

FLUKE®

Calibration

4180, 4181

Precision Infrared Calibrator

Technical Guide

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Introduction

Note

This manual is intended to be used with the Operators Manual and Safety Information documents.

The Fluke Calibration 4180, 4181 Precision Infrared Calibrator (The Product) is a portable instrument or bench-top temperature calibrator used to calibrate IR thermometers. The Product is small enough to use in the field, and accurate enough to use in the lab.

The Product features:

- Rapid heating and cooling
- RS-232 interface capability

Built in programmable features include:

- Temperature scan rate control
- Eight set-point memory
- Adjustable readout in °C or °F
- Adjustable Emissivity

The temperature is accurately controlled by the digital controller. The controller uses a precision platinum RTD as a sensor and controls the surface temperature with a solid state relay (triac) driven heater (4181) and FET driven Peltier modules (4180).

With proper use, the Product will provide continued accurate calibration of IR temperature measurement devices. Familiarize yourself with the safety guidelines and operating procedures of the Product. See [Safety Information](#).

Contact Fluke Calibration

Fluke Corporation operates worldwide. For local contact information, go to our website:

www.flukecal.com

To register your product, view, print, or download the latest manual or manual supplement, go to our website.

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Safety Information

General Safety Information is located in the printed Safety Information document that ships with the Product. It can also be found online at www.Flukecal.com. More specific safety information is listed where applicable in this manual.

A **Warning** identifies conditions and procedures that are dangerous to the user. A **Caution** identifies conditions and procedures that can cause damage to the Product or the equipment under test.

Follow these guidelines closely to make sure that the safety mechanisms in this Product operate properly. This Product must be plugged into an AC-only outlet according to the [Specifications and Environmental Conditions](#). The power cord of the Product has a three-pronged grounding plug for your protection against electrical shock. Plug the power cord directly into a properly grounded three-prong receptacle. The receptacle must be installed in accordance with local codes and ordinances. Consult a qualified electrician.

Caution

To prevent damage to the Product:

- Always replace the fuse with one of the same rating, voltage, and type.
- Always replace the power cord with an approved cord of the correct rating and type.
- Protect the target against dirt and damage - scrapes and scratches. A well-kept target surface, free from dirt and damage, produces better measurements. Use the target cover whenever the Product is not in use to protect the target. Always use the target cover when transporting the Product, but remember to never transport the Product when the target temperature is $>50\text{ }^{\circ}\text{C}$.
- Do not touch the target. Oils and salts from the skin will permanently damage the target surface at high temperatures.
- Do not use fluids to clean the target surface.
- Do not use shop air to clean the target surface. Oil and contaminants in the shop air could contaminate the surface.
- Do not use canned, compressed air (used to clean a computer) to clean the target surface. Chemicals in the air could contaminate the target surface.
- When ice forms on the target, change the instrument set-point $>50\text{ }^{\circ}\text{C}$ to melt the excess ice. DO NOT wipe the front plate (target). Change the set-point to $100\text{ }^{\circ}\text{C}$ or higher to evaporate the excess water.
- Do not force cool the surface. The surface should not be cooled by any method other than natural convection. Forced air can often have oil or water in it. Even water can leave mineral deposits on the surface. Trying to cool the surface too quickly can also cause thermal shock to the emissive surface.
- Do not use liquid nitrogen (LN2) to quick cool the target.
- Do not plug the Product into 230 V if the fuse holder reads 115 V. This action will cause the fuses to blow and may damage the Product.
- Component lifetime can be shortened by continuous high temperature operation.

- Do not change the values of the calibration constants from the factory set values. Calibration constants shall only be changed by qualified and authorized personnel. The correct setting of these parameters is important to the safety and proper operation of the Product.
- Use a ground fault interrupt device.
- Always operate this Product at room temperatures as stated in [Specifications and Environmental Conditions](#).
- The Product is a precision instrument. Handle the Product with care. It is important to keep the calibration well and the IR target surface clean and clear of any foreign matter.
- If a main supply power fluctuation occurs, immediately turn off the Product. Wait until the power has stabilized before re-energizing the Product.
- Always carry the Product in an upright position. The convenient pull-up handle allows one hand carrying.
- Do not operate the instrument in excessively wet, oily, dusty, or dirty environments.
- DO NOT operate near flammable materials.
- If a main supply power fluctuation occurs, immediately turn off the Product. Wait until the power has stabilized before re-energizing the Product.
- Use the target cover at temperatures below ambient (25 °C). If ice or liquid water forms on the target, IR thermometers will not indicate the correct temperature.

Service Information

Contact an authorized Fluke Calibration Service Center if the Product needs calibration or repair during the warranty period. See [Contact Fluke Calibration](#). Please have Product information such as the purchase date and serial number ready when you schedule a repair.

Specifications and Environmental Conditions

The Product specifications can be found in the *4180 Operators Manual* located at www.Fluke.com.

Product Operation

This section discusses how to operate the control panel. Using the front panel you can monitor the target temperature, set the temperature set-point in °C or °F, monitor the heater output power, monitor the stability, set the cutout set-point, set the operating parameters, and configure the communication interface. When active, menu keys are selected using the soft keys (F1-F4).

Main Screen

The display shows the control temperature (actual target temperature), heating or cooling power, stability state, current set-point information, and current program information. The temperature is either in °C or °F. Push C/F to change temperature units.

APPARENT TEMPERATURE

This is the radiometric temperature of the target surface as calculated from the control sensor temperature. The calculation depends on the emissivity setting. The controller heats or cools the target to force the control temperature equal to the set-point.

SET-POINT (SETPT)

This is the current set-point.

IRT ϵ

IRT ϵ is the Product apparent emissivity. The emissivity setting should match that of the device under test (DUT).

CAL λ

CAL λ is the bandwidth of the Product calibration. It can be set to either 8-14 μm or User.

CONTROL - HEAT/COOL

Is the relative heating or cooling power (duty cycle) in percent.

HEATING, COOLING, CUTOUT

Is the status of heating or cooling or the cutout when activated. The bar graph indicates the relative heating or cooling power.

STABLE INDICATION (Graphic)

Is the stability of the target. When the stability is within the STABLE LIMIT setting, this line is flat.

Main Menu

Note

For more information on the menu structure, see Menu Structures in the Operators Manual.

Push **MENU** to access the Main Menu and the main submenus. Use the submenus to set up the Product as desired and to change system parameters as needed.

TEMP SETUP

The TEMP SETUP (TEMPERATURE SETUP) contains functions related to temperature setup. See the *Operators Manual*.

SETUP

The SETUP menu contains the parameters that set the stability limit and scan rate for the Product.

SCAN RATE

The SCAN RATE parameter can be set such that when the set-point is changed, the Product heats or cools at a specified rate, degrees per minute ($^{\circ}\text{C}/\text{min}$ or $^{\circ}\text{F}/\text{min}$), until it reaches the new set-point.

The Scan Rate can be set from 0.1 $^{\circ}\text{C}/\text{min}$ to 500 $^{\circ}\text{C}/\text{min}$ (0.2 $^{\circ}\text{F}/\text{min}$ to 900 $^{\circ}\text{F}/\text{min}$). However, the maximum scan rate is limited by the natural heating or cooling rate of the Product, which is often much less than 500 $^{\circ}\text{C}/\text{min}$ (900 $^{\circ}\text{F}/\text{min}$), especially when cooling.

Use the arrow buttons to adjust the scan rate. Once the scan rate has been set, push **ENTER** to accept the new scan rate.

STABLE LIMIT

Note

The Product should not be expected to operate better than the listed stability specification. The minimum setting of the stability limit should not be less than the stability specification.

The STABLE LIMIT parameter notifies the user when it has achieved the stability limit set in this parameter. There are two notifications: visual and audible. The visual notification is always active. As the Product operates within the stability limit, the stability graph on the main screen remains flat once the Product is within the given specification for 1 minute. Otherwise the graph indicates that the Product is not yet stable. The audible, if enabled, alerts the user once per set-point when the Product achieves the set stability limit. Use the arrow buttons to set the desired stability limit and push **ENTER** to accept the new stability limit.

Example

A special calibration process requires the Product to operate within ± 0.5 °C. Enter **0.5** into the stability limit parameter. When the Product stability is within ± 0.5 °C for one minute, the graph is flat and the audible alarm (if enabled) notifies the user that the Product is operating within ± 0.5 °C. Use the arrow keys to set the desired stability limit and push **ENTER** to accept the new stability limit.

STABLE ALARM

To turn on or off the audible alarm described in [STABLE LIMIT](#), use the STABLE ALARM parameter. Push the left or right arrow button to select either **Enable** or **Disable** and push **ENTER** to accept the selection.

IRT

The IRT menu contains the user-settable emissivity parameter to set the display emissivity.

IRT ϵ

The IRT ϵ parameter allows the user to change the display emissivity setting to match the IR thermometer emissivity setting.

CUTOUT

The CUTOUT menu contains the SOFT CUTOUT and HARD CUTOUT functions of the Product. As a protection against software or hardware fault or user error, the Product has an adjustable cutout device that shuts off power to the heat source if the target temperature exceeds a set value. The factory default is 10 degrees above the high limit of the Product. If the cutout is activated because of excessive target temperature, power to the heat source shuts off and the Product cools. The Product remains in cutout mode and active heating and cooling are disabled until the user manually resets the cutout. If the over-temperature cutout is triggered, the Product displays **CUTOUT** above the duty cycle bar graph, which indicates a cutout condition. The Product remains in cutout mode until the temperature is reduced and the cutout is reset. The target temperature must drop a few degrees below the cutout set-point before the cutout can be reset. For safety reasons, the cutout only has one mode - manual reset. Manual reset mode means the cutout must be reset by the operator after the temperature falls below the set-point.

Note

CUTOUT RESET: If the Product exceeds the temperature set in the soft cutout menu or if it exceeds the maximum operating temperature of the Product, a cutout condition occurs. If this happens, the Product enters cutout mode and will not actively heat or cool until the user resets the Product.

To reset the cutout, the Product temperature must cool to lower than the cutout set-point. Once the Product has cooled, push **SET PT.**, then **ENTER**, and then **ENTER** again to reset and engage the Product.

SOFT CUTOUT

The SOFT CUTOUT is user settable. The SOFT CUTOUT parameter can be set to any temperature under the range of the Product. The cutout should be set within 5 ° to 10 ° of the safety limit of the equipment being calibrated or used with the Product.

HARD CUTOUT

The HARD CUTOUT is not user settable. The HARD CUTOUT parameter is a view-only function and indicates the factory setting for the hard cutout.

PROG MENU

Use the PROG MENU (PROGRAM MENU) to access automated and manual program selections.

SELECT PROG

Use the SELECT PROG menu to select a program, 1 - 8.

PROGRAM

Select the PROGRAM from the listing.

EDIT PROG

Use the EDIT PROG (EDIT PROGRAM) menu edit program parameters.

PROGRAM (view Only)

The PROGRAM parameter indicates the number of the selected program.

NAME (view Only)

Program NAME indicates the program name. To set the program name, see the PROG:[n]NAME serial command. Example: a thermometer model number.

IRT ε

IRT ε is the emissivity setting of the IR thermometer to be calibrated.

DISTANCE

DISTANCE is the distance in centimeters (cm) from the IR target to the DUT.

APERTURE

Select YES or NO. Yes indicates that an external aperture is required during calibration.

NO. SETPOINTS

The NO. SETPOINTS is the number of set-points defined for a given program. The number of set-points for each program can be set from 1 to 8 and vary depending on the needs of the user. Set the maximum number of set-points needed for the program selected. Once the number of set-points is selected, push **ENTER** to accept the new setting.

SETPOINT n:

Use SETPOINT n to set the temperature for each given set-point. n is a number from 1 to No. Set-points.

PROG OPTION

Use the PROG OPTION (PROG OPTION) to set program parameters.

SETTLE TEST

SETTLE TEST is the criteria to determine when the temperature of the surface is stable. The options are: AUTO and LIMIT. AUTO uses a predetermined value for the stability. LIMIT uses the value set by the STABLE LIMIT parameter in the TEMP SETUP|SETUP|STABLE LIMIT window.

SOAK MINUTES

The SOAK MINUTES parameter is the number of minutes that each of the program set-points is maintained. The time starts when the temperature settles to within the specified stability. The stability limit is set in the TEMP SETUP|SETUP|STABLE LIMIT window.

ADVANCE

Use ADVANCE to set the choice to advance to the next step in the program automatically (AUTO) or to be prompted from the screen (PROMPT).

CYCLES

CYCLES is the number of times that the Product repeats the program.

RUN PROG

Use the RUN PROG (RUN PROGRAM) menu to access the program status feature.

PROGRAM (view Only)

The PROGRAM parameter indicates the number of the program that is selected.

NAME (view Only)

Program NAME indicates the program name. To set the program name, see the PROG:[n]NAME serial command. Example: a thermometer model number.

STATUS

The STATUS option controls the state of the program. The user selects RUN to run the program or OFF to turn the program off.

SYSTEM MENU

Use the SYSTEM MENU to set up the display settings, communications protocol, password settings, calibrations settings, and to view system information.

SYSTEM SETUP

The SYSTEM SETUP menu contains the menus for the display and communications parameters.

DISPLY SETUP

The DISPLY SETUP (DISPLAY SETUP) menu contains the language selection, decimal separator, and keypad sound parameters.

LANGUAGE

See *Languages* in the Operators Manual.

DECIMAL

Use the DECIMAL parameter to determine the decimal separator: a comma or a period. Push the right or left arrow to select the desired decimal separator and then push **ENTER** to accept the selection.

KEY AUDIO

The KEY AUDIO parameter (**F1** and **F3** pushed simultaneously) enables or disables the button push beep.

COMM SETUP

The COMM SETUP (COMMUNICATIONS SETUP) menu contains the serial interface parameters. The parameters in the menu are: BAUD RATE and LINEFEED.

BAUD RATE

The BAUD RATE parameter determines the serial communication transmission rate or baud. BAUD RATE may be programmed to 1200, 2400, 4800, 9600, 19200, or 38400 baud.

LINEFEED

The LINEFEED enables (ON) or disables (OFF) transmission of a line feed character (LF, ASCII 10) after transmission of any carriage return. The LINEFEED default setting is on. The line-feed parameter can be turned on or off as needed.

PASSWORD

Use the PASSWORD (PASSWORD SETUP) menu to set the system password or set the level of protection that conditionally engages or disengages protection of certain groups of parameters.

USER PASSWORD

Use the USER PASSWORD parameter to enter and change the system and conditional password used to access protected menus. The PASSWORD is a number between one and four digits. Each digit of the password can be a number from 0 to 9. The default System Password is 1234. Use the up, down arrow buttons to enter the new password, and then push **ENTER**.

PROTECTION

Use the PROTECTION parameter to enable (HIGH) or disable (LOW) password protection for the conditional parameters. The password is the same as the system password. You can conditionally password-protect the SOFT CUTOFF and all of the PROGRAM MENU parameters except SELECT PROG and RUN PROG. Select HIGH or LOW with the left and right arrow buttons and push **ENTER** to accept the selection.

CALIBRATE

Caution

Calibration parameters must be correct for the Product to function properly.

Use the CALIB (CALIBRATION) menu to access to the calibration parameters for the Product. Access to the IR target calibration parameters is password protected. Calibration parameters are programmed at the factory when the Product is calibrated. Qualified personnel can adjust these parameters when needed to improve the accuracy of the Product.

 **Caution**

Do not change the calibration values or control parameters from the factory-set values unless recalibrating the Product. The correct setting of these parameters is important to the safe and proper operation of the Product.

The parameters in the CALIB menu are set at the factory and must not be altered unless recalibrating the Product. Recalibration of the Product should be performed by qualified personnel. The correct values are important to the accuracy and safe operation of the Product. Access to these parameters is password protected. In the event that the calibration parameters need to be reentered into the Product, the constants and their settings are listed in the Report of Calibration shipped with the Product.

CONT SETUP

Use the CONT SETUP (CONTROL SETUP) to access the controller parameters.

TEMP PBAND

The TEMP PBAND parameter is the proportional band in °C that the Product's proportional-integral-derivative (PID) controller uses for control.

TEMP INT

The TEMP INT parameter is the integration time in seconds that the Product's PID controller uses for control.

TEMP DER

The TEMP DER parameter is the derivative time in seconds that the Product's PID controller uses for control.

IR CAL

The IR CAL (IR CALIBRATION) menu contains the IR target calibration constants: IR CAL 1, IR CAL 2, and IR CAL 3. Use the arrow buttons to enter the set-point for each calibration point and push **ENTER** to accept the entry. The calibration points should be selected applicable to model with a low, mid-range, and high set-point.

IR CAL 1

The IR CAL 1 parameter is the offset in °C for the IR target accuracy at the 1st calibration point.

IR CAL 2

The IR CAL 2 parameter is the offset in °C for the IR target accuracy at the 2nd calibration point.

IR CAL 3

The IR CAL 3 parameter is the offset in °C for the IR target accuracy at the 3rd calibration point.

WAVELENGTH

The WAVELENGTH parameter can be set to the default 8 μm to 14 μm or USER selectable. This is to remind the user that the nominal emissivity and calibration of the Product pertains to the 8 μm to 14 μm band.

CALDATE

The CALDATE parameter is the calibration date for the IR target. Use the arrow buttons to enter the calibration date in the format yyyy,mm,dd.

SYSTEM INFO (View Only)

The SYSTEM INFO (SYSTEM INFORMATION) menu displays manufacturer information regarding the Product.

MODEL

The MODEL parameter displays the model number of the Product.

SERIAL

The SERIAL (SERIAL NUMBER) parameter displays the serial number of the Product.

FW VERSION

The FW VERSION (FIRMWARE VERSION) parameter displays the firmware version used in the Product.

CAL DATE

The CAL DATE (CALIBRATION DATE) parameter displays the calibration date of the IR target.

VIEW TEMP

Use the VIEW TEMP (VIEW TEMPERATURE) to view the BLOCK TEMPERATURE parameter.

BLOCK TEMP (View Only)

Use the BLOCK TEMP (BLOCK TEMPERATURE) parameter to view the uncompensated control sensor temperature.

Basic Infrared Thermometry Theory - Relating to the use of the Product

Typically, infrared (IR) thermometers have not been used for measurements requiring low uncertainties. Their application has been for use at extremely high temperatures and in applications where accuracy is less important than repeatability.

As infrared thermometers and our understanding of their advantages improve, both absolute accuracy and calibration become more important. This section gives a brief explanation of some important issues surrounding the use and calibration of IR thermometers and how this information relates to the use of the Product.

Apparent Temperature

The Product is calibrated using a radiometric calibration. The main display temperature is based on this radiometric calibration. This temperature shows the user what an IR thermometer with a given emissivity setting should read. This is called apparent temperature. The apparent temperature is defined as the temperature an IR thermometer set to emissivity (ϵ) should read when measuring the IR calibrator's surface.

In other words, the display temperature shows what temperature the target appears to be to the IR thermometer.

Spectral Response (Wavelength)

Every object with a temperature above absolute zero (0 Kelvin) radiates energy over a wide spectral band. For example, if a significant part of this energy is within the band of 400–700 nm, we can see that energy. This is the visible light band. This is the case with an electric stove burner at a temperature of 800 °C. The burner appears red or orange to the eye (red hot). That burner is also emitting energy at other wavelengths, which we can not see. This includes wavelengths in the infrared portion of the electromagnetic spectrum.

An example of an object emitting energy at wavelengths we can see is the sun. The sun's surface temperature is about 5750 K. According to Wien's Displacement Law, see Equation 1, the peak wavelength for this temperature is about 500 nm which happens to be in the visible light band. Thus the eye detects wavelengths corresponding to the temperature of the Sun.

By the same respect, if we are measuring an object at room temperature, (23 °C or about 296 K), the peak wavelength is 9.8 μm which is inside the 8 μm to 14 μm band. In fact the temperature corresponding to a peak wavelength at 8 μm is 89 °C and the temperature corresponding to a peak wavelength at 14 μm is -66 °C. This is one of the reasons the 8 μm to 14 μm is widely used in handheld IR thermometers.

IR thermometers take advantage of this peak wavelength phenomenon. They measure the amount of energy radiating from an object and calculate temperature based on this measured energy. In most handheld IR thermometers, the sensor and optical system measure IR energy in the 8 μm to 14 μm band.

The mathematical equation describing the spectral power radiated by a perfect blackbody for a given wavelength is Planck's Law. If Planck's Law, see Equation 2, is integrated over the entire electromagnetic spectrum, this gives us the Stefan-Boltzmann Law. This is the T to the 4th law (T_4). The problem with the Stefan-Boltzmann Law, see Equation 3, is that it is not limited to a specific band. To get the energy within a certain band, we would need to integrate Planck's Law for the limits of this bandwidth. This integral cannot be solved analytically.

The mathematical equation describing the peak wavelength for a given temperature is Wien's Displacement Law.

$$\lambda_{\max} T = c_3$$

Equation 1: Wien's Displacement Law

$$L(\lambda, T) = \frac{c_{1L}}{\lambda \left[\exp\left(\frac{c_2}{\lambda T}\right) - 1 \right]}$$

Equation 2: Planck's Law

$$M = \sigma T^4 = \pi \int_0^{\infty} L(\lambda, T) d\lambda$$

Equation 3: Stefan-Boltzmann Law

The relationship between Planck’s Law and Wien’s Displacement Law is shown in Figure 1. Notice that the energy peak for the Sun is about 0.5 μm (500 nm), while at room temperature, 23 °C, it is just below 10 μm.

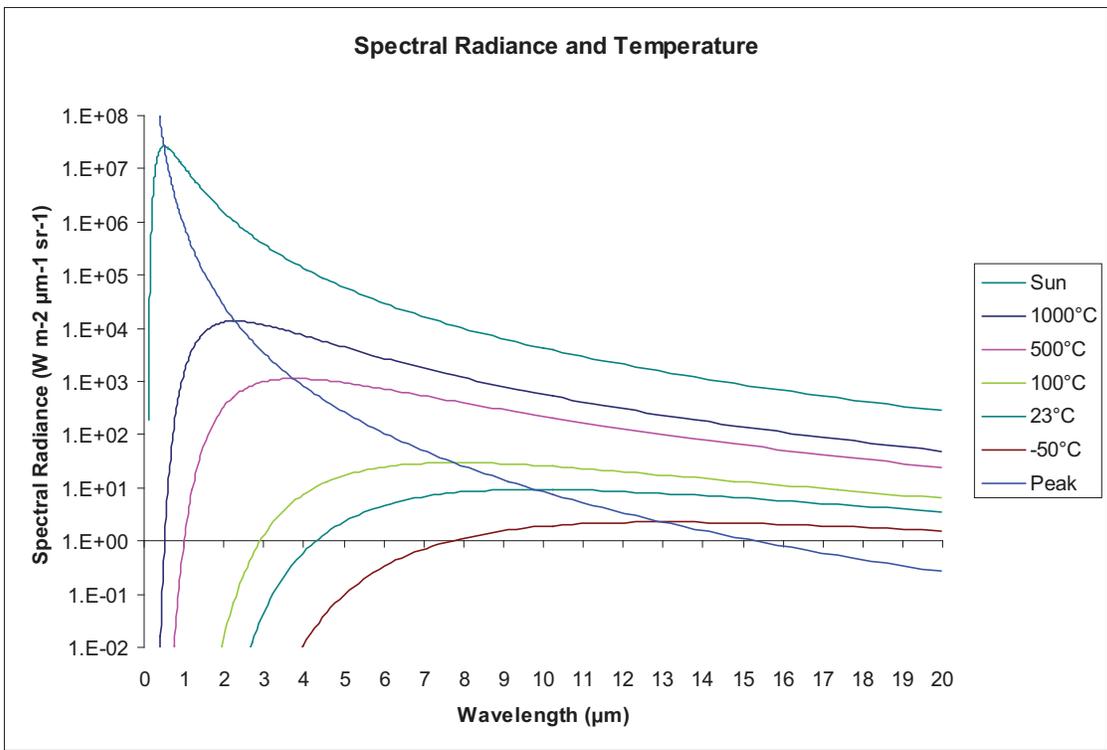


Figure 1. Relation between Planck’s Law and Wien’s Displacement Law

Emissivity

Emissivity is defined as the ratio of the energy emitted at a temperature to the energy emitted by a perfect blackbody at that same temperature. A perfect blackbody would have an emissivity of 1.0. However, in the real world there is no such thing as a perfect blackbody.

For example, if a perfect blackbody emits 10000 W/m² at a given temperature and a material emits 5000 W/m² at that same temperature, then the emissivity of that material is 0.5 or 50 %. If another material emits 9500 W/m² at that same temperature, it has an emissivity of 0.95.

It is important to note that for any opaque material, the ratio of energy rejected plus the ratio of energy transmitted is equal to 1.0 (this is known as Kirchhoff's Law). So if a material's emissivity is 0.95, the material rejects 5 % of the energy radiated by objects facing it. By contrast, if an object has an emissivity of 0.50, the material rejects 50 % of the energy radiated by objects facing it. This means this rejected energy can contribute to measurement accuracy. This is especially true when measuring materials with lower emissivity, and objects at lower temperatures.

Uncertainty Caused by Emissivity

A lack of knowledge of emissivity itself can contribute greatly to inaccuracy in IR temperature measurement. Figure 2 shows a graph of this phenomenon in the 8 μ m to 14 μ m band.

For an example, say we are measuring an object at 500 °C. We assume it has an emissivity of 0.95. However, its emissivity is really 0.93. This would cause our 8 μ m to 14 μ m IR thermometer to read the temperature 6.7 degrees low, a -6.7 °C error in temperature measurement.

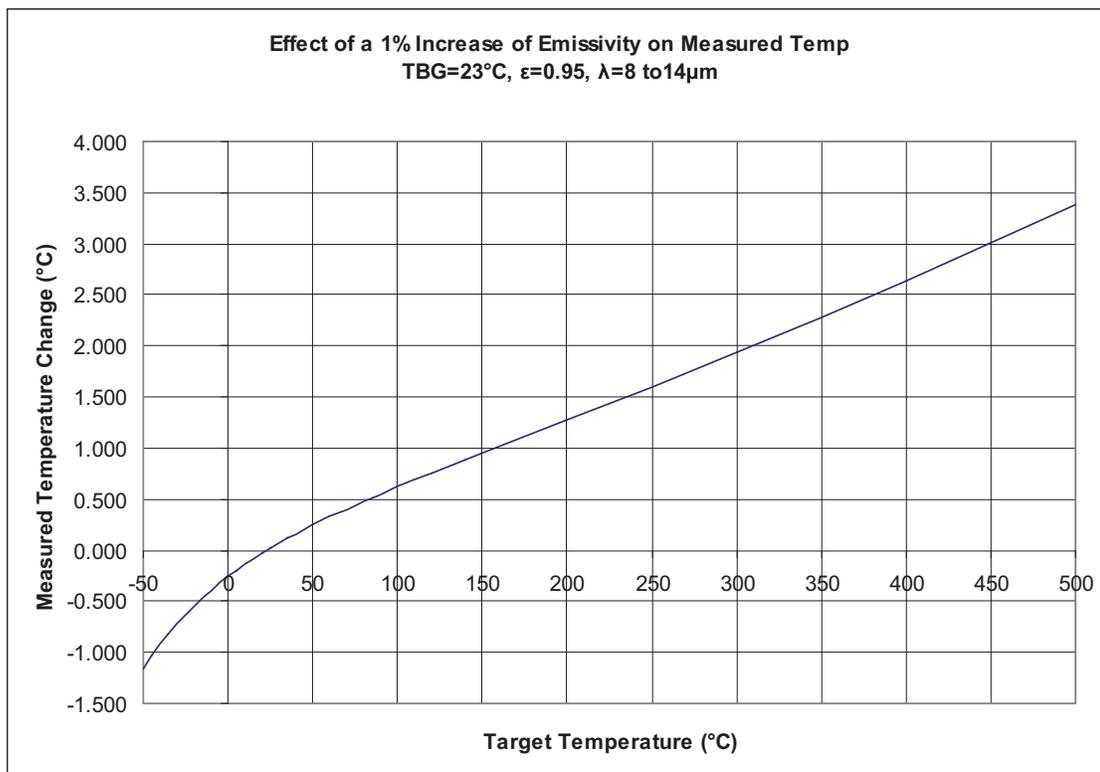


Figure 2. Effect of a 1 % Increase of Emissivity on Measured Temperature

The emissivity of an object is not an easy thing to determine. One method is to take a calibrated variable-emissivity IR thermometer, aim it properly at the object in question, and adjust its emissivity until its reading matches the known temperature of the object. This gives an average emissivity of the object over the IR thermometer's bandwidth. This method assumes the measured object is gray.

We term an object as having constant emissivity over all wavelengths as being gray or a gray body. It should be noted that most objects tend not to have a constant emissivity over all bandwidths, thus these objects are not perfect gray bodies. Uncertainties in emissivity values need to be considered in the total uncertainty of measurements with IR thermometers.

One widely used and accepted method in determining the spectral dependence on emissivity (or how emissivity varies with wavelength) is Fourier Transform Infrared (FTIR) testing. A graph from such a test is shown in Figure 6.

Effect of Background Temperature

Another effect related to emissivity is that of background temperature. Background temperature is the temperature of objects facing the measured surface. Remember that when an object has an emissivity of 0.95, it is rejecting 0.05 of background object's radiation energy. Of course the amount of background radiation is a function of the background objects' temperature. An example of this effect is shown in Figure 3.

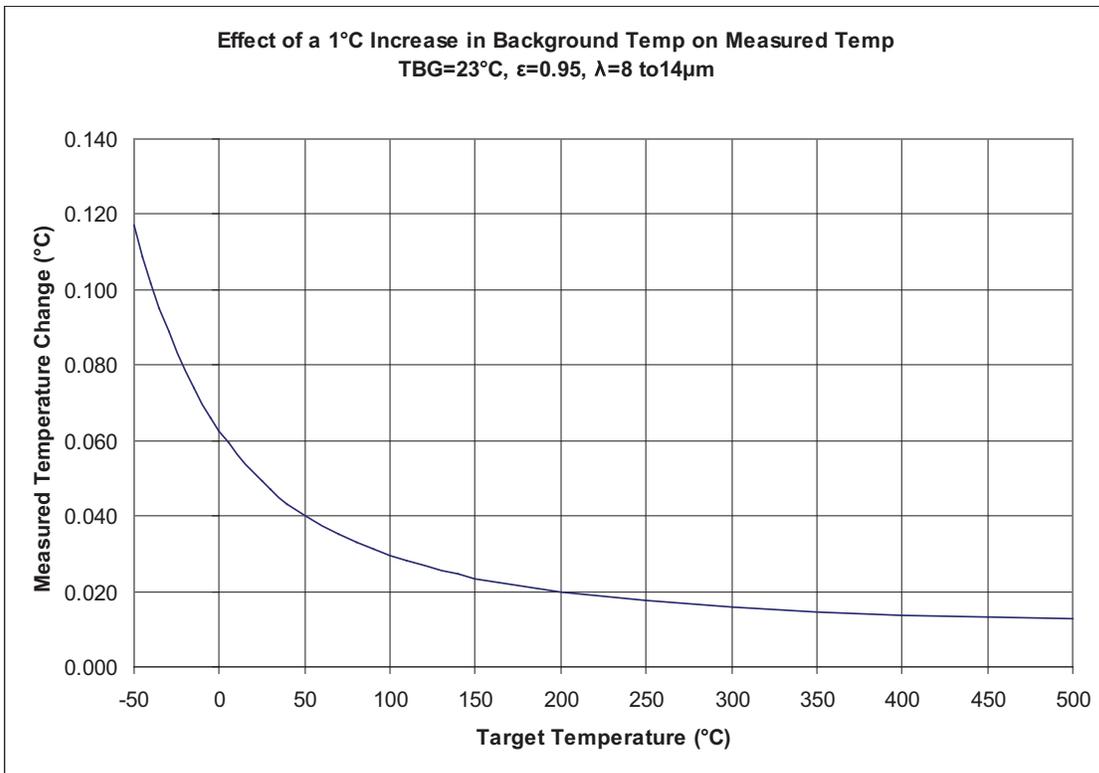


Figure 3. Effect of a 1 % Increase in Background Temperature in the 8 μm to 14 μm Band

As can be seen in the graph, the effect of background temperature is more troublesome when you measure lower temperatures than when you measure higher temperatures. The point of this discussion is that in order to do good IR thermometry, background temperature must be controlled.

Effect of Angle on Emissivity

Another topic to be aware of relating to emissivity is that emissivity varies with angle. Typically, emissivity is maximum when taking a measurement normal to an object and is zero when taking a measurement parallel to an object. An example of this effect when using the Product is shown in Figure 4. As can be seen in the graph, any measurements made within 15° of normal will cause an error less than 0.001 in emissivity. This number can be evaluated against the graph in Figure 4 to obtain uncertainty due to angular deviation from normal.

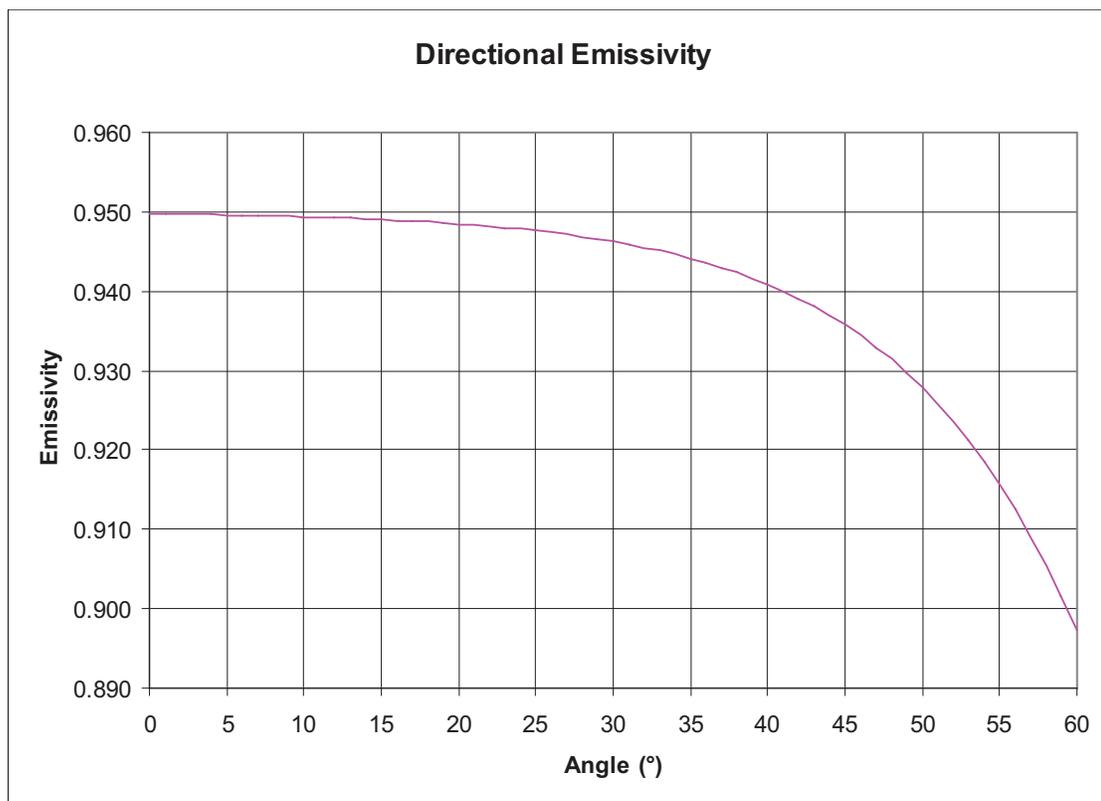


Figure 4. Effect of Angular Emissivity Calibration Geometry

Along with emissivity, calibration geometry is one of the most misunderstood topics related to the calibration and use of IR thermometers. Among the topics that are misunderstood are center of spot, size of spot, scatter, size of source and distance to target.

Center of Spot

Many IR thermometers include lasers as a guide to show the user where to point them. These act as approximating guides only. In reality, IR thermometers see areas much bigger than that small laser dot. Also, an IR thermometer's center of spot may not be exactly at the point where the laser is pointed. To understand the impact of these two factors on a calibration, testing should be done to determine the center of the spot. This information may be provided by the manufacturer as well.

Size of Spot, Size of Source and Scatter

IR thermometer manufacturers frequently indicate a distance-to-spot-size ratio. It is computed at specific distances. The spot size is the diameter that contains a given amount of energy detected by the IR thermometer. This is typically 90 % to 95 % of the energy. This information is also just an approximating guide. The energy outside this detection area is referred to as scatter. This means that a surface area much larger than the given spot size is needed when calibrating IR thermometers. Spot size is often referred to as size of source effect.

Two solutions to size of source effect problems are available through the calibration of the IR thermometer, both related to calibration geometry including distance and target size. One method is to calibrate the instrument under the same conditions under which it is used. That is, you point it at the same size of target at a known surface temperature as what it is used to measure, from the same distance, and under similar ambient conditions.

The other method is to duplicate the calibration geometry used by the manufacturer of that device. This information should be available from the manufacturer. Under either method, you calibrate in a certain intended amount of scatter into your measurement.

The target size needed to calibrate a given IR thermometer is dependent on the IR thermometer's optical system. Many IR thermometers come with a spot size diagram. These diagrams can be misleading. As mentioned above, all of the energy the IR thermometer detects is within the given spot diagram. Generally you will need at least 2 to 3 times the spot size diameter to use for calibration.

The Product provides a 150 mm (6 inch) diameter flat plate. This gives the user a large temperature controlled surface to calibrate IR thermometers. 150 mm (6 inches) is a large enough diameter to accommodate most handheld IR thermometers.

Distance to Target

The third topic of concern with calibration geometry is distance between the calibration target and the IR thermometer being calibrated. It is important not to have the IR thermometer too close to the target. This will cause the IR thermometer's optics to heat excessively which will cause false readings. It is also important to be not too far away. This will cause the target to not fill the IR thermometer's spot size and will cause a false reading.

Knowing the Correct Geometry

Information on these 3 factors, center of spot, size of source, and distance to target, should be provided by the IR thermometer manufacturer. If this information cannot be obtained, ASTM provides a guideline (ASTM Standard E1256-95) to determine some of these parameters.

Traceability

Fluke Calibration's traceability for the Product calibration comes through a radiometric transfer standard. The Product is calibrated with an 8 μm to 14 μm highly-accurate IR thermometer (radiometer). This IR thermometer is calibrated with blackbody cavity baths. The temperature of these baths is measured by PRTs which have a calibration traceable to NIST. A diagram of this traceability is shown in Figure 5.

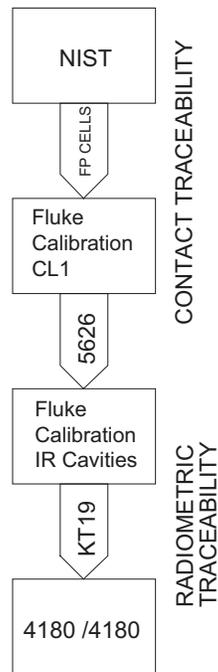


Figure 5. Product Traceability

Note that when an IR thermometer is calibrated against another IR thermometer that uses the same temperature source, both should view the same portion of the electromagnetic spectrum. The Product calibration uses a highly-accurate IR thermometer which operates in the 8 μm to 14 μm band. This should be sufficient to calibrate IR thermometers using this bandwidth. If you need more information about what band the device under test (DUT) operates in, consult the unit's user's guide or the unit's manufacturer.

Radiometric calibration is to account for factors that cannot be accounted for with a contact calibration. The two main factors are the difference between contact temperature and surface temperature, and the difference between the DUT's emissivity setting and the target's surface emissivity. These factors are discussed further in [Use of the Product in the Context of IR Theory](#). The emissivity setting of the IR thermometer used to calibrate the Product is 0.95.

Treatment of IR Thermometers

Three other issues require consideration when using or calibrating IR thermometers.

First, they are subject to thermal shock. If an IR thermometer is suddenly introduced to significantly different ambient conditions, it should be allowed time to reach thermal equilibrium.

Second, IR thermometers are subject to measurement influence by ambient conditions and should be calibrated under similar conditions as those under which they will be used.

Lastly, IR measurements can be influenced by the cleanliness of the IR thermometer's optics. They should be cleaned regularly, including immediately prior to calibration. Check with your IR thermometer manufacturer for proper cleaning methods.

IR thermometry is a powerful and useful tool. Measurements are relatively instantaneous and the surface of the object being measured does not need to be touched. These are definite advantages over contact thermometry. The main disadvantage is accuracy. By considering the topics outlined here, you can reduce uncertainties in measurements made by IR thermometers, both during their calibration and during their use. Time should be taken to understand all uncertainties in any temperature measurement, both in contact thermometry and IR thermometry.

Use of the Product in the Context of IR Theory

The Product provides a number of features to facilitate IR measurements in relation to calibration.

- A large temperature controlled surface is provided to accommodate IR thermometers with larger spot sizes. The target's uniformity is specified as well so that the user can make a proper evaluation of calibration uncertainties as related to spot size.
- The Product provides the user with a radiometric calibration instead of a contact calibration. This gives the user a number that is more usable when calibrating an IR thermometer. The radiometric calibration is done with a highly accurate reference IR thermometer which measures in the 8 μm to 14 μm band. This is a band common to most handheld IR thermometers.

The radiometric calibration is more useful than a contact calibration for these reasons:

- It reduces the uncertainty caused by a lack of knowledge of the surface's emissivity.
- There is heat flow between the reference probe and the target surface.

This causes a temperature drop between the location inside the block where the contact probe is located and the target surface. A contact calibration would not give the target surface temperature. This would create additional uncertainty in the measured temperature.

The emissivity setting of the Product should be set to the same setting as the IR thermometer's emissivity setting. If an IR thermometer has adjustable emissivity, this setting should be 0.95 on both instruments. If this is not possible, the Product can compensate for a limited number of emissivity settings other than 0.95.

If a Product is used to calibrate an instrument that has a spectral response other than 8 μm to 14 μm , additional uncertainty will be introduced to the measurement if the user is using the display reading. To facilitate calculation of this additional uncertainty, a graph of the typical emissivity of the paint used on the product is provided in [Example of the Product Spectral Emissivity and Calibration Spectral Response](#).

The 4180 purge system provides the user a way to ensure the emissivity remains consistent below the dew point. When used properly, the purge system will keep ice or moisture from forming on the target. Any ice or moisture on the target surface changes the surface's emissivity and can cause errors in the range of 2.0 $^{\circ}\text{C}$. The Product's factory radiometric calibration is done in dried air. This environment has a dew point well below -15 $^{\circ}\text{C}$ meaning that no ice or moisture will form on the target.

Example of the Product Spectral Emissivity and Calibration Spectral Response

Figure 6 and Figure 7 help calculate uncertainty budgets for calibrating IR thermometers. They should be evaluated for any unit that is calibrated with the Product.

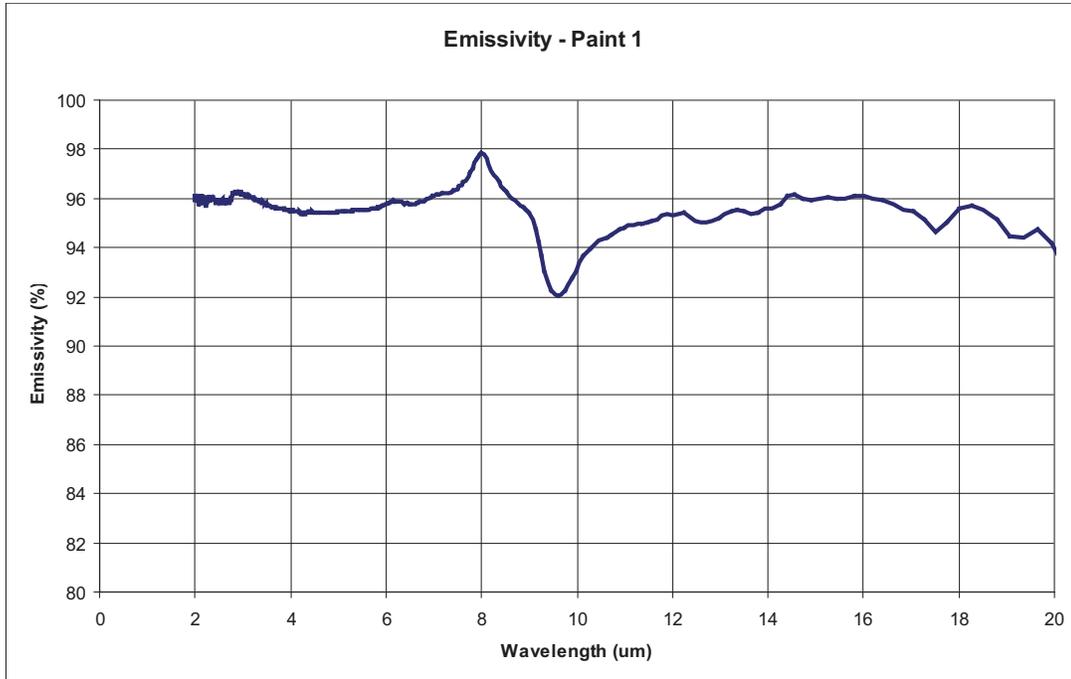


Figure 6. Typical Results of FTIR Testing on the Product Surface Coating

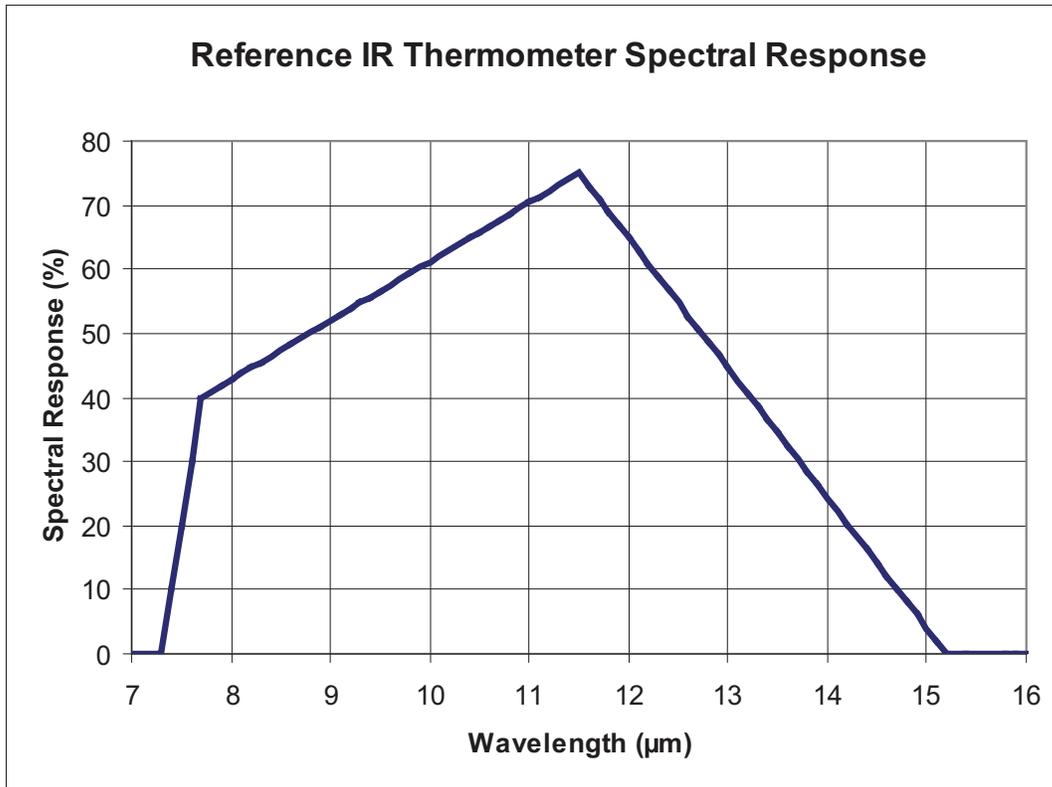


Figure 7. Spectral Response of IR Thermometer Used to Calibrate the Product

Example of an Uncertainty Budget for an IR Thermometer Calibration

This section is an example of an uncertainty budget for the calibration of a theoretical IR thermometer using the Product. It is not intended to be an uncertainty budget for any laboratory calibrating IR thermometers. Instead, it is intended to serve as a framework for laboratories to calculate their own uncertainty budget.

Example IR Thermometer Uncertainty Budget

Uncertainties	Denot.	Type	Dist	Divisor	100°C
Target Uncertainties					
Calibration Uncertainty	u ₁	B	normal	2	0.284
Stability (long term)	u ₂	A	normal	2	0.050
Uniformity	u ₃	B	rectangular	√3	0.145
Noise	u ₄	A	normal	2	0.109
Display Resolution	u ₅	A	rectangular	√3	0.005
IR Thermometer Uncertainties					
Readout Resolution	u ₆	A	rectangular	√3	0.050
Ambient Temperature	u ₇	B	rectangular	√3	0.030
Noise	u ₈	A	normal	2	1.000
Atmospheric Losses	u ₉	B	normal	2	0.010
Angular Displacement	u ₁₀	B	rectangular	√3	0.030
Background Temperature	u ₁₁	B	rectangular	√3	0.116
Spectral Variation	u ₁₂	B	normal	2	0.240
Combined Standard Uncertainty	u _c	k=1	normal		0.549
Combined Expanded Uncertainty	U	k=2	normal		1.097
<p>Note that the values in the 100°C column represents the expanded (k=2) uncertainty for normal distributions and half of the difference of bounds for rectangular distributions. A sum of squares of the values in this column divided by the number in the divisor column will give the square of the value for u_c, the combined standard uncertainty. Multiplying the combined standard uncertainty by 2 will give the value for the combined expanded uncertainty.</p>					

$$u_c = \sqrt{\left(\frac{u_1}{2}\right)^2 + \left(\frac{u_2}{2}\right)^2 + \left(\frac{u_3}{\sqrt{3}}\right)^2 + \left(\frac{u_4}{2}\right)^2 + \left(\frac{u_5}{\sqrt{3}}\right)^2 + \left(\frac{u_6}{\sqrt{3}}\right)^2 + \left(\frac{u_7}{\sqrt{3}}\right)^2 + \left(\frac{u_8}{2}\right)^2 + \left(\frac{u_9}{2}\right)^2 + \left(\frac{u_{10}}{\sqrt{3}}\right)^2 + \left(\frac{u_{11}}{\sqrt{3}}\right)^2 + \left(\frac{u_{12}}{\sqrt{3}}\right)^2}$$

U = 2u_c

Equation 4: Combined Uncertainty for Example Uncertainty Budget

Explanations

u1: Calibration Uncertainty	This is the uncertainty provided by the IR calibrator manufacturer. It follows a normal distribution.
u2: Stability (long term)	This is the contribution from possible drift of the IR calibrator during its calibration interval. It is obtained from historical data of the IR thermometer model. It is expected to follow a normal distribution since it is likely affected by a combination of factors.
u3: Uniformity	This is the contribution from the uniformity of the IR calibrator. The IR thermometer under test has a spot size determined by size of source testing. The contribution of this energy is evaluated against the IR calibrator's uniformity specification. Since the uniformity specification is given as a plus and minus tolerance, it is expected to follow a rectangular distribution.
u4: Noise	This is the contribution from noise of the IR calibrator. It is based on measured data and follows a normal distribution.
u5: Display Resolution	This is the contribution from quantization error of the IR calibrator readout. It has a rectangular distribution.
u6: Readout Resolution	This is the contribution from quantization error of the IR thermometer readout. It has a rectangular distribution.
u7: Ambient Temperature	This is the contribution from the possible range of ambient temperature, which is given limits of 23 °C ±4 °C. It is based on information provided by the IR thermometer manufacturer. Ambient temperature is expected to more often be closer to 23 °C so a normal distribution is used.
u8: Noise	This is the contribution from noise of the IR thermometer. It is based on measured data and follows a normal distribution.
u9: Atmospheric Losses	This is the contribution from differences in atmospheric attenuation between calibration of the calibrator and calibration of the IR thermometer. It is based modeling of standard atmospheric data. It is based on a number of factors, so a normal distribution is used.
u10: Angular Displacement	For this calibration, the angle is controlled within 5° of normal. According to the IR calibrator manufacturer, this could cause a ±0.0005 change in emissivity. This tolerance is converted to a temperature uncertainty for the uncertainty budget. It is expected to follow a rectangular distribution.
u11: Background Temperature	This is the contribution from changes in temperature of surfaces facing the plate. The plate reflects some of the incident background energy. Since the laboratory walls are the main surface facing the plate, it is based on their temperature variance. This temperature is limited by a tolerance during calibration, so it follows a rectangular distribution.
u12: Spectral Variation	This is the contribution from the uncertainty in the spectral response of the IR thermometer measuring the plate. Since the plate is not a perfect gray body, the spectral response of the emissivity of the IR calibrator's surface must be taken into account. The contribution from the spectral response is based on information given by the IR thermometer manufacturer. The spectral response of the paint is based on emissivity data from the IR calibrator manufacturer. These two data are modeled mathematically to determine the effect of the spectral response uncertainty. This uncertainty is based on a number of factors, so a normal distribution is used.

Further Reading

The list below contains excellent resources on IR thermometry theory and good measurement practices.

- *Theory and Practice of Radiation Thermometry* by D.P. DeWitt and Gene D. Nutter (John Wiley & Sons)
- *Thermal Radiative Transfer and Properties* by M. Quinn Brewster (John Wiley & Sons)
- *Introduction to Radiometry and Photometry* by Ross McCluney (Artech House)
- E 1256 - 95 in *Annual Book of ASTM Standards Vol. 14.03*, ASTM International, West Conshohocken, PA
- *U. S. Guide to the Expression of Uncertainty in Measurement (GUM)*.

Digital Communication Interface

Wiring

Use a digital interface to connect the Product to a computer or other equipment. A digital interface lets you input the set-point temperature, monitor the temperature, control operating conditions, and access any of the other controller functions. The RS-232 serial interface allows serial digital communications over fairly-long distances. Access any of the functions, parameters, and settings discussed in this section with the serial interface.

The serial communications cable attaches to the Product through the DB-9 connector at the back of the Product. Figure 8 shows the pin-out of this connector and suggested cable wiring. To eliminate noise, the serial cable should be shielded, with low resistance between the connector (DB9) and the shield.

RS-232 Cable Wiring for IBM PC and Compatibles

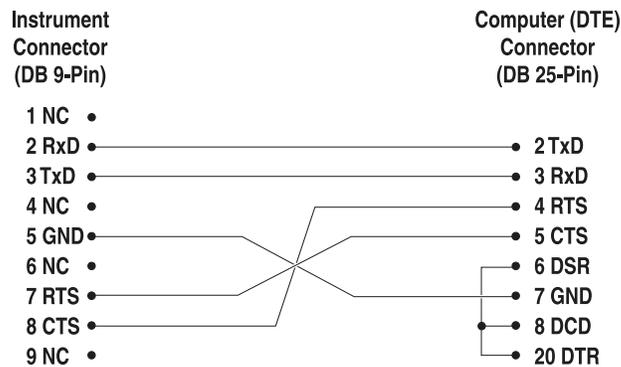
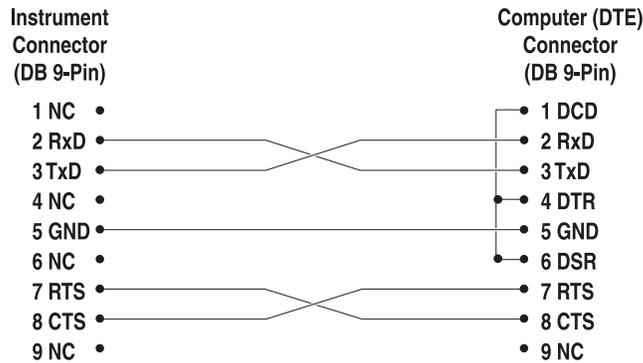


Figure 8. RS-232 Wiring

Setup

Before operation, the serial interface must first be set up by programming the BAUD rate and other configuration parameters. These parameters are programmed within the communications menu. The serial interface parameters can be accessed from the main menu by MENU|SYSTEM SETUP|COMM SETUP|. Refer to *Comm* in the Operators Manual for more information on the serial interface parameters.

Serial Operation

The serial communications uses 8 data bits, one stop bit, and no parity. The set-point and other commands may be sent with the serial interface to set the temperature set-point and view or program the various parameters. The interface commands are discussed in [Product Operation](#).

Command Syntax

Infrared Calibrators accept commands for setting parameters, executing functions, or responding with requested data. These commands are in the form of strings of ASCII-encoded characters. The Product command syntax conforms to SCPI-1994 as closely as possible. One notable exception is that compound commands are not allowed as explained below.

Commands consist of a command header and, if necessary, parameter data. All commands must be terminated with either a carriage return (ASCII 0D hex or 13 decimal) or new line character (ASCII 0A hex or 10 decimal).

Command headers consist of one or more mnemonics separated by colons (:). Mnemonics may use letter characters, the underscore character (_), and possibly numeric digits as well. Commands are not case sensitive. Mnemonics often have alternate forms. Most mnemonics have a long form that is more readable and a short form consisting of three or four characters that is more efficient.

A mnemonic may end with a numeric suffix that specifies one of a set of independent function blocks such as input channel data paths. If a numeric suffix is omitted when a particular block must be specified, an error is generated (*Header suffix out of range*).

Query commands are commands that request data in response. Query commands have a question mark (?) that immediately follow the command header. Responses to query commands are generated immediately and placed in the output buffer. Responses are then transmitted automatically over the RS-232 port. Responses are lost if not read before the next command is received.

Some commands require parameter data to specify values for one or more parameters. The command header is separated from the parameter data by a space (ASCII 20 hex or 32 decimal). Multiple parameters are separated by a comma (,).

The Product does not allow compound commands (multiple commands per line separated with semicolons). All commands are sequential. The execution of each command is completed before subsequent commands are processed.

Commands by Function or Group

In this section, the commands are arranged into the following groups, see Table 1:

- Calibration Commands - commands for the Product calibration parameters.
- Main Screen Commands - commands for parameters displayed on the main screen.
- Program Commands - commands for program setup and status.
- Setup Commands - commands for setting up communication, display, password, measure, and operation parameters.
- System Commands - commands to report and change the status of the Product.
- Temperature Commands - commands for control temperature and cutout functions

Table 1. Commands by Function or Group

	Screen Parameter	Command	Password Protection Group	Read/Write
Calibration - Controller	TEMP PB	SOUR:LCON:PBAN	Unconditional	R/W
	TEMP INT	SOUR:LCON:INT	Unconditional	R/W
	TEMP DER	SOUR:LCON:DER	Unconditional	R/W
Calibration – IR Target	WAVELENGTH	SOUR:CAL:WAV	Unconditional	R/W
	(none)	SOUR:CAL:EMIS	N/A	R
	IR CAL 1	SOUR:CAL:PAR1	Unconditional	R/W
	IR CAL 2	SOUR:CAL:PAR2	Unconditional	R/W
	CAL DATE	SOUR:CAL:DATE	Unconditional	R/W
Main Screen	(apparent temperature)	SOUR:SENS:DATA [TEMP]	N/A	R
	SETPT	SOUR:SPO	N/A	R/W
	(graphic)	SOUR:STAB:DATA	N/A	R
	(none)	SOUR:STAB:TEST	N/A	R
	HEAT %	OUTP:DATA	N/A	R
	ENABLE	OUTP:STAT	N/A	R/W
	IRT E:	SOUR:EMIS	N/A	R/W
	CAL L	SOUR:CAL:WAV	N/A	R/W
	°C/°F key	UNIT:TEMP	N/A	R/W
	SETPT	SOUR:SPO	N/A	R/W
Setpoint	SETPOINT 1	SOUR:LIST:SPO1	N/A	R/W
	SETPOINT 2	SOUR:LIST:SPO2	N/A	R/W
	SETPOINT 3	SOUR:LIST:SPO3	N/A	R/W
	SETPOINT 4	SOUR:LIST:SPO4	N/A	R/W
	SETPOINT 5	SOUR:LIST:SPO5	N/A	R/W
	SETPOINT 6	SOUR:LIST:SPO6	N/A	R/W
	SETPOINT 7	SOUR:LIST:SPO7	N/A	R/W
	SETPOINT 8	SOUR:LIST:SPO8	N/A	R/W
Program - Select	PROGRAM	PROG:SEL	N/A	R/W

Table 1. Commands by Function or Group (cont.)

	Screen Parameter	Command	Password Protection Group	Read/Write
Program - Run	TEST STATUS	PROG:STAT	N/A	R/W
Program - Edit	ADVANCE	PROG:PROM:ADV	N/A	W
	(none)	PROG:PROM:STAT	N/A	R
	(none)	PROG:PAR:CAT	N/A	R
	SETPOINT 1	PROG[x]:PAR SPO1	Conditional	R/W
	SETPOINT 2	PROG[x]:PAR SPO2	Conditional	R/W
	SETPOINT 3	PROG[x]:PAR SPO3	Conditional	R/W
	SETPOINT 4	PROG[x]:PAR SPO4	Conditional	R/W
	SETPOINT 5	PROG[x]:PAR SPO5	Conditional	R/W
	SETPOINT 6	PROG[x]:PAR SPO6	Conditional	R/W
	SETPOINT 7	PROG[x]:PAR SPO7	Conditional	R/W
	SETPOINT 8	PROG[x]:PAR SPO8	Conditional	R/W
	NO. SETPOINTS	PROG[x]:PAR POIN	Conditional	R/W
	IRT E:	PROG[x]:PAR IRTE	Conditional	R/W
	DISTANCE	PROG[x]:PAR DIST	Conditional	R/W
	APERTURE	PROG[x]:PAR APER	Conditional	R/W
	NAME	PROG1:NAME	Conditional	R/W
	NAME	PROG2:NAME	Conditional	R/W
	NAME	PROG3:NAME	Conditional	R/W
	NAME	PROG4:NAME	Conditional	R/W
	NAME	PROG5:NAME	Conditional	R/W
	NAME	PROG6:NAME	Conditional	R/W
	NAME	PROG7:NAME	Conditional	R/W
	NAME	PROG8:NAME	Conditional	R/W
	SOAK MINUTES	PROG:OPT:SOAK	N/A	R/W
	SETTLE TEST	PROG:OPT:SETT	N/A	R/W
	CYCLE	PROG:OPT:CYCL	N/A	R/W
	ADVANCE	PROG:OPT:ADV	N/A	R/W
Setup - Communication	BAUD RATE	SYST:COMM:SER:BAUD	N/A	R/W
	LINEFEED	SYST:COMM:SER:LIN	N/A	R/W
Setup - Display	LANGUAGE	SYST:LANG	N/A	R/W
	LANGUAGE	SYST:LANG:CAT	N/A	R
	DECIMAL	SYST:DEC:FORM	N/A	R/W
	KEY AUDIO	SYST:BEEP:KEYB	N/A	R/W
Setup - Password	PASSWORD (Disable)	SYST:PASS:CDIS	Unconditional	W
	PASSWORD (Enable)	SYST:PASS:CEN	Unconditional	W
Status	(none)	SYST:PASS:CEN:STAT	N/A	R
	USER PASSWORD	SYST:PASS:NEW	Unconditional	W
	PROTECTION	SYST:PASS:PROT	N/A	R/W

Table 1. Commands by Function or Group (cont.)

	Screen Parameter	Command	Password Protection Group	Read/Write
System - Setup	(none)	SYST:KLOC	Conditional	R/W
System - Information	(none)	SYST:ERR	N/A	R
	(all)	*IDN	N/A	R
	(none)	*CLS	N/A	W
	FW VER	SYST:COD:VERS	N/A	R
	(none)	SYST:BEEP:IMM	N/A	W
Temperature - Setup	SCAN RATE	SOUR:RATE	N/A	R/W
	STABLE LIMIT	SOUR:STAB:LIM	N/A	R/W
	STABLE ALARM	SOUR:STAB:BEEP	N/A	R/W
Temperature – Cutout	HARD CUTOUT	SOUR:PROT:HCUT	N/A	R
	SOFT CUTOUT	SOUR:PROT:SCUT:LEV	Conditional	R/W

Serial Commands - Alphabetic Listing

Each command description provides the structure (long and short format), a description of the command purpose, a command example, an example of what the command returns (as applicable to query commands), and notes specific to the command. The list below applies to each group of commands:

L Numeric data, specified by the mnemonic, <num>, uses ASCII characters to represent numbers. Numbers may contain a plus or minus (+ or -) sign, decimal point (.), and exponent (E or e) with its sign. If a fractional component is received when only an integer is required, the number is rounded to the nearest integer without any resulting error message. The mnemonics DEF, MIN, and MAX are often acceptable for the default, minimum, and maximum value respectively. Unit suffixes, such as V or OHM, can be appended to numeric parameters and are accepted without error but ignored.

- Unrecognized commands or commands with incorrect syntax or invalid parameters generate error messages in the error queue.
- Upper case letters designate syntax that is required when issuing the command.
- Lower case letters are optional and may be omitted.
- < > indicates a required parameter.
- [] indicates optional parameters.
- () indicates a group of parameters that must be used together.
- For query commands, specifying the MIN, MAX, or DEF parameter causes the Product to respond with the minimum, maximum, or default setting respectively.
- For set commands, specifying the MIN, MAX, or DEF parameters causes the Product to use the minimum, maximum, or default setting respectively.
- | indicates alternate parameter values.
- <n> indicates a number is required.
- <num> indicates numeric value is required.
- <prog> indicates a program number (SEQ<n> or SWIT<n>) is required.

- <bool> indicates a Boolean value (0 or 1) is required. The mnemonics OFF and ON are also accepted for 0 and 1, respectively.
- <conv> indicates a conversion mnemonic is required.
- <param> indicates a parameter name is required.
- <seri> indicates a serial number is required.
- <unit> indicates a temperature unit is required.
- <temp> indicates a temperature °C/F is required.
- <pass> indicates a password is required.
- <port> indicates a port number is required.
- <label> indicates an eight character label is required.
- <year> indicates a four digit number is required.
- <month> indicates a one or two digit number is required.
- <day> indicates a one or two digit number is required.
- <hour> indicates a one or two digit number is required.
- <minute> indicates a one or two digit number is required.
- <second> indicates a one or two digit number is required.
- <baud> indicates a valid baud number is required.

***CLS**

Clear the status registers.

Example: *CLS

This command has no response.

Clears all status registers (for example, events, and operations).

***IDN?**

Read the product information (Manufacturer, Model Number, Serial Number, and Firmware Version).

Example: *IDN?

Response: FLUKE,4180,A79002,1.00

OUTP:DATA?

Read the main heat output percent.

Example: OUTP1:DATA?

Response: 18.0

This command returns the current main zone heater duty cycle.

OUTP:STAT[?] [0|1]

Read or set the Main Heat output enable, off [0] or on [1].

Read Example: OUTP:STAT?

Response: 0

Set Example: OUTP:STAT 1

This command reads or sets the active heating or cooling output status. 0 is returned if the output status is off, and 1 is returned if the output status is on.

PROG:[n]NAME?

Read or set the program name by identifier by n, 1 - 8. Where name consists of 1 to 10 characters (0 to 9, A to Z and -). If n is omitted, the selected program is assumed.

Read Example: PROG:[1]NAME?

Response: PROG

Set Example: PROG:[1]NAME newprog01A

PROG:OPT:ADV n

Read or set the program advance option, 0 (prompt) or 1 (continue automatically).

Read Example: PROG:OPT:ADV?

Response: 0

Set Example: PROG:OPT:ADV 1

PROG:OPT:CYCL n

Read or set the program cycles, 1 to 999, default 1.

Read Example: PROG:OPT:CYCL?

Response: 123

Set Example: PROG:OPT:CYCL 150

PROG:OPT:SETT n

Read or set the program settle option, 0 (apply default limit) or 1 (apply STABLE LIMIT setting).

Read Example: PROG:OPT:SETT?

Response: 1

Set Example: PROG:OPT:SETT 1

PROG:OPT:SOAK n

Read or set the program soak time, 0 to 500 minutes. Default 1

Read Example: PROG:OPT:SOAK?

Response: 15

Set Example: PROG:OPT:SOAK 350

PROG[n]:PAR? PAR

Read or set a program parameter, for a given program identified by n, n = 1 to 8, where par is the parameter that you want to read. Parameters are SPOi, POIN, IRTE, DIST, and APER.

SPOi = set-points (1-8), where i =the value of one setpoint.

POIN = the number of set-points for the indicated program.

IRTE= the emissivity e value, 0.9 to 1.0, default 0.95

DIST= the distance from the target to the DUT in cm, 0.1 to 999.9.

APER= yes or no to prompt user for the aperture. 0 = none, 1 = prompt user

Read Example: PROG[1]PAR? DIST?

Response: 100.0

Set Example: PROG[1]:PAR DIST,150

PROG:PAR:CAT?

Read a list of program parameters.

Read Example: PROG:OPT:SOAK?

Response: SPO8, POIN, IRTE, DIST, APER

PROG:PROM:ADV

Advance to the next program step if waiting for user input.

Set Example: PROG:PROM:ADV

PROG:PROM:STAT?

Read the manual program advance prompt state, 0 (operating or program off) or 1 (waiting for user input).

Read Example: PROG:STAT?

Response: 0

PROG:SEL?

Read or set the program selection, 1 to 8.

Read Example: PROG:SEL?

Response: 3

Set Example: PROG:SEL 2

PROG:STAT?

Read or set the program execution state for the selected program, 0 (off) or 1 (run).

Read Example: PROG:STAT?

Response: 0

Set Example: PROG:STAT 1

SOUR:CAL:DATE?

Read the Product calibration date in yyyy,mm,dd format.

Read Example: SOUR:CAL:DATE?

Response: 2007,1,18

SOUR:CAL:DATE y,m,d

Note

This command is unconditionally protected, which requires a password to set it.

Set the Product calibration date in yyyy,mm,dd format., year range 2000 to 2999.

Set Example: SOUR:CAL:DATE 2008,12,30

SOUR:CAL:EMIS?

Note

This command is unconditionally protected, which requires a password to set it.

Read the nominal IR calibration emissivity (0.95).

Read Example: SOUR:CAL:EMIS?

Response: 0.950

SOUR:CAL:PARx?

Read a control temperature parameter, where x is a numeric value indicating the parameter, valid values are 1,2, or 3 representing IR CAL 1, IR CAL 2, and IR CAL 3.

Read Example: SOUR:CAL:PAR2?

Response: 0.20

SOUR:CAL:PARx n

Note

This command is unconditionally protected, which requires a password to set it.

Set a control temperature parameter, where x is a numeric value indicating the parameter, valid values are 1,2, or 3 representing IR CAL 1, IR CAL 2, and IR CAL 3. Range = ± 99.0 ; default: 0.0

Set Example: SOUR:CAL:PAR2 0.2

SOUR:CAL:PARx:TEMP?

Read the calibration temperature associated with a calibration parameter, where x is a numeric value indicating the parameter, valid values are 1,2, or 3.

Read Example: SOUR:CAL:PAR1:TEMP?

Response: -15.0

SOUR:CAL:WAV?

Read or set the calibration IR wavelength option, 0 (8-14um) or 1 (undefined); default 0.

Read Example: SOUR:CAL:WAV?

Response: 0

Set Example: SOUR:CAL:WAV 1

SOUR:EMIS?

Read the IR emissivity setting, range 0.90 to 1.0, default 0.95.

Read Example: SOUR:EMIS?

Response: 0.950

Set Example: SOUR:EMIS 0.90

SOUR:LCON:DER[?] [n]

Note

This command is unconditionally protected, which requires a password to set it.

Read or set the main control loop derivative time in seconds, Min: 0.0, Max: 99.9

Read Example: SOUR:LCON:DER?

Response: 1.5

Set Example: SOUR:LCON:DER 5

The main zone derivative is the derivative time in seconds that the unit's PID controller uses for main zone control.

SOUR:LCON:INT[?] [n]

Note

This command is unconditionally protected, which requires a password to set it.

Read or set the main control loop integral time in seconds. Range = {10.0-999.9}

Read Example: SOUR:LCON:INT?

Response: 20.0

Set Example: SOUR:LCON:INT 10

The main zone integral is the integration time in seconds that the unit's PID controller uses for main zone control.

SOUR:LCON:PBAN[?] [n]

Note

This command is unconditionally protected and requires a password to set it.

Read or set the main control loop proportional band, °C. Range = {1.0-99.9}

Read Example: SOUR:LCON:PBAN?

Response: 1.5

Set Example: SOUR:LCON:PBAN 7

The main zone proportional band is the gain inverse in °C that the unit's proportional- integral- derivative (PID) controller uses for main zone control.

SOUR:LIST:SPO<i>[?] [n]

Read or set a main temperature preset set-point.

Read Example: SOUR:LIST:SPO6?

Response: 25.00

Set Example: SOUR:LIST;SPO6 100.00

SOUR:PROT:CLEA

Reset the cutout to enable the system.

Example: SOUR:PROT:CLEA

This command has no response.

If the Product exceeds the temperature set in the SOFT CUTOOUT menu or if it exceeds the maximum operating temperature of the Product, a cutout condition occurs. If this happens, the unit enters cutout mode and does not actively heat or cool until the user issues this command to clear the cutout or resets the Product using the **SET PT.** button to clear the cutout mode and activate the Product.

SOUR:PROT:HCUT?

Read the hard cutout temperature set-point in °C or °F.

Example: SOUR:PROT:HCUT?

Response: 140

Returns the current value of the hard cutout set-point.

SOUR:PROT:SCUT:LEV[?] [n]

Note

This command is conditionally protected and requires a password to set it.

Read or set the soft cutout set-point where n is an integer value from 0 to 700.

4180 Range = {0.00 to 140.00}

4181 Range = {0.00 to 520.00}

Read Example: PROT:SCUT:LEV?

Response: 125

Set Example: PROT:SCUT:LEV 450

Read or set the soft cutout set-point. The soft cutout should be set to protect the temperature limits of the DUT.

SOUR:PROT:TRIP?

Read the temperature cutout tripped state. Range = {0, 1}; 0 = No Cutout; 1 = Cutout

Example: SOUR:PROT:TRIP?

Response: 0

A value of 0 is returned if the cutout set point has not been reached. Otherwise a value of 1 is returned and the cutout set point has been reached.

SOUR:RATE[?] [n]

Read or set the control temperature rate of change (Scan Rate), °C or °F per minute. Min: 0.10, Max: 500.00; Default: 100.00

Read Example: SOUR:RATE?

Response: 0.531

Set Example: SOUR:RAT 1.26

The response to this command starts out high initially and decreases as the set point is reached.

SOUR:SENS:BLOC?

Reads the target temperature (uncompensated sensor temperature MENU|VIEW TEMP|BLOCK TEMP) in °C or °F.

Read Example: SOUR:SENS:BLOC?

Response: 24.091

SOUR:SENS:DATA?

Reads the apparent temperature, in °C or °F.

Read Example: SOUR:SENS:DATA?

Response: 24.091 (current apparent temperature)

SOUR:SPO[?] [n]

Set the control set-point, °C or °F, where "n" is a real value with acceptance limits based on the model.

Parameter	Min	Max	Default
4180	-15.00	120.00	25.0
4181	25.00	500.00	25.0

Read Example: SOUR:SPO?

Response: 50.000

Set Example: SOUR:SPO 100.00

SOUR:STAB:BEEP[?] [n]

Read or set the stability alert (beep) enable where "n" is a value 0 or 1. [0] is disable, [1] is enable beep. Default: 1 (Enable Beep)

Read Example: SOUR:STAB:BEEP?

Response: 1

Set Example: SOUR:STAB:BEEP 0

Enable or disable the audible stability alert.

SOUR:STAB:DAT?

Read the control temperature stability, °C or °F.

Example: SOUR:STAB:DAT?

Response: 0.306

The controller stability is returned.

SOUR:STAB:LIM[?] [n]

Read or set the control temperature stability limit, °C or °F where "n" is a positive real value.
Range = {0.01 to 5.0 (°C)}; Default: 0.1 (°C) (Model 4180) 0.4 (°C) (Model 4181)

Read Example: SOUR:STAB:LIM?

Response: 0.1

Set Example: SOUR:STAB:LIM 0.09

SOUR:STAB:TEST?

Read the temperature stability test results. Stable = 1; Unstable = 0

Example: SOUR:STAB:TEST?

Response: 0

A value of 0 is returned if the controller is not stable at the current set-point. Otherwise a value of 1 is returned if the controller is stable at the current set-point.

SYST:BEEP:IMM

Beep the system beeper.

Example: SYST:BEEP:IMM

The system beeper should make an audible sound in response to this command.

SYST:BEEP:KEYB[?] [n]

Read or set the keyboard beep function, 0=Off, 1=On. Default: 1

Read Example: SYST:BEEP:KEYB?

Response: 1

Set Example: SYST:BEEP:KEYB 1

Turns the keyboard beep function on or off.

SYST:COD:VERS?

Read the main code version.

Example: SYST:COD:VERS?

Response: 1.10

Provides the user with the version of the main processor code.

SYST:COMM:SER:BAUD[?] [<baud>]

Read or set serial interface baud rate where *baud* is a standard baud rate value.
Range baud = {1200, 2400, 4800, 9600, 19200, and 38400}; Default: 9600

Read Example: SYST:COMM:SER:BAUD?

Response: 2400

Set Example: SYST:COMM:SER:BAUD 9600

SYST:COMM:SER:LIN[?] [n]

Set serial interface linefeed enable, where n is a value 1 or 0. [0] = LF OFF, [1] = LF ON; Default: 0 (OFF)

Read Example: SYST:COMM:SER:LIN?

Response: 0

Set Example: SYST:COMM:SER:LIN 1

This command enables or disables line feed.

SYST:DEC:FORM[?] [n]

Read or set the decimal format, where n is period [0], comma [1]. Default: 0 (Period)

Read Example: SYST:DEC:FORM?

Response: 0

Set Example: SYST:DEC:FORM 1

SYST:ERR?

Read the most recent error from the error queue.

Example: SYST:ERR?

Response: command protected

This command response reports the errors in the error queue.

SYST:KLOC[?] [n]

Note

This command is unconditionally protected and requires a password to set it.

Read or set the keypad lockout; [0] = unlock, and [1] = lock. Default: 0 (Unlock)

Read Example: SYST:KLOCK?

Response: 1

Set Example: SYST:KLOC 1

This command locks or unlocks the system keypad providing control only through the serial interface (RS-232 port) or the keypad.

SYST:LANG[?] [lang]

Read or set the display language, where lang is ENGL, FREN, SPAN, ITAL, GERM, RUSS, JAP, CHIN; Default: English.

Read Example: SYST:LANG?

Response: ITAL

Set Example: SYST:LANG ENGL

SYST:LANG:CAT?

Read the available display languages,

Read Example: SYST:LANG:CAT?

Response: ENGL, FREN, SPAN, ITAL, GERM, JAP, CHIN

SYST:PASS:CDIS

Disable access to password protected setting commands.

Example: SYST:PASS:CDIS

This command has no response.

This command disables the system password protection.

SYST:PASS:CEN [n]

Enable access to password protected setting commands, where "n" is a four digit password.

Range = {0000 - 9999};

Example: SYST:PASS:CEN 1234

This command has no response.

This command enables the system password. This password must be enabled in order to use the conditionally-protected commands. When the power of the Product is cycled, system-password protection is disabled.

SYST:PASS:CEN:STAT?

Read the access state of password protected setting commands.

Example: SYST:PASS:CEN:STAT?

Response: 0

This command reports the current status of the system password.

SYST:PASS:NEW n

Note

This command is unconditionally protected, which requires a password to set it.

Set the password, where n is the new four-digit password. Range = {0000 - 9999}; Default: 1234

Example: SYST:PASS:NEW 1234

This command has no response.

This command allows the user to set the system password.

SYST:PASS:PROT[?] [0|1]

Read or set password protection level., [0] = low, [1] = high

Read Example: SYST:PASS:PROT?

Response: 0

Set Example: SYST:PASS:PROT 1

UNIT:TEMP[?] [n]

Read or set the display temperature units, where "n" is a character "C" or "F". Default: C

Read Example: UNIT:TEMP?

Response: C

Depending on units setting, a C (Celsius) or F (Fahrenheit) is returned.

Calibration

Note

For assistance with the process or any questions regarding the calibration of the IR Calibrator, contact an Authorized Service Center. See [Contact Fluke Calibration](#).

This procedure is to be considered a general guideline. Each laboratory should write their own procedure based on their equipment and their quality program. Each procedure should be accompanied by an uncertainty analysis also based on the laboratory's equipment and environment.

Calibrate the Product with a traceable radiometric (non-contact) calibration at the factory. This calibration is supported by good practices including an extensive uncertainty budget. The factory calibration is not based off of a contact calibration.

The radiometer used for the factory calibration has a spectral response of 8 μm to 14 μm . This spectral response is used because it matches the bulk of handheld IR thermometers sold today. It is important that the radiometer used for calibration have the same spectral response as the IR thermometer being calibrated. If they do not have the same spectral response, this will give an IR thermometer calibration using the Product greater uncertainty.

The radiometer must have low enough uncertainties to fit within your uncertainty budget. These uncertainties consist of a number of items including the radiometer's calibration uncertainty and the radiometer's long term drift. There are other uncertain- ties to consider as well.

Terminology

Calibration of the IR Calibrator is referred to as the IR Target Calibration.

This calibration process is for a radiometric calibration. It is not for a contact calibration. The Product was originally calibrated at the factory with a radiometric calibration.

Note

The Measuring and Test Equipment (M&TE) is referred to as the Device Under Test (DUT).

Fundamentals

It is assumed that the technician is familiar with the *Operators Manual* and *Safety Information* documentation.

The operator shall be familiar with the *Operators Manual* and *Safety Information* for the humidity readout. The operator shall be familiar with the *Operators Manual* and *Safety Information* for the radiometer.

It is assumed that the calibration will only be performed by trained personnel.

Environmental Conditions

Temperature range: 23 °C ±3 °C

Ambient relative humidity: <60 %

Calibration Equipment

The test equipment specifications necessary to calibrate the Product is in [Table 2](#)

Table 2. Test Equipment Specifications

Classification	Minimum Use Specifications
Readout	20 ppm
Aperture Sensors	23 °C ± 5 °C Uncertainty: ±0.1 °C
Humidity Readout	Range: - 30 °C Frost Point or lower
Radiometer (Reference Radiation Thermometer)	Spot Size: 99.99 % of energy within 35 mm diameter at 440 mm distance Spectral Response: 8 µm to 14 µm Uncertainties: within your uncertainty budget
Water Cooled Aperture (4180 only)	35 mm in diameter
Chiller (4180 only)	Enough capacity to keep aperture within the specifications
Air Dryer/Filter (4180 only)	Enough capacity so that the system is capable of reaching a dew point 10 ° below the coldest calibration point

For a visual overview of the calibration process, see [Figure 9](#).

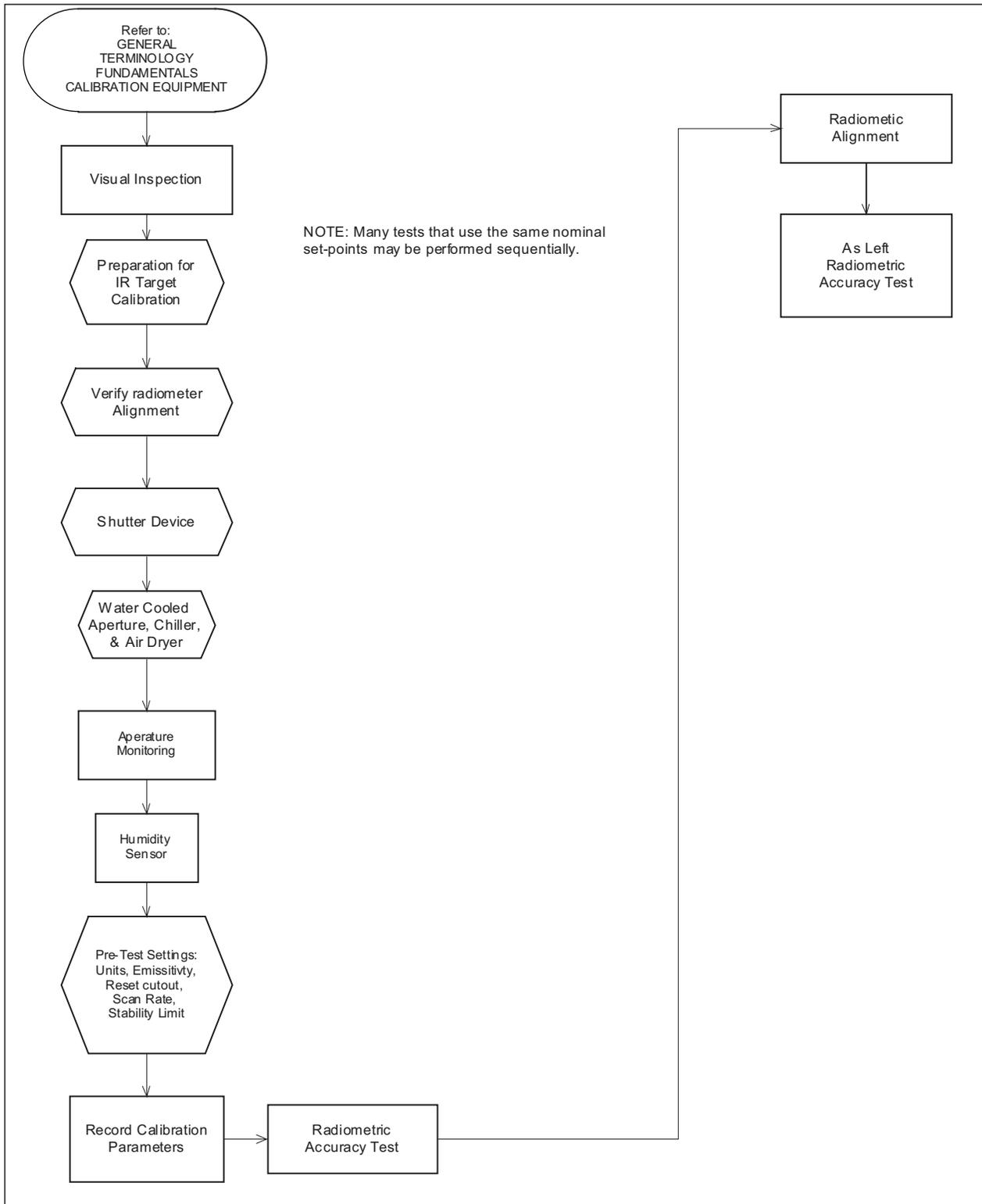


Figure 9. Flow Chart for Manual Calibration

Procedure

Visual Inspection

Do a visual inspection of the DUT for signs of physical damage. If a problem is found, correct it before you proceed with the test.

Examine the target for debris or damage. If the target is damaged, contact Customer Service.

Manual IR Target Calibration

Review the fundamentals in this section before you setup up the calibration environment.

General

Calibration of the Product involves delicate equipment with some unusual requirements. This procedure outlines a manual process that closely follows the way the Product was calibrated at the factory. You are free to adjust this calibration process to meet the needs of your facility and process.

Ensure that calibration technician is familiar with the Infrared Thermometry Theory section of the *Operators Manual*.

Radiometer

The radiometer required as the reference standard has some tight specifications. This means that the Product requires a certain level of care. Keep the lens clean. Dust accumulation on the lens can affect measurement accuracy. Additionally, shield the radiometer from any vibration. Subjecting the radiometer to vibration can cause the radiometer to drift.

Calibration Geometry

Refer to the owner's manual for the radiometer to determine the calibration geometry. If the information is not in the owner's manual, contact the manufacturer. Set up the calibration station as applicable for your radiometer with regards to distance.

Alignment

Proper alignment of the radiometer with the target is essential. Align the radiometer with a laser within 0.15 inches of the center of the IR calibrator target. An adjustable base plate for the radiometer helps to make any adjustments required to align the radiometer in the center of the target. Refer to Figure 10 to see the reference of how the alignment is set.

Aperture

Many radiometers require the use of an aperture to reduce the effect of scatter. Use of a non-temperature controlled aperture requires that the aperture only be in place during the time the measurement is taken, one minute or less. Leaving the aperture in place longer causes measurement error.

Water Cooled Aperture

A water-cooled aperture provides a temperature-controlled environment to control scatter. It reduces uncertainty in measurement. Use a chiller to control the temperature of the aperture throughout the temperature range of the Product. Refer to Figure 10 to see how the water-cooled apertures and chiller fit into the calibration scheme.

The temperature of the aperture needs to be measured if it is to be temperature controlled. PRTs are used to monitor the aperture temperature. (Thermistors could also be used.)

Steps and information about the water-cooled aperture and chiller are provided in the procedure. If you

use a temperature-controlled aperture, these steps may be applicable to your process. If you do not use a temperature-controlled aperture, these steps are not applicable to your process.

Frost Control

The 4180 will form frost on the target at temperatures below the dew point. Thus, during calibration at low temperatures, the Product requires that the surface of the target be purged with clean, dry air. Accomplish this with the purge provided on the 4180 or with a chamber.

Humidity-Controlled Chamber

The humidity-controlled chamber is a chamber built that fits snugly against the front of the 4180 face plate on one side and the radiometer fits snugly into the other side. Clean, dry, filtered shop air is passed through the chamber at a rate sufficient to keep the target from icing. A humidity sensor and readout are used to monitor the humidity in the chamber and ensure the chamber stays below the frost point. Figure 10 shows the location of the humidity chamber in front of the 4180 portion of the test station.

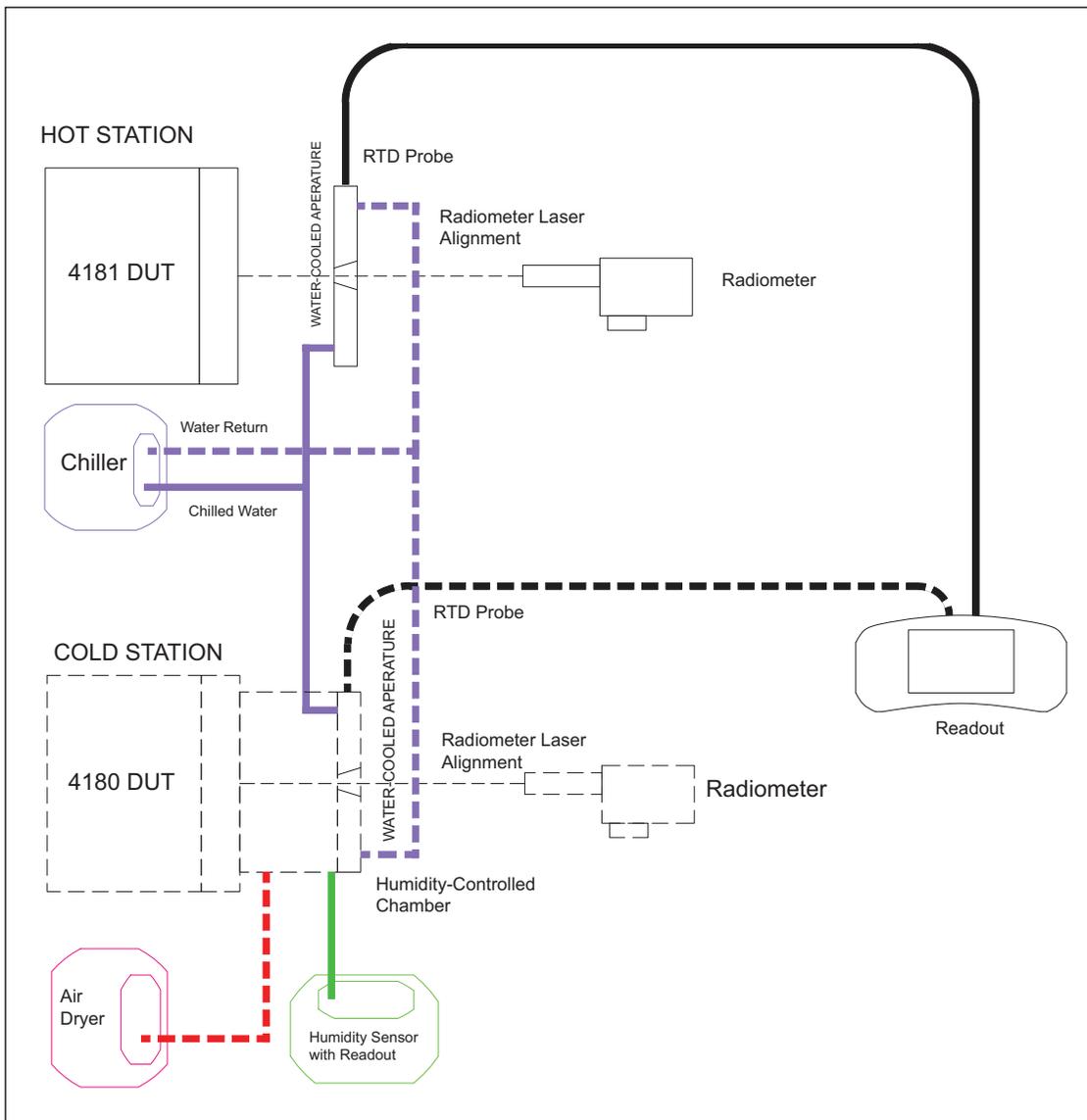


Figure 10. Calibration Model

Preparation for IR Target Calibration

Record Radiometer Calibration Constants

Record the radiometer calibration constants, A, B, C, D and T0 used to perform the apparent temperature calculations from radiance measurements taken from the radiometer.

Verify the Radiometer Mounting Alignment on the Test Station

Activate the laser alignment on radiometer. Check alignment.

Adjust mounting bracket for the radiometer as necessary.

Lens Protection

- Due to the delicate nature of the radiometer lens, keep the lens covered except when you take measurements.
- The lens cover shall be removed prior to taking measurements and replaced immediately after measurements to minimize the lens' exposure.
- The lens cap must be removed at least 30 seconds prior to taking the first measurement from the radiometer.

Water-Cooled Aperture, Chiller, Air Dryer, and Temperature Monitoring

- If using both a hot DUT (4181) and a cold DUT (4180), Fluke Calibration recommends that one aperture is for the hot DUT and one aperture is for the cold DUT.
- Use a chiller to maintain a constant temperature of the water that circulates through the apertures. Set the chiller to maintain the water at a constant 23 °C. Table 3 shows the chiller setting based on the DUT set-point temperature to maintain a constant 23 °C within the given tolerance.

Table 3. Chiller Setting per DUT Set-Point

Nominal DUT Set-point (°C)	Baseline (°C)	Tolerance (±°C)
-15	22.9	0.5
0	23.0	0.5
35	23.0	0.5
50	23.0	0.5
100	23.1	0.5
120	23.1	0.5
200	23.2	0.5
350	23.8	0.8
500	25.0	2.0

- Connect the aperture for each DUT to the chiller in parallel.
- Connect the chiller to the Humidity Sensor as explained in the subsequent section.
- An air dryer and filter are also required for the cold DUT. The air dryer filters the air. The source of the air shall remain on constantly and dry.

- Set a pressure regulator on the line to 30 psi and use a flow meter to limit the air flow to 40 l/m. Check the air flow prior to each calibration.
- Use RTD Aperture probes to monitor the temperature of the water at each aperture to ensure that it remains constant. These probes are connected to the readout. The technician sets the readout to take readings at a 10-second interval from the aperture probes as tests are performed. The technician needs to periodically, throughout the testing process, check that the water is within the range of Table 3.

Humidity Sensor

Calibration of the cold DUT (4180) requires a humidity sensor. The purpose of the humidity sensor is to ensure proper humidity levels for calibrating the cold DUTs.

The humidity readout may be left on when not taking measurements. However, it should only be enabled to take measurements during the calibration process. The measurement capability should be disabled when not calibrating.

The humidity readout needs to be monitored during the testing process. If the dew or frost point rises above -30 °C the dew point measurement is out-of-tolerance.

Settings

Pre-Test DUT Settings

Before you start a calibration, DUT configuration and control settings must be set to the indicated values in Table 4, *even if As Found is to be collected*.

Table 4. Pre-Test DUT Configuration Settings

Setting	Value	Description
Units	°C	Set system temperature units to °C
Emissivity	0.95	Set emissivity setting to 0.95
Reset cutout	N/A	Make sure cutout is not engaged
Scan Rate	DEF	Set scan rate to default value
Stability Limit	DEF	Set stability limit to default value

When the calibration process must collect As Found data, the DUT configuration and control settings shown in Table 5 must remain at their current values until all As Found data has been collected.

Table 5. Pre-Test Controller/Calibration Constants Settings

Setting	Description
Integral	PID controller integration time setting
Derivative	PID controller derivative time setting
Prop Band	PID controller proportional band setting
Cal constants	All IR target calibration constants

Intra-Test DUT Settings

Once all necessary As Found data is collected, but before you do the alignment, the DUT configuration and control settings must be set to the indicated values in Table 6 to ensure the data collection and alignment process is performed as required.

Table 6. Intra-Test Controller Settings

Setting	Value	Description
Integral	DEF	PID controller integration time setting
Derivative	DEF	PID controller derivative time setting
Prop Band	DEF	PID controller proportional band setting

Post-Test DUT Settings

Once the calibration process is complete and all As Left data has been collected, the DUT configuration and control settings must be set to the indicated values in Table 7 to ensure the DUT is ready for use.

Table 7. Post-Test DUT Settings

Setting	Value	Description
Cal Date	<today>	Set calibration date to today (only if IR target alignment performed)
Set-point	25	Set set-point to 25 °C
Scan Rate	<value>	Set scan rate to the value defined for the instrument use
Stable Limit	DEF	Set stable limit to the value defined for the instrument use
Soft Cutout	<value>	Set soft cutout to value defined for the instrument use

Manual IR Target Calibration Process

Note

The Product is tested and calibrated with the tests outlined below in the sequence indicated, see Table 8. Details to do each of the tests can be found in the subsequent section of this document.

Many tests that use the same nominal set-points may be done sequentially as noted. For test specifications, durations, soak times, and other detailed information, refer to the specification tables in the Operators Manual.

All temperature tests are to be done in °C. Before you start any tests, make sure the system temperature units are set to °C.

Table 8. IR Target Testing Sequence

#	Test Name	Notes
1	Radiometric Accuracy Test	As Found/Alignment data - Do once at each point in ascending (4180) descending (4181) order
2	Radiometric Alignment	Calculate offsets using Radiometric Accuracy data
3	Radiometric Accuracy Test	As Left data – Perform once at each point in descending (4180) order

Table 9. 4180 Radiometric Accuracy Test Settings and Specifications

Set-point (Nominal) (°C)	Soak (min)	Samples	Spec (\pm °C)	Radiometric 2S Limit (°C)
-15	15	100	0.400	0.100
0	15	100	0.400	0.050
50	15	100	0.500	0.050
100	15	100	0.500	0.085
120	15	100	0.550	0.100

Table 10. 4181 Radiometric Accuracy Test Settings and Specifications

Set-point (Nominal) (°C)	Soak (min)	Samples	Spec (\pm °C)	Radiometric 2S Limit (°C)
35	15	100	0.350	0.050
100	15	100	0.500	0.095
200	15	100	0.70	0.165
350	15	100	1.200	0.280
500	15	100	1.600	0.400

Radiometric Accuracy Test

1. Ensure that the DUT has stabilized at the first set-point before you start the Radiometric Accuracy Test.
2. The Radiometric Accuracy Test requires one radiometric reference standard which must be aligned at the center of the DUT's black body target. Align the DUT properly with the radiometric reference standard.

3. The Radiometric Accuracy Test collects As Found, Alignment, and As Left data. For the Radiometric Accuracy Test, radiance measurements (S) are taken from the radiometric reference standard. These measurements shall be recorded. The apparent temperature (T_{App}) is calculated from the radiance measurements with this formula:

$$T_{app} = AS^{1/2} + BS^{3/2} + CS^2 + D \ln(S) + T_0$$

where:

S = readout radiance measurement from radiometric reference.

A, B, C, D, T₀ = Calibration constants from radiometric reference.

4. For nominal set-points, soak times, number of measurements, specs, and other settings, refer to Table 9 and Table 10.
5. The apparent temperature 2S is calculated from the radiance measurements with these formulas:

$$\frac{\partial T_{app}}{\partial S} = \frac{1}{2}AS^{-1/2} + \frac{3}{2}BS^{1/2} + 2CS + \frac{D}{S}$$

$$2\sigma T_{App} = \frac{\partial T_{APP}}{\partial S} \times 2\sigma S$$

where:

S = readout radiance measurement from radiometric reference A, B, C, D = Calibration constants from radiometric reference

Note

For all DUTs, do the As Found and Alignment Radiometric Accuracy Tests in ascending order. Start with the coldest nominal set-point. After alignment, do the As Left Radiometric Accuracy Tests in descending order. Start with the hottest nominal set-point.

6. Set the IR target to the nominal temperature set-point and engage temperature control.
7. Monitor the DUT's stability indicator until it reports the IR target is stable.
8. Allow the DUT to soak at the set-point for 15 minutes.
9. Take readout radiance measurements from the radiometric reference standard at 10-second intervals.
10. Calculate the average and 2σ (2x standard deviation) of the measurements. Record the results.
11. Calculate the average and 2σ apparent temperature with the formula provided.

12. Calculate the apparent temperature error using the formula indicated below. Record this result.
error = average – nominal
13. Compare the error with the specification to determine the pass/fail status. Record the result.
14. Compare the apparent temperature 2S result with the 2S spec to determine the pass/fail result. Record the result. See Table 11.

Table 11. IR target Accuracy Adjustment Specifications

Parameter Name	Offset Spec		Corresponding Temperature For 4180 (°C)	Corresponding Temperature for 4181 (°C)
	Nominal	*Variance (±)		
IR CAL 1	0.000	9.999	-15	-15
IR CAL 2	0.000	9.999	50	200
IR CAL 3	0.000	9.999	120	500

Radiometric Accuracy Alignment

The Radiometric Accuracy Alignment process calculates new offsets to be programmed into the Product to correct for temperature errors over the entire range of the IR target.

Note

The Radiometric Accuracy Alignment process must be done with the data that was collected from As Found or Alignment Radiometric Accuracy Tests.

1. Locate the results of the As Found or Alignment Radiometric Accuracy Tests. Data at all set-points is used.
2. Use the nominal temperature set-point and the error that was calculated for each Radiometric Accuracy Test to calculate a best fit least-squares second-order polynomial that characterizes the errors measured at each nominal temperature set-point.
3. Use this polynomial to generate a temperature vs. error table that includes the temperature set-points that correspond to each of the accuracy calibration offset parameters.
4. Calculate the new value for each of the accuracy calibration offset parameters with the previous (current) offset value and the calculated error at the corresponding set-point temperature with the formula below.

$$IR\ CALn_{new} = IR\ CALn_{previous} - error_{set\ -point}$$

5. Enter the new offset values into the instrument.
6. Wait for the instrument to soak/equilibrate for at least 15 minutes before taking any measurements.
7. Proceed and take As Left data.

