SuperSystems
incorporated

SuperOX™

Oxygen Sensor

U.S. Patent No. 5,635,044

Operations Manual

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Introduction

Thank you for selecting the Super Systems Inc. (SSi) **SuperOX™ Sensor** for your combustion control application.

SuperOX™ represents "state of the art" in oxygen sensor technology. It has been designed for use in combustion control systems for glass, power, steel reheat, chemical process and incineration applications.

SuperOX™, with its patented measuring electrode construction, is the product of a team of design and application engineers, each with over twenty years of atmosphere control experience. The SSi engineering team has long recognized that the sensor is the most critical component in a control system and has traditionally been the weakest link. Now, reliability, repeatability and accuracy are assured with the use of SSi's SuperOX™ high temperature, in situ sensor in your system.

Specifications

- Useful O_2 Range:
  10^{-26} to 20.95% (air reference)
  10^{-25} to 100.0% (pure oxygen reference)
- Temperature range: 1150ºF to 3000ºF (620°C to 1650°C)
- Stability: within +/- 1 mvdc
- Impedance: less than 5 kohms @ 1700ºF
- Useful output: -50 to 1250 mvdc
- Overall length: 26.5" (67.31 cm), 35.5" (90.17 cm), and 44.5" (113.03 cm)
- Weight: 3.0 lbs.
- Insertion to 18" (45.72 cm), 27" (68.58 cm), and 36" (91.44 cm)
- Mounting: into 1" (25.4 mm) NPT female
- Sheath diameter: 1.00" (25.4 mm)

Characteristics

The typical zirconia oxygen sensor consists of a closed end tube with the sensing portion at the tip. The tube operates on the principle of yttria-stabilized zirconia. Figure 1 illustrates the SuperOX™ Sensor design with details omitted for clarity. The tip of the tube is spring loaded into contact with the outer, negative platinum electrode, which is in contact with the ceramic sheath. The inner, positive electrode is spring loaded into contact with the inner zirconia surface. A thermocouple is positioned close to the inner electrode surface and reference air bathes the sensing surface.

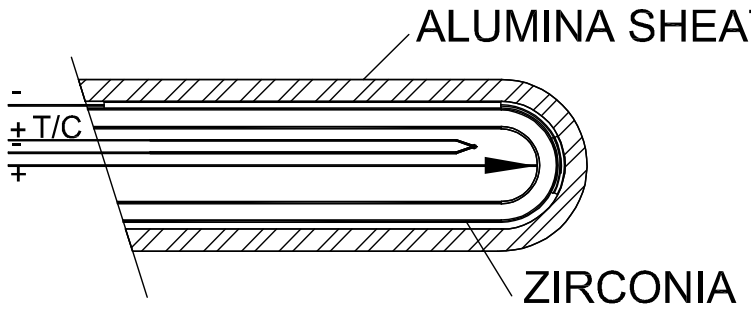


Figure 1

To the instrument technician, the sensor looks like a battery (see Figure 2). It displays a voltage, E_C, from which the carbon potential can be calculated. The probe thermocouple is shown next to the sensing electrode.

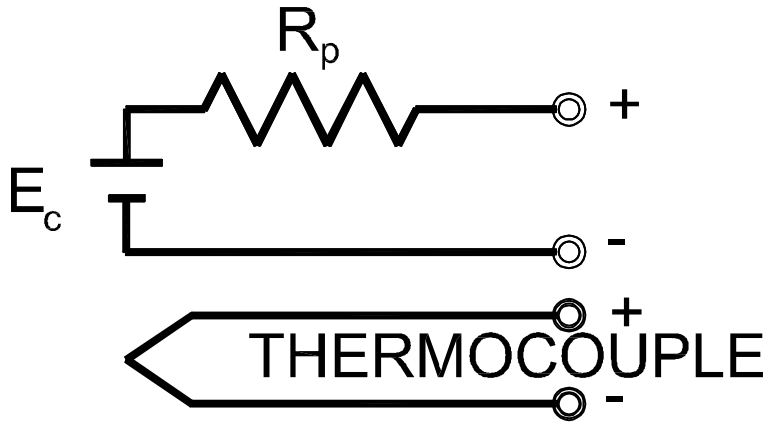
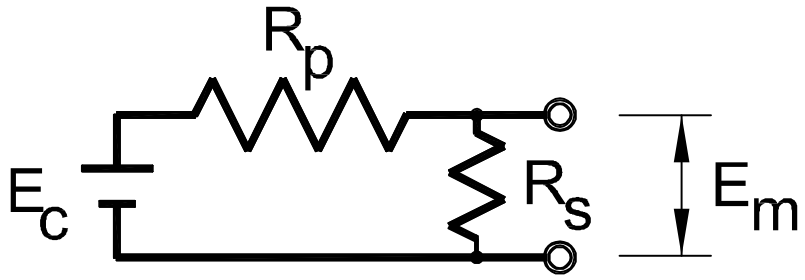


Figure 2

The value of the internal resistance can be measured, as shown in Figure 3, by connecting a shunt resistor across the sensor terminals, measuring the resultant voltage, E_m, and carrying out the simple calculation shown.



$$R_p = ((E_c / E_m) - 1)_s \times R$$

Figure 3

Operating Theory

Oxygen concentration of a conventional combustion atmosphere is measured by an in situ zirconia sensor, which responds to oxygen according to the Nernst equation shown here. Because the equation is logarithmic (to the base 10), the coefficient $0.0496T_R$ is the number of millivolts accompanying a tenfold change in concentration:

$$E_c = -0.02756T_R \log (P_R / P_F) \text{ millivolts}$$

where T_R is the temp in degrees Rankine and P_F and P_R are the % oxygen (O_2) in the furnace and the reference gas.

Installation

If your new sensor is to be installed in an existing entry port, be advised that the sensor is 100% interchangeable with your current sensor.

For new installations in furnaces, an ***entry fitting*** must be provided at the furnace wall to permit the sensor to extend into the furnace chamber. The furnace is prepared by drilling (ideally) a 3" (76.2 mm) diameter hole through the wall and the insulation. A 1" (25.4 mm) coupling may then be welded to the wall to provide the gas-tight entry. As the SuperOX™ has a 1" (25.4 mm) NPT hub; use of conventional 1" (25.4 mm) fittings allows for appropriate installation. A combination of 1" (25.4 mm) nipples and couplings allows for appropriate insertion depth.

Your **SuperOX™ Sensor** has been shipped with Teflon™ pipe tape applied to the gland, so you may insert it directly into the furnace. When installing in a hot furnace, insert the first two inches (50.8 mm) directly, then at a rate of no faster than 4" (101.6 mm) per 5 minutes in order to avoid thermal shock fracture. Support the cover end of the sensor during installation.

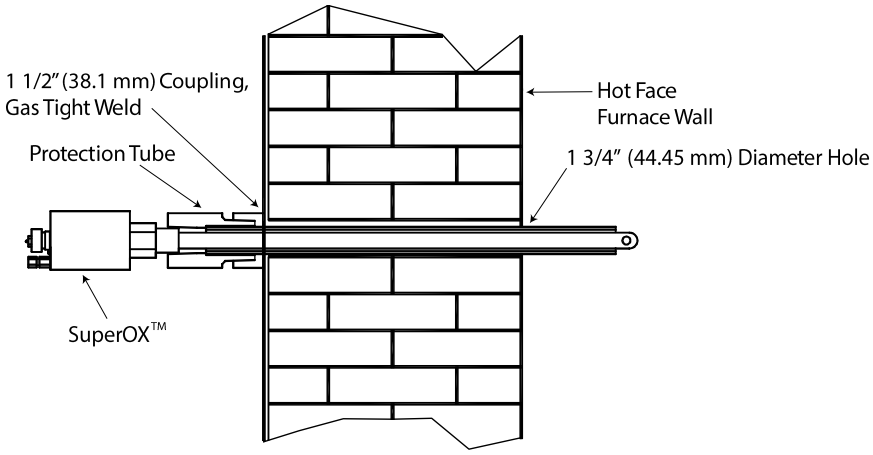
The sensor requires a reference air supply. In addition, the SuperOX™ Sensor has been designed with an optional cooling port that may require an additional air supply. SSi provides a custom system, P/N 13017, that supplies both requirements.

It is imperative to emphasize that the reference air must be ***dry, clean, and oil free.*** Any combustibles in the reference air will cause the sensor to read high in oxygen. Avoid the use of lubricated compressed plant air. The air connection at the sensor should be made of silicone rubber tubing to avoid problems related to the high temperatures normally encountered at the sensor connection block. Reference air flow should be in the range of 0.2 to 2 CFH at no more than 2 psi. Cooling air flow should be in the range of 1 to 10 CFH at no more than 2 psi.

Figure 4 and Figure 5 show installations in furnaces and glass tank regenerators.

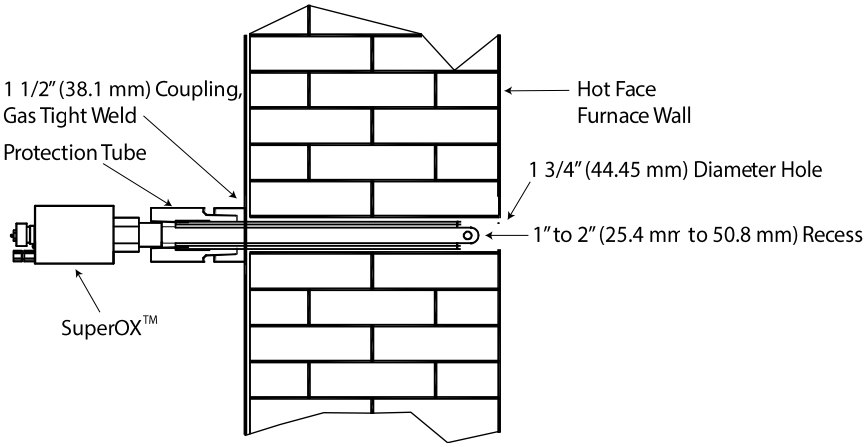
These views show the installation of SuperOX™ probes in the walls of two different furnaces furnace, utilizing a silicon protection tube which requires a 1 ½" (38.1 mm) coupling (or half coupling) entry. This arrangement is typically used for extremely high temperature applications. The wall is typically 13 ½" (342.9 mm) thick. Correct location of the sensor in the protection tube may be accomplished by inserting a 1" (25.4 mm) coupling and appropriate length 1" (25.4 mm) nipple between the sensor and the protection tube. There are three lengths of protection tubes for use with sensors of 18" (45.72 cm), 27" (68.58 cm) and 36" (91.44 cm) lengths. When using the unprotected sensor, a 1" (25.4 mm) coupling (or half coupling) can be used for direct entry.

NOTE: A protection tube is not required for use of the SuperOX™ Sensor.



Standard Installation

Figure 4



Glass Tank Installation

Figure 5

The standard SuperOX™, Ver. 2.0, is provided with a 5 foot long high-temperature cable, as illustrated in Figure 6, so that a plug may be mounted for interconnection with the customer's measurement and control instrumentation. Alternatively (and preferably), the customer may feed his instrument interconnection cable through the cord connector, and make connections directly to the internal connector.

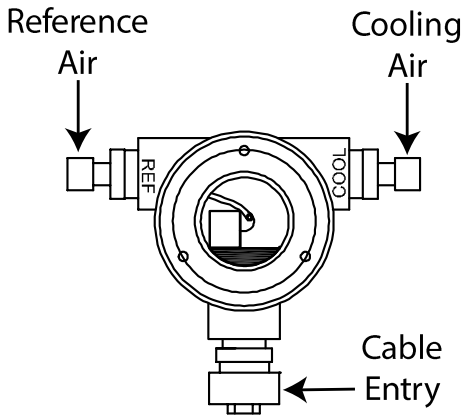


Figure 6

Wire designation:

White (Sensor +)
Black (Sensor -)
Green (Thermocouple +)
Red (Thermocouple -)

Troubleshooting

When trouble arises with an oxygen control system, it is important to establish where the problem is located: the sensor, signal transmission lines, the control instrument, or the combustion chamber itself. Several simple tests can help to isolate the problem quickly. It is most important to first understand the nature of the fault. Aside from erratic behavior like cycling, or failure to stabilize at the setpoint, the most common symptom is non-conformity of the work pieces to quality assurance specifications.

To evaluate most faults, the recommended tools are:

1. A 3 1/2-digit millivoltmeter with at least 10 MΩ input impedance and 0 to 1999 mV range;
2. A temperature calibrator; and
3. A simulator to output 0 to 200 millivolts at less than 50 MΩ output impedance.

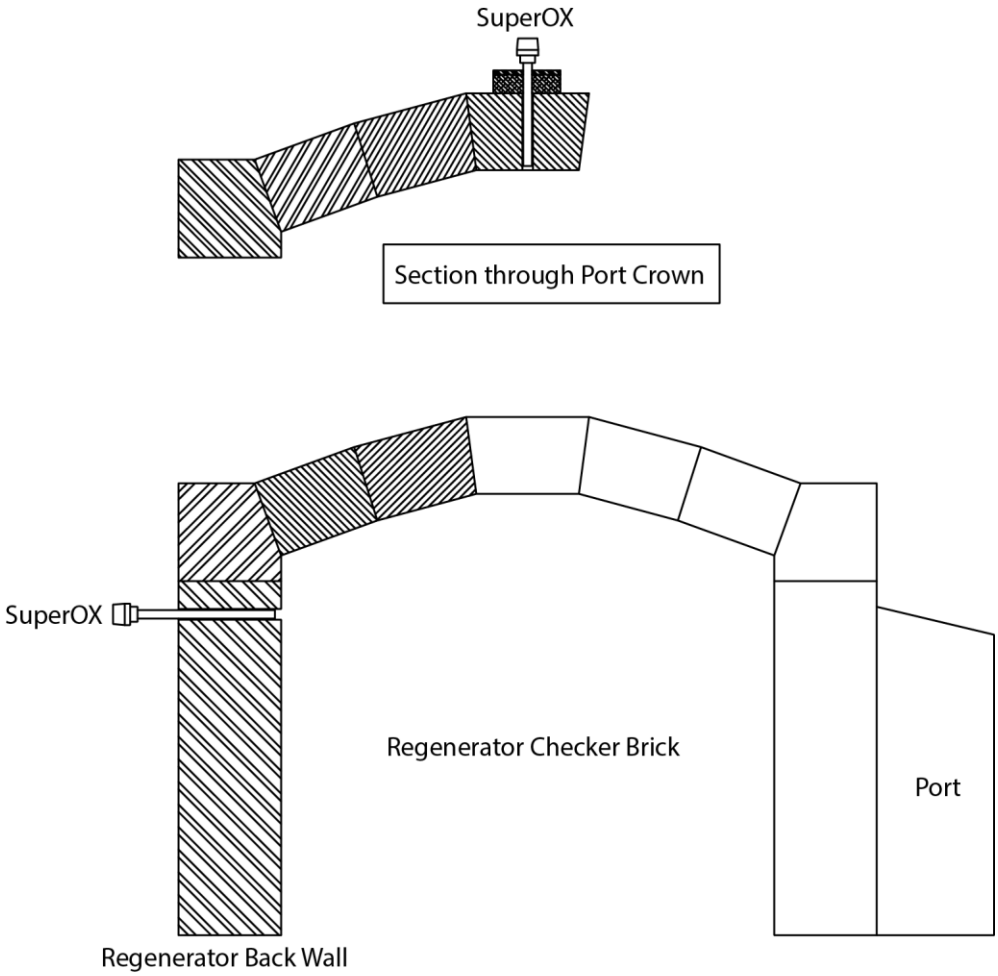
Sensor troubleshooting: In order to establish the source of problems in your installation, first ***avoid removing the SuperOX™ Sensor from the furnace.*** All of the following meaningful questions must be answered while your sensor is at temperature and is exposed to a normal atmosphere under **manual** control:

1. Are the connections from the T/C extension wire and sensor cable clean and firmly attached at the correct sensor and control instrument terminals? Note that the shield wire in the sensor cable should be connected to ground at the control instrument end only!
2. Is the sensor impedance less than 50 KΩ at temperatures above 1550°F? Conduct the test shown in Figure 3 using a shunt resistor of about 100 KΩ. Measure the voltage E_C before shunting, then E_M with the shunt in place. Calculate R_P. If it exceeds 50 KΩ, proceed to step 6 below.
3. How quickly does the sensor react to a change in O_2 concentration? Read the sensor millivolts with the controller or the digital meter. Short the sensor for 5 seconds, remove the short and measure the time required to return to within 1% of the original reading. If it exceeds 60 seconds, proceed to step 6, below.

4. Is there a leak in the zirconia substrate? To test this property, turn off the reference air for one minute. Measure the sensor mV as indicated by the controller or a digital voltmeter. Turn the air back on and measure the mV again. If there is a difference greater than 5 mV, replace the sensor.
5. Should it be necessary to remove your SuperOX™ Sensor from a hot furnace, do so carefully. UNDER NO CIRCUMSTANCES should it be removed faster than 4" (101.6 mm) per 5 minutes.
6. If your atmosphere control problem cannot be resolved, our technical support staff is available Monday through Friday, 7:00 a.m. to 6:00 p.m. Eastern Standard Time. You may call us at (513) 772-0060.

Glass Tank/Glass Furnace Installation

Figure 7 shows a diagram of a typical installation of a SuperOX™ Sensor into a glass tank/glass furnace.



Glass Furnace - Typical Installation
Figure 7

Safety Guidelines

WARNING: You must follow operational safety guidelines when drilling and installing a sensor in an operating glass furnace. It may be possible to use existing furnace openings. When repairing a furnace, or planning for new construction, you should consider drilling the holes for oxygen sensors.

The SuperOX™ Sensor contains a significant number of ceramic parts. It is therefore subject to thermal shock. The sensor must be installed in an area that provides an adequate, turbulent, and consistent gas stream representative of the atmosphere in the process. The sensor must be located so that the "hot" end can measure the oxygen level of the flue gas, at a temperature

greater than 1200°F (650°C), but less than 3000°F (1650°C) in a slightly positive pressure situation to prevent air in-leakage.

The sensor cannot be exposed in an area with excessive turbulence or high gas velocity, especially when there is particulate in the atmosphere. In order to comply with these requirements, SSI recommends that, for glass tanks with regenerative heating, the sensor be installed vertically in the center of the regenerator crown or horizontally on the regenerator "target" wall. Please note that target wall life will be significantly less when compared with a vertical, crown installation.

For glass tanks with recuperative heating, SSI recommends installation in a vertical position in the flue gas collector, behind the branch off, but in front of the gate valve. Please remember the temperature constraints when looking for this location.

You must drill 2 ¾ to 3 inch (19.05 to 76.2 mm) holes through the refractory brick. This will allow easy installation and removal of the SuperOX™ Sensor.

Vertical installation

Sensor should be recessed 1 to 2 inches (25.4 to 50.8 mm) into the refractory away from furnace atmosphere. When installing the probe, it is best to insure this length of insertion. From the hot face, one will recess the sensor until the readings begin to change. Once a change has been observed, lower the sensor approximately ½ inch (12.7 mm) and secure the sensor in place.

Horizontal Installation

SSI recommends that the "hot" end of the sensor extend approximately 3 to 5 ½ inches (76.2 to 139.7 mm) beyond the hot face of the refractory. If there is an excessive amount of batch carry-over, or if the gas stream has a very high velocity, it is recommended that the sensor be recessed. Batch carry-over and high velocity gas will erode the sensor and significantly reduce life.

Sensor Preparation before installation

When using the SSI oxygen mounting assembly, place the sensor at the maximum height possible and lower it toward the furnace 2 to 4 inches (50.8 to 101.6 mm) every five minutes. If you do not have an SSI Mounting Assembly, note that approximately 2 hours before installing the sensor, you should lay the sensor on top of the regenerator (for pre-warming), taking care to protect the sensor head and wiring assembly.

Sensor installation (insertion) rate

WARNING: You must follow operational safety guidelines when drilling, and installing a sensor in an operating glass furnace. It may be possible to use existing furnace openings. When repairing a furnace, or planning for new construction, you should consider drilling the holes for oxygen sensors.

Insertion of the sensor should be no greater than 4 inches (101.6 mm) every 5 minutes.

Installation Hints:

The sensor will need to be supported while being installed. The installation process will take 1 to 4 hours depending upon sensor length and rate of insertion. When the sensor is in its final position, it is recommended that the opening be covered or filled with fiber blanket around the protection tube.

NOTE: The sensor is warranted against workmanship defects, but not against damage caused by installing the sensor incorrectly.

1. SuperOx™ - Maintenance

It is important to check the sensor's position every one to two months. If the fiber placed around the protection tube and the bored hole has shrunk, add fiber into the area between the protection tube and the bored hole. Use wooden sticks or dowels. Touching the HOT ceramic tube with a metal screw driver is NOT recommended.

The sensor head should be observed for any excessive temperature. The internal workings of the sensor head will ideally be exposed to temperatures no greater than 150 to 200°F (65 to 93°C).

During troubleshooting, it may be necessary to read the sensor millivolts from the sensor. If you are asked to supply this information, please remove the electrical connection from the head of the sensor and, using a digital voltmeter, measure the sensor millivolts by touching pins "1" and "2," and then observing the number reading. The number should be between 30 and 125 millivolts during a firing cycle. Check the reading against a millivolt vs temperature Oxygen Chart. You can check the temperature by measuring the millivolts across pins "3" and "4". These values can be correlated using a "B-Type" thermocouple chart.

2. Reference Air System - Installation

The reference air system should be installed in an area protected from excessive heat and dust. It is recommended that it be installed on a column or wall, at a height easily accessible for maintenance of the air pump. The system should be installed with respect to local electrical regulations. The reference airline needs to be run from the reference air system to the head of the sensor. The line can be run using ¼ inch (6.35 mm) tubing (stainless or copper). Terminate the tubing approximately 6 inches (152.4 mm) from the sensor head and finish the connection with flexible tubing included in the sensor carton.

3. Reference Air System - Maintenance

The reference air system requires little maintenance. Changing the filter (dependent on the dust level) 4 - 6 times per year ensures that the sensor receives a quality source of reference air for proper function. The amount of reference air supplied to the sensor should be maintained at 0.5 – 1.5 SCFH. The reference air pump needs to be checked periodically to ensure proper operation.

Warranty

- Super Systems Inc. (SSi), as manufacturer of the SuperOX™ Sensor, warrants it to be free from defects in material and workmanship for a period of twelve (12) months under normal use and service. SSi's obligation under this warranty is limited to repairing or replacing, at its option, the sensor described herein, should failure occur within the warranty period. The warranty period shall commence on installation of the sensor. If premature failure occurs, the sensor must be returned in the complete, original packaging to SSi. Upon receipt, SSi will conduct an examination as to the cause of failure, at which time appropriate action will be taken. See more information on arranging for shipment of the sensor below.

- There are no warranties, expressed or implied, by the distributors or representatives for the SuperOX™ Sensor, except the expressed warranty against defects described above. There will be no applicable warranty in the event of breakage resulting from thermal or mechanical shock. Additionally there will be no applicable warranty for a sensor that has been subjected to misuse or negligence, or was damaged in an accident. SSi shall in no way be liable for special or consequential damages related to the use of this sensor.

- In the case of failure or malfunction, the user must call SSi at (513) 772-0060 to arrange for shipment of the SuperOX™ Sensor to SSi. As part of arranging shipment, SSi will issue a Return Materials Authorization (RMA) number. The product must be returned in the original packaging. It is also recommended that the user fill out the Warranty Claim Report that is sent with the new SuperOX™ Sensor.

Notes

We suggest that you use this space to keep a record of installation date, test data and experiences with your SuperOX™ Sensor.

Revision History

Rev.	Description	Date	MCO #
-	Initial Release	03/21/2001	N/A
A	Added Revision History	07/11/2001	N/A
B	Revised Fig 5 Drawing, changed Step 8 to read Step 6	02/19/2002	2024
C	Changed “eight inches” to “two inches” Page 2 Installation Instructions	06/04/2003	2029
D	Changed company address	05/15/2005	N/A
E	Corrected air flow parameters under Installation	06/23/2011	2082
F	Changed manual to new format; implemented updated artwork to increase clarity; added Glass Tank/Glass Furnace Installation; revised contents as needed to match product parameters.	05/22/2013	2123
G	Adjusted range information	8/20/2020	2297