11049A
11050A
11051A
THERMAL CONVERTERS

HEWLETT hp PACKARD

OPERATING AND SERVICE MANUAL

HEWLETT hp PACKARD

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The Hewlett-Packard Company certifies that this instrument was thoroughly tested and inspected and found to meet its published specifications when it was shipped from the factory. The Hewlett-Packard Company further certifies that its calibration measurements are traceable to the U.S. National Bureau of Standards to the extent allowed by the Bureau's calibration facility.

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OPERATING AND SERVICE MANUAL

(HP PART NO. 11049-90000)

MODEL
11049A, 11050A, 11051A
THERMAL CONVERTERS

P.O. Box 301, Loveland, Colorado, 80537 U.S.A.

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TABLE OF CONTENTS

LIST OF TABLES

LIST OF ILLUSTRATIONS

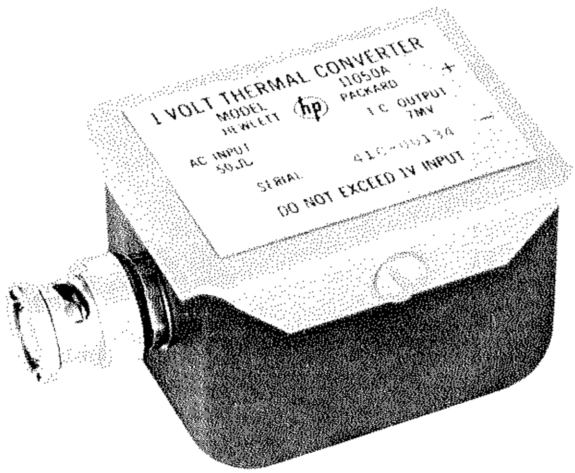


Figure 1. -hp- Model 11050A Thermal Converter

1. GENERAL.

2. The -hp- 11049A, 11050A, and 11051A Thermal Converters accurately convert ac input signals to dc voltages proportional to the rms value of the input. They have essentially a flat response from 5 Hz to 10 MHz, and good frequency response from 10 MHz to 100 MHz. Table 1 shows the frequency response specifications of the thermal converters.

3. SPECIFICATIONS.

MAXIMUM INPUT VOLTAGE:
11049A: 3 volts rms
11050A: 1 volt rms
11051A: 0.45 volt rms

INPUT IMPEDANCE: 50 Ω ±0.15 Ω to 10 MHz

OUTPUT IMPEDANCE: less than 10 Ω

OUTPUT VOLTAGE FOR FULL SCALE INPUT:
Nominal 7.5 mV

Table 1. Calibration Accuracy

Frequency Range	With Reference to Standard	Measurement Uncertainty
5 Hz to 20 Hz	within ±0.05%	±0.12%
20 Hz to 20 kHz	within ±0.01%	±0.02%
20 kHz to 50 kHz	within ±0.01%	±0.03%
50 kHz to 1 MHz	within ±0.01%	±0.06%
1 MHz to 10 MHz	within ±0.05%	±0.12%
10 MHz to 30 MHz		±0.25%
30 MHz to 60 MHz		±0.50%
60 MHz to 100 MHz		±1.50%

OPTION 01: Includes calibration to 60 MHz and correctional data sheet covering frequency range from 5 Hz to 60 MHz.

OPTION 02: Includes calibration to 100 MHz and correctional data sheet covering frequency range from 5 Hz to 100 MHz.

4. CALIBRATION.

5. The Hewlett-Packard Standards Laboratory supplies a calibration report on each thermal converter with a statement of traceability to the National Bureau of Standards, and also supplies correctional data with each Option 01 or Option 02 Thermal Converter. The correctional data is based on the thermal converter's comparison with a known reference thermal converter, and when used with the thermal converters, eliminates all inaccuracies except the measurement uncertainties listed in Table 1. If no correctional data is used, the maximum inaccuracy is the sum of the values listed in the "with reference to standard" and "measurement uncertainty" columns in Table 1.

6. CIRCUIT DESCRIPTION.

7. The heart of the Thermal Converter is a 90 Ω UHF thermoelement containing a heater filament and a thermoelectric junction. The ac current into the thermoelement heats the filament, and the thermoelectric junction generates a dc voltage proportional to the filament heat. Therefore, the voltage out of the thermal converter is proportional to the input power. Resistor R2 adjusts the current through the thermoelement to 5 mA with a full scale input, and R1 adjusts the input impedance to 50 Ω.

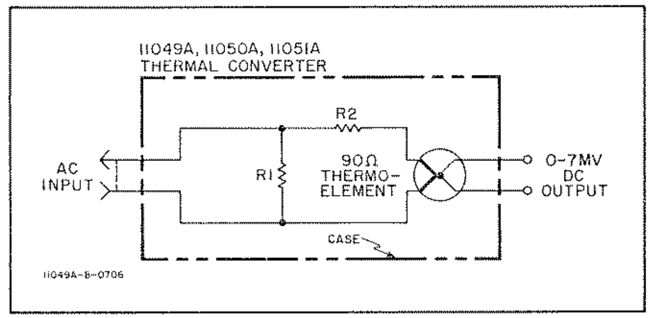


Figure 2. Thermal Converter Schematic Diagram

8. Since the output voltage is a function of input power, the output varies as the square of the input. If the input is doubled, the output will be four times as great; the if the input is halved, the output will drop to one-fourth. For input changes of less than 3%, the input-output relationship is essentially linear; and the percent output change is equal to twice the percent input change. The following formula shows the relationship.

$$\%\ \text{input change} = \frac{\Delta E_{dc}}{2E_{dc}} \times 100$$

where E_{dc} = thermal converter output voltage

Figure 3 shows the input-output relationship.

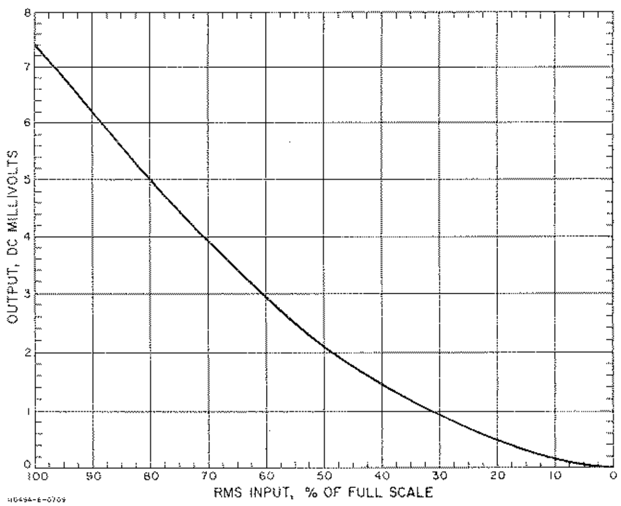


Figure 3. Input-Output Relationship

9. APPLICATIONS.

10. OUTPUT MEASUREMENTS.

11. The accuracy and sensitivity of thermal converter measurements are dependent on the accuracy and resolution of the output measuring circuit. Figure 4 shows a very stable and sensitive output monitor circuit. With this circuit, an output change of 1.5 μV, or 0.01% of full scale, can easily be resolved. The battery powered reference supply generates a stable reference voltage, opposing the thermal converter output; and the dc null meter monitors the difference voltage. The battery's short term stability is good enough that the thermal converter output changes may be read directly on the null meter without taking reference voltage drift into consideration. Another stable and accurate output measuring device would be a high resolution digital voltmeter or differential voltmeter. In order to resolve an input change of 1% of full scale, the output monitor should be able to resolve 0.15 mV; for an input change of 0.1% of full scale, it should be able to resolve 14 μV.

12. To build the reference supply shown in Figure 4 on the next page, use a mercury battery and wirewound resistor. The potentiometers should be 10 turn or 20 turn, and the switch should have low thermal contacts. After constructing the reference supply, place it in a shielded container and allow the mercury battery to age in the circuit for about a week. The longer the battery is allowed to age, the better its short term stability will be.

13. All thermal converter measurements should be made at a constant ambient temperature. Since the thermoelement responds to the heating effect of the input, any change in ambient temperature would cause a slight change in the thermal converter output.

14. FREQUENCY RESPONSE MEASUREMENTS.

15. Figure 4 on the next page shows a test setup for making simple but accurate frequency response measurements. The following steps describe the measurement.

CAUTION

DO NOT EXCEED THE RATED INPUT OF THE THERMAL CONVERTER. ALWAYS REDUCE THE INPUT BEFORE CHANGING FREQUENCY RANGE OF CIRCUIT UNDER TEST. ANY OVERLOAD OR HIGH VOLTAGE TRANSIENT MAY DESTROY THE THERMOELEMENT.

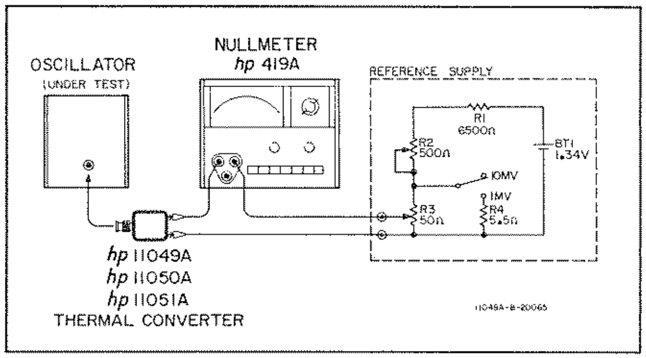


Figure 4. Frequency Response Measurements

a. Set oscillator and reference supply output levels to minimum.

b. Connect null meter, reference supply, and thermal converter as shown in Figure 4. Keep cables connecting oscillator and thermal converter as short as possible.

c. Adjust oscillator amplitude for a null meter indication of about 7 mV.

d. Adjust reference supply for null indication within 1 μV. Once null is obtained, do not readjust oscillator amplitude or reference supply output.

e. Change frequency and note thermal converter output changes. Remember that percent converter output change equals twice percent input signal change.

16. GENERATING AN ACCURATE CALIBRATION SIGNAL.

17. The test setup in Figure 5 on the next page generates a test signal that may be used for both frequency response and absolute value calibration at any frequency within the thermal converter range. A dc standard acts as the absolute value reference, and a stable test oscillator generates the calibration signal. With S1 set to the DC position and the dc standard output set to the desired calibration voltage, the reference supply is adjusted for a null indication on the null meter. Then S1 is switched to AC, and the oscillator output is adjusted to reestablish a null indication. This sets the rms value of the oscillator output equal to the dc standard output. The oscillator output goes to the instrument under test.

18. DC REVERSAL ERROR.

19. DC inputs of opposite polarity will produce slightly different outputs from the thermal converter, and the

difference in outputs is called the dc reversal error. The dc reversal error is usually less than 0.05% and doesn't affect most measurements, but it should be compensated to achieve maximum accuracy. Instructions for compensating dc reversal error are included in the following calibration procedure.

20. CALIBRATION PROCEDURE.

21. The following steps describe a procedure for generating 1 volt calibration signal that is flat within the thermal converter specifications. Steps c through f describe the procedure for compensating dc reversal error.

NOTE

If the instrument under test is average or peak responding, use a low distortion test oscillator. A thermal converter and an average responding circuit react differently to distortion, and any distortion present will create a calibration error between the thermal converter and the instrument under test.

a. Set test oscillator and dc standard outputs to minimum.

b. Connect dc standard, test oscillator, thermal converter, reference supply, null meter, and instrument under test as shown in Figure 5. Keep all connections as short as possible.

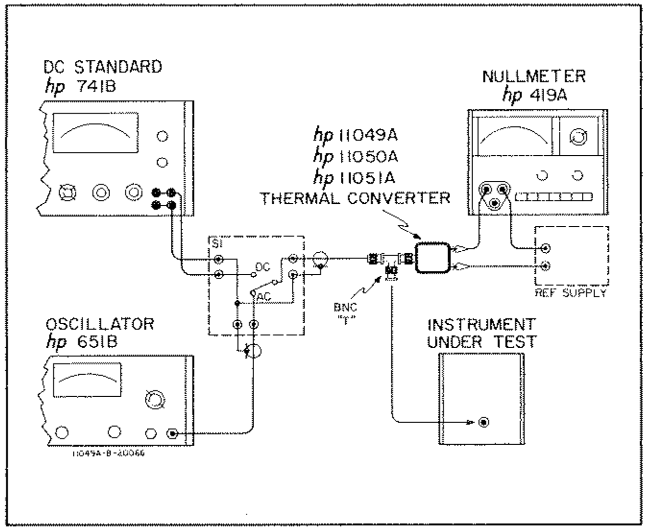


Figure 5. Test Signal Generation

c. Set switch S1 in Figure 5 to DC, and set dc standard output to +1.000 vdc.

d. Adjust reference supply for null indication within less than 1 μV. Record null meter indication (_____). Once null is obtained, do not readjust reference supply output.

e. Reverse polarity of dc standard output and record null meter reading (_____).

f. Set S1 to AC and set oscillator frequency to 10 Hz.

Adjust oscillator output so that null meter indication is half way between indications recorded in steps d and e. This sets oscillator output to 1 volt rms.

g. Record error of instrument under test.

CAUTION

DO NOT CHANGE OSCILLATOR FREQUENCY RANGE WITHOUT FIRST LOWERING OSCILLATOR OUTPUT. SWITCHING TRANSIENTS MAY DESTROY THERMOELEMENT.

h. Adjust frequency to next desired test frequency. Then readjust oscillator output for same indication as in step f. Record error of instrument under test.

i. Repeat steps g through i for each test frequency desired.

22. MAINTENANCE.

23. THERMAL CONVERTER CALIBRATION.

24. Figure 6 shows the setup for calibrating a thermal converter to an NBS calibrated reference thermal converter. With this setup, the thermal converter can be calibrated to within ±0.005% of the reference thermal converter. The following steps describe the calibration procedure.

a. Set test oscillator and both reference supply outputs to minimum.

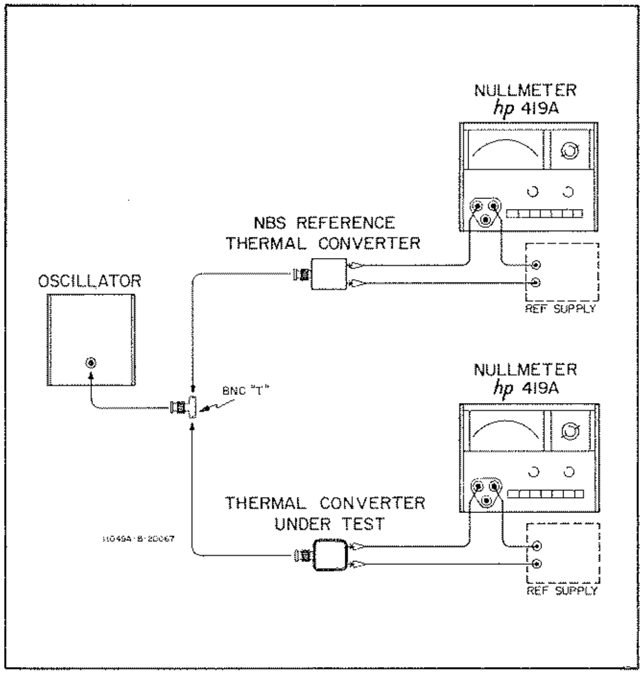


Figure 6. Thermal Converter Calibration

b. Connect both thermal converters, both reference supplies, both null meters, and the test oscillator as shown in Figure 6. Keep connections to thermal converters as short as possible.

c. Adjust the oscillator amplitude for an indication of about 7 mV on both null meters. Set the oscillator frequency for 1 kHz.

d. Adjust both reference supplies for null indications on their respective null meters.

e. Change the oscillator frequency to 5 Hz.

f. Readjust the oscillator amplitude for a null indication on the null meter connected to the reference thermal converter. The null meter connected to the thermal converter under test should read the same as the reference null meter. If not, record the error. Remember, the percent change in the thermal converter output is equal to twice the percent change in the input.

g. Repeat steps e and f at 50 Hz, 500 Hz, 5kHz, 50 kHz, 500 kHz, 1 MHz, 3 MHz, 6 MHz, 8 MHz, 10 MHz, 20 MHz, 30 MHz, 40 MHz, 50 MHz, and 60 MHz. In each case, record the error.

h. Use the error data collected in the previous steps to make corrections whenever using the thermal converter. If the difference between the reference thermal converter and the thermal converter under test is greater than the specifications in the "with reference to standard" column in Table 1, the thermal converter is not operating properly. Refer to repair instructions in paragraph 25.

i. The calibration of a thermal converter should be checked against an NBS reference thermal converter at least once every six months during the first year, and once a year thereafter.

25. <u>REPAIRING THE THERMAL CONVERTER.</u>

26. If the thermal converter is out of calibration below 10 MHz or if it has no output, the UHF thermoelement should be replaced. Since the values of R1 and R2 in Figure 2 depend on slight variations in thermoelement characteristics, they must be reselected when the thermoelement is replaced.

27. SELECTION OF R2.

28. R2 adjusts the current through the thermoelement to 5 MA with a full scale input. In the 11049A, R2 is made up of two resistors with a total value of about 510 Ω. In the 11050A, R2 is about 110 Ω, and in the 11051A, R2 is deleted. R2 should be a 1/2 watt, ±5% metal film resistor.

29. Figure 7 on the next page shows the test setup for selecting R2. The power supply generates a known input, and the dc voltmeter monitors the thermoelement output. R2 is selected to adjust the thermoelement output to 6.5 mV with 90% full scale input. Proceed as follows.

a. With the power supply off, connect the power supply, thermoelement, dc voltmeter and an initial value of R2. For 11049A, R2 should be a 240 Ω and 270 Ω resistor connected in series. For 11050A R2 should be a 110 Ω resistor.

b. Using voltmeter as a monitor, slowly adjust power supply output to 0.9 volts for 11050A or 2.85 volts for 11049A.

c. Connect voltmeter to thermoelement. Output should be 6.5 mV ±0.3 mV. If output is high, increase R2; if output is low, decrease R2.

30. An alternative but not as accurate method of selecting R2 is to assume that the thermoelement resistance is 90 Ω and select R2 as 510 Ω for the 11049A and 110 Ω for the 11050A. If this method is used, the nominal 7.5 mV output may be high or low by as much as 10%.

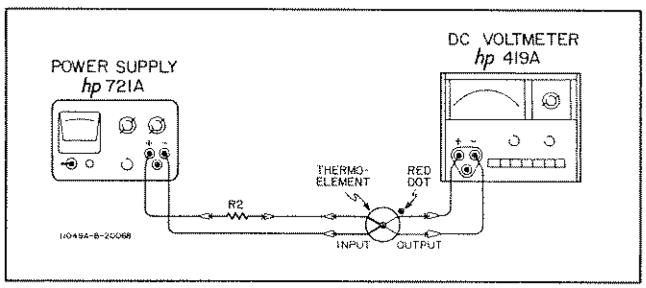


Figure 7. Selection of R2

31. SELECTION OF R1.

32. R1 shunts the series combination of the thermoelement and R2 to adjust the input resistance to 50 Ω ±0.15 Ω and is made up of two approximately equal resistors connected in parallel. In the 11049A R1 is about 55 Ω, in the 11050A R1 is about 65 Ω, and in the 11051A R1 is about 110 Ω. The resistors used for R1 should be 1/2 watt, ±5%, metal film resistors.

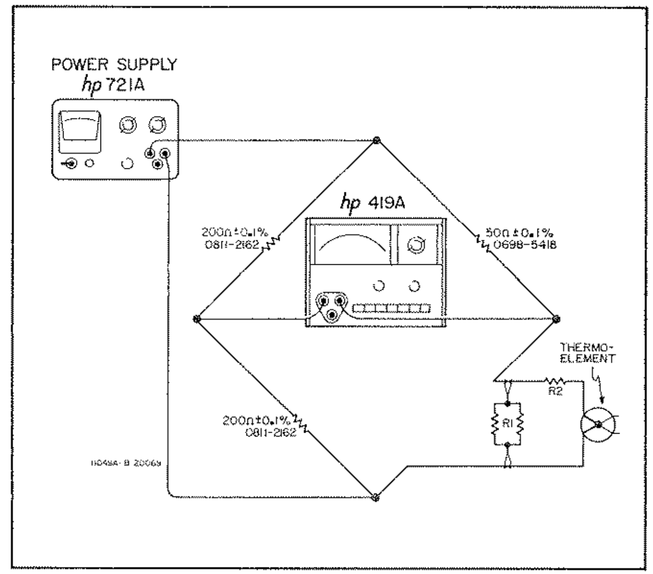


Figure 8. Selection of R1

33. Figure 8 shows a bridge for selecting R1. R1 is adjusted for null with the drive voltage set so that the thermoelement operates at near rated full scale input. Proceed as follows.

a. With the power supply off, construct the bridge shown in Figure 8.

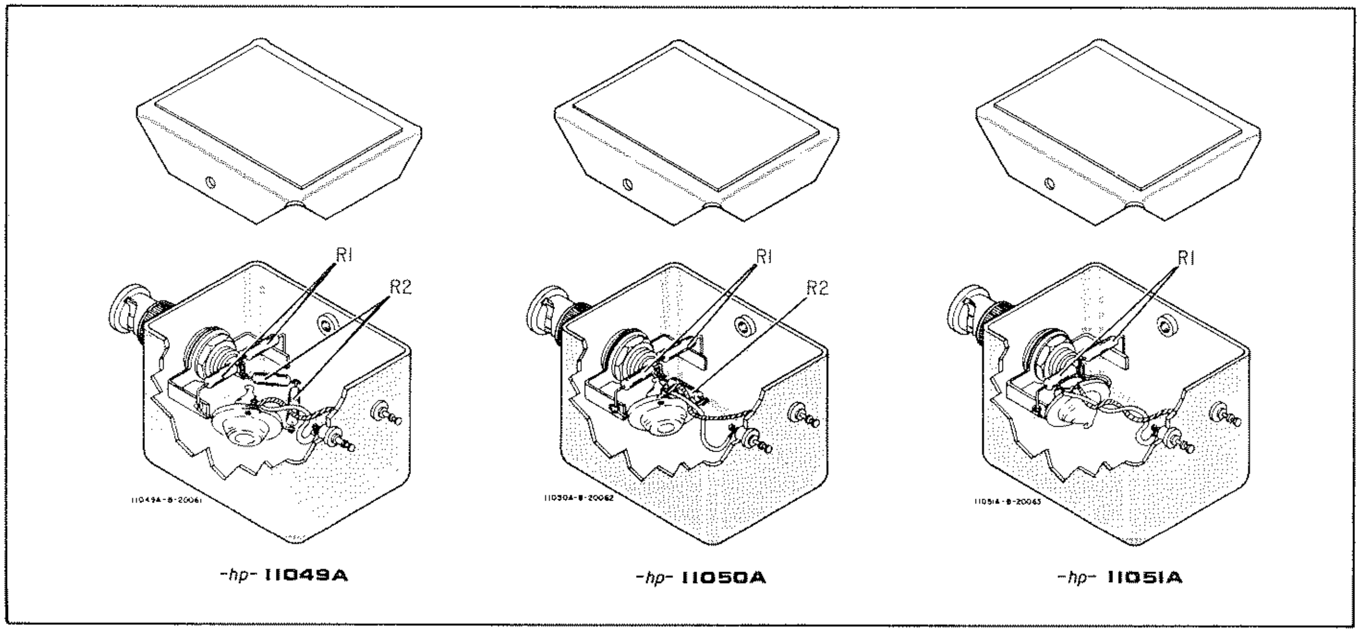


Figure 9. Proper Orientation of Components

b. Connect an initial value of R1 as shown in Figure 8. For 11049A use two 120 Ω resistors in parallel; for 11050A use a 150 Ω and a 120 Ω resistor in parallel; for 11051A use two 220 Ω resistors in parallel.

c. Adjust drive voltage from power supply to the following value.

11049A . . . . . 5.0 volts
11050A . . . . . 1.5 volts
11051A . . . . . 0.6 volts

d. Vary R1 resistors to achieve a null indication on null meter. Maximum deviation from null should be as follows.

11049A . . . . . ±1.25 mV
11050A . . . . . ±0.375 mV
11051A . . . . . ±0.15 mV

A high value carbon resistor may be added in parallel with R1 as a final adjustment.

34. INSTALLATION OF THERMOELEMENT, R1, AND R2.

35. The spatial orientation of the components within the thermoelement is critical. Improper placing of the components may cause serious degradation of the higher frequency response. Figure 9 shows the proper component placement for each of the components in each thermal converter.

36. Observe the following precautions when installing replacement thermoelement and R1 and R2.

CAUTION

USE AN ADEQUATE HEAT SINK WHEN SOLDERING CONNECTIONS TO THERMOELEMENT. EXCESSIVE HEATING WILL CHANGE THERMOELEMENT CHARACTERISTICS.

a. Keep all leads as short as possible.

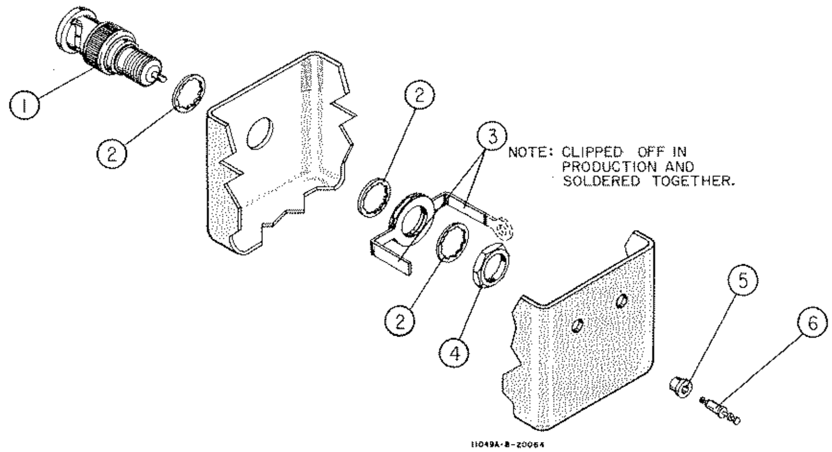
b. Make sure that component mounting matches that shown in Figure 9.

c. Avoid bending thermoelement leads any more than is absolutely necessary. Excessive bending may weaken glass seal and reduce isolation.

d. Red (positive) lead should be connected to thermoelement output lead with red dot.

37. REPLACEABLE PARTS.

38. Figure 10 shows the replaceable parts for the thermal converters. Included with each part is its -hp- part number, description, manufacturer, manufacturer's part number, and total quantity.



Ref. No.	-hp- Part No.	Description	Mfr.	Mfr. Part No.	TQ
1	1250-0045	Connector: male BNC	Dage Electric Co.	30337-2	1
2	2190-0016	Lock washer	Sloss and Brittain	1920-02	3
3	0360-0024	Lug: grounding	P.R. Mallory Co.	A-131023-1	2
4	2950-0001	Nut: hex, 3/8"	H.M. Harper Co.	Obd	1
5	0340-0039	Bushing: insulator	Goe Engineering Co.	HP-3000T-1	2
6	0340-0038	Terminal: output	Goe Engineering Co.	HP-3000M-3	2
	0853-0001	Thermoelement: UHF, 90 Ω 5 mA	Best Products Ltd.	UHF-5 mA	1
	11049-0002	Can: shield	-hp-	11049-0002	1
	11049-0003	Cover: top	-hp-	11049-0003	1
	2470-0001	Screw: machine hardware for top cover, no. 6/32 thread, brass	Schnitzer Alloy Prod. Inc.	Obd	2

Figure 10. Replaceable Parts

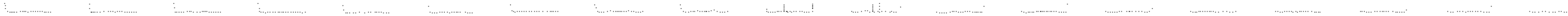
MANUAL CHANGES

MODEL 11049A/11050A/11051A

-hp- Part Number 11049-90000

1. Model 11051A's with serial numbers 416-00275 and above have an added resistor R3 in series with the thermoelement input. R3 is made up of two 10 Ω, 1%, 1/8 W resistors (-hp- Part No. 0757-0346) in parallel and is added to adjust the nominal 7.5 mV output. R3 may not be present on all instruments; it is added only to adjust out-of-tolerance outputs.
2. On page 2, at bottom of page, change output relationship to

$$\% \text{ input change} = \frac{\Delta E_{dc}}{1.7E_{dc}} \times 100.$$



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