UPC·MARATHON

CS87 CARBON SENSOR
ZIRCONIA TIP
Operations Manual

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MANUAL #: 501

Revision #	Revision Date	Revision Description

THIS MANUAL IS SUPPLIED ELECTRONICALLY.

DISCLAIMER:

The **CS87** is to be used by the industrial operator under his/her direction. UPC-Marathon is not responsible or liable for any product, process, damage or injury incurred while using the **CS87**. UPC-Marathon makes no representations or warranties with respect to the contents hereof and specifically disclaims any implied warranties or merchantability or fitness for any purpose.

WARRANTY:

There are no warranties, expressed or implied, including the warranties of merchantability and fitness for use, made by the exclusive distributor or representative for zirconia carbon sensors, except the expressed warranty against defects in material and workmanship described below.

UPC-Marathon, as manufacturer, warrants above to be free from defects in material and workmanship under normal use and service. UPC-Marathon's obligation under this warranty is limited to replacing or repairing, at its option, zirconia carbon sensors herein listed, should failure occur within the warranty period. If premature failure occurs, the sensor, along with warranty claim form must be returned in the original shipping container to UPC-Marathon. Upon receipt at UPC-Marathon an examination shall disclose to its satisfaction the sensor to have been thus defective, at which time action will be taken.

There will be no applicable warranty in the event of breakage resulting from thermal or mechanical shock. Additionally, there will be no applicable warranty to a sensor which has been subject to misuse, negligence or accident. This warranty only applies to sensors being used at temperatures below 1850°F. At temperatures above 1850°F, the warranty is prorated as shown below. Any sensor is covered by the usage warranty as indicated from the date of installation

Operating Temperature	Warranty Length
Less than 1850°F	12 months
1850-1950°F	6 months
1950-2050°F	3 months
Above 2050°F	No warranty

This warranty will not be honored unless the warranty card is filled out and returned to UPC-Marathon and only if installation is accomplished according to UPC-Marathon's specifications and procedures as described in operating/instruction manuals. UPC-Marathon shall in no way be liable for special or consequential damages.

TECHNICAL ASSISTANCE

For all questions or concerns regarding the operation of the **CS87**, please consult the last page of this manual for contact information.

CONGRATULATIONS!

You have purchased the finest oxygen sensor on the market. To realize the capabilities of this superb device, please observe the recommendations in this instruction manual.

Important

When the sensor is placed into service, please send the enclosed postage-paid warranty registration card. In the unlikely event that your sensor fails prematurely, please follow these directions in order to expedite your claim:

1. Carefully fill out the claim form, giving as much information as possible about the sensors conditions of use and failure to help accelerate your claim and help us improve our product.
2. Enclose the claim form with the sensor intact and in the original packaging and return to:

   UNITED PROCESS CONTROLS INC. (Delaware Corporation, USA)
   6724 South 13th Street
   Oak Creek, WI 53154 USA

Table of Contents

Table of Figures

1 UNPACKING YOUR SENSOR

Your sensor contains ceramic parts which can withstand high temperatures and harsh environments. These ceramics are also very fragile, and the sensor must be handled with the utmost care from the time it is unpacked. Your sensor is shipped from UPC-Marathon in a package designed specifically to ensure the sensor's safety in transit to you. **<u>This package should be retained to facilitate any potential return of the sensor to UPC-Marathon.</u>** Please note that the package consists of an outer box and two foam pads which support the sensor.

Follow these steps to remove sensor:

1. Place package on flat surface.
2. Cut tape from top of outer box.
3. Remove top layer of foam.
4. Carefully remove sensor.
5. Reassemble empty pack and hold for possible reshipment.

- *Remember to fill out the registration card and drop it in the mail when you install your sensor. This extends your warranty to be the time in the furnace so that "shelf time" is not included.*
- *If your sensor is not operating properly, please contact your Local UPC-Marathon representative before removing the sensor. There may be trouble shooting technique only accomplished while the sensor is still installed to alleviate the problem.*

1.1 Each pack contains the following:

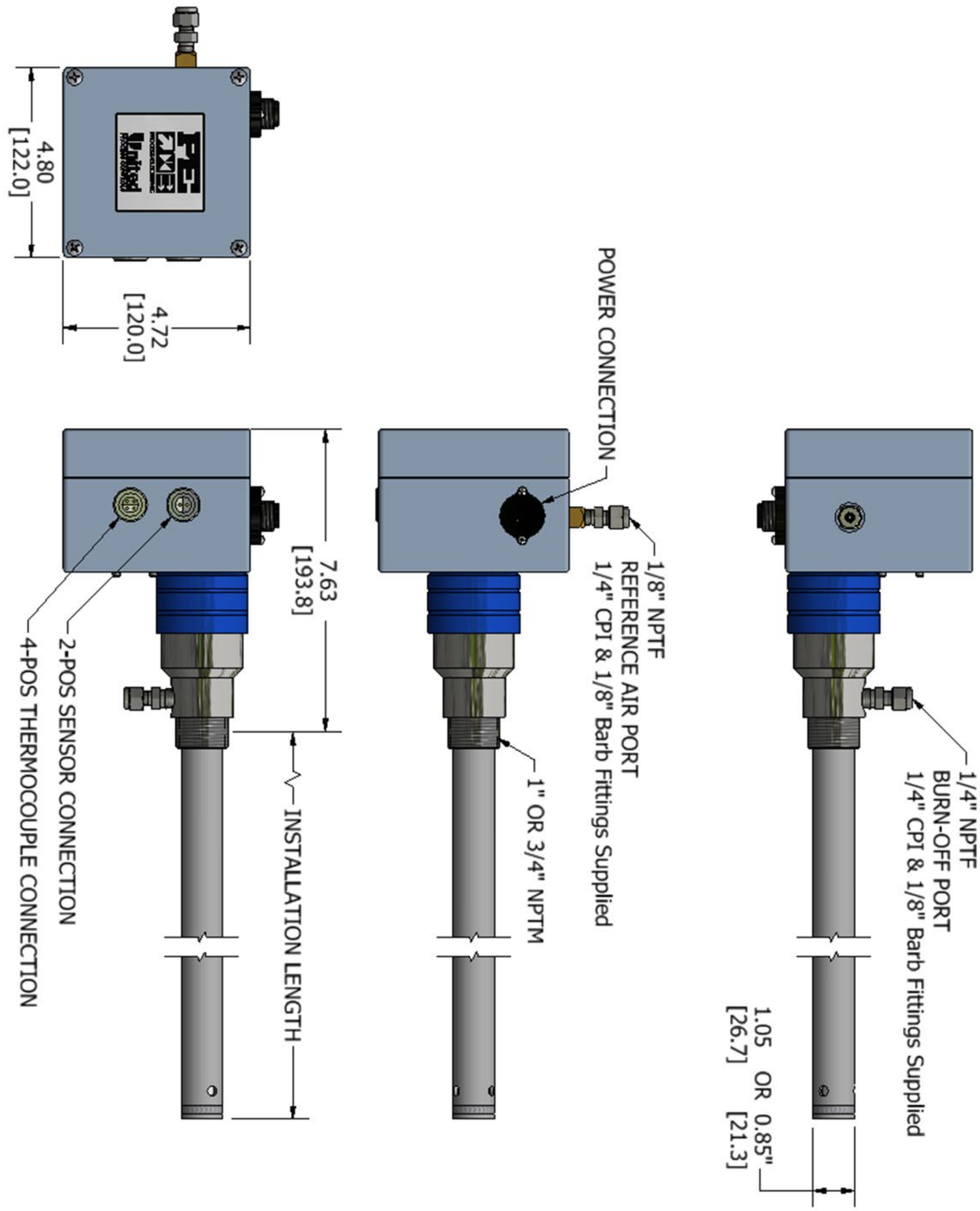
- ☐ Statement of Carbon Sensor Accuracy
- ☐ Sensor Assembly
- ☐ Operating Manual
- ☐ Warranty Registration Card
- ☐ Additional Fittings & Parts

On your sensor's head is the sensor type, part number, and serial number. Please refer to the Sensor Drawing which will show additional fittings and accessories.

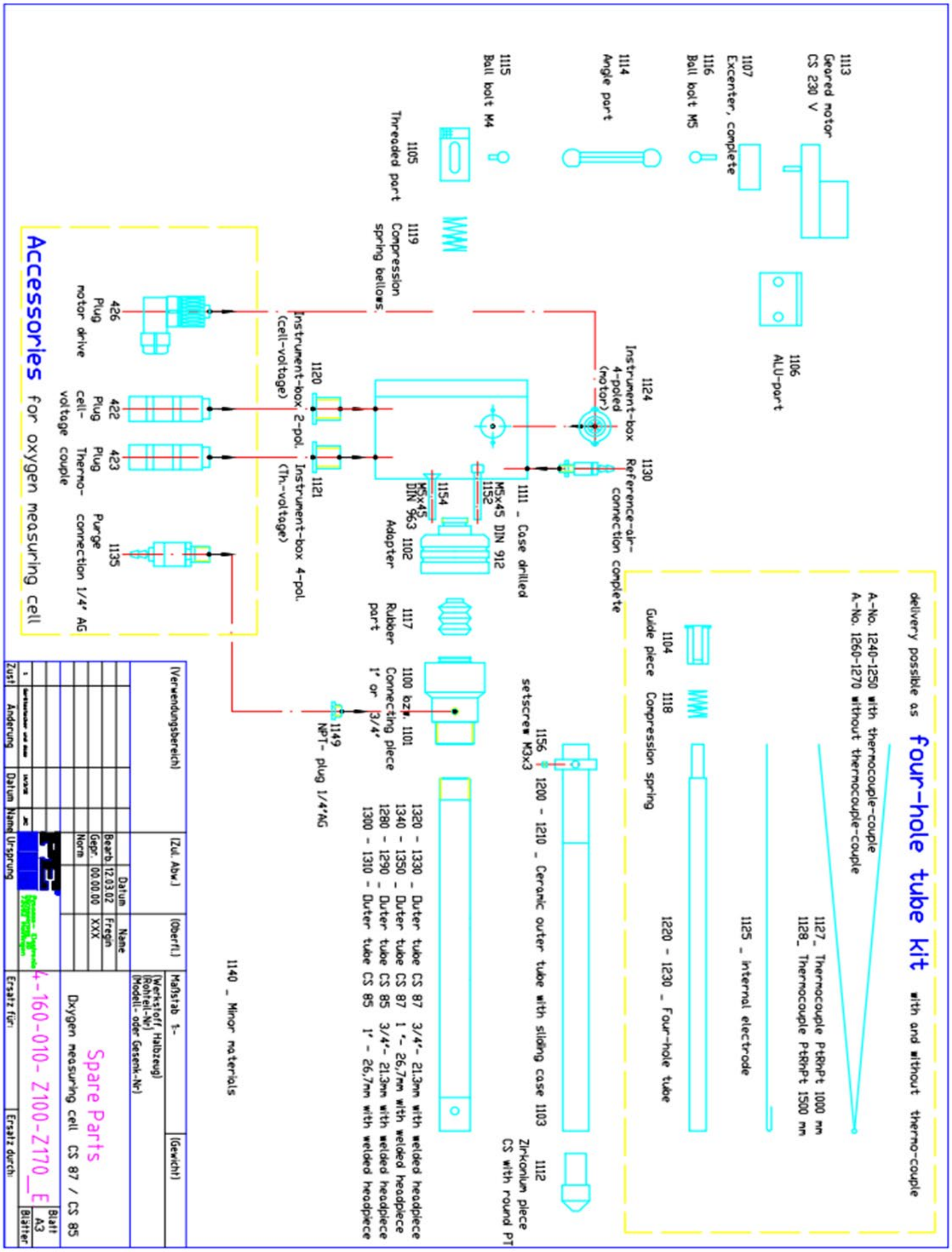
2 SPECIFICATION

CS87 PROBE CHARACTERISTICS	
Carbon Potential Range	0.10% to 1.4%
Output in normal heat treating	1000 to 1200 mV DC
Thermocouple type	K, R, & S type thermocouples available
Normal operating temp	1400°F to 1850°F *SEE WARRANTY CARD*
MIN operating temp	1150 ˚F
Sensor cover temp limit	200 °F max.
Sensitivity	0.02 mV or .0025% C
Accuracy	±0.03% C
Stability	±1 mV over sensor life
Response time	Less than 1 second
Impedance	Less than 6 K ohm
Sensor construction	Stabilized zirconia solid electrolyte
Sensor Length	400mm, 500mm, 600mm…1400mm (600mm & 900mm most popular)
Sensor Life	About 4 years with normal use (see Preventive Maintenance Schedule)
Warranty	1-year usage, non-prorated
Serviceability	(See Preventive Maintenance Schedule)
Motor Power Supply	220/110 Volts AC @ 2 rev/hr (voltage must be specified)
Reference air requirement	0.2 to 0.5 MAX SCFH filtered air *SEE REFERENCE AIR INSTALLATION*

3 SENSOR DRAWING – CS87



3.1 CS87 Components



4 CONNECTION CABLE ASSEMBLY SET

All new installations will require the purchase of an installation cable. Connection cables can be orders in preassembled, 10ft increments (10ft, 20ft... 100ft), for the Power, EMF, and Thermocouple sensor outputs. Using the table below, pick your desired length (in Feet), and sensor thermocouple type.

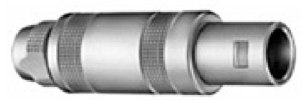
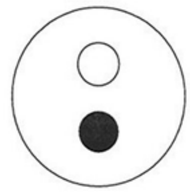
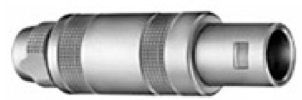
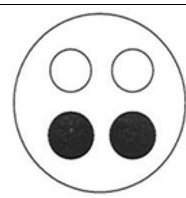
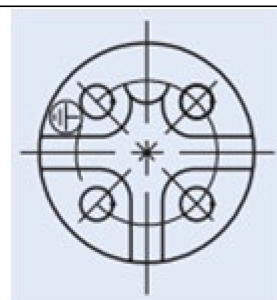
When ordering a probe for the first time, please order a cable assembly set, which includes Sensor & Thermocouple cable assembly to the length specified. Set also includes a Power Plug for assembly on-site (see CS87 POWER PLUG ASSEMBLY).

CA4 = CS87 Sensors

Cable Part #					
CAX-XX-Y-Z		CAX	-XX	-Y	-Z
Sensor Cable Type					
CS87		CA4			
Cable Length					
FT	M				
10	3.0		10		
20	6.1		20		
30	9.1		30		
40	12.2		40		
50	15.2		50		
TC Type					
NO Thermocouple				-X	
Thermocouple Type B				-B	
Thermocouple Type K				-K	
Thermocouple Types R & S				-RS	
Modification					
(BLANK FOR STANDARD BUILD)					

Longer lengths are available upon request
*Example: FPE145S CS87, Type S thermocouple, 80ft cable is required: CA4-80-RS

5 CS87 WIRE CONNECTIONS

		ANSI Cable Wiring		
 2-POS LEMO PLUG EMF SIGNAL		White	1	+
		Black	2	-
 4-POS LEMO PLUG THERMOCOUPLE SIGNAL		Red	3	-
		Black/Yellow	4	+
 4-Position Motor Socket POWER PLUG		Black	1	L
		White	2	N
		Green	⏚	PG

NOTE: PEG insulates the (+) TC wire with RED insulation and the (-) TC wire with CLEAR insulation on the INSIDE of the head. Do not confuse this with the ANSI wire coloring of extension wires connected externally. Make sure to observe the slot numbers on the head connectors regardless of color. POS #3 is (-) TC and POS #4 is (+) TC

The power plug is shipped with each sensor and must be assembled on-site manually. Please see power plug assembly instructions for further information.

Depending on your location, the CS87 sensor motor must be configured accordingly. CS87 sensors have two motor types.

1. 120 VAC, 60 Hz
2. 230 VAC, 50 Hz

6 CS87 POWER PLUG ASSEMBLY

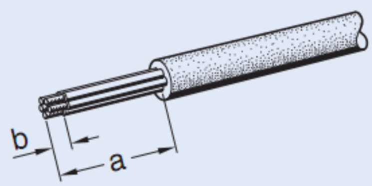
1. Using 16-20 AWG wire, cut the ends as shown below "Measure a" and "Measure b"
2. Run the wires through the assembly, starting at the cable nut ending at the shell terminal
3. Screw the wires into the terminals on the shell according to the Pin Assignment

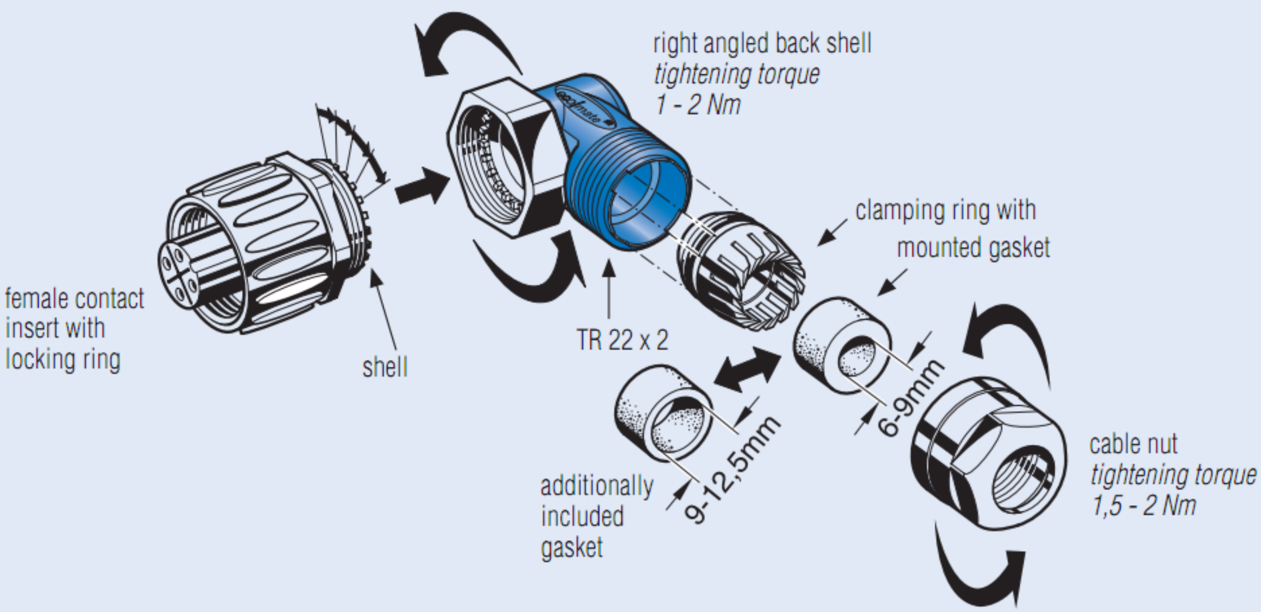
Pin Assignment	
⏚	G
1	Line
2	Neutral

4. Screw the Hex Shell on Female Contact Insert Body
5. Rotate the hex on the Right Angled Back Shell as shown below securing the shell in place
6. Push the Clamping Ring with the 6-9mm Gasket into the Cable Nut
7. Tighten the cable nut onto the Right Angled Back Shell completing the assembly

Mounting Instruction, right angled cable connector

Stripping Lengths	Measure a [1)]	Measure b
Screw contacts without internal cable retention	1-3/8"	1/4"





7 MAINTENANCE & WARRANTY CONDITIONS

Please see "CS87 Tip and Sheath Repair (English) PE CS TechManual" manual for detailed repair instructions.

In the case of a warranty claim of a CS87 probe with an installation longer than 6 months; the warranty will only be honored when the user can prove that maintenance has been performed at regular intervals. Within the warranty period, a major maintenance is required either every 6 months or 4000 hours.

Oxygen measuring cells are high grade and precise measuring instruments, which must be able to operate under harsh conditions. To guarantee measuring accuracy and stability, a defined care and maintenance program is necessary.

The maintenance includes a disassembly of the probe, a check of all the components, replacement of the damaged and worn parts, re-assembly and test. These steps should be carried out only by trained staff.

The regular maintenance includes:

- Remove the probe from the furnace.
- Remove the outer sheath. Thoroughly clean the inside and outside of the tube while checking for any bow or sag. If possible, bend the sheath until it has less than 3/32" of bow overall. If the sheath is beyond refurbishing, please replace accordingly. Analyze the tip of the probe where the zirconia tip comes in contact. If any form of deformation is apparent, then the sheath must be replaced.
    - Failure to replace the sheath at 6-12 month intervals will cause catastrophic failure to internal ceramic components.
- Remove the zirconium piece and thoroughly clean with fine sandpaper 600~1200 grit until the tip has a high gloss appearance. The discolouring condition of the zirconium piece is irrelevant. If this piece cannot be removed easily (an internal electrode is stuck, common occurrence) it can be removed by gently rotating it until it becomes free.
- There is a small metal disc (plate) inside the zirconium piece. If the precious metal contact plate detaches from the zirconium piece, it must be gently pressed in again (use a plastic or wooden stick).

ATTENTION: Violent and overly forceful use can damage the inner electrode. If the thermocouple and/or ceramic components require replacement, please contact UPC-Marathon, request an RMA, and return the probe to UPC-Marathon for repair. The inner electrode and thermocouple can only be repaired by qualified staff

8 PREVENTIVE MAINTENANCE SCHEDULE

Conservative Schedule:

1) 6 months: Replace the sheath, polish the zirconia tip
2) 12 months, <u>return to UPC-Marathon</u>: Replace the sheath, replace the inner electrode, replace the zirconia tip
3) 36 months: replace complete probe

Moderate Schedule:

1) 6 months: Clean the sheath, polish the zirconia tip
2) 12 months, return to UPC-Marathon: Replace the sheath, replace the inner electrode, polish the zirconia tip
3) 18 months: Clean the sheath, polish zirconia tip
4) 24 months, return to UPC-Marathon: Replace the sheath, replace the inner electrode, replace the zirconia tip
5) 48 months: replace complete probe

- We do not recommend replacing the inner electrode on-site. This repair must be accomplished by qualified staff.

- Maintenance schedule will vary depending on atmosphere contents, and probe performance.

- Analyze the condition of each probe component during the maintenance, take detailed notes, and depending on the noted trends; adjust your schedule accordingly.

- Violent and overly forceful use can damage the internal electrode. Do not pull on the zirconia tip if the inner electrode is fused to the tip. Please see "CS87 Tip and Sheath Repair (English) PE_CS_TechManual REV_0" manual for further instructions

- The thermocouple and ceramic components can only be repaired by qualified staff. If the thermocouple and/or ceramic components require replacement, please contact UPC-Marathon, request an RMA, and return the probe to UPC-Marathon for repair.

9 LOCATION CONSIDERATIONS

- Locate sensor near parts/work zone to get a meaningful reading.
- Locate sensor near furnace control thermocouple if possible.
- Locate sensor to avoid unnecessary close contact with heat sources (radiant tubes, heating elements) or fans.
- Locate sensor to avoid direct contact with inlet flow of carrier gas.
- Installation depth, the sensor should extend 2” – 6” (5 – 15 cm) beyond the hot face wall of the furnace.
    - Installations that exceed the 6” (15 cm) depth beyond the hot furnace wall will have an increase in sag (creep). Over time this will cause the sensor to fail prematurely.
- Locate sensor in the upper 1/3 of work zone if possible.
- If installing the sensor in areas which vibration may occur (e.g. in furnace covers or fan assemblies), the sensor must be inserted into a protection tube with mineral fiber packing around the sheath as a damper.

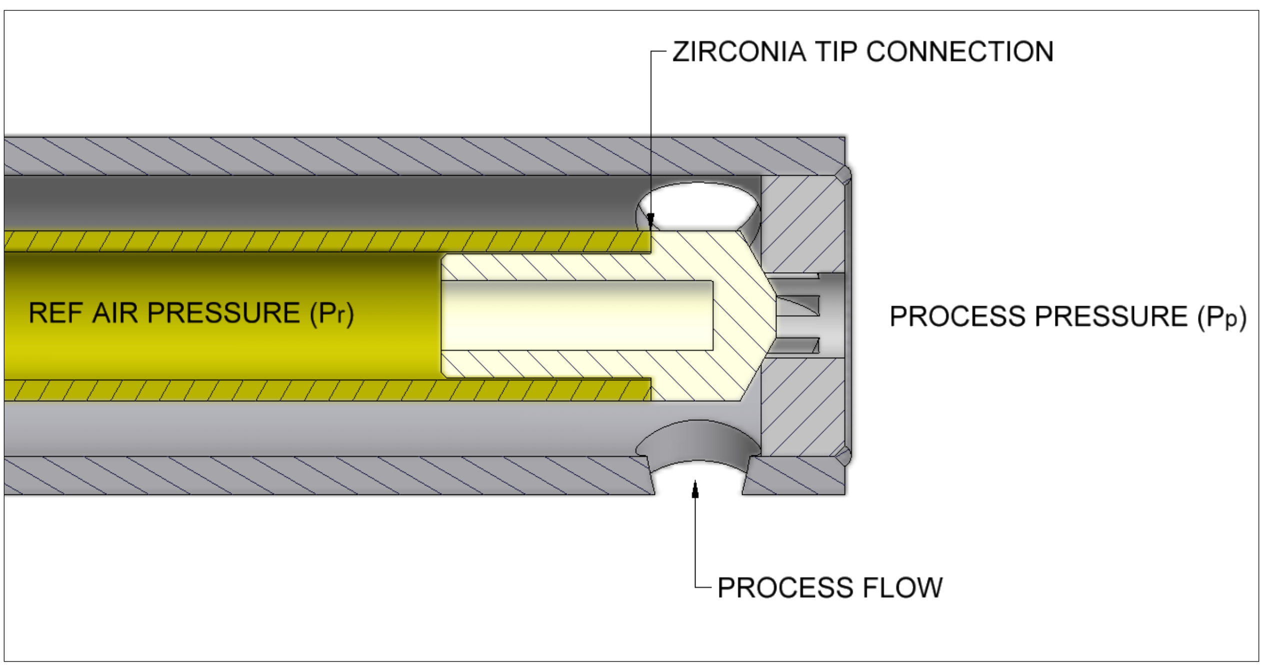
10 PORT FITTING CONSIDERATIONS

- Models are shipped with additional fittings as shown in the Sensor Drawings. Use the fittings that best suit your needs.
- Install sensor in furnace through an access hole with minimum of1½" diameter.
- Assure center lines of access hole and pipe coupling are concentric for correct line up.
- Assure gas-tight weld of pipe coupling to steel furnace shell.
- Assure connections on ALL external fittings adjacent to sensor are gas-tight.
- Teflon tape is preferred to other pipe dope compounds for sealing.

11 REFERENCE AIR INSTALLATION

In order for your sensor to function properly, reference air (20.9% O_2) must be supplied to the inner zirconia electrolyte tip. The flow and quality of the ref air is critical for very important reasons:

1. Carbon potential (C_p) and O_2 calculations
2. O_2 leaks into the process, lowering the Sensor mV signal and artificially lowering C_p levels
3. The reference air flow must be between 0.2 – 0.5 SCFH with a reference air pressure (P_R) of 1.0 – 3.0 inH_2O and equal to or less than the process pressure (P_P).
4. Reference air must be filtered free of contaminants and water in order to eliminate contaminants from reaching the inner electrode, impeding the sensor output.



The process pressure (P_p) must match the ref air pressure (P_r) or be slightly greater in order to prevent false High levels of O_2 in the process. High levels of O_2 will correlate to low C_p levels and high Dew Point temperatures.

12 RECOMMENDED INSERTION/REMOVAL PROCEDURE

- Mark the sheath of the sensor in 1” increments using a permanent marker.
- Insert the (Teflon tape) coated NPT body of the compression fitting into the furnace port and tighten accordingly ensuring a gas-tight seal.
- Place the CPI fitting and ferrule over the body of the sensor.
- Insert the tip of sensor into furnace port 6” deep initially to fully support the sensor. Allow the tip to heat up for 5 minutes.
- Insert carefully and slowly in one motion at 1/2” per second MAX. Use the 1” markings as a visual aid while inserting the sensor. If you are inserting at the correct rate, the 1” markings will insert every 2 seconds.
- Once the sensor is inserted to the desired depth, tighten the compression fitting accordingly ensuring a gas tight seal.
- Remove in the same manner. Place the sensor in an insulated blanket, once completely removed, and allow the sensor to cool to room temperature.

13 SENSOR BURNOFF

A carbon sensor operates in a very harsh environment where carbon deposits (soot) often form on the sensor. As soot accumulates at the tip of the sensor, the sensing surface of the sensor is shielded from the furnace atmosphere. This results in false, elevated carbon readings which will cause the controller to reduce the flow of enriching gas, resulting in low carbon or decarburizing conditions.

This effect is amplified in processes using elevated carbon set points such as boost and diffuse carburizing. Additionally, the high nickel content in the protective sheath alloy, while adding resistance to high temperatures, also acts as a catalyst, accelerating the deposit of carbon on the sheath.

Fact: *Over 80% of carbon sensor electrode failures are due to excessive carbon buildup at the outer electrode.*

Fortunately, removal of carbon deposits is as simple as running air through the “Burnoff” fitting supplied on all UPC-Marathon carbon sensors.

Self-cleaning of carbon sensors using air burnoff of accumulated carbon can be done successfully if the variables involved in the process are understood. The following items all contribute to the process, in order of importance:

- amount of air added for burnoff
- atmosphere circulation around the sensor
- location and amount of carbon that has accumulated

When air is forced into the sensor burnoff system, a combustion reaction between the air and the furnace atmosphere takes place. When air is added, the combustion reaction moves completely outside of the sensor (Figure 1). This process ensures sensor duration and accuracy by removing carbon buildup on the conducting cell.

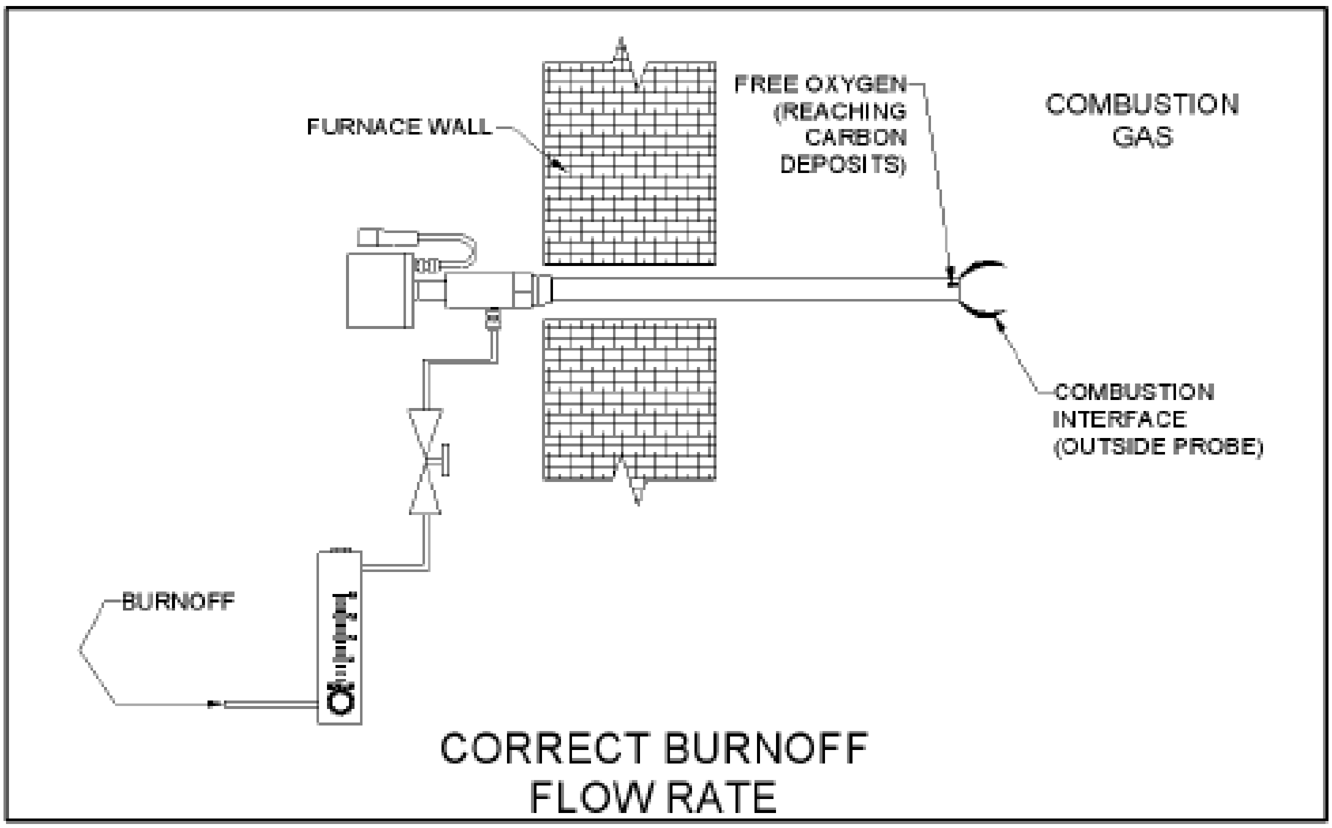


Figure 1

Removal of solid carbon is much more efficient if free oxygen is present to react with it. To judge the free oxygen level, it is necessary to interpret the sensor mV output. For example, at 1700°F, the following values apply:

O_2 mV	$\%O_2$
1150	9.9×10^{-19}

O_2 mV	% O_2
700	3.6×10^{-11}
100	0.43

Table 1

A lower mV reading from the sensor indicates how much burnoff air is reaching the tip. The mV will never reach a 0 mV level with process atmosphere present but it should drop significantly.

The amount of air required in a given installation depends heavily on the amount of circulation of furnace atmosphere around the sensor. The higher the circulation velocity, the more air is required. One example noted that 20 SCFH (9400 cc/min) was not enough to overcome the atmosphere circulation, yet when the furnace fan was shut off, less than 2 SCFH (950 cc/min) was found to be adequate.

When the combustion reaction (burnoff) is centered at the sensor tip, a MAX rise of 100°F may be observed in the sensor thermocouple (T/C). Do not exceed a delta change in temperature of 100°F. Care must be taken to keep the sensor tip below 1850°, or permanent damage may result. Determination of the required flow rate of burnoff air is estimated by plotting the flow rate of air versus the sensor's mV reading.

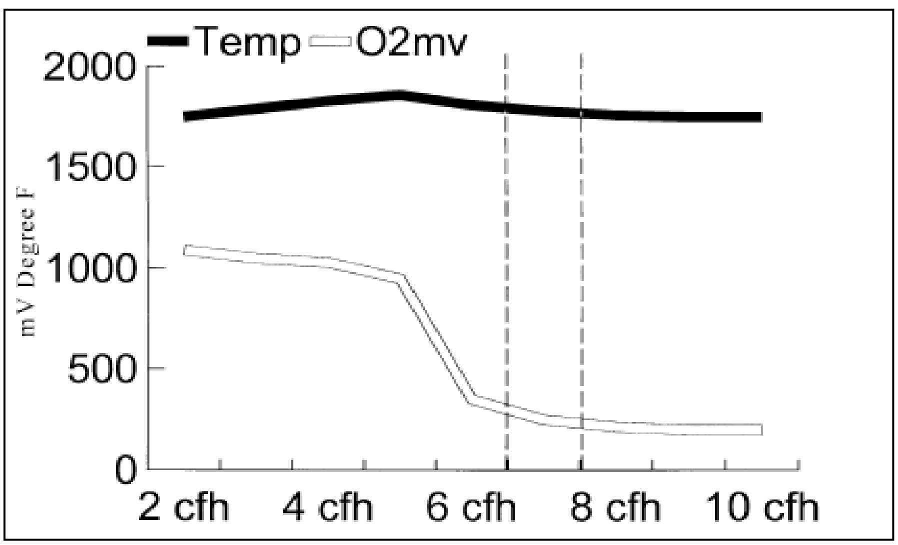


Figure 2

Figure 2 shows a typical example of data used to determine the flow rate of air required for burnoff. In this situation, a flow rate of 7 – 8 SCFH would be selected because this provides a lower temperature as well as some free oxygen at the sensor tip. If the amount of air required is found to be so high that interference with product processing is anticipated, the sensor should be relocated to a spot that will offer less impingement from the atmosphere circulation system.

Burnoff duration should be between 60-180 seconds (1 – 3 minutes). Do not let the sensor temperature rise above its maximum allowable temperature. The frequency of the operation depends upon the rate at which carbon is being accumulated. In continuous furnace applications, the burnoff process is ran 3-6 times daily, while in batch applications, the burnoff should be done at the start and end of each cycle. To verify the effectiveness of the burnoff procedure, simply remove the sensor after a burnoff and examine it.

Note: The protective alloy sheath is made out of ½” [0.84" OD] or ¾” [1.05" OD] schedule 40 pipe. The burn-off frequency must be enough to overcome carbon build up in the region around the substrate (see Figure 3), inside of the sheath. If carbon fills this space, and condenses, the sensor will fail prematurely.

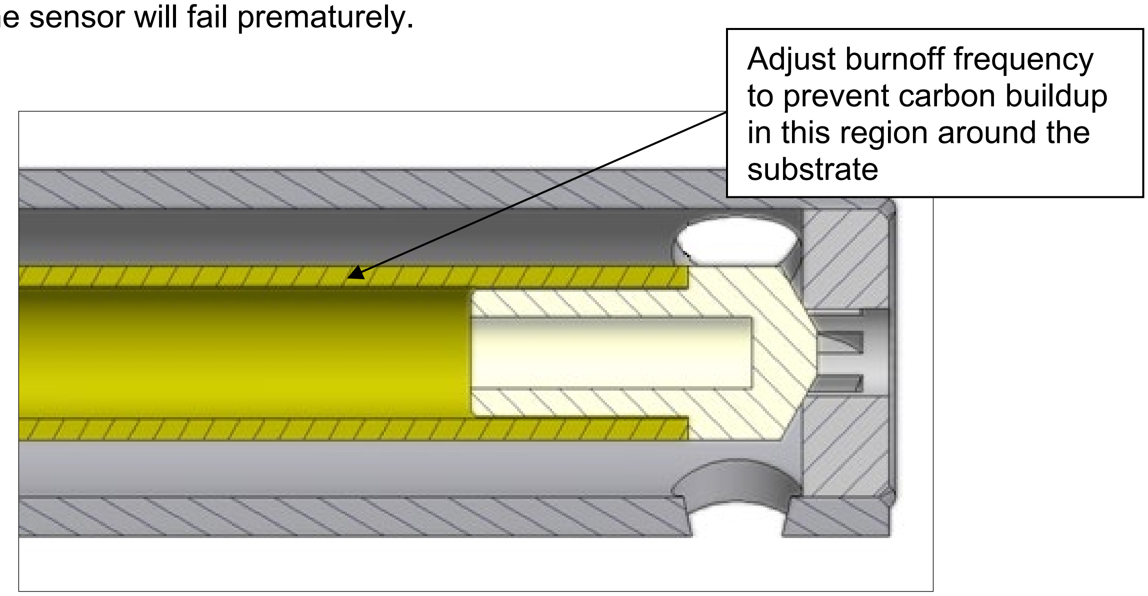


Figure 3

13.1 CS87 Motor Operation During Burnoff

The CS87 sensor is equipped with an internal motor which rotates the ceramic substrate for two beneficial reasons:
Adds to the carbon burn-off cleansing effect
Refinishes the contact between the electrolyte and outer electrode, reduces impedance.

NOTE: Do not operate the motor continuously. The rotation should only occur during burn off only; approximately 90° to 180° of rotation will be sufficient

14 FURNACE BURNOUT

Continuous operation at high carbon levels and temperatures will cause damage to most furnace components, including your sensor. It is recommended that frequent “gentle” furnace burnouts be conducted to avoid the cumulative effects of deposited carbon on furnace components. "Gentle" burnouts are normally conducted at 1500°F and can be monitored for completion by assuring that the carbon sensor output drops to 200 mV and increases to no more than 250 mV in the 15 minutes after burnout air is discontinued

15 ELECTRODE IMPEDANCE TEST

It is important to track sensor impedance over a period of time to help determine the replacement schedule for the sensor. A high impedance (>50 kΩ) indicates that the electrode contact on the sensor's zirconia has deteriorated to a level that warrants replacement.

High sensor impedance results in erratic output from the sensor and an eventual failure of the electrode connection on the process side of the zirconia ceramic. This deterioration is more of a factor in highly reducing atmospheres where it may be necessary to check the impedance at least once a month. Under light reducing, annealing or brazing operations, the impedance may not have to be checked unless there is a question about the sensor's performance.

Typical impedance readings for a new sensor are less than 1 kΩ. As the sensor starts to age, the impedance will increase. Once past 20 kΩ, the sensor should be monitored more closely and above 50 kΩ, the sensor should be replaced.

When it is necessary to replace a sensor with high impedance, remove it following the instructions supplied with the sensor. Do not discard the sensor as it is often possible to rebuild the sensor, provided the ceramic parts are intact. Contact UPC-Marathon for information on rebuilding your sensor.

An impedance test can only be performed if the sensor temperature is at or above 1100°F with stable atmosphere present. All UPC-Marathon instruments capable of performing this test will freeze all control functions and process signals during the test. The sensor must be in a stable atmosphere condition where the mV output will not vary during the test. To test the impedance, a 10 kΩ resistor is shunted across the sensor output. The sensor impedance is calculated using Formula 1.

R_x = sensor impedance E_o = open circuit voltage of sensor E_s = shunted voltage of sensor R_s = shunt resistor's impedance (10 kΩ)	$R_x := \left(\frac{E_o}{E_s} - 1 \right) \cdot R_s$ **Formula 1**

16 APPENDIX A: TROUBLESHOOTING YOUR SENSOR

When there is a problem making consistent product in a carburizing furnace you must consider all the possibilities before replacing the carbon sensor. In many cases, using the sensor and the control instrument to troubleshoot the problem can lead to the actual solution without replacing working equipment, incurring extended down time, sensor damage and expense.

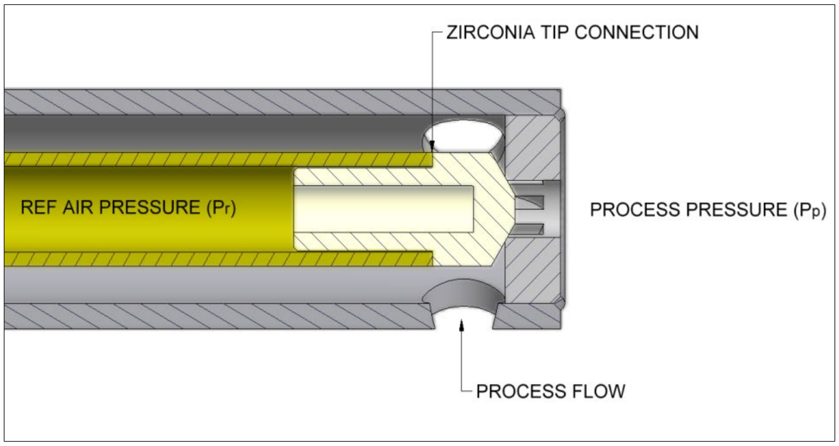
The following table lists typical problems encountered during the operation of a carburizing furnace when carbon levels are monitored or controlled using a carbon sensor. In all cases, the last resort is to replace the sensor, particularly if nothing has been done to try and troubleshoot the problem. It is necessary to consider all the components of the control system, including the control instrument, actuators and linkages, gas supply, furnace seals, burner integrity, as well as the carbon sensor.

Table 2

Problem	Troubleshooting path
Carbon readings are always the same or consistently higher than typical carbon levels under normal furnace conditions.	Go to Burnoff Check.
Carbon readings and/or Dew Point temperatures are too low/high and/or do not change.	Go to Reference Air Check. Go to Furnace Check.
Carbon readings are erratic or carbon level keeps oscillating.	Go to Signal Level Check. Go to Impedance Check. Go to Furnace Check.
Carbon readings drop drastically for short periods of time.	Go to Burnoff Check. Go to Furnace Check.
Carbon readings react with changes in the furnace but the load case depth is heavy or light.	Go to Process Factor Check.
There is no reference air flow.	Go to Reference Air Check.
There is no burnoff air flow.	Go to Burnoff Check.

17 REFERENCE AIR CHECK

1. Ensure that reference air source is providing clean room air that is free of airborne contaminates. Do not use compressed air unless it is free from oil and pressure regulated at 1.0 – 3.0 inH_2O. If in doubt about the reference air source, try an alternative source.
2. If reference airflow is not between 0.2 – 0.5 SCFH on a flow meter, ensure that airflow is getting to the sensor. Disconnect the reference air tube at the sensor and see if tube will bubble in a cup of water and flow meter is working. If bubbles are present then reference air is definitely getting to the sensor. If there is no flow when the tube is reattached to the sensor, the reference air tubing in the sensor is blocked. Replace the sensor.
3. The reference air flow must be between 0.2 – 0.5 SCFH with a reference air pressure (P_R) of 1.0 – 3.0 inH_2O and equal to or less than the process pressure (P_P).



4. The process pressure (P_p) must match the ref air pressure (P_r) or be slightly greater in order to prevent false High levels of O_2 in the process. High levels of O_2 will correlate to low C_p levels and high Dew Point temperatures.

18 BURNOFF CHECK

1. Perform a burnoff with the sensor at 1500°F minimum. The sensor temperature should increase slightly (100°F) above the ambient furnace temperature and the sensor mV should drop from pre-burnoff levels.
2. Check burnoff airflow. Verify that the burnoff event is active and that the burnoff solenoid is on. Verify that airflow is being supplied to the sensor by doing the bubble test as described in "Reference Air Check."
3. If all of the above is correct but the sensor mV still does not drop, repeat the burnoff procedure at a more frequent interval. If after a minimum of five burn offs there is no change in the mV reading and proper response to carbon changes, remove the sensor and inspect for heavy sooting. See Sensor Replacement.

19 IMPEDANCE CHECK

1. Check the sensor's impedance with a minimum temperature of 1500°F. A good sensor's impedance should be between 0.1-20 kΩ. If the impedance is above 20 kΩ, the sensor electrodes are starting to fail. If the levels reach 50 kΩ, the sensor should be replaced. If the impedance is good, check Process Factor or see Furnace Checks.
2. If the sensor impedance is high during one test and low or normal during another test, check the connections between the instrument and the sensor. If the impedance readings are still intermittent, see Sensor Replacement.

20 SIGNAL LEVEL CHECK

1. If the carbon sensor measurement system does, in fact, disagree with alternative measurement technique (e.g. FDPRO IR analyzer, shim stock analysis), check the sensor temperature and mV readings with the Percent Carbon chart (in the back of this manual) and see Process Factor Check. If these values agree then go to the Furnace Checks.
2. If sensor thermocouple display on instrument is not within ±25°F of furnace control thermocouple, make sure the instrument thermocouple type is set to the same thermocouple as the sensor thermocouple. If the reading is negative, check thermocouple connections. If the reading is >2300°F, check for an open or loose connection or open thermocouple.
3. Check the oxygen mV reading and ensure it agrees within ±6 mV of simultaneous readings from a digital voltmeter. Use a voltmeter with a 0.5% DC accuracy and 10 MΩ minimum input impedance. If the reading at the instrument is negative or zero, check for reversed, open or loose connections.
4. Connect a voltmeter directly to the sensor lead wires. When the positive sensor lead wire is disconnected from the sensor terminal block, the reading on the voltmeter should not change more than 2 mV. If the reading does change, make sure that the signal cable shield is connected at only the instrument ground and that the instrument has been properly grounded. Verify that the signal wire has not melted, been crushed or shorted between the leads, shield or ground. If the grounding and cable shield are good, verify that the instrument input is not loading down the sensor signal. Connect the sensor to another controller or change the input board on the controller. If the signal level still drops, go to the next step.
5. Short the sensor mV terminals for 15 seconds. If the sensor mV does not return to its original reading, ±10 mV, within 30 seconds as measured with one voltmeter, go to the Impedance Check.

21 PROCESS FACTOR CHECK

1. Ensure that the process factor is set to an appropriate value. A typical process factor for a new sensor in a methane based endothermic gas (20% CO) would be 150. The process factor would be 128 in a nitrogen-methanol system, but this is dependent on the ratio of methanol to nitrogen. In a pure methanol atmosphere, the theoretical process factor would be 85.
2. Increasing the process factor will lower the calculated percent carbon and cause the controller to increase the trim gas flow to the furnace. Decreasing the process factor will increase the calculated percent carbon and cause the controller to increase the trim air and/or decrease the trim gas. If the process factor has to be adjusted to very high (>300) or very low (<50) values, go to the Impedance Check.

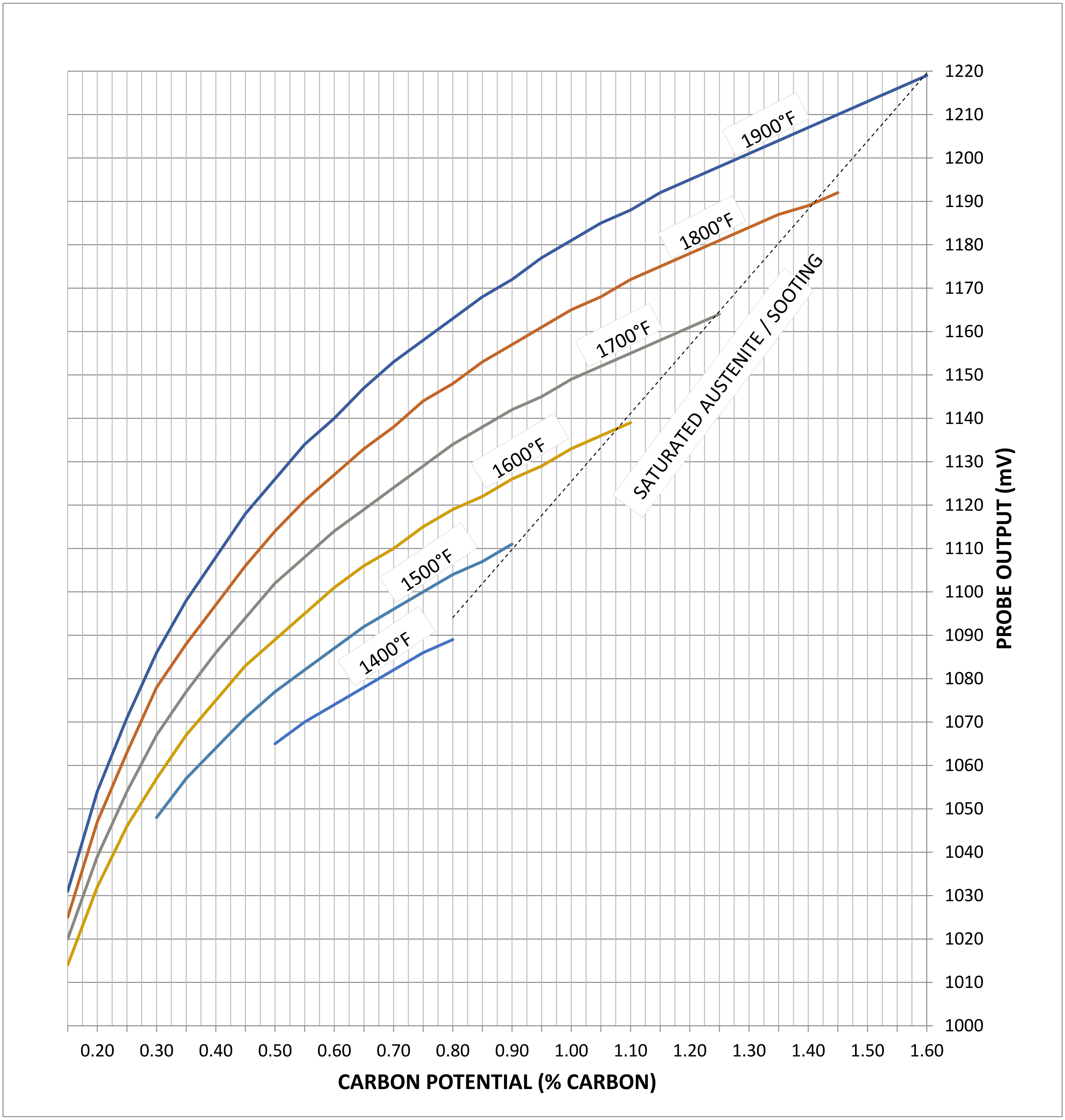
22 FURNACE CHECK

1. Try to determine if changes in the sensor carbon reading occur during other events on the furnace. For example, carbon fluctuations may correspond to gas-fired burners coming on during the early part of the heat cycle. This would indicate that there is a hole in a burner tube, leaking into the furnace.
2. An air leak or a water leak on a water jacket may cause low carbon readings.
3. Check actuator operation or linkage if the control stays at a 0% or 100% output with no resulting change in carbon level.
4. Verify that the controller is moving the actuators properly by placing the controller in manual mode and changing the output from 0% to 100%.
5. Verify that the endo gas, trim gas and trim air lines are opened and that manually adjusted flow meters are fully open.
6. Verify that trim lines are not bypassed if this feature is available.

23 SENSOR REPLACEMENT

- If your sensor is not working properly, please contact your Local UPC-Marathon representative before removing the sensor. There may be trouble shooting technique only accomplished while the sensor is still installed
- Insert/remove the sensor at ½” per second MAX if furnace is hot and place into an insulated blanket until complete dissipation. The modularity of the Carbonseer-M makes possible to rebuild a faulty sensor.
- Ensure that the sensor sheath shows no significant accumulation of soot or other deposits.
- Make sure that the main ceramic tube of the sensor is physically intact.
- Be sure that the sensor sheath is not is not warped.
- Note the above conditions and the sensor’s serial number. Call UPC-Marathon for an RMA to test and possibly rebuild the sensor.

24 CARBON POTENTIAL VS. SENSOR MV OUTPUT @ TEMPERATURE(S) GRAPH

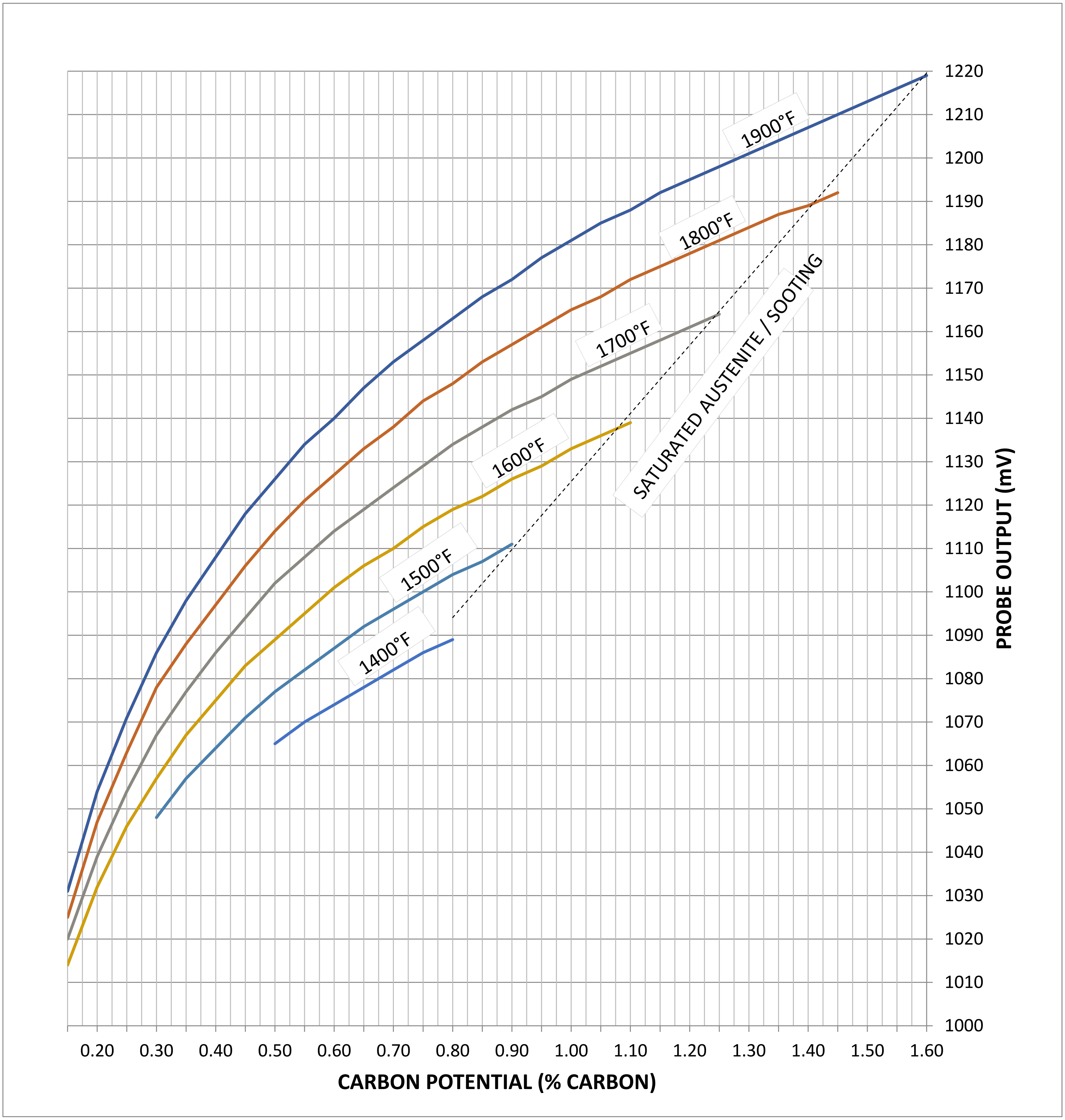


25 CARBON POTENTIAL VS. SENSOR MV OUTPUT @ TEMPERATURE(S) DATA

	TEMPERATURE (°F)																				
CARBON POTENTIAL (%C)	1400	1425	1450	1475	1500	1525	1550	1575	1600	1625	1650	1675	1700	1725	1750	1775	1800	1825	1850	1875	1900
1.60																					1219
1.55																				1212	1216
1.50																			1204	1209	1213
1.45																	1192	1197	1201	1206	1210
1.40																	1189	1194	1198	1203	1207
1.35																1182	1187	1191	1195	1200	1204
1.30															1175	1179	1184	1168	1193	1197	1201
1.25													1164	1168	1172	1177	1181	1186	1190	1194	1198
1.20												1157	1161	1165	1170	1174	1178	1182	1187	1191	1195
1.15										1146	1150	1154	1158	1162	1167	1171	1175	1179	1183	1187	1192
1.10									1139	1143	1147	1151	1155	1159	1163	1167	1172	1176	1180	1184	1188
1.05									1136	1140	1144	1148	1152	1156	1160	1164	1168	1172	1176	1180	1185
1.00								1129	1133	1137	1141	1145	1149	1153	1157	1161	1165	1169	1173	1177	1181
0.95							1122	1125	1129	1133	1137	1141	1145	1149	1153	1157	1161	1165	1169	1173	1177
0.90					1111	1114	1118	1122	1126	1130	1134	1138	1142	1145	1149	1153	1157	1161	1165	1169	1172
0.85			1100	1104	1107	1111	1115	1119	1122	1126	1130	1134	1138	1141	1145	1149	1153	1156	1160	1164	1168
0.80	1089	1093	1097	1100	1104	1107	1111	1115	1119	1122	1126	1130	1134	1137	1141	1144	1148	1152	1156	1159	1163
0.75	1086	1089	1093	1098	1100	1104	1108	1111	1115	1116	1122	1125	1129	1133	1136	1140	1144	1147	1151	1154	1158
0.70	1082	1085	1089	1092	1096	1100	1103	1107	1110	1114	1117	1121	1124	1128	1131	1135	1138	1142	1145	1149	1153
0.65	1078	1081	1085	1088	1092	1095	1099	1102	1106	1109	1112	1116	1119	1123	1126	1129	1133	1136	1140	1143	1147
0.60	1074	1077	1081	1084	1087	1091	1094	1097	1101	1104	1107	1110	1114	1117	1120	1124	1127	1130	1134	1137	1140
0.55	1070	1073	1076	1079	1082	1086	1089	1092	1095	1098	1102	1105	1108	1111	1114	1118	1121	1124	1127	1130	1134
0.50	1065	1068	1071	1074	1077	1080	1083	1088	1089	1092	1095	1098	1102	1105	1108	1111	1114	1117	1120	1123	1126
0.45		1062	1065	1068	1071	1074	1077	1080	1083	1088	1088	1091	1094	1097	1100	1103	1106	1109	1112	1115	1118
0.40			1058	1061	1064	1067	1070	1073	1075	1078	1081	1084	1086	1089	1092	1095	1097	1100	1103	1106	1108
0.35				1054	1057	1059	1062	1064	1067	1069	1072	1074	1077	1080	1082	1085	1088	1090	1092	1096	1098
0.30					1048	1050	1052	1055	1057	1060	1062	1064	1067	1069	1071	1074	1078	1079	1081	1083	1086
0.25						1039	1041	1044	1046	1048	1050	1052	1054	1057	1059	1061	1063	1065	1067	1069	1071
0.20							1028	1030	1032	1034	1035	1037	1039	1041	1043	1045	1047	1048	1050	1052	1054
0.15								1012	1014	1015	1017	1018	1020	1021	1022	1024	1025	1027	1028	1030	1031

* Data only valid with carrier gas composition $CO + CO_2$ = 20% and AISI 1010 Steel

26 CARBON POTENTIAL VS. SENSOR MV OUTPUT @ TEMPERATURE(S) GRAPH



27 CARBON POTENTIAL VS. SENSOR MV OUTPUT @ TEMPERATURE(S) DATA

	TEMPERATURE (°F)																				
CARBON POTENTIAL (%C)	1400	1425	1450	1475	1500	1525	1550	1575	1600	1625	1650	1675	1700	1725	1750	1775	1800	1825	1850	1875	1900
1.60																					1219
1.55																				1212	1216
1.50																			1204	1209	1213
1.45																	1192	1197	1201	1206	1210
1.40																	1189	1194	1198	1203	1207
1.35																1182	1187	1191	1195	1200	1204
1.30															1175	1179	1184	1168	1193	1197	1201
1.25													1164	1168	1172	1177	1181	1186	1190	1194	1198
1.20												1157	1161	1165	1170	1174	1178	1182	1187	1191	1195
1.15										1146	1150	1154	1158	1162	1167	1171	1175	1179	1183	1187	1192
1.10									1139	1143	1147	1151	1155	1159	1163	1167	1172	1176	1180	1184	1188
1.05									1136	1140	1144	1148	1152	1156	1160	1164	1168	1172	1176	1180	1185
1.00								1129	1133	1137	1141	1145	1149	1153	1157	1161	1165	1169	1173	1177	1181
0.95							1122	1125	1129	1133	1137	1141	1145	1149	1153	1157	1161	1165	1169	1173	1177
0.90					1111	1114	1118	1122	1126	1130	1134	1138	1142	1145	1149	1153	1157	1161	1165	1169	1172
0.85			1100	1104	1107	1111	1115	1119	1122	1126	1130	1134	1138	1141	1145	1149	1153	1156	1160	1164	1168
0.80	1089	1093	1097	1100	1104	1107	1111	1115	1119	1122	1126	1130	1134	1137	1141	1144	1148	1152	1156	1159	1163
0.75	1086	1089	1093	1098	1100	1104	1108	1111	1115	1116	1122	1125	1129	1133	1136	1140	1144	1147	1151	1154	1158
0.70	1082	1085	1089	1092	1096	1100	1103	1107	1110	1114	1117	1121	1124	1128	1131	1135	1138	1142	1145	1149	1153
0.65	1078	1081	1085	1088	1092	1095	1099	1102	1106	1109	1112	1116	1119	1123	1126	1129	1133	1136	1140	1143	1147
0.60	1074	1077	1081	1084	1087	1091	1094	1097	1101	1104	1107	1110	1114	1117	1120	1124	1127	1130	1134	1137	1140
0.55	1070	1073	1076	1079	1082	1086	1089	1092	1095	1098	1102	1105	1108	1111	1114	1118	1121	1124	1127	1130	1134
0.50	1065	1068	1071	1074	1077	1080	1083	1088	1089	1092	1095	1098	1102	1105	1108	1111	1114	1117	1120	1123	1126
0.45		1062	1065	1068	1071	1074	1077	1080	1083	1088	1088	1091	1094	1097	1100	1103	1106	1109	1112	1115	1118
0.40			1058	1061	1064	1067	1070	1073	1075	1078	1081	1084	1086	1089	1092	1095	1097	1100	1103	1106	1108
0.35				1054	1057	1059	1062	1064	1067	1069	1072	1074	1077	1080	1082	1085	1088	1090	1092	1096	1098
0.30					1048	1050	1052	1055	1057	1060	1062	1064	1067	1069	1071	1074	1078	1079	1081	1083	1086
0.25						1039	1041	1044	1046	1048	1050	1052	1054	1057	1059	1061	1063	1065	1067	1069	1071
0.20							1028	1030	1032	1034	1035	1037	1039	1041	1043	1045	1047	1048	1050	1052	1054
0.15								1012	1014	1015	1017	1018	1020	1021	1022	1024	1025	1027	1028	1030	1031

* Data only valid with carrier gas composition $CO + CO_2$ = 20% and AISI 1010 Steel

28 CUSTOMER SUPPORT

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