ALPHA OMEGA INSTRUMENTS

SERIES 3500
TRACE OXYGEN TRANSMITTER

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WARRANTY

Alpha Omega Instruments Corp. warrants the products delivered to be free from defects in material and workmanship at the time of delivery to the FOB point specified in the purchase order, its liability under this warranty being limited to repairing or replacing, at Alpha Omega Instruments' option, items (excluding the oxygen sensor) which are returned to it **prepaid** within two (2) years from the date of shipment and found to Seller’s satisfaction to be defective.

Alpha Omega Instrument's one (1) year sensor warranty offers protection for one full year from the date of shipment of the Series 3500 Trace Oxygen Transmitter. Any sensor from a Series 3500 Trace Oxygen Transmitter that fails under normal use must be returned to Seller prepaid and, if such sensor is determined by Seller to be defective, Seller shall provide Buyer a replacement sensor. Buyer must provide the serial number of the transmitter from which the sensor has been removed. If a sensor is found to be defective and a new one issued, the warranty of the replacement sensor (s) is for a period of one year from the date of shipment. At times, it may be necessary to ship a replacement sensor in advance of receiving one returned for warranty claim. In such cases, if the returned sensor is not covered under warranty, the user will be charged the full price of a replacement sensor. **In no event shall Alpha Omega Instruments Corp. be liable for consequential damages. NO PRODUCT IS WARRANTED AS BEING FIT FOR A PARTICULAR PURPOSE AND THERE IS NO WARRANTY OF MERCHANTABILITY.**

This warranty applies only if:

(i) the items are used solely under the operating conditions and manner recommended in this manual, specifications, or other literature;

(ii) the items have not been misused or abused in any manner or repairs attempted thereon;

(iii) written notice of the failure within the warranty period is forwarded to Alpha Omega Instruments Corp. and, the directions received for properly identifying items returned under warranty are followed;

(iv) the return notice authorizes Alpha Omega Instruments Corp. to examine and disassemble returned products to the extent the Company deems necessary to ascertain the cause of failure.

The warranties stated herein are exclusive. THERE ARE NO OTHER WARRANTIES, EITHER EXPRESSED OR IMPLIED, BEYOND THOSE SET FORTH HEREIN, and Alpha Omega Instruments Corp. does not assume any other obligation or liability in connection with the sale or use of said products.

Disclaimer of Warranty

Alpha Omega Instruments Corp. makes no representation or warranties, either expressed or implied, by or with respect to anything in this manual, including, but not limited to, implied warranties of merchantability or fitness for a particular purpose. In no event will Alpha Omega Instruments Corp. be liable for any damages, whether direct or indirect, special, consequential, or incidental arising from the use of this manual. Some states in the USA do not allow the exclusion of incidental or consequential damages. Alpha Omega Instruments Corp. also reserves the right to make any changes to improve the performance of its products at any time and without notice.

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SECTION 1.0
SPECIFICATIONS

PERFORMANCE

Measurement Ranges (parts per million)
0-10, 0-50, 0-100, 0-500, 0-1,000, 0-5,000, 0-10,000, and 0-20,000.

Accuracy [1]	± 1% of full scale.
Linearity	± 1% of full scale.
Response Time	90% of full scale in less than 10 seconds (typical). The response time for ranges of 0-50 PPM or less depend to a great extent on the design of the sample delivery system including the materials used.
Sensor Type	Electrochemical Sensor. (Optional CO2 Resistant Sensor Available).
Temperature Compensation	Standard.
Operating Temp. Range	40° to 105°F (5° to 40°C). <40° F (<5º C) use heated sensor enclosure >104ºF (>40º C) cooling of sample gas/sensor required
Warranty	Two years electronics one year sensor.

ELECTRICAL

Electrical Input	14-32 VDC @ 4-20
Analog Output	4-20 mADC with a maximum loop resistance of 600 ohms.

SAMPLE GAS CHARACTERISTICS

Sample Flow Rate	1.0 to 2.0 standard cubic feet per hour (SCFH). 0.5 to 1.0 liters/ minute (LPM).
Sample Gas Pressure Limits.	0.1 to 1.5 psig (0.007 to 0.1 kg/cm^2).
Entrained Solids	<3 mg/ft^3 no in-line filter required >3 mg/ft^3 in-line filter required

Hydrocarbon Mist
<0.7 mg/ft^3 no in-line filter required
>0.7 mg/ft^3 in-line filter required

CONSTRUCTION

Enclosure
Polycarbonate, rated NEMA 4X (IP66) without optional equipment
Optional NEMA 7 Explosion Proof

Gas Connections:
1/4" compression fittings with manual isolation valves.

Dimensions
5.5 in (139.9 mm) length.
8.8 in (223.5 mm) width.
3.4 in (86.4 mm) deep.
Note: All dimensions are without optional equipment

[1] Stated at constant temperature and pressure

SECTION 2.0
SYSTEM DESCRIPTION

General Description

The Series 3500 Trace Oxygen Transmitter is a DC powered trace oxygen transmitter designed to provide accurate and dependable trace oxygen measurements in a variety of gases. The transmitter enclosure is made from durable polycarbonate, and is rated for NEMA 4 (IP 66) service.

The instrument is powered from 14 - 32 Volts DC and provides a 4-20 mADC output that can be sent to a datalogger, recorder, PLC, DCS, etc. Options include a pressure regulator, flow meter, an in-line filter for sample gases that contain particulate matter, and explosion proof (NEMA 7) housing.

Ambient Temperature Electrochemical Sensor

The Series 3500 Trace Oxygen Transmitter features an advanced trace oxygen sensor. The sensor is a lead-oxygen battery comprised of a lead anode, a gold plated cathode, and an electrolyte consisting of potassium hydroxide. All types of electrochemical transducers have three primary components; a cathode, anode, and electrolyte. In the Alpha Omega Instruments advanced oxygen sensor, the cathode is the sensing electrode or the site where chemical reduction of the oxygen takes place.

The chemical reactions are as follows:

Cathode Reaction $4e^- + O_2 + 2H_2O \longrightarrow 4OH^-$ (1)

In the above reaction, four electrons combine with one oxygen molecule to produce four hydroxyl ions. This cathodic half-reaction occurs simultaneously with the following anodic half-reaction:

Anode Reaction $Pb + 2OH^- \longrightarrow PbO + H_2O + 2e^-$ (2)

The anode (lead) is oxidized (in a basic media) to lead oxide and in the process, two electrons are transferred for each atom of lead that is oxidized. The sum of the half-reactions (1) and (2) results in the overall reaction (3):

Overall Reaction $O_2 + 2Pb \longrightarrow 2PbO$ (3)

From this reaction it can be seen that the sensor is very specific for oxygen providing there are no gaseous components in the sample stream capable of oxidizing lead. The only likely compounds that meet this requirement are the halogens (iodine, bromine, chlorine, and fluorine).

In reaction (1), four electrons are transferred for each oxygen molecule undergoing reaction. In order to be reacted, and oxygen molecule must diffuse through both the sensing membrane and the thin film of electrolyte maintained between the sensing membrane and the upper surface of the cathode. The rate at which oxygen molecules reach the surface of the cathode determines the electrical output. This rate is directly proportional to the concentration of oxygen in the gaseous mixture surrounding the sensor cell.

SECTION 3.0
INSTALLATION PROCEDURES

Unpacking the Instrument
Upon opening the shipping container, carefully unpack the transmitter to check if the outer surfaces have been damaged. If so, report the findings immediately to Alpha Omega Instruments who will provide further instructions. If there is no apparent damage, check the contents to ensure all items were shipped. In some cases, items may be backordered.

ALL DAMAGE AND SHORTAGE CLAIMS MUST BE MADE KNOWN TO ALPHA OMEGA INSTRUMENTS WITHIN 10 DAYS AFTER RECEIPT OF SHIPMENT.

There are four screws securing the cover of the Series 3500 Trace Oxygen Transmitter. Removing these screws allows access to the inside of the enclosure. The cover should be removed and the interior of the enclosure checked to ensure that no components have been loosened or dislodged. **If there are loose or dislodged components, notify the factory for further instructions.** If all is found to be satisfactory, the installation procedure can begin.

For a Series 3500 instrument supplied with an explosion proof NEMA 7 enclosure, access to the inside of the instrument is gained by removing the cast aluminum cover from the base by turning the cover in a counterclockwise fashion. **If there are loose or dislodged components, notify the factory for further instructions.** If all is found to be satisfactory, the installation procedure can begin.

Electrical Installation
The Series 3500 Trace Oxygen Transmitter is powered by a user supplied power supply, and as such, there is no AC power cord. Power to the Series 3500 should be 14 - 32 VDC @ 4-20 mADC. Consideration should be given to the loop resistance of the cable in relation to the DC power used. The following formula should be used to determine the maximum loop resistance allowed for your power supply:

$$RL\ (K\ ohms\ max>) = \frac{Input\ VDC - 12}{20}$$

Wiring to the Analog Output
The Series 3500 Trace Oxygen Transmitter is a true blind transmitter, that is, it has no power source of its own and operates from loop power supplied by an external power supply. The Series 3500 will adjust the load current on the external power supply in such a manner that the loop current that flows will reflect the level of oxygen being measured over the milliamp current range of 4-20 mADC. To wire to the 4-20 mADC output, connect the external power supply to terminals J8(+) and J9(-) Please refer to figure 2, Wiring Details for the 4-20 mADC Output.

Plumbing Installation
The Series 3500 Trace Oxygen Transmitter is equipped with 1/4" compression fittings for both gas inlet and outlet. *CAUTION: WHENEVER TIGHTENING GAS CONNECTIONS, IT IS IMPERATIVE THAT THE MANUAL VALVES NOT BE TWISTED OR TURNED. A CRITICAL GAS SEAL MAY BE DISRUPTED, LEADING TO AIR LEAKAGE! THIS WILL VOID ANY WARRANTY.*

SECTION 4.0
OPERATING PROCEDURES

Gas System Pressure Limits
For sample gases and/or calibration gases that are under pressure, it is imperative that the sample gas pressure to the sensor be kept to under **1.5 pounds per square inch**. If it is expected to be in excess of 1.5 psig (0.1 kg/cm^2) a pressure regulator should be used.

Range Identification
The Series 3500 Trace Oxygen Transmitter is available in eight (8) different ranges. To identify the specific range of the transmitter in question, please refer to the original purchase order document or invoice from Alpha Omega Instruments. In it, you will find a model number starting with the number 3500. The letter immediately following "3500" is the range identifier. The various ranges, with their associated identifier, are as follows:

Range	Identifier
0-10 ppm	A
0-50 ppm	B
0-100 ppm	C
0-500 ppm	D
0-1,000 ppm	E
0-5,000 ppm	F
0-10,000 ppm	G
0- 20,000 ppm	H

Over Range
It is quite important that the sensor not be exposed to high levels of oxygen for prolonged periods of time. Should this happen, response time will be adversely effected. To help eliminate this problem, the Series 3500 Trace Oxygen Transmitter is equipped with valves that are used to isolate the sensor during times when the instrument it is in storage, in transit, or off line. When not in use, it is highly recommended that the sensor housing be purged with an inert gas to ensure an "on scale" oxygen reading is obtained. Once accomplished, the sensor should be isolated by closing both valves. It is recommended that the inlet valve be closed first, followed immediately by the outlet valve (optional AC or DC powered solenoid valves are available from the factory). Alpha Omega Instruments sensor housing has been helium leak tested and shown to provide exceptional protection from ingression of oxygen from sources outside the housing.

Sample Connections
The sample flow connections to the Series 3500 Trace Oxygen Transmitter are 1/4 inch stainless steel compression fittings.

Electrical Output
The standard Series 3500 provides 4-20 mADC output over the range of instrument. A signal of 4 mADC is equivalent to 0 ppm oxygen with 20 mADC equivalent to the full scale value.

SECTION 5.0
CALIBRATION PROCEDURES

Routine Span Gas Calibration Checks

The Series 3500 Trace Oxygen Transmitter has been calibrated at the factory prior to shipment. However, with the potential hazards associated with shipping instrumentation, it is advisable that the transmitter be given a system calibration check prior to start-up. Alpha Omega Instruments trace oxygen sensors feature high accuracy and excellent long term stability characteristics. As a result, routine maintenance is kept to a minimum. As is the case with all gas analyzers and transmitters, it is advisable to periodically check the overall system calibration. The frequency of these checks is often determined by in-house calibration protocols. If none exists, Alpha Omega Instruments Corp. recommends a calibration check be made once every 2-3 months.

Calibration Gas

The oxygen sensor used in the Series 3500 Trace Oxygen Transmitter has a linear output. As a result, it can be calibrated using a single calibration gas as long as the test is performed accurately. The calibration gas should contain a defined concentration of oxygen with a balance of nitrogen (N_2). The actual concentration of oxygen should be chosen based on the range of the transmitter. Alpha Omega Instrument's recommendation is to obtain a calibration gas that has a concentration of oxygen somewhere between 40-60% of full scale. For instance, if a transmitter has a measuring range of 0-10 ppm, a calibration gas containing 4-6 ppm oxygen/balance nitrogen should be used.

Procedure for Checking Calibration

1) Select a cylinder of calibration gas as described above.

2) When selecting a pressure regulator to use with the cylinder gas, it is advisable to use a two-stage regulator with the second stage capable of delivering a gas sample at a pressure of 1.0 psig. Also, be sure to choose a regulator with a **metal diaphragm, preferably stainless steel.**

3) In addition to the selection of the pressure regulator, care must be taken to choose the correct sample tubing materials. For trace oxygen measurements, stainless steel or copper tubing is the material of choice.

4) Begin flowing the calibration gas to the transmitter by connecting the gas to the inlet valve. The flow of calibration gas should be set to 0.5 liter per minute. If the optional flow meter was not purchased with the Series 3500, it is advisable to secure one for use during calibration. Begin monitoring the 4-20 mADC output waiting until a stable reading has been established.

5) Once the oxygen reading has stabilized, check the system for gas leaks. This is best done when step 4 has been completed. An easy method of determining the leak integrity of the system is to vary the flow rate of the calibration gas. If increasing the flow rate from 0.5 liter per minute to 1 liter per minute causes a drop in the reading, there is a good chance that somewhere between the gas source and inlet to the sensor there is a leak. Check all gas fittings, connections, etc. If the integrity of the sample delivery system appears to be good, move on to step 6.

6) The milliamp current output controlled by the transmitter should reflect the oxygen concentration of the calibration gas. As an example, if a 0-10 ppm range transmitter is being calibrated with a 5 ppm calibration gas, an output of 12 mADC should be obtained. The general form of the equation for determining the oxygen concentration reading "*PPM*" from the 4-20 mADC reading in milliamps "*mADC*" is:

$$PPM = (mADC - 4) \times FSV/16$$

where "*FSV*" is the Full Scale Value for the oxygen range selected. In the example given above, $PPM = (12 - 4) \times 10/16 = 5$ ppm.

7) If the oxygen value obtained from the analog output differs from that which is expected from the calibration gas, a span adjustment should be made. (BE SURE TO ALLOW THE READING TO COME INTO EQUILIBRIUM BEFORE MAKING ANY ADJUSTMENTS. OXYGEN ADSORBED ON INPUT LINES, VALVES, REGULATORS AND FILTERS MAY TAKE SOME TIME TO COMPLETELY DESORB) To accomplish this, refer to Figure 1.0 and locate the gain adjustment (R26). Adjust this potentiometer so the oxygen value reflected in the analog output is equal to the oxygen value represented by the calibration gas.

Once step 7 has been completed, resume normal operation.

Zero Adjustment
During factory calibration, the zero adjustment is made to compensate for parts per billion concentrations of oxygen that enter the sensor housing and plumbing system through leakage. In addition, there is a small error produced by oxygen dissolved in the electrolyte of the sensor. The amounts vary from system to system, but it is not uncommon to have an oxygen readings in the range of 0.1 ppm. Alpha Omega Instruments does not recommend the user make any zero adjustments unless a new sensor has been installed. To make a zero gas adjustment, the steps outlined in the aforementioned section should be followed with some important distinctions.

The sample gas used for zeroing the transmitter should be catalytically scrubbed in order to remove residual oxygen. After treatment, the zero gas should contain **< 50 ppb** of oxygen. Do not attempt to make any adjustments to the zero setting unless the quality of the zero gas sample can be assured to be as described above.

Once the transmitter is placed on zero gas, enough time should be given for the reading to stabilize. This length of time will be predicated on factors such as length of tubing, tubing material, flow rate, etc.

Once the zero reading has stabilized, if the oxygen value obtained from the 4-20 mADC output is not equivalent to zero (4 mADC) an offset adjustment should be made. To do this, locate the zero adjustment R18 (Figure 1.0). Adjust this potentiometer so the oxygen value reflected in the 4-20 mADC output is at 4 mADC. Once accomplished, the transmitter can now be placed back in service.

SECTION 6.0
REPLACEMENT OF THE OXYGEN SENSOR

Procedure for Replacing the Oxygen Sensor
The Alpha Omega Instruments oxygen sensor is designed to operate for prolonged periods of time without replacement. However, in time the sensor's performance will dictate that a replacement be made. One indicator is a decrease in time intervals for routine calibrations. When this happens, a replacement sensor should be ordered directly from the factory.

To install a new sensor follow the directions below:

1. Remove power from the instrument.

IT IS ADVISABLE TO KEEP A LOW PPM GAS FLOWING THROUGH THE SENSOR HOUSING WHILE THE SENSOR IS BEING REPLACED. IT IS IMPORTANT THAT WHEN A NEW SENSOR IS INSTALLED, THE TIME BETWEEN WHEN IT WAS UNPACKED AND FIRST EXPOSED TO CALIBRATION GAS SHOULD BE KEPT TO AN ABSOLUTE MINIMUM. THE AMOUNT OF TIME TAKEN TO ACHIEVE THE GAS CALIBRATION LEVEL IS A FUNCTION OF HOW LONG THE SENSOR WAS EXPOSED TO AIR DURING REPLACEMENT. WHEN A NEW SENSOR IS INSTALLED, IT MAY TAKE APPROXIMATELY ONE HOUR TO REACH EQUILIBRIUM ON A CALIBRATION GAS.

2. Locate the sensor housing (metal enclosure mounted below the polycarbonate enclosure).
If the enclosure to which the sensor housing is attached is permanently mounted and the gas lines are rigidly installed, it will be necessary to disconnect both gas inlet and outlet lines.

3. With one hand supporting the sensor housing, loosen (do not remove) the four servo clamp screws that hold the metal ring to the enclosure. The sensor housing will drop from the enclosure.

4. Disconnect the modular connector at the top of the sensor housing.

5. Remove the socket head screws that hold the two halves of the sensor housing together. Once these screws have been removed, the two halves should easily separate.

WHEN SEPARATING THE TOP HALF OF THE SENSOR HOUSING FROM THE BOTTOM HALF, NEVER TWIST THE TWO AS THIS WILL CAUSE DAMAGE TO THE SPRING LOADED PINS THAT ARE USED TO MAKE ELECTRICAL CONNECTION TO THE SENSOR. ALSO, BE CAREFUL NOT TO BEND THESE PINS WHEN THE SENSOR HALVES ARE APART.

6. Remove the old sensor from the bottom half of the sensor housing.

THE SENSOR CONTAINS A SMALL AMOUNT OF CAUSTIC ELECTROLYTE, WHEN DISCARDING SPENT SENSORS, CARE SHOULD BE GIVEN NOT TO PUNCTURE THE SENSOR OR TO TAKE IT APART. DISPOSE OF THE SPENT SENSOR ACCORDING TO LOCAL, COUNTY, OR STATE GUIDELINES.

7. Remove the existing O ring and examine the grooves in the upper and lower halves of the sensor housing to be sure they are clean. Replace the O ring with the new one supplied with the sensor. Apply a light coating of silicon grease to the O ring prior to reinstalling the O ring.
8. Remove the new sensor from its package. Before installing it in the lower half of the sensor housing, REMOVE THE CAP and then install the sensor with the two gold rings facing outward from housing.

9. Take the two halves of the sensor housing and align them so the socket head screws can be reinstalled. Hand tighten the socket head screws being careful to do so evenly. If any resistance is experienced when starting any of these three socket head screws, do not force the screws into the threads. Instead, if resistance is felt, simply rotate the screw CCW while pushing down on it until you feel the threads snap to a new starting location and again try to install the screw in the CW direction. If there is still a resistance to installing the screw, repeat the above procedure until the screw can be started without any difficulty.

10. Reconnect the cable and install the sensor back on the case with the servo clamp.

11. Reconnect the gas lines and begin processing gas through the sensor housing. Apply power and calibrate according to previous instructions.

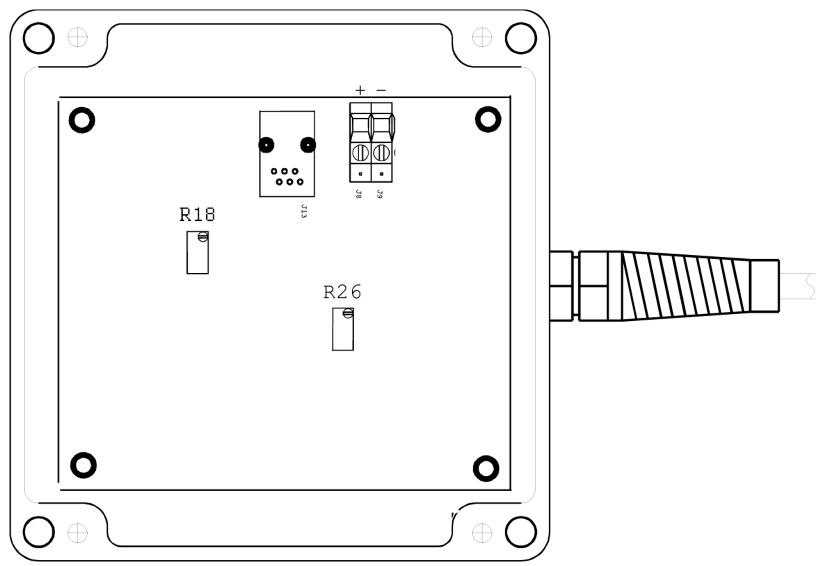

Figure 1.0
Series 3500 Transmitter Board

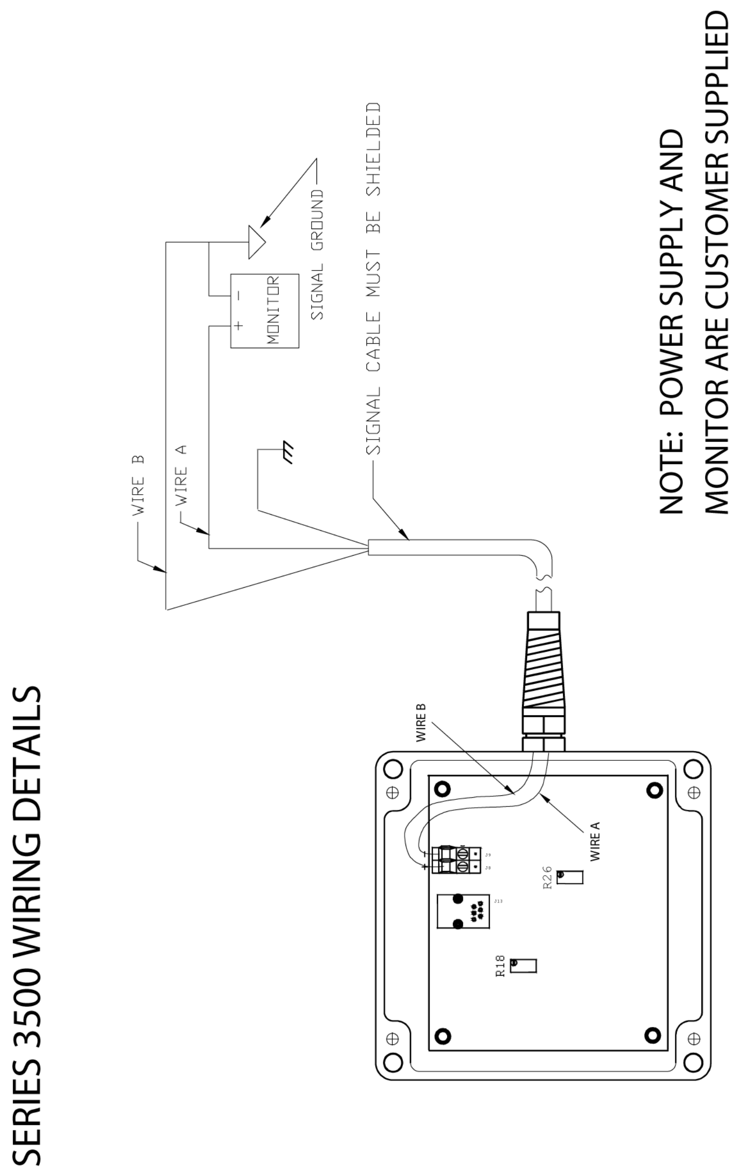

Figure 2.0
Wiring Details for the 4-20 mADC Output

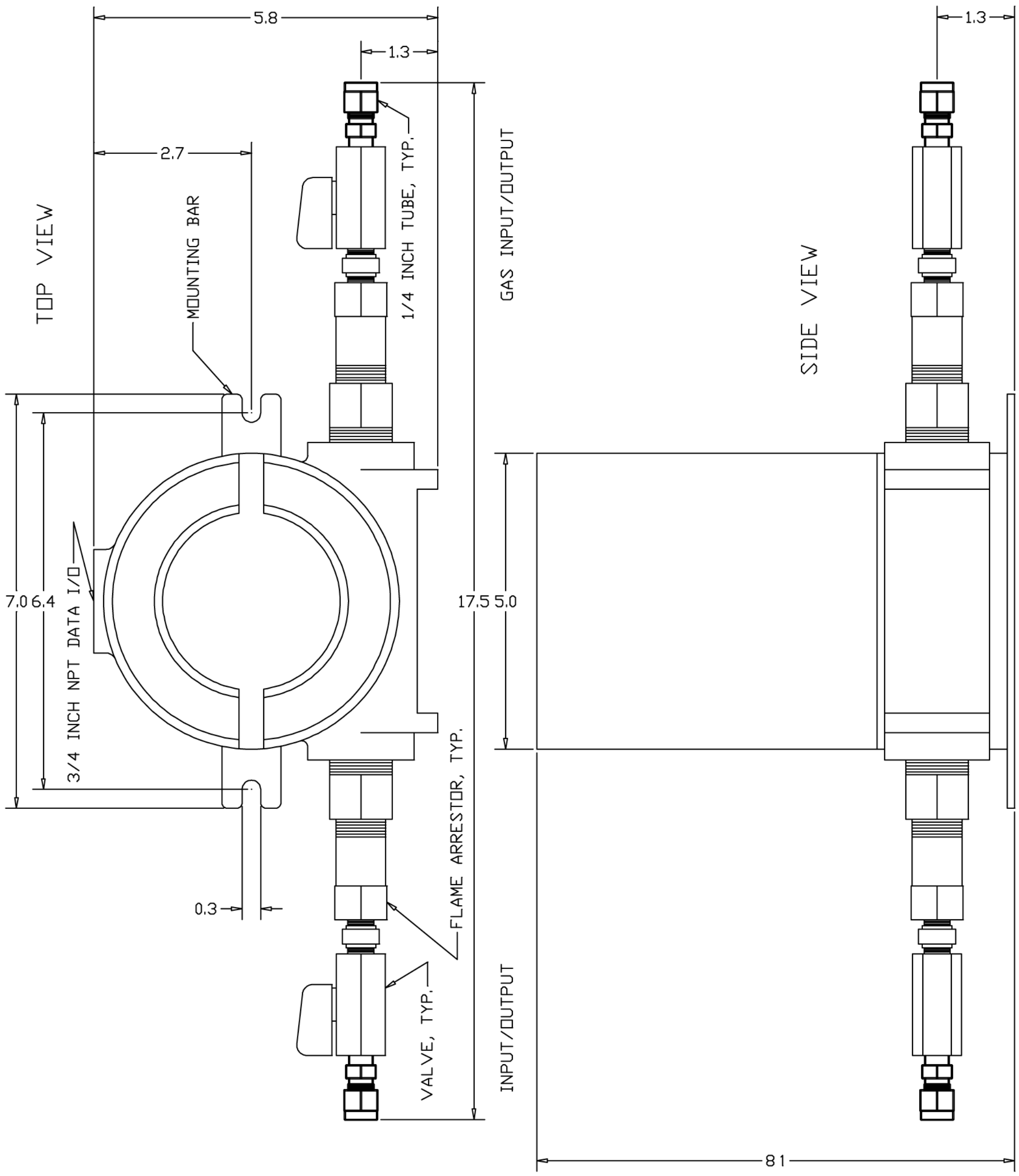

Figure 3.0
Series 3500 with NEMA 7 Enclosure

APPENDIX A
Material Safety Data Sheet for the 3SEN Oxygen Sensor

10.1 Product Identification

Product Name	Oxygen Sensor Model Prefix 3SEN
Synonyms	Electrochemical Sensor, Galvanic Fuel Cell
Manufacturer	Alpha Omega Instruments Corp. 40 Albion Road, Suite 100 Lincoln, RI 02865
Emergency Phone Number	401.333.8580
Preparation / Revision Date	January 1, 1995
Notes	❑ *Oxygen sensors are sealed, contain protective coverings and in normal conditions do not present a health hazard.* ❑ Information applies to electrolyte unless otherwise noted.

10.2 Specific Generic Ingredients

Carcinogens at levels > 0.1%	None
Others at levels > 1.0%	Potassium Hydroxide, Lead
CAS Number	Potassium Hydroxide = KOH 1310-58-3, Lead = Pb 7439-92-1
Chemical (Synonym) and Family	Potassium Hydroxide (KOH) – Base, Lead (Pb) – Metal

10.3 General Requirements

Use	Potassium Hydroxide - electrolyte, Lead - anode
Handling	Rubber or latex gloves, safety glasses
Storage	Indefinitely

10.4 Physical Properties

Boiling Point Range	100 to 115° C
Melting Point Range	KOH -10 to 0° C, Lead 327° C
Freezing Point	-40 to 0° C
Molecular Weight	KOH = 56, Lead = 207
Specific Gravity	1.09 @ 20° C
Vapor Pressure	Not applicable
Vapor Density	Not applicable
pH	> 14
Solubility in H_2O	Complete

% Volatiles by Volume	None
Evaporation Rate	Similar to water
Appearance and Odor	Colorless, odorless aqueous solution

10.5 Fire and Explosion Data

Flash and Fire Points	Not applicable
Flammable Limits	Not flammable
Extinguishing Method	Not applicable
Special Fire Fighting Procedures	Not applicable
Unusual Fire and Explosion Hazards	Not applicable

10.6 Reactivity Data

Stability	Stable
Conditions Contributing to Instability	None
Incompatibility	Avoid contact with strong acids
Hazardous Decomposition Products	None
Conditions to Avoid	None

10.7 Spill or Leak

Steps if material is released

- ❏ Sensor is packaged in a sealed plastic bag, check the sensor inside for electrolyte leakage.
- ❏ If the sensor leaks inside the plastic bag or inside an analyzer sensor housing do not remove it without rubber or latex gloves and safety glasses and a source of water.

Flush or wipe all surfaces repeatedly with water or wet paper towel (fresh each time).

Waste Disposal Method: In accordance with federal, state and local regulations

10.8 Health Hazard Information

Primary Route(s) of Entry	Ingestion, eye and skin contact
Exposure Limits	Potassium Hydroxide - ACGIH TLV 2 mg/cubic meter; Lead - OSHA PEL .05 mg/cubic meter
Ingestion	Electrolyte could be harmful or fatal if swallowed. Oral LD50 (RAT) = 2433 mg/kg
Eye	Electrolyte is corrosive and eye contact could result in permanent loss of vision.
Skin	Electrolyte is corrosive and skin contact could result in a chemical burn.
Inhalation	Liquid inhalation is unlikely.

Symptoms	❏ Eye contact - burning sensation. Skin contact - soapy slick feeling.
Medical Conditions Aggravated	None
Carcinogenic Reference Data	❏ NTP Annual Report on Carcinogens - not listed ❏ LARC Monographs - not listed OSHA - not listed
Other	Lead is listed by some states as a chemical known to cause birth defects or other reproductive harm.