MODELS F1125, F1130, F1135, M1125, M1130, M1135

Coaxial RF Power Transfer Standards

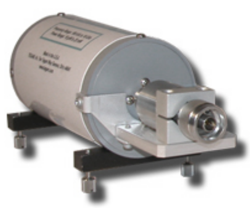
Instruction Manual

PN# IM300
Publication Date: August 2005
REV. C

TEGAM INC.

MODELS F1125, F1130, F1135, M1125, M1130, M1135
Coaxial RF Power Transfer Standards

Model M1125 Model F1125



Model M1130 Model F1130

Model M1135 Model F1135

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NOTE: This user's manual was as current as possible when this product was manufactured. However, products are constantly being updated and improved. Because of this, some differences may occur between the description in this manual and the product received.

TEGAM is a manufacturer of electronic test and measurement equipment for metrology, calibration, and production test. We also provide repair, calibration, and other support services for a wide variety of test and measurement equipment including RF power sensor calibration systems, RF attenuation measurement systems, resistance standards, ratio transformers, arbitrary waveform generators, micro-ohmmeters, LCR meters, handheld temperature calibrators, thermometers, humidity and temperature control devices, and more.

TEGAM also repairs and calibrates test and measurement equipment formerly manufactured by Electro-Scientific Industries (ESI), Gertsch, Keithley Instruments, Lucas Weinschel, and Pragmatic Instruments. A complete list can be viewed on our Product Service Directory at www.tegam.com

For more information about TEGAM and our products, please visit our website at www.tegam.com: or contact one of our customer service representatives at sales@tegam.com or 800-666-1010.

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INSTRUMENT DESCRIPTION

PREPARATION FOR USE
OPERATING INSTRUCTIONS
THEORY OF OPERATION
SERVICE INFORMATION

Abbreviations And Acronyms

The following list contains all abbreviations used throughout this manual. Abbreviations and acronyms that are not listed conform to MIL-STD-12D.

CW Continuous Wave
SUT Sensor Under Test
DMM Digital Multi-Meter
DVM Digital Voltmeter
ESDS Electrostatic Discharge Sensitive
NIST National Institute of Standards and Technology
RF Radio Frequency
DC Direct Current

Figure 1.1 Models M1125 & F1125

Figure 1.2 Models M1130 & F1130

Figure 1.3 Models M1135 & F1135

Description Of Equipment

Functional Description

These Coaxial RF Power Transfer Standards are designed for the precise measurement of microwave power in the 100 kHz to 26.5 GHz frequency range. These units are highly accurate, stable with time and temperature, and are designed for use as a standard for the transfer of calibration factors to other sensors. Each unit is supplied with calibration points traceable to National Institute of Standards and Technology (NIST). These standards are configured in Primary and Working Standard configurations. The Working RF Power Transfer Standard (or Feedthrough RF Power Standard) is a thermistor mount power splitter combination employed as a feedthrough standard for the calibration of terminating power sensors such as bolometer mounts and power meters. This standard was designed for use in the TEGAM System IIA Automatic Power Sensor Calibration System (Figure 1.4). The Primary RF Power Transfer Standard (or Terminating RF Power Standard) is a terminating thermistor mount used for the calibration of feedthrough standards (Figure 1.6) and applications that require direct measurement of RF power (Figure 1.5).

Physical Description

Refer to Table 1.1 for the general specifications for the RF Transfer Standards. The Working RF Power Transfer Standards feature a SENSOR, RF INput, BIAS VOLTAGE and TEMPerature connectors on the front panel. The Primary RF Power Transfer Standards feature an RF INput connector on the front and BIAS VOLTAGE and TEMPerature connectors in the rear. The Working RF Power Transfer Standards can be mounted in any cabinet or rack designed according to EIA RS-310 and MIL-STD-189 using the appropriate hardware.

Specifications

Table 1.1 lists the general specifications for all the RF Power Transfer Standards. Tables 1.2 through 1.4 list specifications unique to each model.

Table 1.1 General Specifications

Power Range	0.01 to 25 mW (-20 to +14 dBm)
RF Impedance	50 Ohms nominal
Power Linearity	<0.1% from 1 to 10 mW
Calibration Factor Drift	<0.5% per year
Individual calibrations traceable to NIST supplied at the following frequencies:	100, 200, 455 kHz 1, 1.25, 3, 5 MHz 10 to 100 MHz in 10 MHz steps 0.1 to 2 GHz in 50 MHz steps 2 GHz to 4 GHz in 100 MHz steps 4 to 12.4 GHz in 200 MHz steps 12.75 to 18 GHz in 250 MHz steps 18 to 26 GHz in 1 GHz steps 26.5 GHz
Thermistor DC Bias Power	30 +/-0.7 mW
Thermistor Resistance at Bias	200 Ohms
Thermistor Power Sensitivity	Approximately 13 Ohms/mW
Temperature **Operating** **Storage**	 +12° to +40° C (+54° to +104° F) -55° to +75° C (-67° to +167° F)
Warm up time	2 hours minimum

Table 1.2 F1125/M1125 Individual Specifications

Model	**F1125**	**M1125**
Frequency Range	100 kHz to 4.2 GHz	100 kHz to 4.2 GHz
Max VSWR	1.06 from 100 kHz to 4.2 GHz	1.40 from 100 to 500 kHz 1.20 from 0.5 to 1 MHz 1.10 from 1 to 1000 MHz 1.20 from 1 to 4.2 GHz
Insertion Loss	6 dB nominal, 8.5 dB max	1 dB max
Calibration Factor Accuracy	+/-0.80% from 0.01 to 10 MHz +/-0.90% from 10 to 4200 MHz	+/-0.80% from 0.01 to 10 MHz +/-0.90% from 10 to 4200 MHz
Connectors		
SENSOR	N-type Female	N/A
RF IN	SMA Female	N-Type Male
TEMP	4-pin mini-microphone	4-pin microphone
BIAS VOLTAGE	Binding Post, standard 0.75" spacing for banana plugs	Binding Post, standard 0.75" spacing for banana plugs
Weight	5.5 lbs (2.5 kg)	2.88 lbs (1.3 kg)
Physical Dimensions		
Height	3.5 in (88.9 mm)	2.88 in (73.2 mm)
Width	8.5 in (215.9 mm)	4 in (101.6 mm)
Depth	15.4 in (391.2 mm)	7.45 in (189.2 mm)
Rack Mounting	Can be mounted in a standard 19" rack with optional hardware.	None

Table 1.3 F1130/M1130 Individual Specifications

Model	**F1130**	**M1130**
Frequency Range	100 kHz to 18 GHz	100 kHz to 18 GHz
Max VSWR	1.06 from 100 kHz to 6 GHz 1.10 from 6 to 15 GHz 1.14 from 15 to 18 GHz	1.30 from 100 to 500 kHz 1.10 from 0.5 to 1000 MHz 1.20 from 1 to 4 GHz 1.30 from 4 to 8 GHz 1.40 from 8 to 18 GHz
Insertion Loss	6 dB nominal, 9 dB max	1.5 dB max
Calibration Factor Accuracy	+/-0.80% from 0.1 to 10 MHz +/-1.20% from 0.01 to 10 GHz +/-1.30% from 10 to 18 GHz	+/-0.80% from 0.1 to 10 MHz +/-1.20% from 0.01 to 10 GHz +/-1.30% from 10 to 18 GHz
Connectors		
SENSOR	N-type Female	N/A
RF IN	SMA Female	N-Type Male
TEMP	4-pin mini-microphone	4-pin microphone
BIAS VOLTAGE	Binding Post, standard 0.75" spacing for banana plugs	Binding Post, standard 0.75" spacing for banana plugs
Weight	5.5 lbs (2.5 kg)	3.22 lbs (1.5 kg)
Physical Dimensions		
Height	3.5 in (88.9 mm)	2.88 in (73.2 mm)
Width	8.5 in (215.9 mm)	4 in (101.6 mm)
Depth	15.4 in (391.2 mm)	9.25 in (235 mm)
Rack Mounting	Can be mounted in a standard 19" rack with optional hardware.	None

Table 1.4 F1135/M1135 Individual Specifications

Model	F1135	M1135
Frequency Range	10 MHz to 26.5 GHz	10 MHz to 26.5 GHz
Max VSWR	1.25 from 0.01 to 18 GHz 1.35 from 18 to 26.5 GHz	1.50 from 10 to 20 MHz 1.40 from 20 to 50 MHz 1.30 from 50 to 100 MHz 1.20 from 0.1 to 4 GHz 1.30 from 4 to 8 GHz 1.40 from 8 to 14 GHz 1.60 from 14 to 26.5 GHz
Insertion Loss	6 dB nominal, 11.0 dB max	2.5 dB max
Calibration Factor Accuracy	+/-1.00% from 0.01 to 10 GHz +/-1.10% from 10 to 18 GHz +/-2.20% from 18 to 26.5 GHz	+/-1.20% from 0.01 to 10 GHz +/-1.30% from 10 to 18 GHz +/-2.30% from 18 to 26.5 GHz
Connectors		
SENSOR	3.5 mm Female	N/A
RF IN	SMA Female	2.92 mm Male
TEMP	4-pin mini-microphone	4-pin microphone
BIAS VOLTAGE	Binding Post, standard 0.75” spacing for banana plugs	Binding Post, standard 0.75” spacing for banana plugs
Weight	6.27 lbs (2.8 kg)	2.88 lbs (1.3 kg)
Physical Dimensions		
Height	3.5 in (88.9 mm)	2.88 in (73.2 mm)
Width	8.5 in (215.9 mm)	4 in (101.6 mm)
Depth	15.4 in (391.2 mm)	7.45 in (189.2 mm)
Rack Mounting	Can be mounted in a standard 19” rack with optional hardware.	None

Additional equipment

Table 1.5 lists the additional equipment required to operate RF Power Transfer Standards. The description for each piece of equipment listed states the minimum recommended requirements for that piece of equipment. There may be many models that meet the minimum requirements; it is up to the operator to select the specific model. Measurement uncertainty will vary depending on the additional equipment used. Please refer to the specifications for the particular model number to get that information.

Table 1.5 Additional Equipment Required

TEGAM Model 1805B RF Level Controller	
Type IV Power Meter	
DVM	DC Volts, 6½-digit minimum.

Applications

The TEGAM RF Power Transfer Standards are an element of a system and are not “stand-alone” instruments. The TEGAM RF Power Transfer Standards are designed to be employed as the fourth arm of a bridge configuration. This unit is designed as the sensing element in RF power calibration and measurement systems.

Figure 1.4 shows a power sensor calibration setup using a TEGAM Model 1805B RF Level Controller and a Working RF Transfer Standard to form a Precision Power Source to perform power sensor calibrations at 1 to 10 mW (0 to +10 dBm).

Figure 1.5 shows a Terminating RF Transfer Standard being used to measure the power of a 50 MHz reference output on a power meter. The Terminating RF Power Transfer Standard can be used in many applications requiring direct measurement of RF power.

Figure 1.6 shows the calibration of a Working RF Transfer Standard using a Primary RF Transfer Standard. The Primary RF Transfer Standard can be calibrated by TEGAM or a national standards agency such as NIST and that calibration can be transferred to a Working RF Transfer Standard.

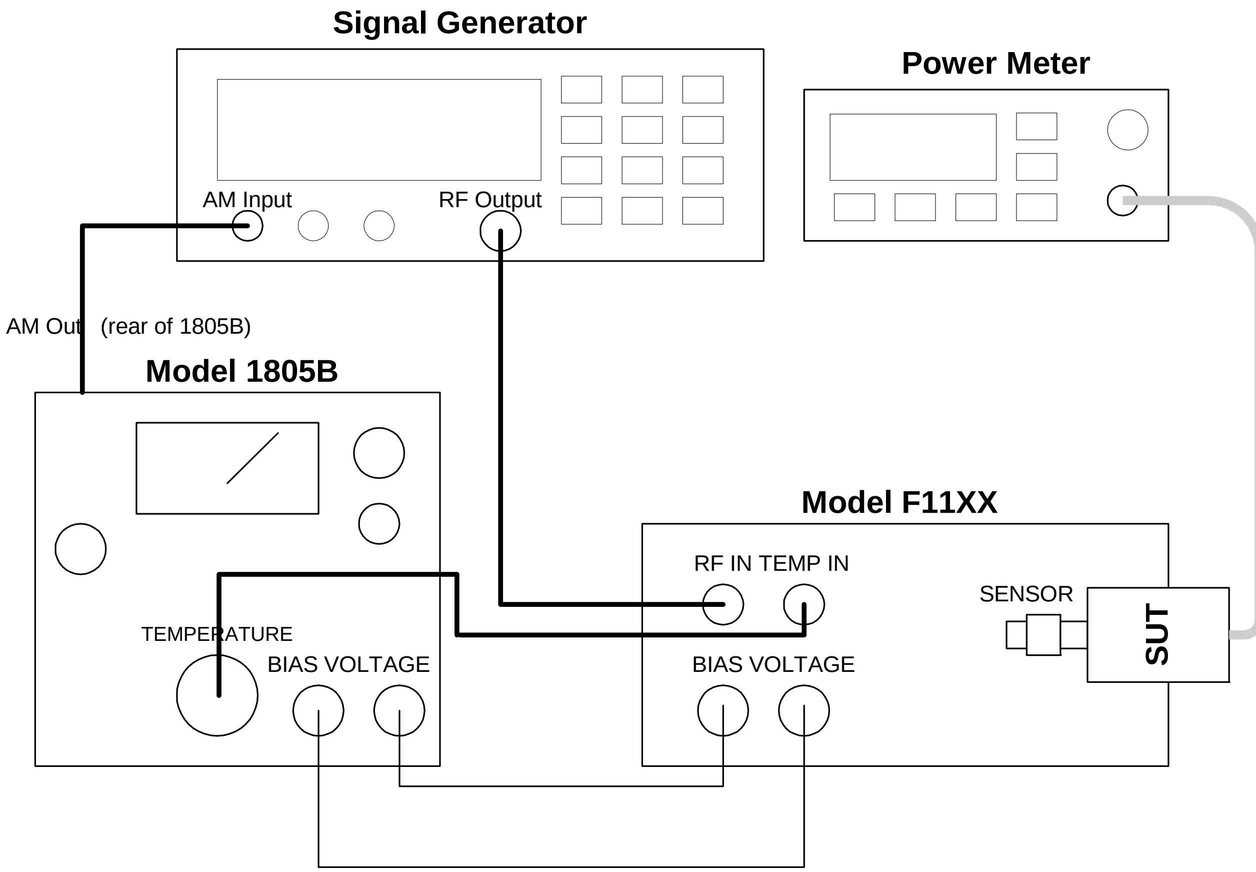

Figure 1.4 RF Power Sensor Calibration Using a Working Transfer Standard (Model F1125, F1130, F1135)

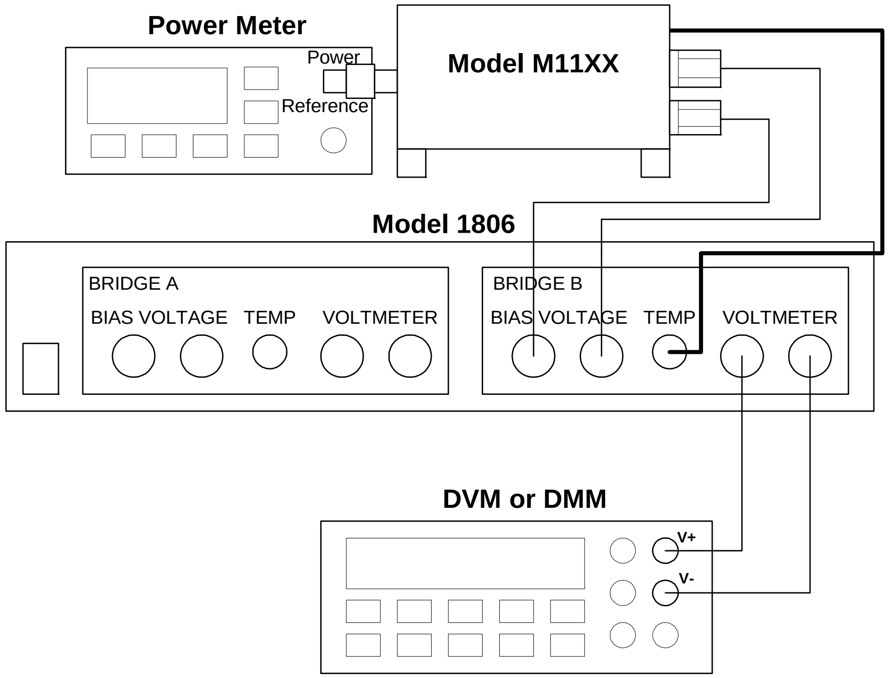

Figure 1.5 Measuring a the 50 MHz Reference Output on a Power Meter using a Primary Transfer Standard (Model M1125, M1130, M1135)

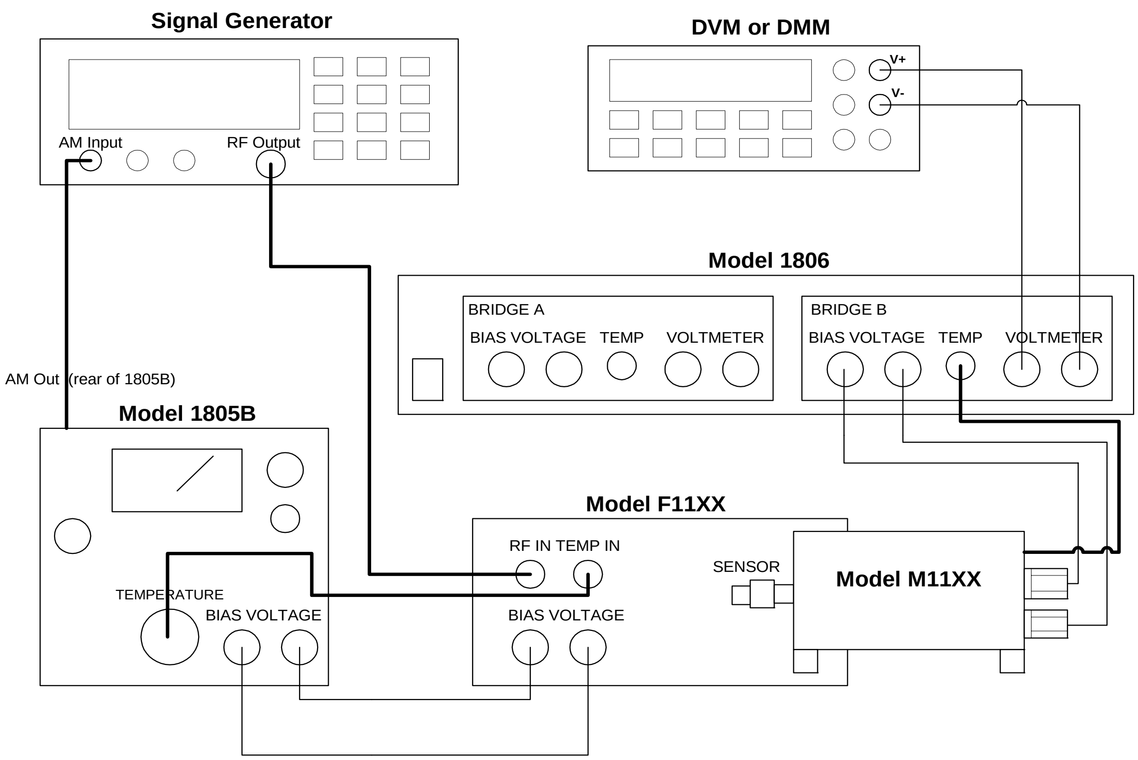

Figure 1.6 Calibration of a Working Transfer Standard Using a Primary Transfer Standard

Unpacking & Inspection:

Each RF Power Transfer Standard is put through a series of electrical and mechanical inspections before shipment to the customer. Upon receipt of your instrument unpack all of the items from the shipping carton and inspect for any damage that may have occurred during transit. Report any damaged items to the shipping agent. Retain and use the original packing material for reshipment if necessary.

Upon Receipt, inspect the carton for the following items:

Model F1125, F1130, F1135, M1125, M1130, or M1135 RF Power Transfer Standard
Model F1125, F1130, F1135, M1125, M1130, M1135 Operating Manual (CD) P/N IM300
Calibration Certificate with data
3.5” floppy disk containing calibration data
F1125, F1130, and F1135 **ONLY -** Heater Cable P/N CBL-F1125-48

Mounting

The Model F1125, F1130, and F1135 are shipped with four plastic feet mounted to the bottom cover. When any of these models are placed on a bench or table, the feet support the instrument. The Model F1125, F1130, and F1135 can also be rack mounted in a standard 19” rack, using the optional rack mount kit F1120-RMK.

The Model M1125, M1130, and M1135 are shipped with four adjustable feet fastened to the base of the unit. Not only are these feet used to support the instrument; they are used to adjust the height of the instrument to ensure the male coaxial connector on the front of the instrument is properly aligned with the mating connector.

⚠ Safety Information & Precautions:

The following safety information applies to both operation and service personnel. Safety precautions and warnings may be found throughout this instruction manual and the equipment. These warnings may be in the form of a symbol or a written statement. Below is a summary of these precautions.

Terms in This Manual:

CAUTION statements identify conditions or practices that could result in damage to the equipment or other property.

WARNING statements identify conditions or practices that could result in personal injury or loss of life.

Terms as Marked on Equipment:

CAUTION indicates a personal injury hazard not immediately accessible as one reads the marking, or a hazard to property including the equipment itself.

DANGER indicates a personal injury hazard immediately accessible as one reads the marking.

Symbols:

As Marked in This Manual:

⚠	This symbol denotes where precautionary information may be found.

As Marked on Equipment:

⚠	CAUTION – Risk of Danger
⚡	DANGER – Risk of Electric Shock
⏚	Earth Ground Terminal
I	On
O	Off
⊥	Frame or Chassis Terminal
⊥	Earth Ground Terminal
∿	Alternating Current

Use in Proper Environment

Normal calibration laboratory practice dictates that the environment should be closely controlled. This will minimize errors introduced by temperature and humidity changes. A nominal temperature of +23°C (+73.4°F) provides a good working condition. A tolerance of ±1°C gives allowable temperature spread. Controlled temperatures also stabilize the aging process of the standards.

CAUTION: The RF Power Transfer Standards have a specified ambient temperature range of +12° to +40°C (+54° to +104°F). Operating beyond these limits can affect the accuracy of the instruments and damage internal circuitry.

CAUTION: When an RF Power Transfer Standard is to be stored for extended periods, pack the instrument into a container. Place container in a clean, dry, temperature-controlled location. If instrument is to be stored in excess of 90 days, place desiccant with items before sealing container. The safe environmental limits for storage are -55° to +75°C (-67° to +167°F) at less than 95% non-condensing relative humidity.

Do Not Use in Explosive Environments

CAUTION: The RF Power Transfer Standards are not designed for operation in explosive environments.

Do Not Operate Without Covers

CAUTION: This device should be operated with all panels and covers in place.

Only Use with Compatible Instruments

CAUTION: These RF Power Transfer Standards are designed to be used with a Type IV Bridge circuit found in the TEGAM Models 1805B, 1806, and 1804. Connecting this device to any other type of circuit or may result in permanent damage to the components. Additionally, the heater elements used for the internal heater are designed to be used only with the heater control circuits found in TEGAM Models 1805B, 1806, and 1820. Connecting these heater elements to any other circuit or device may result in damage. Contact TEGAM for any questions regarding instruments that are compatible with these RF Power Transfer Standards. All equipment should be operated from either a regulated 115 VAC or 230 VAC supply.

General

The TEGAM RF Power Transfer Standards are designed to be employed as the fourth arm of a bridge configuration. These units are designed as the sensing element in RF power calibration and measurement systems. These systems employ other electronic elements to effect control of the measurement routines. An example of this type of system is the TEGAM System IIA Automatic Power Meter Calibration System. Proper use of these transfer standards and the TEGAM System IIA is further documented in other TEGAM Operation and Service Manuals. The Working RF Power Transfer Standards (Models F1125, F1130, and F1135) are feedthrough mount-splitter combinations and are normally used with the TEGAM Model 1805B RF Control Unit. The Model 1805B precisely controls the level of dc substituted power from .5 mW and 1-10 mW in 1 mW steps. The Primary RF Power Transfer Standards (Models M1125, M1130, and M1135) are terminating mounts commonly used with the Model 1806 Dual Type IV Power Meter. The Model 1806 requires an external digital voltmeter (DVM) such as the Agilent(HP) 3458A for readout to precisely measure DC substituted power. Both the Models 1805B and the 1806 provide all-DC precision self-balancing bridges and temperature controllers

Model F1125, F1130, and F1135 Connector Descriptions

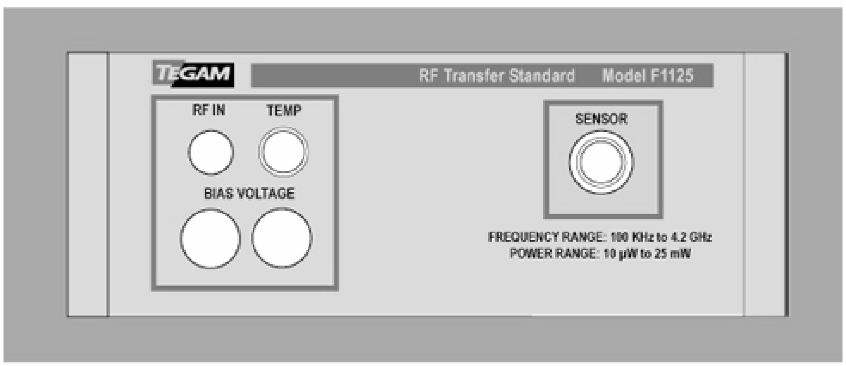

Figure 3.1 Model F1125 Front View

RF IN connector

SMA female connector that connects to signal generator output. The RF power that comes in this connector is applied equally to the SUT and the power standard. The fact that equal RF power is applied to both the power standard and the SUT is what allows the determination the calibration factor of the SUT. There is at least 6 dB of insertion loss in the RF IN path and as much as 10.5 depending on the specific model (see “Specifications” in Section I Instrument Description).

TEMP connector

4 pin mini-microphone connector that is used to connect the internal heater to a heater control circuit found in TEGAM Models 1805B, 1806, and 1820. RF Power Transfer Standards require at least two hours of warm-up time to reach their operating temperature. A Temperature Control cable is supplied with the Models F1125, F1130, and F1135.

BIAS VOLTAGE connectors

Binding posts used to connect the thermistor element to a Type IV bridge circuit as is found in the TEGAM Models 1805B, 1806, and 1804. The Type IV Bridge operates on the principal of DC substitution, so only DC voltages and currents are present at these terminals when connected.

SENSOR connector
Female coaxial connector that provides the RF power to the SUT. The RF power applied to RF IN connector is applied equally to the SUT and the internal thermistor mount. The fact that equal RF power is applied to both the power standard and the SUT is what allows the calibration factor of the SUT to be determined. This connector is a type N on the F1125 and F1130 and a 3.5 mm on the F1135.

Model M1125, M1130, and M1135 Connector Descriptions

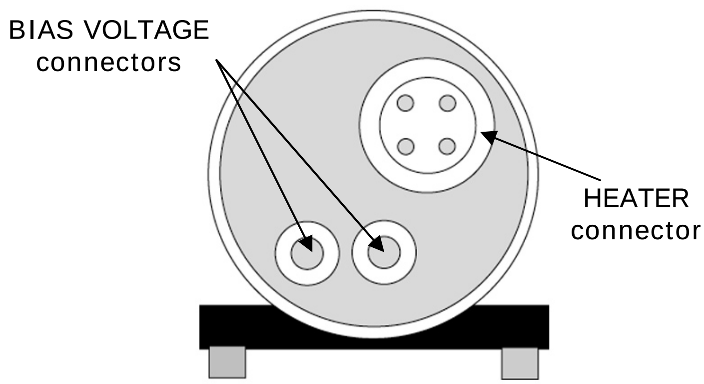

Figure 3.1 Model M1125/M1130/M1135 Rear View

HEATER connector
4 pin microphone connector that is used to connect the internal heater to a heater control circuit found in TEGAM Models 1805B, 1806, and 1820. RF Power Transfer Standards require at least two hours of warm-up time to reach their operating temperature. This connector is compatible with the heater control cable supplied with Models 1805B, 1806, and 1820.

BIAS VOLTAGE connectors
Binding posts used to connect the thermistor element to a Type IV bridge circuit as is found in the TEGAM Models 1805B, 1806, and 1804. The Type IV Bridge operates on the principal of DC substitution, so only DC voltages and currents are present at these terminals when connected.

RF INPUT connector (on the front, not shown)
Male coaxial connector where RF power to be measured is applied. This connector is a type N on the M1125 and M1130 and is a 2.92 mm on the M1135.

Connecting RF Power Transfer Standards

The TEGAM RF Transfer Standards are an element of a system and is not a “stand-alone” instrument. Control of the units is accomplished by other instruments, so it cannot be used until cabling has been correctly installed. Once the cabling is done, there are no further operator adjustments to be made on any of the models. For use of the units in a typical operating system, refer to TEGAM System IIA Automatic Power Meter Calibration System Operation and Service Manual (IM-198).

To connect an RF Power Transfer standard, the internal heater must be connected to an instrument with a heater control circuit such as the TEGAM 1805B, 1806, or 1820. To do this, simply connect one end the appropriate cable to the “TEMP” or heater connector on the Transfer Standard and the other end to the “TEMP” or “TEMPERATURE CONTROL” connector on the instrument. For Models F1125, F1130, and F1135 use cable P/N CBL-F1125-48, one is included with the each unit. For Models M1125, M1130, and M1135 use the cable supplied with the 1805B, 1806, or 1820.

Next, the BIAS VOLTAGE red and black connectors are cabled to the BIAS VOLTAGE red and black connectors on an instrument with a Type IV bridge like the TEGAM Models 1805B, 1806, and 1804. The BIAS VOLTAGE connectors are 5-way binding posts so banana plugs or spade lugs can be used.

The RF IN on the Feedthrough Power Standards (Models F1125, F1130, F1135) is an SMA female coaxial connector that is connected to the output of the chosen signal generator, which should be 50 Ohm nominal impedance. A low loss coaxial cable is recommended to avoid an excessive power loss. These Models have an additional female coaxial connector called the “SENSOR” port. This connector is actually one of the arms of the power splitter (described in Section IV Theory of Operation). The SUT is connected to this port for calibration. When the Working RF Power Standard is being calibrated, the Primary RF Power Standard is connected to this port. This connector is an N type female on the F1125 and F1130 and a 3.5 mm on the F1135. Proper care, cleaning, alignment, and torquing of coaxial connectors should be practiced to reduce insertion loss and extend the life of the connectors.

The RF input on the Terminating Power Standards (Models M1125, M1130, M1135) is a male coaxial connector that is connected to the RF power source to be measured. This connector is a type N on the M1125 and M1130 and is a 2.92 mm (which will mate to the 3.5 mm female connector on the F1135) on the M1135. Again, proper care, cleaning, alignment, and torquing of coaxial connectors should be practiced to reduce insertion loss, improve repeatability, and extend the life of the connectors.

Once cabling has been correctly installed, there are no further operator adjustments to be made to the RF Power Transfer Standards. However, allow at least two hours for the heater in the RF Transfer Standard to reach its operating temperature. Additionally, it is recommended that once the BIAS VOLTAGE terminals are connected, the Type IV Bridge should be on for one hour before measurements are taken.

Temperature Variable Resistance

Each RF Transfer Standard contains a pair of thermistor beads whereby the resistance changes as a function of temperature. Thermistor bead temperature is a function of the combined DC and RF power applied to the beads and the ambient temperature surrounding the beads. The level of power applied to the beads is controlled externally. A heating element, controlled by an external controller, provides ambient temperature stability.
Figure 4.1 depicts the thermistor assembly electrical configuration. DC biasing of the dual thermistor beads to 100 ohms each provides a nominal 50 ohm parallel RF resistance and a 200 ohm series DC resistance. A DC blocking capacitor and bypass capacitors isolate DC from RF signals. Filtering capacitors provide low VSWR in the lower end of the frequency range.
Application of approximately 30 mW of power to the thermistor beads produces a 200 ohm DC resistance. As the power applied to the thermistor beads increases, their effective resistance values decrease (refer to Figure 4.1). This is due to the negative temperature coefficient of the beads. Initially, the beads are DC biased to 200 ohms. Application of RF power increases the power level present at the beads and causes the effective resistance value of the beads to drop. The Type IV bridge circuit reduces DC power until the initial effective resistance value is restored (200 ohms). The total amount of DC power removed is proportional to the amount of RF power that was introduced. Quantitatively, the total power applied to the thermistor beads equals the sum of the two types of power.

Power Splitter

The Models F1125, F1130, F1135 contain a two-element resistive power splitter. The T-shaped divider contains a series 50 ohm resistor in each of the two legs (refer to Figure 4.1). The test port is a Type N precision female. Use of the splitter in a closed loop configuration that applies constant power causes the common point (divider) to become a constant voltage point. This means the source impedance at both splitter output ports is determined by the 50 ohm resistor and the output connector. This provides very good source match. In addition, the power is split equally between the two ports as shown in Figure 4.1.

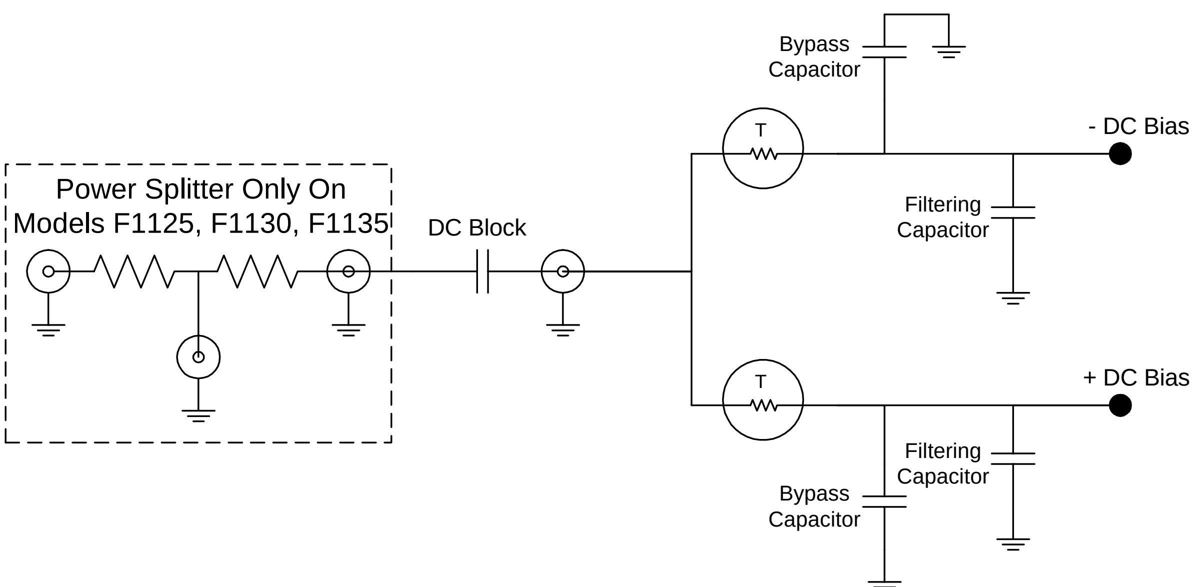

Figure 4.1 Simplified Schematic of RF Power Transfer Standards

Controlling Thermistor Temperature

Since thermistor mounts are temperature sensitive devices, it is necessary to eliminate or minimize the effects of changes in the ambient temperature. This is accomplished by thermally isolating the mount, raising its temperature with a heater element to a level higher than the ambient temperature, and maintaining that level by means of an external temperature controller. The heater element electrical assembly, illustrated in Figure 4.2, is a Wheatstone bridge configuration composed of wiring wound around a thermal mass. The wiring heats the mass to a temperature above the ambient temperature. The thermistor beads are mounted on this thermal mass and insulation surrounds the assembly to improve temperature stability. The proper temperature is determined by the characteristics of the thermistor beads. The 2K-ohm potentiometer is used to adjust the temperature such that the bead bias power (with no RF power applied) is 30mW ± 0.7 mW. An external controller drives the heater.
The Heater Bridge circuit shown in Figure 4.2 balances when the heater windings provide equal resistance. Two windings, represented as R1 and R2, of zero temperature coefficient wire (manganin) make up two legs of the bridge. The remaining two bridge windings, R3 and R4, have a positive temperature coefficient wire (nickel). In an unbalanced condition, the bridge output controls the current output of a temperature controller. Hence, the bridge configuration accomplishes both a temperature sensing and heating function.

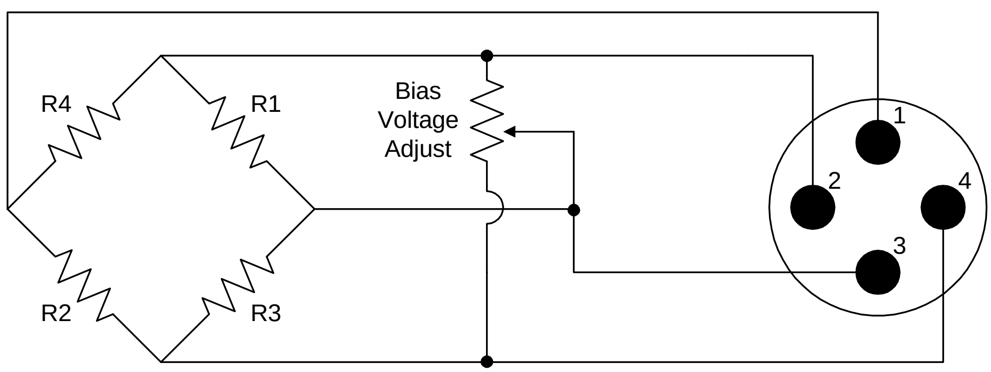

Figure 4.2 Simplified Schematic of RF Power Transfer Standards Internal Heater

Principle Of DC Substitution

The RF Power Transfer Standards use the principle of DC substitution to measure RF power. DC substitution refers to the measurement of RF power according to the amount of DC power that must be substituted for the RF power in a bolometer in order to cause equivalent thermal effects. Since some of the RF power applied to the input of the power standard is lost by reflection and other causes before it is applied to the thermistor element, a calibration factor for the standard is applied by the following formula to determine the actual level of RF power:

$$P_{RF} = \frac{P_{dc}}{K}$$

Where:

P_{RF} = Level of applied RF power,
P_{dc} = DC substituted power which is proportional to the RF power incident on the thermistor beads,
K = calibration factor of the RF Power Transfer Standard traceable to NIST

TEGAM Coaxial RF Power Standards are configured to provide a path for RF energy via a coaxial line. DC Bias is introduced from the Bias terminals to the thermistors via filtering capacitors.

Power Measurements

RF power is measured in terms of a power change across the precision resistance leg of a Type IV Bridge Circuit. A digital voltmeter measures voltage across the precision resistance leg which can be used to determine the power by the following equation:

$$P = \frac{V^2}{200}$$

Where:

P = power across the precision resistance leg
V = voltage measured across the precision resistance leg
200 = resistance value of precision resistance leg

The total power applied to the thermistor leg (in the RF Power Standard) of the Type IV Bridge equals the sum of both DC *and* RF power. The precision resistor leg only has DC power applied to it. Thus, the RF power introduced to the thermistor is directly proportional to the change in DC power across the precision resistor. The change in DC power across the precision resistor leg is given by:

$$\Delta P = P_1 - P_2$$

Where:

ΔP = the change in power across the precision resistance leg when RF power is applied to the thermistor leg,
P_1 = power across the precision resistance leg without RF power applied,
P_2 = power across the precision resistance leg with RF power applied

By substituting for P_1 and P_2 from the previous formula:

$$\Delta P = \frac{(V_1)^2}{200} - \frac{(V_2)^2}{200}$$

Combining terms:

$$\Delta P = \frac{(V_1)^2 - (V_2)^2}{200}$$

Where:

ΔP = the change in power of the precision resistance leg when RF power is applied to the thermistor leg (also represented as P_{dc}),
V_1 = DC voltage across the precision resistor in the absence of RF power,
V_2 = DC voltage across the precision resistor with RF power applied,
200 = nominal resistance of the thermistor in Ohms,

Like all RF power sensors, some of the RF power applied to the input of the RF Power Transfer Standard is lost by reflection and other causes before it is applied to the thermistor element. Thus, calibration factors based on frequency are associated with the RF Power Standards and are applied in the following formula to determine the actual level of RF power:

$$P_{RF} = \frac{P_{dc}}{K}$$

Where:

P_{RF} = Level of applied RF power,
P_{dc} = DC substituted power which is proportional to the applied RF power,
K = calibration factor of the RF Power Transfer Standard traceable to NIST

CALIBRATION FACTORS

For a Terminating RF Power Transfer Standard (M1125, M1130, M1135) K is denoted as the measure calibration factor (K_1), and P_{RF} is the RF power from a match-terminated source incident upon the mount. If the mount is connected to the side arm of a coupler or a port of a power splitter (a Feedthrough RF Power Transfer Standard), K is denoted as the monitor calibration factor (K_2), and P_{RF} is the RF power emerging form the mount into a match terminated load. For a Feedthrough RF Transfer Standard the calibration factor K_2 is given by:

$$K_2 = \frac{P_{dc2}}{P_{RF}}$$

And P_{RF} is given by:

$$P_{RF} = \frac{P_{dc1}}{K_1}$$

Where:

- K_2 = calibration factor of the Feedthrough RF Power Transfer Standard,
- P_{dc2} = DC substituted power measured by the device connected to the Feedthrough RF Power Transfer Standard,
- P_{RF} = Level of applied RF power,
- P_{dc1} = DC substituted power measured by the device connected to the Terminating RF Power Transfer Standard,
- K_1 = calibration factor of the Terminating RF Power Transfer Standard traceable to NIST

The system determines the calibration factor of the tested mount in terms of the known calibration factor of the previously calibrated thermistor mount and the precision measurement of the substituted DC power.
The Feedthrough RF Power Transfer Standard is used to determine the calibration factor for other terminating powers sensors. The calibration factor for a Sensor Under Test (SUT) is denoted as K_{1S} and is determined by first determining P_{RF}:

$$P_{RF} = \frac{P_{dc2}}{K_2}$$

The SUT must be connected to a compatible power meter, the readings are then used to determine the calibration factor of the SUT by:

$$K_{1S} = \frac{P_m}{P_{RF}}$$

Where:

- P_{RF} = Level of applied RF power,
- P_{dc2} = DC substituted power measured by the device connected to the Feedthrough RF Power Transfer Standard,
- K_2 = calibration factor of the Feedthrough RF Power Transfer Standard,
- K_{1S} = calibration factor of the SUT,
- P_m = reading from the SUT compatible power meter.

The calibration factor is ratio of applied vs. measured power. The result of the calibration factor calculation (K) will be a decimal value, typically between 0 and 1. Calibration factors can also be represented as a percentage (%) or in decibels (dB):

$$K(\%) = K * 100 \qquad\qquad K(dB) = 10 * \log(K)$$

Sources Of Calibration Error

Due to the high repeatability of the RF Power Transfer Standards and the accuracy of the Type IV Bridge, the major sources of error stem from impedance mismatch and the uncertainty of the calibration factor of the standard (K1 if calibrating a Feedthrough Power Standard or K2 if calibrating an SUT).

When an RF Power Transfer Standard is calibrated, an uncertainty is reported for each calibration point. Even Transfer Standards calibrated by NIST have a reported uncertainty associated with each calibration factor. This uncertainty figure (for K_1 or K_2) is one of the largest contributors to the uncertainty budget for the calibration at the next stage (K_2 or K_{1S}).

Impedance mismatch is the term used to describe the differences in impedance between RF devices. This difference in impedance causes some of the RF power to be reflected back from one device to another; thus, not all applied RF power is transferred from one device to another. The amount of power that is not transferred can be characterized as the reflection coefficient, or Γ. The reflection coefficient for TEGAM RF Power Transfer Standards is included as part of the factory calibration data. Mismatch error (M_{ER}) is determined from the reflection coefficients of both the Feedthrough Transfer Standard and the SUT as follows:

$$M_{ER} = 1 - \frac{1}{(1 \pm |\Gamma_1| \times |\Gamma_2|)^2}$$

Where:

M_{ER} = residual mismatch error,
Γ_1 = reflection coefficient for the Feedthrough Transfer Standard,
Γ_2 = reflection coefficient for the SUT.

When calibrating the Feedthrough Power Standard, the power splitter is removed and it's reflection coefficient is measured with a network analyzer. The power splitter is replaced in the Feedthrough Power Standard assembly and the reflection coefficient of the "sensor" port of the power splitter is the reflection coefficient for the entire assembly. Since the Feedthrough Power Standard is actually calibrated as an assembly, any impedance mismatch between the actual thermistor mount and the splitter are automatically factored in the calibration factor. Using the equation above, Γ_1 becomes the reflection coefficient for the Terminating Transfer Standard and Γ_2 becomes the reflection coefficient for the Feedthrough Transfer Standard.

Reflection Coefficient is a complex number expressed as a vector quantity. A vector quantity has two components a magnitude and phase angle. The magnitude of the reflection coefficient is symbolized by the Greek letter rho (ρ) and the phase angle by the Greek letter phi (ϕ). Often, the magnitude is the only part of the reflection coefficient used, which will yield a "worse case" mismatch uncertainty. Sometimes the Standing Wave Ratio (SWR) of a device is given rather than the reflection coefficient (Γ). SWR is a scalar quantity and related to ρ follows:

$$\rho = \frac{S - 1}{S + 1}$$

Where:

ρ = magnitude of the reflection coefficient,
S = Standing Wave Ratio (SWR).

Gamma Correction

If both the ρ and ϕ of the reflection coefficient are known for both the K1 and K2 or K2 and K1S (TEGAM provides this data for the RF Transfer Standards as part of the factory calibration), then Gamma corrections can be applied to the calibration factor. Applying Gamma corrections to the calibration factor reduces the total uncertainty of the calibration by eliminating M_{ER}.

Gamma corrections are applied to cal factor as follows:

$$\text{Corrected K} = \frac{K}{|1 + \Gamma_1\Gamma_2|^2}$$

Where:

Corrected K = cal factor after Gamma correction are applied,
K = cal factor before Gamma correction is applied,
Γ_1 = reflection coefficient of K_1 if calibrating a Feedthrough RF Power Standard or K_2 if calibrating an SUT,
Γ_2 = reflection coefficient of K_2 if calibrating a Feedthrough RF Power Standard or K_{1S} if calibrating an SUT.

That equation can be “simplified” to :

$$\text{Corrected K} = \frac{K}{(1 - \rho_1\rho_2 \cos(\phi_1 + \phi_2))^2 + (\rho_1\rho_2 \sin(\phi_1 + \phi_2))^2}$$

INSTRUMENT DESCRIPTION
PREPARATION FOR USE
OPERATING INSTRUCTIONS
THEORY OF OPERATION

SERVICE INFORMATION

Warranty:

TEGAM, Inc. warrants this product to be free from defects in material and workmanship for a period of 1 year from the date of shipment. During this warranty period, if a product proves to be defective, TEGAM, Inc., at its option, will either repair the defective product without charge for parts and labor, or exchange any product that proves to be defective.

TEGAM, Inc. warrants the calibration of this product for a period of 1 year from date of shipment. During this period, TEGAM, Inc. will recalibrate any product, which does not conform to the published accuracy specifications.

In order to exercise this warranty, TEGAM, Inc., must be notified of the defective product before the expiration of the warranty period. The customer shall be responsible for packaging and shipping the product to the designated TEGAM service center with shipping charges prepaid. TEGAM Inc. shall pay for the return of the product to the customer if the shipment is to a location within the country in which the TEGAM service center is located. The customer shall be responsible for paying all shipping, duties, taxes, and additional costs if the product is transported to any other locations. Repaired products are warranted for the remaining balance of the original warranty, or 90 days, whichever period is longer.

Warranty Limitations:

The TEGAM, Inc. warranty does not apply to defects resulting from unauthorized modification or misuse of the product or any part. This warranty does not apply to fuses, batteries, or damage to the instrument caused by battery leakage.

Statement of Calibration:

This instrument has been inspected and tested in accordance with specifications published by TEGAM, Inc. The accuracy and calibration of this instrument are traceable to the National Institute of Standards and Technology through equipment, which is calibrated at planned intervals by comparison to certified standards maintained in the laboratories of TEGAM, Inc.

Contact Information:

TEGAM, INC.
10 TEGAM WAY
GENEVA, OHIO 44041
PH: 440.466.6100
FX: 440.466.6110
EMAIL: sales@tegam.com

Repair Parts

Due to the calibration sensitivity of this instrument, it is not recommended to remove or replace any RF components within the RF Power Transfer Standard. In the event that damage or a malfunction has occurred, return the unit to TEGAM for repair and calibration. If the user chooses to replace an item within the RF Transfer Standard such as a connector or defective cable, the instrument must be recalibrated.

Preventive Maintenance

While the RF Transfer Standard requires very little preventive maintenance, it should not be subjected to physical abuse, severe mechanical shock, high humidity, or operating temperatures outside the specification range. The instrument should be kept free of excessive dirt and dust, since these can interfere with connector functions and with normal heat dissipation.

Connectors

Care should be taken to prevent strain on the interconnecting cables, since damage here may not always be apparent. Occasionally check the external cables and connectors for signs of cracked insulation and/or bent or worn pins. Tests show that connectors must be clean for accuracy and stability. This requires an inspection and cleaning of each connector immediately before use. When cleaning precautions are observed regularly, connectors can maintain their stability for over several thousand connection cycles.

Where small amounts of rust, corrosion, and/or oxide deposits are present on connectors, clean externally with a soft-bristle brush, aluminum wool, or internally with an acid brush; then wash with a noncorrosive solvent. MIL-C 83102 is recommended. Exercise care to ensure no metal filing or residue remains inside the connector and the connector is thoroughly dry. Where rust, corrosion, and/or oxide deposits are present in large quantities, replace the connector.

Calibration

Since the stability of the calibration factor of a thermistor mount depends upon the extent of use, degree of temperature stability and care in handling, TEGAM recommends recalibration of the standard every year. To recalibrate the unit, use one of the following methods:

1. Return the RF Power Transfer Standard to TEGAM indicating that recalibration or repair is necessary. TEGAM provides NIST traceable calibration of K_2 and K_1.
2. Send the Primary RF Power Transfer Standard to NIST (or other national standards agency) for recalibration. NIST only provides K_1 calibrations.
3. Transfer the known calibration factor of another mount to the mount requiring calibration as outlined in Section IV Theory of Operation.

Troubleshooting

Despite their sensitivity, thermistor beads are sturdy elements that can withstand up to 0.2 Watts for burnout. However, a burnout condition is eventually possible. An “open” reading at the DC bias binding post indicates a burnout condition. TEGAM power measuring instruments such as the Models 1805B, 1806, and 1804 have an “Error” light that will also indicates a burnout condition. High SWR or incorrect calibration factors could indicate a defective power splitter or broken RF connector.

The voltage across the bias terminals when RF power is not applied (bias voltage) is adjusted at the factory to be within 2.42 to 2.48 VDC. If the bias voltage is not within this range there may be a defective internal component. Bias voltage drift of more than 0.5 mVDC over a 24 hour period (with the internal heater connected to a heater controller) also indicates a defective internal component.

If any of these conditions exist contact TEGAM for service.

Preparation for Repair or Calibration Service:

Once you have verified that the cause for the RF Power Transfer Standard malfunction cannot be solved in the field and the need for repair and calibration service arises, contact TEGAM customer service to obtain an RMA, (Returned Material Authorization), number. You can contact TEGAM customer service via the TEGAM website, www.tegam.com or by calling 440.466.6100 OR 800.666.1010.

The RMA number is unique to your instrument and will help us identify your instrument and to address the particular service request by you which is assigned to that RMA number. Of even more importance is a detailed written description of the problem, which should be attached to the instrument. Many times repair turnaround is unnecessarily delayed due to a lack of repair instructions or lack of a detailed description of the problem.

The detailed problem description should include information such as type of sensor being tested, what is the voltage across the bias terminals when RF power is not applied?, what device was the Transfer Standard connected to?, is the problem intermittent?, when is the problem most frequent?, has anything changed since the last time the instrument was used?, etc. Any detailed information provided to our technicians will assist them in identifying and correcting the problem in the quickest possible manner. Use the Expedite Repair & Calibration form provided on the next page to provide detailed symptoms of the instrument's problem.

Once this information is prepared and sent with the instrument and RMA number to our service department, we will do our part in making sure that you receive the best possible customer service and turnaround time possible.

Expedite Repair & Calibration Form

Use this form to provide additional repair information and service instructions. The completion of this form and including it with your instrument will expedite the processing and repair process.

RMA#:		Instrument Model #:	
Serial Number:		Company:	
Technical Contact:		Phone Number:	
Additional Contact Info:			

Repair Instructions:

☐ Evaluation ☐ Calibration Only ☐ Repair Only ☐ Repair & Calibration ☐ A2LA Accredited Calibration (Extra Charge)

Detailed Symptoms:

Include information such as measurement range, instrument settings, type of components being tested, is the problem intermittent? When is the problem most frequent?, Has anything changed with the application since the last time the instrument was used?, etc.
