

# ***Sentinel-ES***

## ***INSTALLATION & APPLICATIONS MANUAL***

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## Introduction

Congratulations! You have purchased a Sentinel-ES oxygen sensor from Marathon Sensors Inc., the leader in oxygen sensing and control.

The Sentinel-ES utilizes high-performance probe technology to provide cost-effective and reliable oxygen sensing from parts-per-million up to 10%.

Each Sentinel-ES unit includes a factory calibrated probe. The probe is easily replaced in the field and, if necessary, can be recalibrated using calibration gas of known oxygen concentration and a small flathead screwdriver.

Your Sentinel-ES unit is covered by a one-year conditional warranty as described on the enclosed Warranty Card. Please be sure to complete and return your Warranty Registration card so that Marathon can provide you with the most responsive service and support.

## Package Contents

Please verify that you have received the following:

1. Sentinel-ES enclosure containing wiring terminal, lambda probe, printed circuit board, sintered stainless steel filter, bowl filter (external) and flowmeter (external).
2. Wiring diagram.
3. This manual

If your shipment is missing any of these items please contact Marathon Sensors immediately.

## Installation

### *Location*

Choose a location for installation of the Sentinel-ES enclosure. Keeping the sensor close to the process will minimize the reaction time of your sensor since there will be less gas line for the sample to travel.

Proximity to the monitor or instrument is less important as the Sentinel-ES does not require expensive thermocouple extension wire.

The Sentinel-ES requires ventilation in order to maintain adequate reference air. Do not position the enclosure such that process exhaust flows into the vents on the enclosure as this will result in output error.

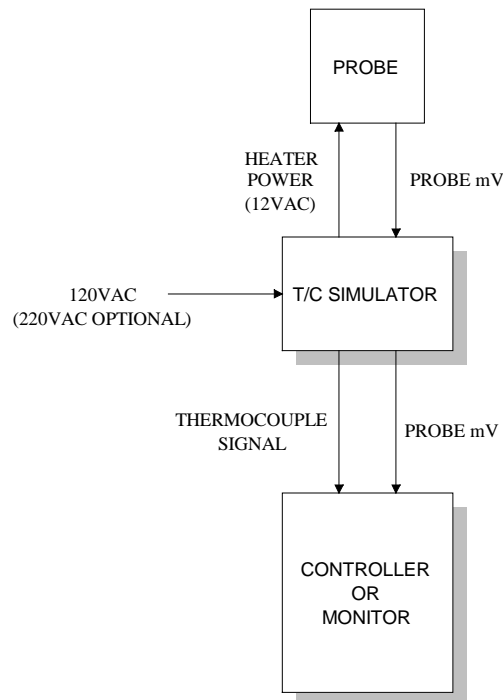
Insure that the temperature of the incoming gas does not exceed 125 degrees F. This is the temperature limitation of the 100 micron filter mounted on the Sentinel-ES enclosure. The gas temperature can be lowered by taking the sample from the output of a heat exchanger or looping metal sample tubing to provide an in-air heat exchange.

If long sample line runs are required it is recommend that filters are installed at the input of the sample line. A combination of a fiber air filter and a 40 micron element filter can be used to prevent sample line clogging. Call Marathon Sensors Inc. for parts and recommendations.

### *Electrical Connections*

Following the enclosed wiring diagram, attach the Sentinel-ES thermocouple and millivolt terminals to your monitor or instrument as you would a normal carbon sensor.

The following diagram shows the basic electrical connections for the Sentinel-ES sensor.



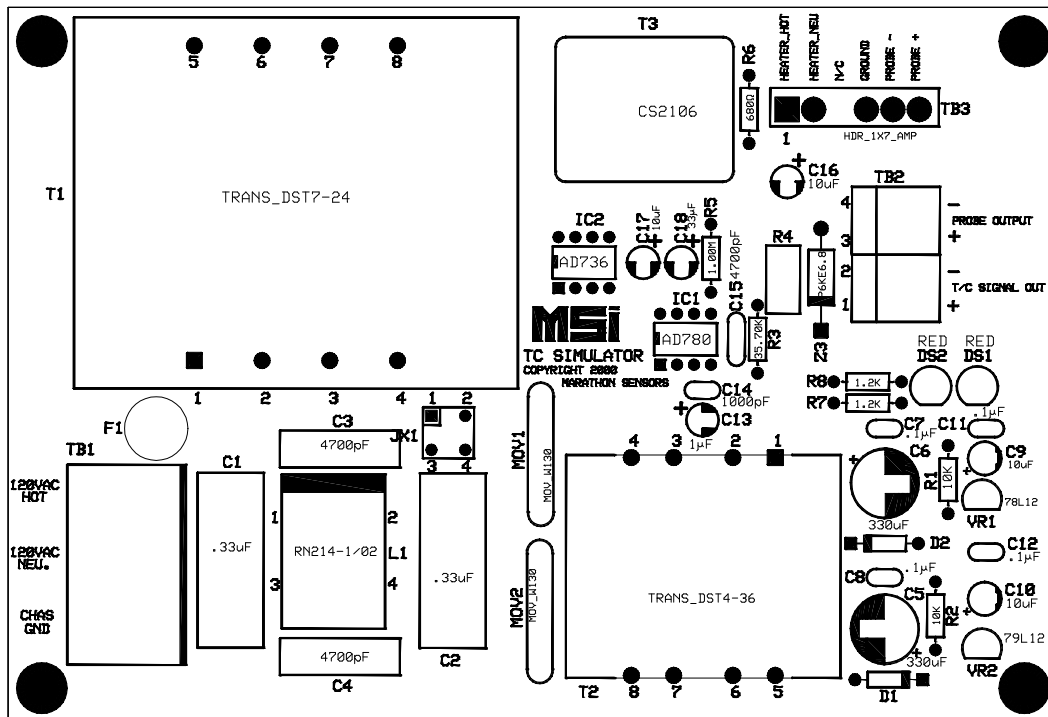
**Figure 1 Basic Sentinel Connections**

The system consists of a self-heating probe and thermocouple simulation circuit board. The thermocouple simulation board provides the connection point for the probe, power to the probe for the internal heater, a connection for the probe millivolt signal and the thermocouple signal.

The thermocouple output is calibrated to the probe heater temperature. This is done at the factory using a certified 1.0% oxygen gas. The thermocouple signal is adjusted for a type "K" thermocouple without cold junction compensation.

All the electrical connections for the system are made on the terminal blocks located inside the Sentinel enclosure. The AC power connections are located on the enclosure subpanel labeled as A1000 (LINE), A1021 (Neutral), and Ground (Green wire). The system is protected by a 1.0 Amp fuse located on the subpanel. An additional fuse (F1) is located on the Thermocouple Simulator near TB1

The DC signal terminal blocks are located on the Thermocouple Simulator board TB2. The following figure shows the parts locations of the Thermocouple Simulator.



**Figure 2 Thermocouple Simulator Board**

The signal output terminal block TB2 is located in the upper right hand section of the board. The thermocouple output is on TB2 – 1 (+) and TB2 – 2 (-). The Probe millivolt output is located at TB2 – 3 (+), and TB2 – 4 (-).

Use a twisted / shielded pair to connect to the signal outputs of the Sentinel. Marathon Sensors Inc. can supply wire if required. We recommend using Belden 89418, Marathon Sensors Inc. part number RO10011.

For all DC signal conductors it is necessary to ground the shield of the conductor on one end only. The shield ground point can be at the Sentinel or at a ground point where the control instrument is located. Follow good wire routing practice. Keep the signal wire away from AC power conductors. Do not run the signal wire in power conduit or trays. Do not expose the wire to temperature greater than 200 deg C.

### **Gas Connections**

Connect the incoming gas to the filter inlet on the left side of the enclosure. This connection is a ¼” CPI fitting with nut and ferrule included. The gas exits at the top of the enclosure through another ¼” CPI fitting. It is recommended that a continuous metal tubing be used to connect the gas to the enclosure. Be sure to properly vent the gas to an appropriate effluent.

Adjust the flow meter on the right side of the enclosure for a 1.0 SCFH (mid-scale) reading.

If your application requires a measurement from multiple retorts it is a good idea to set the sampling system up with small hand valves to allow any retort, or the summed output of all retorts, to be sent to the Sentinel. In normal operation, the summed output would be used and the retort-by-retort options would be reserved for trouble-shooting situations.

## Theory of Operation

The Sentinel relies on the fast response of the Lambda Probe to control changes in the process atmosphere. This sensor has been optimized to work in the normal combustion range for oxygen which is centered around the 1% to 3% range. The probe does not respond to the low or very high oxygen range with the same millivolt output as predicted by the Nurst equation when using standard zirconia oxide ceramics. The probe response is different when used in heat treating application but since it does react to changes in atmosphere it can be calibrated to specific set points used in any endothermic process.

The working range of the sensor is <10.0% oxygen to 4.34 E-19 oxygen. This corresponds to a sensor output of 6 mV to 1100 mV. In ambient air conditions (20.9% O<sub>2</sub>), the probe will output an -8.5 to -12 mV signal level. The sensor can not be used to measure oxygen levels above 10% or below levels for 0.7% carbon.

The Sentinel is factory calibrated with a 1.0 % oxygen cal gas. This sets the baseline for the probe's internal heater and establishes that the probe and the thermocouple simulator are working. When the Sentinel is used for dew point or carbon measurements it is necessary to increase the temperature output of the t/c simulator to get the required reading on the control or monitoring instrument.

The millivolt output of the lambda sensor is close to a standard zirconia oxide in the 1% oxygen range sensor but differs significantly in the % carbon range. **The sensor is well suited for dewpoint control, carbon ranges below 0.7% carbon, and ppm oxygen ranges.** It was necessary to adjust any difference between actual and measured values by changing the process factor of the measuring instrument or by adjusting the temperature of the Thermocouple Simulator.

The lambda sensor response is ideal for **constant setpoint control** in continuous operations such as generators, shakers, or rotary furnaces using carbon levels below 0.7%. The system can be calibrated to the set point of a constant carbon or dewpoint to maintain control around a fixed set point. All applications require a fixed set point where the system can be calibrated.

It is necessary to establish the actual carbon level or dew point level using shim stock for carbon or a portable analyzer that can read carbon and/or dew point. It is then possible to adjust the instrument process factor and/or the TC simulator temperature output to achieve the measured process level. At this point the system is calibrated to the actual process level and will continue to control around this setpoint. Once these adjustments have been made it is recommended the process factor and the temperature level be recorded. It is also recommended that the process factor number be changed if minor changes have to be made to the system calibration.

## Maintenance

### *Filters*

There are two filters in the Sentinel system. The first filter is mounted on the outside the enclosure on the left side. This is a Norgren 100 micron miniature air filter with a porous polypropylene element. The replacement part number of this filter element is Marathon Sensors Inc. part number F980609.

The second filter is located inside the enclosure. It is an in-line stainless steel 10 micron filter and element. The replacement kit includes the filter element, spring and seal. The kit can be ordered from Marathon Sensors Inc. by referencing part number F980632.

### *Probe Replacement*

The probe is a self-heated device that is screwed into the "T" piping fitting inside the enclosure. The probe can reach an operating temperature of 750 deg F or greater. It is important to remove power from the enclosure and allow the probe to cool before replacement is attempted.

Power can be removed from the circuit by pulling fuse A100. Allow 10 to 15 minutes for the probe to cool. Shut off the gas flow at the source and disconnect the probe from the plug-in header on the Thermocouple Simulation board. Unscrew the probe from the "T" fitting.

Replacement probes can be ordered from Marathon Sensors Inc. Request part number F800100. The probe is properly terminated for installation in the Sentinel. Remove the protective cover from the probe tip. Re-install into the "T" fitting. Finger tighten and the wrench tighten no more than a ¼ turn. Be careful not to bend or dent any of the tubing in the enclosure. If any bending of the tubing occurs perform a thorough leak check.

Reconnect the probe to the Thermocouple Simulator and re-install the fuse. Insert the fuse, turn on the sample gas flow and allow the probe to heat up for at least 30 minutes before making any adjustments to the system. If it is necessary to adjust the Thermocouple Simulator output refer to the calibration section for more information.

### ***Leak Testing***

A leak test of Sentinel-ES plumbing is warranted if any deformation or excessive stresses have been placed on the plumbing and/or fittings. To adequately leak test the Sentinel-ES pressurize the system using a nonvolatile gas, such as air or nitrogen, to a pressure of approximately 3-4 psi. Using a commercial leak check solution, swab all joints in the system and look for bubbles. Tighten any leaking joints in quarter-tun increments until all leaks are closed. Do not over-tighten as this may crack tubing.

## Calibration Procedure

The system operates on the assumption that the temperature of the internal probe heater is constant. This temperature is around 800 deg F. The lambda probe only provides a millivolt signal but a temperature signal is required to do many process calculations such as dew point, percent carbon, or oxygen. This is why the thermocouple simulation is provided. There may be minor differences between sensors or a change may be necessary for agreement with other measurement devices. To accomplish this, a trim pot is provided to adjust the temperature signal output level.

The thermocouple signal output is calibrated by adjusting trim pot R4. R4 is located on the Thermocouple Simulation circuit board inside the Sentinel enclosure. The R4 trim pot is just to the left of TB2. The factory calibration uses a 1% oxygen gas flow with a balance of nitrogen. Assuming a type K thermocouple input (no cold junction compensation), we adjust R4 to produce the correct oxygen reading. This temperature is the actual temperature of the internal probe heater.

If oxygen reading between 1% and 3% is are going to be made, no calibration is required when the thermocouple is assumed to be a type "K" with no cold junction compensation. If in-field calibration is required it is recommended that the calibration is checked with a certified calibration gas or against another standard device. Preferably the calibration gas should be one that is close to the oxygen content being measured in the process. An alternative method would be to compare the measured oxygen output to an oxygen analyzer. Adjust R4 (temperature) to provide the same oxygen level on the controller or monitor (if required).

If dew point readings are made, you should adjust the temperature level until the dew point reading agrees with another standard such as an Alnor.

## Specifications

### ***Lambda Sensor***

Temperature Range, storage	-40 deg C to +100 deg C
Sustained exhaust gas with heater on	+150 deg C to +600 deg C
Maximum exhaust gas temperature	+800 deg C
Load current	+/- 1 uA
Internal resistance	< 250 ohm
Output voltage in air	-8.5mV to -12mV
Relative sensitivity @ lambda = 1.30	0.65mV / .25% oxygen
Response time	jump to "lean" = 2.0 sec jump to "rich" = 1.6 sec

### ***Sensor Heater***

Normal Supply Voltage	12VAC
Operating Voltage	12V to 13V
Heater Rating	<16W
Heater Current	1.25A
Insulation between heater and connector	> 90 Mohm

### ***TC Simulator Board***

Operating Voltage	110VAC / 220VAC (jumper configured)
Operating Power	<12W
Heater Output	12VAC
T/C signal accuracy	3 ppm / deg C max

## Appendix A – Application Notes

### A.1 *Endothermic Generator Control*

The Sentinel-ES can be used with a Marathon Sensors Inc. atmosphere control instrument to adjust the generator's base gas/air ratio in order to hold the dewpoint to a setpoint. For example, if the setpoint is 40 deg F and the actual dewpoint is calculated to be 35 deg F, the instrument will decrease the gas/air ratio (by either adding air or subtracting gas) until the dewpoint reaches 40 deg F.

If preferable to let the carburetor do its job in mixing the largest portion of the gas and air from a manual setting. A trim flow of either gas or air is then used to supplement the carburetor's output. The control system actually "trims" the gas/air ratio over a fairly narrow range.

The ratio of the trim should be +/- 15% of the total volume. For example, with natural gas, the normal ratio is approximately 2.7:1 air to gas. The trim scheme should be designed so that this may be allowed to vary anywhere from 2.3:1 to 3.1:1. If the ratio needs to go outside of this range, there is a serious problem that needs to be investigated. As catalyst ages, it will be found that a progressively lower ratio is needed to hold the desired dewpoint.

A generator can be controlled with either gas or air. However, having both available provides the benefit of being able to set the generator up without any trim initially. When the ratio needs to change, it can do so in either direction.

If just one is used, it is necessary to set the generator up with the trim valve at its 50% position initially, so it can go up or down later. This adds a complication to the setup.

Either solenoid valves or motorized valves can be used to control gas flow. Both work well if they are set up properly to begin with. Motorized valves are more expensive and require more setup (linkages, etc.). But, they provide a continuously-variable flow which can be easily observed.

Solenoid valves are significantly less expensive, and when operated in time-proportioning mode, provide overall results that are as good as motorized valves. The downside is that it is difficult to know just how much trim is being applied without looking at the output on the controller itself.

It is critical that the trim flows be set up and monitored through the use of separate flowmeters. While you're at it, add a main gas flowmeter if your generator doesn't have one. This will allow you to compute the overall generator ratio at any time as a cross-check.

A properly tuned generator will normally run with very little control required unless upsets in demand occur. Because of the low volume in the Sentinel-ES™, it is sensitive to small changes in the oxygen content of the gas stream. A large proportional band and very little reset in the control instrument is usually sufficient to adjust for demand requirements. Typical installations can run with a proportional band of 150 or greater and a reset of 0.5.

## **Appendix B – Troubleshooting**

### ***B.1 No Millivolt output.***

Check to flow meter to verify that gas is flowing through the sensor.

Verify that power is applied to the enclosure and that the probe is hot. Do not actually touch the probe to make this determination. The two LED's on the Thermocouple Simulation board should be lit. If not, check fuse A100 and fuse F1. If either fuse had to be replaced, reapply power and allow the probe to heat up.

Verify that the probe connector is plugged onto the Thermocouple Simulation board. The plug and header are keyed to prevent misalignment.

Assuming that the probe is exposed to a process with an oxygen level below 15%, remove the signal wire connections at TB2 and verify that a millivolt signal can be measured at terminals TB2 –3 & 4.

If none of the above tests fix the problem it may be necessary to replace the sensor.

### ***B.2 No Thermocouple output***

Verify that power is applied to the enclosure and that the two LED's on the Thermocouple Simulation board are lit. If not check fuse A100 and fuse F1.

Remove any connections to TB2 – 1 & 2 and measure the output with a volt meter. Verify that the output can be adjusted by turning trim pot R4.

If none of the above tests fix the problem it may be necessary to replace the Thermocouple Simulation board.