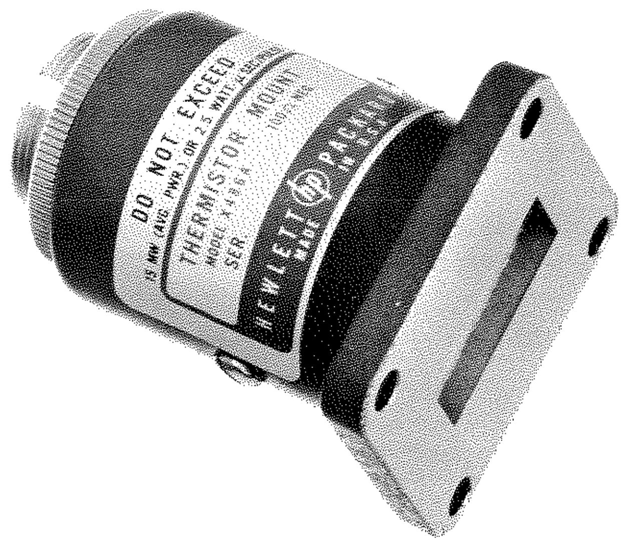
HEWLETT hp PACKARD

THERMISTOR MOUNTS

MODEL 486A

OPERATING NOTE 6 DEC 66



hp Model 486A Thermistor Mount

GENERAL INFORMATION

1. INTRODUCTION.

2. The hp Model 486A Thermistor Mounts are designed for use with the hp Model 431 Power Meter in the measurement of microwave power from 1 μW to 10 mw in the range from 2.6 to 40.0 GHz. Design of power meter and thermistor mount are such that the measurement system is temperature-compensated. This feature permits microwave power measurements that are relatively free of the drift in meter indication that otherwise occurs with changes in ambient temperature.

3. For improved accuracy of measurement results, Calibration Factor and Effective Efficiency are measured at six selected frequencies across the operating range of each mount, and the results recorded on the label of the mount. In addition, each mount is tested on a swept-frequency basis to assure that interpolation between measured points is valid.

Table 1. Specifications

Model	Freq Range (Gc)	Max SWR	Operating Resistance (ohms)	Fits Waveguide Size Nominal OD (inches)	EIA	Equiv Flange JAN Type	Approx Length (inches)	(mm)	Net Weight (oz)	(g)
S486A	2.6 - 3.95	1.35	100	3 x 1-1/2	WR284	UG-53/U	2-7/8	74	24	670
G486A	3.95 - 5.85	1.5	100	2 x 1	WR187	UG-149A/U	3-9/32	83	11	310
J486A	5.3 - 8.2	1.5	100	1-1/2 x 3/4	WR137	UG-344/U	3-5/32	80	8-1/2	240
H486A	7.05 - 10.0	1.5	100	1-1/4 x 5/8	WR112	UG-51/U	2-3/4	70	5-1/4	150
X486A	8.2 - 12.4	1.5	100	1 x 1/2	WR90	UG-39/U	2-1/8	54	3	80
M486A	10.0 - 15.0	1.5	100	0.850 x 0.475	WR75	--	2-1/8	54	3-1/4	90
P486A	12.4 - 18.0	1.5	100	0.702 x 0.391	WR51	UG-419/U	2-3/8	60	3-1/4	90
K486A[1]	18.0 - 26.5	2.0	200	1/2 x 1/4	WR42	UG-595/U	3	76	4-1/2	126
R486A[1]	26.5 - 40.0	2.0	200	0.360 x 0.220	WR28	UG-599/U	3	76	4-1/2	126

Mount Calibration: Calibration Factor and Effective Efficiency furnished at six frequencies. Maximum uncertainty of data:

S- thru P-band	K- and R-band	431 Power Range (mw)
±1.5%	±2.5%	10
±1.5%	±2.5%	3
±1.5%	±2.5%	1
±1.5%	±2.5%	0.3
±2%	±3%	0.1
±3%	±4%	0.03
±4%	±5%	0.01

Plus uncertainty of reference standard.[2] See text for methods of obtaining increased accuracy.

Power Range (with Model 431): 1 μw to 10 mw

Power-Sensing Element: Permanently installed thermistor

Output Connector: 6-pin connector mates with cable furnished with hp Model 431 Power Meter

[1]Circular contact flange adapter available:
K-band (UG-425/U) order hp 11515A,
R-band (UG-381/U) order hp 11516A

[2]Directly traceable to the National Bureau of Standards at those frequencies at which the Bureau offers calibration service.

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4. Each Model 486A Mount is designed to provide a good impedance match (low SWR) over the full frequency range of its waveguide size without external tuning.

5. INCOMING INSPECTION.

6. Unpack and inspect the Model 486A as soon as it is received. Inspect for mechanical damage such as dents, scratches, etc. Also check it electrically; if the mount was subjected to severe mechanical shock during shipment, the match between the thermistors will be affected. To check thermistor match, proceed as described in Paragraph 50.

7. If any damage is found, notify the carrier and your Hewlett-Packard Sales and Service Office immediately.

OPERATION

8. PRECAUTIONS.

9. MECHANICAL SHOCK.

10. DO NOT DROP OR SUBJECT TO SEVERE MECHANICAL SHOCK. SHOCK MAY DESTROY THE MATCH BETWEEN THERMISTORS AND INCREASE SUSCEPTIBILITY TO DRIFT.

11. BIASING THERMISTORS.

CAUTION

Before connecting a 200-ohm thermistor mount (K or R486A) to ⓗⓟ Model 431 Power Meters set MOUNT RES switch to 200 Ω position. CONNECTING A 200-OHM MOUNT TO A POWER METER SET FOR A 100-OHM MOUNT CAN RESULT IN THERMISTOR DAMAGE.

12. MAXIMUM INPUT.

13. The Model 486A/431 combination responds to the average RF power applied. The maximum signal applied to the thermistor mount should not exceed the limitations for 1) average power, 2) pulse energy, and 3) peak pulse power. Excessive input can permanently damage the Model 486A by altering the match between the RF and compensation thermistors (resulting in excessive drift or zero shift) or cause error in indicated power.

14. AVERAGE POWER. The 486A/431 combination can measure average power up to 10 mW. To measure power in excess of 10 mW, a directional coupler (such as one of the ⓗⓟ Model 752 series) can be inserted between the mount and the source. UNDER NO CIRCUMSTANCES APPLY MORE THAN 15 MW AVERAGE TO THE MOUNT.

15. PULSE ENERGY AND PEAK POWER. In measuring pulse power, there is a limit on the energy per pulse which may be applied to the mount. For a pulse repetition frequency (PRF) less than 1 kHz, energy per pulse can be up to 2.5 Watt-μsec; for a PRF 1 kHz and above, up to 5 Watt-μsec (for lack of space, only the lower limit is shown on the mount name plate). However, this energy limit applies only to pulses shorter than 250 μsec. In Figure 1, the pulse energy limit is translated into a maximum power-meter reading for any PRF. For pulses in this category, allowable peak power is inversely proportional to pulse width but should never exceed 100 Watts.

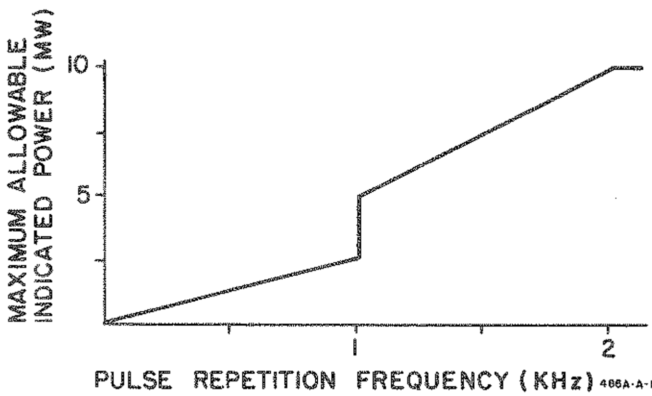

Figure 1. Maximum Power Meter Reading vs. PRF for Pulses Shorter than 250 μsec

16. For pulses longer than 250 μsec, the peak power limitation can be expressed in terms of PRF: 10 mW for a PRF below 1 kHz, 20 mW for a PRF 1 kc or above provided 15 mW average is not exceeded. In Figure 2, the peak power limit is translated into power-meter reading versus duty cycle. (For a PRF less than 1 kHz and an indicated power between 2 and 3 mW, use the 10-mW range. Errors as much as 2% may be introduced if the 3-mW range is used.)

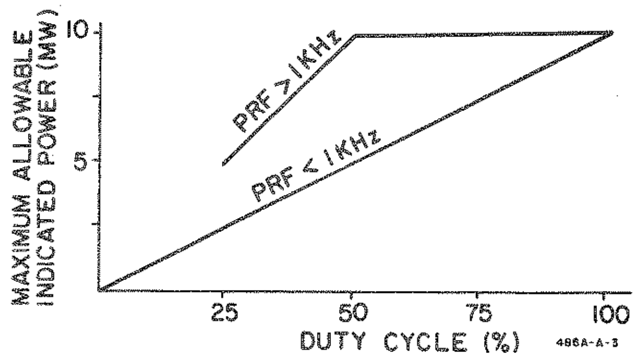

Figure 2. Maximum Power Meter Reading vs. Duty Cycle for Pulses Longer than 250 μsec

17. Square-wave modulation is a special case of pulse modulation, and maximum power-meter reading versus square-wave frequency is illustrated in Figure 3. This figure also holds for sine-wave modulation.

18. In the discussions above, the primary consideration is maximum power or energy. However, for modulation frequencies less than 100 Hz, the low

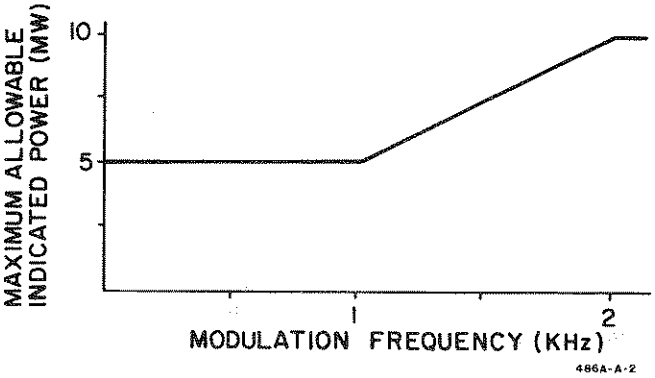

Figure 3. Maximum Power Meter Reading vs. Square- and Sine-Wave Modulation Frequency

repetition frequency itself causes errors in indicated power. These errors may be as large as 2% regardless of range or reading.

19. DRIFT.

20. Thermistors are inherently temperature sensitive devices. A cold thermistor mount connected to a warm piece of equipment or vice versa, produces rapid drift. FOR MINIMUM DRIFT ON SENSITIVE RANGES MAKE SURE THAT THE MOUNT AND THE EQUIPMENT CONNECTED TO IT ARE AT NEARLY THE SAME TEMPERATURE BEFORE MAKING A MEASUREMENT.

21. ZERO-SET.

22. It is necessary to electrically zero-set the Model 431 Power Meter before making a power measurement. To preserve the same zero reference throughout the measurement, especially when operating on the more sensitive ranges, maintain the same thermal environment when RF power is applied. Three recommended setups for zero-set are presented below:

a. RF Power Turned Off for Zero-Set. There is minimum zero drift when zero is set with the RF system connected to the thermistor mount and RF power turned off at the generator or shorted out by a shorting switch. After allowing time for the mount to stabilize thermally, follow the steps for zero-set described in the Model 431 Power Meter manual, and then turn on the RF power for measurement.

b. Use of High Attenuation with RF Source On. When it is inconvenient to turn off the RF source for zero-set, connect a waveguide variable attenuator, such as the ⓗ Model 382A, between the RF system and the thermistor mount. Attenuate the RF power approximately 30 dB for zero-set, and reduce attenuation to zero during the measurement.

c. Disconnect the Mount for Zero-Set. When the RF source cannot be turned off, shorted, or attenuated, connect the mount to the source, and set the range of the Model 431 Power Meter for approximately a mid-scale reading. When the reading no longer drifts, disconnect the mount from the RF source and immediately zero-set the power meter according to the procedure described in the Model 431 manual. Immediately reconnect the mount to the RF source for the power measurement. IN THE PROXIMITY OF A HIGH RF FIELD, SHIELD THE DISCONNECTED THERMISTOR MOUNT FROM POSSIBLE STRAY RF PICK-UP DURING THE ZERO SET.

23. POWER MEASUREMENT.

24. The thermistor has a long thermal time constant, which causes it to respond to average microwave power whether CW or modulated (pulse, sine wave, or square wave).

25. In pulse modulation, response is proportional to the amplitude and the duty cycle of the pulse. The power level of an individual pulse can be determined by dividing the average power reading by the duty cycle of the pulse. Accurate measurements can be made with pulse repetition rates as low as 50 Hz.

26. To measure microwave power in excess of 10 mW insert a calibrated attenuator, such as one of the ⓗ 382A, or 375A series, or a directional coupler, such as one of the ⓗ 752/750 series, between the mount and the RF source to be measured.

27. RESPONSE TO DC (POLARIZATION EFFECT).

28. When a DC current is applied to a thermistor, the power apparently dissipated (as indicated by the power meter when the thermistor is part of a power-measuring bridge) will be slightly different from the power found by calculating I^2R, and the magnitude of this small difference between apparent and actual power will change with a reversal of current-flow through the thermistor. This behavior of the thermistor is called the polarization effect. Maximum error introduced by polarization effect is about 0.3 μW, and typically this error will be only 0.1 μW. Except on the three lowest ranges of the Model 431, therefore, polarization error is insignificant. To determine the polarization-effect correction factor for any given thermistor, apply a known low-level DC power, such as 10 μW, to the Model 431, and take a reading (P_{DCa}); reverse connection between DC source and Model 431 to get a reverse in current flow, and again take a reading (P_{DCb}). Assuming that, under measurement conditions, current-flow will have the direction it had when reading P_{DCa} was made, subtract P_{DCa} from P_{DCb}, and divide the difference by two; this is the polarization-effect correction factor. Step-by-step instructions for determining and applying this correction factor are given in the manual for the HP Model 8402 Power Meter Calibrator.

29. CALIBRATION DATA.

30. The calibration points marked on the label of each 486A permit increased accuracy in measurement results. Both Calibration Factor and Effective Efficiency are shown at specific frequencies, and the

mounts are tested on a swept-frequency basis to assure that interpolation between measured points is valid. Effective Efficiency and Calibration Factor are traceable to the National Bureau of Standards to the extent allowed by the Bureau's calibration facilities.

31. CALIBRATION FACTOR. Calibration Factor is the ratio of substituted audio or DC power in a thermistor mount to the microwave RF power incident upon the mount.

$$\text{Calibration Factor} = \frac{P_{DC}\ \text{Substituted}}{P_{\mu wave}\ \text{Incident}}$$

32. Calibration Factor is a figure of merit assigned to a thermistor mount to correct for the following sources of error: 1) RF reflected by the mount due to mismatch, 2) RF loss caused by absorption within the detection thermistor elements, and 3) DC-to-microwave power substitution error. Calibration Factor is applied as a correction factor to all measurements made without a tuner. When these factors and thermoelectric effect (refer to Paragraph 37) are taken into consideration, the power indicated is the power that would be delivered by the RF source to the characteristic impedance of the transmission line. The total SWR in the transmission line determines a region of uncertainty about the measured power. This subject is discussed in Application Note 64, available from any Hewlett-Packard Sales and Service Office.

33. EFFECTIVE EFFICIENCY. Effective Efficiency is the ratio of substituted audio or DC power in a thermistor mount to the microwave RF power dissipated within the mount.

$$\text{Effective Efficiency} = \frac{P_{DC}\ \text{Substituted}}{P_{\mu wave}\ \text{Dissipated}}$$

34. Effective Efficiency corrects for power absorbed in parts of the mount other than the detection thermistor elements and DC-to-microwave power substitution error in the thermistor mount. Effective Efficiency is applied as a correction factor when a tuner is used to match the thermistor mount to the transmission line or RF source. In this case, all of the RF power incident upon the mount is absorbed in the mount. Since all power is absorbed in the mount, measurement uncertainty due to mount SWR is eliminated.

35. MISMATCH ERROR.

36. Errors caused by mismatch result when the mount does not provide a Z_0 termination. The term Calibration Factor describes the combination of Effective Effficiency and mismatch errors. The Calibration Factor of a thermistor mount equals the percentage of incident power which effectively heats the thermistor. Calibration Factor is always equal to or less than Effective Efficiency. The terms are related by the equation:

$$\text{CAL FACTOR} = \text{EFF EFFICIENCY}\ (1-\rho_m^{\ 2})$$

$(\rho_m^{\ 2}$ = reflection coefficient of the mount)

37. CALIBRATION DATA APPLICATION.

38. When the 486A is used with the Model 431C Power Meter, Calibration Factor or Effective Efficiency correction can be made by the setting of a front panel switch. With the proper setting, the 431C compensates for the Calibration Factor or Effective Efficiency of the 486A. If the 486A is used with a power meter other than the 431C, Calibration Factor or Effective Efficiency correction can be made by dividing the measured power by the Calibration Factor or Effective Efficiency value respectively.

39. THERMOELECTRIC EFFECT.

40. Mount calibration uncertainties given in Table 1 include inaccuracies caused by thermoelectric effect error. Calibration Factor uncertainty of ±1.5% and Effective Efficiency uncertainty of ±2.5% can be maintained on the three lowest power ranges of the Model 431 series Power Meters by correcting for the measurement error introduced by thermoelectric effect. An error correction procedure is given in Paragraph 44.

41. A mild thermocouple exists at each point of contact where the connecting wires join to the thermistor elements. Each thermocouple creates a DC voltage. Thus, two thermocouple voltages of opposite relative polarity are formed, one at each junction to each thermistor element.

42. Ideally, each thermocouple voltage would be equal in magnitude so that they cancel with no resultant effect on the accuracy of power measurement. In practice, however, each point of contact does not have identical thermocouple characteristics, and in addition, the temperatures at each junction may not be the same. These differences cause an incomplete cancellation of the thermoelectric voltages, resulting in a voltage that causes a thermoelectric effect error. The magnitude of the error is important when making DC substitution measurements on the 0.1 mW, 0.03 mW, and 0.01 mW ranges with one of the Model 431-series Power Meters. On other ranges, the effect is negligible. Maximum error introduced by thermoelectric effect is about 0.3 μW and is typically 0.1 μW on the .01 mW range.

43. THERMOELECTRIC EFFECT ERROR CORRECTION.

44. Use the following technique to correct for thermoelectric effect error.

a. Measure power.

b. Connect an ⓗⓟ Model 8402 Power Meter Calibrator to the power meter DC CALIBRATION AND SUBSTITUTION jack.

c. Zero and null power meter.

d. By DC Substitution (refer to procedure in 431 Manual), duplicate power measurement made in step a. Calculate and record substituted power as P_1.

e. Reverse connection polarity between the calibrator and power meter.

f. Re-zero and re-null power meter, if necessary.

g. By DC Substitution, duplicate power measurement made in step a. Calculate and record substituted power as P_2.

h. Calculate arithmetic mean of the two substitution powers P_1 and P_2. This mean power includes a correction for thermoelectric effect error.

$$\text{Power} = \frac{P_1 + P_2}{2}$$

OPERATING PRINCIPLES

45. The matched thermistor pair, C and D (C is used for thermal compensation, and D for RF detection), are mounted in an isolated common thermal environment represented by the shaded rectangle in Figure 4. Electrically, however, the thermistors are isolated from each other, D being mounted inside the waveguide and exposed to incoming RF, while C is entirely shielded from RF. A correct amount of 10-kHz bias is supplied through a cable from the Model 431 Power Meter to heat D to its operating resistance (100 ohms ±1% or 200 ohms ±1%). An equal amount of 10-kHz bias, together with a DC bias, is supplied to heat C to the same operating resistance. As indicated in Figure 4, the total power applied to heat thermistor D consists of incoming RF, 10-kHz bias, and heat from the environment. The total heating power to compensating thermistor C consists of DC bias, 10-kHz bias, and the same environmental heat. As D and C are matched thermally, only equal amounts of heating power can bias them to equal operating resistances. Restating the foregoing algebraically: under normal operation

$$P_{\text{total to D}} = P_{\text{total to C}}$$

where

$$P_{\text{total to D}} = P_{\text{RF to D}} + P_{\text{10kHz to D}} + P_{\text{env heat to D}}$$

and

$$P_{\text{total to C}} = P_{\text{DC to C}} + P_{\text{10kHz to C}} + P_{\text{env heat to C}}$$

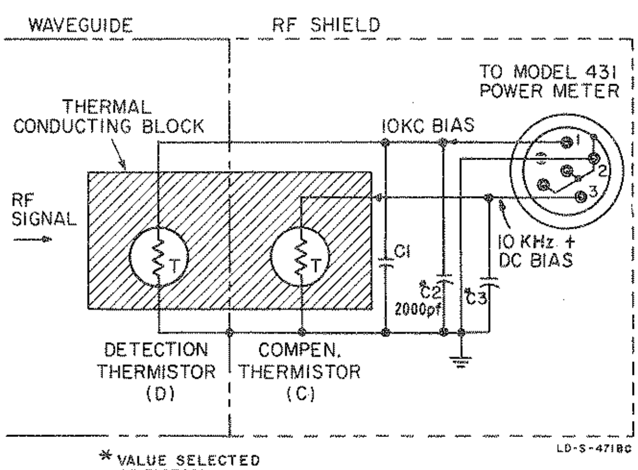

Figure 4. Thermistor Mount Schematic Diagram

Since the thermistors share the same thermal environment

$$P_{\text{env heat to D}} = P_{\text{env heat to C}}$$

and since

$$P_{\text{10kHz to D}} \text{ is made } = P_{\text{10 kHz to C}}$$

this leaves

$$P_{\text{RF to D}} = P_{\text{DC to C}}$$

The P_{DC} to C is monitored by the Model 431 Power Meter, and since P_{DC} is made equal to P_{RF}, the Model 431 meter indicates the magnitude of the RF power.

46. The above equations assume perfect accuracy in the components; in practice, however, there is a small offset which is balanced out by the zero-set adjustment so that the meter indication will be zero with no RF power applied. Also, for best accuracy, the slight differential thermal drift between components may require occasional zero reset on the most sensitive ranges.

MAINTENANCE

47. CHECK ON THERMISTOR MATCH.

48. Damage to the match between the thermistors may be checked at room temperature by comparing the thermistor resistances under simulated operating conditions. Connect the equipment to the pins of the connector at the rear of the thermistor mount as shown in Figure 5. Select a suitable bucking DC voltage to reduce the voltage across the digital voltmeter for readings down to the nearest 0.001 volt. Take readings with switches connected to pin 1 and then to pin 3. Thermistor match is satisfactory if the two readings do not differ by more than 0.015 volt.

49. CLEANLINESS.

50. Except for the K and R Models, thermistor D (mounted inside the waveguide) is protected against air currents, dirt, and mechanical damage by two layers of polyfoam plastic. Polyfoam is soluble in most volatile solvents, such as gasoline, alcohol, benzene, carbon tetrachloride, acetone, etc., so great

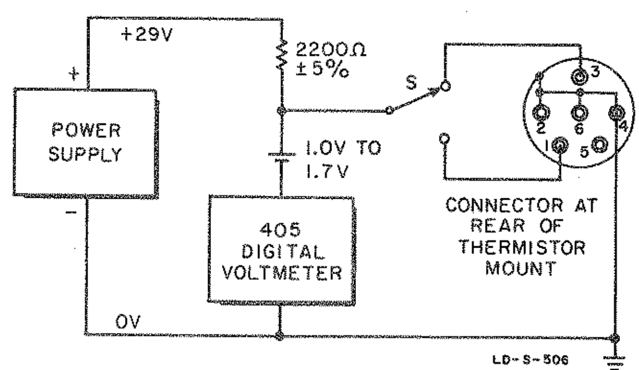

Figure 5. Check on Model 486A Thermistor Resistance Match

care should be used if one of these is used to clean the flange or inner surfaces of the waveguide. Use the plastic flange cover to protect the mount from dirt and mechanical damage whenever it is not in use. Any burn, dents or dirt on the flange or waveguide surfaces will increase the SWR. This is particularly important in the case of the K486A and R486A, which do not have the polyfoam plastic protection.

51. REPAIR.

52. Exceeding the CW or pulse power limits of the Model 486A Thermistor Mount may result in damage such that the mount will no longer zero on the Model 431 Power Meter.

53. Before adjusting the mount in any way, make sure that the mount is the cause of the problem. If the 431 Power Meter remains pegged downscale when ZERO is rotated through its range, measure the resistance between pins 1 and 2, and between pins 2 and 3 of the 6-pin connector. This resistance should be between 500 and 5000 ohms. If the resistance in both cases is within this range, the mount may be repairable. An open or short indication calls for factory repair.

54. If possible, test the mount by connecting it to a Model 431 and cable which are known to be good. A faulty cable will not have continuity through the respective connector pins, or may have poor contact at the mount connector. Poor contact will show up as intermittence or a great deal of noise (visible on the 431 meter) when the cable is gently flexed near the connector end.

55. If the 431 meter remains pegged upscale, factory repair of the mount is indicated.

CAUTION

Under no conditions should the mount be required to carry current higher than 10 ma.

56. MOUNT COMPENSATION.

57. If the resistance reading of the mount is satisfactory, it may be possible to recompensate the mount, and return it to service. The drift with temperature changes will be higher because of damage to the thermistors, but it will be possible to zero the meter and to make measurements.

NOTE

After recompensation the Calibration Factor and Effective Efficiency recorded on the label of the mount will no longer be valid. If desired, the instrument may be sent to the factory for repair and recalibration. Any Hewlett-Packard Sales and Service Office will arrange for such repair.

58. There is an adjusting screw inside the instrument which permits recompensation within limits. Instruments which were manufactured without the adjusting screw are modified when they are sent in for repair.

59. To recompensate the mount, refer to Figure 6, and proceed as follows:

a. Remove cover screws (A).

b. Slide instrument out of cover.

c. Set 431 MOUNT RES to proper value.

d. Plug cover into mount cable.

e. Set ZERO and VERNIER to mid-range.

f. Set RANGE to 10 mW.

g. If meter is pegged upscale, turn compensating screw (B) counterclockwise to zero meter.

h. If meter is pegged downscale, turn screw clockwise to zero meter.

WARNING

If there is a sudden jump in meter indication when turning compensating screw clockwise, back off 1/8 turn. If screw bottoms, do not apply force. Factory repair is indicated.

i. Replace cover and cover screws (A).

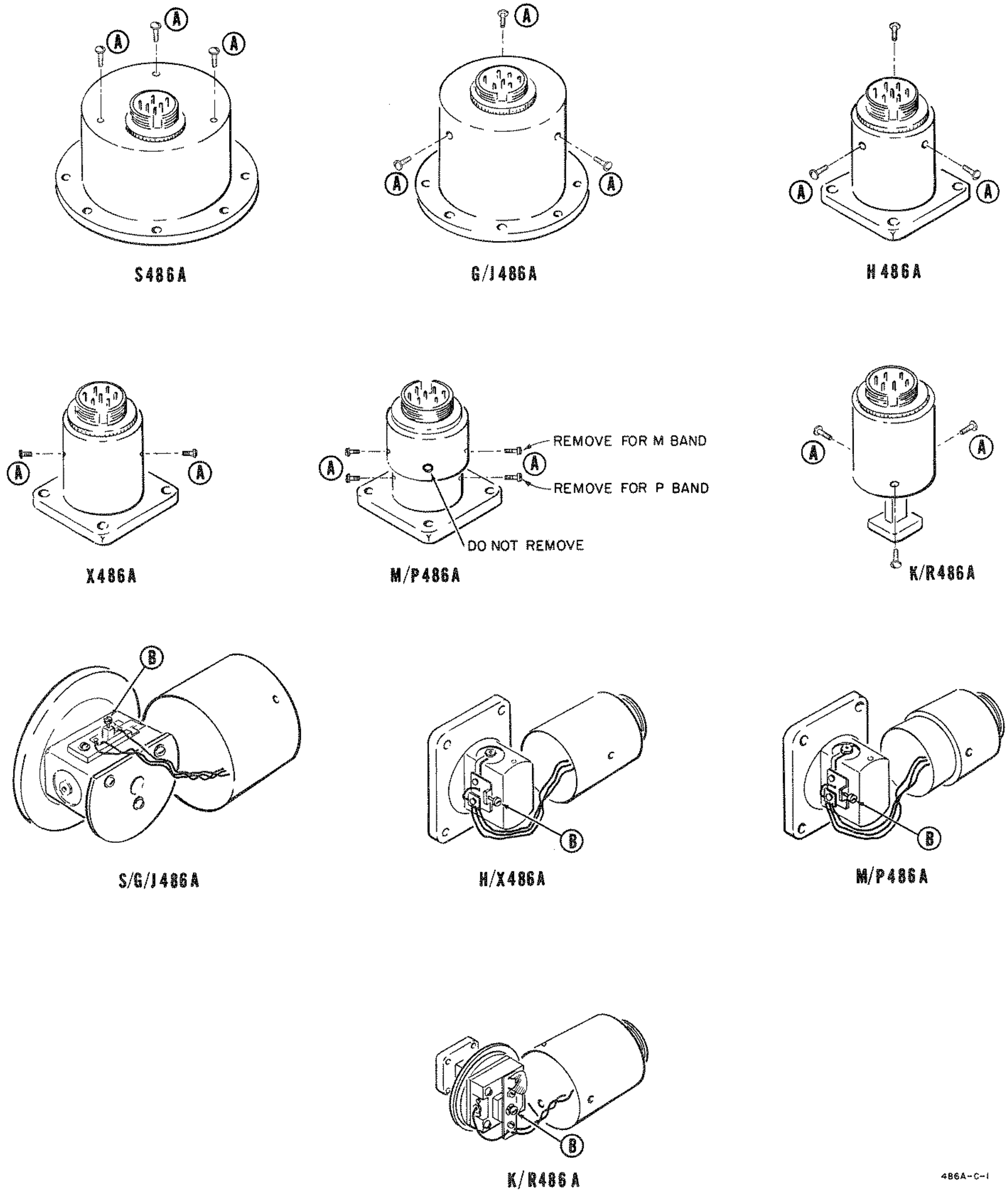

Figure 6. Cover Screws (A) and Compensating Screws (B) in Model 486A Thermistor Mounts

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TWX: 710-541-0482

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TWX: 510-926-1516

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TWX: 810-421-8500

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Dayton 45439
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TWX: 810-459-1925

OKLAHOMA
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TWX: 910-830-6862

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Portland 97225
Tel: (503) 292-9171
TWX: 910-464-6103

PENNSYLVANIA
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TWX: 710-797-3650

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Tel: (215) 248-1600, 828-6200
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Hewlett-Packard Argentina
S.A.C.e.I.
Lavalle 1171 - 3°
Buenos Aires

Lutz, Ferrando y Cia. S. A.
Florida 240 (R.5)
Buenos Aires
Tel: 46-7241, 46-1635
Cable: OPTICA Buenos Aires

BRAZIL
Hewlett-Packard Do Brasil
I.e.C. Ltda.
Rua Cel. Oscar Porto, 691
Sao Paulo - 8, SP
Tel: 71-1503
Cable: HEWPAK Sao Paulo

Hewlett-Packard Do Brasil
I.e.C. Ltda.
Avenida Franklin Roosevelt 84-
grupo 203
Rio de Janeiro, ZC-39, GB
Tel: 32-9733
Cable: HEWPAK Rio de Janeiro

CHILE
Hector Calcagni P.
Casilla 13942
Estado 215 - Oficina 1016
Santiago
Tel: 31-890, 490-505

COLOMBIA
Instrumentacion
Henrik A. Langebaek & Cia. Ltda.
Carrera 7 # 48-59
Apartado Aéreo 6287
Bogota, I. D.E.
Tel: 45-78-06, 45-55-46
Cable: AARIS Bogota

COSTA RICA
Lic. Alfredo Gallegos Gurdián
Apartado 3243
San José
Tel: 21-86-13
Cable: GALGUR San José

ECUADOR
Laboratorios de Radio-Ingenieria
Calle Guayaquil 1246
Post Office Box 3199
Quito
Tel: 12496
Cable: HORVATH Quito

EL SALVADOR
Electrónica
Apartado Postal 1589
27 Avenida Norte 1133
San Salvador
Tel: 25 74 50
Cable: ELECTRONICA San Salvador

GUATEMALA
Olander Associates Latin America
Apartado 1226
7a. Calle, 0-22, Zona 1
Guatemala City
Tel: 22812
Cable: OLALA Guatemala City

MEXICO
Hewlett-Packard Mexicana, S.A.
de C.V.
Apartado Postal 12-832
Eugenia 408, Dept. 1
Mexico 12, D.F.
Tel: 43-03-79, 36-08-78

NICARAGUA
Roberto Terán G.
Apartado Postal 689
Edificio Terán
Managua
Tel: 3451, 3452
Cable: ROTERAN Managua

PANAMA
Electronica Balboa, S.A.
P.O. Box 4929
Ave. Manuel Espinosa No. 13-50
Bldg. Alina
Panama City
Tel: 30833
Cable: ELECTRON Panama City

PERU
Fernando Ezeta B.
Avenida Petit Thouars 4719
Miraflores
Casilla 3061
Lima
Tel: 50346
Cable: FEPERU Lima

PUERTO RICO
San Juan Electronics, Inc.
P.O. Box 5167
Ponce de Leon 154
Pda. 3-Pta. de Tierra
San Juan, P.R. 00906
Tel: (174) 725-3342
Cable: SATRONICS San Juan

URUGUAY
Pablo Ferrando S.A.
Comercial e Industrial
Avenida Italia 2877
Casilla de Correo 370
Montevideo
Tel: 40-3102
Cable: RADIUM Montevideo

VENEZUELA
Hewlett-Packard De Venezuela C.A.
Edificio Arisán-Of. 4
Avda. Francisco de Miranda
Chacaito
Caracas
Tel: 71.88.05
Cable: HEWPACK Caracas
Mailing Address: Apartado del
Este 10934 Caracas

FOR AREAS NOT LISTED, CONTACT:
Hewlett-Packard Inter-Americas
1501 Page Mill Road
Palo Alto, California 94304
Tel: (415) 326-7000
TWX: 910-373-1267
Telex: 034-8461
Cable: HEWPACK Palo Alto

CANADA

ALBERTA
Hewlett-Packard (Canada) Ltd.
11745 Jasper Avenue
Edmonton
Tel: (403) 482-5561
TWX: 610-831-2431

BRITISH COLUMBIA
Hewlett-Packard (Canada) Ltd.
304-1037 West Broadway
Vancouver 9
Tel: (604) 731-5301
TWX: 610-922-5059

NOVA SCOTIA
Hewlett-Packard (Canada) Ltd.
7001 Mumford Road
Suite 356
Halifax
Tel: (902) 455-0511
TWX: 610-271-4482

ONTARIO
Hewlett-Packard (Canada) Ltd.
880 Lady Ellen Place
Ottawa 3
Tel: (613) 722-4223
TWX: 610-562-1952

Hewlett-Packard (Canada) Ltd.
1415 Lawrence Avenue West
Toronto
Tel: (416) 249-9196
TWX: 610-492-2382

QUEBEC
Hewlett-Packard (Canada) Ltd.
275 Hymus Boulevard
Pointe Claire
Tel: (514) 697-4232
TWX: 610-422-3022
Telex: 01-20607

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