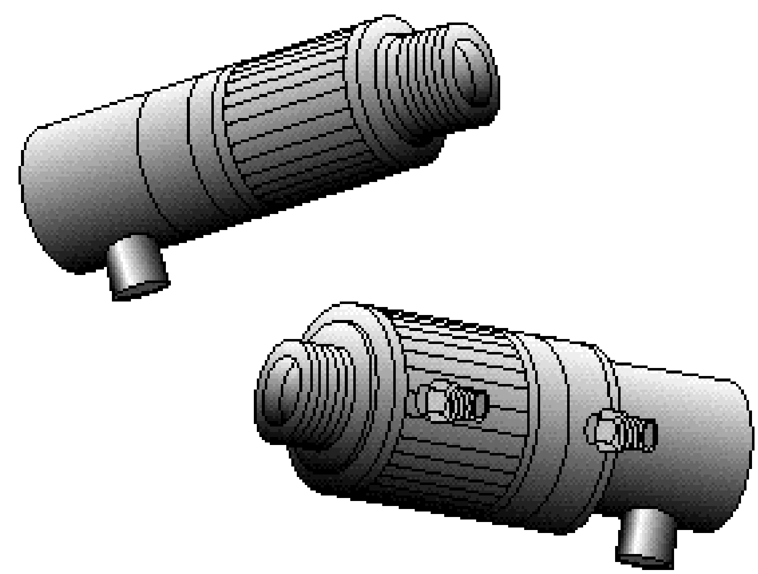
Thermalert®
ET™ Series

Operator's Manual



Raytek®

Noncontact Temperature Measurement

TÜV CERT DIN ISO 9001

Rev. J
3 / 96
55203-1

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1.0 DESCRIPTION

The Thermalert® ET™ series of instruments are noncontact infrared temperature measurement systems. They are energy transducers designed to measure accurately and repeatedly the amount of heat energy emitted from an object and to convert that energy into a measurable electrical signal.

Each model operates as an integrated temperature measurement subsystem consisting of optical elements, spectral filters, integrated detector, digital electronics and a NEMA-4 (IEC 529, IP 65) housing. They are built to operate on a 100 percent duty cycle in industrial environments. Outputs consist of standardized thermocouple or current signals commonly available for use with controllers, recorders, alarms or A / D interfaces.

Table 1-1: Models

MODEL	TEMPERATURE RANGE	OUTPUT
ET2LT (Low Temp)	-18 to 760°C (0 to 1400°F) 0 to 870°C (32 to 1600°F)	Type J Thermocouple Type K Thermocouple 50Ω impedance
ETP7 (Plastics)	10 to 360°C (50 to 650°F)	Type J Thermocouple 50Ω impedance
ET2G5 (Glass)	260 to 1650°C (500 to 3000°F)	Type R Thermocouple 50Ω impedance
ET2HT (High Temp)	500 to 1700°C (1000 to 3000°F)	Type R Thermocouple 50Ω impedance
ET3LT (Low Temp)	0 to 800°C OR 0 to 1400°F (specify °C or °F version when ordering)	4-20mA Current 300Ω impedance
ET3P7 (Plastics)	10 to 360°C OR 50 to 650°F (specify °C or °F version when ordering)	4-20mA Current 300Ω impedance
ET3G5 (Glass)	260 to 1650°C OR 500 to 3000°F (specify °C or °F version when ordering)	4-20mA Current 300Ω impedance
ET3HT (High Temp)	500 to 1700°C OR 1000 to 3000°F (specify °C or °F version when ordering)	4-20mA Current 300Ω impedance

Note: When reviewing this manual, inquire of possible exceptions resulting from customized features. Check with your sales representative whenever a parameter is critical or operation seems abnormal.

Accessories and Options

A full range of accessories and options for mounting and operating in particularly harsh environments are available.

Air / water cooled housing	15m, 30m, 60m (50’, 100’, 200’) cable
Sighting Viewer	ThermoJacket
Right Angle Mirror	– Mounting Flange
Air Purge Collar	– Mounting Bracket
Mounting Nut	– Sighting Tube Mounting Flange
Fixed Bracket	– Sighting Tube, 305mm (12 in)
Adjustable Bracket	– Ceramic Sighting Tube, 305mm (12in)
Swivel Bracket	– Adjustable Pipe Adapter Accessory
110 / 220 to 12 VAC power supply	– Blast Gate Accessory

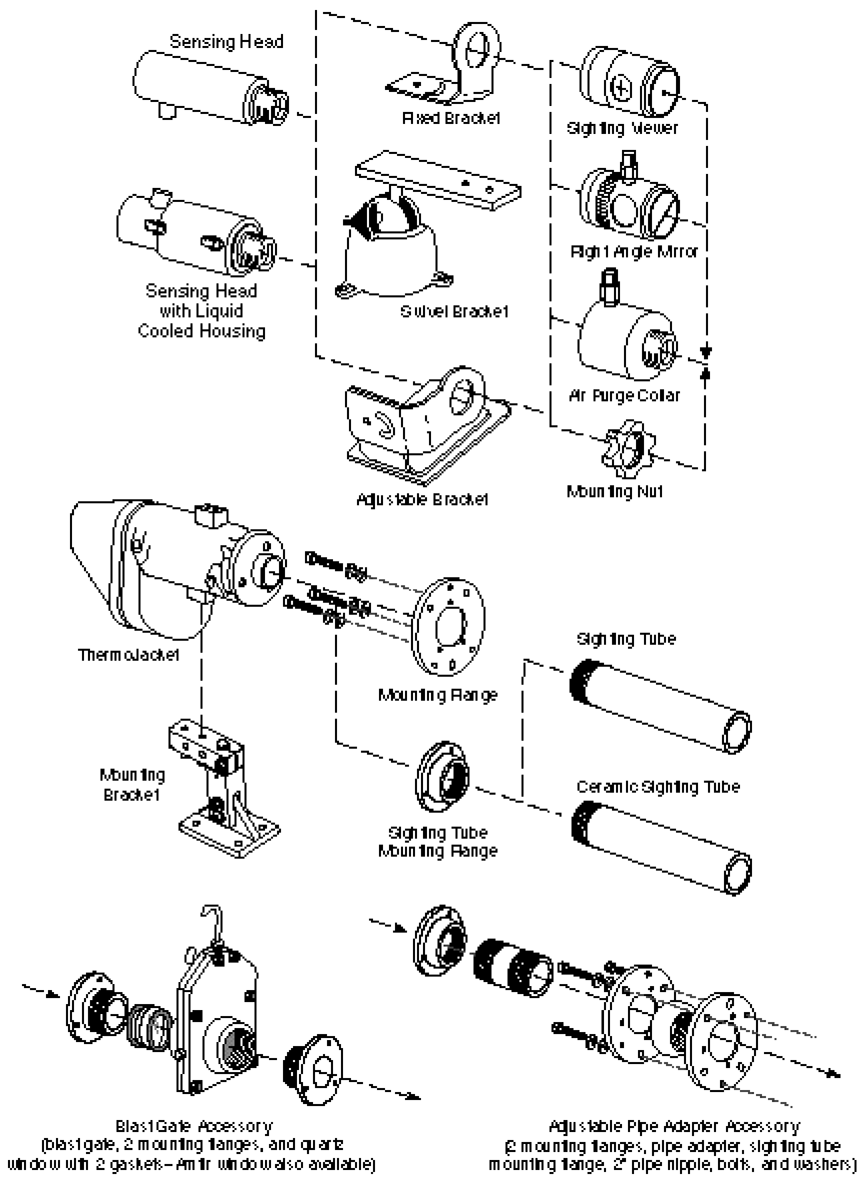


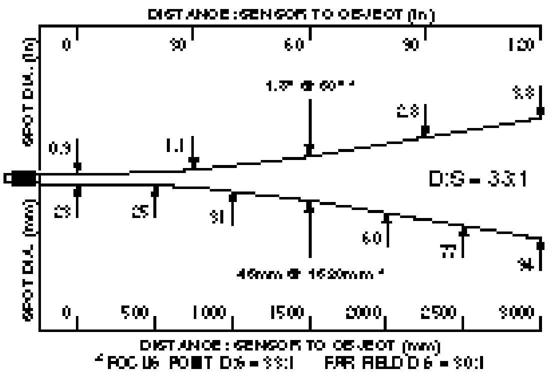
Figure 1-1: Accessories and Options

1.1 SPECIFICATIONS

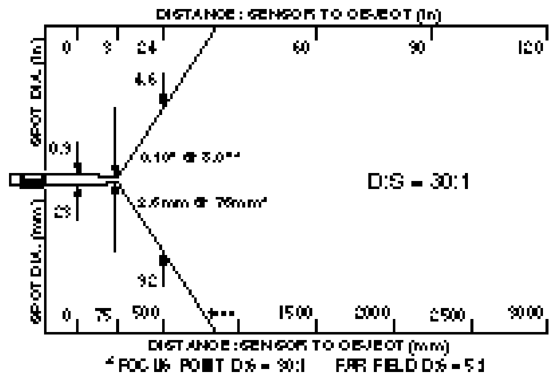
1.1.1 Optical

Nominal optical resolution values are stated at minimum 90% energy. Distance to size (D:S) ratios represent nominal values.

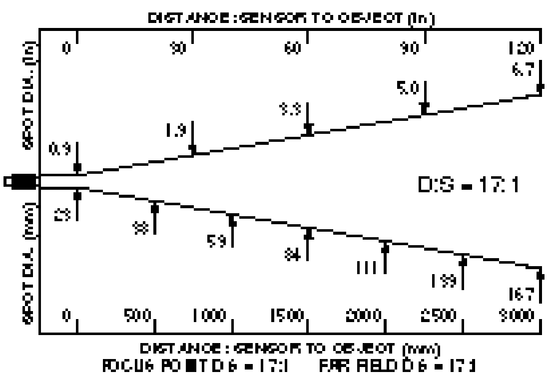
2LT, 3LT
Standard Focus



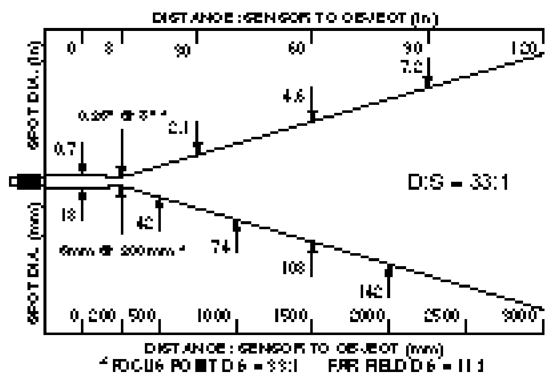
2LT, 3LT
Close Focus



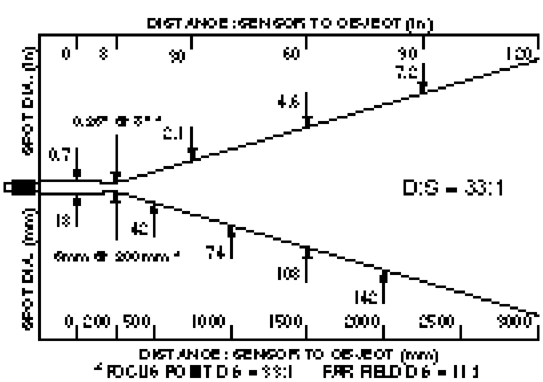
2P7, 3P7
Standard Focus



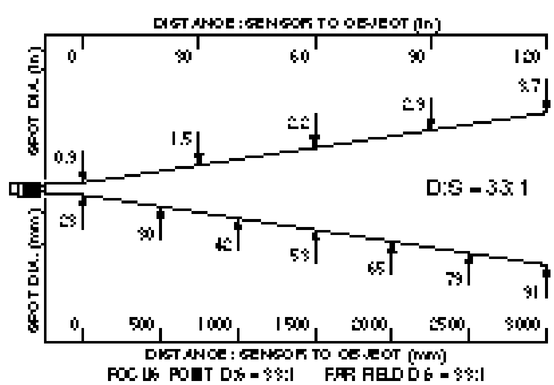
2HT, 3HT
Standard Focus



2HT, 3HT
Close Focus



2G5, 3G5
Standard Focus



1.1.2 Output Ranges

Measurement Range

Thermocouple Output	2LT	-18 to 760°C (0 to 1400°F), Type J
		0 to 870°C (32 to 1600°F), Type K
	2P7	10 to 360°C (50 to 650°F), Type J
	2G5	260 to 1650°C (500 to 3000°F), Type R
	2HT	500 to 1700°C (1000 to 3000°F), Type R

Current Output (switch selectable)

3LT	Range Setting	°F Version	°C Version
	1	0 to 200	0 to 100
	2	0 to 400	0 to 200
	3	0 to 800	0 to 400
	4	0 to 1400	0 to 800
3P7	Range Setting	°F Version	°C Version
	1	50 to 350	10 to 110
	2	50 to 650	10 to 360
3G5	Range Setting	°F Version	°C Version
	1	500 to 1500	260 to 815
	2	500 to 3000	260 to 1650
3HT	Range Setting	°F Version	°C Version
	1	1000 to 2000	500 to 1000
	2	1000 to 3000	500 to 1700

Spectral Response	LT Versions	8 to 14 microns
	P7 Versions	7.9 microns (nominal)
	G5 Versions	5.0 microns (nominal)
	HT Versions	2.2 microns (nominal)

Accuracy: ± 1% of reading or 1.4°C (2.5°F) @ 25°C (77°F) whichever is greater

Repeatability: ± 0.5% of Reading, ± 1 digit °C or °F

1.1.3 Operational

Response Time	• 300 msec, 100 msec option (95% response) • 80 msec is standard on HT (2.2µm) versions
Emissivity	• 0.10 to 0.99, in 0.01 increments
Peak Hold	• 0.1 sec decay time to 50% of peak value (with no peak hold) • 14°C (25°F) per second (nominal decay rate) (with maximum peak hold)
Averaging	• 0.3 sec response time (with no averaging) • 5 sec response time (with maximum averaging)
Fail Safe	• Full scale (20.3 mA) when under or over range or subrange

1.1.4 Electrical

Power 12 VAC nominal (10.5 to 16 VAC), 100 mA, 50 to 60 Hz

Outputs

Thermocouple Versions

2LT	Type J or K
2P7	Type J
2G5	Type R
2HT	Type R

Current Versions

- all ranges: 4-20 mA
- under or over specified operating temperature ranges: 20 mA
- loop impedance, Max: 300 ohms

Interconnection 5-pin DIN connector, 4.5 m (15 ft.) cable standard

1.1.5 Physical

Environmental Rating	NEMA 4, (IEC 529, IP 65) Rated with conduit and compression fitting (which prevents liquid from entering through the connector)

Ambient Operating Temp	0 to 50°C (32 to 120°F)
• with air cooling	0 to 120°C (32 to 250°F)
• with water cooling	0 to 175°C (32 to 350°F)
• with ThermoJacket	0 to 315°C (32 to 600°F)

Storage Temperature	-40 to 65°C (-40 to 150°F)
Environmental Rating	NEMA-4 (IEC 529, IP 65) with conduit and compression fitting
Vibration	MIL STD 810D (IEC 68-2-6) 3G's, any axis, 11 to 200 Hz
Shock	MIL STD 810D (IEC 68-2-27) 50G's, 11 mSec, any axis
Dimensions	
• Length	Standard: 178.3mm (7.02 in) Water-cooled housing: 178.3mm (7.02 in)
• Diameter	Standard: 56.8mm (2.24 in) Water-cooled housing: 75.7mm (2.98 in)
• Weight	Standard: 500 g (1.2 lbs) Water-cooled housing: 800 g (1.7 lbs)

2.0 INSTALLATION

The installation process consists of the following:

- Preparation
- Mechanical Installation
- Electrical Installation

The most important part in the installation process is preparation. Please read Section 2.1, Preparation, thoroughly before proceeding with the mechanical and electrical installation sections.

2.1 PREPARATION

Sensor location and configuration depends on the application. Before deciding on a location, you need to be aware of the ambient temperature of the location, the atmospheric quality of the location, and the possible electromagnetic interference in that location. You need to be aware of the spot size on your target and how far away the sensor needs to be mounted. Also, if you plan to use air purging and/or air or water cooling, you need to have air and water connections available. The following subsections cover topics to consider before you install the sensor.

2.1.1 Sensor Location

The desired spot size to be measured on the target will determine the maximum working distance and appropriate focus model. The target spot size must contain the entire field of view of the sensor (Figure 2-1). It must be the same as or smaller than the desired spot size.

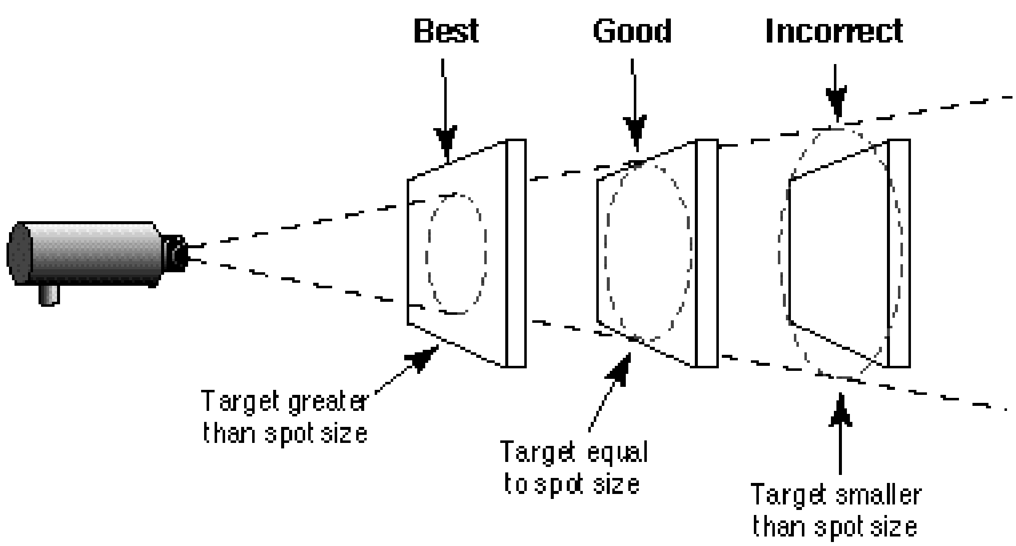


Figure 2-1: Sensor Placement

Proper sensor placement is important for accurate temperature measurements. The sensor must have a clear view of the target. There can be no obstructions, either on the lens, window, or in the atmosphere. **Do not mount the sensor at angles greater than 45° from the target.**

2.1.2 Ambient Temperature

The sensor is designed to operate in ambient temperatures between 0°C (32°F) and 50°C (120°F). In ambient conditions above 50°C (120°F), an air / water-cooled housing option is available, which extends the operating range to 120°C (250°F), with air cooling, and 175°C (350°F), with water cooling. When using water cooling, it is strongly recommended to also use the air purge collar to avoid condensation on the lens. Also available is a ThermoJacket accessory, which allows use of the sensing head in ambient temperatures up to 315°C (600°F).

2.1.3 Atmospheric Quality

It is important to maintain cleanliness of the lens at all times to prevent erroneous readings and damage to the lens. An air purge collar is available and recommended to protect the lens from smoke, fumes, dust, and other contaminants.

2.1.4 Electrical Interference

To minimize electrical or electromagnetic interference or "noise," follow these precautions:

- Mount the sensor as far away as possible from potential sources of electrical interference (e.g., motorized equipment that produce large step load changes).
- Make sure the shield wire in the sensor cable is earth grounded.
- For additional protection, use conduit for the AC power lines and for any external connections. Note that solid conduit is better than flexible conduit in high noise environments.
- Do not run AC power for other equipment in the same conduit.

2.1.5 Wiring

Sensor power will connect to 12 VAC, which should be as “noise free” as possible. Do not ground the secondary of the transformer.

CAUTION

When routing the interface cable, avoid paths running near sources of interference such as large electric motors, welders and generators.

Note that when using thermocouple output models, be sure to use the appropriate thermocouple wire.

2.1.6 Multiple Sensors

There are two types of interfacing to consider when connecting more than one sensor to a controller (or other device): differential and single-ended. Differential configurations are preferred over single-ended since they are less susceptible to noise. This advantage, of course, must be weighed against the disadvantage of using additional input positions. See Figure 2-2 for thermocouple outputs; the longer the cable, the more likely differential hook-ups should be used.

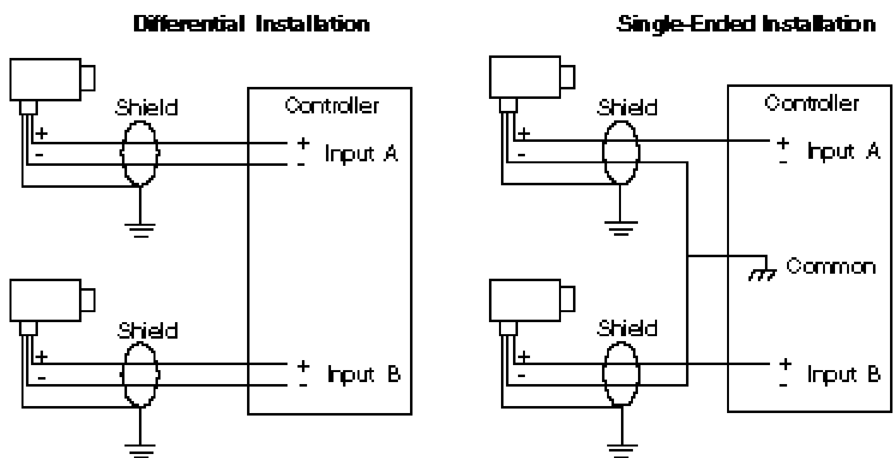


Figure 2-2: Multiple Sensors

2.2 MECHANICAL INSTALLATION

Use the following as a reference for installing the sensors and accessories, as well as the air and water connections.

2.2.1 Sensor (standard)

All sensors are supplied with a fixed bracket and mounting nut. Alternatively, the sensor may be mounted through a hole or may be mounted using a customer-supplied bracket or other accessories. See Section 1.0 for a description of accessories and options for the sensor.

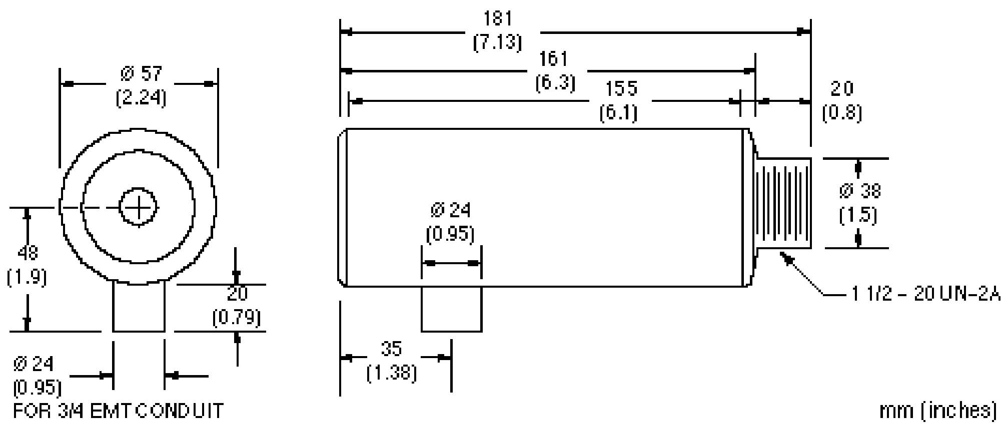


Figure 2-3: Sensing Head

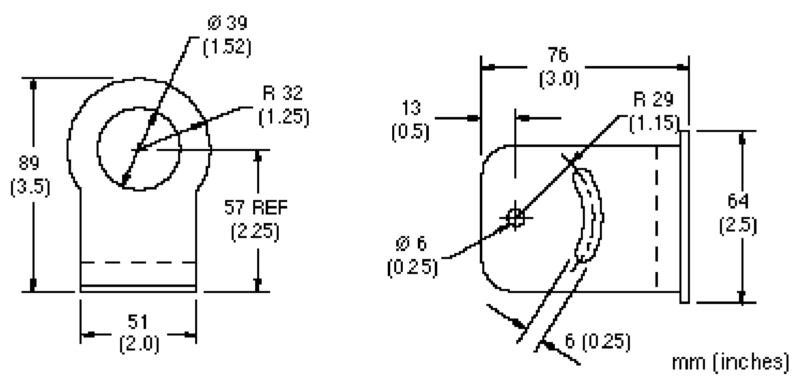


Figure 2-4: Fixed Mounting Bracket

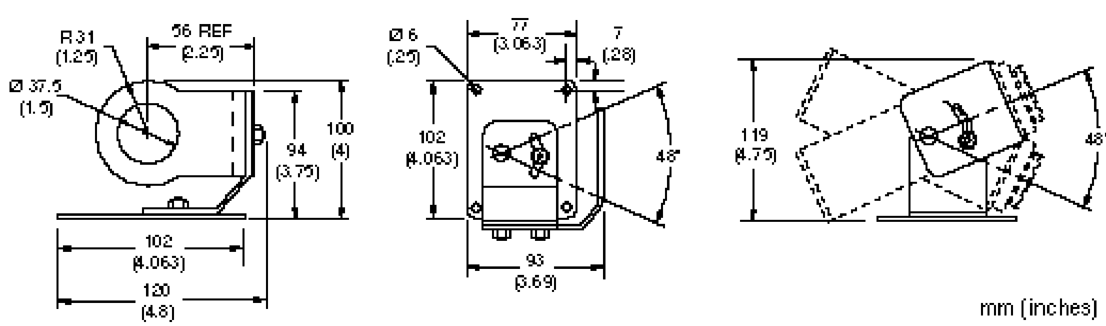


Figure 2-5: Adjustable Mounting Bracket

2.2.2 Sensor (Air/Water-Cooled Housing)

The Air/Water-Cooled Housing option allows the sensor to be used in ambient temperatures up to 120°C (250°F) for air-cooled, and 175°C (350°F) for water-cooled. It is supplied with two 3.2 mm (1/8") NPT brass fittings. Air flow should be 0.1 to 1.5 cmm (3 to 5 cfm). Water flow should be approximately 2 liters (0.5 gallons) per minute, and water temperature should be 10 to 27°C (50 to 80°F) for efficient cooling. Chilled water below 10°C (50°F) is not recommended. To avoid condensation and lens damage, use of the Air Purge Collar with the Water-Cooled Housing is required.

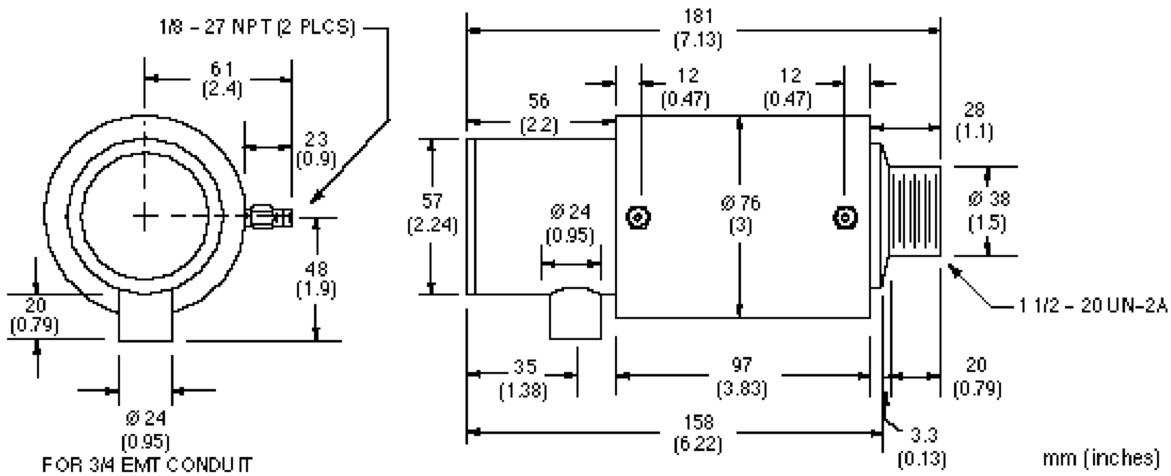


Figure 2-6: Sensing Head with Air/Water-Cooled Housing

2.2.3 Air Purge Collar

The Air Purge Collar accessory is used to keep dust, moisture, airborne particles, and vapors away from the lens. It may be installed before or after the bracket (see accessories drawing in Section 1.0) and screwed in fully. Air flows into the 3.2 mm (1/8") NPT brass fitting and out the front aperture. Air flow should be a maximum of 0.5 to 1.5 liters/sec (1 to 3 cfm). Clean or "instrument" air is recommended to avoid contaminants from settling on the lens.

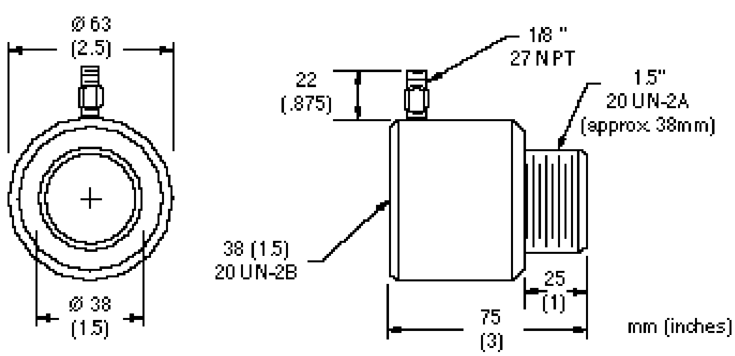


Figure 2-7: Air Purge Collar

2.2.4 ThermoJacket

The ThermoJacket accessory allows use of sensing heads in ambient temperatures up to 315°C (600°F). The ThermoJacket's rugged cast aluminum housing completely encloses the head and provides water cooling and air purging in one unit. Sensing heads can be easily installed or removed from the mounted ThermoJacket housing.

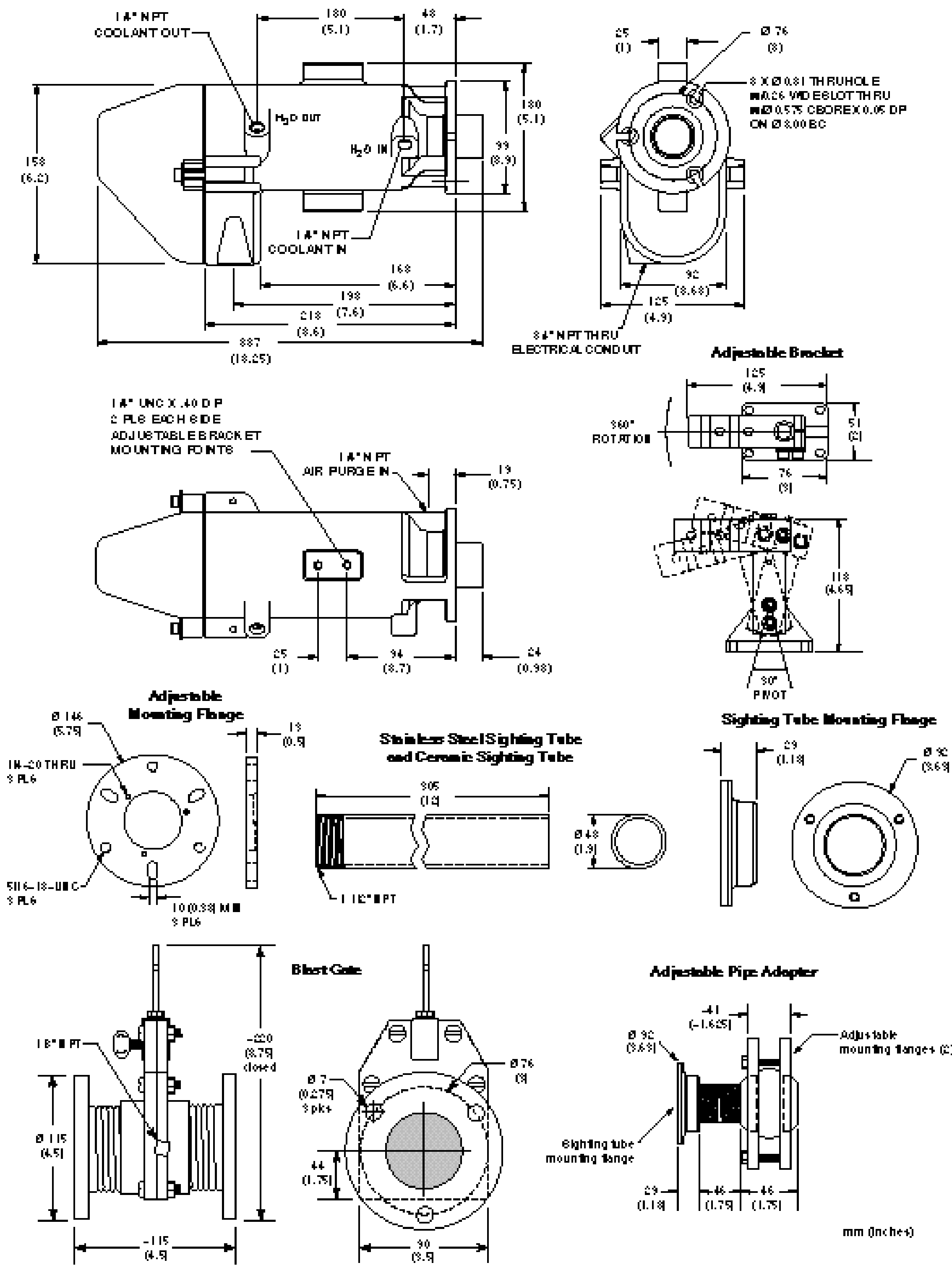


Figure 2-8: ThermoJacket and Accessories

2.2.5 Right Angle Mirror

The Right Angle Mirror is used to get a perpendicular view of a target when space is limited or when you need to avoid excessive radiation to the sensor. It must be installed after the bracket or after the Air Purge Collar, if used, and screwed in fully. In dusty or contaminated environments, connect air to the mirror's nipple to keep the first surface mirror clean. If used in conjunction with the Air Purge Collar, both the Right Angle Mirror and the Air Purge Collar must be air purged.

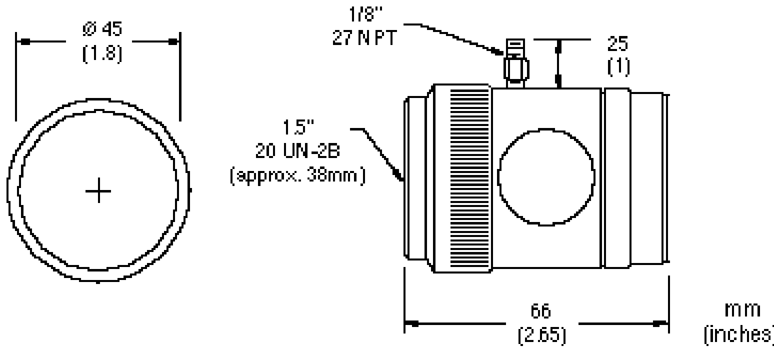


Figure 2-9: Right Angle Mirror

IMPORTANT

When using the Right Angle Mirror, adjust emissivity settings downward by 5% (e.g., for an object with an emissivity of 0.95, use 0.90; for an object with 0.80 use 0.76; for 0.65 use 0.62. This corrects for infrared energy losses due to the mirror.

2.2.6 Sighting Viewer Tool

The Sighting Viewer Tool accessory is used to aid in the alignment of the sensor. It is often used when the object is small and far from the sensor as well as in situations when obtaining a direct in-line sighting is difficult. It can be used both with and without the Air Purge Collar but not with the Right Angle Mirror. For best results, first secure the sensor to the bracket using the mounting nut or Air Purge Collar and then screw on the Sighting Viewer Tool fully. Next, position and secure the bracket, being sure to remove the Sighting Viewer Tool when alignment is complete.

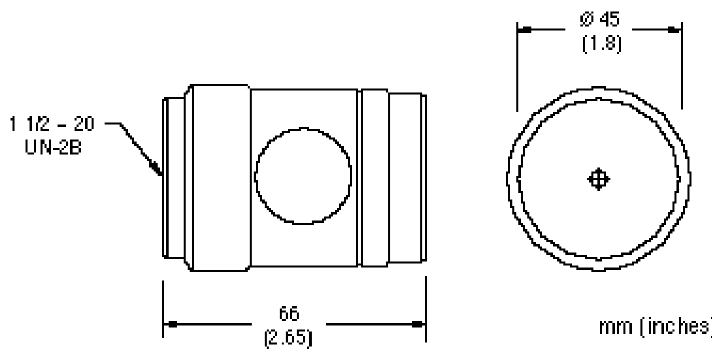


Figure 2-10: Sighting Viewer Tool

2.3 ELECTRICAL INSTALLATION

A standard 4.5 m (15 ft.) cable is supplied with each sensor. It consists of a factory-installed 5-pin DIN connector on one end and four leads plus shield on the other end.

Note: Thermocouple and current output models have different cables. It is important to use the appropriate cables to maintain accuracy.

When using protective conduit, consider the following:

- Use a double-hex water tight compression coupling designed for 19 mm (3/4 inch) EMT thin walled conduit.
- To avoid undue stress on the housing during installation, attach the coupling first to the conduit and then to the sensor. Do NOT suspend the conduit from the sensor, or the sensor from the conduit.

When powered by a transformer, the unit may be susceptible to line noise. Line noise can be eliminated by the addition of capacitors on the secondary of the stepdown transformer. Note that any stepdown transformer shipped with the unit includes the necessary capacitors. Customer supplied transformers will require the modifications shown in the following illustration.

Note: Use 0.01µF/250 VAC capacitors for C1 and C2. An example is Sprague p/n125LS10 Ceramic Disk Capacitor.

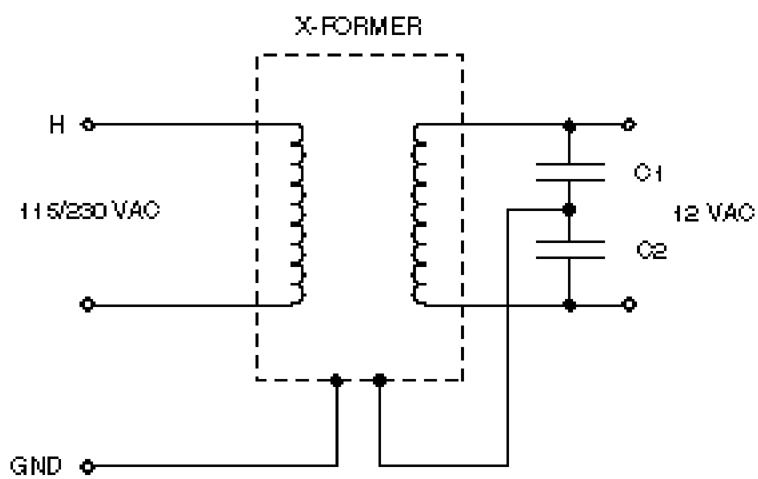
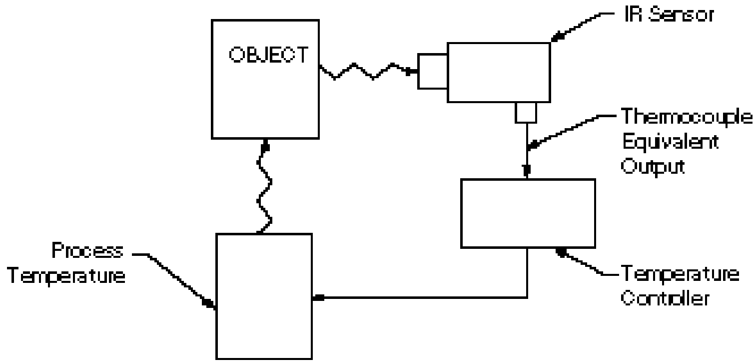


Figure 2-11: Stepdown Transformer Modifications

2.3.1 Thermocouple Output Models

These sensors provide simulated thermocouple outputs. They are calibrated thermocouple equivalent signals that may be interfaced to any controller, data logger, indicator, computer I/O, etc., requiring a specific type of thermocouple input.



Electrical Connections		
Color	**Connector Pin**	**Function**
Brown	1	12 VAC supply
Brown	2	12 VAC supply
Red	3	(-) Thermocouple output
White, Yellow, Black	4	(+) Thermocouple output, J, K, R-type
Uninsulated	None	Cable shield to earth ground

CAUTION

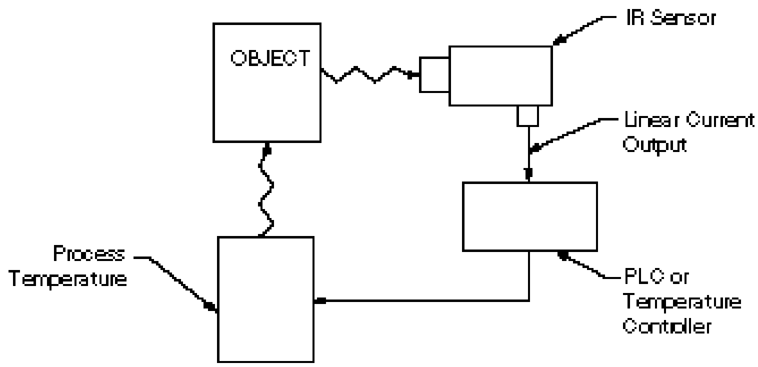
Always use thermocouple wire on pins 3 and 4. Note that Red is minus. For all color coding of thermocouples, ANSI standards are used; these standards vary considerably by country.

Installation Checklist

1. The “power on” LED should be lit when power is supplied.
2. The Average and Peak Hold controls should be turned fully counter-clockwise.
3. Connect a thermocouple meter to the output: white, yellow or black (+), red (-). Make sure the emissivity is less than 1.00.
4. Aim the sensor at objects with different temperatures. The thermocouple meter will respond to changes.

2.3.2 Current Output Models

These sensors provide a 4-20 milliamp linear current output. These calibrated signals may be interfaced to any controller, data logger, indicator, computer I/O, etc., requiring a 4-20 mA linear current input. Note that four (4) wires are required: two (2) for the calibrated linear signal and two (2) for the power supply.



Electrical Connections		
Color	**Connector Pin**	**Function**
Red	1	12 VAC supply
Black	2	12 VAC supply
Green	3	(-) 4-20 mA output
White	4	(+) 4-20 mA output
Uninsulated	None	Cable shield to earth ground

Installation Checklist

1. The “power on” LED should be lit when power is supplied.
2. The Average and Peak Hold controls should be turned fully counter-clockwise.
3. Set a digital voltmeter to measure at least 20 mA and connect it to the output (white [+], green [-]), and make sure the emissivity is less than 1.00.
4. Aim the sensor at objects with different temperatures. The meter will respond to these changes.

3.0 OPERATION

3.1 THEORY OF OPERATION

This type of infrared thermometer is a sophisticated thermal transducer utilizing modern digital logic circuitry but does not include a microprocessor. A thin film thermopile detector along with a spectral filter is used as the infrared sensor. A simple lens designed to transmit infrared energy is used to focus the energy onto the detector. Special baffling techniques are used to avoid any stray radiation from sources both inside and outside of the sensor. Besides the optics and IR detector, an ambient temperature sensor is used to detect varying ambient conditions.

Both the IR detector and the ambient sensor are summed, the signals are modified by the panel settings and fed to a comparator. They are then digitized to a 12-bit level. An EPROM is used to linearize the signals according to the required output task (e.g., thermocouple or current). The 12-bit signal is then fed to a digital-to-analog converter followed by a sample and hold circuit and an output amplifier.

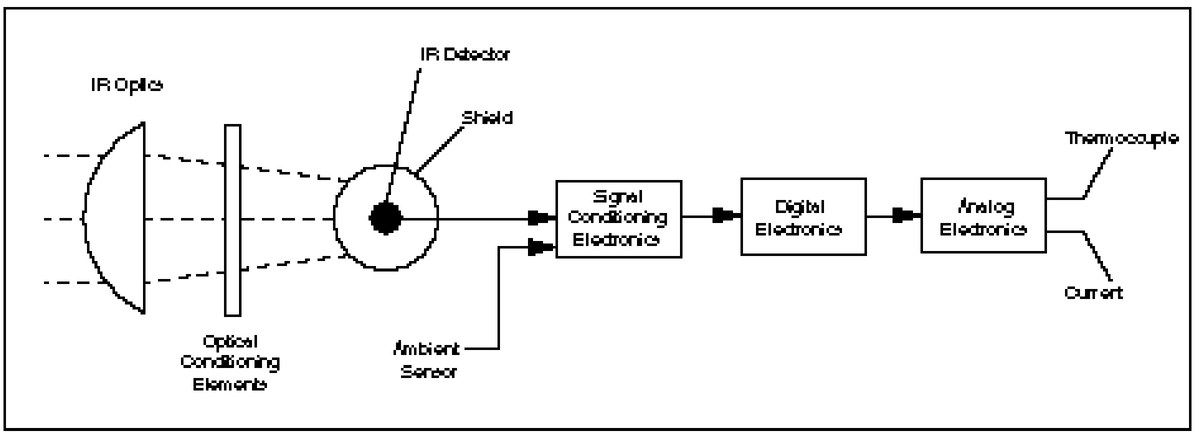


Figure 3-1: Theory of Operation

3.2 CONTROLS

All controls and adjustments are located on the rear panel. Any adjustment may be made while power is on. The thermocouple and current output models have similar controls with the only exception being the addition of the Temperature Range Switch on the current output models. Both models have a default emissivity setting of .95.

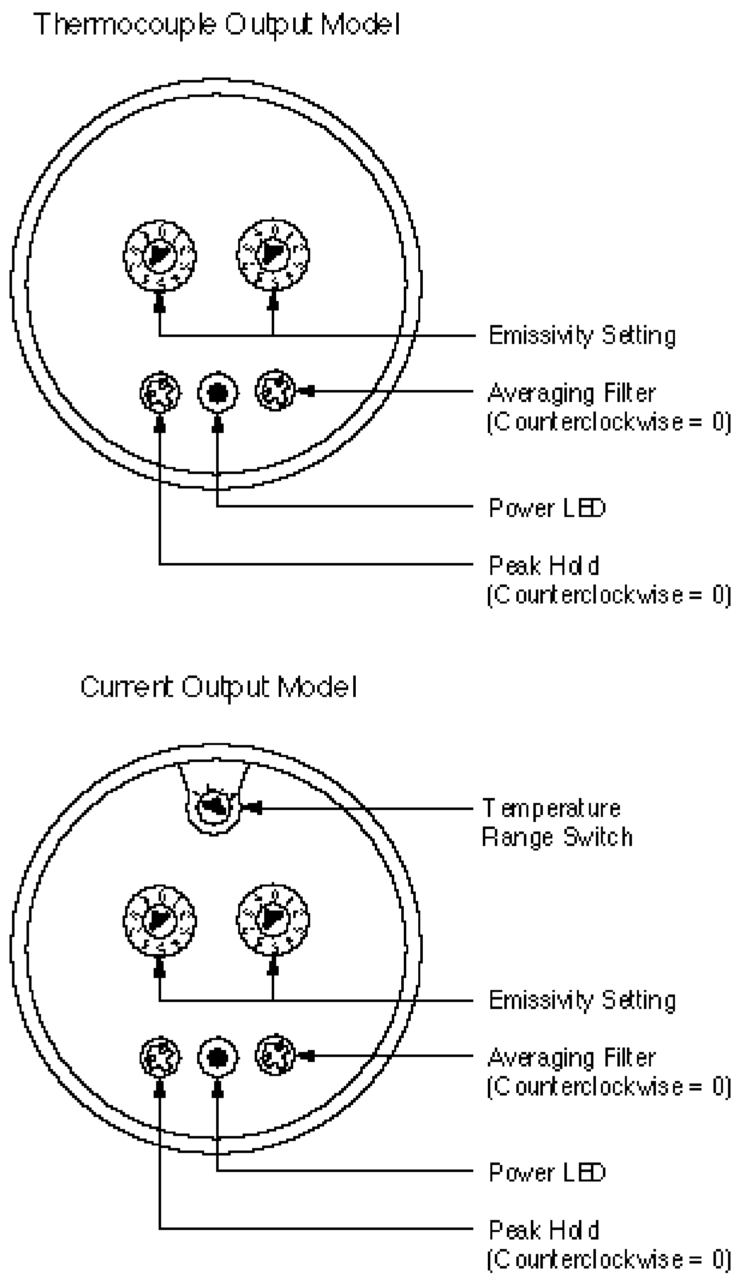


Figure 3-2: Control Panels

3.2.1 Temperature Range

The thermocouple output models have a fixed temperature range base on the simulated thermocouple. No adjustment is necessary.

The current output models have four switch-selectable temperature ranges. The desired temperature range must be set prior to operation.

Current Output			
LT	Range Setting	°F Version	°C Version
	1	0 to 200	0 to 100
	2	0 to 400	0 to 200
	3	0 to 800	0 to 400
	4	0 to 1400	0 to 800
P7	Range Setting	Temperature Range	
	1	50 to 350°F	
	2	50 to 650°F	
	3	10 to 110°C	
	4	10 to 360°C	
G5	Range Setting	Temperature Range	
	1	500 to 1500°F	
	2	500 to 3000°F	
	3	260 to 815°C	
	4	260 to 1650°C	
HT	Range Setting	Temperature Range	
	1	1000 to 2000°F	
	2	1000 to 3000°F	
	3	500 to 1000°C	
	4	500 to 1700°C	

Note: LT models come in °F or °C versions. It is not possible to switch from °F to °C or vice versa.

3.2.2 Emissivity Setting

Turn the emissivity controls to the appropriate setting (See Appendix A). The emissivity indicated by the switch position numbers should be interpreted with a decimal point preceding the two numbers.

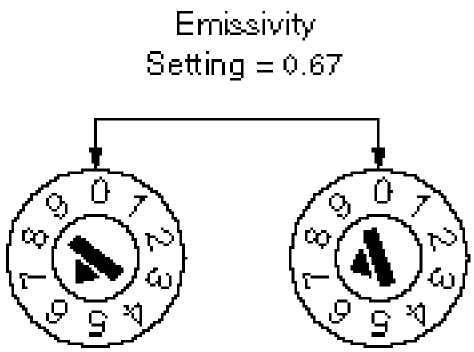


Figure 3-3: Emissivity Setting Switches

3.2.3 Peak Hold

For some applications a slower response to decreasing temperatures is desirable. The peak hold adjustment enables the sensor to respond quickly to a hot object moving into view on a conveyor belt, then decay slowly once it passes by.

If delay is not desired, turn the control fully counter-clockwise. To increase the delay, turn the control clockwise.

3.2.4 Averaging Filter

The averaging filter averages the reading by introducing a slower response to changes in temperature. The degree of averaging is set by the averaging filter control; off is fully counterclockwise and full averaging is clockwise. This feature is particularly useful in obtaining a stable reading in noisy environments or measuring temperatures of objects with varying emissivity. The averaging filter should NOT be used in conjunction with the peak hold.

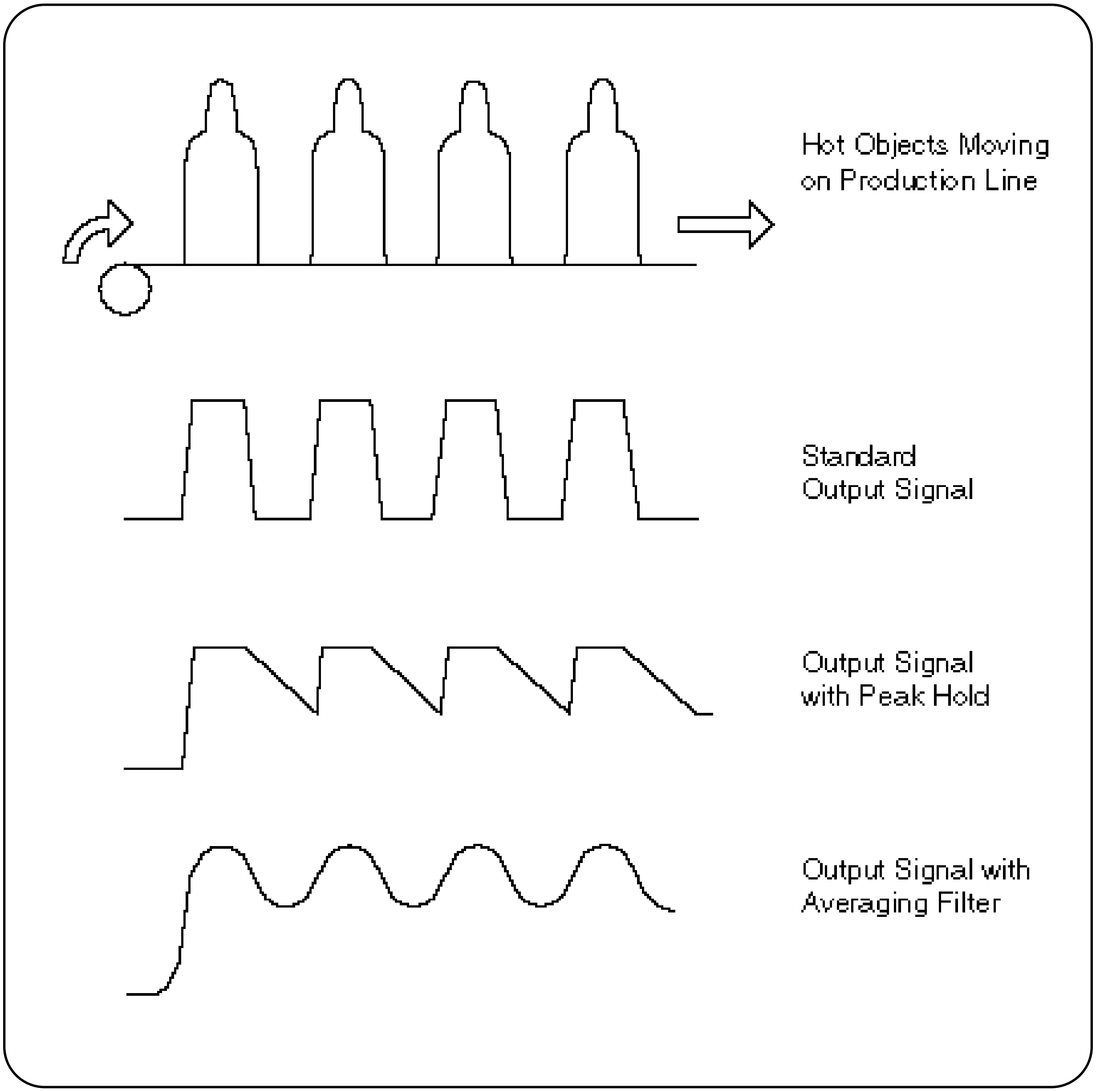


Figure 3-4: Signal Outputs (Standard, Peak Hold, Averaging)

4.0 MAINTENANCE

4.1 TROUBLESHOOTING MINOR PROBLEMS

Symptom	Probable Cause	Solution
LED not “On”	No power to sensing head	Remove connector from sensing head. Verify 12 VAC between the two connector positions.
Erroneous temperature readings	Incorrect type of thermocouple wire	Use correct type thermocouple wire
“ “	Interconnect cable broken	Verify cable continuity
“ “	Field of view obstructed, lens dirty	Remove obstruction clean lens (see below)
“ “	Faulty interconnect cable to data acquisition system	Verify cable continuity replace cable, if necessary
“ “	Wrong emissivity value set	Correct the emissivity setting
“ “	Wrong output range	Correct the range setting

4.2 FAIL-SAFE OPERATION

The fail-safe operation is designed to provide a high output (20.3 mA) in the event the object temperature is above or below the temperature range (or subrange) of the sensor. It will also provide a high output in the event of certain internal failures to the sensor.

4.3 CLEANING THE LENS

Care should be taken to keep the lens clean. Any foreign matter on the lens will affect the accuracy of the measurement. When cleaning the lens, do the following:

1. Lightly blow off loose particles.
2. Gently brush off remaining particles with a soft camel hair brush.
3. Clean remaining “dirt” using “Q-tip” (cotton swab) dampened in distilled water. Do not scratch the surface.
4. For finger prints or other grease, use any of the following:
   - Denatured alcohol
   - Ethanol
   - Kodak lens cleaner

   Apply one of the above to the lens. Wipe gently with a soft clean cloth until you see colors on the surface, then allow to air dry. Do not wipe the surface dry as this may scratch the surface.
5. If silicones (used in hand creams) get on the lens, gently wipe the surface with Hexane. Allow to air dry.

CAUTION

Do not use ammonia, or any cleaners containing ammonia, on the lens. This may result in permanent damage to the lens surface.

4.4 CUSTOMER SERVICE

Application assistance, calibration and repair service is available. The Service Department should be contacted before returning any equipment to allow for the most expeditious response time. In many cases, problems can be solved via telephone, telex or fax. We are at your service.

APPENDIX A: OBJECT EMISSIVITY

HOW TO DETERMINE OBJECT EMISSIVITY

Emissivity is a measure of an object's ability to absorb, transmit, and emit infrared energy. It can have a value from 0 (shiny mirror) to 1.0 (blackbody). If a higher than actual value of emissivity is set, the output will read low, provided the target temperature is above ambient. For example, if 0.95 is set and the actual emissivity is 0.9, the reading will be lower than the true temperature when the target temperature is above ambient.

The emissivity can be determined by one of the following methods, in order of preference:

1. Determine the actual temperature of the material using a sensor such as an RTD, thermocouple or another suitable method. Next, measure the object temperature and adjust the emissivity setting until the correct value is reached. This is the correct emissivity for the measured material.
2. For relatively low temperature (up to 260°C or 500°F) objects, place a piece of tape, such as electrical or masking tape, large enough to cover the field of view, on the object. Next, measure the tape temperature using an emissivity setting of 0.95. Finally, measure an adjacent area on the object and adjust the emissivity setting until the same temperature is reached. This is the correct emissivity for the measured material.
3. If a portion of the surface of the object can be coated, use a dull black paint, which will have an emissivity of about 0.98. Next, measure the painted area using an emissivity setting of 0.98. Finally, measure an adjacent area on the object and adjust the emissivity setting until the same temperature is reached. This is the correct emissivity for the measured material.

TYPICAL EMISSIVITY VALUES

The following table provides a brief reference guide for determining emissivity and can be used when one of the above methods is not practical. Emissivity values shown in the table are only approximate, since several parameters may affect the emissivity of an object. These include the following:

1. Temperature
2. Angle of measurement
3. Geometry (plane, concave, convex, etc.)
4. Thickness
5. Surface quality (polished, rough, oxidized, sandblasted)
6. Spectral region of measurement
7. Transmissivity (i.e., thin film plastics)

Typical Emissivity Values

Metals

Material	Emissivity 2.2µm	5.1µm	8-14µm
Aluminum			
Unoxidized	0.02-0.2	0.02-0.2	0.02-0.1
Oxidized	0.2-0.4	0.2-0.4	0.2-0.4
Alloy A3003, Oxidized	0.4	0.4	0.3
Roughened	0.2-0.6	0.1-0.4	0.1-0.3
Polished	0.02-0.1	0.02-0.1	0.02-0.1
Brass			
Polished	0.01-0.05	0.01-0.05	0.01-0.05
Burnished	0.4	0.3	0.3
Oxidized	0.6	0.5	0.5
Chromium	0.05-0.3	0.03-0.3	0.02-0.2
Copper			
Polished	0.03	0.03	0.03
Roughened	0.05-0.2	0.05-0.15	0.05-0.1
Oxidized	0.7-0.9	0.5-0.8	0.4-0.8
Gold	0.01-0.1	0.01-0.1	0.01-0.1
Haynes			
Alloy	0.6-0.9	0.3-0.8	0.3-0.8
Inconel			
Oxidized	0.6-0.9	0.6-0.9	0.7-0.95
Sandblasted	0.3-0.6	0.3-0.6	0.3-0.6
Electropolished	0.25	0.15	0.15
Iron			
Oxidized	0.7-0.9	0.6-0.9	0.5-0.9
Unoxidized	0.1-0.3	0.05-0.25	0.05-0.2
Rusted	0.6-0.9	0.5-0.8	0.5-0.7
Molten	0.4-0.6	—	—
Iron, Cast			
Oxidized	0.7-0.95	0.65-0.95	0.6-0.95
Unoxidized	0.3	0.25	0.2
Molten	0.3-0.4	0.2-0.3	0.2-0.3
Iron, Wrought			
Dull	0.95	0.9	0.9
Lead			
Polished	0.05-0.2	0.05-0.2	0.05-0.1
Rough	0.5	0.4	0.4

Metals

Material	Emissivity 2.2µm	5.1µm	8-14µm
Lead			
Oxidized	0.3-0.7	0.2-0.7	0.2-0.6
Magnesium	0.05-0.2	0.03-0.15	0.02-0.1
Mercury	0.05-0.15	0.05-0.15	0.05-0.15
Molybdenum			
Oxidized	0.4-0.9	0.3-0.7	0.2-0.6
Unoxidized	0.1-0.3	0.1-0.15	0.1
Monel (Ni-Cu)	0.2-0.6	0.1-0.5	0.1-0.14
Nickel			
Oxidized	0.4-0.7	0.3-0.6	0.2-0.5
Electrolytic	0.1-0.2	0.1-0.15	0.05-0.15
Platinum			
Black	0.95	0.9	0.9
Silver	0.02	0.02	0.02
Steel			
Cold-Rolled	—	0.8-0.9	0.7-0.9
Ground Sheet	0.6-0.7	0.5-0.7	0.4-0.6
Polished Sheet	0.2	0.1	0.1
Molten	0.25-0.4	0.1-0.2	—
Oxidized	0.8-0.9	0.7-0.9	0.7-0.9
Stainless	0.2-0.9	0.15-0.8	0.1-0.8
Tin (Unoxidized)	0.1-0.3	0.05	0.05
Titanium			
Polished	0.2-0.5	0.1-0.3	0.05-0.2
Oxidized	0.6-0.8	0.5-0.7	0.5-0.6
Tungsten	0.1-0.6	0.05-0.5	0.03
Polished	0.1-0.3	0.05-0.25	0.03-0.1
Zinc			
Oxidized	0.15	0.1	0.1
Polished	0.05	0.03	0.02

Non-Metals

Material	Emissivity 2.2µm	5.1µm	8-14µm
Asbestos	0.8	0.9	0.95
Asphalt	—	0.95	0.95
Basalt	—	0.7	0.7
Carbon			
Unoxidized	0.8-0.9	0.8-0.9	0.8-0.9
Graphite	0.8-0.9	0.7-0.9	0.7-0.8
Carborundum	0.95	0.9	0.9
Ceramic	0.8-0.95	0.85-0.95	0.95
Clay	0.8-0.95	0.85-0.95	0.95
Concrete	0.9	0.9	0.95
Cloth	—	0.95	0.95
Glass			
Plate	0.2	0.98	0.85
"Gob"	0.4-0.9	0.9	—
Gravel	—	0.95	0.95
Gypsum	—	0.4-0.97	0.8-0.95
Ice	—	—	0.98
Limestone	—	0.4-0.98	0.98
Paint (non-al.)	—	—	0.9-0.95
Paper (any color)	—	0.95	0.95
Plastic (opaque, over 20 mils)	—	0.95	0.95
Rubber	—	0.9	0.95
Sand	—	0.9	0.9
Snow	—	—	0.9
Soil	—	—	0.9-0.98
Water	—	—	0.93
Wood, Natural	—	0.9-0.95	0.9-0.95

To optimize surface temperature measurements consider the following guidelines:

1. Determine the object emissivity using the instrument to be used for the measurement.
2. Avoid reflections by shielding object from surrounding high temperature sources.
3. For higher temperature objects use shorter wavelength instruments, whenever overlap occurs.
4. For semi-transparent materials such as plastic film and glass, assure that the background is uniform and lower in temperature than the object.
5. Mount sensor perpendicular to surface whenever emissivity is less than 0.9. In all cases, do not exceed angles more than 30 degrees from incidence.

ADDENDUM B: CE CONFORMITY FOR THE EUROPEAN COMMUNITY

This instrument conforms to the following standards:

- EN50081-1:1992, Electromagnetic Emissions
- EN50082-1:1992, Electromagnetic Susceptibility

Tests were conducted over a frequency range of 27–500 MHz with the instrument in three orientations. The instrument’s average error in this frequency range for the three orientations is 0.6° C at an electric field strength of 3 V/m. At some frequencies the instrument may not meet its stated accuracy.