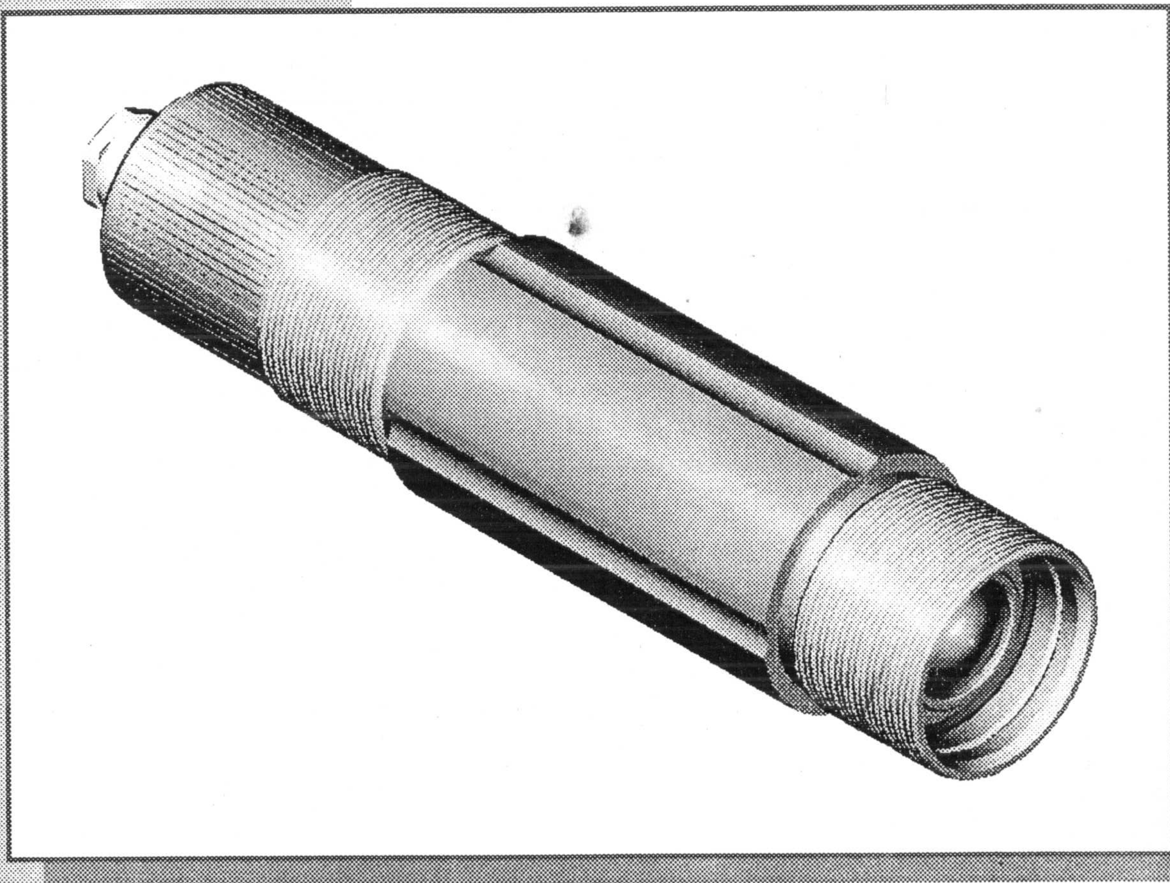
THERMALERT®
TX™ SERIES



OPERATOR'S MANUAL

Raytek®

Noncontact Temperature Measurement

DTX 12

Rev E
05/95
50501

WARRANTY

WARRANTY

Raytek warrants each instrument it manufactures to be free from defects in material and workmanship under normal use and service for the period of one year from date of purchase. This warranty extends only to the original purchaser. This warranty shall not apply to fuses, batteries, or any product which has been subject to misuse, neglect, accident or abnormal conditions of operation.

In the event of failure of a product covered by this warranty, Raytek, will repair the instrument when it is returned to an authorized Service Facility within one year of the original purchase; provided the warrantor's examination discloses to its satisfaction that the product was defective. The warrantor may, at its option, replace the product in lieu of repair. With regard to any instrument returned within one year of the original purchase, said repairs or replacement will be made without charge. If the failure has been caused by misuse, neglect, accident or abnormal conditions of operation, repairs will be billed at nominal cost. In such cases, an estimate will be submitted before work is started, if requested.

THE FOREGOING WARRANTY IS IN LIEU OF ALL OTHER WARRANTIES, EXPRESSED OR IMPLIED, INCLUDING BUT NOT LIMITED TO ANY IMPLIED WARRANTY OF MERCHANTABILITY, FITNESS OR ADEQUACY FOR ANY PARTICULAR PURPOSE OR USE. RAYTEK, SHALL NOT BE LIABLE FOR ANY SPECIAL, INCIDENTAL OR CONSEQUENTIAL DAMAGES, WHETHER IN CONTRACT, TORT OR OTHERWISE.

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CE Conformity for the European Community

CE

This instrument conforms to the following standards:

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

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1. INTRODUCTION

1.0 INTRODUCTION

1.1 DESCRIPTION

The Thermalert® TX™ series of online 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 2 wire, current output, electrical signal.

Each model (**Table 1-1**) 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.

Table 1-1: Models

MODEL	TEMPERATURE RANGE	OPTICAL RESOLUTION	SPECTRAL RANGE
Low Temperature	-18 to 500°C (0 to 1000°F)	15:1	8-14 µ
Low Temperature Close Focus	-18 to 500°C (0 to 1000°F)	7:1	8-14 µ
Low Temperature High Resolution	-18 to 500°C (0 to 1000°F)	33:1	8-14 µ
Low Temperature High Resolution Close Focus (Option 1)	-18 to 500°C (0 to 1000°F)	30:1	8-14 µ
Low Temperature High Resolution Close Focus (Option 2)	-18 to 500°C (0 to 1000°F)	32:1	8-14 µ
Medium Temperature High Resolution	200 to 1000°C (400 to 1800°F)	33:1	3.9 µ
Medium Temperature High Resolution Close Focus (Option 1)	200 to 1000°C (400 to 1800°F)	30:1	3.9 µ
Medium Temperature High Resolution Close Focus (Option 2)	200 to 1000°C (400 to 1800°F)	32:1	3.9 µ
G5 (Glass)	250 to 1650°C (500 to 3000°F)	33:1	5.0 µ
P7 (Plastic	10 to 360°C (50 to 650°F)	33:1	7.9 µ
High Temperature High Resolution	500 to 2000°C (950 to 3600°F)	60:1	2.2 µ
High Temperature High Resolution Close Focus (Option 1)	500 to 2000°C (950 to 3600°F)	60:1	2.2 µ
High Temperature High Resolution Close Focus (Option 2)	500 to 2000°C (950 to 3600°F)	60:1	2.2 µ

1. INTRODUCTION

Each model is built to operate on a 100% duty cycle in industrial environments. Outputs consist of standardized 2-wire current signals commonly available for use with controllers, recorders, alarms or A/D interfaces. Using the HART® (Highway Addressable Remote Transducer) Protocol, the Smart Version is remote online addressable by Frequency Shift Keying (FSK) digital communication on the 2-wire current interface. The Basic Version has manually adjustable emissivity settings by built-in rotary switches.

1.1.1 Accessories

A full range of accessories for various applications and industrial environments is available. Accessories may be ordered at any time and added on-site. The following accessories are available:

For all models

- Lens protector
- Sighting viewer
- Right angle mirror
- Pipe and conduit adapter
- Mounting nut
- Fixed bracket
- Adjustable bracket
- ThermoJacket
  - Adjustable mounting flange
  - Adjustable mounting base
  - Sighting tube Mounting Flange
  - Sighting tube, 305mm (12")
  - Water flow regulator
  - High capacity air flow regulator
  - Air flow/pressure regulator

For Smart TX models only

- Remote communications kit
  - HART® signal conversion module
  - DataTemp™ TX software

HART® is a registered trademark of Rosemount® Inc., Thermalert®TX™, DataTemp™ and ThermoJacket™ are trademarks of Raytek®Inc.

1.1.2 Options

A full range of options for various applications and environments is available. Options are factory installed and must be ordered with base model units. The following options are available:

- °C or °F (basic TX models only)
- Close focus optics
- Air/water-cooled housing
- NIST certification

IMPORTANT
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.

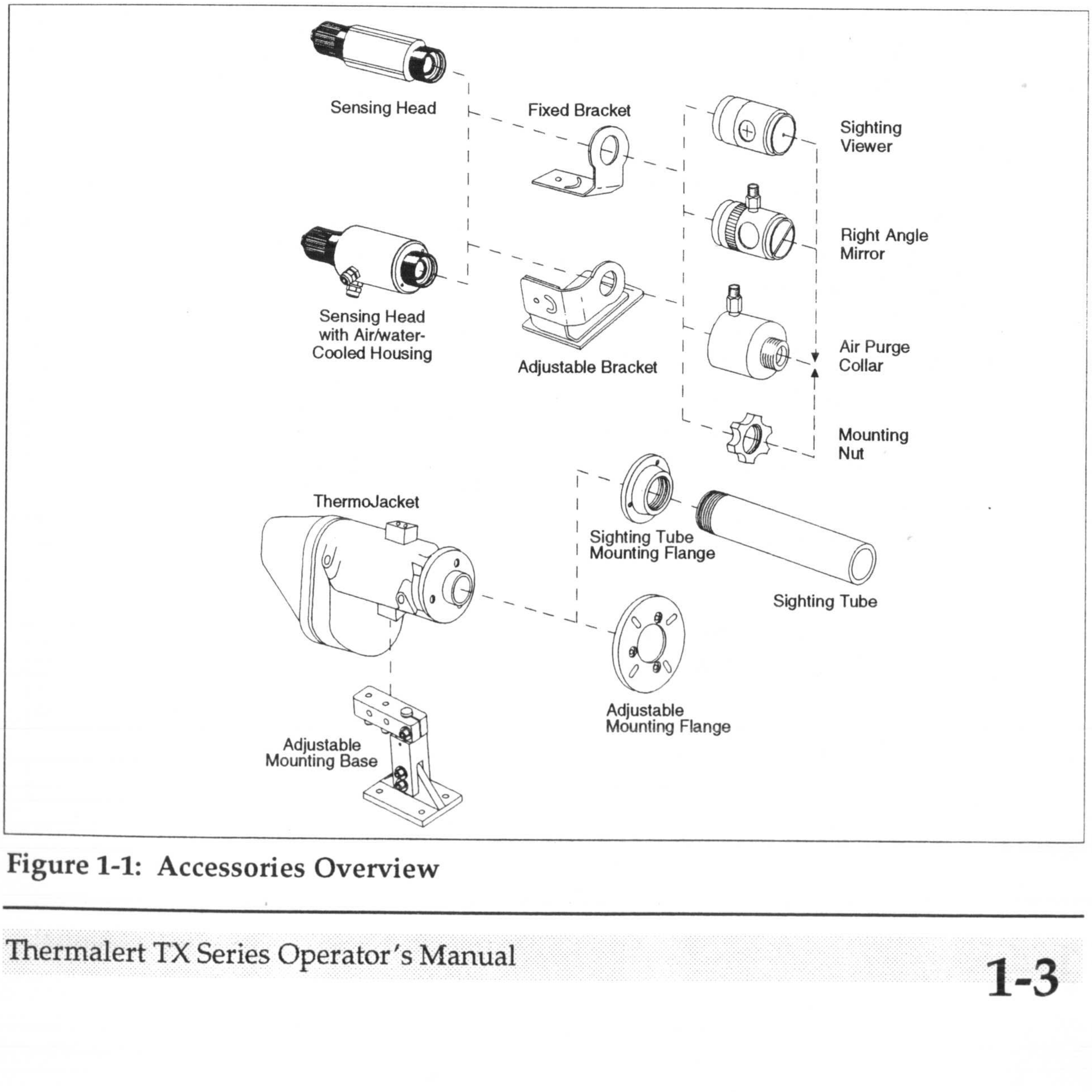


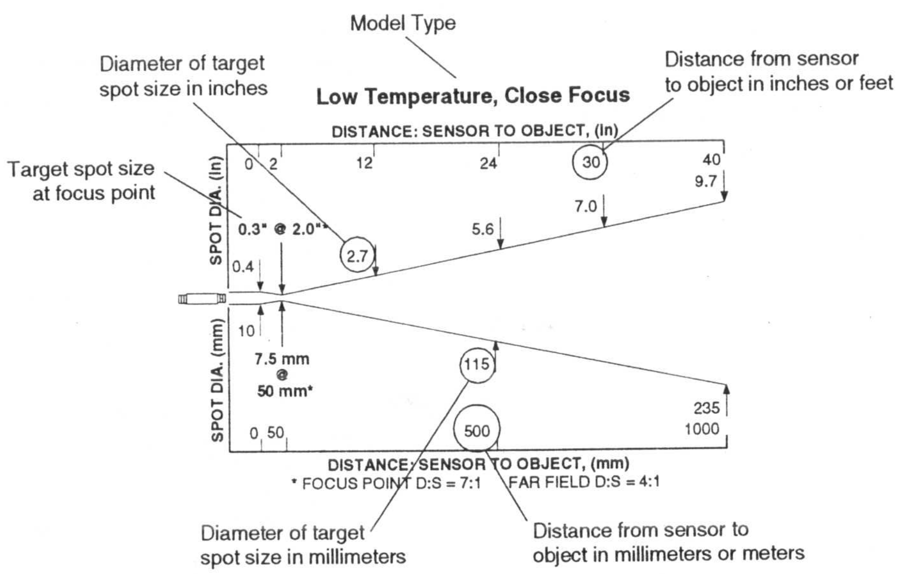
Figure 1-1: Accessories Overview

1. INTRODUCTION

1.2 SPECIFICATIONS

1.2.1 How to Read the Optical Charts

The optical charts indicate the nominal target spot diameter at any given distance from the sensing head. Information in the top half of each chart is in inches or feet, the bottom half is in metric units. All optical charts within this manual assume 90% energy.



Focus Point D:S = Distance to spot divided by spot diameter at the focus point
Far Field D:S = Ratio at distances greater than 10x the focus distance

How to calculate spot sizes

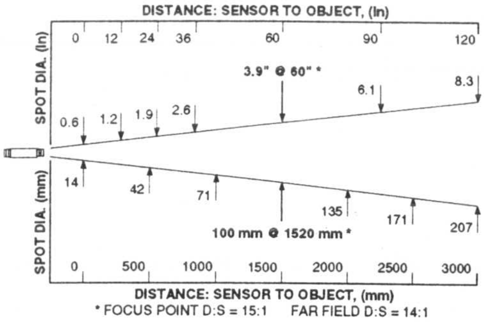
To calculate a spot size between two known points on an optical chart, use the following formula:

$$S_x = S_n + \left[\frac{(D_x - D_n)}{(D_f - D_n)} \times (S_f - S_n) \right]$$

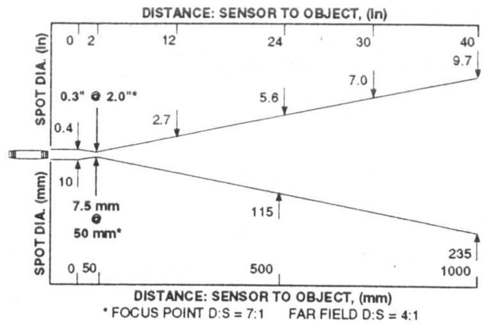
S_x = Unknown spot size
S_n = Smaller known spot size
S_f = Larger known spot size
D_x = Distance to unknown spot
D_n = Distance to smaller known spot
D_f = Distance to larger known spot

Figure 1-2: How to Read the Optical Charts

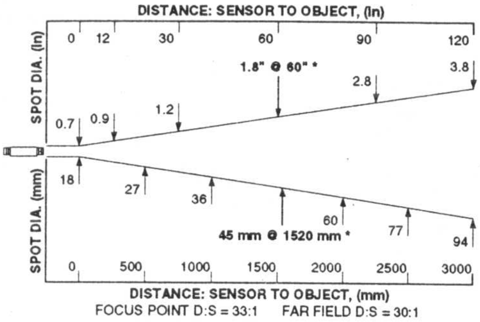
Low Temperature, Standard Focus



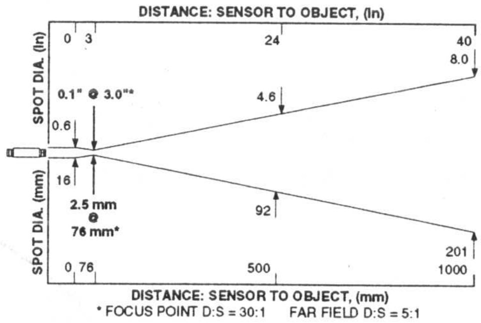
Low Temperature, Close Focus



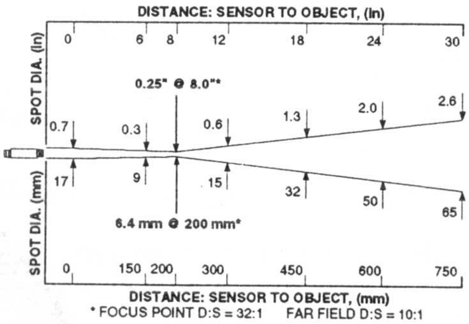
Low & Medium Temperature, High Resolution, G5 (glass), P7 (plastic), Standard Focus



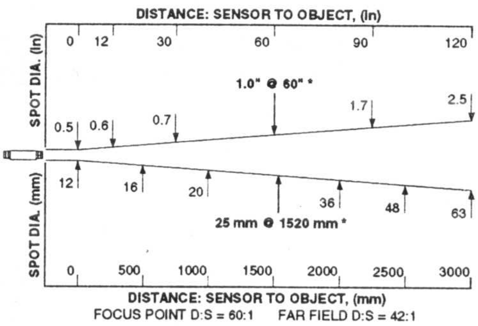
Low & Medium Temperature, High Resolution, Close Focus 1



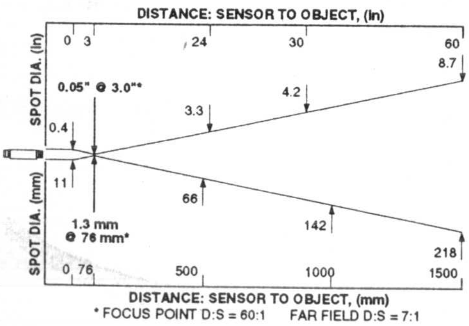
Low & Medium Temperature, High Resolution, Close Focus 2



High Temperature, Standard Focus



High Temperature, Close Focus 1



High Temperature, Close Focus 2

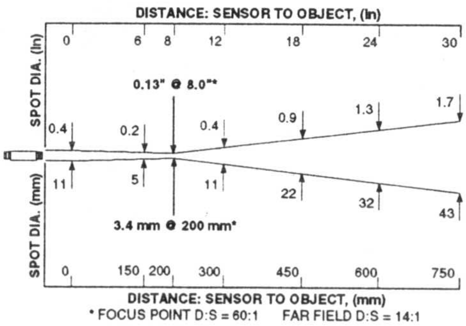


Figure 1-3: Optical Charts

1.2.2 Output Ranges

Refer to Table 1-1 for each model's temperature measurement range and their nominal spectral ranges.

1.2.3 Operational

System Accuracy	± 1% or ± 1.4°C (2.5°F) of target temperature, whichever is greater, at 25°C (77°F) ambient
System Repeatability	0.5 % of reading or ± 0.5°C, whichever is greater

All Versions

Temperature Resolution	0.1K (LT-models)
Emissivity	0.10 to 1.00, in 0.01 increments
Response Time	165 msec, (95% response) 100 msec is standard on High Temp (2.2μm) versions
Fail Safe	Full scale (>20 mA) when over range Low scale (<4 mA) under range

Smart Version

Signal Processing	°C/°F, averaging, peak/valley hold, emissivity, ambient temperature
Peak Hold	0 to 1200 sec
Valley Hold	0 to 1200 sec
Averaging	0 to 60 sec

1.2.4 Electrical

Power	12-24 VDC -10% / +20%
Temperature Output	4-20 mA

Inputs	FSK on mA loop (Smart model) Manually switched at sensing head (basic model)
Max Loop Impedance	750 ohms (in connection with given power supply range)
Interconnection	Terminal blocks and hooks for making easy HART connection
Alarm Output: (smart version only)	Transistor. Max voltage/current of 24 V 150mA. Remotly adjustable setpoint, deadband and normally open/closed settings.

1.2.5 Physical

Detector	Micromachined Thermopile	
Environmental Rating	NEMA- 4, (IEC 529, IP 65) Rated with conduit and compression fitting (which prevents liquid from entering through the connector)	
Ambient Operating Temperature Range	without cooling	0 to 70°C (32 to 158°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	-18 to 85°C (-0 to 185°F)	
Relative Humidity	10-95%, non-condensing	
Shock	IEC 68-2-27 (MIL STD 810D) 50 g's, 11 msec any axis	
Vibration	IEC 68-2-6 (MIL STD 810D) 3 g's, any axis, 11-200 Hz	
Dimensions	187 mm (7.4") L x 42 mm (1.7") diameter (head only) 187 mm (7.4") L x 60 mm (2.4") diameter (with water-cooled housing)	
Weight	330 g (0.72 lb) (head only) 595 g (1.3 lbs) (with water-cooled housing)	

1.2.6 Communication Specifications (Smart Sensor)

Communication Method	HART protocol – Frequency Shift Keying (FSK). Conforms with Bell 202 Modem Standard with respect to baud rate and digital "1" and "0" frequencies.
Baud Rate	1200 bps
Digital "0" Frequency	2200 Hz
Digital "1" Frequency	1200 Hz
Data Byte Structure	8 data bits, 1 start bit, 1 stop bit, 1 odd parity
Single Digital Process Variable Rate	Poll/Response Mode: 2.0 per second Burst Mode: 3.7 per second
Maximum Number of Multidropped Devices	Loop Powered: 15
Maximum Number of Communication Masters	Two

1.2.7 Cable Recommendations

Cables are not included with the sensing head. However, be aware of the following cable specifications when connecting the instrument.

Minimum Cable Size	24 AWG (0.51 mm diameter)
Cable Type	Single twisted-pair shielded or multiple twisted-pair with overall shield
Maximum Twisted-Pair Length	3000 m (10,000 ft)
Maximum Multiple Twisted-pair Length	1500 m (5,000 ft)

2. INSTALLATION

The installation process consists of the following:

- Preparation
- Mechanical Installation
- Electrical Installation

The most important part of the installation process is preparation. Please read the following section thoroughly before proceeding with the mechanical and electrical installations.

2.1 PREPARATION

2.1.1 Distance and Spot Size

The desired spot size to be measured on the target will determine the maximum working distance and appropriate focus model. The target must contain the entire field of view of the sensor. The sensor must be positioned so the field of view is the same as or smaller than the desired target size (**Figure 2-1**).
Have a look at page **1-4** and **1-5**, **Optical Charts**.

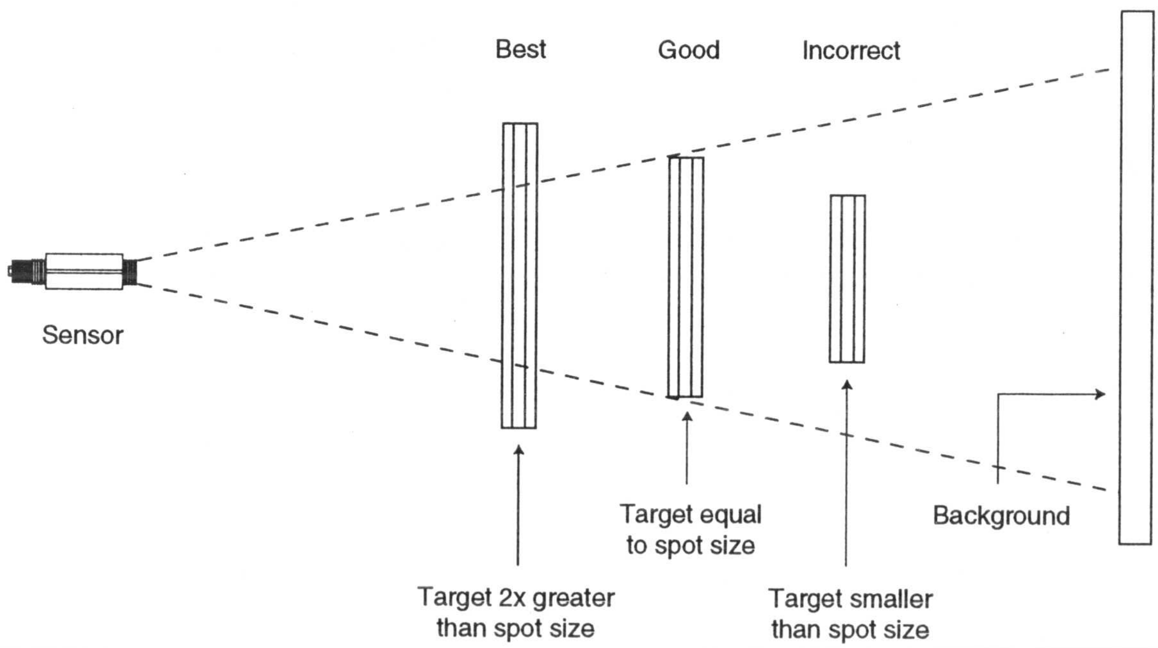


Figure 2-1: Proper Sensor Placement

2.1.2 Ambient Temperature

The sensing head is designed to operate in ambient temperatures between 0°C (32°F) and 70°C (158°F). In ambient conditions above 70°C (158°F), an optional air/water-cooled housing is available, which extends the operating range to 120°C (250°F) with air cooling or 175°C (350°F) with water cooling. When using the water-cooled housing, it is strongly recommended to also use the air purge collar to avoid condensation on the lens. In ambient conditions up to 315°C (600°F), you should use the ThermoJacket accessory.

2.1.3 Atmospheric Quality

It is important to maintain lens cleanliness at all times. A clean lens can prevent erroneous readings and possible lens damage. An air purge collar is available, and recommended, to protect the lens from smoke, fumes, dust and other contaminants. **For changing the protective window - please see page 4-2, chapter 4.4.**

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, such as motorized equipment producing large step load changes.
- Make sure the shield wire in the sensor cable is earth grounded.
- For additional protection, use conduit for the 4-20 mA lines and any external connections. Solid conduit is better than flexible conduit in high noise environments.
- Do not run DC power for other equipment in the same conduit.

2.2. MECHANICAL INSTALLATION

2.2.1 Sensor

All sensors are supplied with a fixed bracket and mounting nut. The sensor can also be mounted through a hole or with a customer-supplied bracket or other accessories. See Sections 1.1.1 and 1.1.2 for descriptions of sensor and mounting accessories and options. **Figure 2-4** shows sensor head dimensions. **Figure 2-5** shows both fixed and adjustable bracket dimensions.

> **CAUTION**
> All sensors and accessories are supplied with 1.5″ by 20 UN-2A machine threads and must not be used with standard pipe fittings.

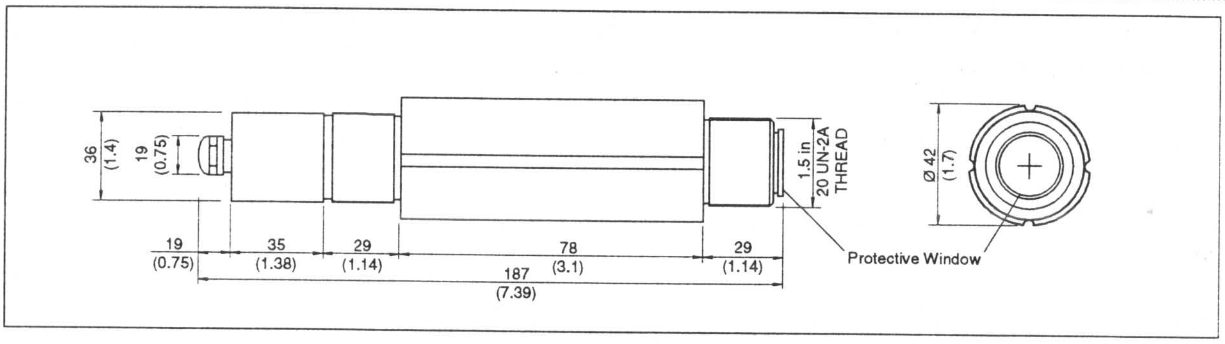


Figure 2–4: Sensing Head

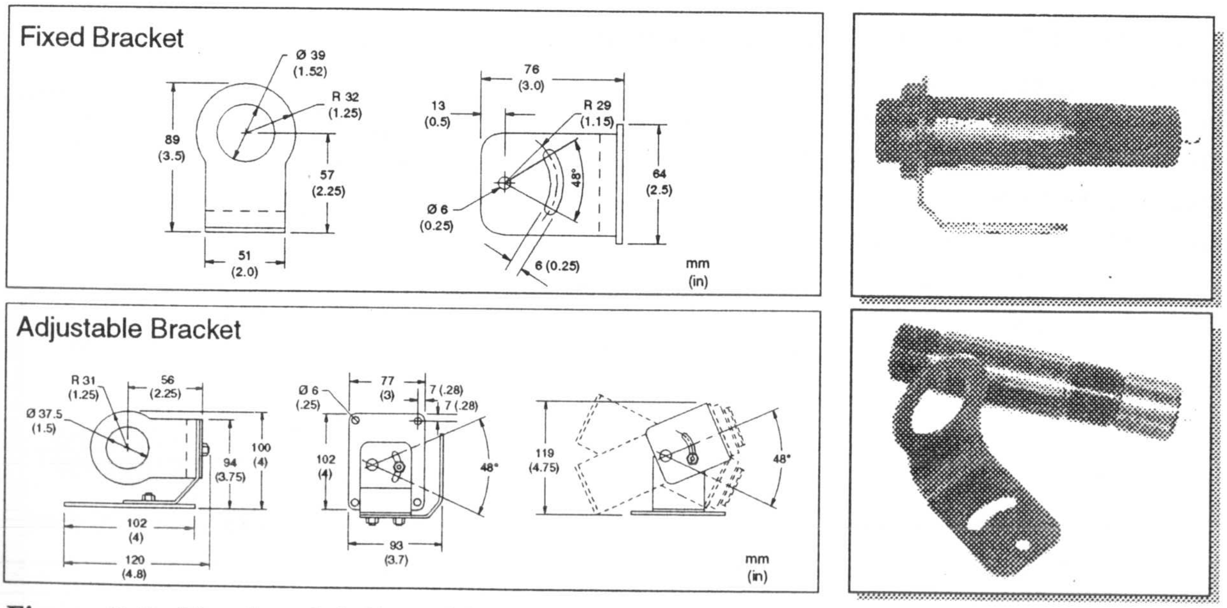


Figure 2-5: Fixed and Adjustable Brackets

2.2.2 Sensor with Air/Water-Cooled Housing

The Air/Water-Cooled Housing option (**Figure 2-6**) allows the sensor to be used in ambient temperatures up to 120°C (250°F) if air-cooled, and 175°C (350°F) if water-cooled. It is supplied with two brass fittings for connection to 6 mm (0.24 in) plastic hoses with a 4 mm (0.16 in) inside diameter. The fittings are threaded to the shell with 1/8" parallel tube thread as per ISO 22817. Air flow should be 0.1 to 1.5 cmm (3 to 5 cfm). Water flow should be approximately 1–2 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.

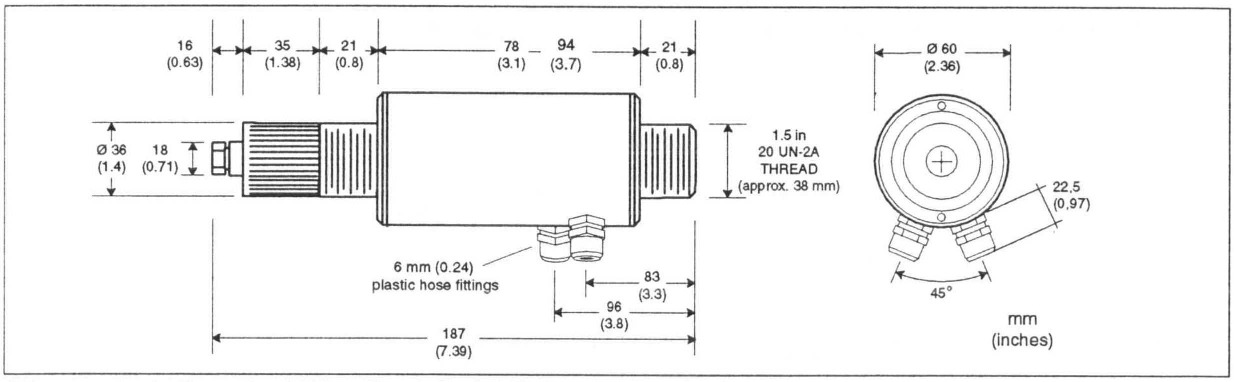


Figure 2–6: Sensing Head with Air/Water–Cooled Housing

2.2.3 Air Purge Collar

The Air Purge Collar accessory (**Figure 2-7**) is used to keep dust, moisture, airborne particles, and vapors away from the lens. It can be installed before or after the bracket (see accessories drawing in Section 1.1.1) 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.

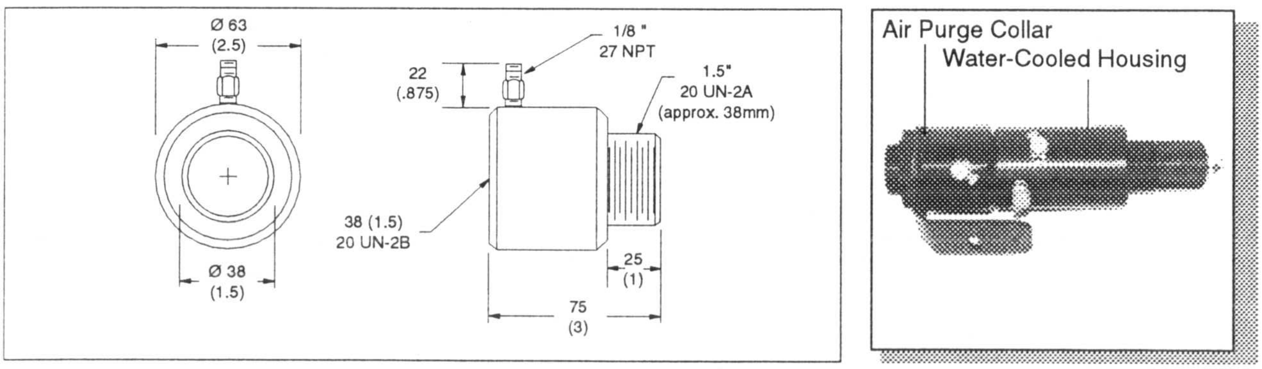


Figure 2-7: Air Purge Collar

2.2.4 Pipe Adaptor

All sensors and accessories are supplied with 38.0mm (1.5in) 20 UN machine threads and must not to be used with standard pipe fittings. A pipe adaptor is available for this purpose, if required.

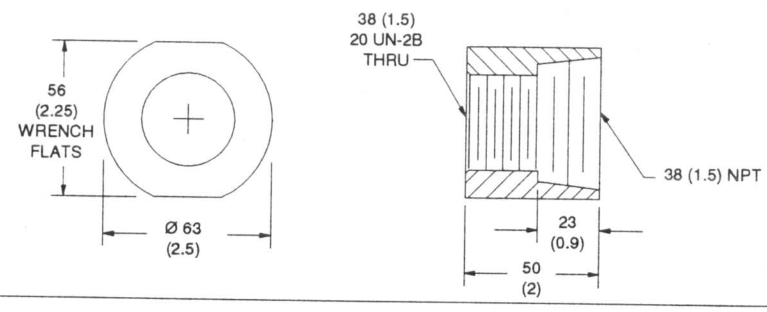


Figure 2–8: Pipe Adaptor

2.2.6 ThermoJacket

2.2.5 Conduit Adaptor

The regular sensor head is rated NEMA–4 (IEC 529, IP65) with conduit adaptor and compression fitting (whitch prevents liquid from entering through the connector). The sighting sensor head is rated NEMA–4 (IEC 529, IP 65) with a compression fitting installed on a conduit connection.

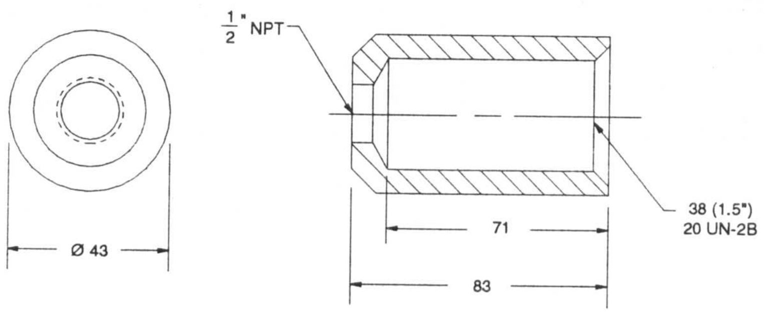
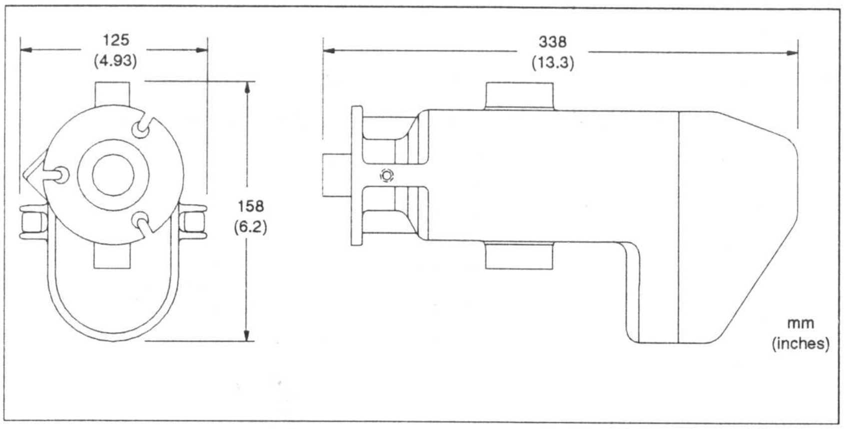


Figure 2–9: Conduit Adaptor

The ThermoJacket accessory (**Figure 2-10**) allows use of the sensing head in ambient temperatures up to 315°C (600°F).
The ThermoJacket's rugged cast aluminum housing completely encloses the head and



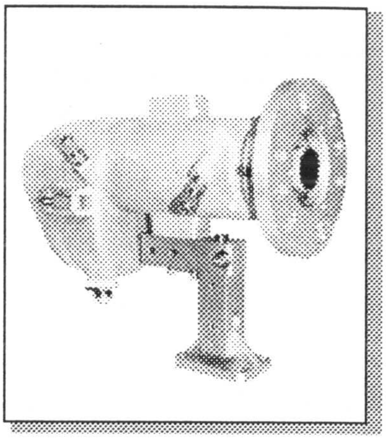
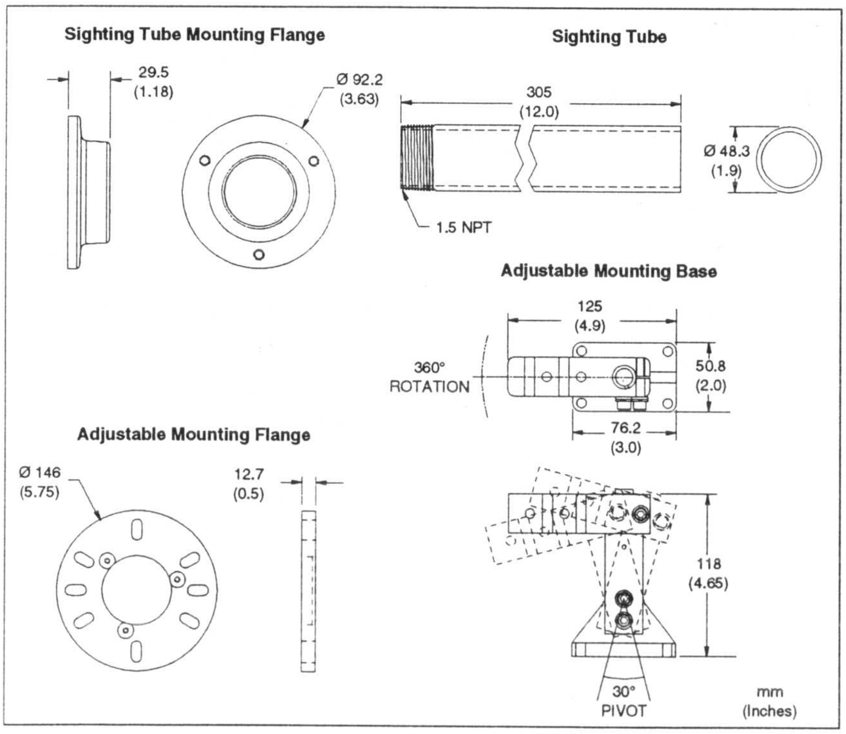
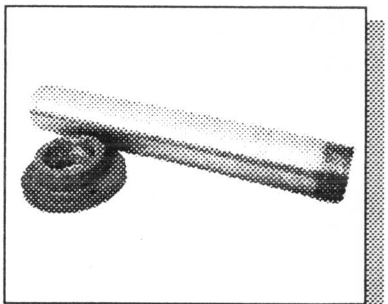


Figure 2-10: ThermoJacket (For more details see brochure "ThermoJacket")

provides water cooling and air purging in one unit. Sensing heads can be easily installed or removed from the ThermoJacket housing in its mounted position. ThermoJacket accessories are shown in **Figure 2-11**.





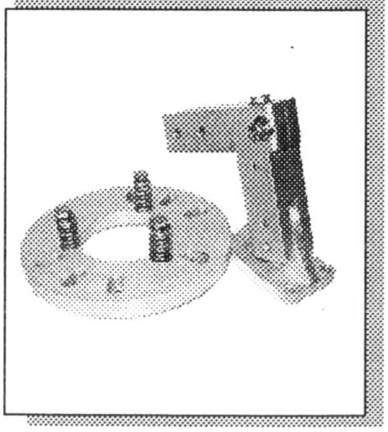
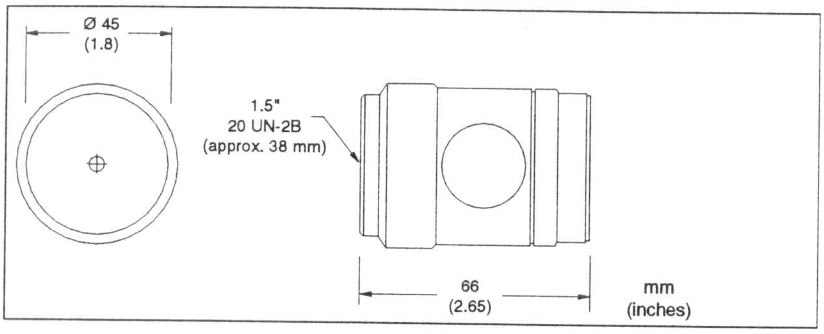


Figure 2-11: ThermoJacket Accessories (not to scale)

2.2.7 Right Angle Mirror

The Right Angle Mirror accessory (**Figure 2-12**) is used to obtain a perpendicular view of the object. It is often used 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, air purging is required 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.



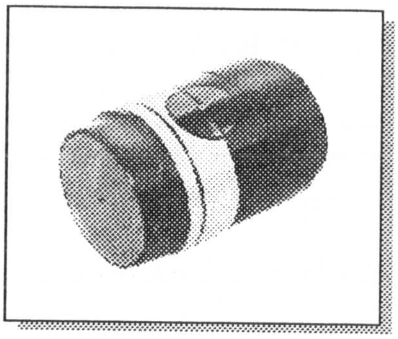


Figure 2-12: Right Angle Mirror

> **IMPORTANT**
> **When using the Right Angle Mirror, adjust the emissivity settings downward by 5%. For example, 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 correction accounts for energy losses in the mirror.**

2.2.8 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.

The dimensions of the Sighting Viewer Tool are the same as the dimensions of the Right Angle Mirror. Please compare with **Figure 2-12**.

Lens Protector - Please refer **APPENDIX B.**

2.3 ELECTRICAL INSTALLATION

2.3.1 Wiring

For proper operation make sure all wiring is installed correctly and the connections are tight. For NEMA 4 (IEC 529, IP65) and for proper strain relief it is required to use the supplied standard PG 9 conduit fitting. This works best for all wires by using a single circular cable-sheath. For optimum performance, the diameter of the cable should be 4 to 8 mm (0.16 to 0.31 inch). **Refer to Section 1.2.7 for minimum cable diameter requirements and maximum cable lengths.**

Be aware of the following grounding requirements:

- The cable shield must be grounded at only one point. This is usually done at the analog controller. However, it can be done at a junction box or other suitable location in the field area.
- Optionally, the cable shield can be connected to the sensor housing if the housing is isolated from ground or if the connection of the shield to ground is the only point in the network where the shield is grounded. In that case, connect the shield wire to the earth ground terminal at the terminal block on the back panel.

IMPORTANT

Do not connect other grounded metal objects to the cable shield.

Basic Model

Sensor to controller and power supply. Apply 12–24 VDC. The maximal loop impedance is 750 ohms as long as the voltage at the sensor stays in the given range.

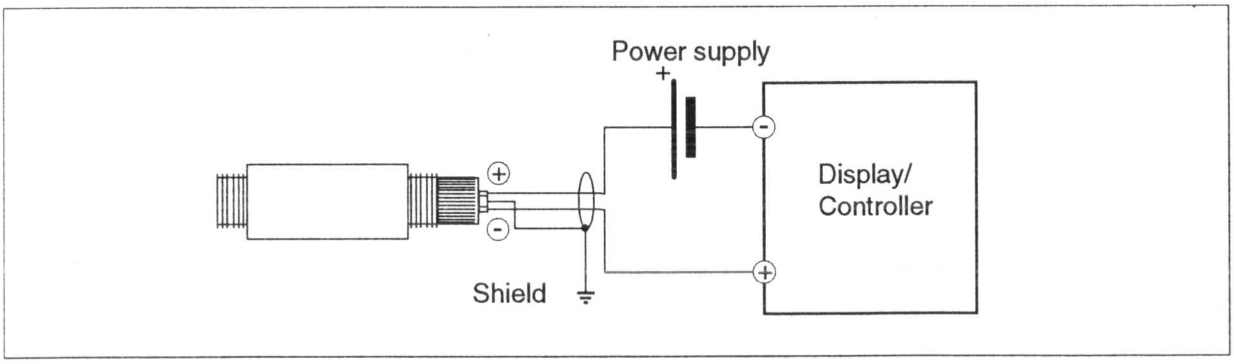
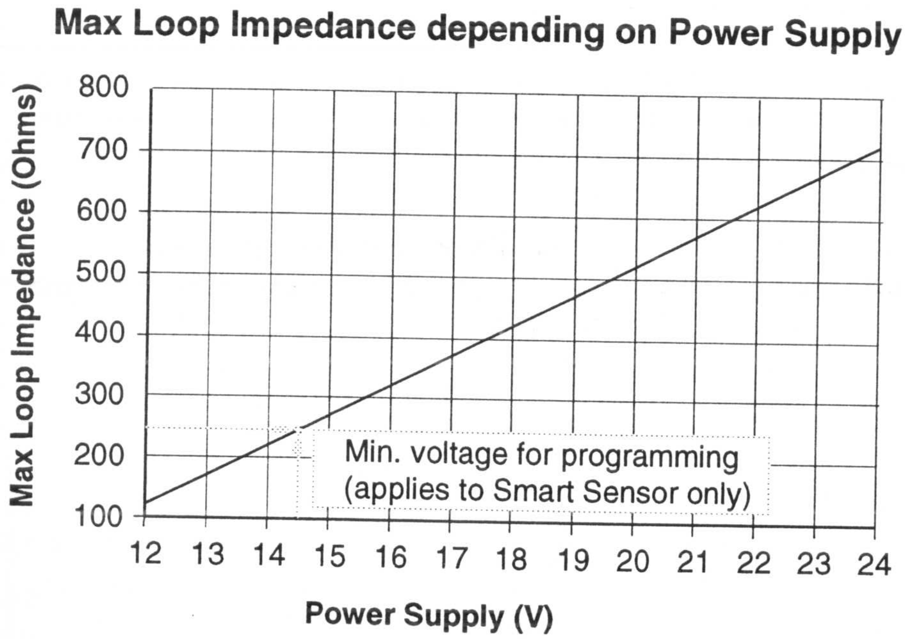


Figure 2-13: Simple Installation for Basic Model

2.3.2 Maximum Loop Impedance

The maximum loop impedance is determined by the power supply voltage. Use **Figure 2–14** to determine the value of the load resistor.



$$\text{Max Loop Impedance} = \frac{V_{supply} - V_{min}}{I_{max}}$$

where V_{supply} : nominal voltage

V_{min} : minimum voltage needed by the sensor (normally $12V^{-20\%}$)

I_{max} : max. current (normally 20mA)

Figure 2-14: Maximum Loop Impedance

2.4 INSTALLATION PROCESS FOR SMART AND BASIC SENSORS

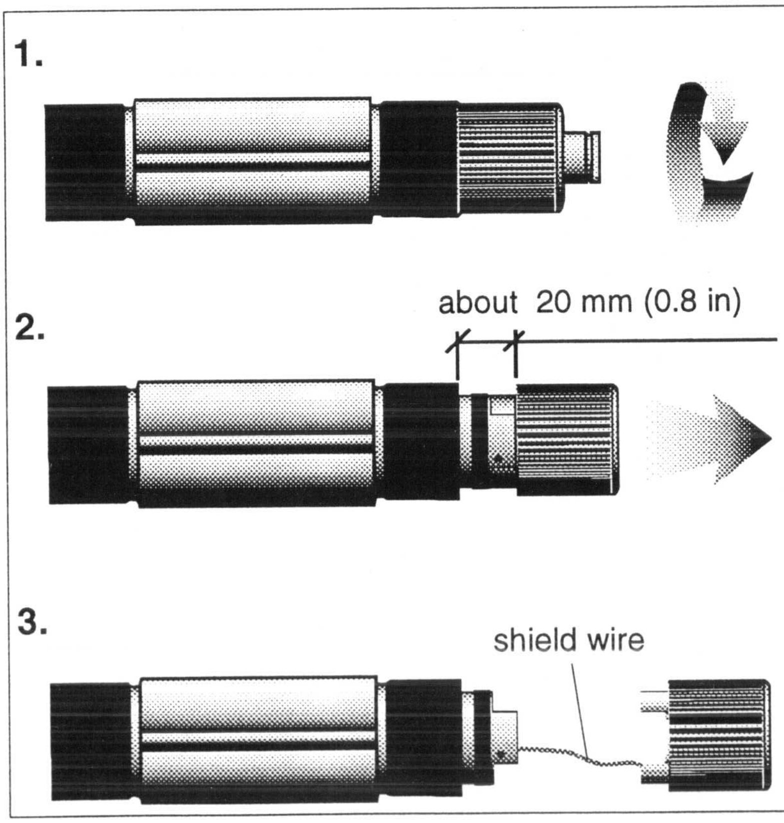
To begin the electrical installation process for both the Smart and Basic sensors, unscrew the enclosure cap at the back end of the sensor and carefully but firmly pull it off.

> CAUTION
>
> **Do not jerk the enclosure cap off with excessive force. The cap may be connected to the housing by its earth ground connection wire, and using too much force might break the connection.**

Behind the enclosure cap is the terminal block. In both Smart and Basic sensors, wiring (one or more single-twisted pair shielded or multiple-twisted pair cables with overall shield) must be first inserted through the compression fitting in the enclosure cap. The compression fitting can be opened and closed by turning the outside nut while holding the nut closest to the enclosure cap.

If no HART adapter is used to change parameters or to receive data, the cable's diameter and length is only restricted by the resulting load resistance of the cable and 4-20 mA controller, which must not exceed 750 ohms.

Figure 2-15: How to open the unit

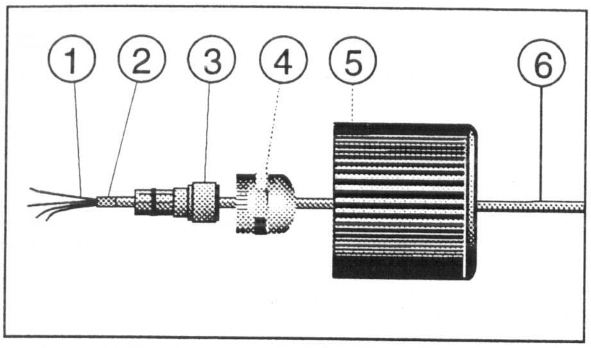


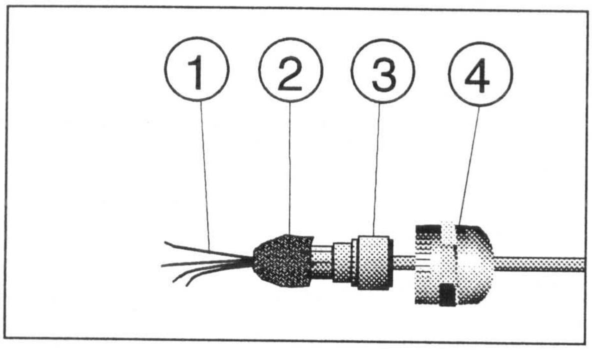
1. Unit as supplied, closed
2. Turn the textured end cover until it can be removed from the housing thread, and continue to turn it to the end cup.
   The distance between the end cover and the housing will then be as shown in the picture.
3. Pull the end cover away- please be careful with the shield wire.

   For wiring see drawing "Cable Assembly" on the following page.
4. Assemble the unit in the reverse order.

CABLE ASSEMBLY

Warning:
Follow the assembly instructions! Do not use the described connection as a strain relief! Otherwise the warranty will be voided!



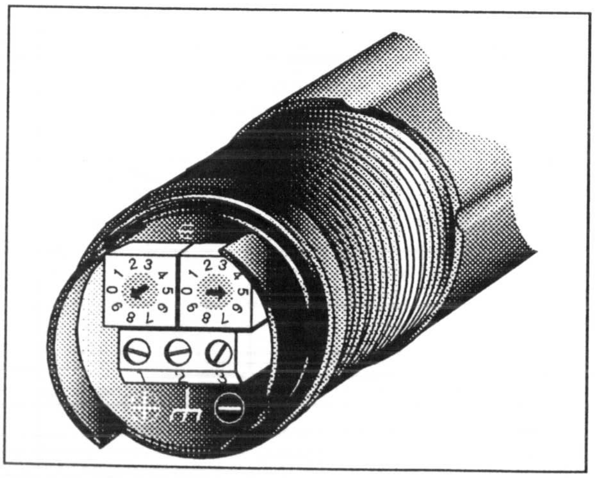


1. Insert the cable **(6)** with an outside diameter of 4 to 8 mm (0.15″ to 0.3″) through the opened end cover **(5)**, nut **(4)** and plastic fitting **(3)**.
2. Preparation: Remove approximately 60 mm (2″) of the outside insulation. Cut the inside cable shield **(2)** at about 10 mm length (0.5″) and push it back over the plastic fitting **(3)**.
3. Thread the nut **(4)** carefully onto the plastic fitting (3) but do not tighten. Connect the wires **(1)** to the terminal block and close the housing with the end cover **(5)**.
   Now tighten the nut **(4)**.

The described connection is not to be used as a strain relief!

2.4.1 Basic Sensor

Above the terminal block are two rotary-style emissivity switches. Emissivity settings can be changed by turning the switches with a small screwdriver. The factory default is 0.95 (first switch is set to 9, second switch to 5).

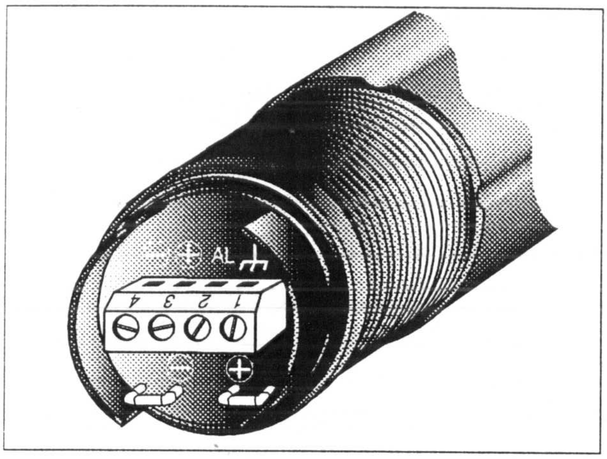


Terminal	Function
⊕	12–24 VDC (±20%)
⏚	Earth Ground
⊖	common

Figure 2-16: Basic Sensor Terminal Block, Emissivity Switches and Connections

2.4.2 Smart Sensor

The Smart Sensor has four terminals and two programming clips (**Figure 2-17**).



Terminal	Function
⊖	common
⊕	12–24 VDC (±20%)
AL	Alarm Output
⏚	Earth Ground

Figure 2-17: Smart Sensor Terminal Block Connections

Wiring connections for the Smart Version

1. Sensor to controller and power supply—Apply 12–24 VDC ± 20%. The maximum loop impedance is 750 ohms.
2. Alarm output—The maximum current allowable through the contact is 150 mA.
3. HART-Adapter to Sensor—HART interface connections can be made anywhere in the current output loop (except over the power supply). This includes at the sensor terminals, with easy-to-use "hooks" that clip on to the terminals, or at remote terminations up to 3000 meters (10,000 feet) away.

When using the alarm output, use one of the following circuits (**Figure 2-18**).

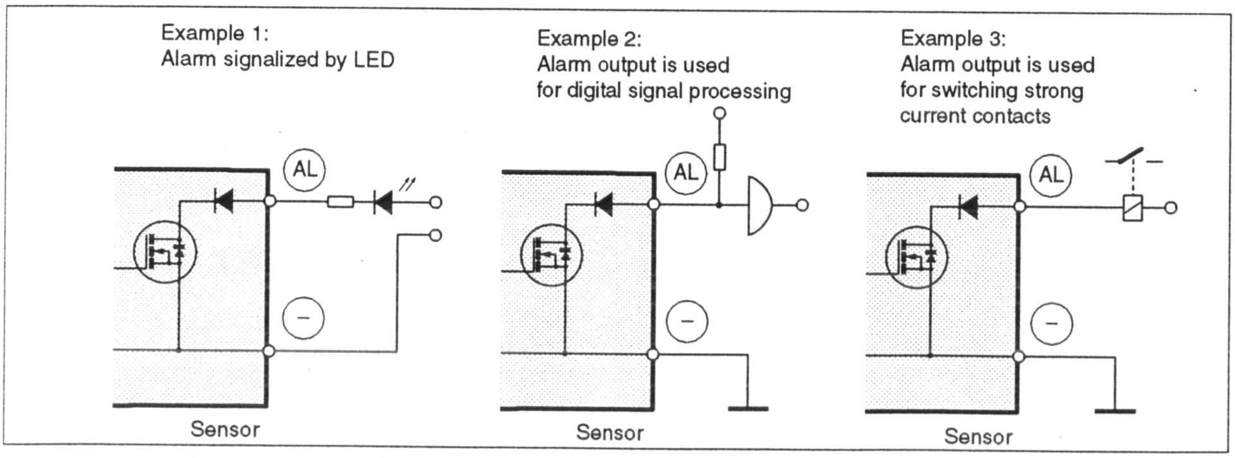


Figure 2-18: Alarm Switch Circuitry Examples

CAUTION
The Alarm Output utilizes an open collector transistor output with maximum voltage / current of + 24 V / 150 mA.

Below the terminal block are two terminal posts for the HART adapter clips. These terminal posts allow easy temporary connection, before, during, and after installation, between the HART adapter and the sensor.

Note: If the Alarm is used, make sure the additional current does not influence the measurement current. Use a circuit like that shown in **Figure 2-19.**

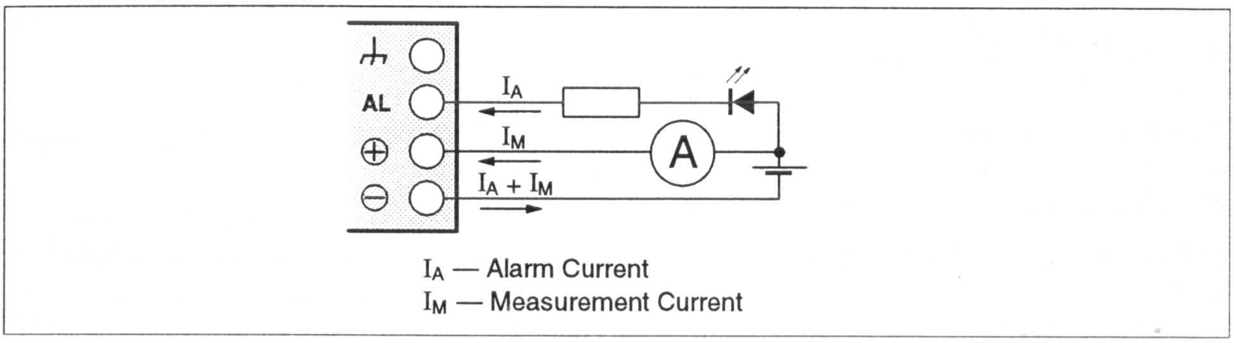


Figure 2–19: Alarm Output Note

2.4.3 Multiple Sensors. Using the HART Protocol Multidrop Mode

When using the HART protocol Multidrop Mode, multiple sensors can be connected in parallel on one 4-20 mA loop. A load resistance of 230 to 750 ohms in series to the parallel connected sensors is required. The HART adapter is than clipped over the load resistance or the group of parallel connected sensors (**Figure 2-20**).

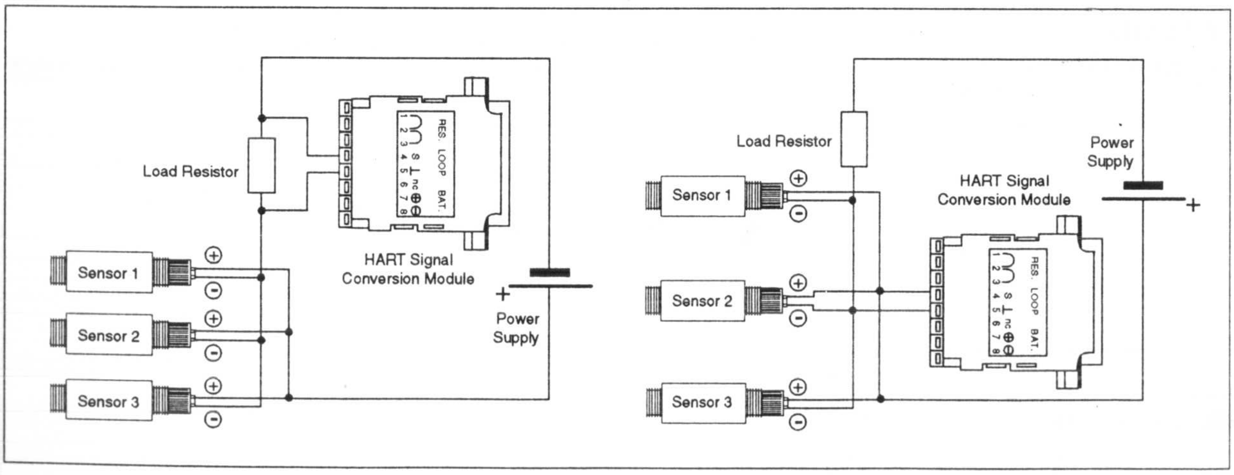


Figure 2-20: Examples of Smart Sensors installed in Multidrop Mode

In the multidrop mode, the analog output is deactivated and the sensor is constantly consuming 4 mA. For a parallel connection of a number of n sensors, a power supply with at least n times 4 mA current output is required. The required voltage output can be derived from the following:

$$V_{Out} = (R_{load} * n * 4\ mA) + 12\ V$$

where V_{Out} is the required minimum voltage output, R_{load} is the load resistance and n is the number of sensors connected in parallel. For example, if a 250 ohm load resistor is used, a parallel connection of four sensors requires a power supply with at least 16 mA and 16 VDC output.

2.5 HART® PROTOCOL

The Smart Sensor was developed for to be used with the HART protocol. HART is the name of a smart communications protocol. It stands for **H**ighway **A**ddressable **R**emote **T**ransducer. It is compatible with existing 4 to 20 mA systems. Simultaneous analog and digital communications is provided by superimposing an FSK (Bell 202) signal on the analog signal. The protocol also supports multidrop networking of several field devices on a single twisted-wire pair. The HART protocol is open and is becoming a defacto standard in the industry. The description "smart" for a field device has been used in the sense of "intelligent", to describe any device that includes a microprocessor.

For easy programming of the TX-smart sensors with a computer we developed the HART Adapter. This device looks like a little box (Fig. 2-21). On one side you may find an RS232-connector for plugging in the computers RS232-port.
On the other side are terminals for connecting the 4-20 mA loop.

The HART-Adapter comes with " DATATEMP TX " software on diskette.
The software-description is included in Section 3, Operation.

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2.5.1 HART Adapter

The HART Adapter (**Figure 2-21**) allows remote communications with sensors in either point-to-point or multidrop installation.

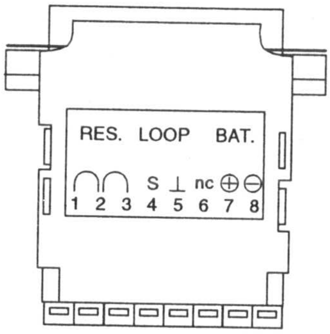


Figure 2-21: HART Adapter

The HART signal is a voltage, produced directly by the HART adapter, that exists at one conductor of the twisted-pair cable with respect to the other. Current signals from the sensors are converted to voltage signals by the load resistance.

HART uses binary, phase-continuous, Frequency-Shift-Keying (FSK) at 1200 bits per second. The HART adapter converts HART signals to RS232 signals. On one side is a female 25-pin RS232 plug and on the other side is a terminal block.

For proper operation of the HART adapter from a PC terminal, you need a PC with an RS232 output. The voltage level of the signal lines should be at least ±5V.

The function of the terminals is described in **Table 2-3**.

Table 2-3: HART Adapter Terminal Block

Terminal Number	Symbol	Function
1		Resistance Bridge
2		Resistance Bridge
3		Resistance Bridge
4	⊕	positive lead HART
5	⊖	negative lead HART
6	nc	no connection
7	⊕	12—24 VDC (±20%)
8	⊖	common

There are generally three ways of wiring the HART adapter:

2.5.2 Wiring Using an Existing Load Resistor

If there exists a load resistor in the 4-20 mA loop (e.g. the load resistor of the analog controller) you can use this when installing the HART adapter. The RS232 connector is plugged into the computer's RS232 port. Terminals 1, 2, 3, 6, 7, and 8 remain open. Terminals 4 and 5 are connected in parallel to the existing load resistor. The polarity is arbitrary (**refer to Figure 2-22**).

Note that the loop power supply voltage must be at least the sum of the minimum sensor voltage and the voltage loss over the external resistor. With the smallest required resistance value of 230 ohms and the highest possible current of up to 22 milliamps. The supply voltage must be at least 12V plus 5.1V equal to 17.1V.

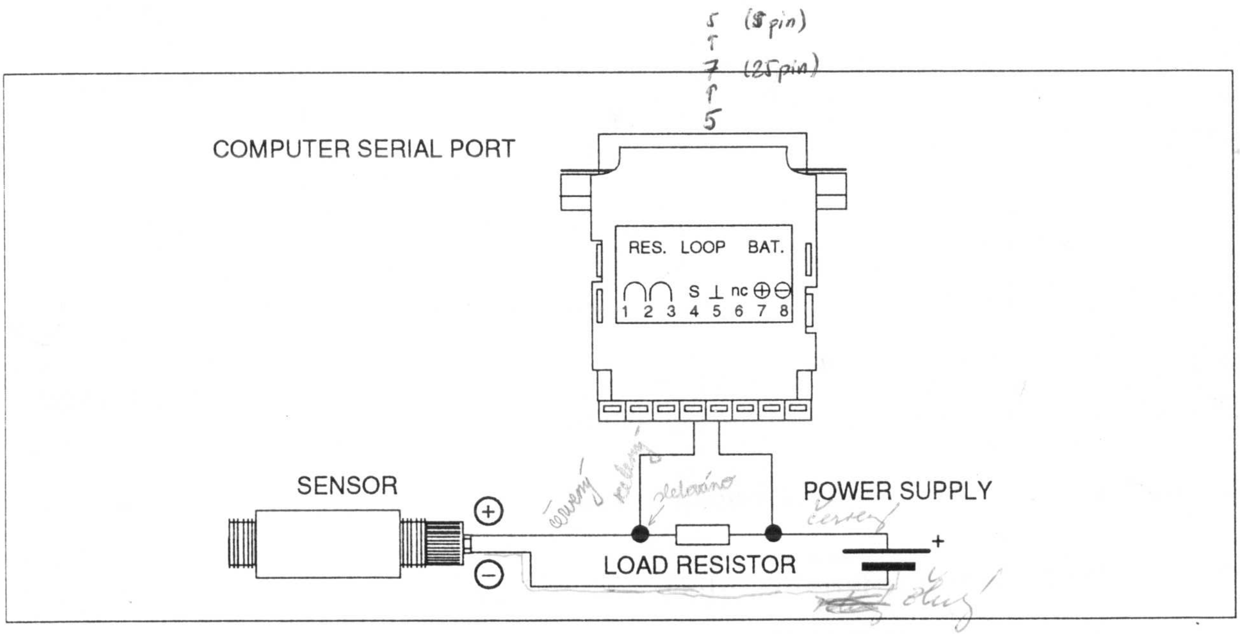


Figure 2-22: Wiring Using an Existing Load Resistor

> **CAUTION**
> The HART adapter´s terminal 5 is always connected to the earth ground of the computer.

2.5.3 Wiring into a Loop Without an Existing Load Resistor

If there exists no load resistor in the 4-20 mA loop, you can use the internal load resistor (240 ohms) of the HART adapter. The RS232 connector is plugged into the computer's RS232 port. Terminals 1, 6, 7, and 8 remain open. Terminals 2 and 3 are bridged. The loop can be installed at any point. The open leads are connected to terminals 4 and 5, the polarity is arbitrary (**refer to Figure 2-23**).
Note that the loop power supply voltage must be at least the sum of the minimum sensor voltage and the voltage loss over the internal load resistor. With the resistance value of 240 ohms and the highest possible current of up to 22 milliamps, the supply voltage must be at least 12V plus 5.3V equal to 17.3V.

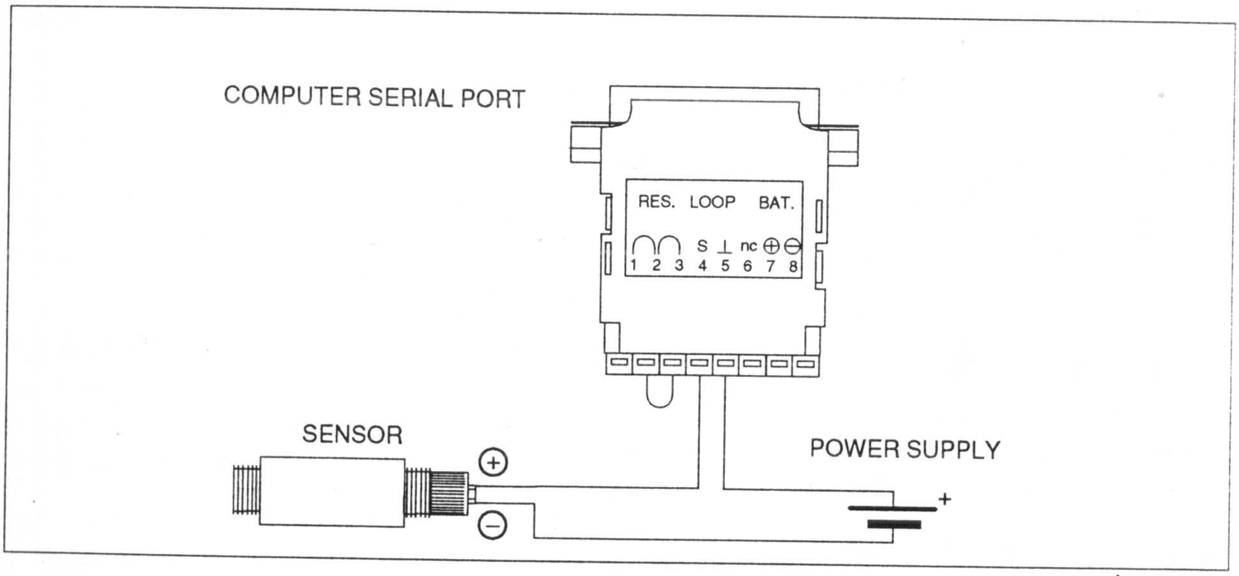


Figure 2-23: Wiring Without an Existing Load Resistor

CAUTION
The HART adapter's terminal 5 is always connected to the earth ground of the computer.

2.5.4 Wiring to a Standalone Sensor

If there is a sensor without a load resistor and a power supply, you can use the HART adapter to create a 4-20 mA loop. The RS232 connector is plugged into the computer's RS232 port. Terminals 3 and 6 remain open. Terminals 1 and 2 are bridged. Terminal 4 is connected to the sensor's + terminal, and terminal 5 is connected to the sensor's – terminal. Terminal 7 is connected to power supply and terminal 8 to the common ground of a power supply or battery (refer to **Figure 2-24**). Note that the loop power supply voltage must be at least the sum of the minimal sensor voltage and the voltage loss over the resistor. With the smallest required resistance value of 240 ohms and the highest possible current of up to 22 milliamps, the supply voltage must be at least 12V plus 5.3V equal to 17.3V.

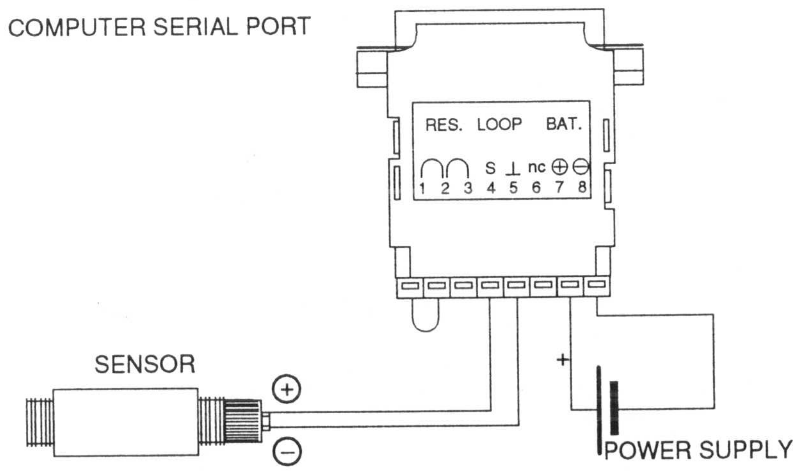


Figure 2-24: Wiring to a Standalone Sensor

> **CAUTION**
> The HART adapter connects the terminal 8 (common ground of power supply) to the earth ground of the PC.

If the HART adapter is used remotely from the Sensor, there are the following cable restrictions:

- Cables should be one or more shielded, single-twisted-pair, or multiple-twisted-pair with an overall shield. Unshielded cable may be used only if it is rated to not affect digital signalling.

- The minimum conductor size (diameter) is the following:
  - Less than 1500 m (5000 ft) total length- #24 AWG (0.51 mm diameter)
  - Beyond 1500 m (5000 ft), single-pair total length- #20 AWG (0.81 mm diameter)

- The maximum length of a single-pair cable per loop, L, shall be related to the loop resistance R, the capacitance per unit length C,
and the sensor capacitance Cs (5 nF) by the following formula:

$$L = \frac{65 \times 10^6}{R \times C} - \frac{C_s + 10{,}000}{C}$$

Where L is in ft, R is in ohms, Cs is in pF, C is in pF/ft or L is in m, R is in ohms, Cs is in pF, C is in pF/m or shall be less than 10,000 ft (3000 m), whichever is less. The length of a multi-pair cable is limited to the value calculated by the above formula or 5000 ft (1500 m).

- A HART adapter or analog controller associated with multiple pairs of the same cable should be located nominally at one end of the multiple-pair cable. (Single-pair cable may not be interposed between the HART adapter or analog controller and the multi-pair cable.)

3. OPERATION

3.1 THEORY OF OPERATION

This type of infrared thermometer is a sophisticated thermal transducer utilizing modern microprocessor technology. A micromachined 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 signal are digitized with a high resolution and then modified by the parameter settings. Calibration parameters which are stored in the EEPROM of the instrument are used to linearize the signals. The 12-bit signal is then fed to a digital-to-analog converter followed by a sample and hold circuit and an output amplifier.

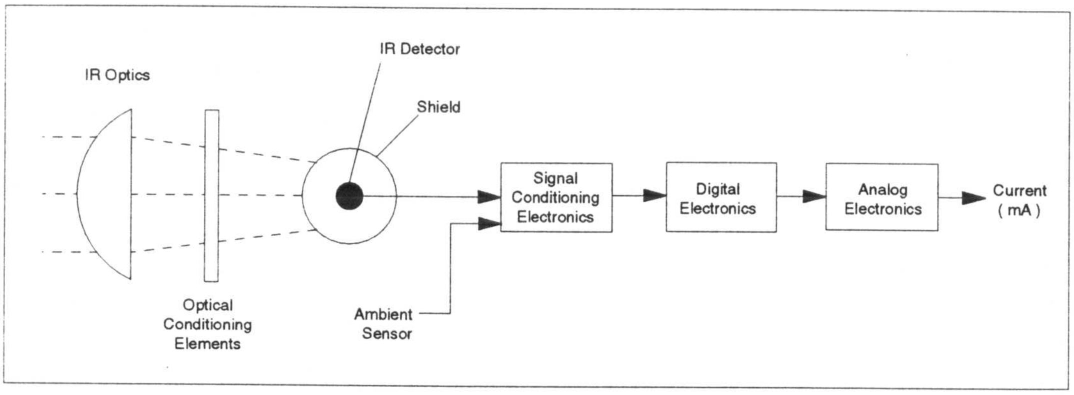


Figure 3-1: Theory of Operation

3.2 CONTROLS

3.2.1 Basic Version

The basic version's emissivity settings are manually operated through switches located on the rear panel (**Figure 3-2, left**). Adjustment can be made while the power is on. All models have a default emissivity setting of 0.95. You can adjust the emissivity with a small flat-blade screwdriver by turning the rotary-style controls to the appropriate setting (refer to Appendix A for emissivity values). The emissivity indicated by the switch position numbers should be interpreted with a decimal point preceding the two numbers.

For example, if the left switch is set to 9 and the right switch is set to 5, the emissivity is .95. Note that if both switches are at 0, the emissivity is 1.00. If you have a basic version, you do not need to read any further in this section.

3.2.2 Smart Version

The smart version has no manual switches, only connecting terminals (**Figure 3-2, right**). Use the HART adapter and the supplied PC communication software for the setting and adjustment of controls.

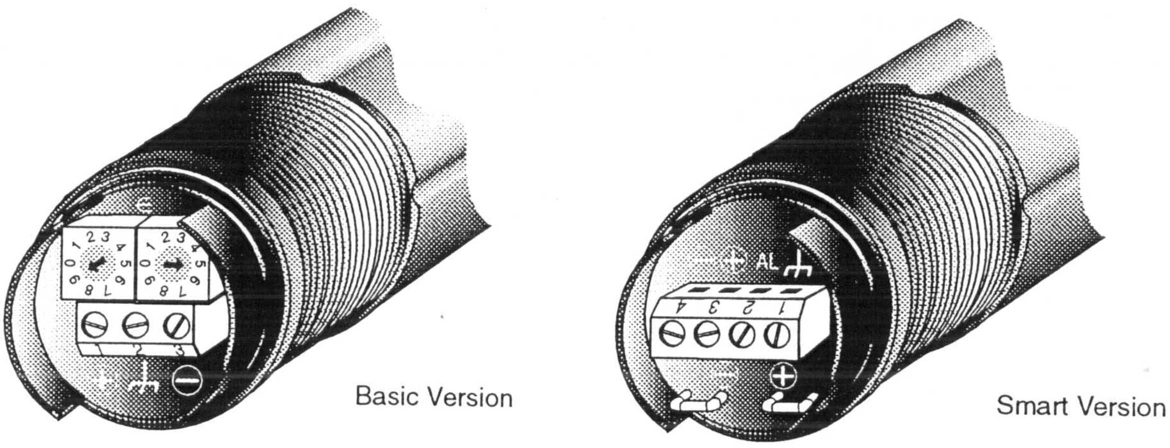


Figure 3-2: Basic and Smart Sensors

The communication software is designed to run on DOS-based palmtop, laptop, and standard PC computers running DOS versions 3.3 and above. The computer should be an XT compatible with at least 256 kByte of free RAM. It should have a 3.5 inch disc drive.
The memory needed for recorded data depends on:

memory = (header rows + measuring values) * (10)(number of values to be recorded*)
where "values to be recorded" stands for example for
- measured temperature
- internal temperature,
- emissivity, ... and so on.

The leading "10" is the number of bytes any of the values is recorded with.

(The software comes on a 3.5 inch diskette.)

Note:
Before running the software, check to see if a README file exists. README, if present, will contain information received too late to be included in this manual. To see the README file, insert the communication software diskete in drive A: or B: and enter TYPE A: README/MORE (or you can open the file in a text editor or word processor as ASCII-File)

THE COMMUNICATION SOFTWARE

The diskette contains a file named **DTX.EXE**. You may start it directly from disk or copy that file onto your hard disk or working floppy disk. To copy the file to your hard disk, complete the following steps.

1. Insert the original disk in drive **A:** or **B:**.
2. Create a directory on your hard disk where you will copy the file (and store any related data files). At your C prompt, type and enter
   MD SMART

   Note: These directions assume you are using your C: drive; however, you can install to any drive partitions or drives other than C: (e.g., D;, E;, etc.).

3. Change to the new directory. Type and enter: **CD SMART**
4. Copy the file. Type and enter:

COPY A:DTX	for using COM1 or
COPY A:DTX /2	if you want to use COM2,
DTX /?	for a listing of other available commands.

You can now run the program. Type and enter **DTX**. After the program initializes the communications (COM) port and scans the polling addresses, it will then detect any attached devices and read the parameters. During the initialization it displays a screen similar to **Figure S-1**. The next screen follows automatically after the initialization.
It looks like **Figure S-6**, Edit Menu.

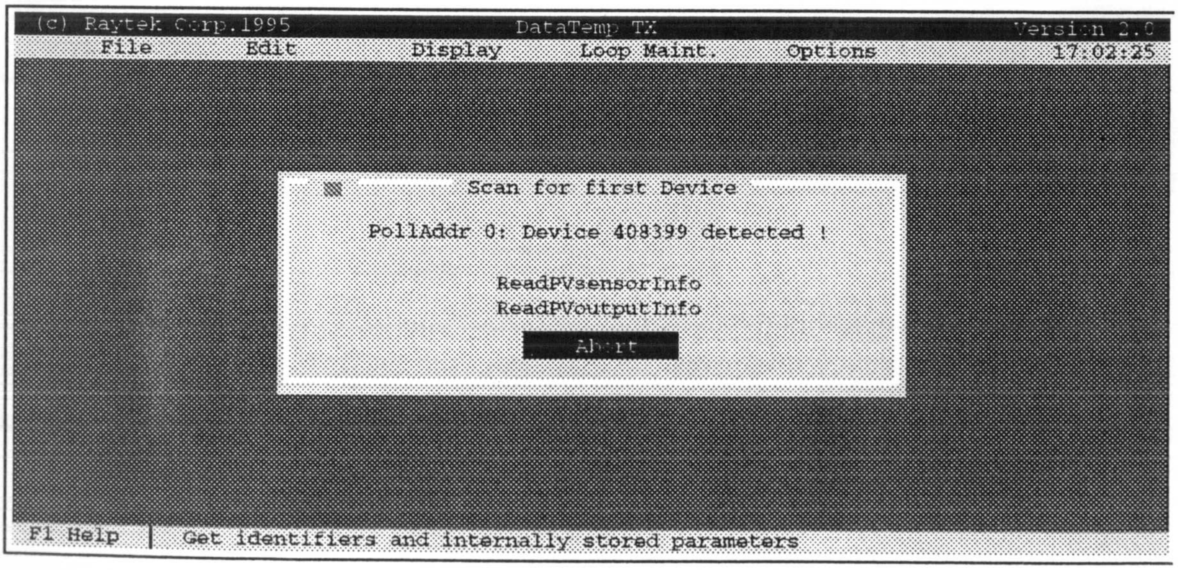


Fig. S-1: Initialization Screen

Across the top of the screen are the program commands. These are activated at startup or when you press the <F10> key. You can select a command by using the side arrow keys (the command will be highlighted) and pressing the <ENTER> key. (You can also press the key with the first letter of the command.)
For becoming basic knowledges about the online help function press <F1>.

?

While working with this software you can be assisted at any time by the online help function.
To use this help function, press F1 or click the right mouse button to get help text for the current active item.
The arrow keys help you to scroll through the text.
Highlighted words indicate additional available help information about this topic. Move the block cursor with TAB forward or with Shift+TAB backward to the topic of interest and press <ENTER> or simply double-click on the topic with the mouse to get the information.

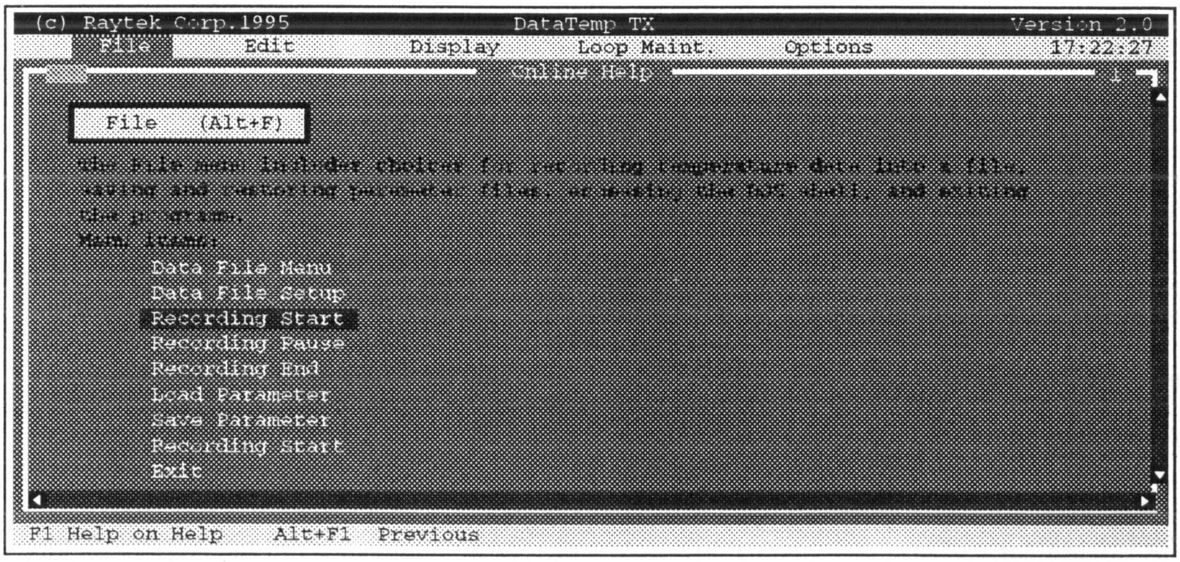


Fig. S-2: Help-Menu

You can select a command from the top of the screen by using the side arrow keys and pressing the <ENTER> key. (You can also press the key with the first letter of the command.)

When you highlight File or press <F><ENTER>, it display a screen similar to **Fig. S-3**.

1. THE FILE MENU

The file menu includes choices for recording temperature data into a file, saving and restoring parameter files, accessing the DOS shell, and exiting the program.

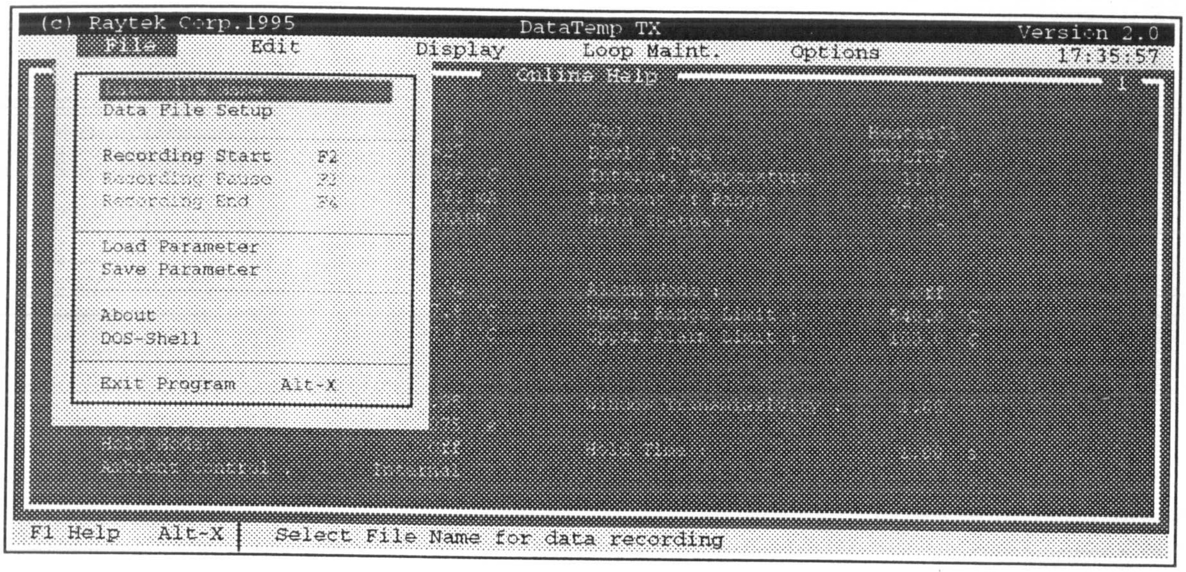


Fig. S-3: File Menu

Data File Name

Before you can record temperature data into a file, you have to specify a file name for this function. The file will be an ASCII-based file that can be loaded into any editor and may also be loaded into table calculation programs.

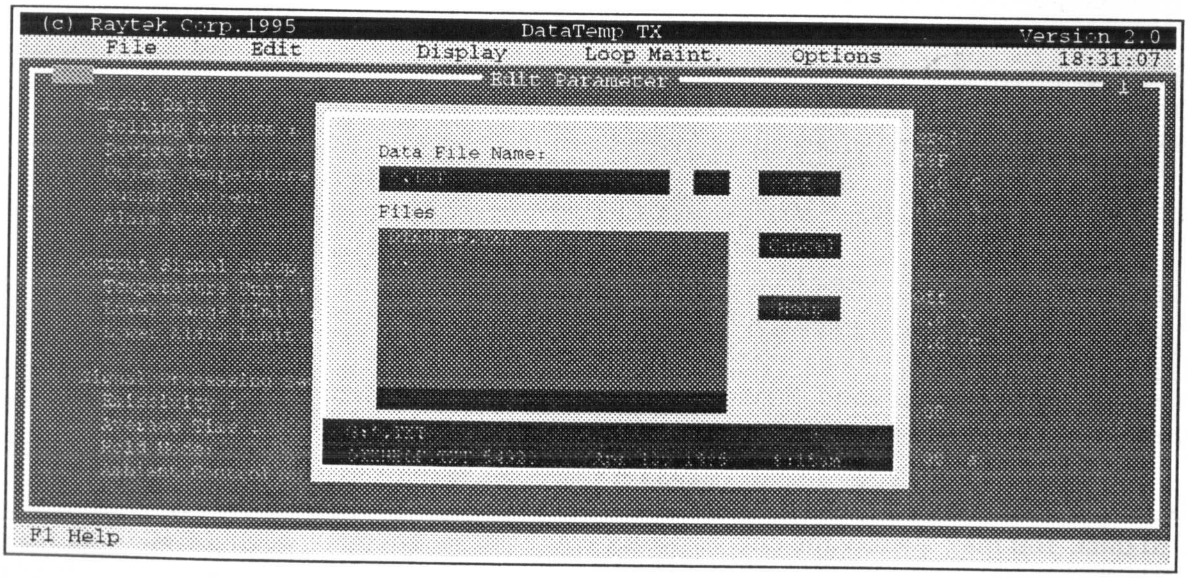


Fig. S-4: Data File Name

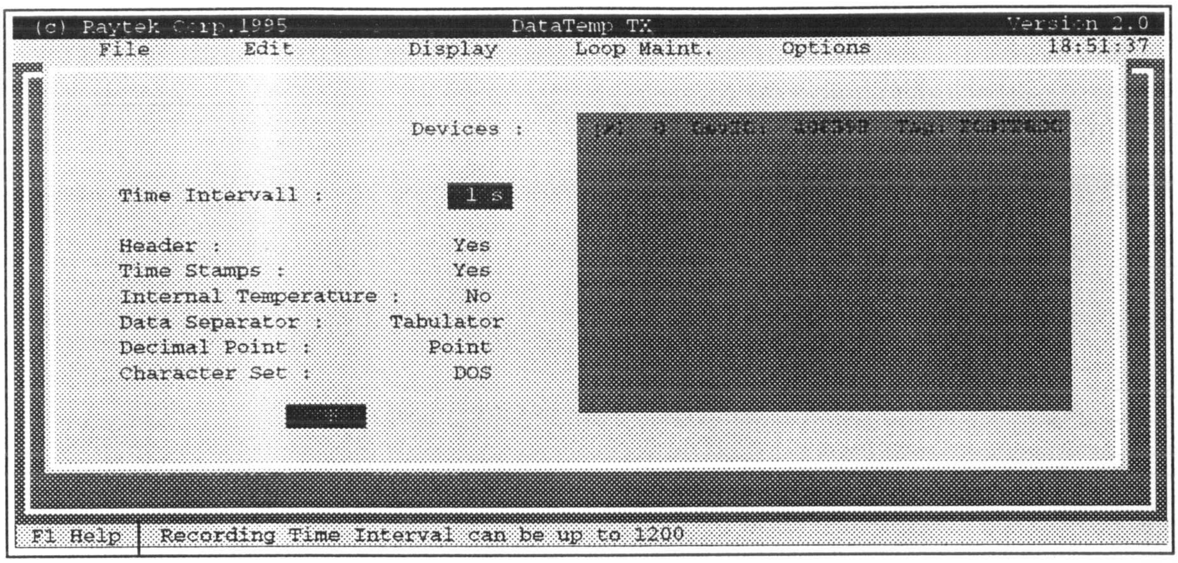


Fig. S-5: Data File Setup

Before you can record temperature data into a file via (Recording Start), you must set up a few parameters which determine how the data will be stored. It is possible to select a format you´d like to have for an editor, printer or a format that works best with a table calculation program.

Time Intervall:	Time between cyclic measurements. (Note: each sensor needs about 0.5 sec for data transfer, which determines the shortest possible value.)
Header:	You can store with or without header.
Time Stamps:	By typing "yes" the actual time of the measurement will be stored.
Internal Temperature:	You can store the internal temperature of the sensor.
Data Separator:	Determines how to separate the data.
Decimal Point:	You can choose between comma or dot.
Character Set:	Choose DOS or Windows.

Recording Start <F2>

With the F2 hot key you may start or resume recording at any time, except in the graphics mode. If activated in text mode without a specified file name, the (DataFileName) and the (DataFileSetup) dialog will be executed automatically. If there is at least one sensor available and the file name is valid, this function writes the headings into the file and cycles through the selected sensors.

To monitor the data, a protocoll window will be opened on the screen showing the recorded data. You may overlay the display window with other screens without interfering with the recording function.

Recording Pause <F3>

If the recording function is active, this command pauses the function and holds everything open until (Recording Start <F2>) or (Recording End <F4>) is selected.

Recording End <F4>

If the recording function is active, this command stops the process and closes the file (to make it available for other programs). A reset or power down of the computer before this point will result in a loss of the recording. When exiting the program, a recording will be closed & saved automatically.

Load Parameter

This function is used to download customized sets of parameters to the sensors or for switching between different standard setups.

Save Parameter

This function is used to save customized sets of parameters to the sensors. The files are ASCII-based and can be printed or viewed with an editor. They can be loaded with (Load Parameter).

2. Edit Menü

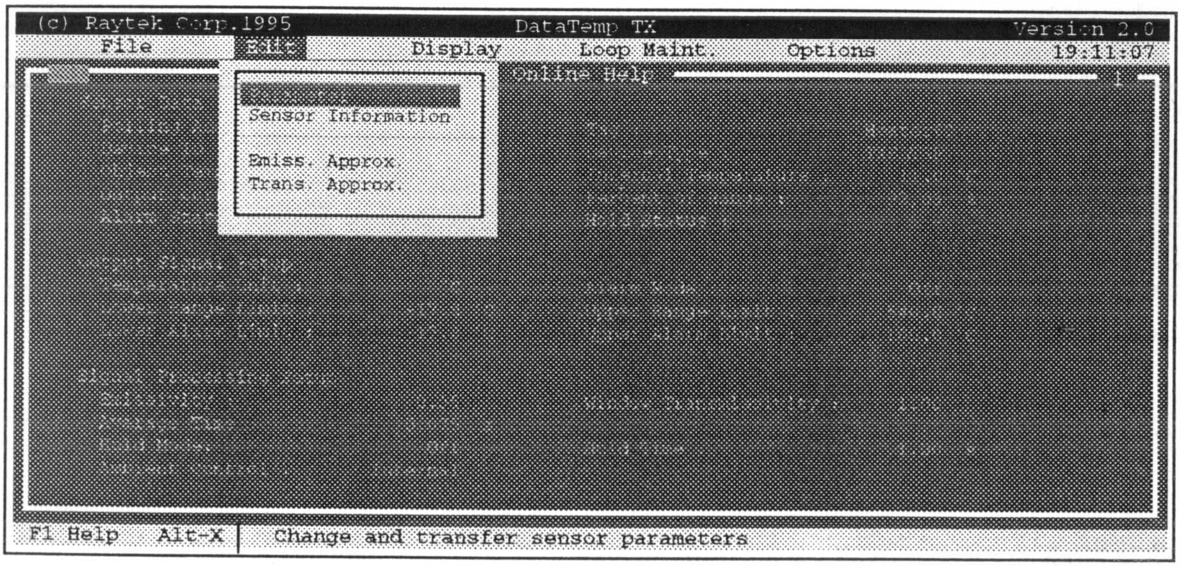


Fig. S-6: Edit Parameter

Edit Parameter shows the parameters and allows the user to change them.
Use the TAB key /Shift +TAB key or the side arrow keys for selecting a command.
Those parameters which allow only a limited number of choices, like the **Temperature Unit** or **Alarm Mode**, can be changed via the space bar or the mouse.

In fields that require a direct input, like the numeric or character fields, a blinking cursor shows the current position. A block cursor shows the overwrite mode. It can be changed to insert mode via the INS key (underline cursor).
The entry will automatically be checked when selecting the next parameter, and if necessary, limited to the allowed values. An invalid entry causes an error message and prohibits the user from selecting other fields.
The **Edit Menu** allows the selection of:

- Polling Address :	According to HART-Protocol each device has his own adress. In Analog-Mode 4-20 mA you can connect only one device. This is to set at address zero. In Digital-Mode all devices must be adjusted at 4.0 mA. The polling addresses have to be different from zero.

Note: When installing a multidrop loop for the first time it is best to start with only one device connected in the loop. After giving the specific polling address, go on to connect the second device and so on. Factory installed is for each device polling address zero.

- Tag:	Each device can get a tag (like oven1, process4)
- Temperature Unit:	Temperature scale (°C/°F)
- Alarm Mode:	You can determine the polarity of the alarm output.
- Lower/Upper Range Limit:	Determine the representation of the object temperature on the current output in the analog mode (Polling Address 0). The lower range limit corresponds to 4.0 mA, the upper to 20 mA.
- Lower/Upper Alarm Limit:	The alarm condition occurs if the output value is below the lower limit or above the upper limit.
- Emissivity:	You can set the value in accordance with the measured material (please refer to the help function by pressing the F1 key).
- Transmissivity:	The radiation loss by a protective window can be compensated by this parameter
- Average Time:	The response time in the data sheet of the sensor is related to an averaging time of 0 s. It can be made longer in increments equal to the internal software loop time (25 ms).
- Hold Mode:	Available are peak and valley. During peak hold, the output value tracks the measured value as long as it is rising. If it falls to a lower value, the highest value will be held for the hold time or until a new higher value comes along.
- Hold Time:	It can be set in increments of 25 ms.
- Ambient Control:	To avoid errors in case the internal sensor temperature is different from the external ambient temperature, choose external.
- Ambient Temp.:	If Ambient Control was set to external, you can give the value now.

After changing the parameters for each sensor of the loop press enter to make it valid. Switch to **Transfer Mode** (lower menu bar). This Mode allows the parameters transfer. Activate with the mouse or press the <T> key.

Emissivity Approximation / Transmissivity Approximation

If the emissivity of the target object is unknown, but the exact object temperature is known, this function can help establish emissivity (or transmissivity).
For more information please refer to the help function by pressing the F1 key.

3. Display Menu

The Display Menu gives choices for different methods of showing the temperature measurements. You can choose between graphic display or table visualization.
For more information, if necessary, refer to the help function by pressing the F1 key.

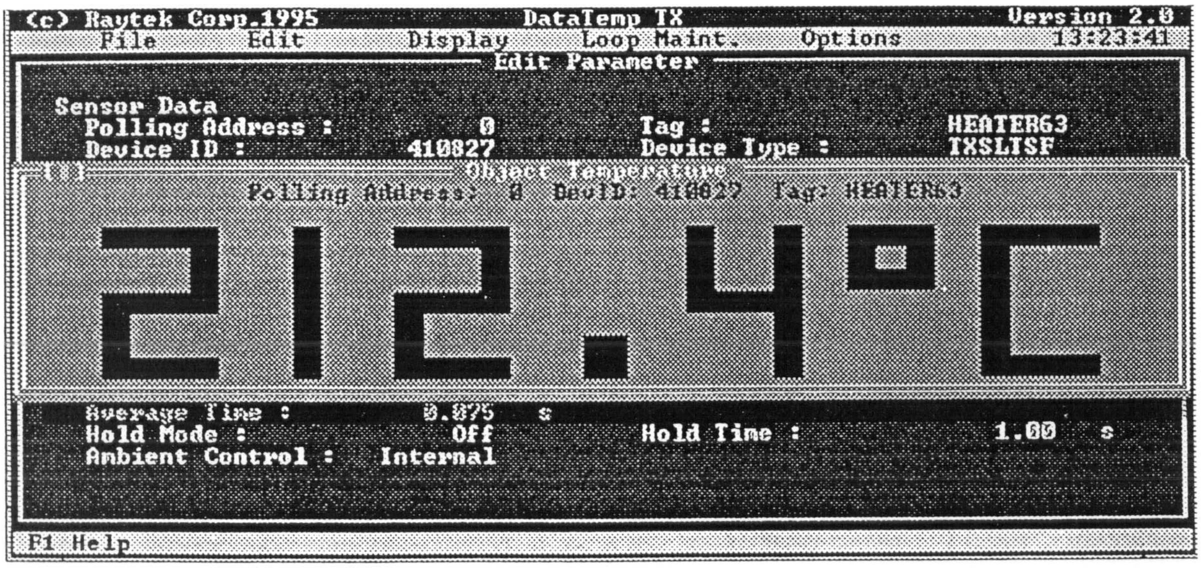


Fig. S-7: Digital Display

4. Loop Maintenance

This menu allows current draw settings.

- **Fix Current** : To trim display meters in the loop or to perform other checks, it is necessary to maintain the current at specific values regardless of the temperature reading. After leaving this function, the sensor is returned to its normal working state.

- **Scan First**: This clears all device specific memory locations, starting with the polling address 0 and continues scanning until it finds the first device. At this time, its information and parameters are read. This function is executed automatically after the program starts.

- **Scan All**: This function works in the same way as Scan First, but it doesn´t stop after finding the first device. It continues until the last polling address is scanned.

- **Continue Scan**: This function doesn´t clear all the current sensor information. It checks which polling addresses have already been scanned and starts then from the next address. It is automatically executed after scan first and works in the background. When starting any display function, the scan will be stopped to avoid collisions.

5. Options Menü

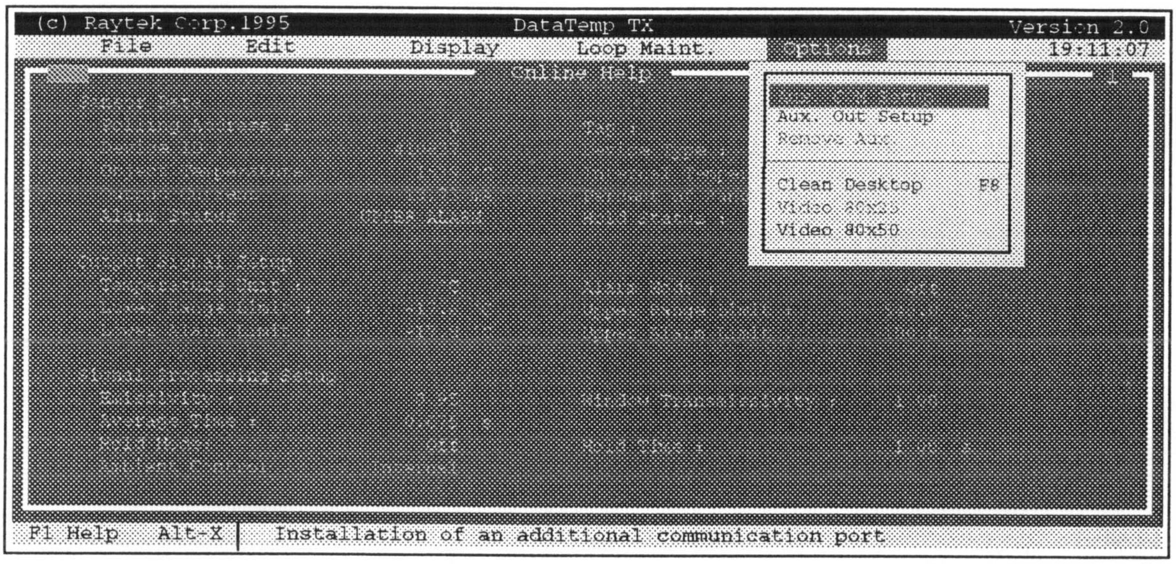


Fig. S-8: Options Menu

Under this menu additional functions are grouped.

Auxiliary COM Setup

This program provides the possibility of using a second COM port for additional ASCII-based data transfer. If a free port is detected, it can be configured via this menu section. The Auxiliary COM port can be used for output and input separately. (Fig. S-9).

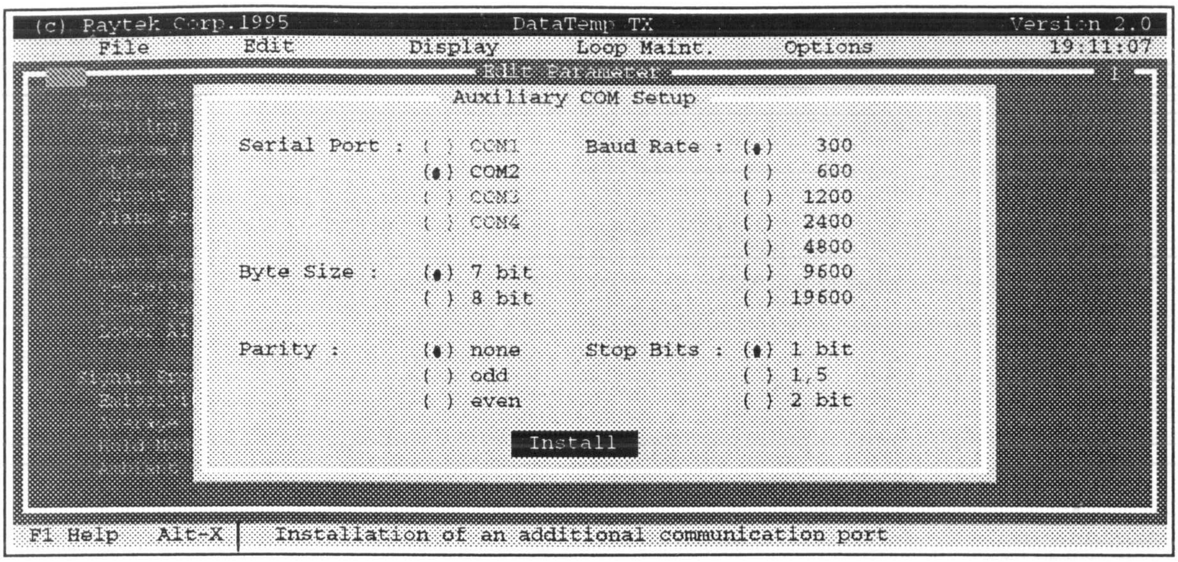


Fig. S-9 Auxiliary COM Setup

Auxiliary Output Setup

As an output, Auxiliary Output Setup works similar to the file recording function except that the data is transmitted via the RS232. A simple terminal program (such as Windows Terminal) can be used on another PC to receive the data. Connect the serial ports of the transmitting and of the receiving PC .

- Load the terminal program at the receiver side and choose the data receive function.
- Change to the transmitter side and install the correct parameters for the serial port (refer Fig. S-9).
- Activate now **Auxiliary Output Setup** (Options Menu). Screen and function are the same as shown in Fig. S-5, Data File Setup.

Auxiliary Monitor Setup

With this function, ASCII strings terminated with the Return character (ASCII #13) can be read from other devices and added to the temperature data in the recording file. Because of the special string formats of other pyrometers, the program only works with the object temperatures.

Additional functions:

Remove Auxiliary COM - The current internal driver must first be removed before a new installation with newer parameters can be made.
Clean Desktop - After executing this command the desktop area will be empty.
Video 80 x 25 and **Video 80 x 50** - allow textmode with different line numbers.

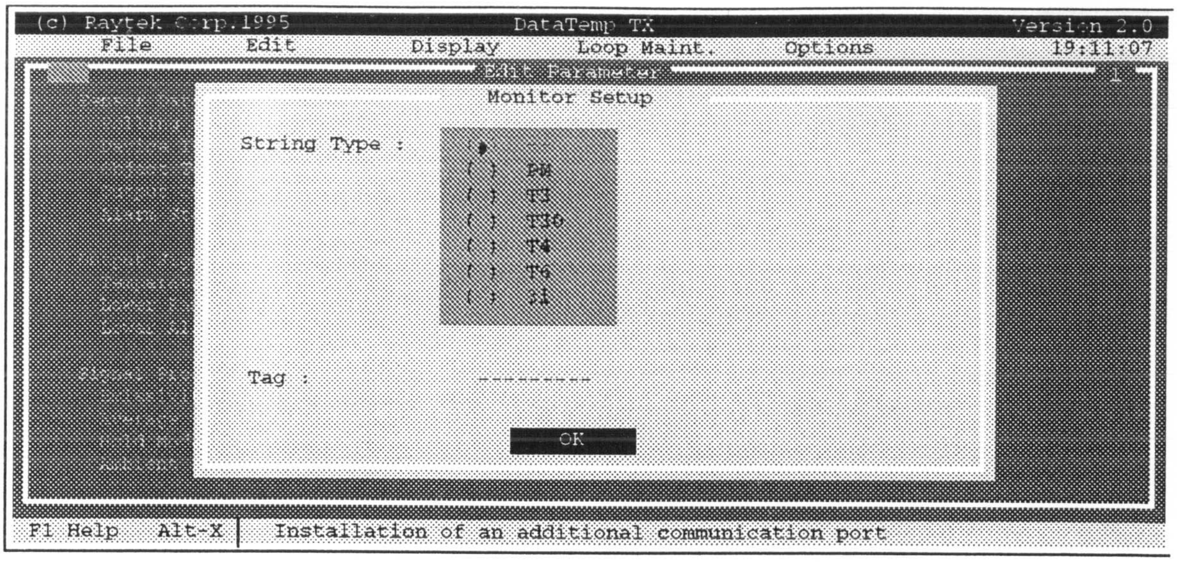


Fig. S-10: Auxiliary Monitor Setup

The Software-Diskette contains a path called UTILS with the following files:

A1: SAMPLE1.BAS

This is a program for temperature measuring in a Multidrop-Loop.
You can set up communication port COM1 ... COM4.
The communication itself works like a black box.

A2: SAMPLE2.BAS

This program is designed with open structure. Comments and hints allow the adaption for special applications.

A3: HARTCMDS.TXT

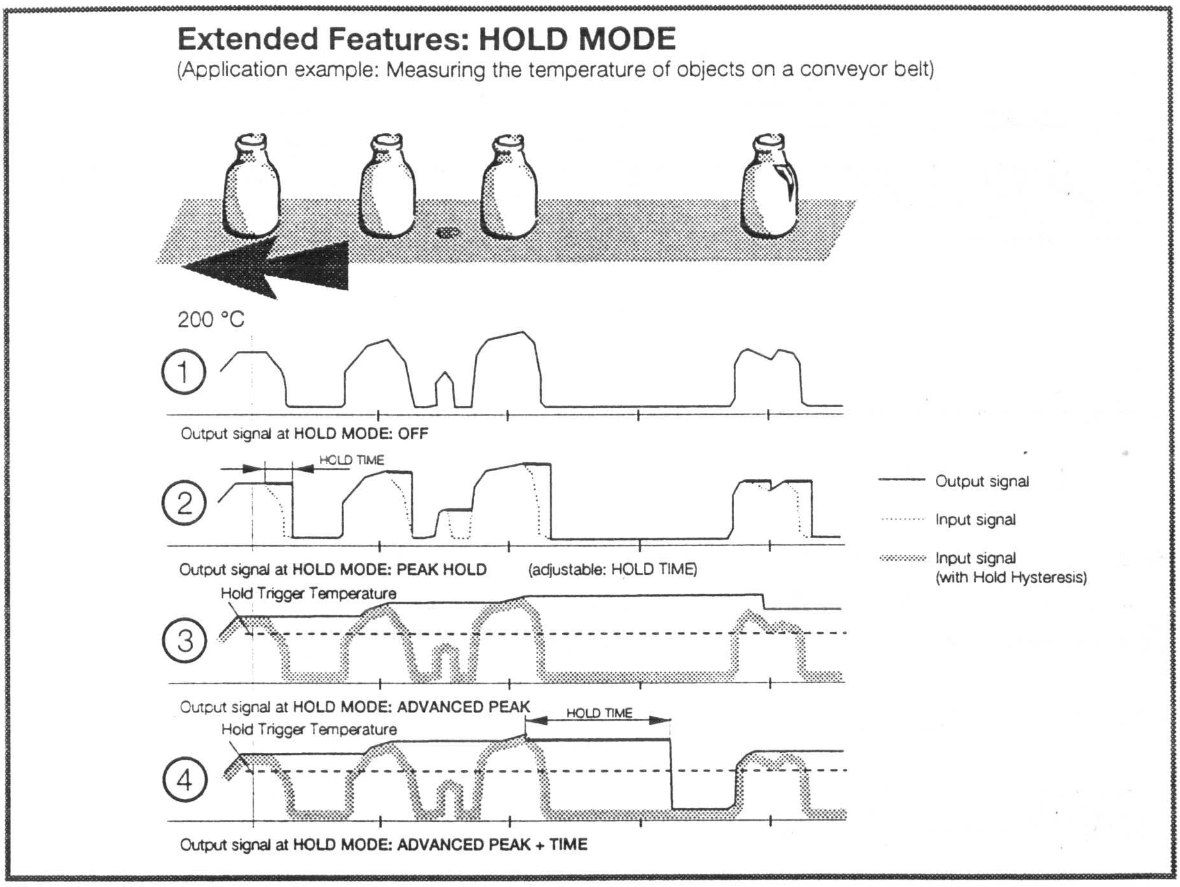
The HART Commands were listed. Several hints for the implementation of the HART protocol follow, also a description of the HART commands used by the sensor.

SOFTWARE -NEWS Rev. 2.11

We are pleased to introduce an improved version of our software.
Please refer to the **Edit menu** which is described in chapter 2 of the software description.
The screen display of the EDIT Menu (fig. S-6) is shown on page S-5.
In the past, the following parameters could be set at the bottom of the screen:

Hold Mode: Valley/Peak/Off **Hold Time:** 1.00 s

Setting "Valley" and "Peak" is explained on page S-6 (holding maximum or minimum temperature).
The new software version now offers additional options for the Hold Mode.



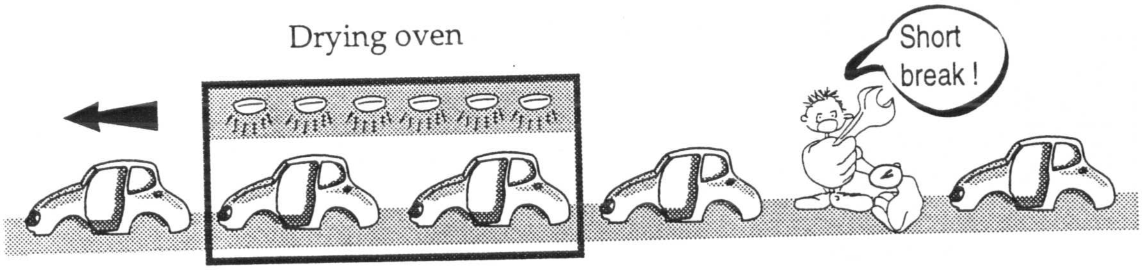
1) When setting **HOLD MODE** to **"OFF"**, the output voltage corresponds to the input signal.
2) When setting **HOLD MODE** to **"PEAK HOLD"**, the respective last peak value is held for the duration of the **Hold Time.**
3) When setting **HOLD MODE** to **"ADVANCED PEAK"**, each peak about the HOLD TRIGGER TEMPERATURE is held until a new peak (above the HOLD TRIGGER TEMPERATURE) occurs. However, the new peak value is not displayed until the temperature drops by an amount equal to the adjustable HOLD HYSTERESIS value.
4) When setting **HOLD MODE** to **"ADVANCED PEAK"**, each peak about the HOLD TRIGGER TEMPERATURE is held until a new peak (above the HOLD TRIGGER TEMPERATURE) occurs, or until the HOLD TIME is exceeded. Again, the new peak value is not displayed until the tem perature drops by an amount equal to the adjustable HOLD HYSTERESIS value.

Hold Hysteresis: In order to damp out slight variations of temperature (pulse spikes, noise), a tolerance range may be defined. Thus, a value of 5°C for Hold Hysteresis means that the input signal may have a tolerance of ± 5°C without activating one of the ADVANCED PEAK features.

SOFTWARE -NEWS Rev. 2.11

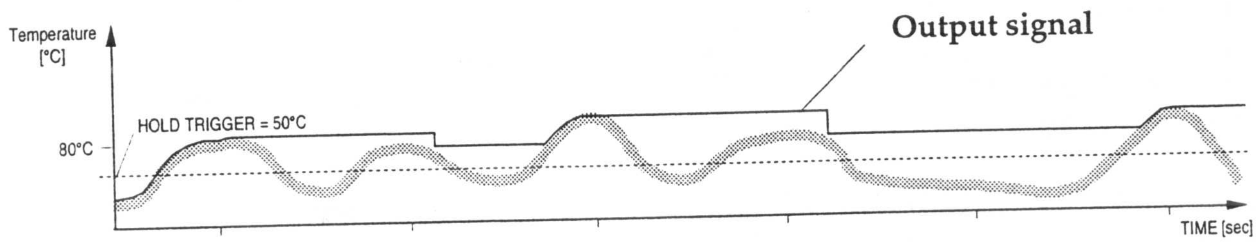
Practical example to explain the Extended Peak Hold Features:

In an automobile manufacturing plant, auto bodies are moved through a drying oven on a conveyor belt to cure the metallic paint. A new auto body enters the drying oven every two minutes. In order to achieve uniform curing of the paint, the oven temperature has to be kept at a certain level, even when no auto bodies enter the oven (short interruptions in production may occur).
The process may be illustrated in the following way:



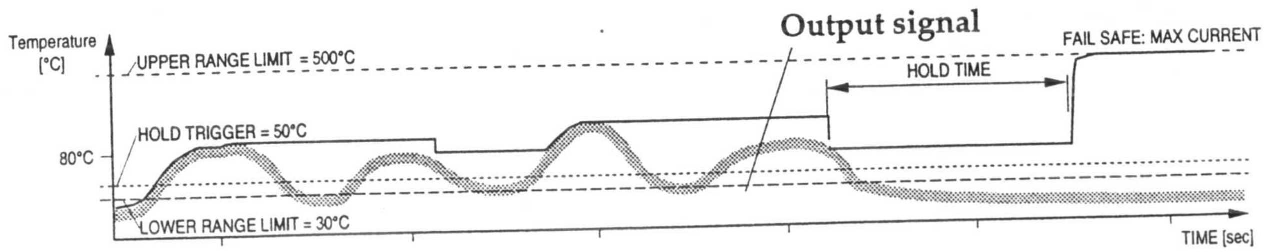
ADVANCED PEAK HOLD

The "Peak" (maximum value) is held until a new value above the **HOLD TRIGGER TEMPERATURE** occurs. The input signal may fluctuate within the **HOLD HYSTERESIS** without changing the output signal.



ADVANCED PEAK HOLD + TIME

The "Peak" (maximum value) is held until a new value above **HOLD TRIGGER TEMPERATURE** occurs or until the **HOLD TIME** is exceeded. This is important, if oven heaters should be turned off when no parts have gone through for a long time (the curve below shows a long interruption in production).



SOFTWARE -NEWS Rev. 2.11

Please observe the following when using the ADVANCED PEAK HOLD + TIME feature:

Only set the FAIL SAFE output signal to maximum (FAIL SAFE: MAX CURRENT) or to minimum (FAIL SAFE: MIN CURRENT) when the following three conditions are met:

1. HOLD TIME was exceeded but no new value above the HOLD TRIGGER TEMPERATURE occured.
   Our example: No more auto bodies passing through the oven.

2. Temperature was below the LOWER RANGE LIMIT.
   Our example: The temperature of the conveyor belt is below the LOWER RANGE LIMIT.

3. FAIL SAFE was set to MAX CURRENT (for an output voltage of 21 mA).
   Our example: FAIL SAFE: MAX CURRENT is set.

How to set ADVANCED PEAK HOLD + TIME :

Chose a HOLD TRIGGER TEMPERATURE value that prevents "non-process" temperatures from controlling the process.
In our example, the auto bodies have a higher temperature than the moving conveyor belt. HOLD TRIGGER TEMPERATURE was set at a value above the conveyor belt temperature.

Chose an UPPER RANGE LIMIT value which is above the expected maximum temperature of your process.
In our example, 500°C was set, the temperature in the oven is approx. 80°C.

Chose a LOWER RANGE LIMIT value which is slightly above the minimum temperature of the process, but below HOLD TRIGGER TEMPERATURE.
In our example, the LOWER RANGE LIMIT value was set slightly above the temperature of the conveyor belt.

To set FAIL SAFE, enter MAX CURRENT if you want an output current of 21 mA.
In our example, FAIL SAFE: MAX CURRENT was chosen.

We hope you enjoy using our software!

4. MAINTENANCE

Our customer service representatives are always at your disposal for questions regarding application assistance, calibration, repair, and solutions to specific problems. Our Service Department should be contacted before returning any equipment to us. In many cases, problems can be solved over the telephone.

4.1 TROUBLESHOOTING MINOR PROBLEMS

If your infrared thermometer is not performing as it should, try to match the symptom in Table 4-1 to its particular problem before calling Customer Service. If you are unable to correct the problem by using the following table, call our Customer Service department at one of the phone numbers listed on the title page or the warranty page.

Table 4-1: Troubleshooting Table

Symptom	Probable Cause	Solution
No output	Cable disconnected	Check cable connections
Erroneous Temperature	Faulty sensor cable	Verify cable's integrity
Erroneous Temperature	Field of view obstruction	Remove the obstruction
Erroneous Temperature	Lens dirty	Clean the lens (see Section 4.3)
Erroneous Temperature	Wrong emissivity setting	Correct the setting (see Appendix A)
Temperature Fluctuates	Wrong signal processing	Correct Peak, Valley, or Average settings

4.2 FAIL-SAFE OPERATION

The Fail-Safe operation is designed to alert the operator and provide a safe output in case of any system failure. The Fail-Safe operation provides a high output (>20.5 mA) in the event the object temperature is above the temperature range (or subrange) of the sensor. It also provides a high output in the event of certain internal failures to the sensor.

Note: The Fail-Safe circuit should never be relied on exclusively to protect critical heating processes. Other safety devices should also be used to supplement this function.

4. MAINTENANCE

4.3 CLEANING THE LENS

You should keep the lens clean at all times. Any foreign matter on the lens will affect measurement accuracy. Care should be taken when cleaning the lens. To clean 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 a cotton swab dampened in distilled water. Do not scratch the surface.

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, because this may scratch the surface.

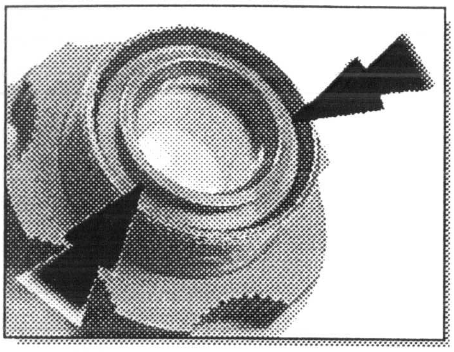
If silicones (used in hand creams) get on the lens, gently wipe the surface with Hexane. Allow to air dry.

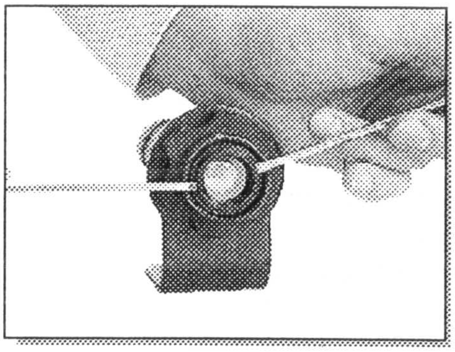
CAUTION
Do not use ammonia, or any cleaners containing ammonia, on the lens. This may result in permanent damage to the surface of the lens.

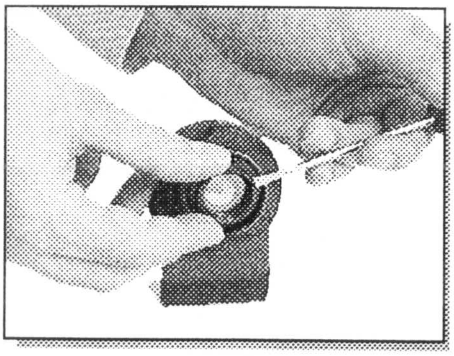
4.4. CHANGING THE PROTECTIVE WINDOW

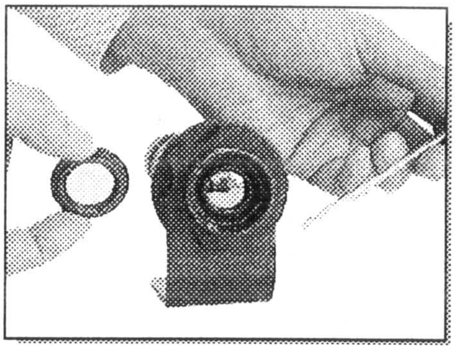
The protective window can be easily replaced. **However, make sure you have the appropriate protective window for the spectral range of your model before proceeding.**

You can remove the old window with a small flat-blade screwdriver. Position the screwdriver, as shown by the two top photos, and snap the window and its mounting ring out (bottom two photos). to snap the window and its mounting ring out.









The new protective window can be mounted by pressing its mounting ring into place. **Do not press directly on the protective window.**

Window Material Recommendations and Transmission values see Appendix B.

4.5 CUSTOMER SERVICE

Application assistance, calibration and repair service is available. The Service Department should be contacted before returning any equipment. In many cases, problems can be solved over the telephone or by fax. We are at your service.

Refer to the phone numbers on the Warranty page at the beginning of this manual.

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.

APPENDIX

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
Aluminum			
Iron, Wrought			
Dull	0.95	0.9	0.9

APPENDIX

TYPICAL EMISSIVITY VALUES

METALS

Material	Emissivity 2.2µm	5.1µm	8-14µm
Lead			
Polished	0.05-0.2	0.05-0.2	0.05-0.1
Rough	0.5	0.4	0.4
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

TYPICAL EMISSIVITY VALUES

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

APPENDIX

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.

APPENDIX B: WINDOW TRANSMISSION

HOW TO DETERMINE WINDOW TRANSMISSION

If the window transmission is not known from the data sheet, it is possible to determine it by doing the following:

1. Measure the object temperature without installed protective window.

   Follow the instructions given in **Appendix A - Object Emissivity** for correct emissivity settings.

   Basic version: Adjust the emissivity by turning the rotary-style controls to the appropriate setting.

   Smart version: Set the value for "TRANSMISSION" to 1.00.

2. Install the protective window into the sensor.

   Using the basic version, change the emissivity setting until you obtain the same reading as before (without the protective window).

   Using smart version, minimize the value for transmission until you obtain the same reading as before (without the protective window).

TRANSMISSION OF STANDARD WINDOWS

Table A-1 (page A-7) shows the different window materials recommended for specific models.
If there are special requirements, please ask your Sales Representative about the availability of special windows.

Table A-1: Window Material Recommendations and Transmission Values

Material	Recommended for Model	Identification
Glass	HT	3 red dots
Amtir1	LT	-
CaF2	G5, P7	2 red dots
Sapphire	MT	4 red dots

APPENDIX

TRANSMISSION OF STANDARD WINDOWS

Table A-1 (page A-7) shows the different window materials recommended for specific models.
If there are special requirements, please ask your Sales Representative about the availability of special windows.

APPENDIX C: TRACEABILITY OF INSTRUMENT CALIBRATION

Traceability of temperature source (blackbody) and infrared thermometer calibration can be followed from the U.S. National Institute of Standards and Technology (NIST), to a NIST certified calibration laboratory, and to Raytek.

NIST calibrates instruments used by the calibration laboratory, the laboratory calibrates precision instruments in accordance to NIST standards, and Raytek calibrates products to an instrument calibrated by the laboratory (**see figure below**).

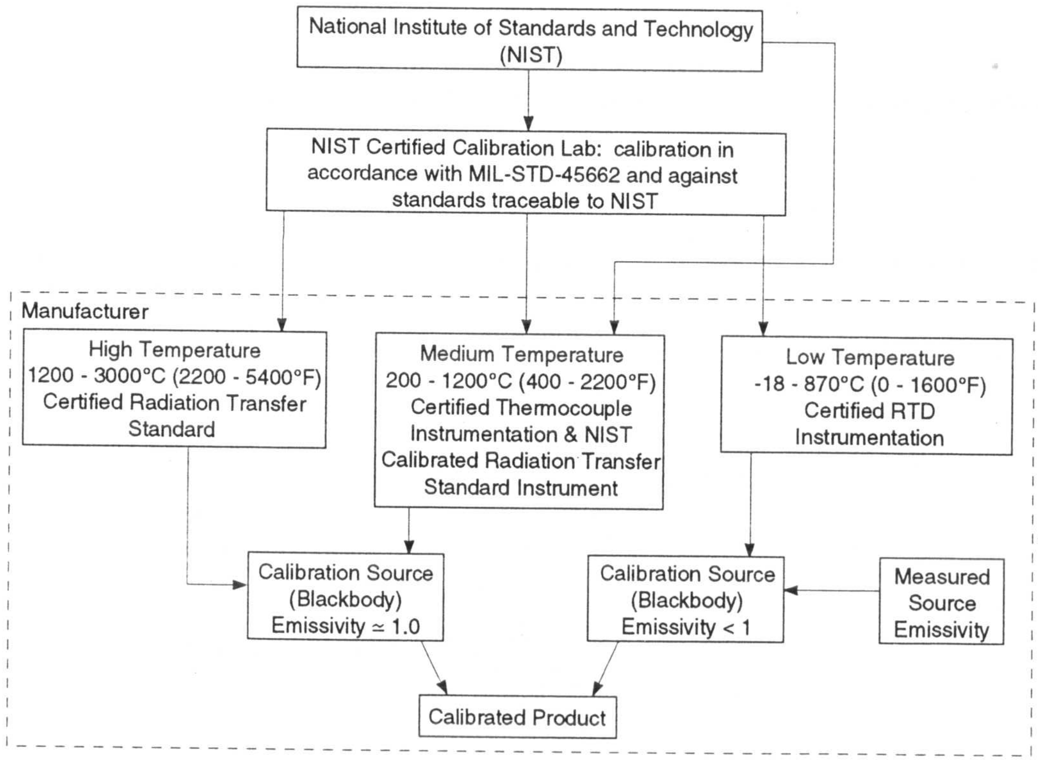


Figure A-1: Traceability of Temperature Instrumentation Calibration

GLOSSARY

GLOSSARY OF TERMS

1-Way Or 2-Way RS232	A uni-directional or bi-directional (1-way or 2-way, respectively) transfer of digital information to/from a digital input or output. RS232 is a standardized format for asynchronous serial transfer of data.
Absolute Zero	The temperature (0 Kelvin) of an object defined by the theoretical condition where the object has zero energy.
Accuracy	Maximum deviation, expressed in temperature units, or as a percentage of the temperature reading, or as a percentage of the full scale temperature value, or as a percentage of the target temperature, indicating the difference between a temperature reading given by an instrument under ideal operating conditions, and the temperature of a calibration source (per the ASTM standard test method E 1256-88).
Ambient Operating Range	Range of the ambient temperature conditions over which the thermometer is designed to operate.
Ambient Temperature	Room temperature or temperature surrounding the instrument.
Ambient Temperature Compensation (TAMB)	Refer to Reflected Energy Compensation.
ASTM	American Society for Testing and Materials.
Atmospheric Windows	Infrared spectral bands in which the atmosphere best transmits radiant energy. Two predominant atmospheric windows are located at 2-5 µm and at 8-14 µm.
Background Temperature	Temperature behind and surrounding the target, as viewed from the instrument.
Blackbody	A perfect emitter; an object that absorbs all the radiant energy incident on it at all wavelengths and reflects and transmits none. A surface with emissivity of unity (1.00).
°C (Celsius)	Temperature scale based on 0° (zero degrees) as the freezing point of water, and 100° as the vaporization point of water, at standard pressure. °C = (°F - 32) ÷ 1.8.
Calibration	A methodical measurement procedure to determine all the parameters significantly affecting an instrument's performance.
Calibration Source	A source (blackbody, hot plate, etc.) of known and traceable temperature and emissivity. Usually NIST traceable in the USA, with other recognized standards available for international customers.

GLOSSARY

Colored Body	See Non-Gray Body.
D:S	Distance to size ratio. See Optical Resolution.
Deadband	Temperature band (±) about the setpoint wherein an alarm output or relay cannot change state, thus providing hysteresis.
Detector	Transducer which produces a voltage or current proportional to the IR energy incident upon it. See also thermopile, MCT, TE-cooled, pyroelectric, PbSe and Si detectors.
Dielectric Withstand Voltage (Breakdown Voltage)	The voltage up to which a dielectric (insulator) can endure before conduction through the material occurs.
Digital Data Bus	A means for transmitting coded digital data on a common buss in accordance with a standard format such as RS232 or IEEE-488.
Digital Output Interval (DOI)	The time interval between variable length digital message transmissions containing temperature and system status information.
DIN	Deutsches Institut für Normung (DIN). The German standard for many instrumentation products.
Display Resolution	The level of precision to which a temperature value can be displayed, usually expressed in degrees or tenths of degrees.
Drift	The change in instrument indication over a long period of time, not caused by external influences on the device (per the ASTM standard test method E 1256-88).
Emissivity	The ratio of infrared energy radiated by an object at a given temperature and spectral band to the energy emitted by a perfect radiator (blackbody) at the same temperature and spectral band. The emissivity of a perfect blackbody is unity (1.00).
EMI/RFI Noise	Electro-magnetic or radio frequency interference, EMI and RFI respectively, which may cause disturbances to electrical signals within IR thermometers.
Environmental Rating	A rating given (IEC, IP, or NEMA) to indicate the severity of the environmental operating conditions under which the unit will function reliably.
External Reset (Trigger)	Initialization of signal conditioning features (Peak Hold, Valley Hold, Sample Hold, Average, 1-way RS232, etc.) via the external reset input.
°F (Fahrenheit)	Temperature scale where °F = (°C x 1.8) + 32 = °R - 459.67.

GLOSSARY

Fail-Safe Operation	A feature designed to alert the operator via display, and to bring a process to a safe shutdown via output, in the event of a particular control system or process failure.
Far Field	A measured distance substantially greater than the focus distance of the instrument; typically greater than 10 times the focus distance.
Field of View (FOV)	The region, at the target, measured by the IR thermometer. Typically presented by giving the spot diameter as a function of distance from the instrument. Also presented as the angular size of the spot at the focus point. See Optical Resolution.
Filter (Optical)	Refer to Spectral Filter or Neutral Density Filter.
Focus Point (or Distance)	The distance from the instrument where the optical resolution is greatest.
Full Scale	The maximum of the temperature range or output signal.
Full Scale Accuracy	A convention for expressing the accuracy as a percentage of an instrument's (highest) full scale temperature.
Gray Body	A radiating object whose emissivity is in constant ratio (not unity) at all wavelengths to that of a blackbody at the same temperature, and does not transmit infrared energy.
Hertz (Hz)	Units in which frequency is expressed. Synonymous with cycles per second.
IEC	International Electrotechnical Commission; a European organization that coordinates and sets standards among the European Community.
IEEE-488	A communications format standard. See digital data bus.
Infrared (IR)	The portion of the electromagnetic spectrum extending from the far red visible at approximately 0.75 µm, out to 1000 µm. However, because of instrument design considerations and the atmospheric windows, most infrared measurements are made between 0.75 µm and 20 µm.
Infrared Thermometer	An instrument that converts incoming IR radiation from a spot on a target surface to a measurement value that can be related to the temperature of that spot.
Insulation Resistance	The electrical resistance of the insulating material as measured by the ratio of the applied voltage (applied for example between a conducting wire and the case or chassis ground) to the leakage current, and normally expressed in megohms.

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Interchangeability (of heads)	The ability for a head sensor to be interchanged with another of the same type without the need to recalibrate the system (also referred to as Universal Electronics). Some monitors support the interchangeability of different types of heads.
Intrinsically Safe	A standard for preventing explosions in hazardous areas by limiting the electrical energy available to levels that are insufficient to cause ignition of explosive atmospheres during normal operation.
IP Designation	Grades of protection pertaining to enclosures per the British Standard 4752. The type of protection is defined by two digits, the first relating to accessibility and the second to environmental protection. The two numbers are preceded by the letters IP.
Isolation (Inputs, Outputs and/or Power Supplies)	A feature which allows for a difference in voltage between inputs, outputs, and/or power supply grounds, and the grounds associated with the user's instrumentation (for example, the user's controller).
J,K,N,R,S T/C	Thermocouple types available, depending upon the temperature range to be measured.
K (Kelvin)	The unit of absolute or thermodynamic temperature scale where 0 K is absolute zero and 273.15 K is equal to 0° C. There is no (°) symbol used with the Kelvin scale, and K = °C + 273.15.
Lockout Mode	A function of some devices protecting them from accidental value changes or from tampering. Settings are locked in place.
mA	Milli-ampere, or 0.001 amp.
Maximum Current Loop Impedance	Describes the size of load that can be driven by an instrument with a mA output. For example a 500 ohm maximum loop impedance means that the instrument can supply 10 volts at 20 milliamps into this load.
Micron (or µm)	10^{-6} meters (m), or 0.000001 m.
Minimum spot size	The smallest spot an instrument can accurately measure.
mRad	Milli-Radians (0.001 Radians), an angular measure where π (3.14159) radians is equal to 180° of rotation.
mV	Milli-volts, or 0.001 volt.
NEMA	National Electrical Manufacturer's Association; sets U.S. standards for housing enclosures, similar to IEC IP.
NET	Noise Equivalent Temperature. Peak to peak system electrical noise normally measured at the output (display or analog) expressed in °F or °C.

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Neutral Density Filter — An optical element used to restrict the amount of energy reaching an instrument's detector by ideally attenuating the energy at all wavelengths by the same amount.

NIST Traceability — Calibration in accordance with and against standards traceable to NIST (National Institute of Standards and Technology, USA). Traceability to NIST is a means of ensuring that reference standards remain valid and their calibration remains current.

Non-Gray Body — A radiating object that is partly transparent to infrared (transmits infrared energy at certain wavelengths). Also called Colored Bodies. Glass and plastic films are non-gray body examples.

Optical Pyrometer — A system that, by comparing a source whose temperature is to be measured to a standardized source of illumination (usually compared to the human eye), determines the temperature of the former source.

Optical Resolution — The distance to size ratio (D:S) of the IR measurement spot, where the distance is usually defined at the focus distance, and the size is defined by the diameter of the IR energy spot at the focus (typically at the 90% IR energy spot diameter). Optical resolution may also be specified for the far field by using values of far field distance and spot size.

Output Impedance — Describes the size of load which can be driven by an instrument with voltage or thermocouple outputs. In order to guarantee accurate readings, the user should make sure that the input impedance of connected instrumentation is at least 1000 times greater than the thermometer's output impedance. For mA outputs refer to Maximum Current Loop Impedance.

Peak Hold — Output of the maximum temperature for a specified duration or decay rate; used for example when the background temperature between discrete targets is less than that of the target.

Photodetector — A type of IR detector that has a fast response (typically in microseconds), limited spectral response, and usually requires cooled operation. Photodetectors are commonly used in IR thermometers, linescanners and imagers.

Pyroelectric Detector — Infrared detector which behaves as a current source with an output proportional to the rate of change of the incident IR energy.

°R (Rankine) — Temperature scale where °R = 1.8 x K, or also °R=°F+460.

Radiation Thermometer — A device that calculates an object's temperature (given a known emissivity) from measurement of either visible or infrared radiation from that object.

Reference Junction — Refers to the "cold" or ambient thermocouple junction, which is held at a known temperature. Also see thermocouple.

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Reflectance	The ratio of the radiant energy reflected off a surface to that incident on the surface; for a gray body this is equal to unity minus emittance; for a perfect mirror this approaches unity; and for a blackbody the reflectance is zero.
Reflected Energy Compensation	Correction feature used to achieve greater accuracy when, due to a high uniform background temperature, IR energy is reflected off the target into the instrument. If the background temperature is known the instrument reading can be corrected by using this feature.
Relative Humidity	The ratio, expressed as a percent, of the amount of water vapor actually present in a sample of air to the greatest amount of water vapor possible at the same temperature.
Relays or contact closures	Switching components that allow changes of state in one circuit (usually of higher current and voltage), to be controlled by another circuit (usually of lower current and voltage).
Repeatability	The degree to which a single instrument gives the same reading on the same object over successive measures under the same ambient and target conditions (per the ASTM standard test method E 1256-88).
Resolution	See Temperature Resolution, Optical Resolution or Spatial Resolution (linescanner only).
Response Time	A measure of an instrument's change of output corresponding to an instantaneous change in target temperature, generally expressed in milli-seconds, for 95 percent of full scale temperature indication (per the ASTM standard test method E 1256-88). The specification for Raytek instruments also includes the average time required for software computations.
Sample Hold	A temperature taken from a target and displayed or held for a set period of time or until the next external reset occurs.
Scatter	See size of source effect.
Setpoint	Temperature setting which when crossed by the actual temperature value will trigger an event and/or cause a relay to change state.
Shock Test	An impact test per MIL-STD-810D where a force is applied to any axis of an object over a specified duration. The force is usually measured in g's ($1g = 9.81 m/s^2 = 32.2 ft./s^2$), and the duration is usually measured in msec.
Signal Processing	Manipulation of temperature data for purposes of enhancing the data. Examples of signal processing functions include Peak Hold, Valley Hold and Averaging.
Silicon (Si) Detector	A photodiode detector typically used in high temperature IR thermometers.

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Size of Source Effect
An undesirable increase in temperature reading caused by IR energy outside the spot reaching the detector. The effect is most pronounced when the target is much larger than the field of view.

Spectral Filter
An optical element used to restrict the spectral band of energy reaching an instrument's detector.

Spectral Response
The wavelength region in which the IR Thermometer is sensitive.

Spot
The diameter of the area on the target where the temperature determination is made. The spot is defined by the circular aperture at the target which allows typically 90% of the IR energy to be collected by the instrument, as compared with the 100% spot diameter which is defined by the IR energy collected from a very large target. The actual size and distance to the target for the 100% spot diameter is specified in the calibration procedure for each instrument.

Storage Temperature Range
Ambient temperature range that the thermometer can safely withstand in a non-operating mode, and subsequently, operate within published performance specifications.

Target
The object upon which the temperature determination is intended to be made.

Temperature
A degree of hotness or coldness of an object measurable by a specific scale; where heat is defined as thermal energy in transit, and flows from objects of higher temperature to objects of lower temperature.

Temperature Coefficient (or Ambient Derating)
An indication of the instruments ability to maintain accuracy when the ambient conditions are subject to a slow change or drift. The temperature coefficient is usually expressed as the percent change in accuracy per degree change in ambient temperature. For a rapid change in ambient conditions refer to Thermal Shock.

Temperature Resolution
The minimum simulated or actual change in target temperature that gives a usable change in output and/or indication (per the ASTM standard test method E 1256-88).

Thermal Shock
A short term error in accuracy caused by a transient ambient temperature change. The instrument recovers from its accuracy error when it comes back into equilibrium with the new ambient conditions.

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Thermocouple

A junction, comprising two dissimilar metals, that develops a small voltage dependent upon the temperature of the junction. Typical thermocouples types include:

J	iron/constantan
K	chromel/alumel
T	copper/constantan
E	chromel/constantan
R	platinum/platinum-30% rhodium
S	platinum/platinum-10% rhodium
B	platinum-6% rhodium/platinum-30% rhodium
G	tungsten/tungsten-26% rhenium
C	tungsten-5% rhenium/tungsten-26% rhenium
D	tungsten-3% rhenium/tungsten-25% rhenium

Time Constant

The time it takes for a sensing element to respond to 63.2% of a step change at the target.

Transfer Standard

A precision radiometric measurement instrument with NIST traceable calibration in the USA (with other recognized standards available for international customers), used to calibrate radiation reference sources.

Transmittance

The ratio of IR radiant energy transmitted through an object to the total IR energy received by the object for any given spectral range; the sum of emittance, reflectance, and transmittance is unity.

Warm-Up Time

Time, after turn on, until the instrument will function within specified repeatability (per the ASTM standard test method E 1256-88).

Valley Hold

Output of the minimum temperature over a specified duration or decay rate; for example, obtaining a minimum target temperature when the background temperature between discrete targets is greater than that of the target.

Verification

Confirmation of accuracy.

Vibration Test

An oscillatory or repetitive motion test of the instrument per MIL-STD-810D or IEC 68-2-6 , often specified as an acceleration in g's

(1g = 9.81m/s^2 = 32.2 ft./s^2),
over a frequency range typically measured in Hertz (sec^{-1}).

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