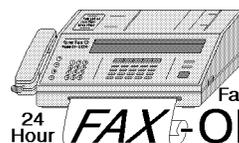


Thermal Sentry

— Instruction Book —

**This instruction book contains valid documentation
for the Thermal Sentry, version 1.00.**

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Section 3 — Safety Information

3.1



The Thermal Sentry should be installed only by qualified technical personnel. Incorrect or inappropriate installation could result in a hazardous condition.

The Thermal Sentry is designed for indoor use in a dry location. Installation and operation in other locations could be hazardous. Use only the original wall-plug power supply supplied with the unit.

Section 4 — Specifications

4.1

Size: 19 inches wide, 1.75 inches high, 6 inches overall depth; designed for mounting in standard EIA 19 inch equipment rack.

Front Panel: A digital display (green LED) which indicates differential temperature and a red "Alarm" LED which indicates when the differential temperature exceeds a preset limit. The digital display indicates from 0°F to 199.9 °F differential temperature. With an internal jumper, the display can be made to indicate the alarm temperature.

Rear Panel:

Screw-terminal connections for the following:

- Intake Sensor
- Exhaust Sensor
- Analog Outputs
 - Intake
 - Differential
 - Exhaust
- Alarm Output
- Power Input

Adjustments: (both internal)

- Differential temperature zero set
- Differential temperature alarm set

Power Requirements:

- Wall-plug power supply input: 120 volts AC, 5 watts
- Wall-plug power supply output: 12 volts DC at 200 milliamperes maximum

Maximum Ambient Temperature of Rack-Mounted Unit: 140°F

Temperature Sensors:

- Number included: 2
- Operating range: 0°F to 230°F ambient air temperature
- Absolute accuracy (at 72°F): $\pm 2^\circ\text{F}$
- Differential accuracy (0°F to 100°F difference): $\pm 2^\circ\text{F}$

Analog Outputs: Intake temperature, exhaust temperature, and differential temperature. Each output is linear and precalibrated to 10.0 millivolts (DC) per degree Fahrenheit. Load impedance should be 1000 ohms or greater.

Alarm Output: Operates when the differential temperature exceeds the preset limit, set with an internal potentiometer. Using internal jumpers, the output can be configured as a normally-open or normally-closed relay contact rated at 6 amperes, or a normally-high or normally-low 5 volt logic-level.

Section 5 — Equipment Description

5.1 GENERAL DESCRIPTION AND FUNCTION

The Thermal Sentry is designed to monitor the overall operating condition of a broadcast transmitter (or other industrial device) by measuring specific thermal conditions. It provides important early-warning information about conditions which, if uncorrected, could lead to down-time and costly damage. To accomplish this, the Thermal Sentry uses two precision air-temperature sensors; one located at the cooling-air intake and the other at the cooling-air exhaust of a transmitter. The Thermal Sentry then computes and displays the temperature difference between the two sensors.

The Thermal Sentry also has an alarm output which activates whenever the temperature differential exceeds a preset value.

5.1.1 Physical Description

The Thermal Sentry is designed for mounting in a standard 19 inch equipment rack and is 1.75 inches in height. The front panel contains a green LED display to indicate differential temperature from 0°F to 199.9°F and a red "Alarm" LED which indicates when the temperature differential exceeds a preset limit. The rear panel contains screw-terminal connections for the air-temperature sensors, the auxiliary analog outputs, the alarm output, and the power-supply connection. The Thermal Sentry is powered by a 12 volt DC wall-plug power supply (included). The two air-temperature sensors (included) can be located up to 100 feet from the control unit.

The interior of the Thermal Sentry case contains adjustments to "zero set" the temperature differential and to set the alarm temperature. Several jumpers are also present and are used to configure the display and the alarm output.

5.2 TEMPERATURE-DIFFERENTIAL MONITORING

5.2.1 The Advantages of Differential Temperature Monitoring

While it is a common practice to monitor transmitter exhaust temperature, this information is, by itself, of limited value. The exhaust temperature can vary over a wide range due to nothing more than changes in the intake temperature. The differential temperature (intake to exhaust) provides information which is much more meaningful. The differential temperature has the capability to reveal even small changes in both the transmitter's thermal-output and cooling-air volume.

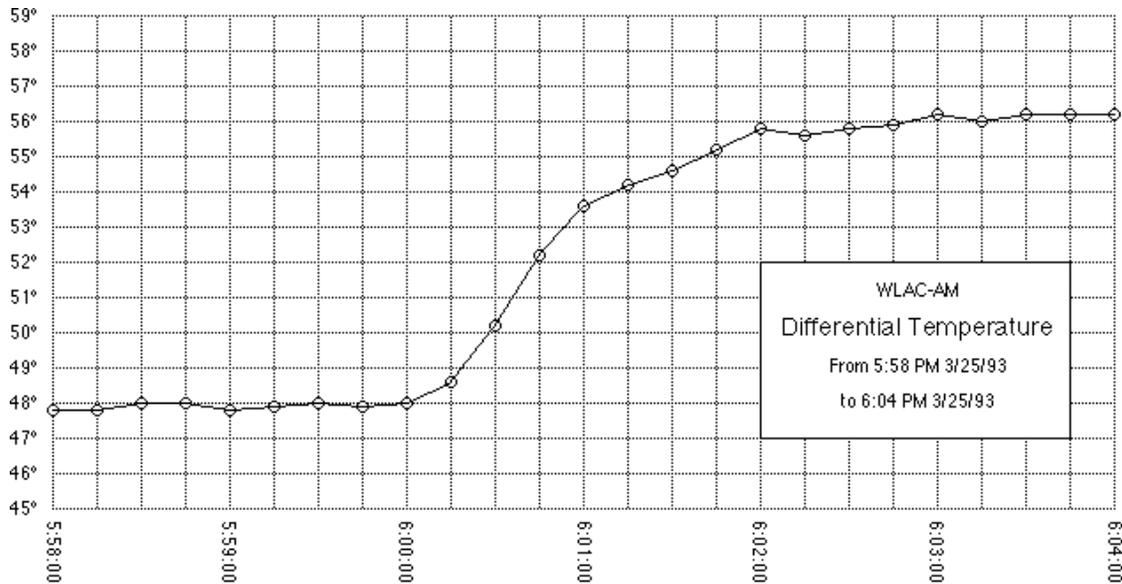
The key to interpreting the significance of differential-temperature data is to first determine the "baseline" differential temperature of a normally operating transmitter. A feel for this can be developed after only a short period of observation. After the "normal" range is established, the differential temperature data can be used to provide an overall early-warning system for a host of potential problems. Here are some examples of conditions that can be detected:

1. Dirty, blocked, ruptured, defective, or incorrectly installed air filters
2. Blower-motor problems, loose blower-belts, dirty blower-impellers, loss of power phase
3. Missing, leaking, or incorrectly replaced panels in transmitter air plenum (at 3:00

AM it's easy to forget)

4. High feedline VSWR or antenna mismatch (antenna/feedline failures or antenna icing)
5. Overheating components
6. Faulty output-power indications (your transmitter meter says 100% but you're really at 80%, or worse—120%)
7. Loss of efficiency due to change in tuning or other RF problems, loss of drive, change in screen or filament voltages
8. Operator error in adjusting power level
9. Wind effects due to intake and/or exhaust ports being ducted to the building's exterior

To illustrate how sensitive an indicator differential temperature can be, consider the following data recorded at a broadcast transmitter:



The transmitter is a 50 kW AM, nondirectional day, directional night. The graph consists of differential temperature recorded every 15 seconds from 5:58 PM to 6:04 PM. The station switches to directional at 6:00 PM. The transmitter output increases somewhat in the directional mode due to losses in the antenna phasor. This is clearly and quickly indicated by the rise in differential temperature.

5.2.2 Factors Which Affect Differential Temperature

The static factors which affect differential temperature, such as altitude and transmitter model, are inalterable and determine the "baseline" differential temperature. Other factors are variable and can be used as indicators of problems or potential problems. In interpreting differential temperature data, it is important to be aware of the variable factors which influence the data. The following section discusses the main (variable) factors that effect differential temperature:

5.2.2.1 Primary Factors

Transmitter Thermal Output
Cooling-Air Volume

The primary controlling factors in temperature differential are thermal output of the transmitter and cooling-air volume. Either an increase in the first or a decrease in the second will cause the differential temperature to rise. It is this characteristic that gives the Thermal Sentry its power to detect so many problems.

Keep in mind that the thermal output of an AM transmitter can change with modulation. Also, the thermal output of all transmitters will change if the output power changes, due to either operator adjustment or line-voltage changes. This is why a short period of observation is needed to establish the "normal" range of differential temperature.

5.2.2.2 Secondary Factor

Intake-Air Temperature

A smaller but not insignificant factor which influences temperature differential is intake-air temperature. This is because cool air is denser than warm air (at a given pressure) and is capable of transferring more heat for a given volume. The temperature differential of a typical transmitter will be about 12% less with 35° intake air as compared to 95° intake air, all other conditions being equal. This is observed as a slow, predictable, seasonal change in differential temperature, typically 2° to 7° depending on the power level of the transmitter. With the application of a simple formula, this effect can be eliminated and changes in a transmitter's thermal output or cooling-air volume as small as 2% can be detected.

Suppose, for example, an operator notices that a transmitter's differential temperature is running a little higher than it has been recently. He observes that the current temperature differential is 52.2° and the current intake temperature is 38°(F). He has previously established a baseline temperature differential of 53.5° at a reference intake temperature of 72°. The question is: What would the differential temperature be now if the intake temperature were 72°? To answer this question we can use the following simple formula:

$$\text{Converted Differential} = \text{Current Differential} \times \frac{\text{Reference Intake Temp} + 460}{\text{Current Intake Temp} + 460}$$

Plug in the data and we get the following results:

$$\text{Converted Differential} = 52.2 \times \frac{72 + 460}{38 + 460} = 55.76^\circ$$

In other words, if the current intake temperature were 72° instead of the current 38°, we can predict that the differential temperature would be 55.76° instead of the current 52.2°. Since the baseline reference adjusted to 72° is 53.5°, we can see that the differential temperature is indeed running 2.26° over baseline and might warrant further investigation.

5.2.2.3 Tertiary Factors

Atmospheric Pressure
Relative Humidity
Inherent blower-efficiency/air-density interrelations

Tertiary factors with still lessor effects on differential temperature are atmospheric pressure and relative humidity, which both effect cooling-air density. Also, because of the designed shape of the impeller (and other factors), the efficiency of the blower is optimum at a specific air density. Within the scope of the Thermal Sentry, these tertiary factors are small enough to be disregarded.

5.3 ALARM OUTPUT

The Thermal Sentry has an alarm output which activates when the differential temperature exceeds a user-set limit. This can be used to alert a remote operator by means of a remote-control-system or it can be used to control equipment directly. The alarm output can be either a relay contact or a voltage source.

After a baseline differential temperature is established, the alarm trip-point can be set to a value which will alert an operator to significant changes in differential temperature yet not produce false alarms. This is usually about 5° to 10° above the highest differential temperature encountered in normal operation. This normally occurs on the hottest day of the year and can be predicted using the formula in section 5.2.2.2.

Instructions on how to configure the Alarm output and set the Alarm temperature are contained in the Installation section of this book.

5.4 AUXILIARY ANALOG OUTPUTS

The Thermal Sentry provides auxiliary analog outputs for intake temperature, exhaust temperature, and differential temperature. The outputs are linear and precalibrated to 10.0 millivolts per degree Fahrenheit (0.000 volts= 0° F; 1.000 volts= 100.0°F), and may be used for local or remote indication.

Section 6 — Installation



WARNING!

Installation of the Thermal Sentry should be performed only by a qualified technician. Installation is not difficult; however, an attempted installation by a person who is not technically qualified could result in danger to operating or maintenance personnel, or damage to the unit.

6.1 Unpacking

When the Thermal Sentry is unpacked, it should be inspected for obvious signs of mechanical damage or loose parts. Loose parts should be tightened before installation. If damage is found, save the packing material and report it to the shipping company and the dealer from which it was purchased. Do not install the unit.

6.2 Mechanical Installation

The Thermal Sentry is designed to be mounted in a standard 19 inch EIA equipment rack. It is 1.75 inches high. The Thermal Sentry generates little heat and can be mounted in just about any convenient location where the ambient temperature does not exceed 140°F.

6.3 Electrical Installation

All electrical connections to the Thermal Sentry are made with 14 screw-terminals located on the rear of the unit. These include:

Intake Sensor Input:

Ground
Sensor
+5 volts

Exhaust Sensor Input:

Ground
Sensor
+5 volts.

Auxiliary Analog Outputs:

Ground
Exhaust
Differential
Intake

Alarm Output:

A (ground if logic-level output enabled)
B (active if logic-level output enabled)

Power Supply:

+12 volts DC
-12 volts DC

6.3.1 Air-Temperature Sensors

The Thermal Sentry is supplied with two air-temperature sensors. These consist of small PC boards with three screw-terminals. The sensors are identical but once installed and calibrated, they should not be interchanged (unless recalibrated). The three terminals on each sensor should connect to the corresponding terminals on the rear panel of the Thermal Sentry.



WARNING!

Two-conductor-with-foil-shield cable, such as Belden 8451, should be used for the connection. It is very important that foil-shielded cable be used. Braid-shielded cable is inadequate.

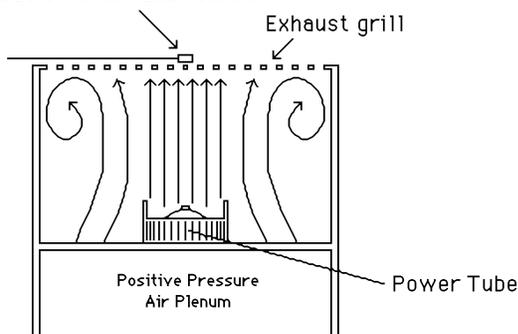
The air-temperature sensors may be located up to 100 feet from the Thermal Sentry. The length of the cable may be changed after calibration as the wire resistance (up to about a hundred feet) has no significant effect on calibration. The shield of the cable should connect to the ground (G) terminal, the black wire should connect to the sensor (S) terminal and the red wire should connect to the +5 volt (+) terminal. To reduce RF susceptibility, the unshielded portions of the wire at the end of the cable connected to the sensor should be as short as possible (one inch or less).

Before the air-temperature sensors are placed in their final positions, they will need to be calibrated. When this is done, the sensors should be placed within one inch of each other. See section 6.4 for the calibration procedure.

After calibration, the intake air-temperature sensor should be placed in the air flow at the transmitter's air intake, and the exhaust air-temperature should be placed in the air flow of the transmitter's air exhaust. The sensors can be used in air temperature up to 230°F. If the air-temperature sensor is installed in such a way that the lower side of the PC board could come in contact with metal, a piece of insulating tubing (supplied) should be installed over the sensor. This is heat-shrinkable tubing but it should not be shrunk in order to allow good air flow over the sensor.

In order to obtain the most accurate and meaningful data from the Thermal Sentry, care should be used in the placement of the air-temperature sensors. As an example, the following illustration shows the air-flow in a common broadcast transmitter:

Correct location of exhaust sensor



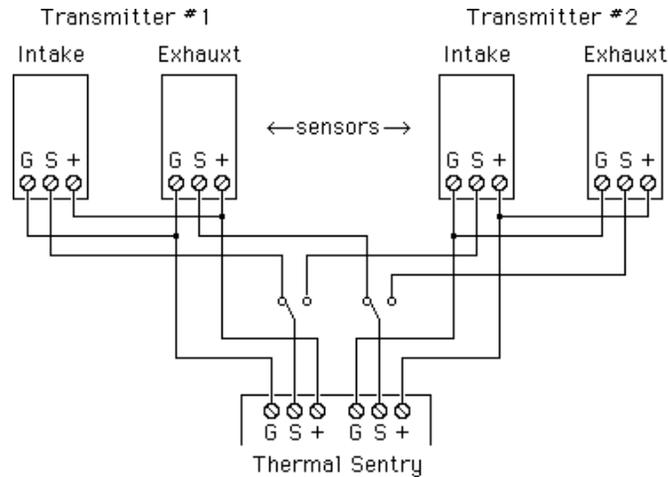
Here, the exhaust air-temperature sensor is shown directly over the power tube. If the sensor were located significantly off center, the air flowing across it will be a mixture of air flowing through the tube fins, leakage air, and circulating vortices cooled by the inside walls of the cabinet. This mixture is less stable in temperature and significantly cooler than the undiluted air flowing through the tube. The type of amplifier and cooling system varies from transmitter to transmitter but the principal remains the same: locate the exhaust air-temperature sensor as close as possible to the core of the airflow coming from the largest heat producer in the transmitter.

Care should also be used in the placement of the intake air-temperature sensor. If a transmitter is drawing-in room air, it might seem that the intake sensor could be located anywhere in the room. While this can be done, a short term variation of about $\pm 1^\circ$ to $\pm 2^\circ$ in differential temperature will be noticed having no correlation to the actual transmitter differential. This is because of random drafts within the room. The ideal location for the intake sensor is near the blower intake. Here the air is funneled and flowing rapidly. The next best location is on the outside of the air filters as close to the blower intake as possible.

When installing the air-temperature sensors, be sure there is no way they could fall into, or be sucked into, any portion of the transmitter where they could do harm. Nylon cable-ties are a good way to securely fasten the air-temperature sensors in place.

The Thermal Sentry is designed to operate properly in high RF fields. In extreme cases it may be necessary to connect the air-temperature sensor ground connections to the ground connection in the rack in which the Thermal Sentry is mounted.

Sometimes it may be desirable to use the Thermal Sentry with more than one pair of temperature sensors. A main and alternate-main transmitter, a dual transmitter, or a transmitter having two or more major heat sources are examples where this might be needed. Additional pairs of air-temperature sensors may be ordered as part number TS-2. The only limitation in using multiple pairs of temperature sensors is that the "zero" calibration in the Thermal Sentry can be set to only one pair of sensors. This is normally not a significant problem because the calibration of any given pair of sensors is usually to within a degree of each other. Once this is accounted for in the "baseline" observations it is really of no consequence. Switching between pairs of sensors can be done manually with a switch or automatically with a relay. The air-temperature sensors require very little power from the Thermal Sentry and as a result can be connected to power and ground at all times. Only the sensor output needs to be switched. Up to 20 or so pairs of sensors can be powered by one Thermal Sentry. Here is an example of a system using two pairs of sensors:



6.3.2 Auxiliary Analog Outputs

The Thermal Sentry provides auxiliary analog outputs for intake temperature, exhaust temperature, and differential temperature. The outputs are linear and precalibrated to 10.0 millivolts per degree Fahrenheit (0.000 volts = 0° F; 1.000 volts = 100.0°F) referenced to the "G" terminal, and may be used for local or remote indication. The outputs may be checked with a digital multimeter set to 2 volts DC.

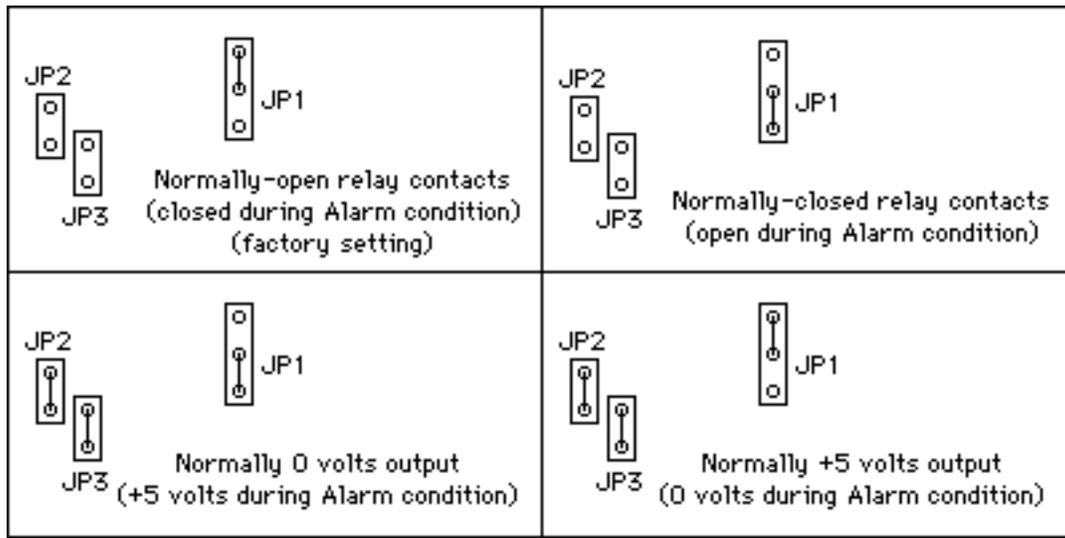
The auxiliary analog outputs should not be connected to a load of less than 1000 ohms.

6.3.3 Alarm Output

The Thermal Sentry has an alarm output which activates when the differential temperature exceeds a preset limit. The alarm condition is indicated by a red LED on the front panel and an alarm output on the rear panel. This can be used to alert a remote operator by means of a remote-control-system or it can be used to control equipment directly. The alarm output can be either a relay contact or a voltage source. Instructions for setting the alarm temperature are located in section 5.5.

6.3.3.1 Configuring Alarm Output

The Alarm output is configured with two jumpers located inside the Thermal Sentry case. To open the case, remove the two Phillips-head screws on the rear panel. Remove the rear panel and bezel, and slide the top cover off the base. These are the four ways the Alarm output can be configured:



When the Alarm output is configured for 0 volts/+5 volts, the "A" terminal is ground and the "B" terminal is the output.

When the Alarm output is configured as a relay contact, the contacts are floating and are rated at 6 amperes. The "A" and "B" terminals are interchangeable.



WARNING!

Do NOT connect 120 or 240 volts AC to the Thermal Sentry. Because of the exposed terminals, a painful or lethal shock could result to maintenance personnel.

6.3.4 Power Supply Connection

The Thermal Sentry is powered by 12 volts DC. The included wall-plug power supply should be used. If the power supply cord has a connector attached, cut it off and strip the leads. The wire with the white stripe is positive and should be attached to the "+" terminal. The other wire should be attached to the "-" terminal.



WARNING!

Do not ground either the "+" or the "-" power supply connections. Connect them only to the indicated terminals on the rear panel of the Thermal Sentry.

6.4 AIR-TEMPERATURE SENSOR CALIBRATION

The air-temperature sensors are precalibrated, typically within 1° of each other. In order to match the two sensors exactly to each other, a "Zero Set" adjustment is available inside the case. To open the case, remove the two Phillips-head screws on the rear panel. Remove the

rear panel and bezel, and slide the top cover off the base. The control is labeled "Zero Set" on the PC board. Before setting the adjustment, locate the two air-temperature sensors within one inch of each other. Allow about 5 minutes for the sensors to stabilize. Then adjust the Zero Set control until the display reads 0.0.

6.5 SETTING ALARM TEMPERATURE

The control used to set the Alarm temperature is located inside the Thermal Sentry case. To open the case, remove the two Phillips-head screws on the rear panel. Remove the rear panel and bezel, and slide the top cover off the base. The control is labeled "Alarm Set" on the PC board. To set the control, first move jumper JP3 from the Operate to the Set position. Then adjust the Alarm Set control until the desired Alarm temperature is indicated on the front panel display. Finally, return jumper JP3 to the Operate position.

Section 7 — Troubleshooting and Repair

7.1 Circuit Description

The external 12 volt DC power supply is split by diodes D3 through D5 and U2 to form a dual voltage power supply. The negative supply is necessary to allow the op amp outputs to reach zero volts in the negative direction.

U1c forms a differential amplifier with a gain of unity. R2 provides a means to trim out DC offset and sensor miscalibration. This drives the analog input of the display board and U1a, a comparator, which uses the output of R11 as a reference. In the Alarm condition, the output of U1a is driven "low" to about 0 volts. This turns on Q1 which turns on RY-1 and the front panel Alarm LED, D1.

U1b and U1d are unity gain buffers for the Intake and Exhaust telemetry outputs.

7.2 Field Repair



WARNING!

Field repair of the Thermal Sentry is not difficult. However, incorrect repair could result in a condition which could cause damage to equipment or be hazardous to personnel. Only a qualified service technician should attempt to repair the Thermal Sentry.

There are no critical or unusual parts in the Thermal Sentry. All semiconductors can be replaced with EGC equivalents except the temperature sensors themselves. These, as well as all other parts are available from Sine Systems. If either temperature sensor is replaced, the Zero Set will need to be recalibrated.

7.2.1 Power Supply

The wall-plug power supply that is supplied with the Thermal Sentry contains an internal nonreplaceable fuse. If this fuse blows, or the power supply fails for any other reason, the power supply should be replaced.