10kW Model 1316 Precision Calorimeter

User Manual

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Safety Information and 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.

> ⚠ **CAUTION:**
>
> DO NOT USE IN EXPLOSIVE ENVIRONMENTS!
>
> The 1314 is not designed for operation in explosive environments.

> ⚠ **WARNING:**
>
> DO NOT OPERATE WITHOUT COVERS!
>
> This device should be operated with all panels and covers in place. Operation with missing panels or covers could result in personal injury.

Terms in this Manual

> ⚠ **CAUTION:**
>
> CAUTION indicates a potentially hazardous situation that, if not avoided, could result in minor or moderate injury, and/or property damage. CAUTION is also used for property-damage-only accidents.

> ⚠ **WARNING:**
>
> WARNING indicates a potentially hazardous situation that, if not avoided, could result in death or serious injury, and/or property damage.

> **DANGER:**
>
> DANGER indicates an imminently hazardous situation that, if not avoided, will result in death or serious injury. DANGER is limited to the most extreme situations.

NOTE statements identify best practices or tips for efficiency.

Terms on Equipment

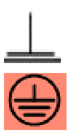
CAUTION indicates a personal injury hazard not immediately accessible as one reads the marking, or a hazard to property including the equipment itself.

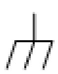
DANGER indicates a personal injury hazard immediately accessible as one reads the marking.

Symbols as Marked on Equipment

 CAUTION – RISK OF DANGER

 DANGER – Risk of Electric shock

 Earth ground terminal

 Frame or Chassis terminal

 Alternating current

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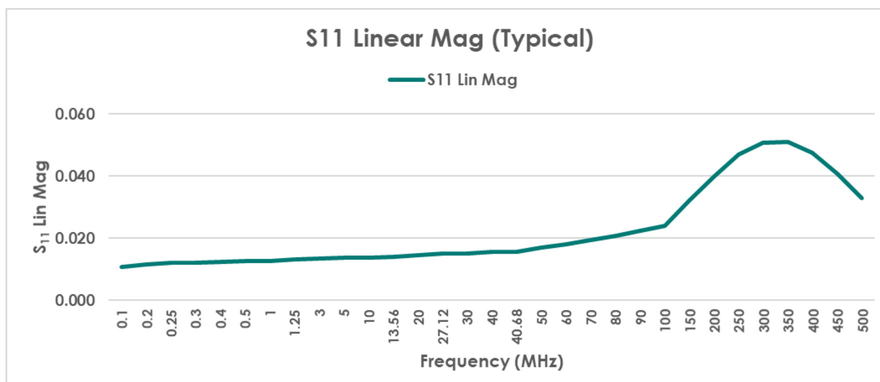
Product Overview and Specifications

Specifications

Measurement Ranges	Specification
Frequency (MHz)	50 Hz to 500 MHz
Power (W)	Connector/Frequency Dependent: **With standard HN connector**: 10 W to 10,000 W: 50 Hz to 2 MHz 10 W to 8,900 W: >2 MHz to 13.56 MHz 10 W to 6,200 W: >13.56 MHz to 27.12 MHz 10W to 5,000 W: >27.12 MHz to 40.68 MHz 10W to 4,100 W: >40.68 MHz to 60 MHZ 10 W to 2,200 W: >60 MHz to 200 MHz 10 W to 1,300 W: >200 MHz to 500 MHz **With optional 3-1/8" connector**[5]: 10 W to 10,000 W: 50 to 500 MHz
Connector Type	HN (female) standard, 3-1/8" optional[5]
Basic Accuracy	1.5 W + 0.3% Rdg[1, 2, 3, 5]
Power Requirements	
Calorimeter	220 – 240 VAC, 20 A
Chiller	220 – 240 VAC, 20 A
Course Chiller (optional)	208 VAC, 3-Phase, 16.5 A[6]
AC Source (optional)	208 VAC, 3-Phase, 42 A[6]
AC Standard (Optional)	100 – 240 VAC, 10 A[6]
Physical Dimensions (Approximate)	

Specifications (continued...)

Calorimeter/Chiller	56” height, 23” width, 30”/50” depth (together in single bay rack (/w/table))
Calorimeter	9” height, 19” width, 30” depth (removed from rack)
Fine Chiller	11” height, 19” width, 25” depth (removed from rack)
Course Chiller (Optional)	63” height, 33” width, 30” depth[6]
AC Source (Optional)	58” height, 25” width, 34” depth[6]
AC Standard (Optional)	8” height, 12” width, 23” depth[6]
Coolant Flow Rate	4 gallons (15.2 Liters) per minute nominal
Drift	< 50% of uncertainty over 48 hours
Input Impedance	50 Ω nominal
Communication	Ethernet
Cooling Fluid	25% DOW-Therm SR-1, 75% distilled water
Operating Temperature	68 to 86 °F (20 to 30 °C)
Storage Temperature	14 to +122 °F (-10 to +50 °C)[4]
Warranty	1-year Parts & Workmanship for AE-TEGAM-manufactured components
S11 Linear Magnitude (Typical)	Typical < 0.025 at *f* < 100 MHz, and <0.1 at *f* >= 100 MHz  Typical S_{11} Linear Mag Performance

Optional System Components (contact your AE-TEGAM representative for more information).

AC Source	Required for routine calibration of the Calorimeter.
AC Power Meter	Required for routine calibration of the calorimeter.
Course Chiller-Air/Water Cooled	Required to pre-cool cooling fluid before fine cool chiller.
P/C	For control of calorimeter and ancillary equipment.
Other	Contact TEGAM for further details and options.

[1] Average of ten (10) consecutive points taken 25 seconds apart, where the standard deviation of those points is < 0.05 W.

[2] The 1316 is intended for use as a primary standard. Measurement repeatability and uncertainties will vary among laboratories depending upon various factors, including ambient environment, user experience, and elapsed time since the most recent system calibration. TEGAM will provide

guidance where possible, but users are ultimately responsible for establishing their own measurement uncertainties consistent with the laboratory's capabilities.

[3] Optional items required to achieve specifications listed. Must use recommended options.

[4] Assumes proper preparations are followed prior to storage, including draining the coolant system.

[5] Optional 3-1/8" connector may increase transfer uncertainties if using with adaptors to calibrate non- 3-1/8" devices.

[6] Example based on optional equipment in a typical configuration (Air Cooled Orion Chiller, Preen AC source and Zimmer AC standard). Other options are available.

Product Overview

Figure 1a: Model 1316 Precision Calorimeter (necessary optional items not shown)

The model 1316 is a precision calorimeter that can provide highly accurate RF power measurements up to 10,000 W in the 50 Hz to 500 MHz frequency range, and is traceable to the International System of Units (SI) through the National Institute of Standards and Technology (NIST) or other recognized National Metrology Institutes, by comparison to equipment and standards maintained in the laboratories of AE-TEGAM Inc. The calorimeter design is based on first principles of fundamental physics in the following way. If we know a calorie is a defined as the amount of energy in the form of heat to raise the temperature of a certain mass of liquid by a given amount, then conversely, if we know the temperature rise and the mass of the liquid, we can determine the amount of heat and therefore, the amount of energy applied to the liquid. The calorimeter utilizes these fundamental relationships to precisely measure input power in the form of RF energy.

The physics definition of Work is also related to heat by being defined as energy in transition and work per unit time is power. We can then expand the concept of a calorie to include the rate at which this heat energy is delivered to the mass of the substance to directly derive power, which can then be equated to the more useful watt terminology describing our applied RF energy. One joule (or 1 BTU) of heat equals .239 calories (or 778 ft-lbs) of work, and 1 joule/sec (or 1 BTU/hr) has its electrical equivalent to 1 watt (or .293 W).

Therefore, the fundamental calorimetric relationship between electrical power in watts and the thermal quantities measured inside the calorimeter are temperature rise ΔT (°C), rate of mass flow (gm/sec) and specific heat of the transfer medium cp (J/gm-°C):

$$\text{Watts} = \text{J/sec} = \text{mass flow rate (gm/sec)} \times \Delta T\ (^\circ\text{C}) \times \text{specific heat (J/gm-}^\circ\text{C)}$$

The system design utilizes the absolute flow method which means it measures the absolute flow within the system keeping it nearly constant in order to determine ΔT. A basic absolute flow calorimeter system in general is typically comprised of a liquid cooled RF load with a closely coupled thermopile, circulating pump/heat exchanger, and signal conditioning circuits with a display. The 1316 block diagram is shown in Figure 2a, 3a, and 4a. To begin, RF energy is converted to heat energy inside a RF load containing a circulating coolant flow. The heat energy is dissipated in the coolant, carrying this heat away in the coolant. The fluid circuitry causes the coolant to come in contact with the heat sensing surfaces of a closely coupled thermopile located between the load coolant inlet and outlet and thereby senses the temperature rise across the coolant and produces a DC voltage. The resultant voltage is not proportional to the absolute temperature of the coolant but to the difference in temperatures of the coolant streams. The entire heated coolant stream is involved in the measurement, not just a fraction. Since temperature is read out as a difference (rather than an absolute quantity) within the thermopile, the only absolute measurement required is the rate of flow made by the flow meter- and this can be made reasonably accurately. More importantly, if the flow meter is highly repeatable, the minor absolute flow measurement errors can be calibrated out with extreme accuracy. A chiller then removes the heat picked up by the fluid and exhausts it to the ambient air. The cooled fluid is then recirculated back to the load in a closed loop. The DC voltage from the thermopile and the flow meter output pulses are fed into a signal conditioning board and then on to a display, calibrated in RF watts (also available on the remote computer interface for automated system configurations). Thermistors are utilized on both the input and output water pipes to sense the absolute temperatures of the water stream at their respective points and are then used to compensate for errors introduced in the specific heat and gravity characteristics of the system fluid as a function of temperature. The system is set to produce a coolant flow rate of approximately 4 gallons per minute as this is the recommended minimum flow rate required by the RF load to achieve the system specification of 10k watts.

Figure 2a: Calorimeter Internal Block Diagram

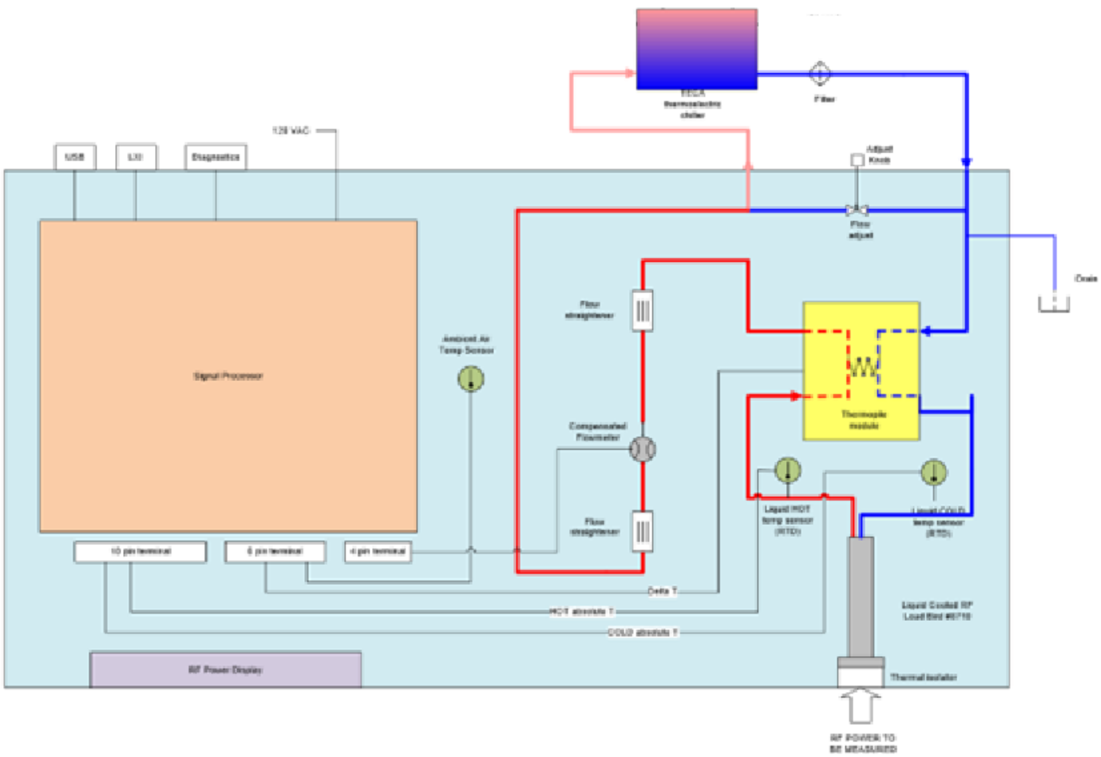


Figure 3a: Signal Processing Block Diagram

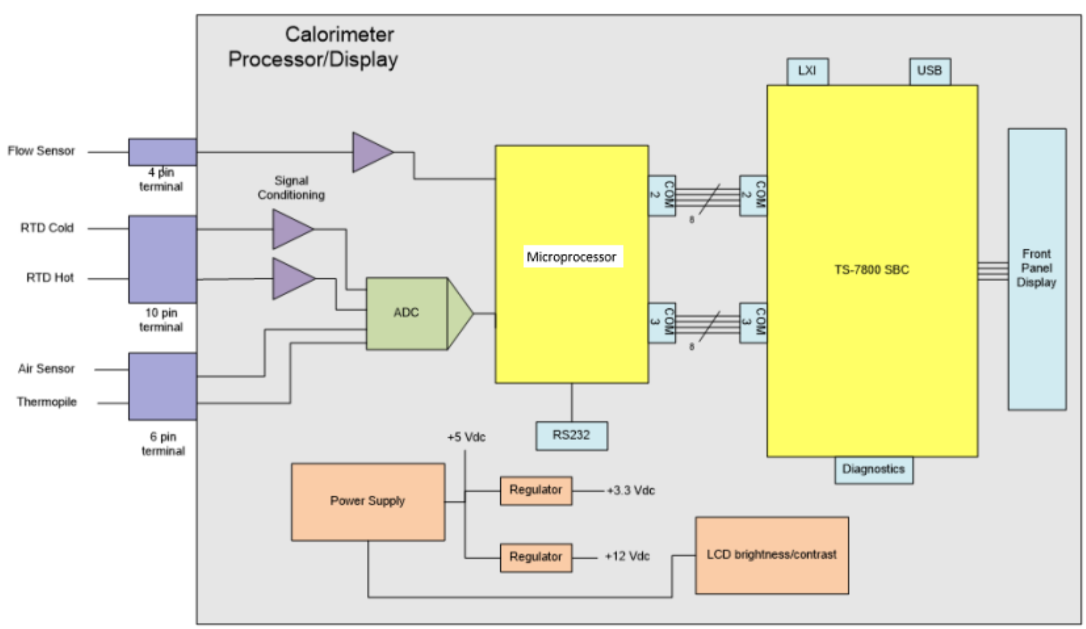
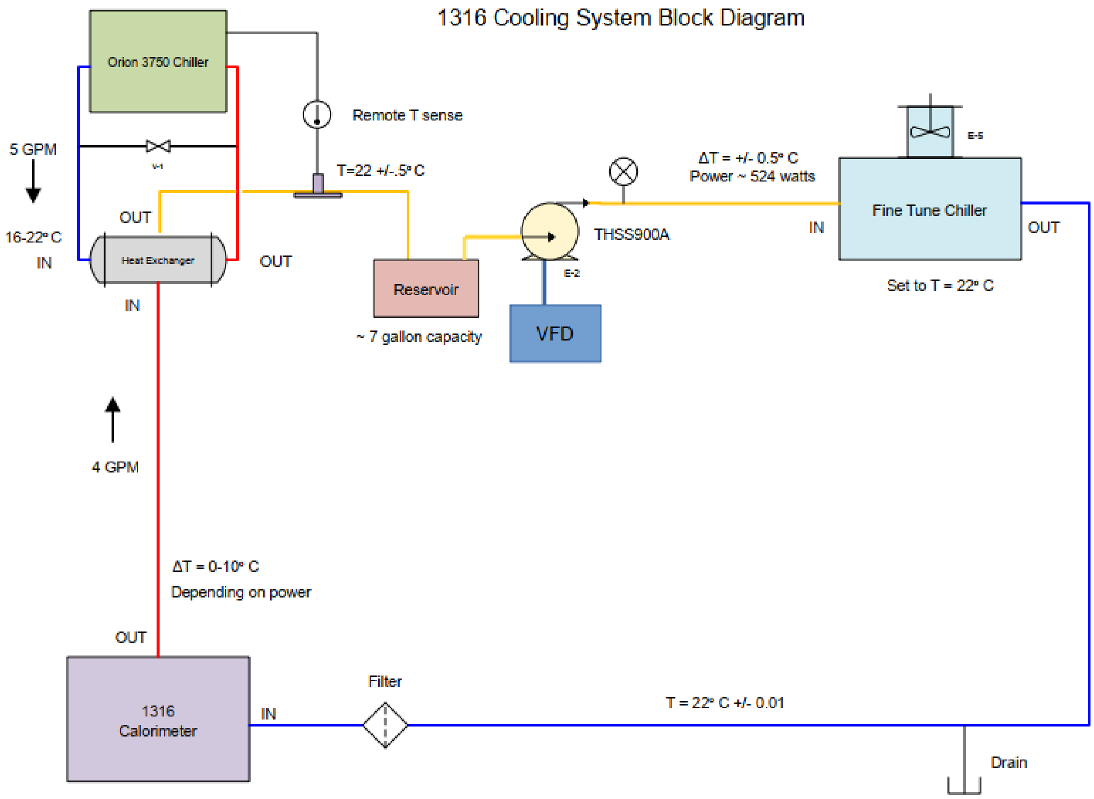


Figure 4a: 1316 Cooling System Block Diagram



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Installation and Set-Up

Unpack the Shipment and Inspect the Contents

Each calorimeter is put through a series of electrical and mechanical inspections before shipment to the customer.

1. Upon receipt of your instrument unpack all the items from the shipping carton.
2. Inspect for 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.
3. Inspect the carton for the following items:

Table 1: Packing List (1316 Calorimeter and 1316-388 Chiller will be installed in a rack)

Item	Part Number
Model 1316 Precision Calorimeter	1316-300
Technical (Operation and Maintenance) Manual	1316-841(CD) or 1316-900(Printed)
Chiller (Fine Control)	1316-388
Calibration Certificate with Data	n/a
Software	HPC-CAL
Calibration Cable Kit HN Version (3-1/8 version)	1300-912-KIT (1300-912-KIT-318)
Optional Accessories	Various

Control the Installation Environment

Normal calibration laboratory practice dictates the environment should be closely controlled. This minimizes errors introduced by temperature and humidity changes. A nominal temperature of +23ºC (+73.4ºF) provides a good working condition. A tolerance of ±1ºC gives an ideal temperature spread. Controlled temperatures also stabilize the aging process of the standards.

Check the Location Where the Unit Will Be Installed

1. Make sure the surface is level. An unbalanced system rack can produce faults and/or inaccuracies.
2. Select a spacious area with good airflow. Avoid placing the unit next to heat producing equipment or in locations subject to drafts or sudden changes in temperature. Free flowing air through the intake and outlet are important. Notice the air intake in Figure 5a below.
3. Lock caster wheels once location is determined.

Figure 5a: Airflow

Typical Equipment List

The following equipment is required to complete the calibration:

- TEGAM 1316A, RF High-Power Calorimeter
- TEGAM 1300-912, Voltage/Current RF Adapter Assembly
- Preen AFV+ 31015 (optional model), High Power Programmable AC Power Source
- Zimmer L64-BAS (optional model), Precision Power Analyzer
- Solid State Cooling Systems 1316-388, Thermorack Solid State Chiller (1 kW)
- Orion 1316-389 (optional model), DC Inverter Chiller (12 kW)
- TEGAM HPC-CAL, Automated Calorimeter Calibration Software

⚠ **WARNING:** High voltage, current, and RF power are present in the system at various times throughout this procedure. This procedure should only be performed by qualified personnel sufficiently trained in the safe operation of high voltage, current, and RF power systems. Failure to follow these precautions may result in death or bodily injury, or equipment damage.

Instrument Connections

⚠ WARNING: High voltage and current are present on the system. Install proper safety equipment (e.g., fuses, breakers, etc.) as necessary between the AC Power Source and Voltage/Current RF Adapter. Failure to install adequate safety equipment may result in death or bodily injury, or equipment damage.

1. Connect the Voltage/Current RF Adapter through an appropriately sized fuse or breaker to the AC Power Source. See *Figure 1* below.

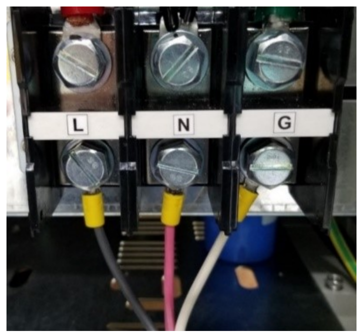

Figure 1: Voltage/Current RF Adapter connections to the AC Power Source.

⚠ WARNING: Dangerous voltage, current, and RF power may be present on the system. Users should install interlock devices as appropriate for safe operation.

2. Connect interlocks (user-supplied) to the Calorimeter and system as necessary.
3. Connect the Calorimeter and Power Analyzer ethernet ports to the network.
4. Connect the AC Power Source to the network using the ethernet port or the RS-232 serial connection. Ethernet is preferred.
5. Connect the thermocouple from the Calorimeter to the 12 kW Chiller as shown in *Figure 2*.

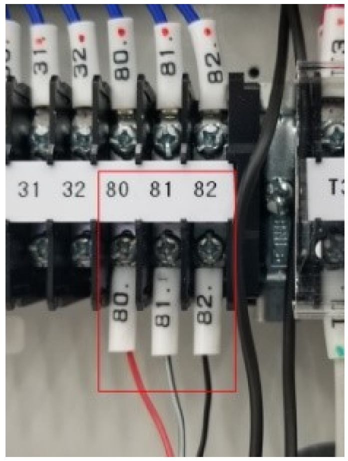

Figure 2: Thermocouple Wire Connection

> ⚠ **WARNING:** Comply with all local codes and regulations for installation of all instrumentation. Follow guidelines in supplier manuals for connections to AC Power Source and 12 kW Chiller. Failure to install equipment properly may result in death or bodily injury, or equipment damage.

6. Connect AC mains power to the Calorimeter, AC Power Source, 12 kW Chiller, and Power Analyzer. The Power Analyzer and Calorimeter are powered from separate 200-240 VAC outlets. The Calorimeter requires a 20A service.

Chiller Preparation

> ⚠ **CAUTION:**
>
> Never operate cooling pump dry! Severe damage will occur.
>
> Never apply AC or RF power to the unit until proper coolant levels and sufficient air flow are established.

> ⚠ **CAUTION:**
>
> Use only pure distilled water in the coolant mix.
>
> Do not fill the unit with de-ionized water, flammable fluids, corrosive fluids, explosive, or any other hazardous fluids.

1. Fill the 1 kW Chiller coolant reservoir, located at the top of the system rack cabinet (see *Figure 3* below), 4 cm ($1^{5}/_{8}$ inches) above the return inlet with a coolant mixture of 25% SR-1 antifreeze to 75% distilled water.

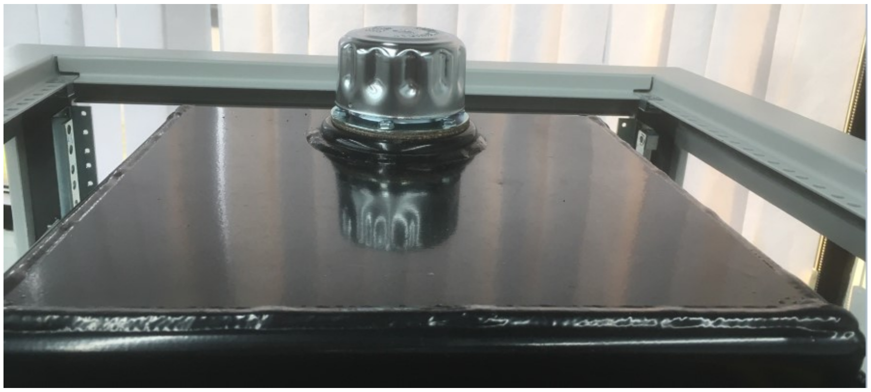

Figure 3: 1 kW Chiller coolant reservoir

2. Power ON the Calorimeter and the 1 kW Chiller. Once the Calorimeter completes the boot process:
    a. On the Calorimeter front panel, press the *SETUP* softkey.
    b. Navigate to *Instrument* using the arrow keys and press **ENTER.**
    c. Navigate to *PUMP* and press **ENTER.**
    d. Navigate to *USE PUMP* and press **ENTER.**
    e. Press **ENTER** again to begin editing the parameter value.
    f. Press the **UP** arrow key to change the parameter value to *TRUE* and press **ENTER.**
3. Allow sufficient time for the coolant to circulate through the system before proceeding to the next step.

NOTE: *The coolant level may drop as coolant fills the system hoses, Calorimeter, and 1 kW Chiller. If necessary, add additional coolant mixture as necessary to the 1 kW Chiller reservoir to bring the coolant level back to 4 cm above the return inlet.*

4. Power OFF the 1 kW Chiller.
5. Power OFF the Calorimeter and chiller pump using the system rack power switch.
6. Connect the supply and return hoses between the 12 kW Chiller and the system rack cabinet as shown in *Figure 4*.

Figure 4: Supply and return hose connections

7. Fill the 12 kW Chiller coolant reservoir using about 50 liters (13.2 gallons) of a 25% SR-1 antifreeze and 75% distilled water mixture.
8. Power ON the 12 kW Chiller.

9. On the 12 kW Chiller display, touch the **PUMP ONLY** icon and hold for 2-3 seconds to circulate coolant.
10. Allow sufficient time for the coolant to circulate through the system before proceeding to the next step.

NOTE: *If the coolant level drops and triggers a low coolant alarm, add additional coolant mixture as necessary to the 12 kW Chiller reservoir until the alarm turns off. Clear the alarm on the 12 kW Chiller display.*

11. On the 12 kW Chiller display, touch the **PUMP ONLY** icon and hold for 2-3 seconds to stop flow circulation coolant.
12. Power OFF the 12 kW Chiller.

Calibration Preparation and Instrument Setup

1. Install the HPC-CAL calibration software on the system workstation.
2. Power ON the 12 kW Chiller.
3. On the 12 kW Chiller display, touch **RUN** and hold for 2-3 seconds.
4. Power ON the Calorimeter. Once the Calorimeter completes the boot process:
    a. On the Calorimeter front panel, press the *SETUP* softkey.
    b. Navigate to *Instrument* using the arrow keys and press **ENTER.**
    c. Navigate to *PUMP* and press **ENTER.**
    d. Press **ENTER** again to begin editing the parameter value.
    e. Navigate to *USE PUMP* and press **ENTER.**
    f. Press the **UP** arrow key to change the parameter value to *TRUE* and press **ENTER.**
5. Verify that the green **FLOW OK** indicator is lit.
6. Power ON the 1 kW Chiller.
7. Connect cables CA-70-5 and CA-71-5 to the Power Analyzer as shown in *Figure 5* below.

Figure 5: CA-70-5 and CA-71-5 connections to Power Analyzer

8. Connect cables CA-70-5 and CA-71-5 to the Voltage/Current RF Adapter as shown in *Figure 6* below.

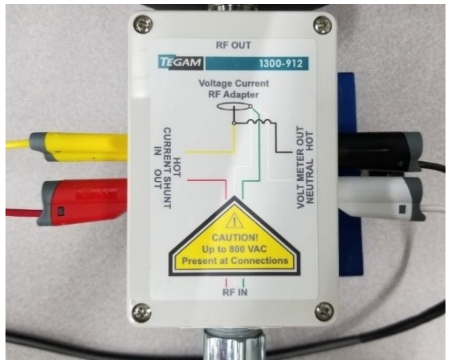

Figure 6: CA-70-5 and CA-71-5 connections to Voltage/Current RF Adapter

9. Connect the Voltage/Current RF Adapter output HN RF connector to the Calorimeter input HN RF connector.
10. Allow the system to stabilize for no less than two (2) hours before performing the remaining steps of this procedure.

Calibration

1. Launch the HPC-CAL calibration software on the system workstation.
2. Click the **Test Definition** tab (see *Figure 7* below).
3. Click the **Read Test Definition** button (see *Figure 7*).

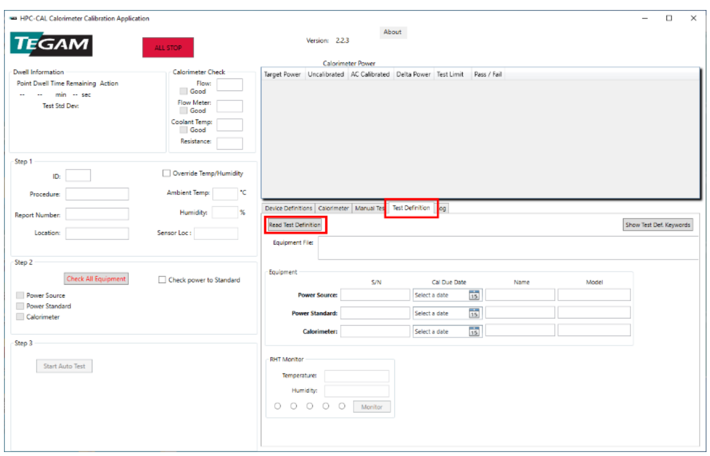

Figure 7: HPC-CAL calibration software main window

4. In the *Open File* dialog box, select the Test Definition file titled *HPC-Cal_TestDefinitions_SNxxxx.XML*.
5. Click **Open** to load the selected calibration test parameters into the HPC-CAL calibration software as shown in *Figure 8* below.

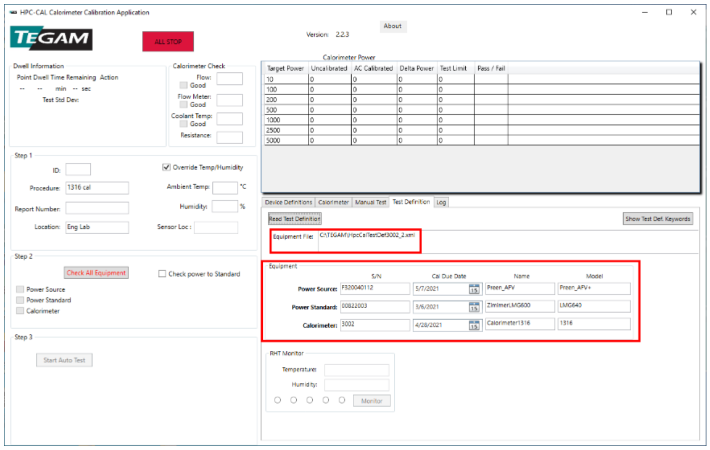

Figure 8: HPC-CAL calibration software with Test Definitions file loaded

6. Click the **Device Definitions** tab (see *Figure 9, Step 1* below).
7. Click the **Configure Definition** drop-down box (*Figure 9*, Step 2).
8. Click *Calorimeter1316* in the drop-down box (*Figure 9*, Step 3).
9. Click the **Network** tab (*Figure 9*, Step 4).
10. Verify that the IP address displayed in the **IP Addr** textbox matches the Calorimeter IP address (*Figure 9*, Step 5).
11. Click the **Check** button. If communication is properly configured, the Calorimeter will respond with the instrument model number (*Figure 9*, Step 6).
12. Repeat *Steps 7* through *11* above for the AC Power Source and Power Analyzer. In Step 9, click the tab that corresponds to the appropriate communication protocol for the instrument being configured.

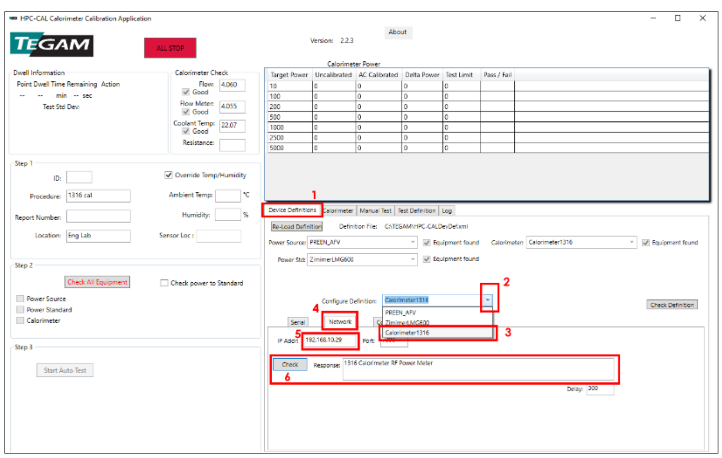

Figure 9: HPC-CAL calibration software Device Definitions tab

13. Complete the fields contained in the **Step 1** group as shown in *Figure 10*. TEGAM has defined the fields as described in *Table 1* below, but the user may choose to input additional or different information in any field. Note that the information will appear in various HPC-CAL calibration software output files.

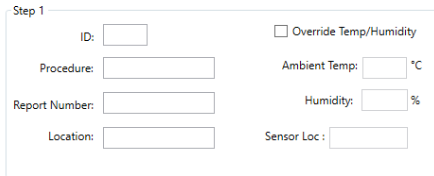

*Figure 10: **Step 1** group fields*

Field	Description
ID	Technician ID or initials.
Procedure	The calibration authority/procedure for the test.
Report Number	The report number must be 10 characters and should be unique. The date, including minutes (yymmddhhmm), is recommended to ensure each report number is unique.
Location	Company or department name, or test station number.
Ambient Temp	Ambient temperature of the calibration environment.
Humidity	Ambient humidity in the calibration environment.
Sensor Loc	Physical location of the temperature/humidity sensor

Table 1: Step 1 group field definitions

14. In the **Calorimeter Check** group, verify the Calorimeter **Flow:** and **Flow Meter:** fields indicate 4.05 GPM ±0.03, and that **Coolant Temp:** indicates 22.1 °C ±0.4 (see *Figure 11*, Step 1 below).
15. (Optional) In the **Step 2** group, click to select the **Check power to standard** check box (*Figure 11*, Step 2).This setting instructs the HPC-CAL calibration software to verify the connection between the Power Analyzer and AC Power Source.
16. In the **Step 2** group, click the **Check All Equipment** button (*Figure 11*, Step 3).
17. Wait approximately 60 seconds for the HPC-CAL calibration software to verify communication with the connected instruments. Verify the **Power Source**, **Power Standard**, and **Calorimeter** checkboxes are checked. The **Check All Equipment** button text should be black (*Figure 11*, Step 4).
18. In the **Step 3** group, click the **Start Auto Test** button (*Figure 11*, Step 5).

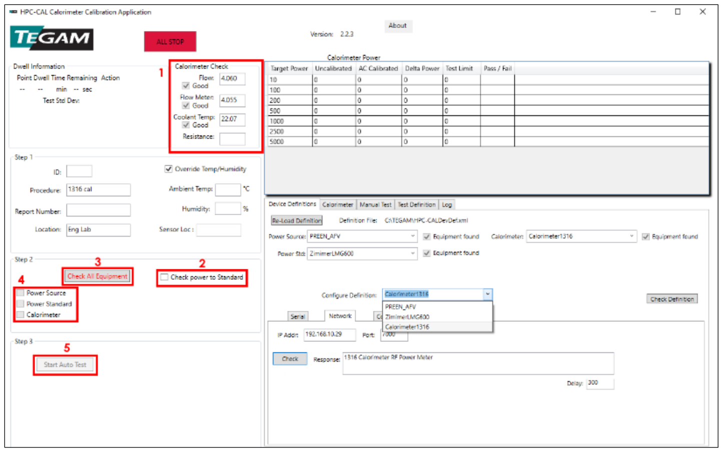

Figure 11: HPC-CAL calibration software communication and test parameter verification

19. In the dialog box, verify that the test power level, and Calorimeter serial and model numbers are correct.
20. Click **OK** to dismiss the dialog box and begin the automated calibration.
21. The HPC-CAL calibration software will save a calibration data file in the current user's *Documents* directory at the completion of the test.

Data Analysis

NOTE: *In rare cases, pop-ups may appear announcing that the measurement settling criteria have not been met. If this happens, evaluate the warning and obtain Engineering approval to continue test or abort test. Failure to meet settling criteria could be a sign of an equipment malfunction, and each such failure should be analyzed. Repeated failure on one step may indicate that the criteria is too tight, or the settling time is too short. In either of those cases, the test definition can be changed consistent with quality requirements.*

1. Navigate to the current user's *Documents* directory (*%userprofile%\documents*).
2. Locate and open the data file from the calibration completed in the previous steps. The filename will be *HPC-CALTest_yyyy_MM_dd_HH_mm_ss.log* (*yyyy* = four-digit year, *MM* = month, *dd* = day of month, *HH* = 24-hour clock hour, *mm* = minutes, *ss* = seconds). The date/time portion of the file name corresponds to the time the calibration finished.
3. If required for reporting or auditing purposes, copy the data file to an appropriate location.

Alignment

1. In the HPC-CAL calibration software, click the **Calorimeter** tab (see *Figure 12* below).

2. Click **Create Cal. File and Save** to create a new calibration file based on the calibration data collected in *Step 3.2. Calibration* above (*Figure 12*).
3. In the dialog box, save the new calibration file in appropriate location. The file name must be *Calibration.ini* as the Calorimeter will not read a calibration file with any other name.

NOTE: *It is recommended to store the calibration file in its own directory, and name the directory using the current date and other descriptive information as necessary. The directory should contain no other calibration.ini files. Save the file as "Calibration.ini" and not as any other name. The calorimeter will not use files with a different name.*

4. Click **Send Cal. File and Restart (***Figure 12***).**

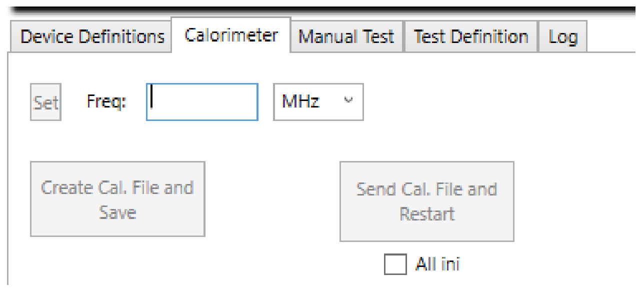

Figure 12: HPC-CAL calibration software Calorimeter alignment tab

5. In the dialog box, pick the calibration file saved in *Step 3* above.
6. Click **OK** to load the calibration file.
7. The Calorimeter will restart after loading the calibration file. The alignment is complete when the Calorimeter restarts and completes the boot process.

Features and Settings

Over Temperature Safety

HPC-CAL software monitors the temperature. If an over temperature condition occurs, HPC-CAL will either produce a warning or shutdown the AC source, depending on the level of the overtemperature condition. If shutdown occurs, the test will need restarted.

Adaptive Fan Control

The cooling fan on the 1316 chiller will cycle on/off as needed to maintain the chiller temperature. Fan cycling is normal operation and should not be cause for alarm.

General

Warm Up and Stabilization

Permit the unit to operate at a minimum of approximately 2 hours prior to application of AC or RF power once everything is powered on and the chillers are engaged. Manual dwell times at desired calibration power levels should be > 10 minutes (the temp control loop needs this minimum time to react and settle) and it is suggested to be at least 20 minutes for best accuracy.

AC Substitution

Calibration procedures are based on AC substitution. A source of AC power is applied to the load to simulate the heating effect of the unknown RF power and is measured using readily available AC power sources and measuring equipment. The accuracy of the AC power meter (known to be extremely accurate) can then be transferred to the RF measurement since a well-designed RF load will respond nearly identically to either AC or RF power up to a specified high frequency limit.

Many calorimeters in use today express accuracy as a percentage of full scale, less load error. Only the power that is absorbed by the load is measured and displayed. All other power (reflected, etc.) is considered part of the load error and is not measured. This may be convenient for the manufacturer, but to achieve a more precise measurement, this load error can be characterized by determining the reflection coefficient of the RF load as a function of frequency and compensating for it at the frequency of interest. The 1316 automatically compensates for this error term by storing the RF load reflection data in memory and then applying it as a frequency correction term to obtain the final calibrated RF answer in watts.

Correction of Error Terms

All of the error term parameters collected and analyzed by the 1316 are incorporated into four separate initialization files comprised of one file representing the actual reflection coefficient of the load, one characterization file that defines constants and dynamic correction terms specific to the design/construction of the calorimeter, one file representing the efficiency of the RF load to convert the electrical energy into thermal energy as a function of power and frequency, and one file of calibration constants defining the slope and intercept points of a piecewise linear approximation to a calibrated AC reference power source. These files are shown geographically in Figure 16 and are uploaded to the 1316 prior to making calibrated RF measurements.

Defining the parameters of the error terms contained within these files allows the system firmware to be flexible and adapt easily to situations where the load or fluid components may need to be changed in the future. When the calorimeter makes its final calculation of either calibrated AC or RF power, applicable error parameters are called and used to refine the final displayed power.

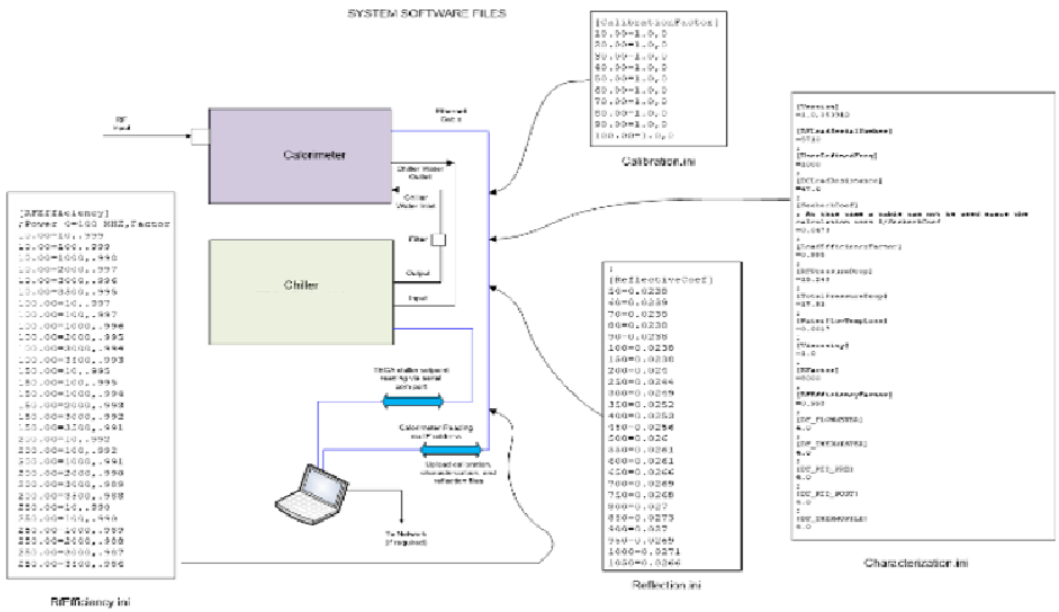

Figure 16: Software System Files

Calibrate the Calorimeter Before Use

To calibrate a RF device using the calorimeter, the calorimeter must first be calibrated against an AC power meter standard traceable to a governing authority i.e. NIST, etc. Configure the equipment setup and perform the calorimeter calibration as described above.

4

Maintenance

Periodic Inspection and Servicing

WARNING–This unit must be disconnected from all AC or RF power before any repairs are attempted. Any attempt to repair without disconnecting ac or RF power could be fatal.

The coolant reservoir should be checked each time the unit is used, add coolant when low. The life expectancy for the gear pump used inside the chiller is approximately 20,000 hours.

The following should be performed at intervals of one to six months depending upon usage:

- Remove cover to access internal components.
- Remove accumulations of dust, dirt, and other obstructions to air flow on the rack system.
- Inspect hardware and tighten as required.
- Check all coolant lines are clear of obstructions.
- Clean or replace any strainer element added between the chiller outlet and unit inlet.
- Clean air inlet, air outlet/fan filters on the chiller using a vacuum.

5

Troubleshooting Guide

Unresponsive to power

If the unit fails to respond to either AC or RF power, check to see if the RF load is still functional.

1. Use an ohmmeter to check the DC resistance from the center pin to the outer shell on the N connector.

   The reading should be between 50 +/- 5 ohms and should not have deviated from the original value significantly (+/-.5 ohms) at the time of delivery.

If it becomes necessary to replace the load for any reason, the following can be performed by a qualified service provider, however, it is best to return the calorimeter to AE-TEGAM for repair:

1. Measure the DC resistance of the new load and enter the value into the characterization.ini file under "DCLoadresistance."

   The DC load resistance value is also used as a reference value to determine the transmission coefficient for RF calibration.

   The DC load resistance values is used by the control feedback algorithm within the CalProg program to set the requested power on the AC power source under automated conditions (not under manual operation).

2. Next, upload the new file to the system program to ensure proper operation.

3. Measure any reflection coefficients desired specific to your application as a function of frequency of the new load using a vector network analyzer with the system coolant running inside the load.

4. Enter the list of frequencies versus reflection coefficients obtained into the reflection.ini file.

5. Then, upload the new file to the system program to ensure proper operation. Again, these values are used in determining the reflection coefficient for RF calibration.

It is good practice to measure the DC resistance of the load annually and chart the results to identify any significant trends taking place. A load will naturally increase very slightly in resistance as the carbon film becomes oxidized with age but any significant jumps in value (> +/- .5 ohms annually) may be an indication of a potential pending failure.

Table 3: General Troubleshooting Guide

Symptom	Corrective Action
No power displayed	Check load DC resistance for possible failure
Power won’t settle or excessively long settling time	Check RF amp for possible power drifting Make sure chiller set point and PID parameters are correct
Flow rate much less than nominal	Check for blockage in fluid filter
AC calibrated power equals input power	Check calibration.ini file for proper values
RF calibrated power equals AC calibrated power	Check reflection.ini file for proper values
Extreme ambient temperature readings	Check for fan failure or inlet air blockage
No communication with 1316 Calorimeter	Check for proper IP address

6

Appendix A

PARAMETER NOMINAL VALUES AND APPROXIMATE LIMITS

Field Values	Low Limit Value Reading	High Limit Value Reading	Units	Expected Values (10k watts @ 25°C ambient)
THERMISTOR	22	28	°C	26°
RTD_TEMP_PRE	21.6	22.4	°C	22°
RTD_TEMP_POST	21.6	32	°C	31.5°
THERMOPILE	0	0.8	volts	0.73
WATERFLOW_TEMP_LOSS	0	0.002	°C	0
SPECIFIC_HEAT	3.6	3.8	J/g-C	3.75
GRAVITY	1	1.05	g/cm3	1.03
VISCOSITY	0.5	2	mPa-sec	1.51
FLOWMETER	300	320	pulses/sec	310
K_FACTOR			pulses/liter	1239
FLOWRATE	4	4.07	GPM	4.055
FLOW_VOLUME			cm3/sec	255
MASS_FLOWRATE	250	275	gm_sec	265
SEEBECK_CONSTANT			volts/C	.08
DELTA_T	0	10	°C	9.05
LOAD_EFFICIENCY_FACTOR			--	1
FRICTIONAL_WATTS	0	25	watts	20
RF_PRESSURE_DROP			psi	7.5
TOTAL_PRESSURE_DROP			psi	26.04
INPUT_POWER	-5	10000	watts	8900-10500
RF_LOAD_DC_RESISTANCE	45	55	ohms	49.6
SERIAL_NUMBER_OF_RF_LOAD			--	
REFLECTION_COEFFICIENT	0	1	--	0.01 Frequency Dependent
TRANSMISSION_LOSS_FACTOR			--	0.999
CAL_FACTOR	-5	10000	watts	10000
RF_TRANS_LOSS_FACTOR			--	0.999
RF_EFFICIENCY_FACTOR			--	0.998
USER_DEF_FREQ	0	500	MHx	0 to 500 MHz
RFCALPOW	-5	10000	watts	10000
POWER_ADJ	-4	4	watts	1.25
T_PIVOT	23	27	°C	25
T_POWER	-2	2	watts/°C	-1
USE_PUMP			--	True
PUMP_SET_FREQ	44.5	45	Hz	44.8
PUMP_CONTROL			--	True
PUMP_FREQ	44.5	45	Hz	44.8
PUMP_RPM	1335	1350	rpm	1344
FLOWRATE_RPM	3.95	4.15	gpm	4.055
FLOWRATE_METER	3.9	4.1	gpm	4
n/a = not applicable for model #1316				

Appendix B – Service Assistance

Returns for Repairs

Once you have verified that the cause for the Coaxial RF Power Standards 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 (All Locations) OR 800.666.1010 (United States Only).

The RMA number is unique to your instrument and will help us identify you instrument and to address the service request by you which is assigned to that RMA number.

Of even importance, a detailed written description of the problem should be attached to the instrument. Many times repair turnaround is unnecessarily delayed due to a lack of repair instructions or of a detailed description of the problem.

This description should include information such as measurement range, and other instrument settings, type of components being tested, are the symptoms intermittent, conditions that may cause the symptoms, 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 a copy of the Repair and Calibration Service form provided on the next page.

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

Warranty

TEGAM, Inc. warrants this product to be free from defects in material and workmanship for a period of one 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.

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 calibration of this instrument is traceable to the International System of Units (SI) through the National Institute of Standards and Technology (NIST) or other recognized National Metrology Institutes, by comparison to equipment and standards maintained in the laboratories of TEGAM Inc.

Document publishing dates may lag product changes.
Visit www.tegam.com to download the latest version of this manual.

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Storage and Shipment

> ⚠ **CAUTION:**
>
> Do not store calorimeter system, chillers, or load where ambient temperatures fall below freezing without proper preparations.

Drain the calorimeter system of all coolant

1. Prior to shipment of the calorimeter system or storage where temperatures may fall below freezing, it is necessary to drain the coolant. If only part of the system is to be shipped or stored in a below freezing environment, only that part of the system needs to be drained.

2. Draining the coolant from the calorimeter system can be broken into three main sections consisting of the calorimeter/small chiller/reservoir tank as one section, the large chiller as a second section, and the chiller to chiller heat exchanger as the third section. Since each of these have some isolation from each other, each will need individual draining.

3. For the calorimeter/small chiller/reservoir combination, disconnect the hoses that feed into the pump at the lowest point in the bottom of the calorimeter rack assembly and drain into a container to capture the fluid. Be prepared to capture several gallons of fluid. Allow to drain for several hours as some draining will occur very slowly with a syphon affect. It will also be necessary to disconnect all other hoses that may contain fluid and/or attach to lower coolant drain points of individual chambers that may not have fully drained during the primary draining process. There is also a drain valve on the reservoir tank that should be utilized during the draining process. Check the reservoir tank to confirm it is empty when you are done.

4. The large chiller contains a drain outlet that can be used to remove the majority of the its fluid. Prepare to capture a large amount of fluid (approximately 13 gallons) with a container beneath the drain outlet and open the outlet. It may be necessary to disconnect the chiller hoses from the lower connection point to further drain residual fluid. Allow the chiller to drain for several hours. Check the reservoir tank to confirm it is empty.

5. The chiller to chiller heat exchanger will partially drain during the previous processes, assuming the large chiller and small chiller were still attached to the heat exchanger when they were drained. Some fluid may remain and is difficult to remove. Removing the hoses from the lowest point and allow it to drain for several hours.

6. As stated above, if only parts of the system require shipment or storage, it is possible to drain individual pieces. Disconnect the proper hoses for those pieces while plugging the hoses to the rest of the system to prevent draining unintentional parts. Pay attention to connections with quick disconnects that prevent fluid flow when disconnected and apply proper fittings or disconnect the main hoses to drain those items.

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 Info:	

REPAIR INSTRUCTIONS:

☐ Evaluation ☐ Repair & Calibration
☐ Calibration Only ☐ Repair only
☐ Provide Data (May incur 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.