exactly one half of the voltage applied across the I and C terminals.

2-7. CASCADE OUTPUT. To increase the resolution of the unit, proceed as follows:

a. Connect external voltage divider across CASCADE OUTPUT connections as shown in figure 2-2.

b. Null in the normal manner except use external divider to obtain final null.

c. Multiply ratio setting of divider by .0001.

d. Add product obtained in step c to setting of RatioTran to obtain final ratio reading.

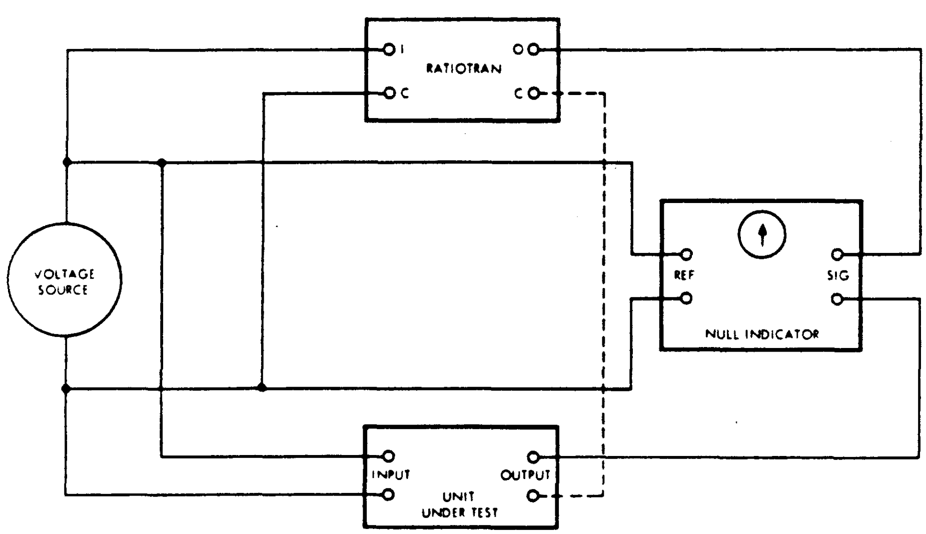


Figure 2-1. Typical Application

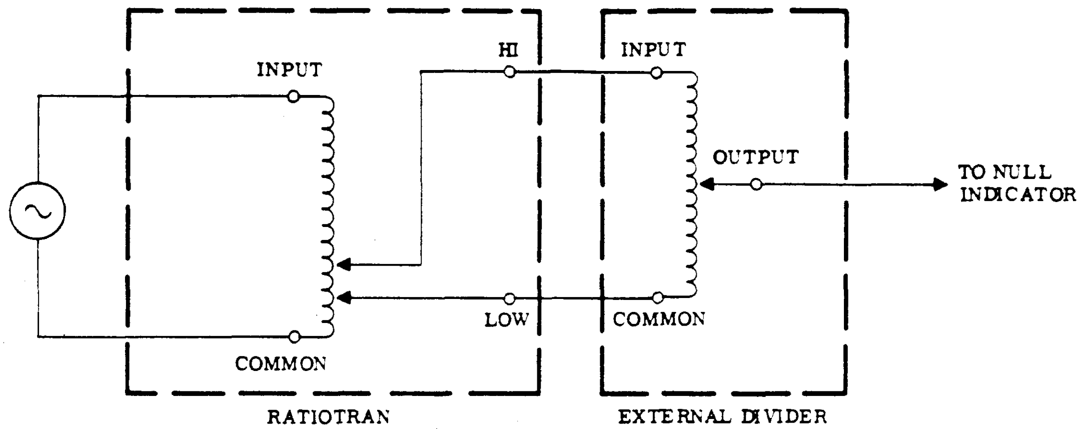


Figure 2-2. Cascade Output Connections

SECTION III
THEORY OF OPERATION

3-1. GENERAL. (See figure 3-1.)

3-2. The RatioTran consists of five transformer windings and five rotary switches. A portion of the input voltage is selected from each winding by the applicable decade switch and these portions are added together to form the output voltage.

3-3. The full input voltage is applied across the first winding which is tapped to provide ten precise voltage divisions. When the first decade switch (X.1) is turned to a selected position, the lower wiper arm selects a portion of the input voltage. The two wiper arms apply reference points to the second winding which is inductively coupled to the input winding. The lower wiper arm of the X.01 switch selects a 0.01 to 0.1 portion of the input voltage which is added to the voltage selected by the X.1 switch. The process continues through the unit until the final and smallest portion of the voltage is selected by the .00001 switch.

3-4. The five transformer windings are included in one transformer. Switching transients are virtually eliminated by resistors which maintain continuity between voltage steps while settings are being changed. Both the input and output circuits are fused.

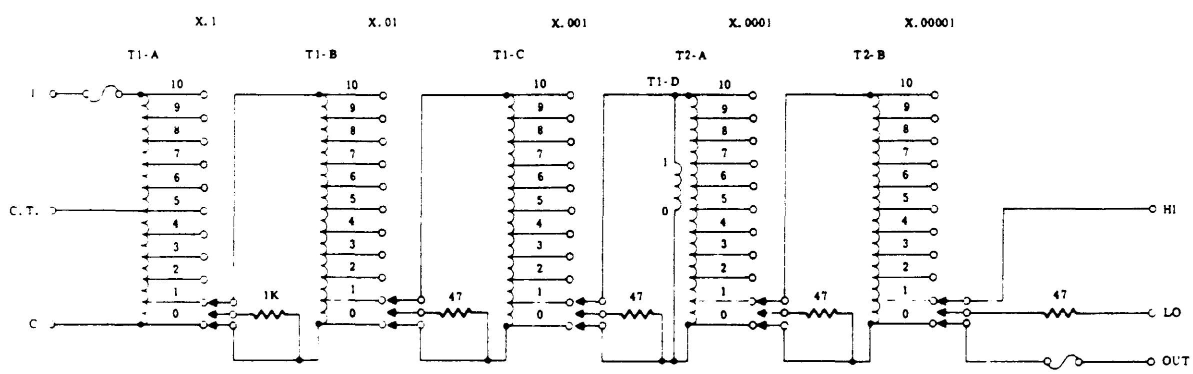


Figure 3-1. Typical Schematic

SECTION IV
MAINTENANCE

4-1. GENERAL.

4-2. Since the RatioTrans are passive devices, a minimum of maintenance is required. With the exception of cleaning switch contacts, no maintenance on a regularly scheduled basis is required. Moving parts are lubricated at the factory and should require no further lubrication.

4-3. SWITCH CONTACTS.

4-4. Once every three to six months, clean switch contacts with a good grade of solvent such as alcohol or acetone.

4-5. DEGAUSSING, MODEL RT-60.

4-6. To degauss the 0.35f units, proceed as follows:

a. Connect a 1K resistor in series with the input connection.

b. By means of a variac or other suitable voltage control, apply a 60 Hz signal between the open end of the 1K resistor and the common terminal.

c. Starting with the voltage control at zero, increase voltage to 40 vrms.

d. Slowly decrease the voltage to zero. The period of time to reduce the voltage from 40 vrms to zero should be between 10 and 15 seconds.

4-7. DEGAUSSING, MODEL RT-61.

4-8. To degauss the 2.1f units, proceed as follows:

a. Set the RatioTran to 0.100000.

b. Connect a 1K resistor in series with the 0 output terminal.

c. By means of a variac or other suitable voltage control, apply a 60 Hz signal between the open end of the 1K resistor and the common terminal.

d. Starting with the voltage control at zero, increase voltage to 30 vrms.

e. Slowly decrease the voltage to zero. The period of time required to reduce the voltage from 30 vrms to zero should be between 10 and 15 seconds.

SECTION V
CALIBRATION

5-1. GENERAL.

5-2. The accuracy of the unit should be maintained for a period of not less than three years, provided that the unit is kept in a normal laboratory environment, has clean, low resistance contacts, and does not suffer injury or insulation damage.

5-3. Under the above conditions, the unit should only require a calibration check every three years. Under more severe conditions, the calibration period must be shortened.

5-4. This section includes two tests: an input impedance test and a simplified ratio accuracy test. Refer to Table 5-1 for a list of test equipment required. For a complete calibration procedure, refer to National Bureau of Standards Report 6738.

5-5. IMPEDANCE CHECK.

5-6. To check input impedance, proceed as follows:

a. Connect unit into test setup as shown in figure 5-1.

b. Set input frequency to 400 Hz for Model RT-60 or 60 Hz for Model RT-61.

c. Adjust voltage source until VTVM V1 indicates twice the desired voltage through the unit under test.

d. Adjust decade resistance box until VTVM V2 shows equal indications with switch SW-1 in either position A or B.

e. Read input impedance from the decade resistance box. The input impedance shall be 400K or more.

5-7. RATIO ACCURACY TEST.

5-8. To test the ratio accuracy, proceed as follows:

a. Connect unit into test setup as shown in figure 5-2.

b. Set input frequency to 400 Hz for Model RT-61 or 1 KHz for Model RT-60.

c. Apply input voltage of 20 vac as indicated on VTVM V1.

d. Set RT standard controls for an output reading of 0.0000000.

e. Adjust unit under test controls until the null indicator indicates a null.

f. Check the ratio indicated by the unit under test against the ratio indicated by the RT standard unit. The two ratios shall agree within the limits listed in table 5-2.

g. Repeat steps e through f for each switch position of the RT standard unit (0.11111, 0.22222, etc.). The CT connection shall provide a .50000 output with the same accuracy as a .50000 ratio.

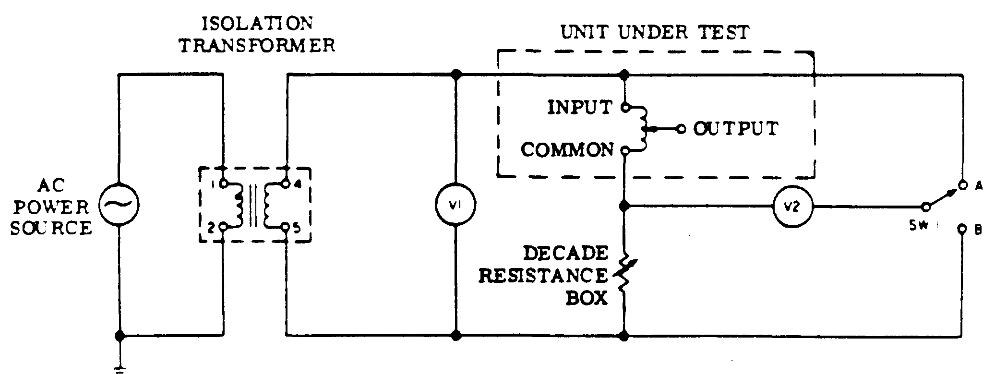


Figure 5-1. Impedance Test Setup

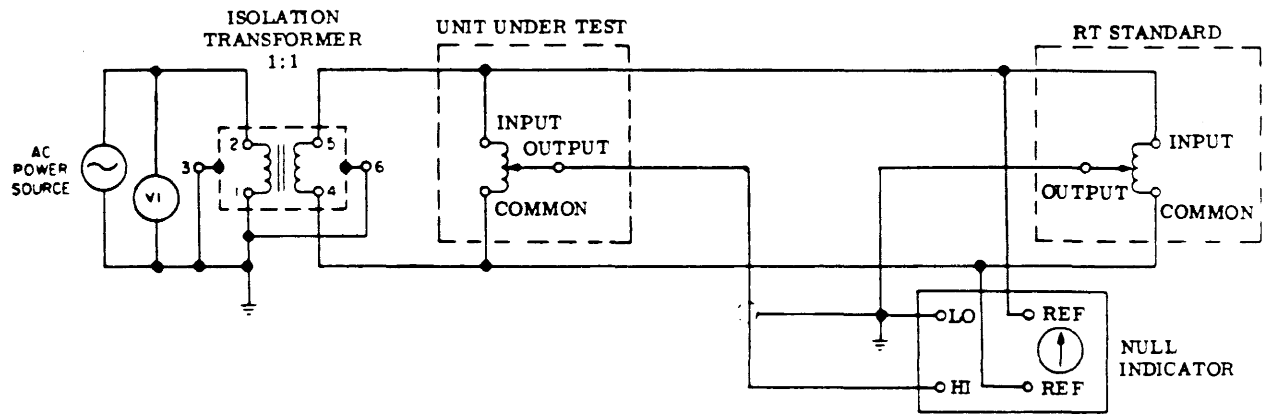


Figure 5-2. Ratio Accuracy Test

TABLE 5-1. LIST OF TEST EQUIPMENT

NOMENCLATURE	PART NUMBER OR MODEL	APPLICATION	RANGE	ACCURACY
AC Ratio Standard	Model 1011 (Singer Metrics)	Provides comparison standard for ratio test	1.111111 to -0.111111 ratios	Per National Bureau of Standards Calibration Test
Isolation Transformer	Model ST248 (Singer Metrics)	Provides signal isolation	120 vac, 400 Hz (maximum)	
Null Indicator	Model NI-3 (Singer Metrics)	Provides means of comparing output voltage		
Decade Resistance Box		Provides voltage divider network	1 megohm range	±0.5%
Vacuum Tube Voltmeter	Model 410B (Hewlett-Packard)	Measuring voltages		±0.5%
Audio Oscillator	Model 201C (Hewlett-Packard)	Voltage Source	20 Hz to 20 KHz 0 to 45 vrms	

SECTION VI
PARTS LIST

ITEM	MFR	PART NO.	QTY RT 60	QTY RT 61
Binding Post, Red	Superior	DF30RC	3	3
Binding Post, Black	Superior	DF30BC	3	3
Knob	Gertsch	OP-8	5	5
Switch, Rotary	Gertsch	SW-126	5	5
Resistor, comp, 1K ± 10%, 1/2 w			1	1
Resistor, comp, 47 ohms ± 10%, 1/2 w			4	4
Fuse, 1.5 amp	Bussmann	MDL 1-1/2	4	4
Fusepost	Bussmann	HKP	2	2
Terminal Strip (cascade output)	Cinch	17-2	1	1
Terminal Strip	Cinch	17-6	1	1
Transformer Assy	Gertsch	TA-249	1	
Transformer Assy	Gertsch	TA-267		1
Feet, rubber	Rubbercraft	9102-J	8	8
Cover, Top	Gertsch	OM-904	1	1
Bracket, rack mounting	Gertsch	OM-902	2	2

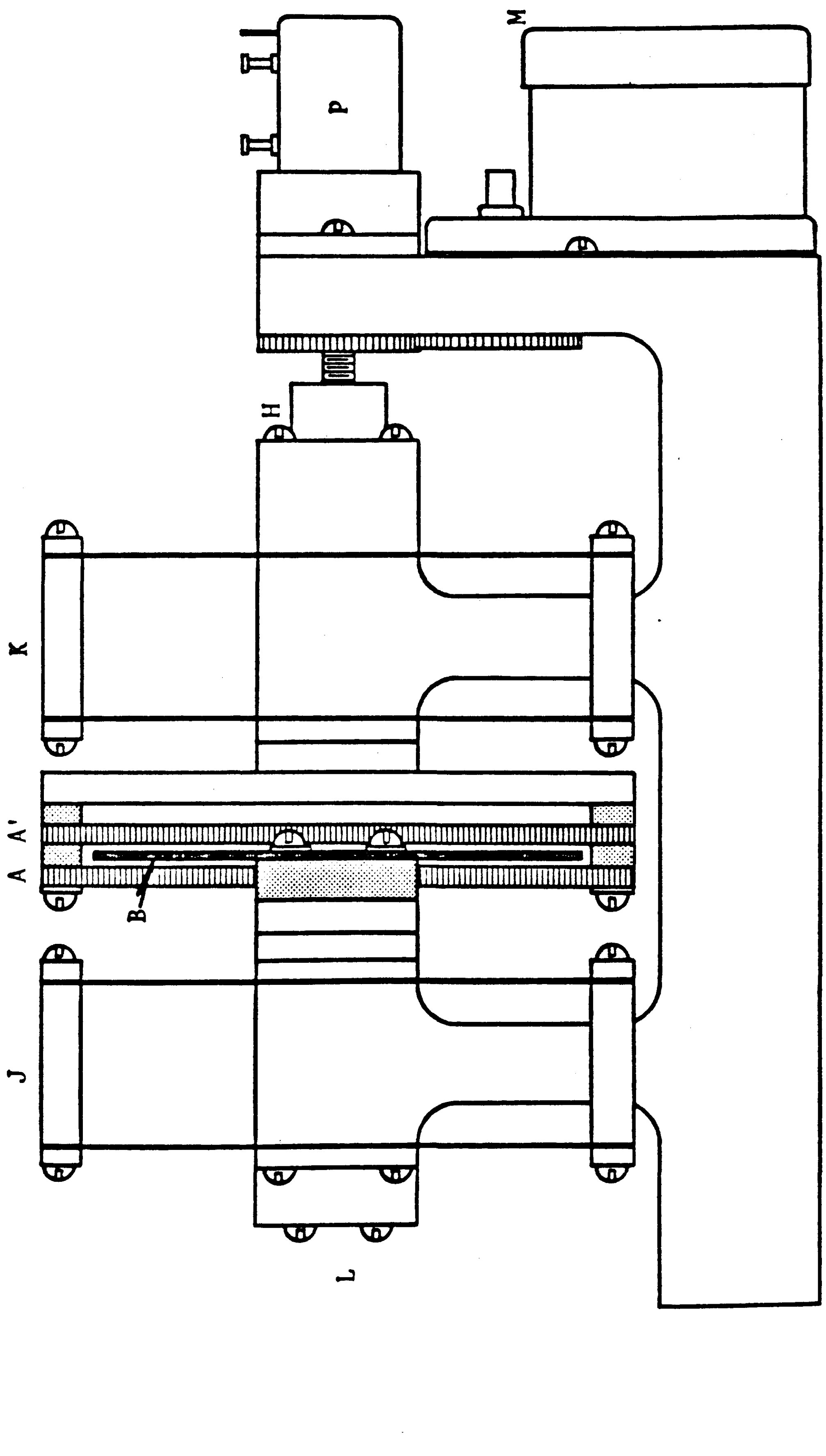


Fig. 1