MODELS F1125 (A), F1130 (A) (B), F1135 (A) (B), M1125 (A), M1130 (A), M1135 (A)

Coaxial RF Power Standards

Instruction and Service Manual

TEGAM INC.

MODELS F1125(A), F1130(A)(B), F1135(A)(B), M1125(A), M1130(A), M1135(A)
Coaxial RF Power Standards

Model M1125   Model F1125

Model M1130   Model F1130

Model M1135   Model F1135

Instruction and Service Manual
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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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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
DUT Device 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 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 Reference and Working Standard configurations. The Working RF Power 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 II Power Sensor Calibration System (Figure 1.4). The Reference RF Power 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 Power Standards. The Working RF Power Standards feature a SENSOR, RF INput, BIAS VOLTAGE and TEMPerature connectors on the front panel. The Reference RF Power Standards feature an RF INput connector on the front and BIAS VOLTAGE and TEMPerature connectors in the rear. The Working RF Power 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 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 0.1 to 10 mW
Calibration Factor Drift	<0.5% per year
Individual calibrations traceable to NIST supplied at the following frequencies:	100, 200, 300, 455, 500 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 26.5GHz
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 (typical)	+/-0.80% from 0.1 to 10 MHz +/-0.90% from 10 to 4200 MHz	+/-1.0% from 0.1 to 10 MHz +/-1.1% from 10 to 4200 MHz

Connectors
    SENSOR
    RF IN
    TEMP
    BIAS VOLTAGE
	
	N-type Female
	SMA Female
	4-pin mini-microphone
	Binding Post, standard 0.75" spacing for banana plugs
		
		N/A
		N-Type Male
		4-pin microphone
		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
    Width
    Depth
	
	3.5 in (88.9 mm)
	8.5 in (215.9 mm)
	15.4 in (391.2 mm)
		
		3.3 in (83.8 mm)
		3.0 in (76.2 mm)
		7.45 in (189.2 mm)

Rack Mounting	Can be mounted in a standard 19" rack with optional hardware. See "Mounting" in section 2.	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 3 GHz 1.45 from 3 to 18 GHz
Insertion Loss	6 dB nominal, 9 dB max	1.5 dB max
Calibration Factor Accuracy (typical)	+/-0.80% from 0.1 to 10 MHz +/-1.00% from 0.01 to 10 GHz +/-1.10% from 10 to 18 GHz	+/-1.0% from 0.1 to 10 MHz +/-1.20% from 0.01 to 10 GHz +/-1.30% from 10 to 18 GHz

Connectors
   SENSOR
   RF IN
   TEMP
   BIAS VOLTAGE
	
	N-type Female
	SMA Female
	4-pin mini-microphone
	Binding Post, standard 0.75"
	spacing for banana plugs
		
		N/A
		N-Type Male
		4-pin microphone
		Binding Post, standard 0.75"
		spacing for banana plugs

Weight **(B) Model**	5.5 lbs (2.5 kg) 8.2 lbs (3.7 kg)	3.22 lbs (1.5 kg)

Physical Dimensions
   Height
   Width
   Depth
(B) Model
   Height
   Width
   Depth
	
	3.5 in (88.9 mm)
	8.5 in (215.9 mm)
	15.4 in (391.2 mm)
	
	3.5 in (88.9 mm)
	8.5 in (215.9 mm)
	13.875 in (352 mm)
		
		3.3 in (83.8 mm)
		3.0 in (76.2 mm)
		9.25 in (235 mm)

Rack Mounting	Can be mounted in a standard 19" rack with optional hardware. See "Mounting" in section 2.	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 18 GHz 1.75 from 18 to 26.5 GHz
Insertion Loss	6 dB nominal, 11.0 dB max	2.5 dB max
Calibration Factor Accuracy (typical)	+/-1.0% from 0.01 to 0.04 GHz +/-1.25% from 0.05 to 4.0 GHz +/-1.5% from 4.20 to 12.0 GHz +/-2.2% from 12.2 to 17.5 GHz +/-2.5 from 17.75 to 26.5 GHz	+/-1.2% from 0.01 to 0.04 GHz +/-1.4% from 0.05 to 4.0 GHz +/-1.7% from 4.20 to 12.0 GHz +/-2.3% from 12.2 to 17.5 GHz +/-2.6% from 17.75 to 26.5 GHz

Connectors
   SENSOR
   RF IN
   TEMP
   BIAS VOLTAGE
	
	3.5 mm Female
	SMA Female
	4-pin mini-microphone
	Binding Post, standard 0.75" spacing for banana plugs
		
		N/A
		3.5 mm Male (older version may have 2.92 mm)
		4-pin microphone
		Binding Post, standard 0.75" spacing for banana plugs

Weight **(B) Model**	6.27 lbs (2.8 kg) 7.64 lbs (3.5 kg)	2.88 lbs (1.3 kg)

Physical Dimensions
   Height
   Width
   Depth
(B) Model
   Height
   Width
   Depth
	
	3.5 in (88.9 mm)
	8.5 in (215.9 mm)
	15.4 in (391.2 mm)
	
	3.5 in (88.9 mm)
	8.5 in (215.9 mm)
	13.875 in (352 mm)
		
		3.3 in (83.8 mm)
		3.0 in (76.2 mm)
		7.1-7.45 in (180.3 to 189.2 mm) depending on version

Rack Mounting	Can be mounted in a standard 19" rack with optional hardware. See "Mounting" in section 2.	None

Coaxial RF Power Standards with an "A" & "B" Suffix in the Model Number

Some of these Coaxial RF Power Standards have a model number with "No" letter suffix at the end and some have an "A" or "B" suffix. There is no fit, form, or function difference between the "A" versions and the "No" letter suffix. On the "B" version the internal workings and external electrical connections are identical and the case is the only difference. Therefore, the information contained in this manual applies to all three. If in the text of this manual a model number is used without the letter suffix, the information also applies to the same model with a letter "A" and "B" suffix.

It was discovered that a small amount of the RF signal could leak through the thermistor mounts into the DC Substitution circuit (see Chapter IV Theory of Operation). This leakage only occurs at specific frequencies (100 kHz for the F&M1125 and F&M1130 and 10 MHz for the F&M1135) and could cause errors in the DC substitution measurement (typically less than 1%). In order to reduce this leakage, a common mode choke was added in the models with an "A" and "B" suffix. An external common mode choke assembly (P/N 1000027) can be used with models without the "A" or "B" suffix to reduce the RF leakage. Contact TEGAM for more information.

Additional Equipment

Table 1.5 lists the additional equipment required to operate RF Power 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

RF Level Controller	TEGAM Model 1805B
Type IV Power Meter	1806 (A), 1804/1820
DVM	DC Volts, 6½-digit minimum resolution.
Power meter	1830A

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

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

Signal Generator

Power Meter

AM Input

RF Output

AM Out (rear of 1805B)

Model 1805B

Model F11XX

RF IN TEMP IN

SENSOR

DUT

TEMPERATURE

BIAS VOLTAGE

BIAS VOLTAGE
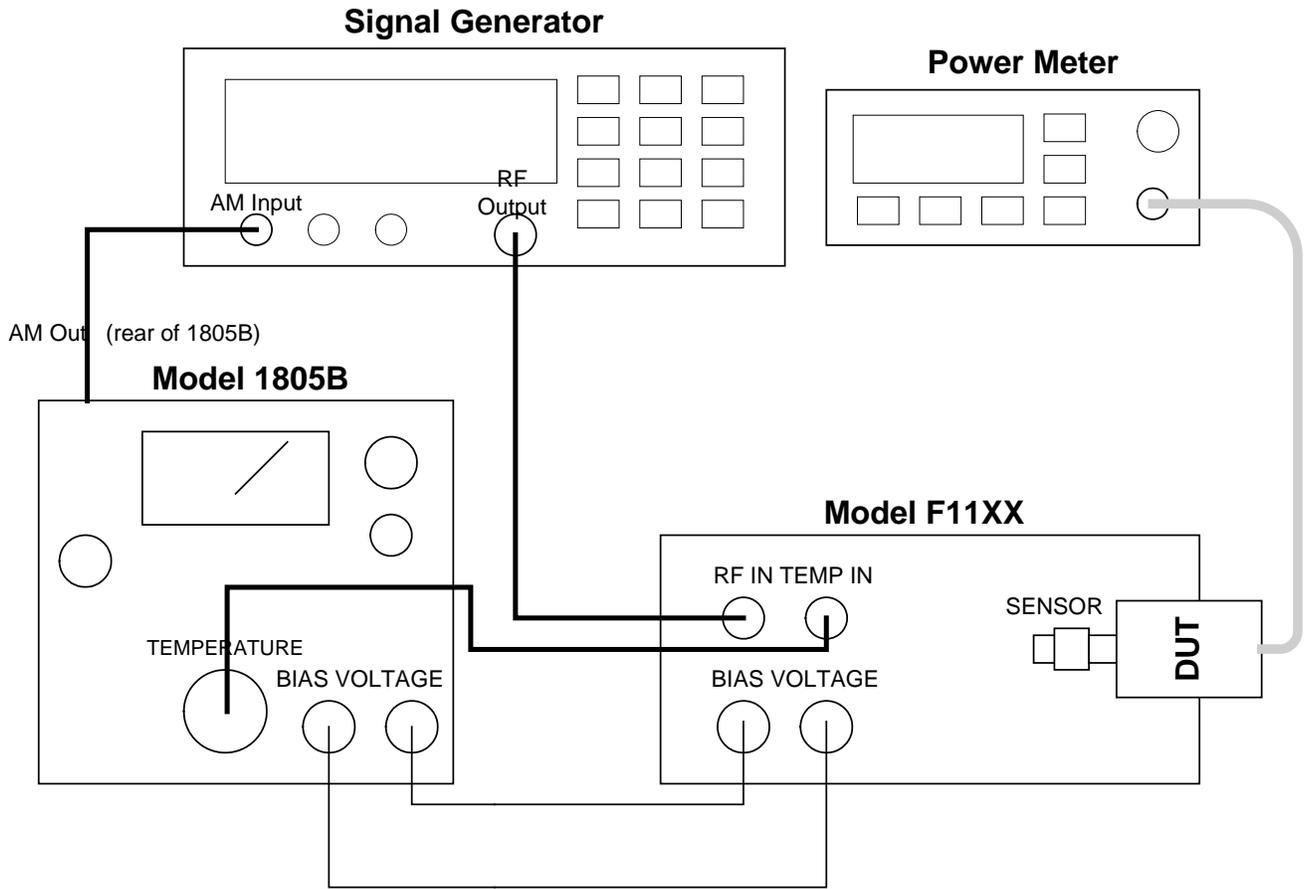
**Figure 1.4 RF Power Sensor Calibration Using a Working Standard
(Model F1125, F1130, F1135)**
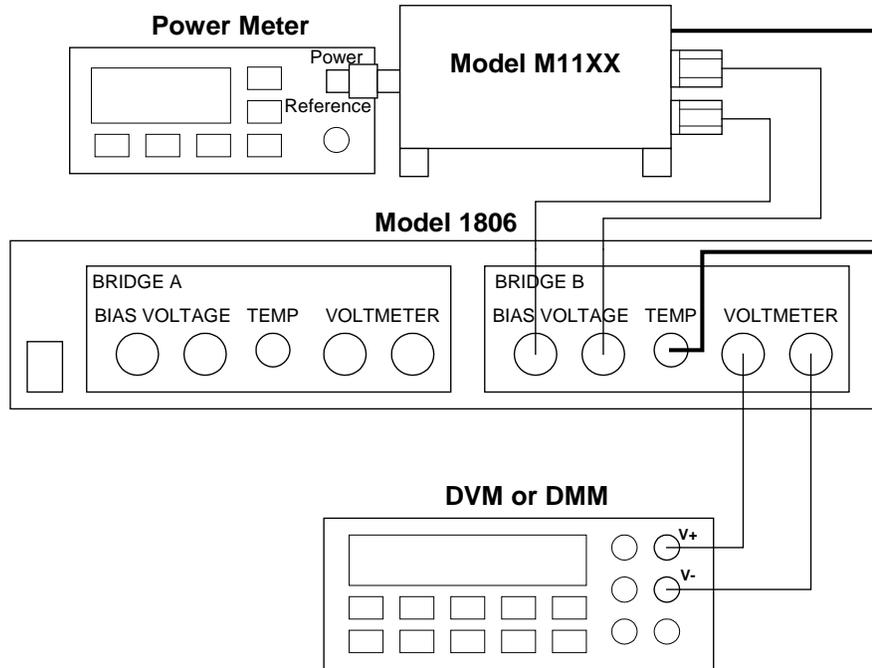
Figure 1.5 Measuring a 50 MHz Reference Output on a Power Meter using a Terminating RF Power Standard (Model M1125, M1130, M1135)
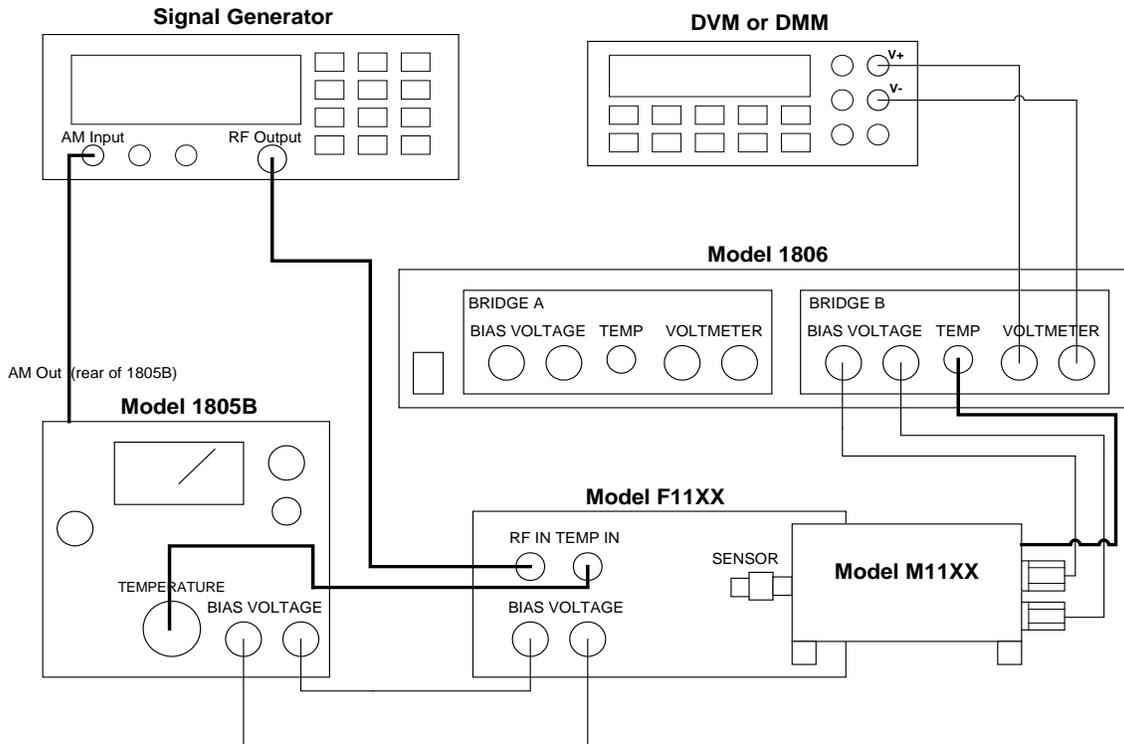
Figure 1.6 Calibration of a Working Power Standard Using a Reference Power Standard

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Unpacking & Inspection:

Each RF Power 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 (A), F1130 (A) (B), F1135 (A) (B), M1125 (A), M1130 (A), or M1135 (A) RF Power Standard
Operating Manual (CD)   P/N IM300
Calibration Certificate with data
Electronic storage device containing calibration data
F1125 (A), F1130 (A), and F1135 (A) **ONLY -** Heater Cable   P/N CA-10-48

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 (A), F1130 (A), and F1135 (A) can also be rack mounted in a standard 19" rack, using the optional rack mount kit F1120-RMK.
For Model F1130B and F1135B use rack mount kit, (Single) P/N 1830-910 – (Dual) P/N 1830-911.

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
(ESD symbol)	CAUTION – Electrostatic sensitive terminals discharge to ground before touching read manual for procedure.
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 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 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 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 Standards are designed to be used with TEGAM Models 1805B, 1806(A), 1804, 1830A, or an instrument that uses a Type IV DC Substitution Bridge. 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(A), 1820 and 1830A. 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 Standards. All equipment should be operated from either a regulated 115 VAC or 230 VAC supply.

⚠ Servicing Safety Summary:

Do Not Service Alone

Do not perform service or adjustment on this product unless another person capable of rendering first aid is present.

Use Care When Servicing with Power On or Off

Dangerous voltages may exist at several points in this product. To avoid personal injury or damage to this equipment, avoid touching exposed connections or components while the power is on. Assure that the power is off by disconnecting the instrument when removing panels, soldering, or replacing components.

WARNING: Do not wear jewelry (rings, bracelets, metal watches, neck chains) while working on exposed equipment.

CAUTION – SENSITIVE TO ELECTROSTATIC DISCHARGE

The Red and Black binding posts for the Bias connection are sensitive to Electrostatic Discharge. The binding posts are directly connected to the thermistor beads, which can be damaged by ESD. Before touching the binding posts, discharge both the product and your body, by touching a known ground and the outer conductor of the RF connector on the product. Connect the Bias leads to your bridge balancer (TEGAM 1806 or 1830A) before connecting them to the product.

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General

The TEGAM RF Power 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 II Power Sensor Calibration System. Proper use of these standards and the TEGAM System II is further documented in other TEGAM Operation and Service Manuals. The Working RF Power Standards (Models F1125, F1130, and F1135) are feedthrough mount-splitter combinations are use to calibrate thermoelectric, diode, and thermistor power sensors. The Reference RF Power Standards (Models M1125, M1130, and M1135) are terminating thermistor mounts commonly used as a reference standard for calibrating working standards. Both types of standards are used with a precision DC Substitution Bridge such as found in the TEGAM Models 1806(A), 1805B, and 1830A.

## Model F1125, F1130, and F1135 Connector Descriptions
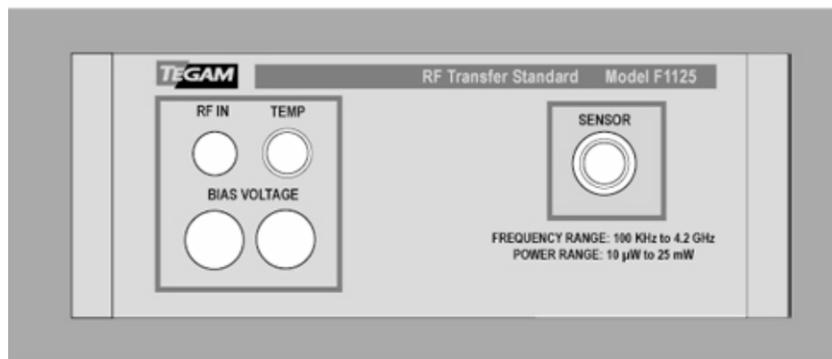
Figure 3.1 Model F1125 Front View

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 DUT and the power standard. The fact that equal RF power is applied to both the power standard and the DUT is what allows the determination the calibration factor of the DUT. 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 Chapter 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(A), 1830A, and 1820. RF Power 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 DC Substitution bridge circuit as is found in the TEGAM Models 1805B, 1806(A), 1830A, and 1804. The 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 DUT. The RF power applied to RF IN connector is applied equally to the DUT and the internal thermistor mount. The fact that equal RF power is applied to both the power standard and the DUT is what allows the calibration factor of the DUT 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
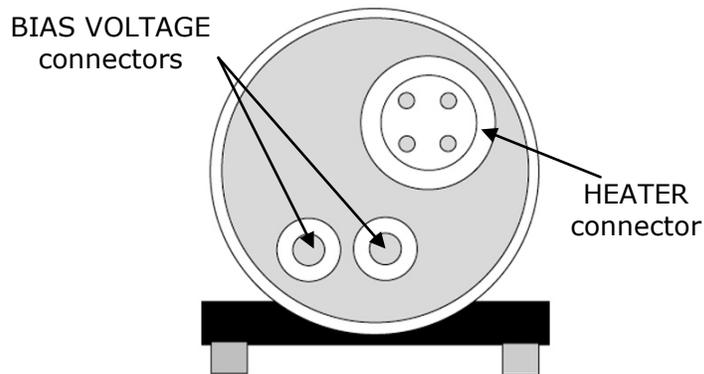
Figure 3.2 Model M1125/M1130/M1135 Rear View

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(A), 1830A, and 1820. RF Power 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, 1830A, and 1820.

BIAS VOLTAGE connectors

Binding posts used to connect the thermistor element to a DC Substitution bridge circuit as is found in the TEGAM Models 1805B, 1806(A), 1830A, and 1804. The 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 3.5 mm on the M1135 (older version may have a 2.92 mm connector).

Connecting RF Power Standards

The TEGAM RF 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 standard, the internal heater must be connected to an instrument with a heater control circuit such as the TEGAM 1805B, 1806(A), 1830A, or 1820. To do this, simply connect one end the appropriate cable to the "TEMP" or heater connector on the Standard and the other end to the "TEMP" or "TEMPERATURE CONTROL" connector on the instrument. Use one of the following cables that meet your equipment applications.

> P/N CA-10-48 (MIC to Mini-MIC): F1125, F1130, and F1135 to 1805B, 1806, and 1820
> P/N CA-11-48 (Mini-MIC to Mini-MIC): F1125, F1130 and F1135 to 1806A and 1830A
> P/N 138-477 (MIC to MIC): M1125, M1130 and M1135 to 1805B, 1806, and 1820
> P/N CA-10-48 (MIC to Mini-MIC): M1125, M1130 and M1135 to 1806A and 1830A

Models F1125 (A), F1130 (A) and F1135 (A) heater cable P/N CA-10-48 is provided. For Models M1125, M1130 and M1135 use the cable supplied with the 1805B, 1806(A) or 1820. For Models F1130B and F1135B cables may be purchased separately.

Next, the BIAS VOLTAGE red and black connectors are cabled to the BIAS VOLTAGE connectors on an instrument with a DC Substitution bridge like the TEGAM Models 1805B, 1806(A), 1830A, and 1804. The BIAS VOLTAGE connectors of the standards are 5-way binding posts so banana plugs or spade lugs can be used. See the mating equipment instruction manual for the correct Bias Voltage cable part number.

The RF IN on the Working (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 DUT is connected to this port for calibration. When the Working RF Power Standard is being calibrated, the Reference 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 Reference (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 3.5 mm on the M1135 (older version may have a 2.92 mm connector). 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 Standards. However, allow at least two hours for the heater in the RF Standard to reach its operating temperature. Additionally, it is recommended that once the BIAS VOLTAGE terminals are connected, the DC Substitution Bridge should be on for one hour before measurements are taken.

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Temperature Variable Resistance

Each RF 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.
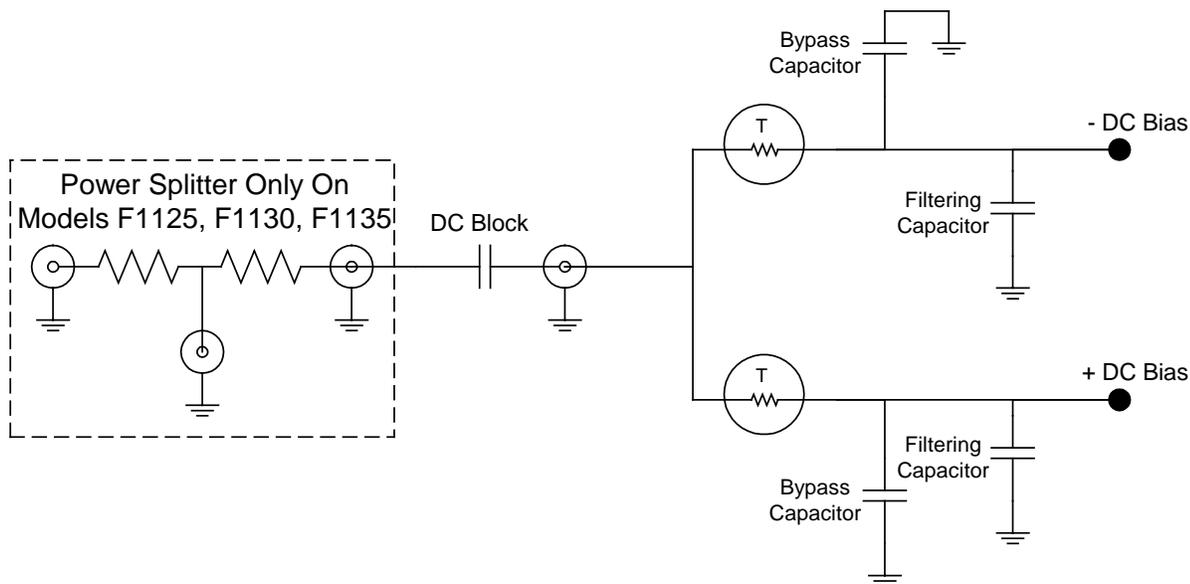
Figure 4.1 Simplified Schematic of RF Power Standards

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 all the heater windings are equal in 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.
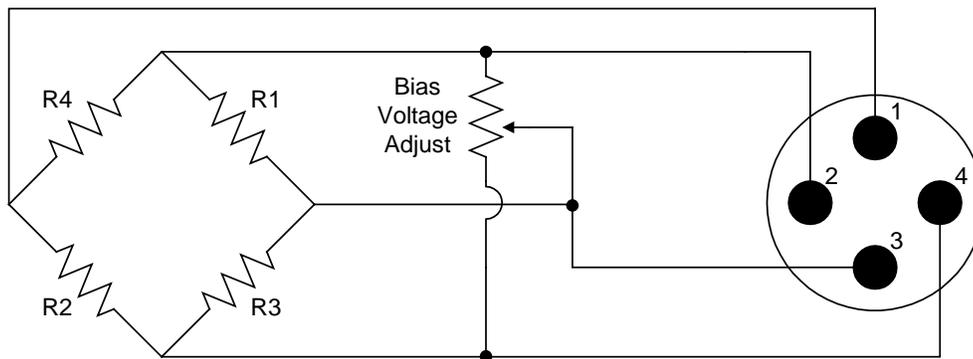
Figure 4.2 Simplified Schematic of RF Power Standards Internal Heater

Principle of DC Substitution

The RF Power 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 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 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 Standard traceable to NIST

CALIBRATION FACTORS

For a Terminating RF Power 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 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 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 Standard,
   P_{dc2} = DC substituted power measured by the device connected to the Feedthrough RF Power
        Standard,
   P_{RF} = Level of applied RF power,
   P_{dc1} = DC substituted power measured by the device connected to the Terminating RF Power
        Standard,
   K_1 = calibration factor of the Terminating RF Power 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 Standard is used to determine the calibration factor for other terminating powers sensors. The calibration factor for a Device Under Test (DUT) is denoted as K_{1S} and is determined by first determining P_{RF}:

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

The DUT must be connected to a compatible power meter; the readings are then used to determine the calibration factor of the DUT 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
        Standard,
   K_2 = calibration factor of the Feedthrough RF Power Standard,
   K_{1S} = calibration factor of the DUT,
   P_m = reading from the DUT 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 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 a DUT). When an RF Power Standard is calibrated, an uncertainty is reported for each calibration point. Even 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 Standards is included as part of the factory calibration data. Mismatch error (M_{ER}) is determined from the reflection coefficients of both the Feedthrough Standard and the DUT 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 Standard,
Γ_2 = reflection coefficient for the DUT.

When calibrating the Feedthrough Power Standard, the power splitter is removed and its 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 Standard and Γ_2 becomes the reflection coefficient for the Feedthrough 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 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:

$$\text{Corrected } K_2 = \frac{K_2}{|1 - \Gamma_1\Gamma_2|^2}$$

Or

$$\text{Corrected } K_{1S} = K_{1S}\, |1 - \Gamma_2\Gamma_{1S}|^2$$

Where:

K_2 = calibration factor of the Feedthrough RF Power Standard,
K_{1S} = calibration factor of the DUT,
Γ_1 = reflection coefficient of the Terminating RF Power Standard,
Γ_2 = reflection coefficient of the Feedthrough RF Power Standard,
Γ_{1S} = reflection coefficient of the DUT,

The "Gamma Correction" part of the previous equations can be rewritten in terms of reflection coefficient magnitude (ρ) and angle (ϕ):

$$(1 - \rho_1\rho_2 \cos(\phi_1 + \phi_2))^2 + (\rho_1\rho_2 \sin(\phi_1 + \phi_2))^2$$

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Table 5.1 List of Equipment Required for Calibration

Voltmeter (X2)	
Range:	10 V
Minimum Resolution:	6.5 digit
Input Impedance:	100 Kohm or greater (resistive)
Accuracy:	+/- 0.005%
Scalar Network Analyzer	
Frequency Range:	Same as the Power Standard being calibrated
Vector Network Analyzer (optional)	
Frequency Range:	Same as the Power Standard being calibrated
TEGAM Model M11XX Reference RF Power Transfer Standard	
Frequency Range:	Same as the Power Standard being calibrated
Dynamic Range:	0 to +10 dBm (1 to 10 mW)
TEGAM Model 1806 Type IV Power Meter or equivalent	
Nominal Bridge Resistance:	200 Ohms
Bridge Accuracy:	+/-0.003%
CW RF Signal Source:	
Frequency Range:	Same as the Power Standard being calibrated
Power Output:	+6 dBm minimum, up to +16 dBm
13/16" Torque Wrench	
Torque Value	14 +/-1 in-lbs for N-type connectors
5/16" Torque Wrench	
Torque Value	7-8 in-lbs for SMA and 3.5 mm connectors
9/64", 7/64", and 5/64" Allen (Hex) Wrench	
#1 and #2 Philips head screwdriver	
1/4" wrench	

Note: The procedures in this chapter apply to the F1125, F1130, and F1135 Working RF Power Standards. If one of these units fails any Calibration procedure and cannot be adjusted to its specifications, contact TEGAM for assistance. Contact information and instructions for returning an instrument to TEGAM can be found in Chapter VI Service Information in this manual.

Remove the Top Cover

Remove the top cover of the Working Power Standard to access the internal assemblies.

1. Remove four screws in rear panel on "No" suffix and "A" version or top and bottom cover screws on "B" version using Philips screwdriver.

"No" suffix and "A"   "B" Suffix

Figure 5.1 Locations of Four Rear Screws

2. On "No" suffix and "A" versions remove the rear panel and slide the top cover towards the rear of the unit.

3. On "B" versions lift the rear of the top and bottom covers upward and remove.

Power Splitter Calibration

The power splitter calibration characterizes the impedance match of the output port of the Working RF Power Standard and verifies it is within specification. While a Scalar Network Analyzer can be used, **TEGAM recommends a Vector Network Analyzer be used to measure not only the magnitude but also phase of the reflection coefficient**; that data can be used later to apply Gamma corrections to the cal factor of the Standard.

1. Disconnect all cables from rear of the Thermistor Mount Assembly inside the Model F1125, F1130, or F1135. Disconnect the semi-rigid coaxial cable from the back of the RF IN bulk head connector.

   a. On "No suffix and "A" versions slide the Thermistor Mount Assembly toward the rear far enough so the SENSOR port clears the front panel. Disconnect the semi-rigid cable from the input of the power splitter.

   b. On "B" versions remove the four large screws holding the mount assembly to the chassis plate.

Four large screws
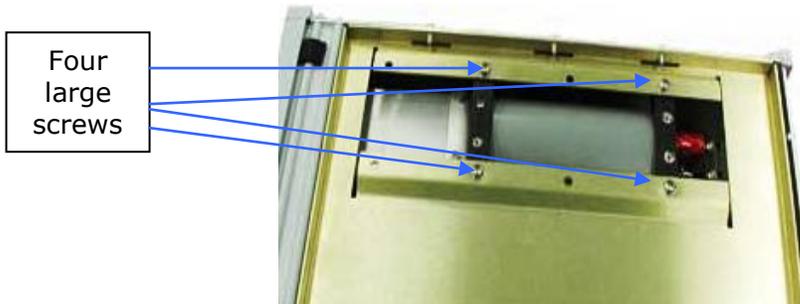
Figure 5.2 Location of Power Splitter in the F1125/F1130 and F1135

2. Remove the power splitter from the Thermistor Mount Assembly. The power splitter is connected to the Thermistor Mount by a Splitter Support Bracket.
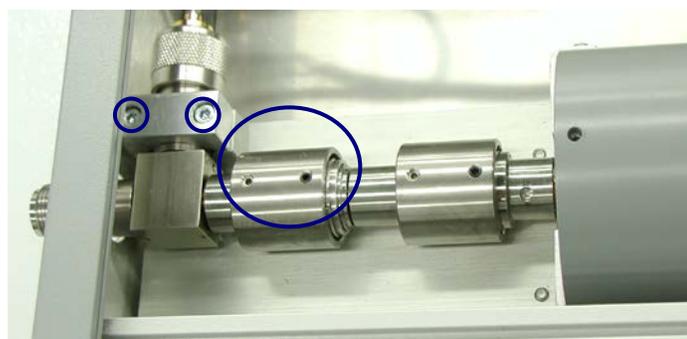
Figure 5.3 Locations of Allen Head Screws and Collar on F1125 and F1130

a) **For Models F1125 and F1130 (Type N connectors):** Refer to figure 5.3. Remove 2 Allen head screws that clamp power splitter input to Splitter Support Bracket. Remove collar that is over the thermistor mount output connector by loosening two set screws and sliding the collar forward. Then loosen the nut on the type N male connector. **NOTE:** The F1130 have two type N junctions; only loosen the junction that is connected to the power splitter.

Figure 5.4 Locations of Phillips Head Screws on F1135 Splitter Support Bracket

b) **For Model F1135 (3.5 mm connectors)**: Remove 2 Phillips head screws and nuts that clamp power splitter input to Splitter Support Bracket. If there is a cover (not all F1135's have one) over the thermistor mount output connector, remove it by loosening two set screws and lifting the cover off. Then loosen the nut on the 3.5 mm male connector.
NOTE: Some F1135's may have two type 3.5 mm junctions, only loosen the junction that is connected to the power splitter.

3. Setup and calibrate the Network Analyzer to measure insertion loss and SWR of the power splitter. Clean and inspect all coaxial connectors on the Network Analyzer, power splitter, and thermistor mount. TEGAM also recommends checking the pin depth of the power splitter and thermistor mount. Use care when connecting and disconnecting all coaxial connectors and use proper torque wrench when connecting.

4. Terminate Output Port 3 of the power splitter. Connect Input Port 1 and Output Port 2 to the network analyzer to measure insertion loss (S21) and the reflection coefficient of Port 2 (S22). Record these measurements for each calibration frequency. The insertion loss (S21) should not exceed 7.5 dB for the Type N power splitter and 8.5 dB for the 3.5 mm splitter.

5. Terminate Output Port 2 of the power splitter. Connect Input Port 1 and Output Port 3 to the network analyzer to measure insertion loss (S31) and the reflection coefficient of Port 2 (S33). Record these measurements for each calibration frequency. The insertion loss (S31) should not exceed 7.5 dB for the Type N power splitter and 8.5 dB for the 3.5 mm splitter.

6. Terminate Input Port 1 of the power splitter. Connect Output Port 2 and Output Port 3 to the network analyzer to measure insertion loss (S23). Record these measurements for each calibration frequency.

7. Calculate the equivalent source match (Γ_2) of the power splitter at each frequency by one of the following equations.

<div align="center">

If Port 2 is to be the SENSOR port of the Working Standard:
Γ_2 = S22 − ((S21/S31) X S23)

If Port 3 is to be the SENSOR port of the Working Standard:
Γ_2 = S33 − ((S31/S21) X S32)

</div>

Note: The preceding steps can be simplified assuming the splitter has good tracking between the output ports, that is, S21 very nearly equals S31. That would mean the ratio of S21 to S31 would equal approximately 1, and those values would cancel each other out in the equations in step 7. Thus the equivalent source match would equal the measured reflection coefficient of the output port minus the insertion loss between the output ports. Those two measurements can be obtained without changing connections.

8. Record the equivalent source match as the reflection coefficient magnitude (ρ) and angle (ϕ), or SWR, for the Working Standard at each frequency point. Verify the reflection coefficient magnitude (ρ) or SWR is within the specified limits for the particular model of Working Standard (refer to specifications table for the particular model in Chapter I Description in this manual). If using SureCal calibration software enter the reflection coefficient in a SureCal ".dat" file for the Working Standard.

9. Reassemble the power splitter to the thermistor mount. Make sure all coaxial RF connectors are properly torqued. The type N connectors should be torqued to 14 +/-1 in-lbs and the 3.5 mm connectors to 7-8 in-lbs.

10. Slide the Thermistor Mount Assembly toward the front of case making sure the splitter output port that is the SENSOR port is all the way through the front panel. Reconnect all cables to the Thermistor Mount Assembly.

Thermistor Bias Voltage Calibration

This test verifies the DC bias voltage of the thermistor mount. The DC bias voltage is the voltage across a DC Substitution Bridge with no RF signal applied to the thermistor detector and the bridge circuit balanced and stable. Not only should this procedure be performed on the Working Standards (F1125, F1130, F1135) but also on the Reference Standards (M1125, M1130, M1135) before sending them to a primary standards lab for calibration.

1. Connect the standard to an instrument with a compatible heater control circuit and a Type IV DC Substitution Power Meter (TEGAM 1806(A)) (see "Connecting RF Power Standards" in Chapter III Operating Instructions). Make sure the standard has been warmed up for at least two hours. Do not connect an RF signal generator to the input of the standard.

2. Connect a DVM to the red and black VOLTMETER connectors on the 1806(A). Connect red to positive and black to negative.

3. The voltmeter should read 2.45 +/- 0.03 VDC. If it does not, then the DC bias voltage will have to be adjusted.
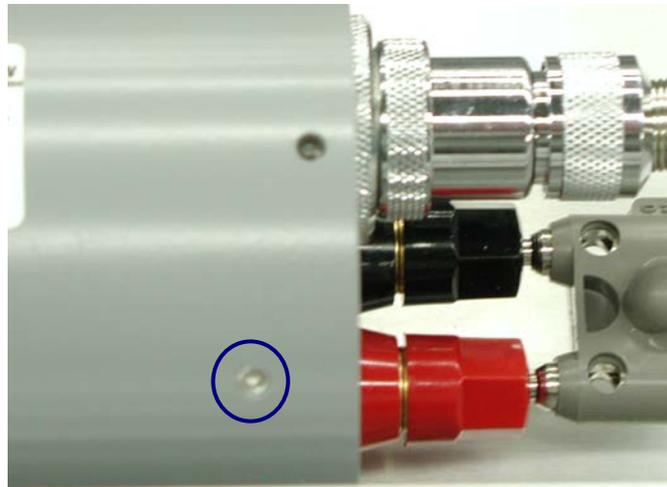
Figure 5.5 Location of Bias Adjustment

4. To adjust the DC bias voltage, locate the small hole in the Thermistor Mount casing near the back. Remove any cal void stickers if necessary. Remove the plug using a 5/64" Allen wrench

5. Using a small tip slotted screw driver, turn the Bias Voltage Adjustment. CCW will increase the bias the voltage, CW will decrease it. This must be done very slowly. Only turn the adjustment screw a quarter turn at a time. It will take the bias voltage up to half an hour to settle after one quarter turn adjustment is made.

6. Once the Bias Voltage has been adjusted to 2.45 V, replace the plug in the Bias Voltage Adjustment access hole.

Calibration Factor

This test characterizes the calibration factor of the Working Power Standards (F1125, F1130, and F1135). The Working standard is characterized from the SENSOR port using a Reference Power Standard (M1125, M1130, or M1135). This procedure can be automated using SureCAL Automated Metrology Software.

1. Replace the top cover on the Working Power Standard. It should be fully assembled for the rest of the calibration.

2. Connected both the Reference and Working Power Standards to an instrument with a compatible heater control circuit and a DC Substitution Power Bridge (TEGAM 1806(A)) (see "Connecting RF Power Standards" in Chapter III Operating Instructions). Make sure both standards have been warmed up for at least two hours.
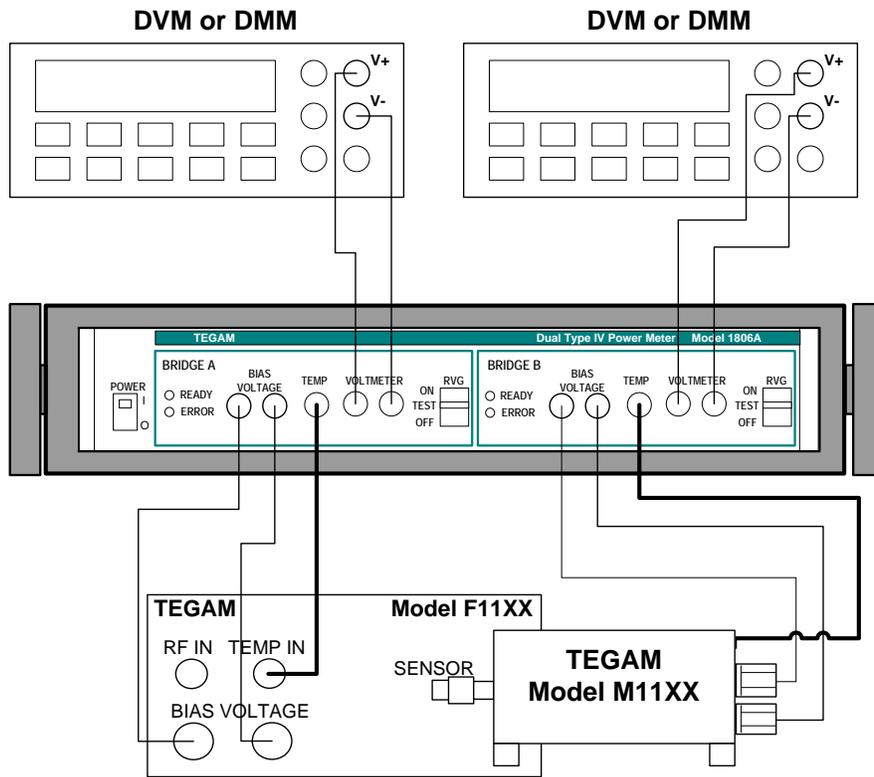
Figure 5.6 Connection Diagram for Characterizing a Working Standard

3. Connect the Reference (Terminating) RF Power Standard to the Sensor port of the Working Standard (refer to Figure 5.6). To connect the standards, turn the feet on the Reference Standard so they're all the way up. Support the mount with one hand while tightening the nut on the male connector, taking care to get a good connection between the connectors. Once a good connection has been made adjust the feet of the Reference Standard (while still supporting with the other hand) so they will hold the weight. Make sure RF connectors are clean and use proper torque wrench to tighten.

4. Connect Signal Generator output to the input of the Working (Feedthrough) Power Standard (refer to Figure 5.6). Make sure RF connectors are clean and use proper torque wrench to tighten.

5. Connect a voltmeter to the VOLTMETER connectors on the Type IV Power Meter that is being used with the Reference Standard. Connect another voltmeter to the VOLTMETER connectors on the Type IV Power Meter that is being used with the Working Standard (refer to Figure 5.6).

6. Make sure the output of the Signal Generator is off. Record the DC voltage from the Type IV Power Meter that is being used with the Reference Standard as V_{OFF1} and the DC voltage from the Type IV Power Meter that is being used with the Working Standard as V_{OFF2}.

7. Set the Signal Generator frequency to the first frequency that the Working Standard will be calibrated at and set the power level for +6 dBm (for 0 dBm at SENSOR port) with a Continuous Wave (CW) output. Turn the output of the Signal Source on. After the voltage has settled, Record the DC voltage from the Reference Standard as V_{ON1} and the DC voltage from the Working Standard as V_{ON2}.

8. Change the frequency of the signal source to the next frequency at which the Working Standard is to be calibrated. Record the DC voltage from each voltmeter after the voltage has settled as described in Step 7. Repeat this step for each remaining calibration frequency.

Note: A nominal power level setting of +6 dBm on the Signal Generator will provide approximately 0 dBm (1 mW) at the SENSOR port of the Working Standard. That is due to losses in the coaxial power splitter, cables, and adapters. This level can be adjusted according to actual losses which can be determined by measurements made from the Reference Power Standard. It is recommended the level at the SENSOR port be kept as close to 0 dBm (1 mW) as possible at each calibration frequency.

9. Calculate the calibration factor for the Working Standard at each frequency by:

$$K_2 = K_1 * \frac{(V_{OFF2}^2 - V_{ON2}^2)}{(V_{OFF1}^2 - V_{ON1}^2)}$$

Where:

    K_2 = Calibration factor of the Working Standard,
    V_{OFF2} = DC voltage from Working Standard with no RF Power applied,
    V_{ON2} = DC voltage from Working Standard with RF Power applied,
    V_{OFF1} = DC voltage from Reference Standard with no RF Power applied,
    V_{ON1} = DC voltage from Reference Standard with RF Power applied,
    K_1 = Calibration factor of Reference Standard.

Gamma Corrections (optional)

This part of the procedure is optional and only applies if the Reflection Coefficient magnitude (ρ) and angle (ϕ) was measured and recorded during the Power Splitter Calibration. The Reflection Coefficient magnitude (ρ) and phase angle (ϕ) must also be known for the Reference RF Power Standard. **TEGAM strongly recommends applying Gamma Corrections as it will provide a more accurate calibration with the lowest uncertainty**.

10. Apply Gamma Corrections to the calibration factor of the Working Standard at each frequency by:

$$\text{Corrected } K_2 = \frac{K_2}{|1 - \Gamma_1\Gamma_2|^2}$$

Where:

Corrected K_2 = cal factor of the Working Standard after Gamma correction is applied,

K_2 = cal factor of the Working Standard before Gamma correction is applied,

Γ_1 = reflection coefficient of the Reference Power Standard,

Γ_2 = reflection coefficient of the Working Standard

The same formula in terms of magnitude (ρ) and phase angle (ϕ):

$$\text{Corrected } K_2 = \frac{K_2}{(1 - \rho_1\rho_2 \cos(\phi_1 + \phi_2))^2 + (\rho_1\rho_2 \sin(\phi_1 + \phi_2))^2}$$

Where:

Corrected K_2 = cal factor of the Working Standard after Gamma correction are applied,

K_2 = cal factor of the Working Standard before Gamma correction is applied,

ρ_1 = reflection coefficient magnitude of the Reference Standard,

ϕ_1 = reflection coefficient phase angle of the Reference Standard,

ρ_2 = reflection coefficient magnitude of the Working Standard,

ϕ_2 = reflection coefficient of the phase angle Working Standard.

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Warranty:

TEGAM, Inc. warrants this product to be free from defects in material and workmanship for a period of 3 years 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 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 Standard such as a connector or defective cable, the instrument must be recalibrated.

Preventive Maintenance

While the RF 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 Standard to TEGAM indicating that recalibration or repair is necessary. TEGAM provides NIST traceable calibration of K_2 (Working Standard) and K_1 (Reference Standard).
2. Send the Reference RF Power Standard to NIST (or other national standards agency) for recalibration. NIST only provides K_1 calibrations.
3. Calibrate the Working Power Standard using a Reference Power Standard as described in Section V Maintenance.

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(A), 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 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 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.