

AccuCarb[®]

INSTALLATION & OPERATION MANUAL

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INTRODUCTION

Congratulations, you have purchased the newest and technologically most advanced zirconia probe on the market. The AccuCarb® carbon probe, manufactured by United Process Controls, (UPC), is intended to be used with carbon control systems to control the carbon potential of an endothermic or nitrogen/methanol based heat treating atmosphere. A typical control system, shown in Figure 1, has three functional sections: (1) AccuCarb Carbon Probe, furnace flange and reference air supply; (2) control and recording instrumentation; and (3) enriching gas control valve. This manual pertains only to components in functional section 1, which are shown in Figure 1.

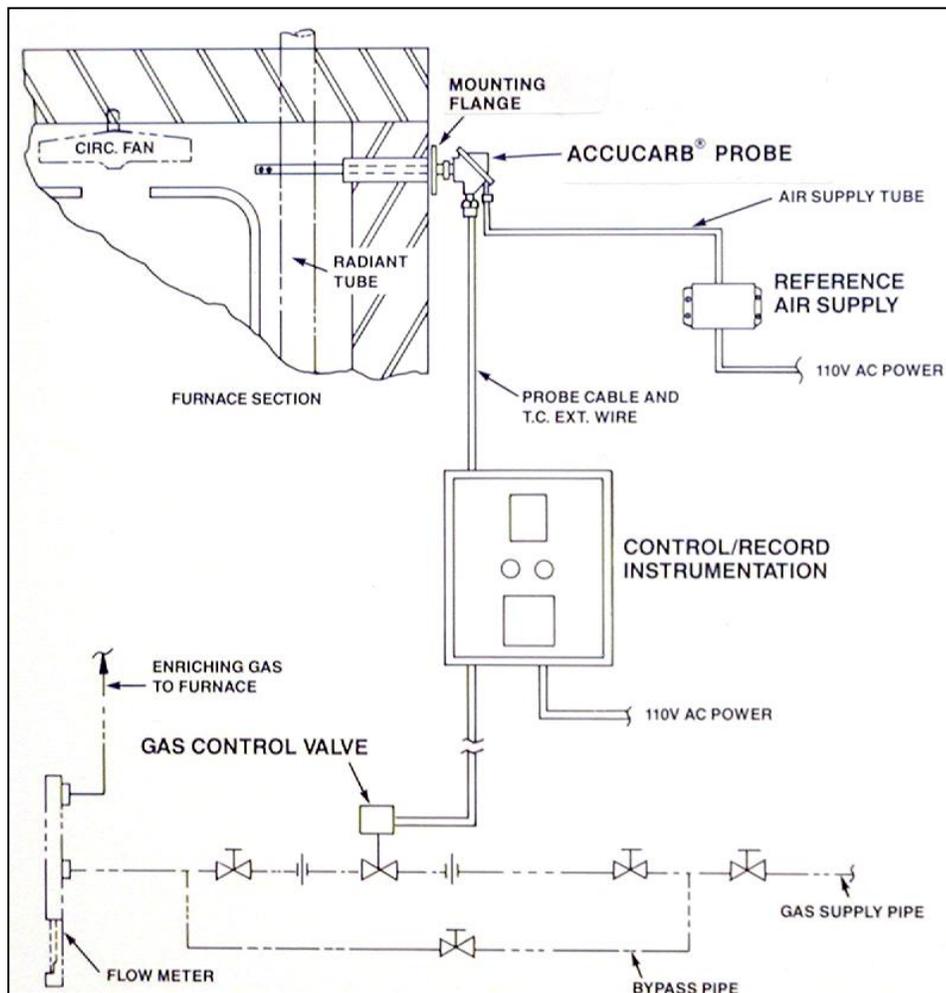
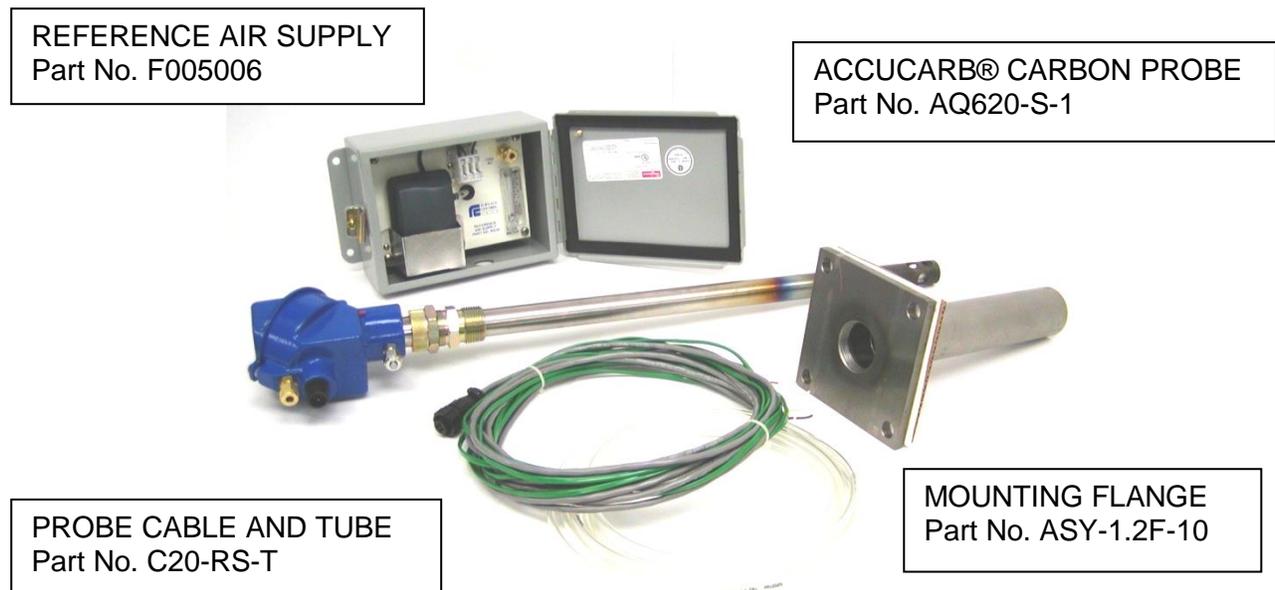


Figure 1 - Typical Carbon Control System

PRINCIPLE OF OPERATION

The AccuCarb® probe is a unique “second generation” zirconia probe. Its design was prompted by our previous experience in the design and manufacture of “first generation” probes and their limitations in the heat treating industry. The AccuCarb® probe is the result of extensive research and developmental testing. This probe represents a major breakthrough in probe design technology resulting in higher accuracy, longer service life and lower cost. The unique design and materials used in the AccuCarb® probe is protected by U.S. Patent No. 4,588,493 and pending foreign patents.



An AccuCarb® probe located directly in the furnace hot zone responds almost instantly to changes in the carburizing. Carbon potential control in heat treating using a zirconia carbon probe is described in detail in Metals Handbook 9th Edition, Vol. 4; pages 417 through 431.

Following is a brief summary of the principle of carbon potential controls using an AccuCarb® probe.

In a carburizing atmosphere containing CO and CO₂ gases, the carbon potential is a function of the ratio $(P_{CO})^2/P_{CO_2}$ under constant temperature CONDITIONS. The AccuCarb® probe provides a voltage output from which the P_{CO}/P_{CO_2} ratio in the carburizing atmosphere may be determined.

Therefore the voltage output of the probe is related to the carbon potential and may be represented graphically in much the same manner as the relationship between dew point or percent CO₂ and weight percent carbon.

The relationship between the voltage output of the AccuCarb® probe and the weight percent carbon for constant temperatures between 1500°F and 1900°F was determined using the following procedure.

A specially designed holder was used to insert thin steel shim specimens into a carburizing furnace for a sufficient length of time to equilibrate with the furnace atmosphere. During this equilibration period, the furnace atmosphere was adjusted so that the voltage output of the AccuCarb® probe remained constant. After equilibration, the shim specimen was rapidly removed from the furnace and quenched in water. The shim carbon content was then determined by chemical analysis. (See Operating Instructions, True Carbon Test for specific details).

ACCURACY

The accuracy of any carbon probe depends upon many factors. Most influential is the design and selection of materials used for major components such as the electrolyte, the electrode and the electrical leads that are attached to the electrodes.

The electrolyte is made of stabilized zirconia and is usually in form of a closed end tube. Electrodes are placed in contact with both the inner and outer surfaces at the bottom of the tube. Electrical leads bring the voltage signal from the electrodes to the outside of the probe to an appropriate connector. The design and the materials used for the electrodes affect probe accuracy. Three of the most important requirements for probe electrodes are:

1. The electrodes must not impede the flow of the atmosphere to the electrode-electrolyte interface.
2. The electrodes must act as reversible oxygen electrodes.
3. The electrodes must not alter the composition of the furnace atmosphere.
4. The AccuCarb® probe design has many patented features that cover the electrodes (See Figure 2).

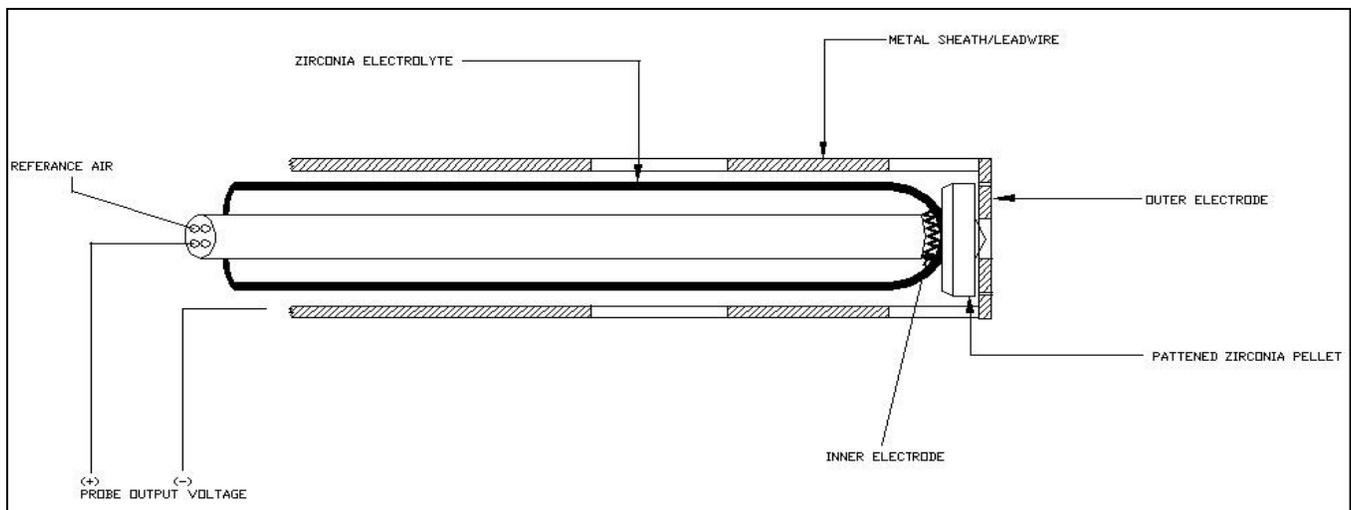


Figure 2

The voltage output of the AccuCarb® probe may be measured with a precision of about ± 0.2 mV which would correspond to a change in weight percent carbon of approximately ± 0.0025 . However, because of temperature irregularities in typical heat treating furnaces, the resultant combined accuracy with which the AccuCarb® probe controls carbon potential is approximately ± 0.03 weight percent carbon.

When high accuracy control instrumentation is employed for both temperature and carbon, accuracy of ± 0.01 weight percent carbon has been achieved.

It should be noted that there is no loss of sensitivity at high temperatures (i.e., 1800°F to 1900°F) with the AccuCarb® probe. For deeper case applications, high temperature carburizing offers significantly increased productivity and energy conservation as a result of shortened processing time. Another feature of the AccuCarb® probe is that it is virtually maintenance free for the life of the probe. No calibration, no cleaning or adjustments are required.

SERVICE LIFE

The useful life of the AccuCarb® probe, in comparison to other probes, has been significantly increased. In “first generation” carbon probes the most common failure modes are electrode and/or lead wire failure. The AccuCarb® probe uses a patented heat resistant alloy electrode welded to a metal sheath, which acts as a lead wire. Failure of these components in the AccuCarb® probe is virtually eliminated. Because of these significant improvements, the AccuCarb® probe has an expected life time of about two years with normal use.

INSTALLATION

If this is a new installation of an AccuCarb® carbon probe, carefully read the following steps:

- Probe Location
- Furnace Preparation
- Probe Installation

If the AccuCarb® probe is used to replace another probe, proceed directly with Probe Installation.

PROBE LOCATION

The general guideline is that the probe should be exposed to the same gas atmosphere and temperature as the work is exposed to. Typically, the AccuCarb® probe should be installed on the side of the furnace, near the center of the heat zone to be controlled. If possible, the horizontal location should correspond to the center line of the atmosphere fan.

The vertical location of the probe should be at approximately a few inches above the maximum work load height. This will prevent the possibility of probe damage caused by the load, and also expose the probe to a fresh and moving furnace atmosphere. In furnaces with an internal muffle, the probe should extend horizontally above the muffle arch and sidewall to within 6 to 10-inches of the fan.

NOTE: Determine the proper probe length at the location selected to make sure that it will not interfere with the furnace load, muffle components, radiant tubes, fan blades, gas ports, or any other furnace component. Be careful not to locate the probe too close to a radiant tube or electric heat source. Thermal cycling of the heat source may make control difficult. The probe length is adjustable and need not be inserted to the maximum length.

FURNACE PREPARATION

WARNING

Before proceeding, if possible remove all combustible atmospheres from furnace, open all doors and cool to room temperature.

The above warning ensures that there can be no positive pressure or flammable gases inside the furnace. Failure to perform this step may result in injury to personnel.

After the location of the probe is determined to be acceptable, as described above, a port with a female 1-inch NPT thread and 1 3/8-inch I.D. clearance is required. The use of furnace flange part #: ASY-1.2F-10, simplifies the task to prepare a port in the furnace.

The “furnace flange” has a precision 1 ¼-inch NPT thread machined into it and has an alloy pipe extension to line and support the furnace refractory. Use of this part is strongly recommended to minimize problems and to simplify the installation of the AccuCarb® probe.

1. Saw or Torch-cut a 2 1/2–inch diameter hole in the steel shell of the furnace at the probe location determined above.
2. Using an insulation boring tool, bore a 2-inch diameter hole through the thermal insulation, concentric with the 2-1/2-inch hole in the steel sidewall and perpendicular to the sidewall. Remove boring tool and core of insulation.
3. Insert “furnace flange” into hole in furnace sidewall. Flange should fit flush against sidewall. If not, take necessary steps to remove interference material.
4. Using the “furnace flange” as a template, mark location of the four mounting holes on the furnace wall and remove the furnace flange.
5. Drill and tap the four holes with 3/8-inch NC thread.
6. Insert the “furnace flange” in the furnace sidewall hole with a gasket between the flange and the furnace sidewall.
7. Secure the flange to the furnace sidewall with four (4) 3/8-inch NC hex head bolts 1-inch long. A 1-inch pipe plug should be used to close hole in furnace flange, allowing normal furnace operation until AccuCarb® probe is ready for installation.
8. We recommend the installation of a second “furnace flange,” same as described above, to be available for carbon accuracy shim tests or possibly for another probe. Shim tests are essential during troubleshooting or if there is a question about the accuracy of the probe. Location of the second port should be as close as possible to the probe location.

NOTE: In new furnaces or newly re-bricked furnaces it is important that the refractory be fully dried and cured before the probe is installed. Binders and some mortar components released during curing can affect probe accuracy and shorten the probe life. It is strongly recommended to operate the furnace for at least 8 hours at 1700°F or higher with a reducing atmosphere (endothermic gas), to flush out potential detrimental refractory components.

PROBE INSTALLATION

Installation of the AccuCarb® carbon probe should only be attempted after a proper furnace port is ready and all interconnecting wiring, reference air tubing and air supply are in place.

READ THESE INSTRUCTIONS COMPLETELY BEFORE ATTEMPTING THE INSTALLATION.

NOTE: If you plan to install the AccuCarb® probe in a furnace port previously used for another probe or some other function, make certain that the threads are 1-inch pipe thread (NPT), the I.D. is at least 1 ½-inch and that the hole is straight and open on the end.

WARNING

Before proceeding, if possible remove all combustible atmospheres from furnace, open all doors and cool to room temperature.

The above warning ensures that there can be no positive pressure or flammable gases inside the furnace. Failure to perform this step may cause injury to personnel.

Use extreme care when handling and installing the AccuCarb® probe. It is susceptible to thermal and mechanical shock and may be damaged if mishandled.

1. Carefully remove the AccuCarb® probe from the shipping box and inspect for damage by looking for broken ceramic pieces. It is not necessary to open the probe cover for damage inspection. If damage is observed or is suspected, notify the carrier who delivered the probe. Keep the box and foam in case the probe is shipped back after its life.
2. Fill out our warranty card and retain your portion of it and send the other portion back to UPC.
3. Remove 1-inch NPT plug from center of furnace flange or port, which has been installed on furnace sidewall according to previous instructions.
4. Check the port I.D. for any obstruction and remove collected debris using compressed air or brush.
5. Remove compression fitting body from the AccuCarb® probe. Leave the nut and seal rings, or O-rings on the probe sheath. Put Teflon plumbers tape on pipe

threaded end of compression fitting. Thread compression fitting into furnace flange. Tighten with wrench but do not exceed 20 ft-lb.

6. If the furnace is 300°F or cooler (Cold Installation), slide probe into compression fitting to the desired depth. Make sure seal rings or O-ring is between compression fitting body and nut. Hand tighten nut on probe sheath. Do not rotate probe while tightening nut.

It is preferable that the furnace be at 300°F or cooler for probe insertion; however, if the temperature is above 300°F, the following instructions must be followed in the sequence given or thermal shock may damage the probe.

7. Measure 6 inches from the end of the probe sheath and mark with a felt tip pen. Mark the remainder of the AccuCarb® probe in 1-inch graduations.
8. Make a ball of soft refractory fiber material and place it in the opening of the furnace wall where the probe is going to be inserted. It is probably easier to place the fiber ball into the opening before the probe compression fitting is screwed into the threads. The fiber ball should fit the I.D. of the port, thereby eliminating any flames and reducing the volume of hot gases exiting from the opening. Do not proceed to the next step unless flames are completely extinguished
9. As you continue to install the probe, the fiber ball will be gradually pushed into the furnace interior.
10. Carefully insert probe into compression fitting to the first mark on the probe sheath (6-inch mark). Make sure seal rings or O-ring is between compression fitting body and nut. Wait 5 minutes while the probe warms up.
11. Insert probe at the rate of about 1-inch per 5 minutes.
12. Repeat the previous step until probe is installed to proper length.
13. Hand tighten the compression fitting nut on the probe sheath, and then wrench tighten 1/4 turn securing/sealing the probe in place. Do not over tighten

Connections for the probe signal and also integral thermocouple are made through the black electrical connector located at the underside of the probe cover. If you are using a probe cable supplied by UPC, the connector installed on the end of the cable and T/C extension wire, will mate with the connector on the probe cover. If you did not purchase a new cable, your new probe was shipped with the mating half of the connector attached to a short piece of wiring. It is necessary for you to splice this short wire to the existing wiring with proper polarity.

NOTE: The gray shielded cable contains the probe lead wires.

The black insulated wire is positive (+)
The clear insulated wire is negative (-)

The thermocouple extension wires are contained in:
Yellow insulation for type K
Green insulation for Type R & S
The red wire is always negative for types K, R, and S thermocouples.

Reference air connection is made through the brass 1/4-inch tube fitting adjacent to the electrical connector. Urethane, Teflon or copper tubing can be used. Remove nut and ferrules from brass body of air fitting on the underside of the probe cover. Place nut and ferrules on reference air tube and connect to air fitting. Hand tighten nut on air fitting, then turn $\frac{3}{4}$ turn with a wrench to set ferrules on the tubing, hand tightening of the nut is adequate.

CAUTION: Do not remove REF AIR and BURNOFF FITTING BODY from probe head. Removing the FITTING body will cause the probe to malfunction. The CAP is the only component able to be removed, NOT THE BODY.

HOT REMOVAL

If the probe is not functioning normally, do not remove the probe from the furnace before contacting UPC technical support. UPC technical support may be able to troubleshoot and resolve the issue.

**(US & Canada) 1-800-547-1055
(Outside US) +1-513-772-1000**

If the furnace is at or below 300°F, the probe can be removed without any precautions.

If the furnace is above 300°F do not remove the probe from the furnace abruptly or this will cause thermal shock to the ceramic components. The probe must be removed in the same manner as in which it was installed.

1. Remove connections from the head and burnout port. Plug the burnout port with the initially supplied plug
2. Loosen the compression fitting nut on the probe sheath.

NOTE: If the probe does not coming out freely, do NOT twist the head of the probe in a counterclockwise direction, remove the compression fitting.

3. Remove the probe at rate of 1-inch per 5 minutes until the tip reaches 6” from the installation port.
4. Remove the probe and place in a protective thermal blanket until it has completely cooled down
5. If the probe is being shipped back, use the packaging (box and foam) shipped initially.

OPERATION

START-UP PROCEDURE

1. Heat furnace to normal operation temperature (1700°F) and introduce carrier gas atmosphere into heat chamber according to furnace operating instructions. Make sure circulating fan is operating. Enriching gas manual safety shut-off valve should be open, but the controller-operated valve should be closed. Do not add enriching gas to an empty furnace.
2. Ensure that 110V AC power is applied to the probe air reference pump and also to all recording and controlling instruments. If your control system requires the use of a signal conditioner, ensure that it is also powered.
3. Allow about an hour for the furnace temperature to stabilize. Compare the average integral temperature to the average furnace control thermocouple temperature. A difference of less than 20°F is acceptable, but usually it is less than 10°F. If the difference is more than 20°F, refer to the Troubleshooting Section.
4. Select the desired carbon potential for the parts being carburized. Make certain that the controller is set up for the AccuCarb® probe. If that selection is not available, contact UPC.
5. Set the controller setpoint to the desired reading established in Step 4.
6. Put work into the furnace and allow the system to control. Follow manufacturer's instructions for the specific control system that you are using.

PROBE BURNOFF

A carbon probe operates in a very harsh environment where carbon deposits (soot) often form on the probe. As soot accumulates at the tip of the probe, the sensing surface of the probe 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.

Frequent or continuous operation of the AccuCarb® probe at carbon potentials near the austenite saturation is not recommended because of soot formation in the furnace and on the probe. To determine the saturated austenite level, refer to the AccuCarb® probe output vs. carbon potential graph included with this manual.

If soot buildup occurs in the furnace or on the AccuCarb® probe, the condition must be alleviated by a “burnoff” of the probe. Caution must be exercised in selecting the combination of burnoff temperature and amount of air addition to the furnace so that the probe temperature does not rise or fall more than 100 °F during burnoff.

This effect is amplified in processes using elevated carbon set points such as boost and diffuse carburizing.

A rapid burnoff could elevate the probe temperature up above 2000°F if improperly implemented. This rapid elevation of temperature could also cause thermal shock damage to the probe, therefore voiding the warranty. Low frequency of burnoff cycles could cause the probe sheath to get packed with carbon, limiting the inner mechanics. This limiting effect could cause probe failure, therefore voiding the warranty.

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

Self-cleaning of carbon probes 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 probe
- temperature

When air is forced into the probe sheath (**Figure 3**) a combustion reaction between the air and the furnace atmosphere takes place. The location of this reaction will naturally settle at some equilibrium location. In some furnaces, it is possible to see exactly where this reaction is taking place by watching the probe sheath during burnoff. A “hot spot” will mark the location.

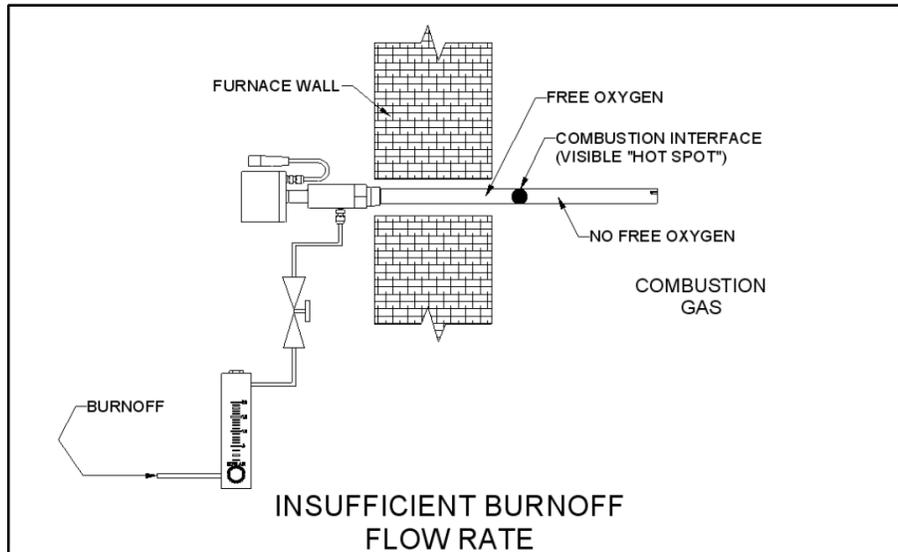


Figure 3

As the amount of air is changed, the location of the combustion interface can be changed. The higher the air flow, the further out in the probe sheath the interface will move (**Figure 4**). If enough air is added, the combustion reaction can actually be moved completely outside of the probe (**Figure 5**).

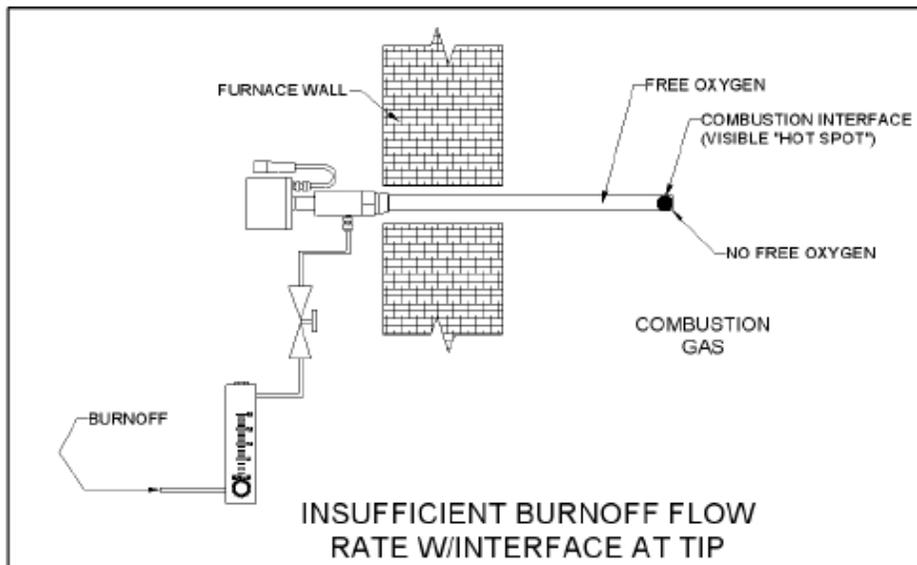


Figure 4

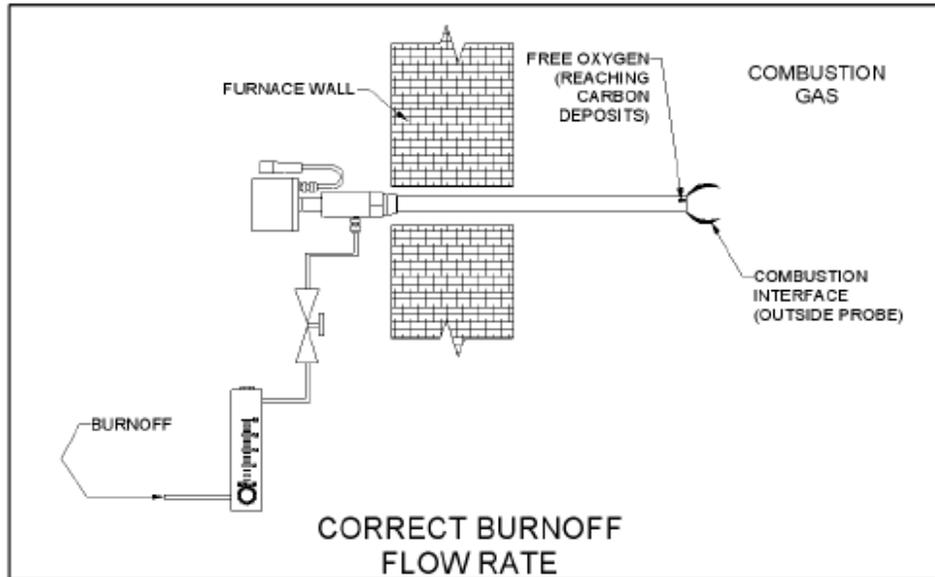


Figure 5

Note that the atmosphere in front of the interface does not contain significant amounts of free oxygen while the atmosphere behind the interface does. Removal of solid carbon is much more efficient if free oxygen is present to react with it. This means that enough air should be used to push the combustion interface at least to the probe electrode and preferably slightly beyond. To judge the free oxygen level, it is necessary to interpret the probe millivolt output

A lower mV reading from the probe 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. You should see the probe mV reading drop at least 200 mV from normal readings and ideally go below 800 mV.

The amount of air required in a given installation depends heavily on the amount of circulation of furnace atmosphere around the probe. The higher the circulation velocity, the more air is required to get the carbon out to the probe tip. Disable the circulation fan, if possible, during burnoff.

If the amount of air required is found to be so high that interference with product processing is anticipated, the probe should be relocated to a spot that will offer less impingement from the atmosphere circulation system.

When the combustion reaction (burnoff) is centered at the probe tip, a rise of as much as 100°F may be observed in the probe thermocouple (T/C). Care must be taken to keep the probe tip below 1850°F, 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 probe's mV reading.

All AccuCarb® probes should have a burnoff length between 2-5 minutes. Do not let the probe 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 run 3-6 times daily, while in batch applications, the burnoff should be done at the start of each cycle. To verify the effectiveness of the burnoff procedure, simply remove the probe after a burnoff and examine it.

TRUE CARBON TEST

This test is performed to compare the true atmosphere carbon potential with that indicated by the AccuCarb® probe and associated carbon control system. The indicated percent carbon is Determined from either the graph or chart included with this manual.

The true carbon potential of the furnace atmosphere can be determined by inserting a steel shim sample into the furnace for a period of time and then determining carbon content of the shim by chemical analysis. For this test, an additional port adjacent to the AccuCarb® carbon probe (discussed in the Installation Section, Furnace Preparation), a Shim-Holding Cartridge and a Shim Cooling Chamber will be necessary. All these items are available from UPC. See Parts List Section at the back of this manual for Shim Stock components.

To perform the shim test, proceed as follows:

1. Use .003-inch thick shim sample of AISI 1010 material
2. Make sure that this sample size is of adequate weight for your method of carbon analysis.
3. Roll shim samples into cylindrical shape of about ¾-inch diameter.
4. Slide the shim sample into the holding cartridge.
5. Before proceeding, make sure that:
 - a) Furnace is operating about 1600°F
 - b) There is some work in the furnace
 - c) The doors have been closed and the circulation fan and atmosphere have been running for about ½ hour to have uniform temperature and carbon potential.
 - d) The Shim Cooling Chamber is attached to the furnace port and the gate valve on the cooling chamber is closed.

WARNING

Personnel operating shim test equipment must wear fire protection gear, or personal injury may occur. Combustible carrier gas may ignite.

6. Insert the Shim Holder into the end of the Cooling Chamber and thread the pipe plug in place to close up the end of the Cooling Chamber. Open the gate valve completely and slide the Shim Holder into the furnace approximately to the depth

that the AccuCarb® probe end is located. (from the gate valve this is about 24 inches)

7. Leave the shim sample in the furnace for 30 minutes if the furnace temperature is 1700°F, or 45 minutes if the temperature is between 1600 and 1650°F.
8. Record average furnace temperature and average probe millivolt output during the test. If a direct reading carbon controller is used and millivolt reading of probe cannot be obtained, record wt% carbon from controller.
9. Retract Shim Holder from furnace into the Cooling Chamber and allow cooling for 10 minutes with gate valve open.
10. Close gate valve and remove Shim Holder from the Cooling Chamber by unscrewing pipe plug at the end.
11. Remove shim sample from holder. If the shim surface appears to have flaking oxidation, the carbon results will be questionable and the test should be repeated. If the shim has thin adherent oxidation, etch it in a weak solution of about 10 percent hydrochloric acid and water for several minutes to remove the oxidation.
12. Determine carbon content of the shim sample by using a Leco Carbon Analyzer or any other combustion carbon analysis method.
13. Compare the carbon content of the shim to either that predicted by the graph or chart using the temperature and millivolt readings made in Step 7, or with the wt% carbon from the controller. A difference of less than 0.03% carbon should be obtained with a good AccuCarb® probe and a proper sampling technique. If the difference in % carbon is greater than 0.03%, refer to Troubleshooting Section (Carbon Control System Accuracy and Probe Thermocouple Accuracy.)
14. It should be noted that the relationship between the AccuCarb® probe output and the carbon potential (wt% carbon) shown in the table and graph included with this manual, was determined for AISI 1010 steel. The type and concentration of alloying elements in the work can affect the amount of carbon transferred from the atmosphere to the work surface. For example, if AISI 9310 steel is carburized at a setpoint of 0.90 wt% carbon, the surface carbon content of the 9310 steel would be 0.80 wt% Carbon compensating the controller setpoint for the effect of alloy content is the responsibility of the operator or the metallurgist specifying the heat treat operation.

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 (>20 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 probe's performance.

Typical impedance readings for a new probe are less than 1 kohm. As the probe starts to age, the impedance will increase. Once past 20kohm, the sensor should be monitored more closely and above 50 kohm, 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 for information on rebuilding your sensor impedance test can only be performed if the probe temperature is at or above 1100°F with stable atmosphere present. All UPC instruments are capable of performing this test. The test will freeze all control functions and process signals during the test, eliminating erratic furnace control, and resuming control after probe recovery.

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.

$$R_x = \left(\frac{E_o}{E_s} - 1 \right) \cdot R_s$$

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)

TROUBLESHOOTING

This section is to be used if an atmosphere control malfunction occurs or is suspected. The objective of the following test procedure is to determine which part of the system (e.g. probe, interconnecting cable or control instrumentation) is malfunctioning.

TEST EQUIPMENT

1. Digital voltmeter with resolution of at least 1 millivolt DC and minimum input impedance of 10^9 ohms.
2. Ohm meter, capable of measuring resistance to a minimum of 10^9 ohms.
3. 1 mega Ohm resistor, any wattage.

TEST PROCEDURE

1. For the following procedure, the furnace should be at 1700°F with an atmosphere of endothermic gas at 40°F dew point or lower. The furnace may have a load in it, although it is not necessary. Put the control system in manual mode.
2. At the control panel or signal conditioning amplifier, disconnect the shielded probe cable from the control system. Check the DC voltage between (+) and (-) lead wires.

If the measured DC voltage is less than 1.0 v, the problem may be with the air pump. Check to see that reference air is flowing into the probe at the reference air connector on the probe cover. If the reference air system is functioning and the voltage output is less than 1.0 V the problem is with the probe. Initiate an impedance test from your control equipment.

If the measured voltage is between 1.0 and 1.2 V, the problem may be in the connecting cable. To check the probe cable, disconnect the connector at the probe cover. Check each lead of the cable (resistance less than .5 ohms) and that there is no shorting to the other leads and/or to ground. If the cable fails the above test, replace or repair cable as needed. Reconnect cable connector at the probe cover. Measure the probe output voltage to the nearest millivolt at the control panel end of the cable. Put a 1 mega ohm resistor in series with the probe cable positive lead and measure the probe output voltage again. A normal probe will show a drop of less than 15 mV. If the voltage drop is more than 15 mV, contact UPC for instructions.

CONTROL SYSTEM ACCURACY

If the carbon control system is controlling, but incorrect surface carbon content is suspected on carburized parts, check that the percent CO content of the carrier gas used is $20 \pm 1\%$. For this check a properly calibrated infrared analyzer such as the Furnace Doctor® Pro gas analyzer is recommended. This analyzer measures %CO, %CO₂, %CH₄ and calculates %carbon, dew point, and expected oxygen millivolts from the measured gasses and user entered temperature.



Figure 6 - Furnace Doctor® Pro Infrared gas analyzer

Using direct carbon reading instrumentation, make sure the controller is set up for the AccuCarb® probe. To verify this, measure the probe output in millivolts. Using the table or graph supplied with this manual, look up the predicted percent carbon for the AccuCarb® probe voltage at the furnace operating temperature. Compare this percent carbon value with the value read from the control instrument. If they are in agreement, proceed to test the AccuCarb® probe using the true carbon level test described in the Operation Section (True Carbon Test).

THERMOCOUPLE ACCURACY

The accuracy of the temperature input with direct percent carbon instruments is especially important. We recommend that you make available an alternate temperature

source for direct percent carbon reading instruments, other than the integrated probe thermocouple. There could be several reasons for temperature discrepancies involving the integral AccuCarb® probe thermocouple in comparison to the control thermocouple.

The furnace control thermocouple has drifted in accuracy. Normal replacement will remedy this condition.

The probe location within the furnace is not suitable initially or may have become unsuitable due to sagging or changing heating units (radiant tube, ribbons or wires) since initial Installation. If this condition is ascertained, the probe must be moved to a new location.

Step-by-step instruction to track down the various causes of a temperature discrepancy involving the probe thermocouple is not feasible here. A logical, systematic approach using portable ice point compensation and a millivolt meter or an equivalent instrument will be necessary. If assistance is required contact UPC.

CHARTS

MILLIVOLTS for COMBINATIONS of TEMPERATURE and CARBON POTENTIAL

°F	1400	1425	1450	1475	1500	1525	1550	1575	1600	1625	1650	1675	1700	1725	1750	1775	1800	1825	1850	1875	1900	
°C	760	774	788	802	816	829	843	857	871	885	899	913	927	941	954	968	982	996	1010	1024	1038	
1.65																						
1.60																						1218
1.55																					1211	1215
1.50																				1204	1208	1213
1.45																	1192	1196	1201	1205	1210	
1.40																	1189	1194	1198	1203	1207	
1.35																	1182	1187	1191	1196	1200	1204
1.30															1175	1180	1184	1188	1193	1197	1201	
1.25													1164	1168	1172	1177	1181	1185	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	1188	1192	
1.10									1139	1143	1147	1151	1155	1159	1163	1168	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	1126	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	1157	1160	1164	1168	
0.80	1089	1093	1096	1100	1104	1108	1111	1115	1119	1122	1126	1130	1133	1137	1141	1145	1148	1152	1156	1159	1163	
0.75	1086	1089	1093	1097	1100	1104	1107	1111	1115	1118	1122	1125	1129	1133	1136	1140	1144	1147	1151	1154	1158	
0.70	1082	1086	1089	1093	1096	1100	1103	1107	1110	1114	1117	1121	1124	1128	1131	1135	1138	1142	1146	1149	1153	
0.65	1078	1082	1085	1089	1092	1095	1099	1102	1106	1109	1113	1116	1119	1123	1126	1130	1133	1136	1140	1143	1147	
0.60	1074	1078	1081	1084	1087	1091	1094	1097	1101	1104	1107	1111	1114	1117	1121	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	1086	1089	1092	1095	1098	1102	1105	1108	1111	1114	1117	1120	1123	1126	
0.45		1062	1065	1068	1071	1074	1077	1080	1083	1086	1089	1091	1094	1097	1100	1103	1106	1109	1112	1115	1118	
0.40			1059	1062	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	1070	1072	1075	1077	1080	1082	1085	1088	1090	1093	1095	1098	
0.30					1048	1050	1053	1055	1057	1060	1062	1064	1067	1069	1072	1074	1076	1079	1081	1083	1086	
0.25						1040	1042	1044	1046	1048	1050	1052	1054	1057	1059	1061	1063	1065	1067	1069	1071	
0.20							1028	1030	1032	1034	1036	1037	1039	1041	1043	1045	1047	1048	1050	1052	1054	
0.15								1013	1014	1015	1017	1018	1020	1021	1023	1024	1025	1027	1028	1030	1031	
°F	1400	1425	1450	1475	1500	1525	1550	1575	1600	1625	1650	1675	1700	1725	1750	1775	1800	1825	1850	1875	1900	
°C	760	774	788	802	816	829	843	857	871	885	899	913	927	941	954	968	982	996	1010	1024	1038	

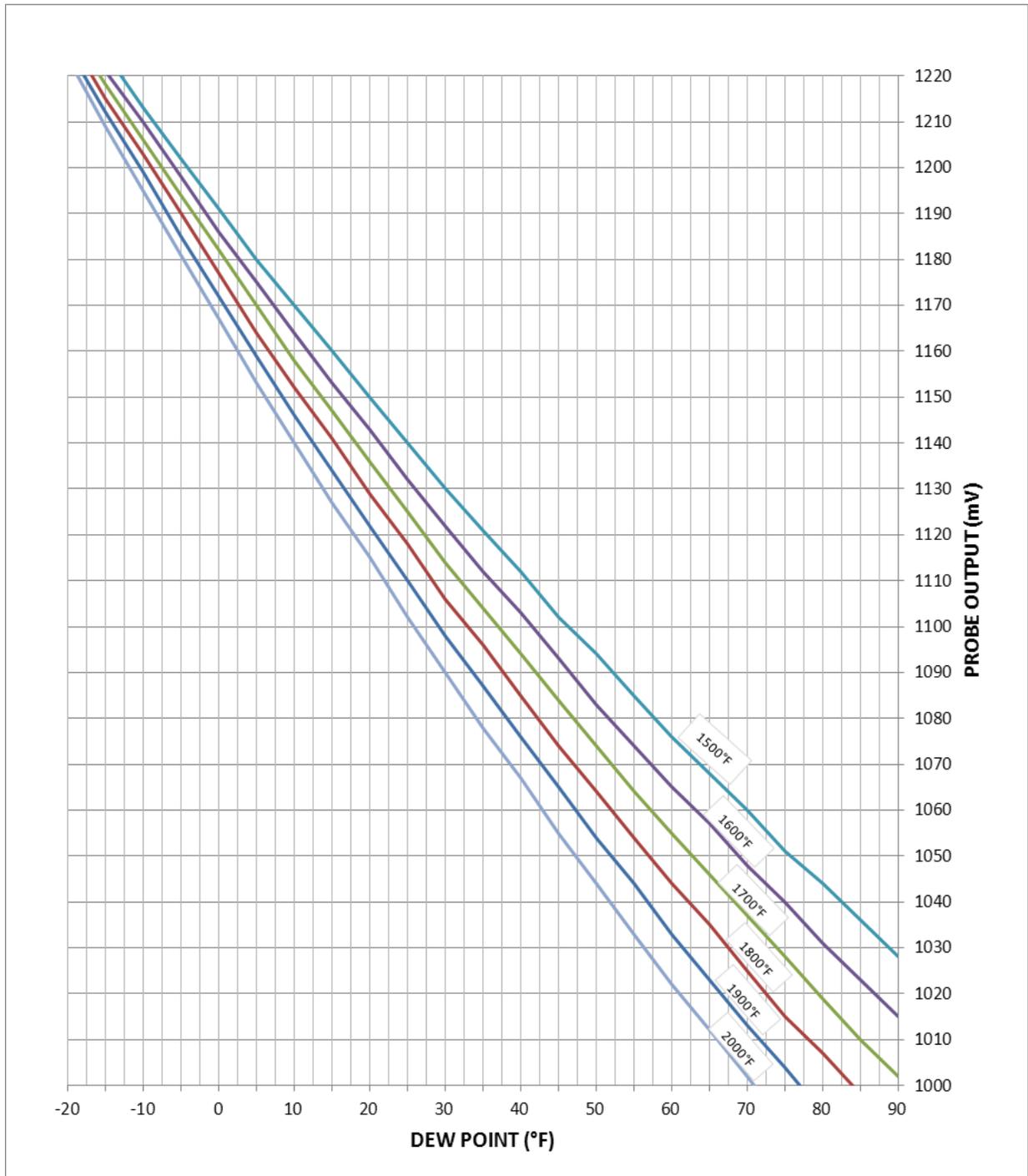
Data valid with carrier gas composition CO + CO2 = 20% and AISI 1010 Steel

MILLIVOLTS for VARIOUS COMBINATIONS of TEMPERATURE and DEW POINT

		TEMPERATURE (°F)															
		1400	1450	1500	1550	1600	1650	1700	1750	1800	1850	1900	1950	2000	2050	2100	2150
Dew Point (°F)	90	1041	1035	1028	1021	1015	1008	1002	995	989	982	976	969	962	955	949	942
	85	1048	1042	1036	1029	1023	1017	1010	1004	998	991	985	978	972	965	959	952
	80	1055	1049	1044	1037	1031	1025	1019	1013	1007	1000	994	988	981	975	969	962
	75	1063	1057	1051	1045	1040	1034	1028	1022	1015	1009	1004	997	991	985	979	973
	70	1071	1065	1060	1054	1048	1042	1037	1031	1025	1019	1013	1007	1002	996	990	984
	65	1078	1073	1068	1062	1057	1051	1046	1040	1035	1029	1023	1018	1012	1006	1000	995
	60	1086	1081	1076	1071	1065	1060	1055	1050	1044	1039	1033	1028	1022	1017	1011	1006
	55	1094	1090	1085	1080	1074	1069	1064	1059	1054	1049	1044	1038	1033	1028	1022	1017
	50	1103	1098	1094	1089	1083	1079	1074	1069	1064	1059	1054	1049	1044	1039	1034	1029
	45	1111	1107	1102	1098	1093	1088	1084	1079	1074	1070	1065	1060	1055	1050	1045	1041
	40	1120	1116	1112	1107	1103	1098	1094	1089	1085	1080	1076	1071	1067	1062	1058	1053
	35	1129	1125	1121	1116	1112	1108	1104	1100	1096	1091	1087	1083	1078	1074	1070	1065
	30	1137	1134	1130	1126	1122	1118	1114	1110	1106	1102	1098	1094	1090	1086	1082	1077
	25	1147	1143	1140	1136	1132	1129	1125	1121	1118	1114	1110	1106	1102	1098	1094	1090
	20	1156	1153	1150	1146	1143	1139	1136	1132	1129	1125	1122	1118	1115	1111	1107	1104
	15	1166	1163	1160	1156	1153	1150	1147	1144	1141	1137	1134	1131	1127	1124	1120	1117
	10	1175	1172	1170	1167	1164	1161	1158	1155	1152	1149	1146	1143	1140	1137	1134	1130
	5	1185	1183	1180	1176	1175	1172	1170	1167	1164	1161	1159	1156	1153	1150	1147	1144
	0	1195	1193	1191	1189	1186	1184	1182	1179	1177	1174	1172	1169	1167	1164	1161	1159
	-5	1206	1204	1202	1200	1198	1196	1194	1191	1190	1187	1185	1183	1181	1178	1176	1173
-10	1217	1215	1213	1211	1210	1208	1206	1204	1203	1201	1199	1197	1195	1193	1191	1189	
-15	1227	1226	1225	1223	1221	1220	1218	1217	1215	1214	1212	1210	1209	1207	1205	1203	
-20	1238	1237	1236	1235	1234	1233	1231	1230	1229	1227	1226	1225	1224	1222	1221	1219	

* Data only valid with gas composition H₂ + H₂O = 40%

MILLIVOLTS at VARIOUS TEMPERATURES and DEW POINTS



SPECIFICATION / PARTS LIST

Alloy Probe Models	AQ#[#][LL]-[t/c]-1 → AQ620-K-1 = Alloy Sheath, Alloy I.E., 20" L, K T/C
Ceramic Probe Models	CQ#[#][LL]-[t/c]-1 → CQ826-S-1 = Ceramic Sheath, High Temp I.E., 26" L, S T/C
Carbon Potential Range	0.10% to 1.4%
Output in normal heat treating	1000 to 1200 mV DC
Normal probe operating temp	1400 to 1850°F
MAX Operating temp AQ ALLOY	1850°F for AQ8XX-Y-Z Alloy Sheathed Probes,
MAX Operating temp CQ CERAMIC	2100°F for CQ8XX-Y-Z Ceramic Sheathed Probes
Probe cover temp limit	200°F max.
Sensitivity	0.02 mv or .0025% C
Accuracy	±0.03% C
Stability	±1 mV over probe life
Response time	Less than 1 second
Impedance	Less than 4000 ohm
Probe construction	Stabilized zirconia solid electrolyte; patented alloy electrode
Probe thermal shock	Caution, outer sheath protects electrolyte, but care must be taken to avoid thermal shock
Probe Life	About 2 years with normal use
Warranty	1 year usage, non-prorated
Serviceability	No field service required, completely rebuildable at factory with substantial savings
Reference air requirement	0.2 to 1.0 MAX SCFH filtered ambient air

Description

UPC Part No.

AccuCarb® Carbon Probe with Type K Thermocouple	AQ620-K-1
AccuCarb® Carbon Probe with Type S Thermocouple	AQ620-S-1
Mounting Flange	ASY-1.2F-10
Reference Air Supply Panel 0.2 - 2.0 SCFH	F005006
Probe Cable with Type K T/C Extension Wire (20 ft.)	C20-K-0
Probe Cable with Type R & S T/C Extension Wire and Air Tube (20 ft.)	C20-RS-T
Shim-holding Cartridge (1-inch dia.)	H36-1
Shim Cooling Chamber	V1.2-6
Shim Coupons (25)	S25

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