CARBON SENSOR

Operations Manual

Carbonseer
QuickSilver-XS
QuickSilver-XTS

Manual #: 026

Initial Release 3/14/2008

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For assistance please contact:

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www.group-upc.com

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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. Call UPC for an RMA number (ph) 513 772 1000
3. Enclose the claim form with the sensor intact and in the original packaging and return to:

   United Process Controls
   8904 Beckett Road
   West Chester, OH 45069

SPECIFICATION

Carbon Potential Range-	0.10% to 1.4%
Output in normal heat treating-	1000 to 1200 mV DC
Normal sensor operating temp.-	1400 to 1850˚F **
Sensor cover temp limit-	200^{O}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 6 K ohm
Sensor construction-	Stabilized zirconia solid electrolyte; patented alloy electrode
Sensor thermal shock-	Caution is advised, outer alloy sheath protects ceramic zirconia tube.
Sensor Life-	About 2 years with normal use
Warranty-	1 year usage, non-prorated
Serviceability-	No field service required, rebuildable at factory with substantial savings
Reference air requirement-	0.2 to 1.0 MAX SCFH filtered ambient air
	** minimum operating temp 1150 ˚F

DISCLAIMER

All zirconia oxygen sensors manufactured by United Process Controls Inc. are to be used by the industrial operator under his/her direction. United Process Controls Inc. is not responsible or liable for any product, process or damage or injury incurred while using these sensors. United Process Controls Inc. makes no representation or warranties with respect to the contents hereof and specifically disclaims any implied warranties of merchantability or fitness for any particular purpose.

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 United Process Controls Inc. in a package designed specifically to ensure the sensor's safety in transit to you. **This package should be retained to facilitate any potential return of the sensor to UPC.** Please note that the package consists of an outer box and two foam pads which support the sensor.

Follow these steps to remove sensor:

Place package on flat surface.
Cut tape from top of outer box.
Remove top layer of foam.
Carefully remove sensor.
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.

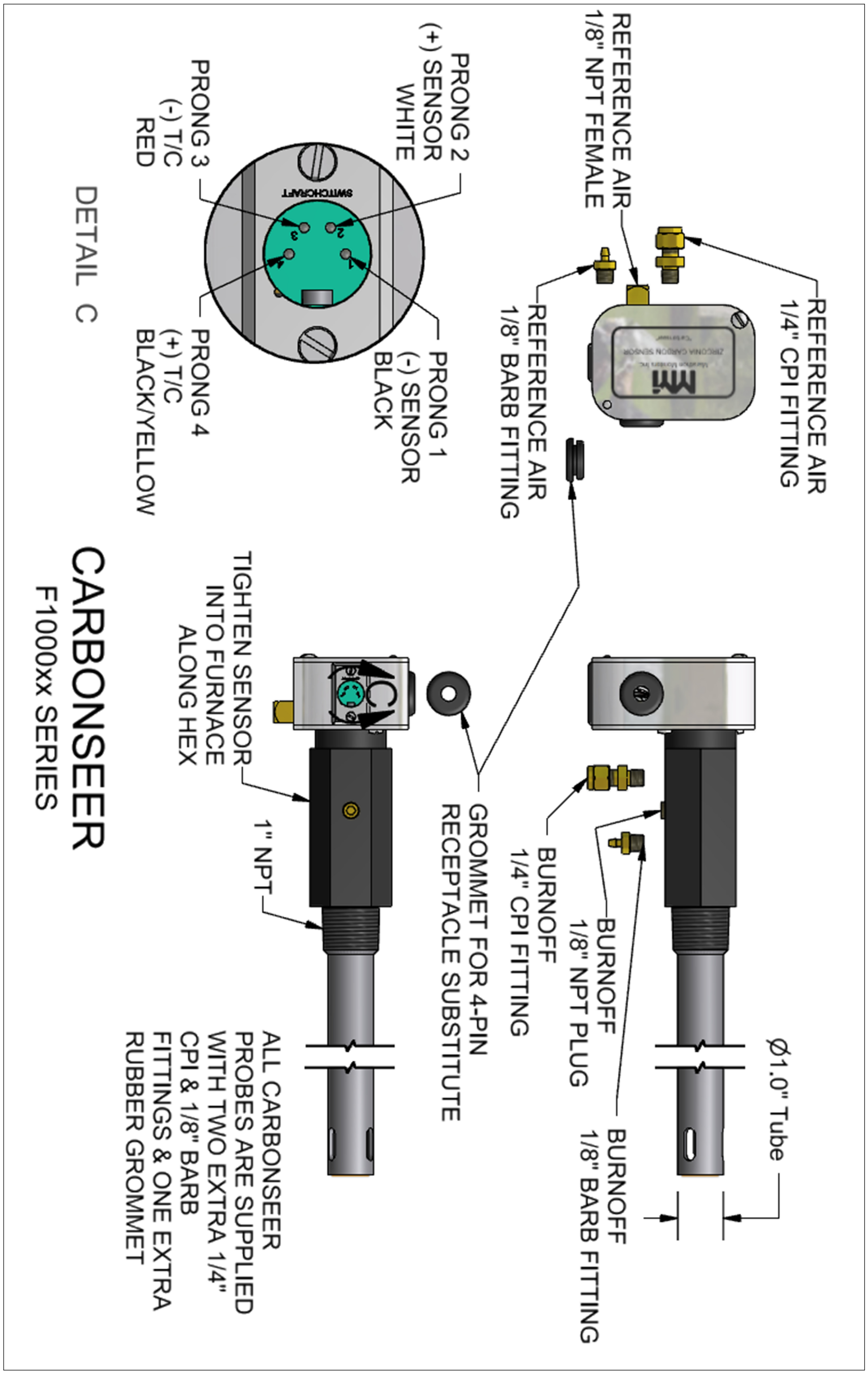
CONTENTS

Each pack contains the following components:

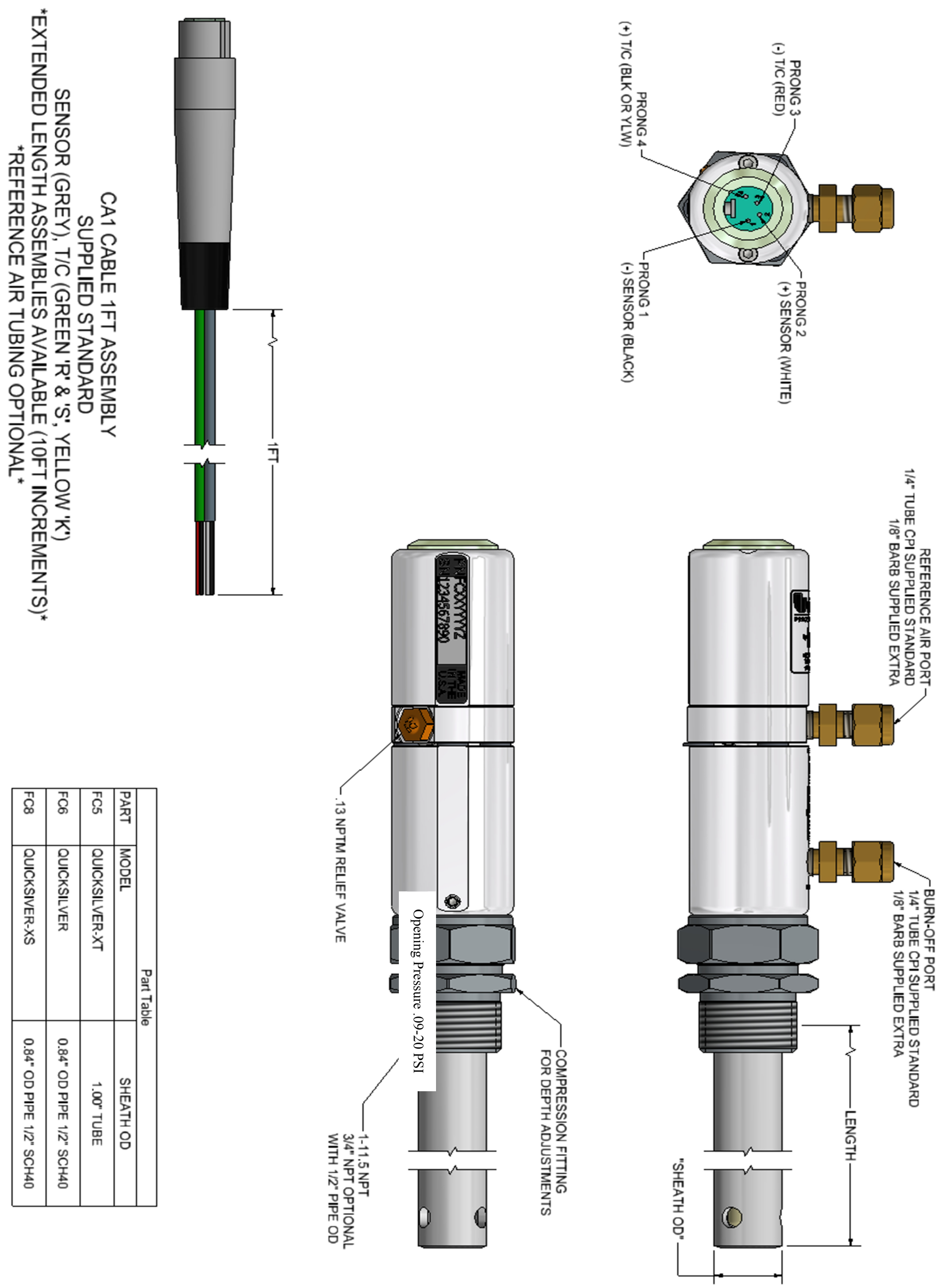
- ☐ Statement of Carbon Sensor Accuracy
- ☐ Sensor Assembly
- ☐ Operating Manual
- ☐ Warranty Registration Card
- ☐ Additional Fittings & Parts

On your sensor's head is a label which lists the sensor type, part number and serial number. Please refer to Figures 1-2 for diagrams of our most popular sensors which also show any additional fittings or accessories and installation requirements.

SENSOR DRAWING - CARBONSEER FAMILY



SENSOR DRAWING - QUICKSILVER FAMILY



Part Table

PART	MODEL	SHEATH OD
FC5	QUICKSILVER-XT	1.00" TUBE
FC6	QUICKSILVER	0.84" OD PIPE 1/2" SCH40
FC8	QUICKSIVER-XS	0.84" OD PIPE 1/2" SCH40

INSTALLATION CONSIDERATIONS

If this is a new installation of a CARBON SENSOR, carefully read the following steps:

Sensor Location
Furnace Preparation
Sensor Installation

If the CARBON SENSOR is used to replace another sensor, proceed directly with Sensor Installation.

SENSOR LOCATION

The general guideline is that the sensor should be exposed to the same gas atmosphere and temperature as the work is exposed to. Typically, the CARBON SENSOR 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 sensor should be at approximately a few inches above the maximum work load height. This will prevent the possibility of prove damage caused by the load, and also expose the sensor to a fresh and moving furnace atmosphere. In furnaces with an internal muffle, the sensor should extend horizontally above the muffle arch and sidewall to within 6 to 10-inches of the fan.

NOTE: Determine the proper sensor 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 sensor too close to a radiant tube or electric heat source. Thermal cycling of the heat source may make control difficult. The sensor 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 sensor 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, 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 CARBON SENSOR.

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 CARBON SENSOR 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 sensor. Shim tests are essential during troubleshooting or if there is a question about the accuracy of the sensor. Location of the second port should be as close as possible to the sensor location.

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

SENSOR INSTALLATION

Installation of the CARBON SENSOR 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 CARBON SENSOR in a furnace port previously used for another sensor 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 CARBON SENSOR. It is susceptible to thermal and mechanical shock and may be damaged if mishandled.

1. Carefully remove the CARBON SENSOR 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 sensor. Keep the box and foam in case the sensor 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 CARBON SENSOR. 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 90deg past hand tight (20 ft-lb)

If the furnace is 300ºF or cooler (Cold Installation), slide sensor 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 sensor sheath. Do not rotate probe while tightening nut.

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

1. Measure 6 inches from the end of the sensor sheath and mark with a felt tip pen. Mark the remainder of the CARBON SENSOR in 1-inch graduations.

2. Do not insert the sensor into a port with flames exiting. Make a ball of soft refractory fiber material and place it in the opening of the furnace wall where the sensor is going to be inserted to reduce combustion reactions. Do not proceed to the next step unless flames are completely extinguished

3. As you continue to install the sensor, the fiber ball will be gradually pushed into the furnace interior.

4. Carefully insert probe into compression fitting to the first mark on the sensor sheath (6-inch mark). Make sure seal rings or O-ring is between compression fitting body and nut. Wait 5 minutes while the sensor warms up.

5. Insert sensor at the rate of about 1-inch per minute.

6. Repeat step 5 above until sensor is installed to proper length. Hand-tighten the compression fitting nut on the sensor sheath.

Connections for the sensor signal and also integral thermocouple are made through the electrical connector located at on the sensor head. If you are using a sensor 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 sensor cover. If you did not purchase a new cable, your new sensor 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. See sensor drawings for detailed wiring information.

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

- The black insulated wire is negative (-)
- The white insulated wire is positive (+)
- 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 ¾ turn with a wrench to set ferrules on the tubing, hand tightening of the nut is adequate.

In order for your sensor to function properly, reference air (20.9% O_2) must be supplied to the inner electrolyte tip. A .13 NPTM relief valve (opening pressure .09 - 20 psi) has been added to the head of the sensor to protect from over pressurizing the sensor and also allows accurate flow to the tip of sensor.

MAINTENANCE

Do not disassemble your sensor!

The carbon sensor which you have purchased requires no mechanical maintenance. Any attempt to dismantle it could cause irreparable damage and will invalidate the warranty.

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 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 CARBON SENSOR at carbon potentials near the austenite saturation is not recommended because of soot formation in the furnace and on the sensor. To determine the saturated austenite level, refer to the CARBON SENSOR output vs. carbon potential graph included with this manual.

If soot buildup occurs in the furnace or on the CARBON SENSOR, the condition must be alleviated by a "burnoff" of the sensor. 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 more than 100 degrees F during the burnoff.

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

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

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
- temperature

When air is forced into the sensor 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.

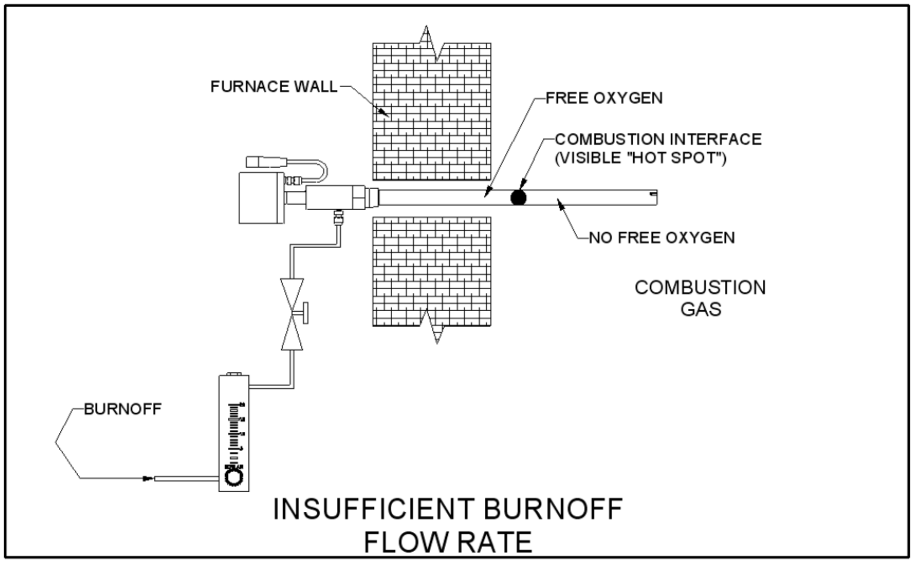


Figure 3

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 sensor sheath the interface will move (**Figure 4**). If enough air is added, the combustion reaction can actually be moved completely outside of the sensor (**Figure 5**).

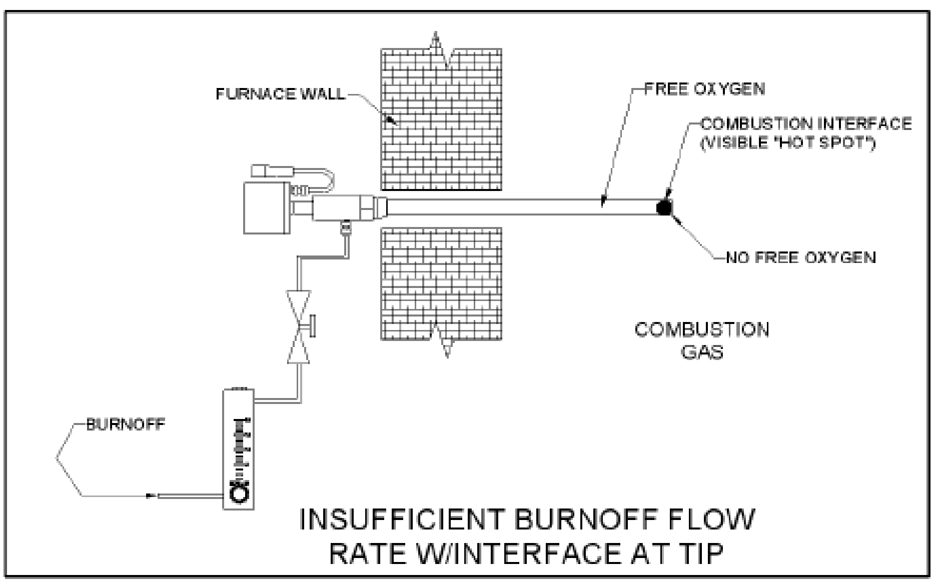


Figure 4

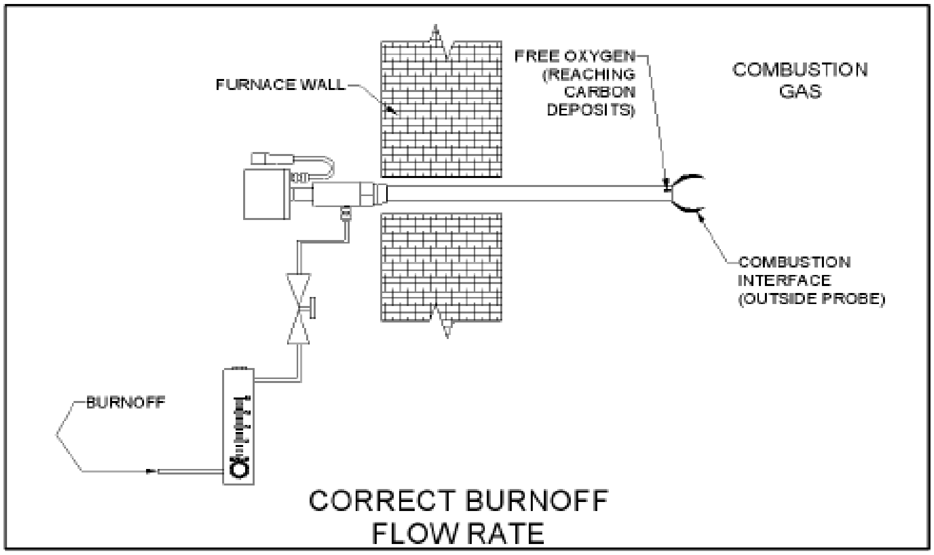


Figure 5

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 sensor

electrode and preferably slightly beyond. To judge the free oxygen level, it is necessary to interpret the sensor millivolt output

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. You should see the sensor 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 sensor. The higher the circulation velocity, the more air is required to get the carbon out to the sensor 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 sensor 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 sensor 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 sensor's mV reading.

All CARBON SENSORS should have a burnoff length between 2-5 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 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 sensor after a burnoff and examine it.

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 burnouts be conducted to avoid the cumulative effects of deposited carbon. “Gentle” burnouts are normally conducted at 1500-1600°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.

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 kohm. As the sensor 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 sensor temperature is at or above 1100°F with stable atmosphere present. All UPC 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.

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

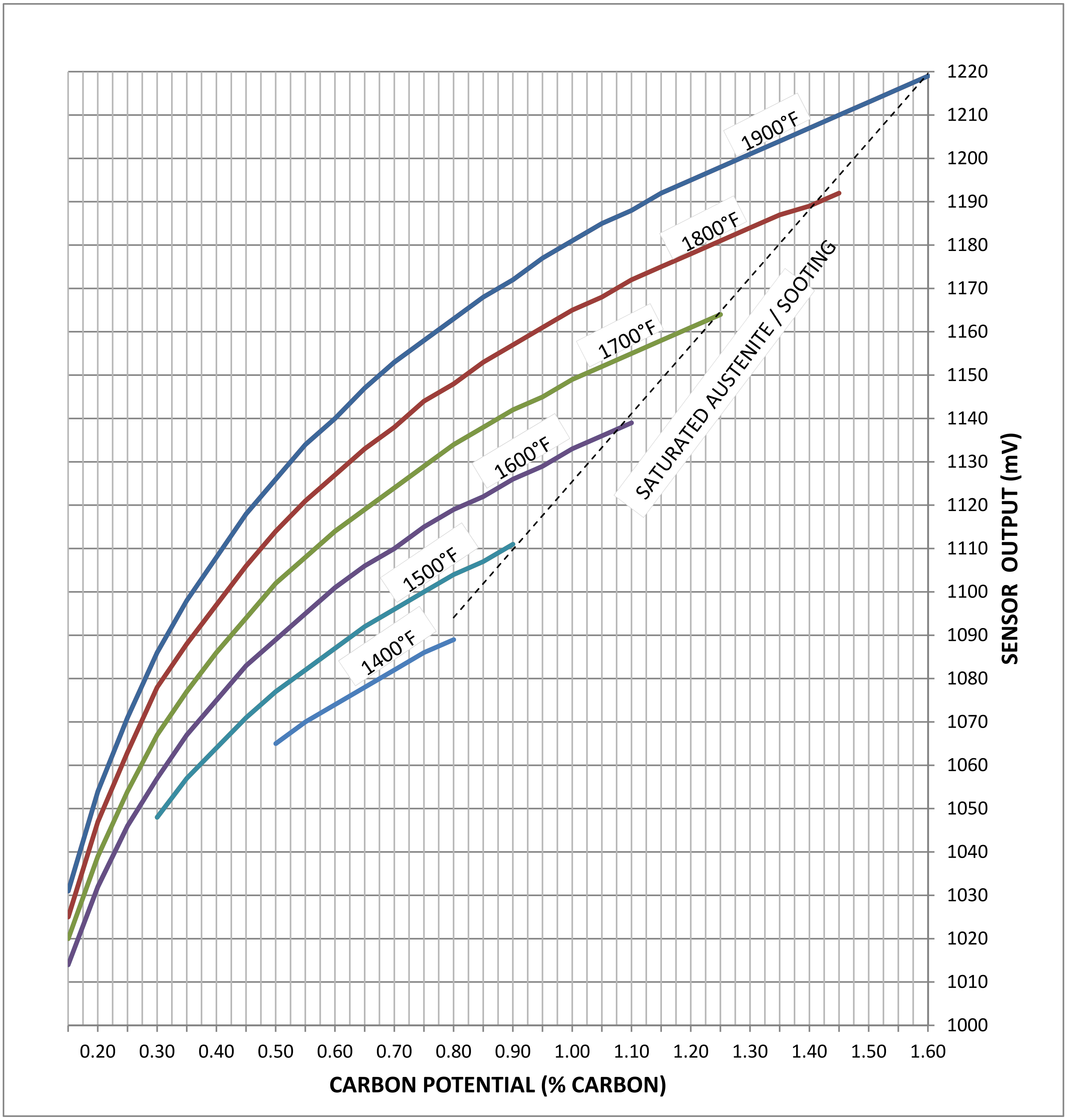
R_x = sensor impedance
E_o = open circuit voltage of sensor
E_s = shunted voltage of sensor
R_s = shunt resistor's impedance (10 kΩ)

FURNACE STOP OFF COATINGS

The platinum on the outside of the sensor will be attacked by any boric acid, lead and tin present in the furnace. Exposure to these substances will erode the outer electrode, increasing sensor impedance and lowering the mV reading. If possible, reduction of these contaminants will result in longer sensor life.

One source of the "platinum attackers" is carburizing stop-off coatings. If you use a carburizing stop-off, check its composition for boric acid, lead or tin. Some brands of stop-off contain boric acid and tin, which attacks the sensor.

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

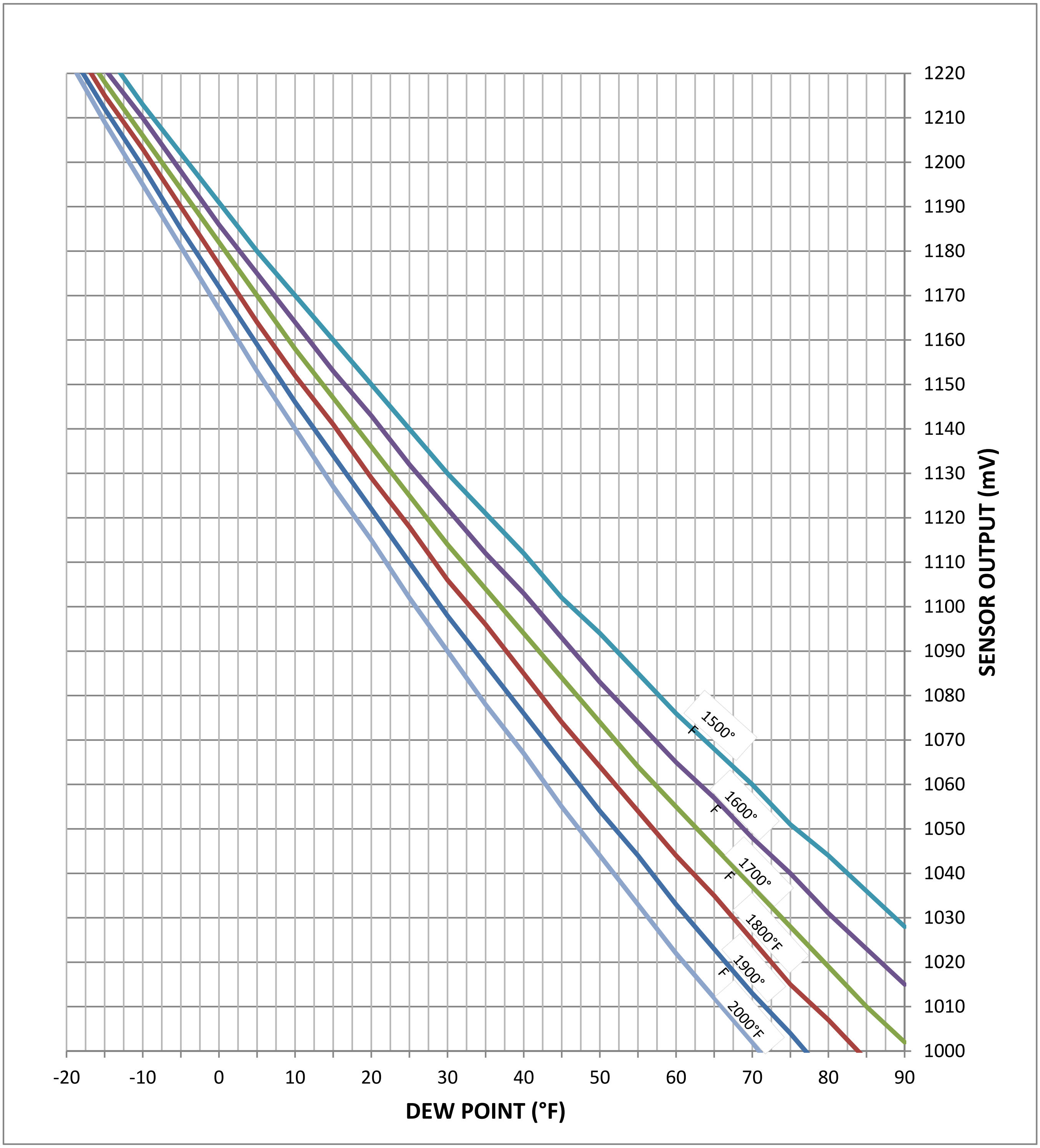


CARBON POTENTIAL VS. SENSOR MV OUTPUT @ TEMPERATURE(S) DATA

CARBON POTENTIAL (%C)	TEMPERATURE (°F)																				
	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**

DEW POINT VS. SENSOR MV OUTPUT @ TEMPERATURE(S) GRAPH



DEW POINT VS. SENSOR MV OUTPUT @ TEMPERATURE(S) DATA

Dew Point (°F)	TEMPERATURE (°F)															
	1400	**1450**	**1500**	**1550**	**1600**	**1650**	**1700**	**1750**	**1800**	**1850**	**1900**	**1950**	**2000**	**2050**	**2100**	**2150**
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 $H_2 + H_20 = 40\%$**

TROUBLESHOOTING

When there is a problem making consistent product in a carburizing furnace you must consider all the possibilities before replacing the oxygen 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. The system includes the control instrument, actuators and linkages, gas supply, furnace seals, burner integrity, as well as the carbon sensor.
NOTE
All of the following tests assume that the oxygen sensor is operating above 1200°F and the process that is being read is stable.

Problem	Troubleshooting Path
Carbon readings are always the same or consistently higher than typical carbon levels under normal furnace conditions.	Go to the Burnoff Check.
Carbon readings are too low and/or do not change.	Go to Reference Air Check, Leak Check, and Signal Level Check. Go to Furnace Check
Carbon readings are erratic or carbon level keeps oscillating.	Go to Signal Level Check, 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 light.	Go to Process Factor Check.
Carbon readings react with changes in the furnace but the load case depth is heavy.	Go to Process Factor Check.
There is no reference air flow.	Go to Reference Air Check
There is no burn off air flow.	Go to Burnoff Check

Reference Air Check

1. Reference air consists of clean room air, free of airborne contaminants. Do not use compressed air. Try using an alternate source of reference air if in doubt. Reference airflow is 1.0 CFH on flow meter, if not do next step.
2. Disconnected at the reference air tube at the probe 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 probe. If there is no flow when air is reattached to the probe, the reference air tubing in the probe is blocked. Replace the probe.

Leak Check

1. Put the control instrument in manual control mode and verify that the probe millivolt reading is stable.
2. Shut off the reference air for 30 seconds.
3. Verify that the probe millivolt reading does not drop more than 5 mV. If the reading drops more than this it is probably due to a crack in the probe substrate and the probe should be replaced.

Burn off Check

1. Do a probe burnoff check with sensor at 1500°F minimum. The sensor temperature should increase slightly (100°F) above ambient furnace temperature and the probe millivolts should drop from pre-burnoff levels.
2. If these responses do not occur, check the burnoff air flow. Verify that the burnoff event is active and that the burnoff solenoid is on. Verify that air flow is being supplied to the probe (See Reference Air Check). **MAKE SURE THAT THE BURNOFF AIR AND REFERENCE AIR TUBES ARE CONNECTED TO THE CORRECT PORTS ON THE PROBE**.
3. If all of the above is correct, but the probe millivolts still do not drop, repeat the burnoff procedure at a more frequent interval. If after a minimum of five burnoffs there is no change in the millivolt reading and proper response to carbon changes, remove the probe and inspect for heavy sooting. See Sensor Replacement.

Impedance Check

1. Do a probe impedance check with probe at 1500°F minimum. Good sensor impedance should be between 0.1 Kohm to 20 Kohm. If the impedance is above 20 Kohm, the sensor electrodes are degrading and the sensor should be monitored more closely and above 50 kohm, 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. Replace the sensor if the impedance readings are still intermittent. See sensor Replacement.

Signal Level Check

1. Oxygen sensor measurement system does in fact disagree with alternative measurement technique (e.g. FDPRO IR analyzer, shim stock analysis). Check the sensor temperature and millivolt readings with the Percent Carbon chart below and see Process Factor Check. If these values agree then go to the Furnace checks.
2. Sensor thermocouple display on instrument is within ±25°F of furnace control thermocouple. If not, make sure the instrument thermocouple type is set to the same thermocouple as the sensor thermocouple. If reading is negative, check thermocouple connections. If reading is > 2300°F check for an open or loose connections or open thermocouple.
3. mV reading on instrument 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 sensor terminal block the reading on voltmeter should not change more than 2 mV. If the reading does change, make sure the signal cable shield is connected at only the instrument ground and that the instrument is properly grounded. Verify that the signal wire has not melted, been crushed, or is shorted between the leads, the shield, or ground. If the grounding and cable shielding is 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 millivolt terminals for 15 seconds. The sensor millivolt signal should return to its original reading, ±10 mV, within 30 seconds as measured with the voltmeter. If not go to Impedance Check.

Process Factor Check

1. Process factor is set to 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 % carbon and cause the controller to increase the trim gas flow to the furnace. Decreasing the process factor will increase the calculated % 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 (>500) or very low (<50) values, go to the Impedance Check.

Furnace Check

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

Sensor Replacement

- Always remove and insert a sensor at 1” inch per minute if furnace is hot. Even if the sensor has been found at fault always remove it at the 1” inch per minute rate. It is usually possible to rebuild a faulty sensor but if the substrate cracks as a result of thermal shock, the most expensive part of the sensor must be replaced.

- Check Sensor/Sheath combination for significant accumulation of soot or other deposits
- ensure that the main ceramic tube is physically intact and
- Check the protection sheath for warping, pitting, and/or carbon sooting.
- Call United Process Controls for an RMA to test and possibly rebuild the sensor.

Reach us at www.group-upc.com

United Process Controls brings together leading brands to the heat treating industry including Waukee Engineering, Furnace Control, Marathon Monitors and Process-Electronic.

We provide prime control solutions through our worldwide sales and services network with easy-to-access local support.

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