ACP Probe

invensys
Eurotherm

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Contents

Instruction Manual

After Unpacking
Compare the contents of the shipping container against the packing slip. If the instrument is damaged in shipping, report the extent of the damage to the carrier.

1. Specifications

Useful C% Range: 0.01 to 1.60%
Operating Temperature: 1400°F (760 °C) to 1950°F (1065°C).
Stability: within +/-1 mVDC
Mounting: 1” (25.4mm) NPT
Sheath Diameter: 0.84”, 1/2” pipe (21mm, 13mm pipe)
Output: 0 to 1250 mVdc over operating range.
Immersion Depth: 2-4 inches
Readout: % oxygen sensors should be used with controlling, recording and indicating instruments having an input impedance of 10 meg ohms or higher.

Thermal & Mechanical Shock: Zirconia is thermal shock sensitive. Insert into hot furnace no faster than 2” (51mm) per minute after first 4” (101mm).

Accuracy: Typical Accuracy is ± 0.05 weight percent carbon in normal operating range (equivalent to +/- 4mV DC).

Response Time: Less than 1.0 second.

Reference Air: Uncontaminated air at maximum = typical rate of 236 cc per minute = 0.5 SCFH (standard cubic feet per hour).

Protection Tube: Special alloy is resistant to corrosion and oxidation up to 2000°F (1093°C).

Thermocouple: Types K, N, R and S.

Model Codes (in bold):

21" Probes insertion depth (27.2” 690mm overall length) boxed weight 4.0lbs (1.8kg)

ACP21X Carbon Probe 520mm No T/C
ACP21R Carbon Probe 520mm R T/C
ACP21N Carbon Probe 520mm N T/C
ACP21S Carbon Probe 520mm S T/C
ACP21K Carbon Probe 520mm K T/C

28" Probes insertion depth (34.3” 871mm overall length) boxed weight 4.6lbs (2.1kg)

ACP28X Carbon Probe 705mm No T/C
ACP28R Carbon Probe 705mm R T/C
ACP28N Carbon Probe 705mm N T/C
ACP28S Carbon Probe 705mm S T/C
ACP28K Carbon Probe 705mm K T/C

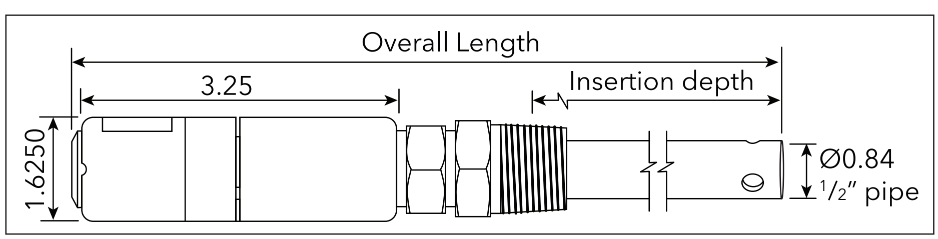
33" Probes insertion depth (39.5” 1003mm overall length) boxed weight 5.4lbs (2.4kg)

ACP33X Carbon Probe 840mm No T/C
ACP33R Carbon Probe 840mm R T/C
ACP33N Carbon Probe 840mm N T/C
ACP33S Carbon Probe 840mm S T/C
ACP33K Carbon Probe 840mm K T/C

QD (Quick Disconnect) Connectors

ACP-XEUR QD Conn. Eurotherm
ACP-NEUR QD Conn. Eurotherm N type T/C
ACP-SEUR* QD Conn. Eurotherm S type T/C
ACP-KEUR QD Conn. Eurotherm K type T/C
ACP-NFCC QD Conn. FCC N type T/C
ACP-SFCC* QD Conn. FCC S type T/C
ACP-KFCC QD Conn. FCC K type T/C
ACP-KMMI QD Conn. MMI K type T/C
ACP-SMMI* QD Conn. MMI S type T/C
ACP-XNGK QD Conn. NGK

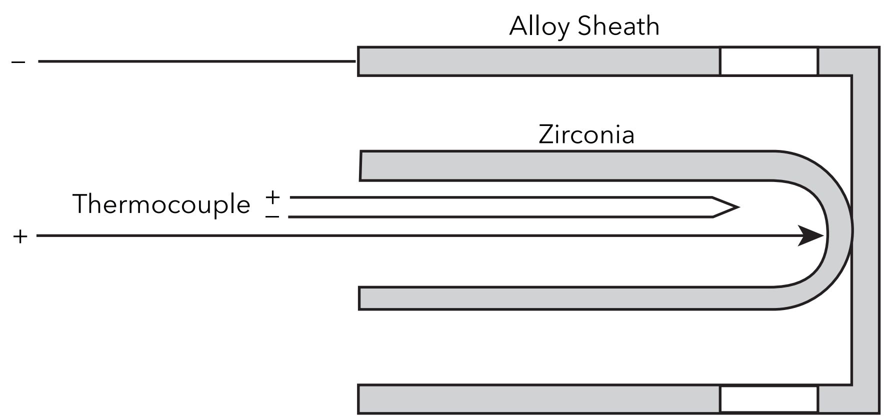
*S type QD connectors are suitable for probes using both R and S type thermocouples.



2. % Oxygen Sensor Operation

In this manual, the word “probe” means the assembly consisting of % oxygen sensor, thermocouple sensor, their protection tube and the cold end termination head.

Two electrodes make contact with the platinum coated zirconium element at the tip of the sensor, one outer electrode, one inner electrode.



The special alloy protection tube is one conductor for the oxygen probe signal, which eliminates the need of a small signal wire normally exposed to the furnace environment. The protection tube has excellent resistance to corrosion and oxidation at high temperature, and has good mechanical strength (since Hydrogen causes embrittlement).

The ACP Probe is suitable for high temperature carburizing, heat treating, carbonitriding and gas endogenerators. The ACP Probe is NOT suitable for nitriding applications.

Zirconia is a solid state electrolyte which conducts oxygen ions at temperatures above 1400°F. The ion conduction results in a voltage between the two electrodes. The magnitude of the voltage is dependent on the temperature of the Zirconia and on the ratio of the oxygen partial pressure on the reference side of the electrolyte to the oxygen partial pressure on the process side of the electrolyte.

Probe Vdc = 0.0276 x TR x Ln (O1/O2)

Probe Vdc = Sensor output, in millivolts

TR = Sensor temperature, in Degrees Rankine

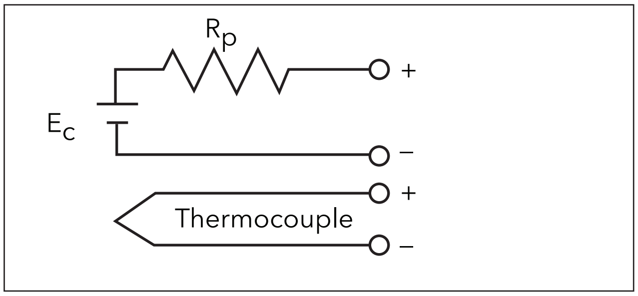
Ln = Natural logarithm

O1 = Oxygen concentration on the inside surface of the sensor, namely, ambient air which is 20.9% oxygen

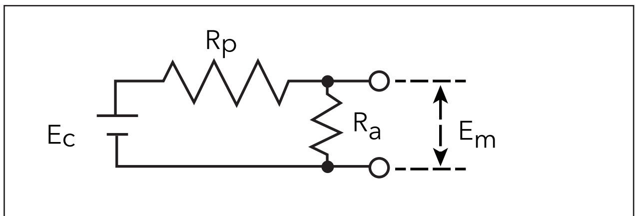
O2 = Oxygen concentration on the outside surface of the sensor, namely, furnace atmosphere

Two connections to the Zirconia cell conduct the voltage to the four pin connector.

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



The value of the internal resistance can be measured, as shown below, by putting a shunt resistor across the probe, measuring the resultant voltage, EM and carrying out the simple calculation shown.



$$R_p = (|E_c/E_m) - 1) \times R_s$$

Carbon potential of a conventional furnace atmosphere is defined as the %C achieved in a coupon of carbon steel shim stock equilibrated in the furnace atmosphere. Unfortunately, equilibration time is long, so it is important to continuously control the atmosphere on the basis of shim stock measurements. A zirconia sensor, however, can be used to measure and control the carbon potential precisely, and on a continuous basis.

Strictly speaking, the zirconia probe is not sensing carbon at all. It is an oxygen sensor with a mVDC output.

Fortunately, an empirical (experimental) relationship exists between oxygen concentration and carbon potential, and this relationship has been used in carbon control instruments since the early "70's". The equation used by most control manufacturers today is illustrated by the equation below, which states that there are only three variables affecting the measured millivoltage. Because the actual equation used is somewhat complex, it is not reproduced here.

All competitive probes will invariably agree within one or two millivolts when exposed to the same atmosphere under equilibrium conditions. Differences in values listed by probe vendors relate to differences in manufacturers, source data, but the true value of the zirconia probe is its repeatability.

Zirconia Probe Algorithm %C = ϕ (Ec, %CO, TR) mVDC

%C = Carbon Potential

ϕ = „is a function of“

Ec = Probe output in mV

%CO = Carbon Monoxide percentage

TR = Absolute Temperature in degrees Rankine (deg F + 460)

3. Probe Location on Furnace

If the enriching gas supply has a separate inlet, locate the probe in the following manner:

- Away from carrier gas entry
- In top third of work zone
- Close to control thermocouple
- Clear of work baskets
- Distant from radiant tubes (not a hot spot)

Generally, locate the oxygen probe in an area where the furnace gases are known to be thoroughly mixed. Locate in a wall area reasonably free from other pipes and valves to simplify installation and replacement.

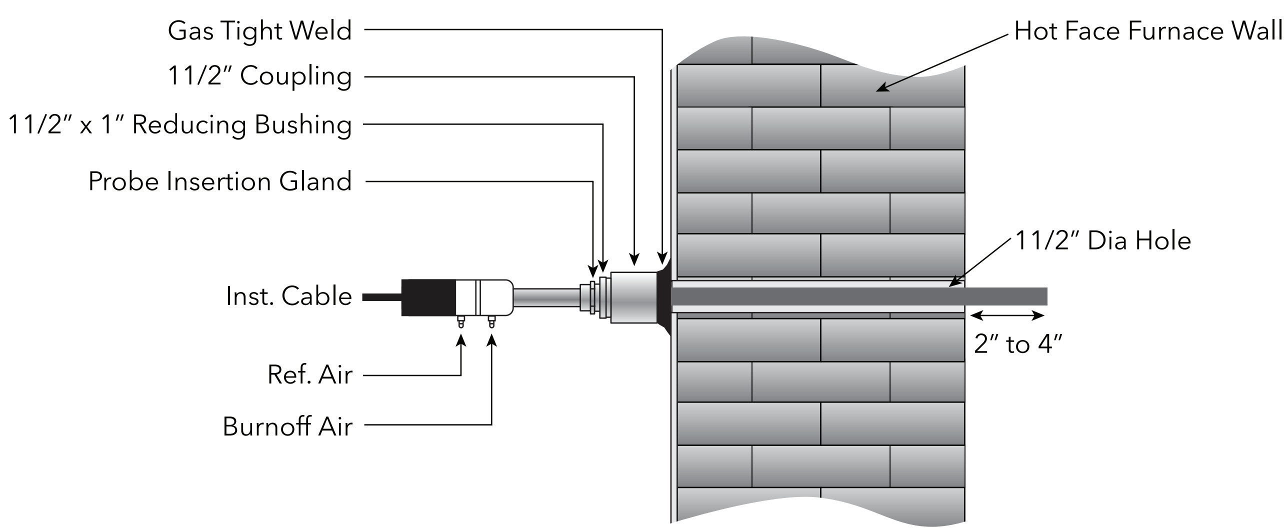
4. Mounting the Probe and Air Supply

The probe is supplied with a compression fitting which has 1” NPT male threads. Install a mounting fitting (at right-angles to the wall) with 1-1/2” NPT female threads and use a 1” x 1-1/2” reducing bushing. This permits easy removal after soot buildup on the protection tube.

The ACP Accurate probe has been shipped with an o-ring compression fitting which allows you to adjust the insertion length. Manual tightening of the cap is adequate for side mounting. A wrench should be used for vertical mounting to assure probe will not move.

Mount the reference air supply in an area where the ambient temperature is less than 125°F. if mounting on the furnace, have at least 8 inches of air space between the supply and the furnace wall.

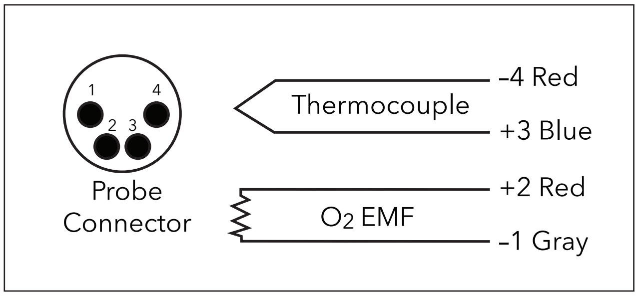
If you already have a control system for you probe and air supply it is important to emphasize that the reference air be clean and dry. Any combustibles or moisture in the reference air will cause the sensor to read low. It is also important to use silicone rubber tubing for the air connections to avoid problems related to high temperatures.



WARNING
You must observe the maximum insertion depth to ensure that your warranty will be honored. If you must insert beyond 4”, rotate the probe 180° every two months to counter the sag that occurs with temp.

5. Oxygen Sensor Wiring

A cable containing wiring for the thermocouple compensating cable and leadwire for the probe and reference air supply tube should be free from interference from other electrical or heat sources. See Figure below.



Do not place power wiring and sensor wiring in the same conduit or wiring trough. The wires from several oxygen probes may be placed in the same conduit or wiring trough. Recommended Leadwire 22 gauge, Teflon insulated.

Readout – for direct millivolt readout, a 4-1/2 digit meter with a basic accuracy of 0.05% or better is recommended.

6. Thermocouple Wiring

NEVER wire thermocouples using ordinary copper wire. Wire only with thermocouple extension wire. Observe the correct thermocouple and thermocouple extension wire polarity. The negative wire of both thermocouple and thermocouple extension wire is coded red (American ANSI/MC 96.1).

7. Reference Air Supply

7.1 Reference Air

Clean reference air must be supplied to the probe.

The air passages inside the probe to the Zirconia element are a fraction of a millimeter wide and can be blocked with air dust if the reference air is not clean. Dead air at the Zirconia element reduces the output voltage of the % Oxygen sensor to meaningless values.

The following simple equipment is required: instrument air supply of 0.5ft 3 per hour (236 cc per minute). A complete air supply system, Part Number A-13893, is available. Distance from the air supply source and probe is determined by the capacity of the reference air source. The A-13893 air supply system can be used up to approximately 50ft from the probe. The A-13893 has an intake filter in the air pump. (Refer to Section 15. Air Supplies)

7.2 Air Flow

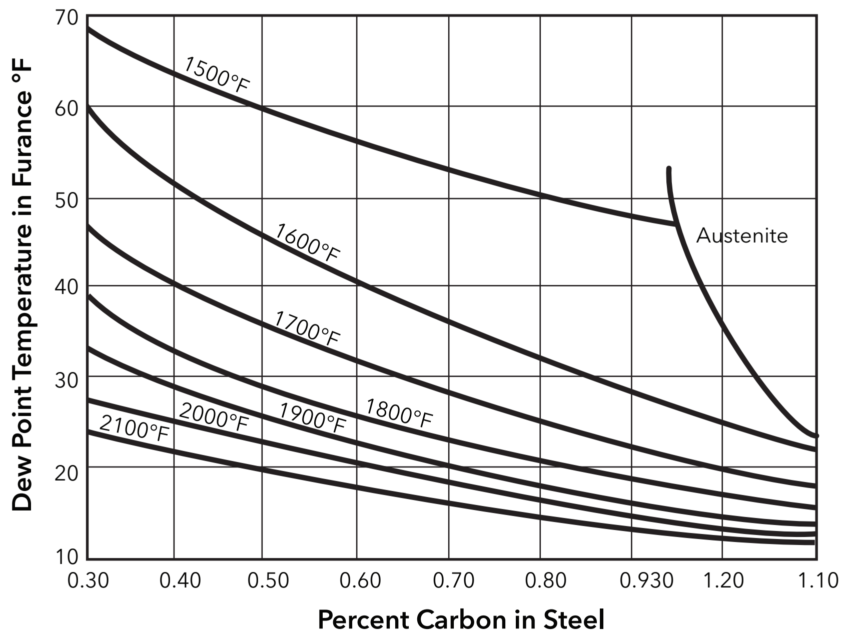
Invensys Eurotherm recommends air flow any time the probe is heated. The Type K thermocouple in the probe will last longer at elevated temperatures with an air flow. When the tube and furnace are not hot, air flow is not required.

Cold furnace installation does not require air flow, but the air supply should be connected as soon as possible after installation.

8. Furnace Startup

Turn on reference air to the probe at furnace startup. If the probe is either installed or replaced in a hot furnace, turn reference air on as soon as possible.

The tables at the end of this manual are required in order to interpret the output voltage of the oxygen sensor in the probe. These tables are not required when a Carbon Controller is used (eg. 2400, 3500, nanodac). Also see graph below.



Equilibrium Between Carbon Potential and Dew Point of Endothermic Furnace Atmosphere for Straight Carbon Steels (Courtesy Lindberg Engineering Corporation)

9. During Furnace Operation

A probe can be installed in a hot furnace. The probe is NOT resistant to thermal shock.

CAUTION! When a probe is exchanged or removed from a furnace which has an atmosphere in it (always under positive pressure), great caution must be taken to insure that there is no entry of air into the furnace which could cause an explosion!

When removing a probe from a hot furnace, place the probe on either a dry brick or dry concrete surface. Allow the probe to air cool. Never attempt to speed up the cooling of the probe.

10. Furnace Precautions

Probe changes are recommended when there is no atmosphere in the furnace and the furnace door can be open; for example, between loads.

Heat treated parts must be cleaned and any grease or zinc compounds must be removed. The parts must then be thoroughly rinsed. Do not use zinc coated baskets to hold small parts during operation. Zinc will deteriorate the oxygen probe electrode.

Oxygen probe life will be shortened if the furnace operates in the sooting range for a long period of time and is not burned out at regular intervals.

Mercury and certain other heavy metals will attack the oxygen probe. Consult the factory for any unusual application.

New and rebricked furnaces should be fully dried and fully cured before installing the oxygen probe. New and rebricked furnaces require several days to stabilize so the new brick can absorb carbon atmosphere. During this time, exact carbon control will be difficult. It is common procedure to operate a new and rebricked furnace at an elevated temperature with a carburizing atmosphere to eliminate harmful components.

11. Maintenance

Check the air pump daily.

Check the air supply to the probe once a week. Remove the air tube fitting from its connection at the probe head and submerge the air tube into a container of water. A steady flow of air bubbles indicates proper operation. Reconnect the air tube fitting to the probe head.

Check the air supply filters once a month.

Proper Carburizing - If heat treated parts are not being properly carburized, there are several items to check:

1. Reference air flow should be 0.5 SCFH.
2. Make certain the vent holes in the end of the probe are clear and free of carbon buildup.
3. Check that the probe output voltage is stable.
4. Place a voltmeter across the probe to get a probe output reading. Then disconnect the thermocouple from the controller and get a second reading. The probe output should remain constant.
5. Use an ohmmeter to check the thermocouple for an open element.
6. Make certain reference air is reaching the probe tip.
7. Check the enriching gas for proper expected Carbon carrying element content.
8. Check the furnace door for air leaks.
9. Check the furnace completely for air leaks (including the floor).
10. Check for air blocks in the furnace.
11. Make certain parts are clean before loading them into the furnace.
12. Make certain to give a new or rebuilt furnace a two day curing time.

12. Probe Burnout

Furnaces are only capable of carrying a finite amount of carbon. Carbon will "drop out" as the atmosphere cools, resulting in a buildup of soot inside the protection tube. The soot is removed by purging the probe with a controlled amount of air, which allows the soot to burn off. Failure to purge can result in a damaged probe.

Ideal flow rates should be between 10 to 15 scfh and limited to 90 seconds maximum to avoid overheating the tip.

We recommend not to exceed a burnout more than every 8 hours (although for high carbon levels this may be shorter period but this will limit the life of the probe).

The burn off of excessive soot should be monitored closely with a probe thermocouple monitor. It may be necessary to remove the probe from the furnace and remove excess soot with compressed air (after first cooling the probe to ambient temperature) or light brushing. Do not strike the unit or insert hard objects into the probe.

Sooted probes should not be allowed to burn off in an air atmosphere without monitoring the temperature rise. Visually observe the hot probe end. Sparks or white heat indicates an excessive soot condition. Excessively sooted probes should be returned to the factory for refurbishing.

13. Troubleshooting

When trouble arises with a furnace control system, it is important to establish where the problem is located; the probe, signal transmission lines, the control instrument, or the furnace 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 set point, the most common symptom is non-conformity of the work pieces to quality assurance specifications.

To evaluate most faults, the recommended tools are:

1. 3 ½ digit millivolt meter with at least 10 meg ohm input impedance and 0 to 1999 mV range,
2. Temperature calibrator and,
3. Simulator to output 0 to 1300 millivolts at less than 50 meg ohms output impedance.

Probe troubleshooting: In order to establish the source of problems in your installation, first resist the temptation to remove the ACP Accurate Probe from the furnace. All of the following meaningful questions must be answered while your ACP Accurate Probe (or any other carbon sensor) is in the furnace, at temperature, and exposed to a normal atmosphere under manual control:

SYMPTOM	POSSIBLE CAUSE
High %C	Low reading due to: • High probe resistance • Cracked zirconia • Dirty reference air • Faulty cable insulation • Instrument calib./ calc. • Air leak to burnoff fitting • Furnace air leak at probe • Oily parts or sooted furnace • Wrong recipe time/temp
Low % C	High Reading due to: • Probe plugged with soot • Instrument calib./calc. • Wrong recipe time/ temp
Erratic	Faulty signal due to: • Bad sensor connections • Electrical noise source • Radiant tube leak • Bad Endo • Mixing valve setting • Instrument setting
Sooted furnace	• Endo not cracked (temp too low in generator or catalyst inactive)

13.1 Troubleshooting Questions

1. Does an Alnor dew point reading or other gas analysi (or shim stock analysis) verify the indicated value from the probe? If there is reasonable correlation, the problem is NOT the probe.
2. Are the connections from the T/C extension wire and sensor cable clean and firmly attached at the correct probe and control instrument terminals? Note that the shield wire in the sensor cable should be connected to ground at the control instrument end only!
3. Is the control instrument CO or H2 factor set to the appropriate value? This “factor” is referred to by various manufacturers as Zone Factor, Process Factor, Gas, Furnace Factor, CO Factor, Calibration Factor, etc. This factor may require adjustment in order to make the calculated %C or dew point agree with other measurements.
4. Do the actual ACP Accurate Probe temperature and O2 mV signal, as measure by the temperature calibrator, and digital voltmeter, agree with the displayed values on the control instrument? If not, an instrument calibration problem is likely.
5. Is the probe impedence less than 50 kilohms at temperature above 1550°F (843°C)? Conduct the test shown in the figure on page 4 using a shunt resistor greater than 50 kilohms. Measure the voltage EC before shunting, then EM with the shunt in place. Calculate RP. If it exceeds 50 kilohms, proceed to step 8, below.
6. How quickly does the probe react to a change in O2 concentration? Read the probe millivolts with the controller or the digital meter. Short the probe for 5 seconds, remove the short and measure the time required to return to within 1% of the original reading. If it exceeds 30 seconds, proceed to step 8, below
7. Is there a leak in the zirconia substrate? To test this property, turn off the reference air for one minute. Measure the probe 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 25 mV, replace the probe.
8. If probe resistance or response times are questionable as indicated in steps 5 and 6, we recommend that the probe be burned off. Introduce 10 to 15 CFH of air to the burn-off fitting for about 90 to 120 seconds, and then repeat the tests. Should problems persist, it may be necessary to conduct a thorough furnace burnout so that all potentially contributing contamination is removed from all parts of the furnace, including the ACP Accurate Probe. Burning off the probe will not harm this product provided the probe temperature does not exceed 1950°F (1065°C) during the burn-off procedure.
9. Should it be necessary to remove your ACP Accurate Probe from a hot furnace, do so carefully, UNDER NO CIRCUMSTANCES should it be removed faster than 2" (51mm) per minute.

Returning a Unit for Reconditioning
When returning a probe to the factory, package it carefully in the original packaging material and mark the carton “Fragile Instrument.”

Send to:
Invensys Eurotherm
44621 Guilford Drive Suite 100
Ashburn, VA 20147
USA

The unit will be examined and reconditioned at a standard charge, providing ceramic components have not been broken. The Repair Order will be acknowledged and an authorization requested.

14. Recommended Practice for Retrofitting Carbon Controls to Carburizing Furnaces

1. The furnace MUST be in excellent condition, with no leaks and door seals in good condition. If air migrates into the furnace, the % carbon atmosphere will not be consistent in the chamber, causing erratic load results. Intermittent leaks can cause intermittent % carbon results.
2. The furnace must be operated under positive pressure. Furnace manufacturers recommend +0.25” W.C. furnace pressure.
3. The furnace must be clean. Any soot present must be burned out by running the furnace at 1600°F for several hours, with the atmosphere turned off and air flowing through the chamber.
4. The AP probe must be installed close to the work area, but as far removed as possible from the point where enriching gas is introduced into the chamber.
5. The AP probe must be brought up to temperature gradually, or else the Zirconia Oxide cell will be damaged. When installing the probe into a hot furnace, insert slowly (one inch every five minutes).
6. Manufactured gases, such as N -Methanol, must be introduced by means of an injector tube (Sparger) or drip plate to insure that Methanol is cracked and mixed with N before reaching the AP probe. Uncracked Methanol reaching the probe will cause erroneous % carbon readings
7. The flow rate of N2 and Methanol must be consistent. Variation of either gas flow will cause erroneous % carbon readings. Controllers are usually calibrated to a known gas composition.
8. If several furnaces are fed by one source of N- Methanol, each furnace should have its own set of pressure regulators and flowmeters so as to avoid flow rate changes as other furnaces are added to, or removed from production.
9. An accurate dewpoint analysis and a trained operator are essential for setting up and checking the furnace atmosphere.
10. An atmosphere calibration chart from the supplier of the N -Methanol gas is essential.
11. Close temperature control is desirable since % carbon readings vary inversely with temperature cycling. Fluctuations of temperature will cause cyclic conditions of carbon control.
12. In order to provide extended, trouble-free service, Platinum thermocouples should be employed in ACP probes used at 1700°F and above.
13. Enriching gas should have a maximum flow rate of approximately 10% of total gas flow (e.g., 90 CFH natural gas to 900 CFH atmospheric gas).

15. Air Supplies

A-13893 Air Supply

A-13893-X00-X-0X

0 = 120 Vac 50/60 Hz
1 = 240 Vac 50/60 Hz

0 = Front Panel Assembly Only
1 = Assembly with Case

000 = Single Sensor without Burnoff Option
100 = Dual Sensor without Burnoff Option
200 = Single Sensor with Optional Remote Burnoff Solenoid
400 = Single Sensor with Optional Remote Burnoff Solenoid (International Model)
500 = Single Sensor without Burnoff Option (International Model)
(International Models have flow gauges scaled in Liters per minute)

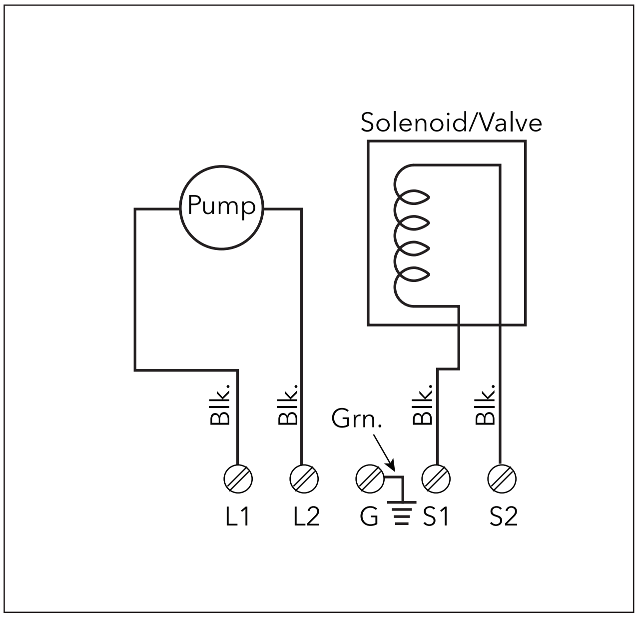
The A-13893 Series of air supplies is designed to provide reference and purge air for the ACP Series of Carbon and O2 probes. All models use a rugged double-diaphragm pump designed for an industrial environment. The flow gauges have two-inch scales for readability and easy adjustment. A replaceable filter prevents particulate infiltration of the supply lines.

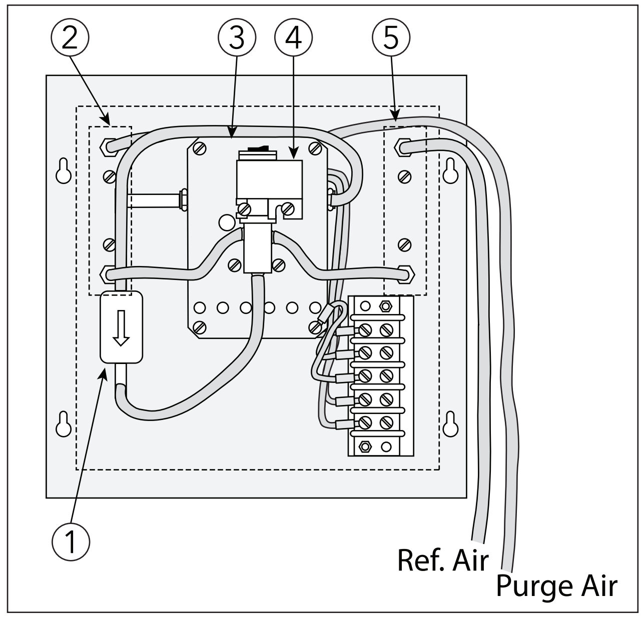
Models are available with a complete housing for surface mounting or with a front panel only for installation into a control panel. All versions are 50/60 Hz at 28 Watts.

A-13893-000-x-xx	has a single output with a 0-2 SCFH flow meter for use as a reference air supply for a single probe.
A-13893-100-x-xx	has dual outputs with 0-2 SCFH flow meters for use as a reference air supply for two probes.
A-13893-200-x-xx	has one output for reference air and a second solenoid activated output with a 0-10 SCFH flow meter for purge air.
A-13893-400-x-xx	has one output with a 0.06-0.50 LPM flow meter for reference air and a solenoid activated output with a 0.15-1.00 LPM flow meter for purge air.
A-13893-500-x-xx	has a single output with a 0.06-0.50 LPM flow meter for use as a reference air supply for a single probe.

Installing the Air Supply:

1. Mount the housing with a minimum of 8 inches (200mm) of air gap between the housing and the furnace wall. The air supply should be within 50 ft. (15 meters) of the probe.
2. Remove the front cover.
3. Remove the safety cover on the terminal block.
4. Connect power leads to terminals L1 & L2. The air supply should be connected directly to the furnace control power. The air supply should be ON whenever the furnace is powered up.
5. On models with a purge air solenoid, connect the purge control leads to the terminals marked S1 & S2. S2 may be jumpered to L2 when the power leads and the purge control share the same circuit.
6. Connect terminal G to earth ground.
7. Reinstall the safety cover to the terminal block.





			Model Number									
			A-13893 -000-X-X0	A-13893 -100-X-X0	A-13893 -200-X-X0	A-13893 -400-X-X0	A-13893 -500-X-X0	A-13893 -000-X-X1	A-13893 -100-X-X1	A-13893 -200-X-X1	A-13893 -400-X-X1	A-13893 -500-X-X1
Item	**Part Number**	**Description**	**Qty.**	**Qty.**	**Qty.**	**Qty.**	**Qty.**	**Qty.**	**Qty.**	**Qty.**	**Qty.**	**Qty.**
1	AI-431	Filter	1	1	1	1	1	1	1	1	1	1
2	36-151	1 to 10 SCFH Flow Meter			1					1		
	6-152	.15 to 1 LPM Flow Meter				1					1	
3	50-1746	Air Pump 120V 50/60 Hz	1	1	1	1	1					
	50-1746-100	Air Pump 240V 50/60 Hz						1	1	1	1	1
4	AL-171	Solenoid 120V 50/60 Hz			1	1						
	AL-183	Solenoid 240V 50/60 Hz								1	1	
5	36-130	.2 to 2 SCFH Flow Meter	1	2	1			1	2	1		
	36-158	.06 to .5 LPM Flow Meter				1	1				1	1

Table 1. CARBON vs. DEW POINT WITH TEMPERATURE

%CO = 20.0 %H2 = 40.0 Af = 1.00 Note: Dewpoint shown in degrees Farenheit

TEMP → % C ↓	1450F (788C)	1475F (802C)	1500°F (815C)	1525F (829C)	1550F (843C)	1575F (857C)	1600F (871C)	1625F (885C)	1650F (899C)	1675F (913C)	1700F (927C)	1745F (940C)	1750F (954C)
0.05	142	137	133	129	124	120	117	113	109	106	103	99	96
0.10	117	113	108	104	101	97	94	90	87	84	81	78	75
0.15	103	99	95	91	88	84	81	77	74	71	68	66	63
0.20	93	89	86	82	78	75	72	69	66	63	60	57	55
0.25	86	82	78	75	71	68	65	62	59	56	53	51	48
0.30	80	76	73	69	66	63	60	57	54	51	48	46	43
0.35	75	71	68	64	61	58	55	52	49	46	44	41	39
0.40	71	67	64	60	57	54	51	48	45	43	40	37	35
0.45	67	63	60	57	53	50	47	45	42	39	37	34	32
0.50	64	60	57	53	50	47	44	41	39	36	34	31	29
0.55	60	57	54	50	47	44	41	39	36	33	31	28	26
0.60	58	54	51	48	45	42	39	36	33	31	28	26	24
0.65	55	52	48	45	42	39	36	34	31	29	26	24	21
0.70	53	49	46	43	40	37	34	31	29	26	24	21	19
0.75	50	47	44	41	38	35	32	29	27	24	22	19	17
0.80	48	45	42	39	36	33	30	27	25	22	20	18	15
0.85	46	43	40	37	34	31	28	25	23	20	18	16	14
0.90	44	41	38	35	32	29	26	24	21	19	16	14	12
0.95	42	39	36	33	30	27	25	22	19	17	15	12	10
1.00	41	37	34	31	28	26	23	20	18	15	13	11	9
1.05	39	36	33	30	27	24	21	19	16	14	12	9	7
1.10	37	34	31	28	25	22	20	17	15	12	10	8	6
1.15	36	32	29	26	24	21	18	16	13	11	9	6	4
1.20	34	31	28	25	22	19	17	14	12	10	7	5	3
1.25	33	29	26	24	21	18	15	13	11	8	6	4	2
1.30	31	28	25	22	19	17	14	12	9	7	5	2	0
1.35	30	27	24	21	18	15	13	10	8	6	3	1	–1
1.40	28	25	22	19	17	14	11	9	7	4	2	0	–2
1.45	27	24	21	18	15	13	10	8	5	5	1	–1	–3
1.50	26	23	20	17	14	11	9	7	4	2	0	–2	–5

Table 2. CARBON vs. MILLIVOLTS WITH TEMPERATURE

%CO = 20.0

TEMP → % C ↓	1450F (788C)	1475F (802C)	1500°F (815C)	1525F (829C)	1550F (843C)	1575F (857C)	1600F (871C)	1625F (885C)	1650F (899C)	1675F (913C)	1700F (927C)	1745F (940C)	1750F (954C)
0.05	961	963	965	967	968	970	972	974	976	978	979	981	983
0.10	993	996	998	1000	1002	1005	1007	1009	1011	1014	1016	1018	1020
0.15	1012	1015	1018	1020	1023	1025	1028	1030	1033	1035	1038	1040	1043
0.20	1026	1029	1032	1034	1037	1040	1042	1045	1048	1050	1053	1056	1059
0.25	1037	1040	1043	1046	1048	1051	1054	1057	1060	1063	1065	1068	1071
0.30	1046	1049	1052	1055	1058	1061	1064	1067	1070	1073	1076	1078	1081
0.35	1054	1057	1060	1063	1066	1069	1072	1075	1078	1081	1084	1087	1090
0.40	1061	1064	1067	1070	1073	1076	1079	1082	1086	1089	1092	1095	1098
0.45	1067	1070	1073	1076	1079	1083	1086	1089	1092	1096	1099	1102	1105
0.50	1072	1075	1079	1082	1085	1089	1092	1095	1099	1102	1105	1108	1112
0.55	1077	1080	1084	1087	1091	1094	1097	1101	1104	1107	1111	1114	1117
0.60	1082	1085	1089	1092	1095	1099	1102	1106	1109	1103	1106	1119	1123
0.65	1086	1090	1093	1097	1100	1104	1107	1110	1114	1117	1121	1124	1128
0.70	1090	1094	1097	1101	1104	1108	1111	1115	1119	1122	1126	1129	1133
0.75	1094	1098	1101	1105	1108	1112	1116	1119	1123	1126	1130	1134	1137
0.80	1098	1102	1105	1109	1112	1116	1120	1123	1127	1131	1134	1138	1141
0.85	1101	1105	1109	1112	1116	1120	1123	1127	1131	1134	1138	1142	1146
0.90	1105	1109	1112	1116	1120	1123	1127	1131	1135	1135	1142	1146	1149
0.95	***1108***	1112	1116	1119	1123	1127	1131	1134	1138	1142	1146	1149	1153
1.00	***1111***	***1115***	1119	1123	1126	1130	1134	1138	1142	1145	1149	1153	1157
1.05	***1114***	***1118***	***1122***	***1126***	1130	1133	1137	1141	1145	1149	1153	1157	1160
1.10	***1117***	***1121***	***1125***	***1129***	***1133***	***1137***	1141	1144	1148	1152	1156	1160	1164
1.15	***1120***	***1124***	***1128***	***1132***	***1136***	***1140***	***1144***	1148	1152	1155	1159	1163	1167
1.20	***1123***	***1127***	***1131***	***1135***	***1139***	***1143***	***1147***	***1151***	1155	1159	1162	1166	1170
1.25	***1126***	***1130***	***1134***	***1138***	***1142***	***1146***	***1150***	***1154***	***1158***	***1162***	1166	1170	1174
1.30	***1128***	***1132***	***1136***	***1140***	***1144***	***1149***	***1153***	***1157***	***1161***	***1165***	***1169***	1173	1177
1.35	***1131***	***1135***	***1139***	***1143***	***1147***	***1151***	***1155***	***1159***	***1164***	***1168***	***1172***	***1176***	***1180***
1.40	***1134***	***1138***	***1142***	***1146***	***1150***	***1154***	***1158***	***1162***	***1166***	***1171***	***1175***	***1179***	***1183***
1.45	***1136***	***1140***	***1144***	***1149***	***1153***	***1157***	***1161***	***1165***	***1169***	***1173***	***1178***	***1182***	***1186***
1.50	***1139***	***1143***	***1147***	***1151***	***1155***	***1160***	***1164***	***1168***	***1172***	***1176***	***1180***	***1185***	***1189***

Note. mV values in ***italic bold*** correspond to saturation limits in steel

1. Carbon absorption and diffusion rates limit the actual level attainable on the steel work surface. (Carburizing time and temperature and steel composition affect the relationship between atmospheric carbon potential and resultant surface carbon level.) Specific conditions, such as shorter carburizing cycles, may necessitate controlling at a carbon potential as much as 0.25 wt. %C higher than required on the work.
2. This chart pertains only to endothermic base atmospheres generated from predominantly methane (i.e., 20% CO).
3. Controlling carbon potential at a level exceeding the carbon content of saturated austenite is discouraged. An optimum combination of productivity and control might be realized by a boost-diffuse carburizing technique.

Warranty

This product is warranted according to the General Warranty Statement that is part of the Terms and Conditions of Invensys Systems Inc.

The warranty for this product is effective for twelve months after shipment from Invensys Eurotherm.

The warranty requires that the probe should extend no more than 4” (101mm) into the furnace chamber – this is to avoid any distortion on the sheath that could result in breakage to the zirconia sensing element.

For sensors operated at elevated temperatures above 1750°F(954°C) a prorated approach is used; the warranty is granted for six months between 1750°F(954°C) and 1850°F(1010°C) and the warranty is granted for three months between 1850°F(1010°C) and 1950°F(1065°C).

Please register the probe at http://www.carbonsensor.info/ or scan the QR Code shown below and enter the registration details (Name, Company, Email, Probe Model No.,Serial No., Date Installed).

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