NitroCarb

INSTALLATION AND OPERATION

MANUAL

DISCLAIMER:

The NITROCARB is to be used by the industrial operator under his/her direction. Furnace Control Corp. is not responsible or liable for any product, process, damage or injury incurred while using the NITROCARB. FURNACE CONTROL CORP. makes no representations or warranties with respect to the contents hereof and specifically disclaims any implied warranties or merchantability or fitness for any particular purpose.

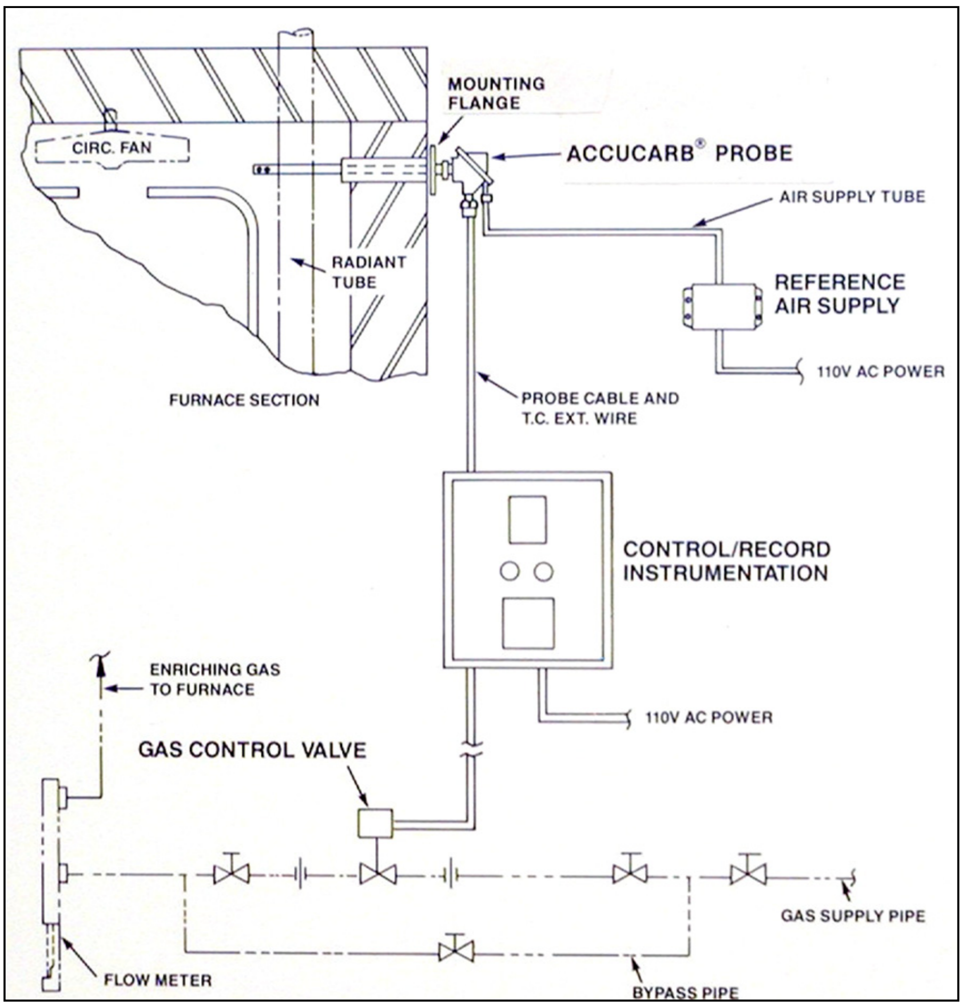
For assistance please contact: Furnace Control Corp.
TEL: +1 513 772 1000 • FAX: +1 513 326 7090
Toll-Free North America +1-800-547-1055
erika.leeds@group-upc.com
www.group-upc.com

REV000 10/16/12 JMC
REV002 05/08/14 GGD

TABLE OF CONTENTS

INTRODUCTION

Congratulations, you have purchased the newest and technologically most advanced zirconia probe on the market. The NITROCARB probe, manufactured by Furnace Control Corp., (FCC), is intended to be used with carbon control systems to control the carbon potential of an endothermic, nitrogen/methanol, and nitrocarburizing based atmospheres. A typical control system, shown in **Figure 1**, has three functional sections: (1) NITROCARB 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**



Typical Carbon Control System
FIGURE 1

PRINCIPLE OF OPERATION

The NITROCARB carbon probe is a unique 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 NITROCARB 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.

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

In a carburizing atmosphere containing CO and CO_2 gases, the carbon potential is a function of the ratio $(Pco)^2/Pco_2$ under constant temperature CONDITIONS The NITROCARB probe provides a voltage output from which the Pco/Pco_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 CO_2 and weight percent carbon.

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 the 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.

The outer electrode sheath material is a high temperature, non-catalytic material, which acts as a reversible oxygen electrode. The material composition minimizes the alteration of the gas at the electrolyte-electrode interface, which also maximizes the accessibility of the gas to the electrolyte-electrode interface by its open design.

The voltage output of the NITROCARB 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 NITROCARB 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.

Another feature of the NITROCARB probe is that it is virtually maintenance free for the life of the probe. No calibration, no cleaning or adjustments are required.

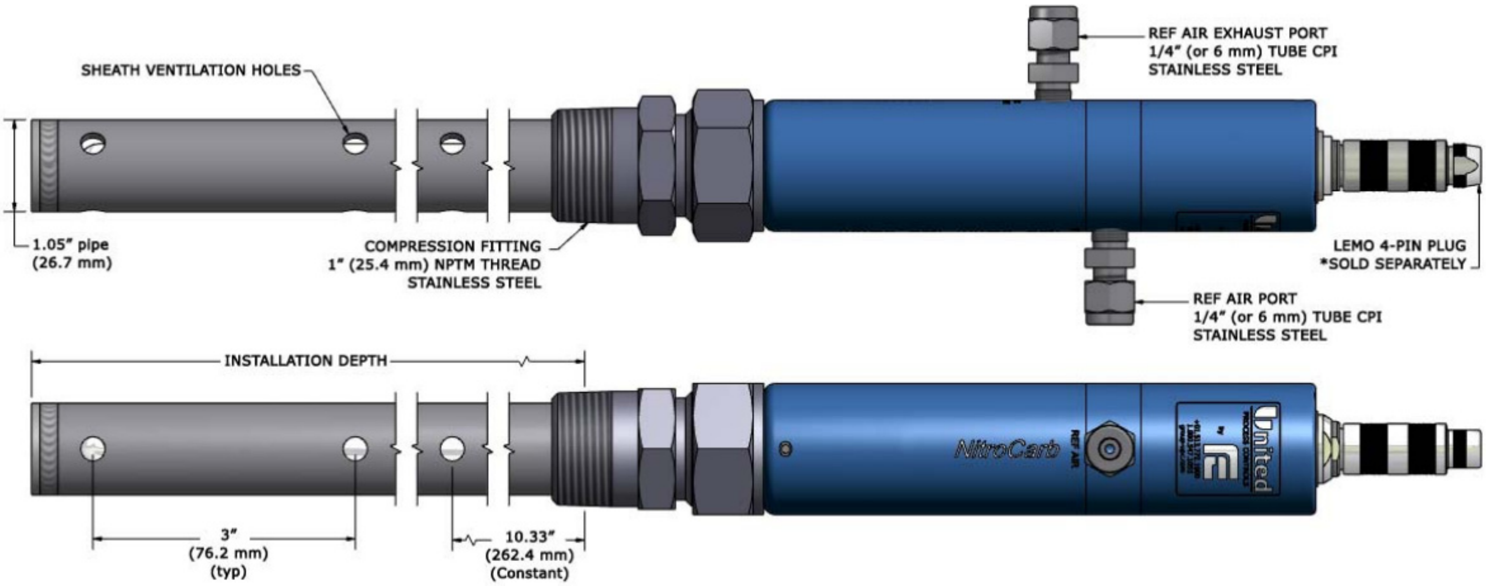
SERVICE LIFE

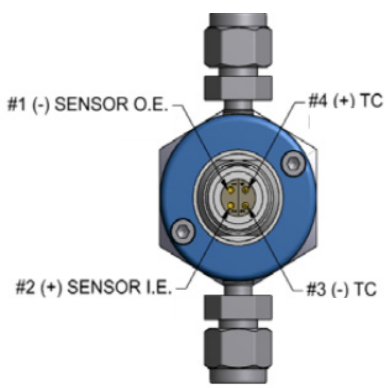
If all installation procedures and thermal constraints are obeyed, then the NITROCARB probe will have an expected life time of about two years.

Specification

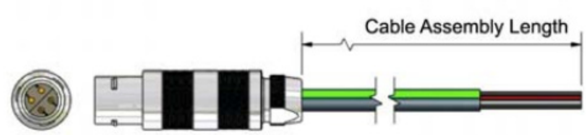
Output in a heat treating atmosphere	1000 to 1200 mV DC
MIN operating temp	800°F [425°C]
MAX operating temp	1200°F [650°C]*SEE WARRANTY CARD*
Sensor head temp	200 °F max.
Sensitivity	0.02 mV or .0025% C
Accuracy	±0.03% C
Stability	±1 mV over sensor life
Response time	Less than 1 second
Impedance	Less than 6 K ohm
Sensor construction	Stabilized zirconia solid electrolyte; patented alloy electrode
Thermal shock	Caution is advised, obey installation & removal procedures
Sensor Life	About 2 years with normal use
Warranty	1 year usage, non-prorated
Serviceability	No field service required, rebuildable at factory
Reference air requirement	0.2 to 0.5 MAX SCFH filtered air *See Reference Air Installation*

Probe Drawing





A cable assembly is required for first-time installations. To order, please consult the table below.



AA6XX-Y-Z NitroCarb Probe Ordering						
	Part #:		AA6	XX	-Y	-Z
Probe						
NitroCarb			AA6			
Insertion Length						
in		mm				
20	in	508	mm	20		
26	in	660	mm	26		
32	in	813	mm	32		
38	in	965	mm	38		
Thermocouple Type						
NO Thermocouple					-X	
Thermocouple Type K					-K	
Thermocouple Types R					-R	
Thermocouple Types S					-S	
Connection Tube OD						
6mm OD Tube CPI						-18
1/4" OD Tube CPI						-19

CA6-XX-Y Cable Assembly Ordering						
	Part #:		CA6	-XX	-Y
Plug					
FFA 4-POS LEMO			CA6		
Cable Assembly Length					
ft		M			
10	ft	3.0	M	10	
20	ft	6.1	M	20	
30	ft	9.1	M	30	
40	ft	12.2	M	40	
50	ft	15.2	M	50	
Thermocouple Type					
NO Thermocouple					-X
Thermocouple Type K					-K
Thermocouple Types R & S					-RS

INSTALLATION

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

Probe Location
Furnace Preparation
Probe Installation

If the NITROCARB 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 NITROCARB 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 prove 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

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.

PROBE INSTALLATION

Installation of the NITROCARB 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 NITROCARB 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 NITROCARB probe. It is susceptible to thermal and mechanical shock and may be damaged if mishandled.

1. Carefully remove the NITROCARB 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 FCC.

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 NITROCARB probe. Leave the nut and ferrule on the probe sheath. Place Teflon tape, or equivalent, 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 NITROCARB 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.

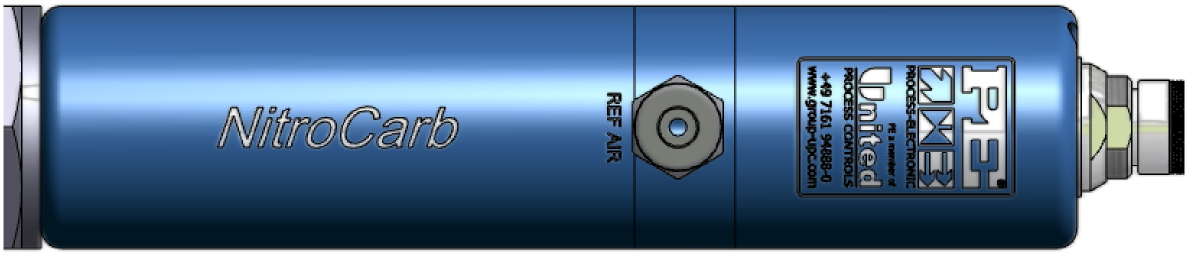
10. Carefully insert probe into compression fitting to the first mark on the probe sheath (6-inch mark). Make sure seal rings or O-ring is between compression fitting body and nut. Wait 5 minutes while the probe warms up.

11. Insert probe at the rate of about 1-inch per 5 minutes, repeat until probe is fully installed

12. 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

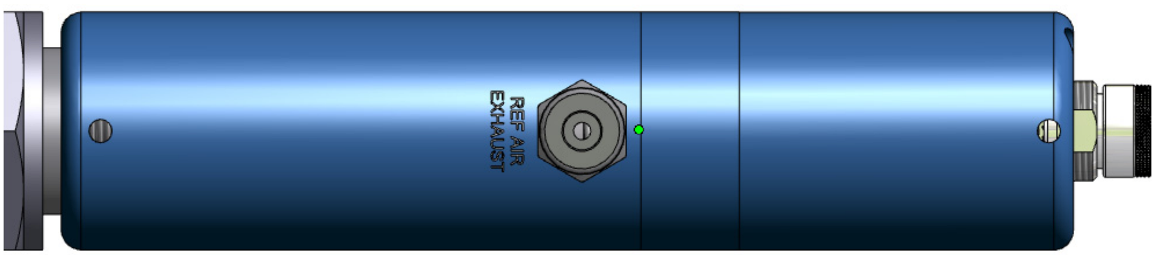
13. Using the CPI port, install the reference air tube on the port labeled "REF AIR" on the front of the probe. Urethane, Teflon or copper tubing can be used. Place nut and ferrules on reference air tube and connect to air fitting. Hand tighten nut on air fitting, then turn ¾ turn with a wrench to set ferrules on the tubing.

REFERENCE AIR INSTALLATION & SAFETY



The probe requires 0.2 to 1.0 MAX SCFH filtered ambient air installed on the front "REF AIR" port. The air must be filtered free of contaminants in order to maintain proper output. If dirty reference air is pumped inside of the electrolyte, then soot will build up dramatically affecting furnace control and probe life.

The NitroCarb head is sealed by design for safety purposes. If the electrolyte fractured for any reason, then reference air would be able to flow into the furnace, and/or furnace process would be able to flow out of the probe head. On the rear of the NitroCarb probe, you have the ability to install exhaust tubing on the "REF AIR EXHAUST" port for controlled venting purposes. If venting control is not required, then this port can be left unaltered.



Otherwise, for added safety, a differential pressure shut-off panel could be installed on the reference air ports. If the differential pressure drifts outside of the normal operating range, due to a fracturing of the electrolyte, then the panel will shut-off of each port preventing process contamination.

Contact your local FCC representative for safety flow panel options.

For assistance please contact:
Furnace Control Corporation
TEL: +1 513 772 1000 • FAX: +1 513 326 7090
Toll-Free North America +1-800-547-1055
erika.leeds@group-upc.com
www.group-upc.com

CABLE ASSEMBLY

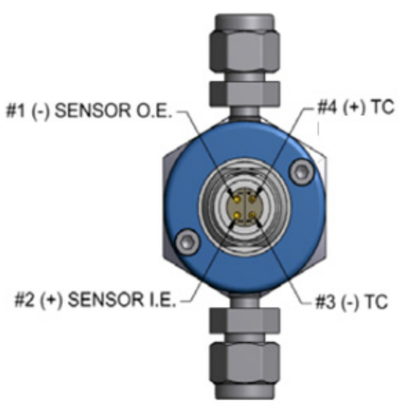
The cable assembly wires are colored as follows:

- The gray shielded cable contains the probe (mV) lead wires.
  - The black insulated wire is negative (+)
  - The white insulated wire is positive (-)

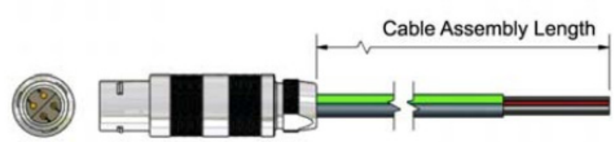
The thermocouple extension wires are jacketed per ANSI color coordination:

- Yellow jacket for type K
  - Red insulated wire is negative (-)
  - Black Insulation is positive (+)
- Green jacket for Type R & S
  - Red insulated wire is negative (-)
  - Black Insulation is positive (+)

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.



A cable assembly is required for first-time installations. To order, please consult the table below.



ORDER CODE	AA6 ___ - ___ - ___
LENGTH	
20" / 50.8 cm	20
26" / 66.0 cm	26
32" / 81.3 cm	32
38" / 96.5 cm	38
T/C TYPE	
Thermocouple Type K	K
Thermocouple Type R	R
Thermocouple Type S	S
No Thermocouple	X
CONNECTION FITTINGS	
6 mm Tube, CPI Ferrules	8
1/4" Tube, CPI Ferrules	9

ORDER CODE	CA6 - ___ - ___
LENGTH	
1' / 30.5 cm	01
10' / 304.8 cm	10
20' / 609.6 cm	20
50' / 1524.0 cm	50
T/C TYPE	
Thermocouple Type K	K
Thermocouple Type R & S	RS
No Thermocouple	X

HOT REMOVAL

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

(US & Canada) 1-800-547-1055 ex 216
(Outside US) +1-513-772-1000 ex 216

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

<u>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.</u> 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 is 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 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. Reference air must be filtered free of particulate and liquids. Pumping dirty reference air into the NITROCARB will cause a false mV output, ultimately damaging the inner electrode and zirconia electrolyte.

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^{o}F is acceptable, but usually it is less than 10^{o}F. if the difference is more than 20^{o}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 NITROCARB probe. If that selection is not available, contact FCC.

5. Set the controller setpoint to the desired reading

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.

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 temperature with an operating atmosphere. 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, 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 you're 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 FCC for instructions.

CONTROL SYSTEM ACCURACY

If the carbon control system is controlling, but incorrect surface carbon content is suspected on carburized parts, check the %CO content of the carrier gas. For this check, a properly calibrated infrared analyzer such as the FURNACE DOCTOR® PRO gas analyzer is recommended. Using the FURNACE DOCTOR® PRO confirm that the CO value is 20% ±1%. The FURNACE DOCTOR® PRO analyzer measures %CO, %CO_2, %CH_4 and calculates %carbon, dew point, and expected oxygen millivolts from the measured gasses and user entered temperature

Furnace Doctor® Pro Infrared gas analyzer

Using direct carbon reading instrumentation, make sure the controller is set up for the NITROCARB 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 NITROCARB probe voltage at the furnace operating temperature. Compare this percent carbon value with the value read from the control instrument.

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 NITROCARB probe thermocouple in comparison to the control thermocouple.

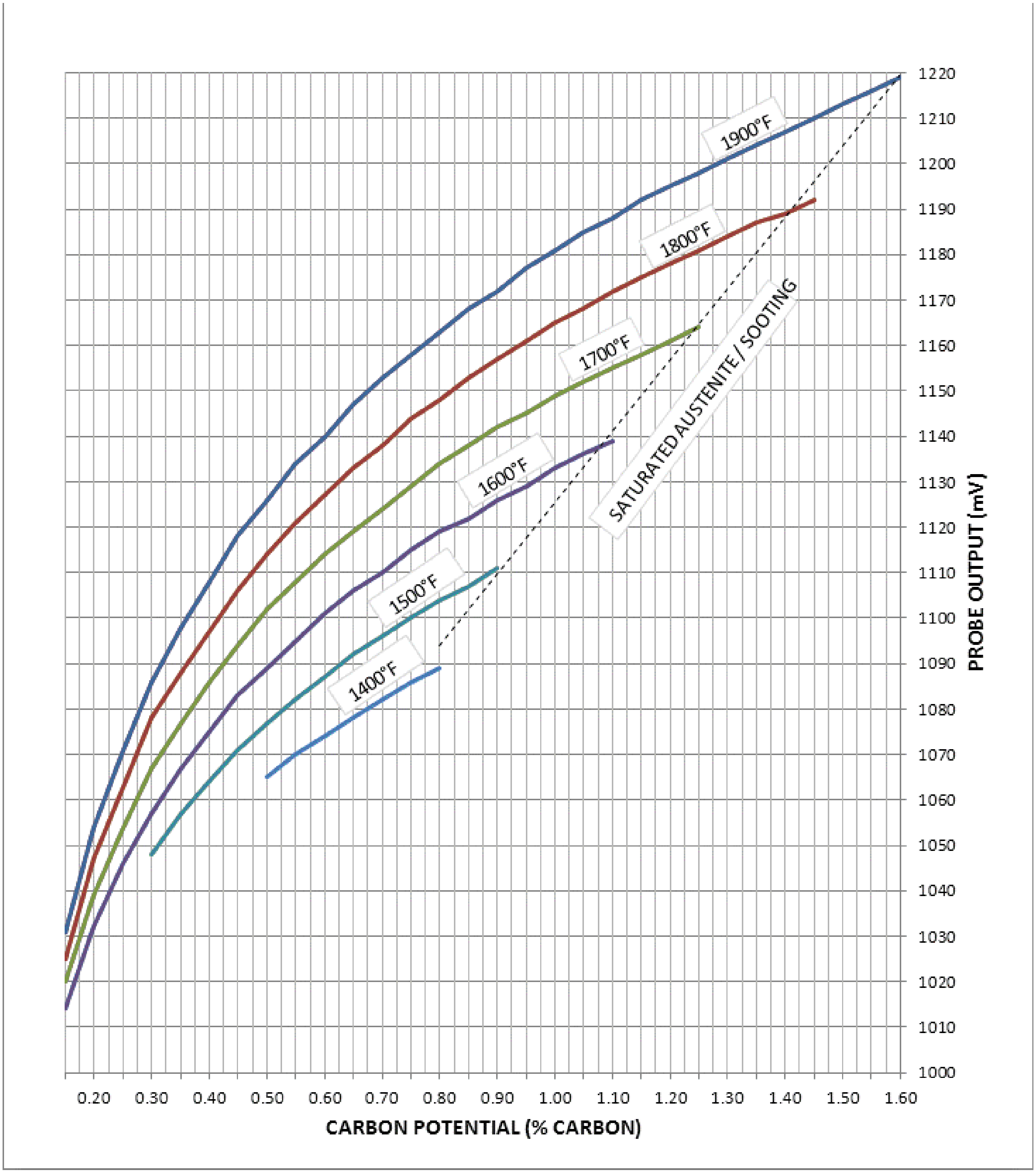
The furnace control thermocouple has drifted in accuracy. Normal replacement will remedy this condition.

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 FCC.

CHARTS

Carbon Potential vs. Probe mV Output @ Temperature(s) GRAPH

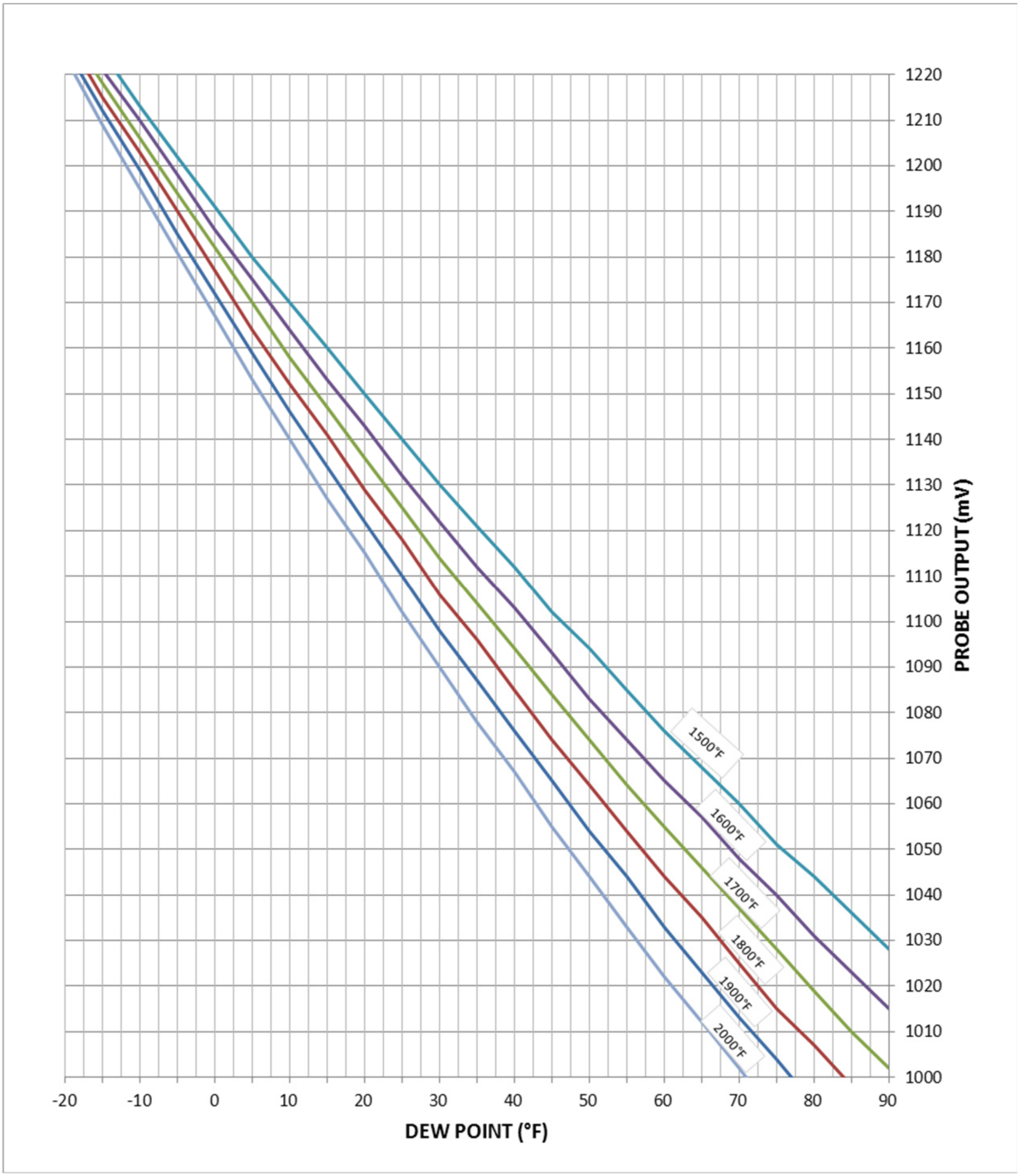


Carbon Potential vs. Probe mV Output @ Temperature(s) DATA

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. Probe mV Output @ Temperature(s) GRAPH



Dew Point vs. Probe 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 $H_2 + H_2 0 = 40\%$**