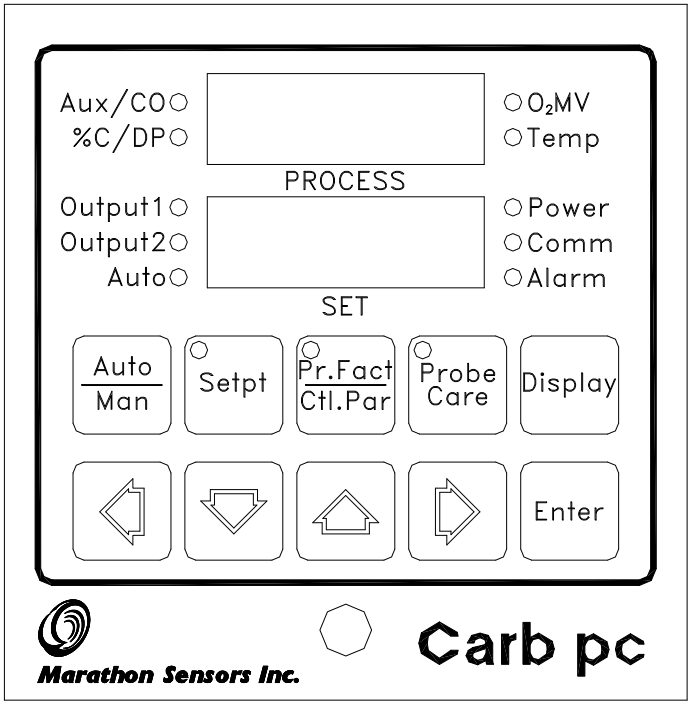
CarbPC

Reference Manual

(2005)



Firmware version .09 and above

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Rev. 910409
Rev. 021021
Rev. 050225
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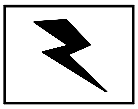
CONVENTIONS

The following are symbols or standards used in this manual and their definitions:



The lightening symbol is used to indicate the presence of 115vac or higher voltages.

This is the WARNING symbol and it points out personnel or equipment safety hazards.

NOTE will point out important facts for related topics.

[ ] Brackets are used to indicate a front panel key. For example: **[Enter]** is used to represent this key.

x Denotes multiplication

/ Represents division

1 INTRODUCTION

The following features are standard with the CarbPC to allow the use of the instrument in a variety of applications:

-Fully site-configurable as an easy to operate, non-programmable, single process controller. With a variety of options for control type, probe care, and alarm functions.
The CarbPc can be configured to meet your specific needs.

-Three (3) analog inputs, setup as a probe temperature input, an oxygen millivolt input, and an auxiliary input for special applications are provided to get the information needed to calculate carbon or dewpoint.

-Two (2) configurable process control triacs are used for contact closures. One or both of these may be used depending on whether single or dual action control is desired.

-Two analog outputs are provided, each supplying a 0 to 5VDC signal which may be used for process control (%C or dewpoint) or sent to a chart recorder to provide a permanent record of process levels.

-One (1) configurable alarm triac is available as a contact closure. This contact can be assigned to sound an alarm (horn, light, switch, etc.) based on various conditions of the process including actual process level or deviation of the process from its setpoint.

-One (1) triac is assigned as a probe care contact to be used when burnoff air is to be applied to the probe for cleaning. The probe care processes are configured at the front panel to run automatically.

-A communications port is provided so that a host computer may retrieve all needed information about the process and also send control values to the instrument.

2 INSTALLATION

2.1 Installation Preparations

The CarbPC is designed for 1/8" panel mounting in a DIN standard opening of 5.43" square (adapter panels available by special order). Required rear clearance is 10" to allow for wiring.

As with all solid state equipment, the controller should be located away from excessive heat, humidity, and vibration (Refer to Section 1.8 for specifications). Since the unit uses red LED display devices, it should also be located such that direct sunlight will not interfere with the display's visibility. The instrument requires 100/120 or 200/240 VAC 50/60 Hz and should not be on the same circuit with other noise-producing equipment such as induction machines, large electric motors, etc. All instrument wiring must be run separate from all control wiring.

2.2 Panel Mounting/Removal

Because the instrument uses a ventilated enclosure, it is not dust-tight and should therefore always be mounted in a dust proof control panel.

To mount the CarbPC in a control panel, a 5.43" square hole must be cut in the necessary location on the panel. This location must allow for a minimum of 10 inches depth clearance for the instrument and associated wiring. The CarbPC has four mounting brackets, one at each corner, to secure it in place. Remove the brackets prior to placing the case in the panel cutout. After the case is in place install the mounting brackets and tighten down the bracket screws.

WARNING

All connections at the REAR PANEL must be done with power removed from the unit. All boards should only be removed or installed with power off . SERIOUS PERSONAL AND/OR EQUIPMENT DAMAGE CAN OCCUR IF THESE PROCEDURES ARE NOT FOLLOWED.

2.3 Thermocouples and Other Signal Wires

All signal wires connected to the instrument should be run in conduit, separate from any AC lines in the area. Signal wires include the thermocouple wire, oxygen millivolt wire, and any analog output wiring. This provides noise

immunity and physical protection. Thermocouples should be wired with the appropriate alloy extension wire with no termination other than at the instrument.

NOTE

As with all cold-junction compensating instruments, **EXTREME CARE** should be used when an existing thermocouple is to be used for both the Controller and another instrument at the same time.

2.4 Control Devices

The CarbPC can provide simple ON/OFF as well as Proportional control through two contact closures known as CONTROL OUTPUTS and one 0 to 5VDC signal output (ANALOG OUTPUT) . Refer to Sections 2.2, 2.4 and 9.0 for more details on outputs . Appendix D has sample drawings of common control type connections.

ON/OFF - When the control mode is set for ON/OFF control a contact closure is provided (control output #1) for positive control of enriching gas and, if dual mode is selected, dilution air (output #2). These contacts are turned on and off based solely on where the process is, as compared to the setpoint. This mode would typically be used when the process is easily controlled and the control device is single function. (ie: solenoid)

The CarbPC supports two types of proportional control which are defined below.

1) Time-Proportioning refers to the adjustment of the duty cycle, or changing the ratio of On Time versus Off Time. If the control device has only two positions (on and off) this type of control can be effectively utilized. The typical application for time-proportioning is the two solenoid setup (dual), with one for enriching gas and one for dilution air.

2) Position-Proportioning is the adjustment of the position of a valve so that varying levels of flow are allowed through to control the process. A motor driven, adjustable valve is generally used with this type of control.

The CarbPC provides many ways to use the above control methods. Sections 3.7 and 5.3 have details for setting the Control Mode. Some typical applications for the Proportioning methods are:

ENRICHMENT GAS/DILUTION AIR application : Set Control Mode for Time-Proportioning dual. This setup provides for CONTROL OUTPUT #1 (gas) to be on at one extreme of the control range (100%) and CONTROL OUTPUT

#2 (air) to be on at the other extreme of the control range (-100%). Both are OFF at the midpoint (0%) of the control range.

POSITIONING MOTOR : Set Control Modes for Position-Proportioning. CONTROL OUTPUT #1 will drive the motor in the open direction, CONTROL OUTPUT #2 in the close direction.

Remember, the above methods are just two of the typical applications of the CarbPC. Please call your MARATHON representative or application engineer for questions concerning your particular system.

2.5 Chart Recorders

If a chart recorder is to be used it must have an input range of 0 to 5 VDC. The ideal location of the recorder is adjacent to the instrument but it may be located remotely if the connecting wires are properly shielded. (see section 1.3 for more information on signal wires) Long wiring runs from the chart recorder outputs may require resistive termination (2K ohms or so) at the remote end to decrease the effects of shop noise. For best results, the chart recorder input(s) should be isolated from ground.

2.6 Computer Interface

If your system will utilize the CarbPC's RS-422 digital communications capabilities several considerations must be made. Communication cables must be properly run, instrument addresses assigned and set, and the host computer must be properly configured. Refer to Appendix F "Communications" for more details. Valuable data can be attained by using the Process Master Control's Process Master system in communication with the CarbPC. Especially when more than one CarbPC is used or if other Marathon instruments are also connected to the host computer. See your Marathon sales representative for more details.

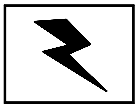
2.7 Alarm

One user-configurable alarm contact is available for connection in appropriately-engineered systems. This contact may be connected in many different applications, which are determined by the configuration (see section 5.2 for details).

2.8 Electrical Connections

2.8.1 AC Power

The CarbPC requires 100/120 or 200/240 VAC @ 1 AMP for supply power connected as follows:

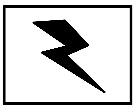


HOT (L1)	-TBA-1
NEUTRAL	-TBA-2
EARTH GROUND	-TBA-3

2.8.2 Control Connections

NOTE

The use of isolation relays on all 115vac connections to the CarbPC is **<u>STRONGLY RECOMMENDED</u>** ,this practice should be followed if electrical connections to the CarbPC are made without the assistance of Marathon Monitors.



CONTROL FORWARD	-TBA-4
CONTROL REVERSE	-TBA-5
CONTROL COMMON	-TBA-6
ALARM N.O.	-TBA-10
ALARM COMMON (ALT COMMON)	-TBA-8
PROBE BURNOFF CONTACT N.O.	-TBA-9
PROBE BURNOFF COMMON (ALT COMMON)	-TBA-8

2.8.3 Analog Inputs

The CarbPC allows for three analog inputs. The connections for this are made at the rear panel. The first input is for the probe thermocouple, the second for the probe oxygen millivolt, and the third optionally used to input voltage or milliamp signals.

INPUT #1 (positive)	-TBB-1
INPUT #1 (negative)	-TBB-2
INPUT #2 (positive)	-TBB-3
INPUT #2 (negative)	-TBB-4
INPUT #3 (positive)	-TBB-5
INPUT #3 (negative)	-TBB-6

2.8.4 Analog Outputs

Two separate and isolated analog outputs are provided as follows:

ANALOG OUTPUT #1 +	-TBB-9
ANALOG OUTPUT #1 -	-TBB-10
ANALOG OUTPUT #2 +	-TBB-11
ANALOG OUTPUT #2 -	-TBB-12

2.8.5 Communications

The communication buss is RS-422 half-duplex 1200 baud even parity. (Refer to Appendix F for more on “Communications”). If the instrument communications are to be used the HOST port must be connected to a host computer. The terminal positions are as listed.

HOST PORT:	
RX+	-TBB-13
RX-	-TBB-14

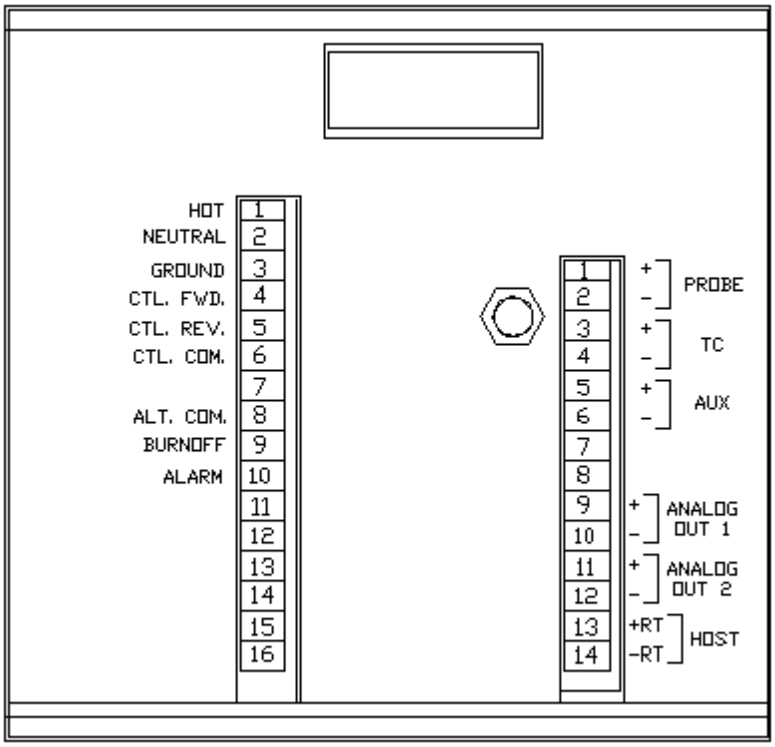


Figure 2-1 Back Panel

3 INSTRUMENT SETUP

3.1 Introduction

The CarbPC must be configured to your specific application by entering data at the front panel keyboard. This information will be stored in non-volatile memory. The larger part of the setup is entered using the **[Pr.Fact/Ctl.Par]** key and the **[Probe Care]** key. To begin the setup process it is necessary to first gain a good understanding of your particular application. The individual pieces of equipment in your process control system will determine what values are selected in the CarbPC setup parameters.

3.2 Instrument Version

The instrument version is determined by the programed chip located within the instrument. The instrument version may be seen when the power is first applied to the CarbPC. C_Pc will be displayed in the top window and a version number in the bottom window. This message will appear for a few seconds, then the display will return to normal mode. This message may also be accessed by the dual key function of **[Display]-[Left Arrow]**. (See section 5.1 Keyboard functions).

3.3 Password Entry

Your CarbPC should arrive from Marathon Monitors with no password entered. This means that a single press of the **[Enter]** key will clear any occurrences of the PASS prompt. When the PASS prompt will be displayed for any particular key press is determined by the lock level function. (See OPERATIONS section 5.3 for more details) If a password is enabled you must know the password in order to clear it from the front panel. The password function may however, be bypassed. For this procedure see appendix C.

3.4 Control Loop

The CarbPC's control loop is affected by the inputs, the control parameters, the control mode, and the outputs. Of these variables only the control parameters and control mode are fully selectable from the front panel. The inputs and outputs are only adjustable by type. These means that the inputs can vary according to the process measurement device (oxygen probe) and the outputs will control only the device they are connected to. Simply put, factors outside of the CarbPC can have a great effect on how well the instrument can control.

All of the variables discussed are important to smooth control of a process and each must be considered when setting up your CarbPC.

3.5 Input Selection

The following CarbPc parameters affect the inputs:

TC- Lets the instrument know what type of thermocouple is connected to analog input #1

CJC- Must be “yes” if thermocouple wire is used and any type other than “lin” is selected for TC.

dEGC- Should be set to “no” for temperature readout in Fahrenheit.

CO C- Determines if input #3 will be used as a %CO in the calculation of carbon. Set to “nO” if you have no connection at input #3.

3.6 Control Parameters

The “control parameters” (also referred to as P.I.D.) are a set of instrument parameters whose values determine the controlling action of the CarbPC. When the CarbPC is placed in the ‘Auto’ mode it will automatically calculate the control action required in order to maintain the process variable at the setpoint. This control action is the percent output. In other words the control action at any given time is some percentage of the total available control (100%). In order to calculate the percent output the instrument uses a complex formula which, has several variables that can be adjusted from the front panel. These parameters are; Pb - Proportional Band, rES-Reset, RAt - rate, and CyC -Cycle time.

For an in depth discussion on PID control see section 8.0. For examples of starting values see appendix D.

3.7 Control Mode

The control mode selection determines what type of electrical response will take place at the rear panel based on the calculated percent output. The CarbPC has two contact closures for 115VAC and one analog output that supplies 0 to 5 VDC. How these outputs are used must be based directly on the type of device to which they are connected. In other words the controlled device determines which control mode must be selected.

See section 1.4 and Appendix D for more information on control devices and typical control modes and section 5.3 for control mode selection.

3.8 Output Selection

The following instrument parameters affect the outputs:

HiPO- Sets the high limit for the percent output. No matter what value is calculated as the percent output it will not be allowed to exceed the HiPO value.

LOPO- Sets the low limit for the percent output.

AO 2- Analog output #2 is a 0 to 5 volt dc output. When needed this output can be configured to control based on the calculated percent output. When the “PO” option is selected the 0 to 5vdc corresponds to the low and high ends of the percent output range. In single mode 0% = 0 volts and 100% = 5 volts, when in dual mode -100 = 0 volts and 100 = 5 volts.

3.9 Alarm Settings

One contact is provided at the CarbPC rear panel for the alarm settings. This contact will typically be connected to a buzzer, horn, light, or switch. The sources used for activation of this alarm contact are selectable from the front panel. The alarm may be activated by three sources. These three sources are the alarm configuration, instrument fault indication, and Probe Care alarm. These alarms act independently and all three might possibly be on at the same time. The alarm configuration is set using the **[Setpt]** key (see section 5.2) and can be used to alert the operator to a number of different conditions occurring in the process control.

The instrument fault alarm occurs when one or both of the inputs from the probe are detected as open (not connected). This alarm condition is also marked by an “Err” displayed in the process window.

The Probe Care alarm may be activated by either the Probe Test Impedance (“Pt I”) or Probe Test Recovery Time (“Ptrt”). If the minimum values set in these two parameters are not met by the values generated during a probe test sequence an alarm will occur. This alarm can be cleared by viewing the Probe Resistance (“PrES”) or Probe Test Recovery Time (“Ptrt”) and pressing the **[Setpt]** key. “PrES” and “Ptrt” can be accessed by first pressing **[Probe Care]** and then pressing **[Enter]** until the desired message is displayed in the PROCESS window. Once the message is displayed press **[Setpt]** to clear the alarm and **[Probe Care]** to exit the probe care data entry mode.

3.10 Probe Care

The CarbPC can be configured for an automatic or manual probe care function (see section 5.4). The probe care functions are provided to allow you to configure your instrument to easily test and clean the probe on a routine basis. A contact has been provided at the rear panel which may be connected to a probe burnoff air pump. This burnoff air when properly applied to the probe will remove carbon buildup.

3.11 Dip Switch Setup

Their are two dip switch banks, SW 1 (front) and SW 2 (rear), on the CarbPC. All configuration and setups are entered through the front panel keyboard except for the host port address setting. This setting separates this instrument from any other instrument on the same communication line from the host computer.

Switch Bank 1

No switches on this bank are for the operators use and should be left in the off position.

Switch Bank 2

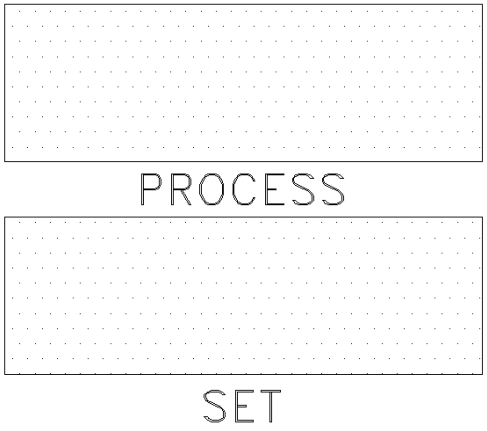
Dip switches 1, 2, 3, and 4 in this bank are use to set the Host SIO address of the CarbPC. All other switches are not used and should be left in the off position. The following table shows the switch settings for the various addresses.

Address		SWITCH #1	SWITCH #2	SWITCH #3	SWITCH #4
DEC	HEX				
0	0	OFF	OFF	OFF	OFF
1	1	ON	OFF	OFF	OFF
2	2	OFF	ON	OFF	OFF
3	3	ON	ON	OFF	OFF
4	4	OFF	OFF	ON	OFF
5	5	ON	OFF	ON	OFF
6	6	OFF	ON	ON	OFF
7	7	ON	ON	ON	OFF
8	8	OFF	OFF	OFF	ON
9	9	ON	OFF	OFF	ON
10	A	OFF	ON	OFF	ON
11	B	ON	ON	OFF	ON
12	C	OFF	OFF	ON	ON
13	D	ON	OFF	ON	ON
14	E	OFF	ON	ON	ON
15	F	ON	ON	ON	ON

4 DISPLAY AND DATA ENTRY

This section will describe the uses of the two four digit displays and the LED indicators on the CarbPC. The descriptions in this section assume no keys are being pressed at the time of viewing (the instrument is in normal mode).

4.1 PROCESS Display



This display is the top window on the front panel. A four digit, seven segment display normally displaying the process variable (percent carbon or dewpoint) or one of the three analog inputs. The four LED indicators around the display indicate which of the four items is being displayed. When the LED corresponding to the input is lit the current value for that input is displayed. While in any of the data entry modes of the CarbPC, this display will show a four character message indicating what parameter is being entered. The OPERATION section 5 will describe these messages and what they mean.

NOTE

An “Err” message will be displayed when either one or both of the analog inputs are open or not connected to the CarbPC.

NOTE

A “CAL” message is displayed to indicate an error in the calibration values stored in memory. This message requires the CarbPC to be calibrated. If after the instrument is calibrated this message immediately returns, the instrument should be returned to Marathon Monitors for repair.

NOTE

When a probe test or probe burnoff is started the front panel display will automatically switch to the O2mv display. The **[Display]** key can still be used however, to change the displayed value if desired. At the end of the selected test the display will return to what was selected before the test began. Also during the Probe Care cycle the Probe Care LED will flash.

4.2 SET Display

The SET display is the bottom of the two windows on the front panel. This four digit display normally displays either the setpoint or the percent output. The setpoint is displayed when the CarbPC is in automatic control mode. The percent output is displayed when the CarbPC is in manual control mode.

While in any of the data entry modes of the CarbPC, this display will show the present value of the parameter being changed. One of the digits of the display will be flashing. This flashing digit is the one that may be changed.

4.3 LED Indicators

The thirteen LED indicators on the CarbPC convey the operational conditions of the CarbPC. A description of each indicator follows.

This LED indicates the state of the alarm. The LED is ON when the instrument is in an alarm condition. The led is off when there is no alarm condition. How the alarm condition (on or off) relates to the alarm contact (open or closed) is dependent on the alarm output type selection (see the explanation for “Aout” in section 5.2). The alarm LED (and contact) may be activated by three sources. These three sources are the alarm configuration,

instrument fault indication, or Probe Care alarm. These alarms act independently and all three might possibly be on at the same time. The fault indication and Probe Care alarms also have a secondary indication to help distinguish between the three possible alarms. In addition to the alarm LED being on, the Probe Care alarm will also cause the **[Probe Care]** key LED to flash. The Instrument fault alarm will be indicated by an “Err” in the process window when “%C/DP” is selected with the **[Display]** key.

Auto●

This LED indicates whether the CarbPC is in automatic control mode (ON) or in manual control mode (OFF).

Aux/CO●

This LED indicates that the value shown in the PROCESS display is the auxiliary analog input.

●Comm

This LED is ON whenever the CarbPC is transmitting a message out of the Host SIO port. During normal communications it will flash.

●O_2MV

This LED indicates that the value shown in the PROCESS display is the oxygen probe millivolt input.

Output1●

This LED is ON whenever the output 1 contact is closed and off when it is open.

Output2●

This LED is ON whenever the output 2 contact is closed and off when it is open.

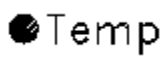
●Power

This LED indicates that the main power supply of the CarbPC is on.

This LED indicates that the CarbPC is in the data entry mode for the process factors and control parameters.

This LED indicates that the CarbPC is in the data entry mode for the probe care parameters. This LED also indicates by flashing that a probe care cycle is in progress or a Probe Care alarm condition exists.

This LED indicates that the CarbPC is in the data entry mode for the setpoint and alarm parameters.



This LED indicates that the value shown in the PROCESS display is the probe temperature. The temperature reading is selectable and may be either in degrees C or degrees F.

This LED indicates that the value shown in the PROCESS display is the process variable (percent carbon or dewpoint in degrees F). The decimal point placement in the display is determined by whether control is based on percent carbon or dewpoint. The percent carbon display will have two digits following the decimal. The dewpoint display will have no digits following the decimal point.

4.4 Data Entry

This section describes the use of the keys on the front panel and the methods used for data entry. The function of the keys may change with the various entry modes of the instrument but, there are several MARATHON standards

used. There are four cursor or arrow keys on the front panel that are indicated by graphic symbols. These will be referenced in the text as **[Left Arrow]**, **[Down Arrow]**, **[Up Arrow]**, and **[Right Arrow]** respectively.

There are a few two key combinations which require the use of the **[Display]** key as a shift key. To properly generate these combinations, press and hold the **[Display]** key, then press the second key, release the second, and then release the **[Display]** key. The use of two key combinations are limited to special modes that are not used in normal operations.

The three data entry modes of the CarbPC are activated by pressing the **[Setpt]**, **[Pr.Fact/Ctl.Par]**, or **[Probe Care]** keys. The same key is pressed to exit from the data entry mode. During a data entry mode the upper display shows a message identifying the parameter that is available for change. The lower display shows the value of the parameter with one digit flashing. The four arrow keys are used to modify the value of the parameter. The **[Up Arrow]** or **[Down Arrow]** keys increase or decrease the value of the flashing digit without effecting any other digit. Only the digit that is flashing may be changed. The flashing may be moved to another digit with the **[Left]** or **[Right Arrow]** keys.

Each parameter has an upper and lower limit to its range. If a value is entered which is outside the specified range and the operator attempts to move to another parameter the whole lower display will flash with the value of the limit that was violated. After you have entered a data entry mode pressing the **[Enter]** key will advance to the next parameter in the list of available parameters. Pressing the **[Display]** key will backup to the previous parameter in the list. The list is circular, that is, advancing past the bottom will go to the top. Likewise, backing up at the top will go to the bottom.

5 OPERATION

5.1 Keyboard functions

[Auto/Man]

Pressing this key toggles the control mode of the CarbPC from auto to manual or manual to auto. In MANUAL mode the SET window displays the current percent output of the instruments control action. The Arrow keys can be used to adjust the percent output giving the operator manual control of the process control action. In AUTOMATIC mode the SET window displays the process setpoint. The instrument will then automatically calculate the percent output needed to hold the process variable (percent carbon or dewpoint) to the setpoint. This calculated percent output may be seen while in automatic mode by pressing and holding the **[Left Arrow]** key.

NOTE

If the instrument is placed in Automatic mode, adjustments will begin based upon the percent output currently held in Manual mode. A drastic, or large 'jump' will not occur.

[Setpt]

Pressing this key will place the CarbPC in the data entry mode for the setpoint and alarm parameters. This mode is described later in this section. This key is also used to exit this data entry mode.

[Pr.Fact/Ctl.Par]

Pressing this key will place the CarbPC in the data entry mode for the process factor and control parameters. This mode is described later in this section. This key is also used to exit this data entry mode.

[Probe Care]

Pressing this key will place the CarbPC in the data entry mode for the probe care parameters. This mode is described later in this section. This key is also used to exit this data entry mode.

[Display]

This key is used to select which parameter is to be displayed in the PROCESS display. Each press of the **[Display]** key changes the displayed parameter from %C/Dp to O2mv to Temp to Aux to %C/Dp etc.. The parameter being displayed is indicated by the corresponding LED. The **[Display]** key is also used in two key combinations as described later. During a data entry mode, the **[Display]** key is used to back up to the previous parameter.

[Left Arrow]

The function of the **[Left Arrow]** key depends on which mode the CarbPC is operating in. In the data entry modes, each press of this key will move the selected (flashing) digit to the left. In the manual control mode, each press of this key will decrease the percent output by 10%. In automatic control mode, pressing and holding the **[Left Arrow]** key will display the percent output in the SET display. The percent output will only be displayed as long as the key is held down.

[Down Arrow]

The function of the **[Down Arrow]** key depends on which mode the CarbPC is operating in. In automatic control mode, the **[Down Arrow]** key has no function. In the manual control mode, each press of this key will decrease the percent output by 1%. In the data entry modes, each press of this key will decrease the value of the selected digit by 1.

[Up Arrow]

The function of the **[Up Arrow]** key depends on which mode the CarbPC is operating in. In automatic control mode, the **[Up Arrow]** key has no function. In the manual control mode, each press of this key will increase the percent output by 1%. In the data entry modes, each press of this key will increase the value of the selected digit by 1.

[Right Arrow]

The function of the **[Right Arrow]** key depends on which mode the CarbPC is operating in. In automatic control mode, the **[Right Arrow]** key has no function. In the manual control mode, each press of this key will increase the percent output by 10%. In the data entry modes, each press of this key will move the selected digit to the right.

[Enter]

Pressing and holding down the **[Enter]** key when the CarbPC is displaying the process variable (%C/Dp LED on) will cause the alternate process variable to be displayed. When the controlled process variable is percent carbon, pressing and holding this key will cause dewpoint to be display in the PROCESS display as long as the key is held down. Likewise, percent carbon will be displayed if dewpoint is the controlled variable. Displaying the alternate variable does not change any of the control actions of the CarbPC. This feature is only a display function and only works when the %C/Dp LED is ON. In the data entry mode the **[Enter]** key will display the next parameter in the parameter list for the entry mode selected.

[Pr.Fact/Ctl.Par] & [Display]

This two key command places the CarbPC in the password entry mode. The upper display will show ‘PSEn’ for password entry. The lower display will show ‘PSSd’ for password. The old password must be entered first

followed by the **[Enter]** key. The lower display changes to a ‘ 0’. This is a count of the key presses to form the new password. The password may consist of any combination of single keys except the **[Enter]** or **[Display]** keys. The combination may be up to 10 key presses long. When the desired sequence is entered, press **[Enter]** to save the sequence. The lower display will show ‘OK’. Press **[Enter]** again to return to normal operation.

[Left Arrow] & [Display]

When these two keys are pressed and held down, the CarbPC will display its version/startup message. The upper display will show ‘C_Pc’ and the lower display will show the firmware version number.

[Up Arrow] & [Display]

When these two keys are pressed and held down, the CarbPC will perform an LED test. Every LED, display segment and decimal point will be turned on.

[Right Arrow] & [Display]

When these two keys are pressed and held down, the lower display will show the temperature reading of the cold junction sensor.

[Display] > [Enter] > [Setpt] > [Pr.Fact/Ctl.Par]

When this keys are pressed in the listed sequence calibration mode will be initiated. (See section 6.0 CALIBRATION for more information).

5.2 Setpoint and Alarm Data Entry

This mode is entered by pressing the **[Setpt]** key.

Message	Range	Description
StPt	-100 to 250 for dewpoint 0 to 2.50 for %C	Setpoint This parameter sets the controlled variable setpoint for either Dewpoint or percent carbon control.
rEF	-999 to 9999	Reference number This parameter is for the operators use, its value has no bearing on the operation of the instrument.
Al t	see table	Alarm Type This parameter selects the alarm type per the following table.

NOTE

A fault condition or a Probe Care alarm will always activate the alarm contact. This will occur without regard to the selection made for this parameter.

Message	Description
d.Pr	direct, process variable
r.Pr	reverse, process Variable
d.bn	direct, deviation band
r.bn	reverse, deviation band
d.dE	direct, deviation + or -
r.dE	reverse, deviation + or -
d.PO	direct, percent output
r.PO	reverse, percent output
d.O2	direct, oxygen millivolts
r.O2	reverse, oxygen millivolts
d.AU	direct, auxiliary
r.AU	reverse, auxiliary
OFF	alarm not used

NOTE

See TERMS Section 10 for definitions of direct and reverse as they apply to alarms.

AL	-300 to 4000	Alarm Value This sets the value of the alarm condition.
A tn	0 to 250	Alarm Turn On This sets the alarm turn on delay time. An alarm condition must be present for the whole delay time before the alarm is activated.
A tF	0 to 250	Alarm Turn Off This sets the alarm turn off delay time. An alarm condition must be absent for the whole delay time before the alarm is de-activated.
Aout	n.o. or n.c.	Alarm output type This parameter will set the alarm contact

5.3 Process Factor and Control Parameter Data Entry

This mode is entered by pressing the **[Pr.Fact/Ctl.Par]** key.

Message	Range	Description
Pb	0 to 9999	Proportional Band

NOTE: With ON/OFF control the Proportional Band value is used to set a deadband, that is an area of the range in which the CONTROL OUTPUTS cannot change state. The hysteresis is 80% of the deadband.

rES	0 to 99.99	Reset
rAt	0 to 9.99	Rate
CyC	1 to 250	Cycle Time
HIPO	0 to 100	High Percent Output Limit
LOPO	-100 to 100	Low Percent Output Limit
LdLn	-100 to 100	Load Line
PFC	0 to 999	Carbon Process
PFd	0 to 999	Dewpoint Process Factor
Con	PC or dPt	Controlled Variable, Percent Carbon or Dewpoint
COnt	See table	Control Mode

	Message	Description
	d tP	direct, time proportioning
	d tC	direct, time proportioning w/comp
	d td	direct, time proportioning dual
	d nu	direct, no contact used
	d OF	direct, On/Off
	d OC	direct, On/Off with complement
	d Od	direct, On/Off dual
	d PP	direct, position proportioning
	r tP	reverse, time proportioning
	r tC	reverse, time proportioning w/comp
	r td	reverse, time proportioning dual
	r nu	reverse, no contact used
	r OF	reverse, On/Off
	r OC	reverse, On/Off with complement
	r Od	reverse, On/Off dual
	r PP	reverse, position proportioning
TC	See table	Thermocouple Type Ten thermocouples types plus linear. Lin for linear, TC types B, C, E, J, K, N, NNM(nn), R, S, and T.
CJC	yES or nO	Cold Junction Compensation Cold Junction Compensation
dEGC	yES or nO	Degrees CelsiusDegrees Celsius If this parameter is yes than all temperatures will be in degrees celsius (except dewpoint).
AO 1	see table	Analog Output 1Analog Output 1
	CArb	Percent Carbon, 0 to 2.00
	dPt1	Dewpoint range 1, 0 to 200
	dPt2	Dewpoint range 2, 0 to 100
	dPt3	Dewpoint range 3, -100 to 100
AO 2	see table	Analog Output 2Analog Output 2
	tC	Temperature
	O2	Oxygen
	AU	Auxiliary
AO2O	-999 to 4000	Analog Output 2 Offset

		Offset value to scale analog output 2. This value is subtracted from the actual value. Percent output is not affected by this offset.
AO2r	0 to 4000	Analog Output 2 Range This parameter selections what portion of the selected variable will be full scale. Analog output 2 will be 0 when the selected variable equals the offset and will be full scale when the selected variable is equal to the offset plus the range. Percent output is not effected by this parameter.
LOCK	0 to 3	Lock LevelLock Level This parameter sets the level of security of the parameters in the CarbPC. The lower the number the higher the level of security. This security level determines which parameters require the password to have access to them. See following table for details.

LOCK LEVEL	Parameters locked at this level
LL-0	All Parameters require a password at this level. (Locked)
LL-1	AL Alarm Value A tn Alarm Turn On A tF Alarm Turn Off Pb Proportional Band rES Reset rAt Rate CyC Cycle Time HIPO Hi Percent Output Limit LOPO Lo Percent Output Limit LdLn Load Line PFC Process Factor Carbon PFd Process Factor Dewpoint dEGC Degrees Celsius AO2O Analog Output 2 Offset AO2r Analog Output 2 Range

Ptrt	Probe Test Recovery Time
Pt I	Probe Test Impedance
PttC	Probe Test Temperature
Pt t	Probe Test Time
Pb t	Probe Burnoff Time
Pb d	Probe Burnoff Delay
Pbrt	Probe Burnoff Recovery Time
PbO2	Probe Burnoff Oxygen
PbtC	Probe Burnoff Temperature
Pbtr	Probe Burnoff Temperature Rise
Al t	Alarm Type
Aout	Alarm contact Output type
Con	Controlled Variable
COnt	Control Mode
TC	Thermocouple Type
CJC	Cold Junction Compensation
AO 1	Analog Output 1
AO 2	Analog Output 2
CO C	CO Compensation
LOCK	Lock Level

LL2

Al t	Alarm Type
Aout	Alarm contact Output type
Con	Controlled Variable
COnt	Control Mode
TC	Thermocouple Type
CJC	Cold Junction Compensation
AO 1	Analog Output 1
AO 2	Analog Output 2
CO C	CO Compensation
LOCK	Lock Level

LL-3

LOCK	Lock Level

CO C	yES or nO	CO Compensation This selection will allow you to use the auxiliary input as the CO input. This value will then be used in the calculation of percent

		carbon. When the CO compensation option is selected as “yES” the Process Factor will still used but, will have a modified effect on the carbon calculation based on what value the actual CO input is. The input is scaled to a 0 to 30% CO value from a 0 to 2 VDC input.
O2of	0000	Positive or negative number used to offset probe millivolts, default = 0000.

5.4 Probe Care Data Entry

This mode is entered by pressing the **[Probe Care]** key.

NOTE

When a probe test or probe burnoff is started the front panel display will automatically switch to the O2mv display. The **[Display]** key can still be used however, to change the displayed value if desired. At the end of the selected test the display will return to what was selected before the test began. Also during the Probe Care cycle the Probe Care LED will flash.

Message	Range	Description
Strt Pb	y or n	Start Probe Burnoff A probe burnoff may be started by changing the n to a y using the **[Up]** or **[Down Arrow]** keys. The probe burnoff will start within a few seconds after exiting the data entry mode.

NOTE

If both a probe test and a probe burnoff were requested, the probe test will always start first.

NOTE

Once started a probe burnoff or a probe test may be terminated at any time by pressing the **[Setpt]** key.

WARNING

If a probe test or probe burnoff is terminated before it has completely finished its cycle, control of the process variable %C or Dewpoint) may be erratic. This is due to the probe not having the proper time to recover before resuming control.

NOTE

During a probe test or probe burnoff the input filter for the O2mv is disabled. This will tend to make the O2mv input appear jumpier than it is during normal operation. The input filter is disabled in order to get a more accurate measurement of probe recovery time.

Strt Pt	y or n	Start Probe Test A probe test may be started by changing the n to a y using the **[Up]** or **[Down Arrow]** keys. The probe test will start within a few seconds after exiting the data entry mode.
PrES	n/a	Probe Resistance This parameter is a display only of the probe resistance computed during the last probe test. This value is displayed in kilo ohms.
Prt	n/a	Probe Recovery Time This parameter will display the probe recovery time (in seconds) as measured during the last probe test.
Ptrt	0 to 200	Probe Test Recovery This sets, in seconds, the maximum time allowed for the probe to recovery without generating a probe test alarm. The time is measured for the probe to return to within 10mv of the original millivolts.

Pt I	0 to 100.0	Probe Test Impedance This sets the probe impedance in kilo ohms that will cause a probe test alarm.
PttC	0 to 2000	Probe Test Temperature This sets the minimum temperature at which the probe must be operating before a probe test will start. If the temperature is below the minimum, a manual probe test is ignored, whereas, a automatic probe test is reset to try again in 30 minutes.
Pt t	0 to 99.99	Probe Test TimeProbe Test Time This sets the time interval for automatic probe tests in hours. A value of zero inhibits the automatic probe test.
Pb t	0 to 99.99	Probe Burnoff Time This sets the time interval for automatic probe burnoffs in hours. A value of zero inhibits the automatic probe burnoff.

NOTE

When either of the Probe Burnoff or Probe Test timers have been set to any nonzero number and then set to a longer time, the timer will continue to count the original (shorter) time until it has counted down and performed the burnoff or test which was set. The timer will then reset the time to the new longer time selected. If the timers however, are set to any nonzero number and then set to a shorter time, the timers will count down to the new shorter time disregarding the previous longer time setting.

Pb d	30 to 1000	Probe Burnoff Delay This sets the length of time in seconds for the burnoff section of the burnoff cycle.
Pbrt	30 to 1000	Probe Burnoff Recovery Time

		This sets, in seconds, the time allowed for the probe to recover after the burnoff.
PbO2	0 to 2000	Probe Burnoff Oxygen This sets the minimum oxygen millivolts at which the probe must be operating before a probe burnoff will start. If the millivoltage is below the minimum, a manual probe burnoff is ignored, whereas, an automatic probe burnoff is reset to try again in 30 minutes.
PbtC	0 to 2000	Probe Burnoff Temperature This sets the minimum temperature at which the probe must be operating before a probe burnoff will start. If the temperature is below the minimum, a manual probe burnoff is ignored, whereas, an automatic probe burnoff is reset to try again in 30 minutes.
Pbtr	0 to 1000	Probe Burnoff Temperature Rise This sets the maximum differential temperature rise that the probe is allowed during a burnoff cycle. If the temperature should rise by more that this setting, the probe burnoff cycle is cut short. That is, the burnoff section is stopped and the recovery time started.
hthr	n/a	High Temperature Hours This parameter is a display only of the numbers of hours the probe has been subjected to a temperature above the value set in the high temperature limit parameter. This value may be reset to zero by pressing the **[Setpt]** key.
ht L	0 to 2000	High Temperature Limit

This parameter sets the high temperature limit. If the probe is operating above this value then the high temperature hours timer runs. You can reset the high temperature timer by pressing the **[Setpt]** key when viewing this parameter.

6 CALIBRATION

6.1 Information

When in the calibration mode the displays and front panel keys take on special assignments. The process display shows the value of the input being calibrated with a flashing digit. This flashing digit indicates the relative sensitivity of the arrow keys. The farther to the left the flashing digit is the more change one press of the up or down arrow key will make. The set display indicates whether the zero value or the span value is being modified. The set display messages are as follows:

Message	Description
nu.AU	Zero (null) Auxiliary Input
SP.AU	Span Auxiliary Input
nu.O2	Zero (null) Oxygen millivolt Input
SP.O2	Span Oxygen millivolt Input
nu.tC	Zero Probe Temperature Input
SP.tC	Span Probe Temperature Input
SP.CJ	Span Cold Junction

NOTE

It is very important to be sure the set display is indicating the proper mode before making an adjustment or the wrong value will be changed.

In the calibration mode, the following keys perform the described functions:

Key	Function

[Left Arrow]

Increases the adjustment sensitivity. When the adjustment is at the most sensitive position (far left position), a further press of the key loops the adjustment to the least sensitive position (far right position).

[Right Arrow]

Decreases the adjustment sensitivity. When the adjustment is at the least sensitive position (far right position), a further press of the key loops the adjustment to the most sensitive position (far left position).

[Up Arrow]

Increases the indicated calibration factor by the value set with the adjustment sensitivity (left or right arrow keys).

[Down Arrow]

Decreases the indicated calibration factor by the value set with the adjustment sensitivity (left or right arrow keys).

[Enter]

Alternates between Zero and Span and saves the calibration factors.

[Display]

Changes which input value is to be calibrated by toggling through the four choices.

[Pr.Fact/Ctl.Par]

Saves the calibration factors and exits from calibration mode.

Adjustment Sensitivity

The adjustment sensitivity works in the following manner. If the right most digit in the process display is flashing then each press of the **[Up]** or **[Down]** arrow keys will change the indicated factor by one calibration unit. This is the least sensitive position. If the left most digit is flashing then each press of the up or down arrow keys will change the indicated factor by a thousand calibration units. Likewise the middle digits will indicate sensitivities of a hundred and ten calibration units respectively. The input value will usually change by an amount less then the calibration factor; however, by observation of the change, the sensitivity can be selected in order to allow the calibration factors to be adjusted more quickly.

6.2 Preparing for Calibration

Before placing the CarbPC into calibration mode, check to be sure that the proper thermocouple type has been selected. First determine what type of thermocouple is connected to the instrument back panel. Then insure that the correct type has been selected in the CarbPC configuration. Press the **[Pr.Fact/Ctl.Par]** key and then the **[Enter]** key until “TC “ is displayed in the PROCESS window to set or check for the proper thermocouple setting (See section 5.3 for details).

Follow the calibration procedure in section 6.4 .

NOTE

Once the input has been calibrated, be sure to press the **[Enter]** key in order to be assured that the latest calibration factors are stored.

6.3 Equipment Needed

An external DC voltage output device is required in order to calibrate the instrument. This device must be capable of producing a millivolt output high enough to equal the maximum corresponding temperature in the range and thermocouple type you will be using. It is necessary that the output be cold junction compensated when in temperature mode.

You will also need a voltage source capable of at least 1500 millivolts (or 1.5 volts) in order to calibrate the oxygen probe input. You will need two copper wires for the linear calibration and a thermocouple wire of the same type as selected at the instrument to do the final thermocouple calibration.

NOTE

If the thermocouple type you select at the front panel and the type of the wire you use are not the same an error in calibration will occur.

6.4 Input Calibration Procedure

6.4.1 Temperature input

Step #1
Place the instrument in calibration mode. This is accomplished by the following key press sequence: **[Display]** then **[Enter]** then **[Setpt]** then the **[Ctl.Par]** key.

Step #2
Connect the copper wire from the instrument panel (TBB 3 and 4) to your millivolt source and input 0 millivolts. Applying a short across positions 3 and 4 can produce the same results.

Step #3
Use the **[Display]** and **[Enter]** keys to display “SP.CJ” on the bottom display window. Adjust the reading in the top window so that it is equal to the ambient temperature of the instruments rear panel. When this is completed press **[Enter]** to save the new value.

Step #4
Use the **[Display]** and **[Enter]** keys to select “nu.tC” in the bottom display window. Adjust your external millivolt source to the 0.00mV (or short the TC input terminals). Then using the arrow keys adjust the top display to 0000.

Step #5

Use the **[Display]** and **[Enter]** keys to select “SP.tC” in the bottom display window. Adjust your external millivolt source to the level that equal 50mV. Use the arrow keys to adjust the value in the top window so that it equals 2500. Press the **[Enter]** key to save your changes.

Repeat steps 4 through 5 until you can verify that these values are stable. This process will need to be repeated more times for instruments that are far off calibration. Press the **[Ctl.Par]** key to exit the calibration menu. After the **[Ctl.Par]** key is pressed “ End” will be displayed in the SET window while the calibration values are stored in memory. This process may take up to one minute.

Step #6
Remove the copper wire from the instrument temperature input and calibration device and replace it with the appropriate T/C wire. Insure that the correct T/C type has been selected in the instrument configuration. Press the **[Display]** key and then the **[Alarm Set]** key until “TC “ is displayed in the PROCESS window to set or check for the proper thermocouple setting (See section 5.3 for details).

Step #7
Setup your calibration device to output a value based on a cold junction compensated temperature. Then choose a temperature from the upper end of your normal operating range (typically 1800°F to 2000°F).

Step #8
Select the temperature display by pressing the **[Display]** key until the temperature is displayed in the upper window. Compare the input temperature to the value displayed on the instrument front panel. If these temperatures do not agree repeat the calibration process.

Step #9
Check the calibration by exiting the calibration mode and comparing the input temperature to the value displayed on the instrument front panel. If these temperatures do not agree make sure you have selected the correct T/C input type with CJC (cold junction compensation) set to Yes.

If the temperature reading is above or below the input temperature slightly, it is possible or correct this offset by adjusting the cold junction span. Leave the calibration source and T/C wire connected. Repeat Step 3 by making small adjustments to the displayed temperature. **Do not** adjust the temperature span value. Exit calibration mode by pressing the **[Ctl.Par]** key.

6.4.2 Oxygen Input

Step #1
Place the instrument in calibration mode. (See Step 1 above "Calibration Procedure: Temperature Input".

Step #2
Connect the copper wire from the instrument back panel (TBB 1 and 2) to your millivolt source and input 0 millivolts. The same results can be produced by applying a short across positions 1 and 2.

Step #3
Use the **[Display]** and **[Enter]** keys to get "nu.O2" in the bottom display window. Then using the arrow keys adjust the top display to read "0000". Press **[Enter]** to store the changed values.

Step #4
"SP.O2" should now be in the bottom display window (this changed when you pressed the **[Enter]** key). Adjust your external millivolt source to 1500 millivolts. Use the arrow keys to adjust the value in the top window so that it also reads "1500". Press the **[Enter]** key to save your changes.

Step #5
Repeat steps 3 and 4 until you can verify that these values are stable. This process will need to be repeated more times for instruments that are out of calibration by a large amount..

Step #6
Check the calibration by exiting the calibration mode and comparing the input millivolts to the value displayed on the instrument front panel. If these values do not agree repeat the calibration process. Exit calibration mode by pressing the **[Cntrl.Parm]** key.

TABLE I
Recommended Calibration Values

Thermocouple type	Zero F(C)	Span F(C)
B	200 (90)	3000 (1800)
C	32 (0)	3000 (1800)
E	32 (0)	1300 (900)
J	32 (0)	1300 (900)
K	32 (0)	2300 (1200)
N	32 (0)	2300 (1200)
NNM	32 (0)	2000 (1100)
R	300 (150)	3000 (1800)

S	300 (150)	3000 (1800)
T	32 (0)	700 (350)

The usable ranges of the thermocouple types are shown in Table II. If it is desirable to have a high accuracy over a specific operating range then the input should be calibrated over that range. Follow the calibration procedure for normal calibration except use the low end of the desired range as the zero value and the high end as the span value. There will be more interaction between zero and span with this method. The desired operating range must fit within the limits of table II.

Table II
Usable Thermocouple Range

Thermocouple type	Minimum Value	Maximum Value
B	110	3330
C	-105	4000
E	-340	1845
J	-335	1400
K	-340	2505
N	-325	2395
NNM	-10	2395
R	-450 *	3340
S	-300 *	3260
T	-380	755

Due to the extreme non-linearity at low level signals, the use of type R and S below 300 F is not recommended.

6.5 Analog Output

The analog outputs are voltage sources only and can not be used or calibrated as current sources. The only calibration equipment required for this procedure is a volt meter. Connect the volt meter to TBB-9 (+) and TBB-10 (-) for analog output 1 or TBB-11 (+) and TBB-12 (-) for analog output 2.

The analog output calibration mode is entered by pressing the **[Display]**, **[Enter]**, **[Setpt]**, **[Auto/Man]** key sequence. No trim pots are used form this calibration. The **[Enter]** key selects the zero or span adjustments. The **[Left]** and **[Right]** arrow keys select the sensitivity as indicated by the flashing dash in the upper display. The **[Up]** and **[Down]** arrow keys adjust the output. The **[Display]** key selects between output 1 or output 2.

No numbers are displayed while in calibration mode. Dashes are displayed in the upper display to indicate the sensitivity selection of the adjustment. Any changes to the outputs must be monitored with a volt meter.

The **[Setpt]** key presets the selected analog output for a 0 to 5 volt output range. This preset calibration is more accurate than the earlier version 3 CPU board presets.

Press the **[Cntrl.Parm]** to exit from the analog output calibration procedure.

7 THEORY OF PROCESS CALCULATION

7.1 %CARBON CALCULATION

Under equilibrium conditions, it is possible to view the carburizing activity in a furnace from the simple equation:

$$CO = C(\gamma) + \tfrac{1}{2}O_2$$

The thermodynamics of this equation are such that when equilibrium between carbon monoxide and oxygen exists (which is a reasonable assumption most of the time), then the carbon potential of the atmospheres is fixed at a value determined by the relative amounts of these two gases. Assuming that the carbon monoxide content of the atmosphere does not vary significantly (again a reasonable assumption if proper atmosphere generation and furnace operation techniques are being employed), then the carbon potential will depend mostly upon the oxygen content of the atmosphere.

The oxygen in the atmosphere is measured by a technique that exposes a simple in-situ zirconia-platinum (or some variation thereof) probe to the gas. The emf (millivoltage) generated by this probe is transmitted to the Controller for processing. Also transmitted is the atmosphere temperature by virtue of a thermocouple located in or near the oxygen probe. Again, assuming that the oxygen and carbon monoxide are in equilibrium and that the carbon monoxide level does not vary significantly, we now have all the information required to produce an approximate calculation of %C in the atmosphere.

The equation used as the basis for the Controller's calculation of %C is:

$$\%C = \frac{(5.102)EXP\left[\frac{E - 786}{.0431\ T}\right]}{\frac{.2}{PcoM} \times \frac{945.7(af)}{PcoA} + EXP\left[\frac{E - 786}{.0431\ T}\right]}$$

Where E = oxygen probe output millivoltage

T = temperature of atmosphere (Kelvin)

PcoA = assumed partial pressure of carbon monoxide in atmosphere (= %CO/100 at 1 atm. pressure)

PcoM = measured partial pressure of carbon monoxide in atmosphere (= %CO/100 at 1 atm. pressure)

af = alloy factor for a given steel (Close to 1 for most carburizing steels); can be calculated from the equation:
af (for low-alloy steels only) =
1 + %Si(.15 +.033%Si) + .0365(%Mn)
- %Cr(.13 -.0055%Cr) + %Ni(.03 +.00365%Ni)
- %Mo(.025 +.01%Mo) - %Al(.03 +.002%Al)
- %Cu(.016 +.0014%Cu) - %V(.22 -.01%V)

NOTE

PcoM is automatically set to .2 if the auxiliary input is not being used for CO measurement

It should be noted that if the Carbon Monoxide content of the furnace is not known, the term in the equation involving af and Pco can be thought of as a single, overall constant for a given set of furnace and load conditions. It is for this reason that this term was chosen as the location for the “Process Factor” adjustment in the Carbon Controller. Mathematically, the “Process Factor” adjustment as entered on the front panel for a given case relates to the term in the above equation as follows:

$$29(PF) + 400 = \frac{945.7\ af}{Pco}$$

Where PF = Process Factor (0-999)

Adjustment of the Process Factor by the user will allow compensation to be made for a wide range of conditions. Looking at the above equation, it can be seen that for a nominal 20% carbon monoxide atmosphere (as in methane-based endothermic gas), with an assumed alloy factor of 1, the Process Factor should be entered as 149. If a propane-based endothermic (23% carbon monoxide) is used, the Process Factor would be 128. For nitrogen-methanol systems, the Process Factor used will normally be the same as for methane-based endo. However, this will depend entirely on the ratio of methanol to nitrogen, and some experimentation would be required to arrive at a working value. Note that for pure methanol, the theoretical process factor would be 85. Note also that if high-nickel steels such as 3115 are to be accurately carburized, an alloy factor (af) will be important in determining the correct Process Factor. A complete chart of process factors for AISI grades at

various CO levels appears in Appendix A. Process factors for high alloy steels such as tool steels are not directly calculable because of carbide interaction. These must be arrived at experimentally.

Unless configured otherwise , the Controller will use a constant value for CO (PcoM =.2). If the auxiliary input of CO is to be taken into account and assuming the switch setup is correct, the Controller will use that value as PcoM, and the %C calculation will vary as the input of CO to the instrument varies. The nominal input range for interact CO compensation is 0-2 Vdc corresponding to 0-30% CO.

As a practical matter, the exactly-correct Process Factor for a given set of circumstances is best determined from experimentation with shim stock and/or carbon test bars; the above equations may then be used as a basis for correcting the factor from a mathematical standpoint. It is usually easier, however, to correct the Process Factor in real-time by simply changing its value and observing the results in the %C display in relation to a known %C in the furnace. When using this method, care must be taken to gather enough solid data before making adjustments; not allowing for statistical variations between loads can be a potential cause of serious error in setting up a Process Factor.

If a significantly different Process Factor than seems logical must be used to get a correct %C display, a number of things must be investigated. The necessity of using a relatively high Process Factor (for example, a value of 250 in methane-based endo) can possibly be taken to mean (among other things) that soot is present in the furnace, or that the oxygen probe is incorrectly located (a condition for which the Process Factor can never be reliably adjusted). A low value for Process Factor might indicate a problem with reference air supply to the probe or impending failure of the probe altogether.

7.2 DEWPOINT CALCULATION

As a convenience for use mainly in the control of endo-thermic generators, the CarbPC may be used to calculate and control Dewpoint, in °F, from the probe input and temperature.

The reaction of interest is:

$$H_20 = H_2 + 1/20_2$$

By assuming a hydrogen content in the atmosphere (usually reasonable) and by measuring oxygen and temperature, the Dewpoint (water vapor content) may be calculated.

The method of calculation is much more complex than that for %C therefore, it will not be explained here.

The Process Factor interacts in the calculation of dewpoint in much the same way as in the carbon calculation, as follows:

$$29(PF) + 400 = \frac{1888.4}{pH_2}$$

This equation is scaled so that if a Process Factor of 149 is selected for the carbon calculation (indicating 20 %CO), then this same process factor will imply a 40% hydrogen content for the dewpoint calculation. Thus for normal 20/40 endo, the instrument may use the same process factor for %C and Dewpoint without a process factor adjustment.

- The auxiliary input cannot be used in the calculation of dewpoint. The normal method of setting the Process Factor in Dewpoint mode is to adjust it as required until the displayed Dewpoint is equal to the Dewpoint measured by a more direct method (e.g. Alnor)*.
- The range of Dewpoint as displayed on the instrument is -99 to +212°F. Even when the instrument is run in °C, the Dewpoint reading will still be in °F.
- The Setpoint in Dewpoint mode may range from -99 to +250°F. The process deviation band ALARM, if used, is ± 10°F around setpoint.

NOTE

*For endo generators where the probe is operating at 200-400°F below the catalyst bed temperature, the process factor may have to be set to 250-450 to get agreement with Alnor dewpointer.

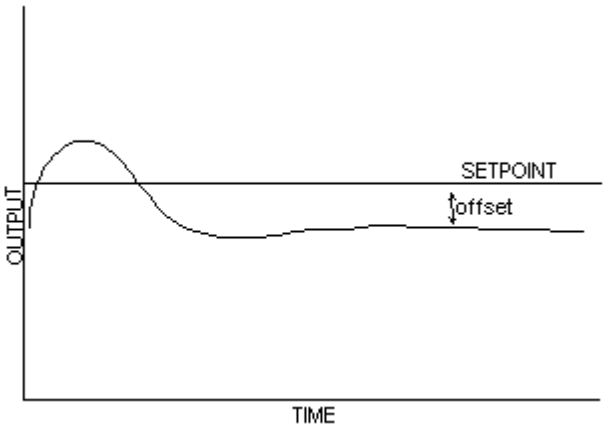
8 PID CONTROL

8.1 PID Theory and Basic Principles

PID is a control system designed to lessen the modulating effect of various equipment such as dampers, valves, and variable-speed devices. The term PID is a convenient mnemonic for the various operations that take place in the system. These operations are Proportional, Integral, and Derivative; thus creating Proportional-Integral-Derivative Control, or PID control.

8.2 Proportional

Proportion control creates a signal that is proportional to the actual condition, or signal, that is present. The magnitude of this signal is based upon the error that is present between the actual condition and the desired condition, such as a setpoint. (i.e. if the actual condition is 3/4 that of the desired condition, then the error is 1/4 and the signal created by the proportional control is an increase of the actual condition by a factor of the error condition.)
Proportional control alone however will not completely eliminate the error. This is due to the proportional controls ability to deal with large errors, but not small ones. Therefore a small error will always be present and will appear as an offset from the desired condition when graphed. See Figure below.

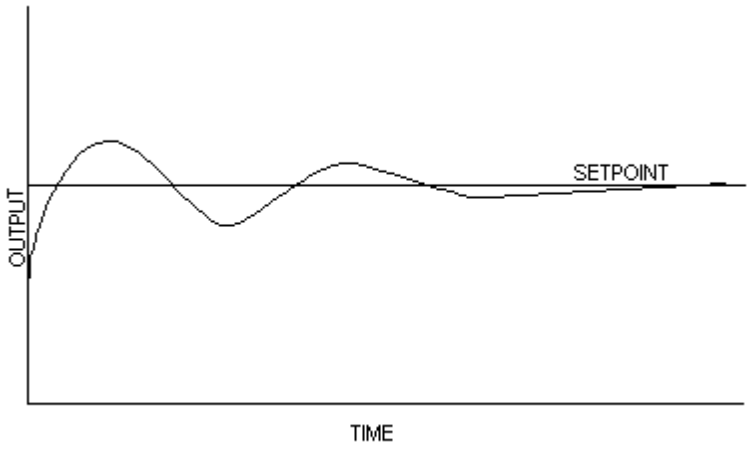


8.3 Integral

Integral control creates a signal that when added to the signal produced by the proportional control eliminates the offset, or remaining error. This integral signal is produced by summing the error over time.

Thus, a combined proportional and integral control will one, eliminate error and two, eliminate offset, or the remaining error.

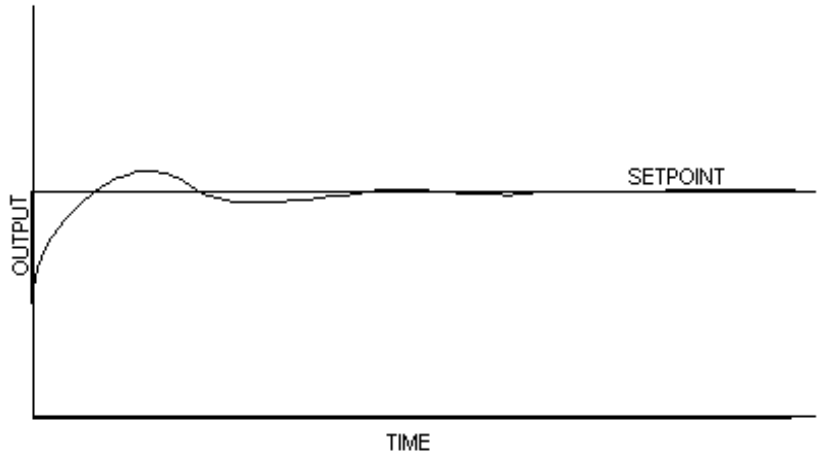
The integral control method is designed to eliminate the offset, or constant remaining smaller error, therefore it does not eliminate overshoot. Overshoot is a condition that occurs when an error is overcompensated for. (i.e. in the example earlier, the 1/4 error may create a signal that causes the new signal to become more than the desired.) When graphed, this overshoot will occur above the line of desired value. See Figure below.



8.4 Derivative

Derivative Control creates a signal that is used to eliminate or control possible overshoots. The signal is created from the rate that the error changes over time. (i.e. in the earlier example the error was 1/4, as this error is compensated it changes, at a given rate, to smaller and smaller values.) The derivative control measures the rate that the error is changing and tries to predict when the actual will intersect or reach the desired. The control will then produce a signal to stop, or hold, the control output when it reaches the desired condition.

Thus, the combination of the proportional, integral, and derivative signals produce a signal that reaches and maintains the desired condition with very little to no error, offset, and overshoot. See Figure next page.



8.5 Creation of a PID - Example

A common example for the use of PID control is that of a hot water convertor that converts steam, received through a valve, into hot water. For this example, the direction of the controlled device is reverse-acting. If the direction were direct-acting, then sections of the equations about to be derived would need to be changed.

8.6 The Proportional Equation

As mentioned above, the proportional section of PID control creates a signal in proportion to the amount of error present. Therefore, the first step is to define the setpoint (SP). After the setpoint is defined, then the error produced may be measured. (i.e. ERROR = HWT- SP, where HWT is the hot water temperature, and SP is the setpoint temperature)

With the amount of error known, the process of creating the output signal can begins. As was stated earlier, the signal is in proportion to the error, this Proportioned Signal, or PS, is often denoted as follows:

PS = ERROR x (units of control signal/unit of error)
(as a convention, x denotes multiplication and / represents division)
The (units of control signal/unit of error) term is used to insure that the output signal produced is in the correct units.

But, this is not the whole equation; just as a conversion from degrees Fahrenheit to degrees Celsius must have a +32 factor in order to align 0°C with 32°F (the freezing point of water), the PS equation must also have a 'zeroing' factor. This zeroing factor, represented by ZF, is the control signal required by the control loop at zero error.

Thus the final proportion equation is:
PS = ERROR x (units of control/units of error) + ZF

8.7 The Integral Equation

As discussed earlier, the integral section of PID control creates a signal designed to eliminate offset by summing the error over time. Therefore, first an equation for the summation must occur as follows:

INTEGRAL = INTEGRAL + (ERROR x TIME)

In this equation, INTEGRAL stands for the sum of the error over time, therefore the previous value is always added to the new error and time value. (TIME is the elapsed time)

After the integral value has accumulated for some time, this value is multiplied by a term similar to that used in the proportion section to insure that proper units are used. This term is (units of control/units of error, time).

When this new value is added to the PS formula, a new Proportioned Integrated Signal is produced as follows:

PIS = ERROR x (units of control/units of error) + INTEGRAL x (units control/units of error,time) + ZF

8.8 The Derivative Equation

As previously mentioned, the derivative section of PID control is designed to eliminate overshoot by 'predicting' when setpoint will be achieved. This 'predicting' is achieved by measuring the differences in error and dividing that value by the amount of time it took to achieve that difference. Thus an equation occurs as follows:

DERIVATIVE = (ERROR - PE)/TIME

where PE is the value of the previous error, and TIME is the amount of elapsed time between the previous error value, and the present error. This

derivative term is then multiplied by a constant term to insure the proper units of the signal. This term is ((units of control x units of time)/units of error).

When this term is then added to the PIS formula, a new Proportioned integrated and Derived Signal is produced as follows:

PIDS = ERROR x (units of control/units of error) + INTEGRAL x (units of control/units of error, time) + DERIVATIVE x ((units of control x units of time)/units of error) + ZF

8.9 Implementation of PID control on the CarbPC

The CarbPC uses the Proportional Band as a representation of the Proportion section of PID, the Reset as a representation of the Integral section of PID, and the Rate as a representation of the Derivative section of PID. Thus by following a simple procedure, PID tuning can easily be implemented on the CarbPC instrument. A suggested procedure is diagramed on the following page.

All of the PID parameters may be altered by following the procedures outlined in section 5.3. If after following the procedure the process appears not to be tuned, it may be necessary to adjust the HIPO parameter.

Record all operating parameters in a secure place for later reference.

9 GLOSSARY

ALARMS
The term “alarm” is used with a slightly different meaning then normal when discussing the CarbPC. An alarm in the CarbPC context is the occurrence of an event which has been predetermined to be important enough to cause a contact closure at the back panel. This contact closure will not necessarily be connected to a horn or buzzer and may be used to start a process or allow some other event to occur. (For example: A 1400 deg “alarm” will not typically sound a horn, instead it will be used to close a contact which will allow the introduction of endothermic gas into the furnace.)

ANALOG INPUT
Analog input is a description of the electrical connections on the back panel which are used to input low voltage signals. These inputs represent temperature, oxygen level as measured by the probe and possibly a percentage of carbon monoxide if the third input is used. The CarbPC’s analog inputs are designed for a 0 to 2 VDC input signal, which includes all selectable thermocouple types.

ANALOG OUTPUT
The electrical connections on the instrument back panel which supply 0 to 5 VDC signals. This output will vary as to what it represents based on the front panel selections for the analog output.

CONTROL OUTPUT
The control output is the contact on the instrument back panel which when properly wired will provide the control device (typically a valve or motor) with 115 VAC. The control output duty cycle is directly related to the percent output.

DEVIATION
This is the term used to describe the separation of the actual process value from the process setpoint. This term also is used for the alarm type which triggers based on how far the actual process value deviates from the setpoint in either the positive or negative direction.

DEVIATION BAND
The Deviation Band alarm type is very similar to the Deviation alarm. The Deviation Band alarm will activate when the distance between the process and the setpoint is greater than the alarm value. The difference between the two alarms is that for the deviation band alarm if the process is to far off the setpoint in **either** direction the alarm is activated. With the deviation alarm the alarm value is set to either a positive **or** a negative number and the alarm is activated only when the process deviates to far in that direction.

DIRECT
In terms of the alarms “direct” refers to the condition where when the process variable is below the alarm value or in band (for the deviation selection) the alarm is off (alarm LED is off). Then when the process variable is above the alarm value or out of band the alarm is on (alarm LED is on).
When discussing control action “direct” is used to describe the typical control action needed to control the process variable selected (percent carbon or dewpoint) for control. For example when controlling percent carbon direct control will increase the percent output (add more gas) to increase the carbon level and decrease the percent output (add less gas or add air) to lower the carbon level.

FAULT
An instrument fault alarm indicates that one or both of the inputs from the probe are detected as open (not connected). This alarm condition is also marked by an “Err” displayed in the process window.

HYSTERESIS
The lag in response by the control output in comparison to the calculated percent output. Basically the control does not react exactly when it should but, allows a slight delay to occur. This is done to prevent the output from rapidly cycling on and off.

PERCENT OUTPUT
The percent output is the value calculated by the instrument which represents the duty cycle or position of the control valve.

POSITION PROPORTIONING
Position proportioning without feedback is sometimes referenced as ‘bump’ mode because it bumps the control motor forward or reverse to position the valve. The length of the bump is a function of the cycle time and the change in percent output. If a control calculation computes a new percent output that is 10 percent higher than the old value, then the forward contact is closed for 10 percent of the cycle time. Likewise, if the new percent output is 5 percent below the old value then the reverse contact is closed for 5 percent of the cycle time. At the extremes of the percent output 0% and 100%, the reverse or forward contact is closed continuously. If the cycle time is set to the motor travel time from fully closed to fully open, then the valve position will approximate the percent output. For example, consider a 30 second valve motor is connected to an instrument with a cycle time of 30 seconds. Assume that the control percent output at 0% which will close the valve because the reverse contact stays closed. If when the instrument is placed in automatic control the first control calculation yields a percent output of 20% the motor will be driven open for 6 seconds (0.20 times 30). Should the next control calculation yield 30% the motor would be driven open for 3 more seconds ((0.30-0.20) times 30). This would be the same as driving the motor once for

9 seconds or 30% or the travel time. The position proportioning mode will only approximate the percent output due to motor coast and valve linkage non-linearity.

PROBE BURNOFF
Probe Burnoff is a process of applying air to the probe in order to remove carbon buildup. See appendix A for more information.

PROBE TEST
The CarbPC Probe Test is a procedure where the probe's impedance and the amount of time it takes for the probe to recover to its original output after an upset are measured. This information is useful in monitoring probe life.

PROCESS FACTOR
The Process Factor is a number that is entered at the instrument front panel which will adjust the calculated percent carbon or dewpoint without changing the input temperature, oxygen millivolts, or CO (if used). See section 8.1 for a description of how the Process Factor is used in the calculations of carbon and dewpoint.

PROCESS VARIABLE
Process Variable is the description of the actual calculated %C or dewpoint displayed in the PROCESS window on the CarbPC front panel.

REVERSE
The "reverse" alarm refers to the condition where when the process variable is below the alarm value or in band (for the deviation selection) the alarm is on (alarm LED is on) Then when the process variable is above the alarm value or out of band the alarm is off (alarm LED is off).
When discussing control action "reverse" is used to describe the opposite of the typical control action needed to control the selected process variable (percent carbon or dewpoint). For example when controlling percent carbon reverse control will decrease the percent output to decrease the carbon level and decrease the percent output to lower the carbon level.

SIGNAL WIRES
The low voltage wiring used for inputs or output of the instrument. These wires transmit temperatures, 0 to 5 VDC, and 0 to 2 VDC.

TIME PROPORTIONING
Time-Proportioning refers to the adjustment of the duty cycle, or changing the ratio of On Time versus Off Time. This type of control utilizes a device that has only two positions (on and off). The typical application for time-proportioning is the two solenoid setup (dual), with one for enriching gas and one for dilution air. As an example if the percent output is set to 25% and the

cycle time is set at 20 then the valve will be open for 5 seconds (25% of 20) and closed for 15 seconds (the rest of the cycle time). If the percent output is then set to 75% the valve will stay open 15 seconds and closed for 5 seconds.

TRIAC

Triac is the name of the component in the CarbPC which acts as a relay for a contact closure on the instrument back panel.

10 SPECIFICATIONS

Dimensions	5.63"W X 5.63"H X 10.5"L
Weight	8 pounds
Ambient Temperature	0 to 130°F
Humidity	0 to 85% non-condensing
Line Voltage	85 to 140 VAC, 50/60 Hz 190 to 250 VAC, 50/60 Hz
Panel Cutout Requirements	5.43"H X 5.43"W
Auxiliary Input Impedance	10k ohm
Oxygen Input Impedance	22M ohm
Auxiliary and Oxygen Input Range	0 to 2000 mVDC
Analog Outputs	Two user selectable 0 to 5VDC outputs
Control Outputs	Two Triac outputs selectable for Time-Proportioning or Position-Proportioning.
Alarm Output	One user selectable Triac output for process alarms.
Probe Care Output	One user selectable Triac for Probe Burnoff.
Output Triacs	1 A, 125/240 maximum (fused at 1A).

PID Constants	
Proportional Band	1 to 9999% of Range
Reset	0 to 99.99 RPM
Rate	0 to 9.99 minutes
Cycle Time	0 to 250 seconds
Load Line	0 to 100%

Setpoint	0 to 2.50
Signal Input Range	-10 to +64 mV
Signal Display Range	-300 to 3500 (±4) Depending on thermocouple type.

Thermocouple types accepted

- -Linear
- -B: Platinum 30% Rhodium vs. Platinum 6% Rhodium
- -C:Tungsten 5% Rhenium vs.Tungsten 26% Rhenium
- -E:Chromel-Constantan
- -J:Iron-Constantan
- -K:Chromel-Alumel
- -N:Nickel 14.2% Chromium 1.4% Silicon vs. Nickel 4.4% Silicon 0.1% Magnesium
- -NNM:Nickel vs. Nickel 18% Molybdenum
- -R:Platinum vs. Platinum 13% Rhodium
- -S:Platinum vs. Platinum 10% Rhodium
- -T:Copper-Constantan

Serial Interface:	Full/Half Duplex, Even/NO Parity, MARATHON protocol and partial BC-560 emulation.

APPENDIX A

Oxygen Probe Self Cleaning

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

Self-cleaning of oxygen 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
-location and amount of carbon that has accumulated

When air is forced into the probe sheath (Fig. 1) a combustion reaction between the air and the furnace atmosphere takes place. The location of this reaction will naturally settle at some equilibrium location. It is often possible to see exactly where this reaction is taking place by watching the probe sheath during burnoff. A "hot spot" will mark the location.

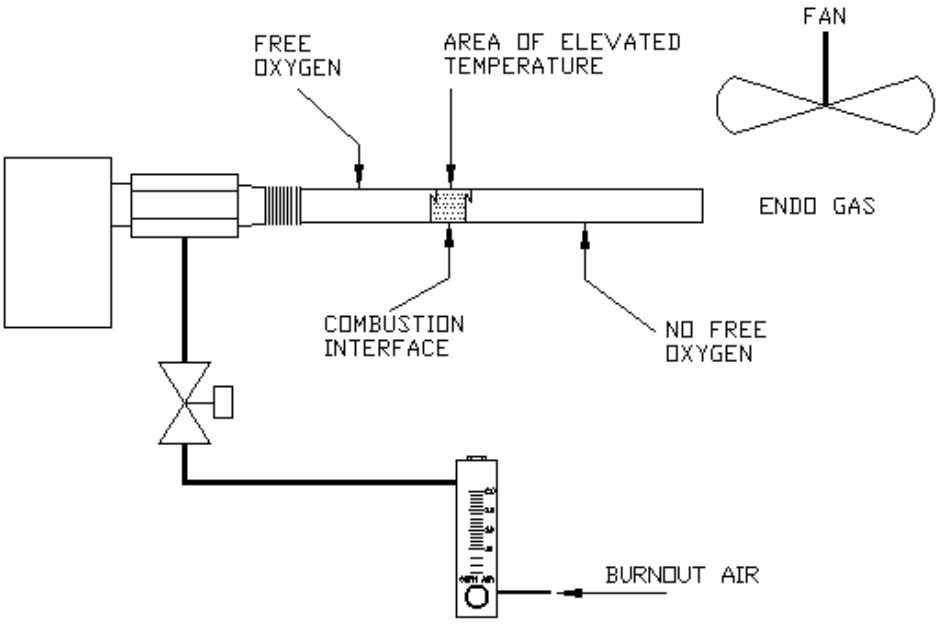


Figure 1 HOT SPOT DURING PROBE BURNOFF

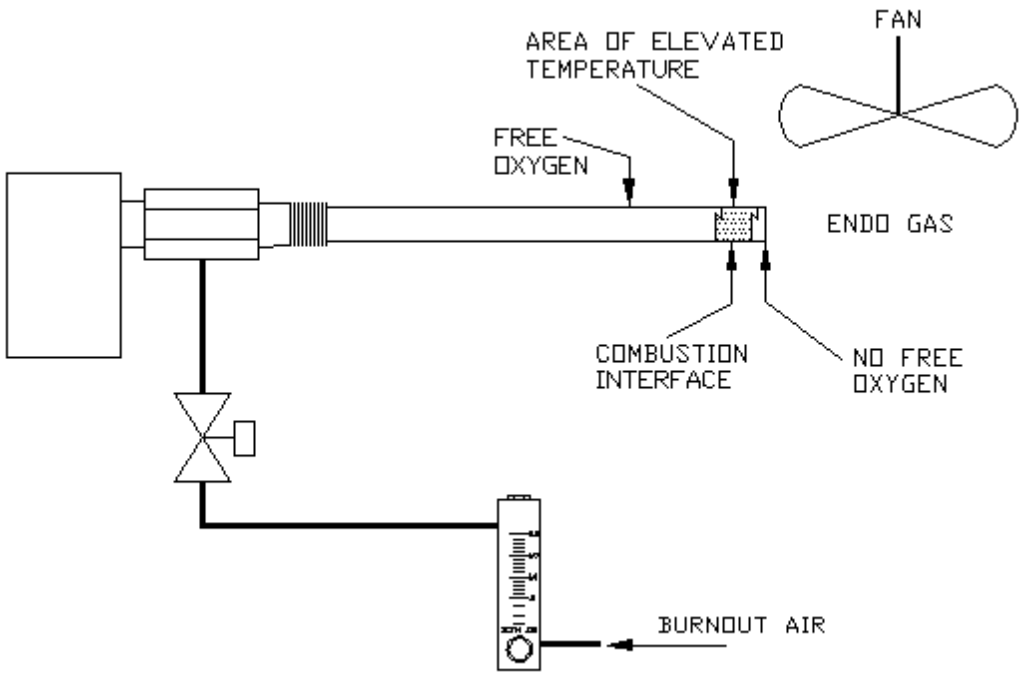


Figure 2 MOVING BURNOFF FLAME FRONT

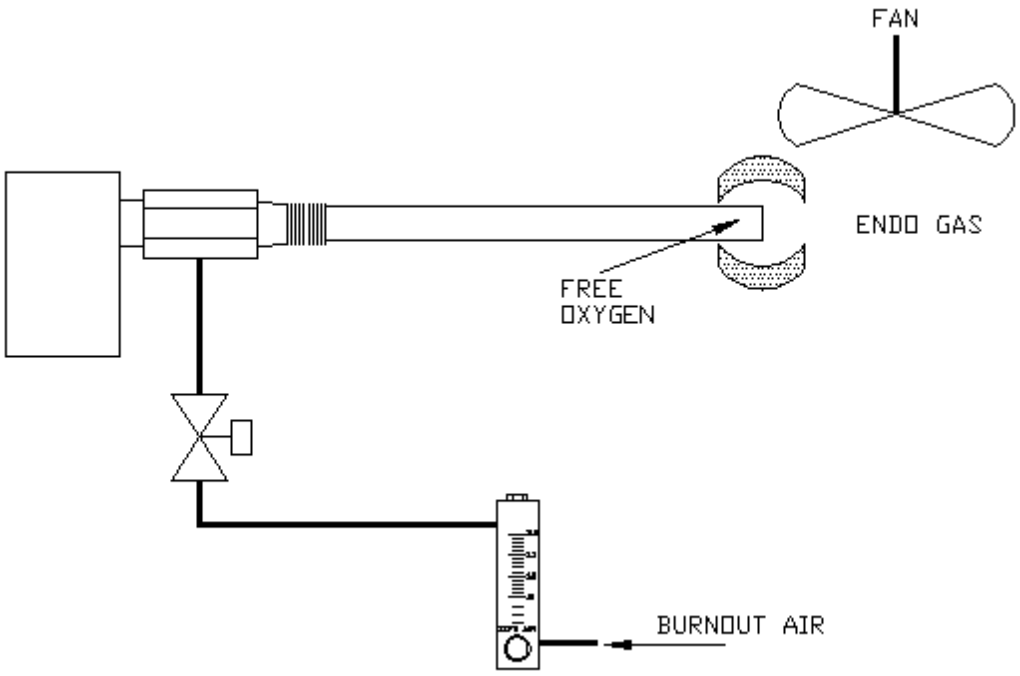


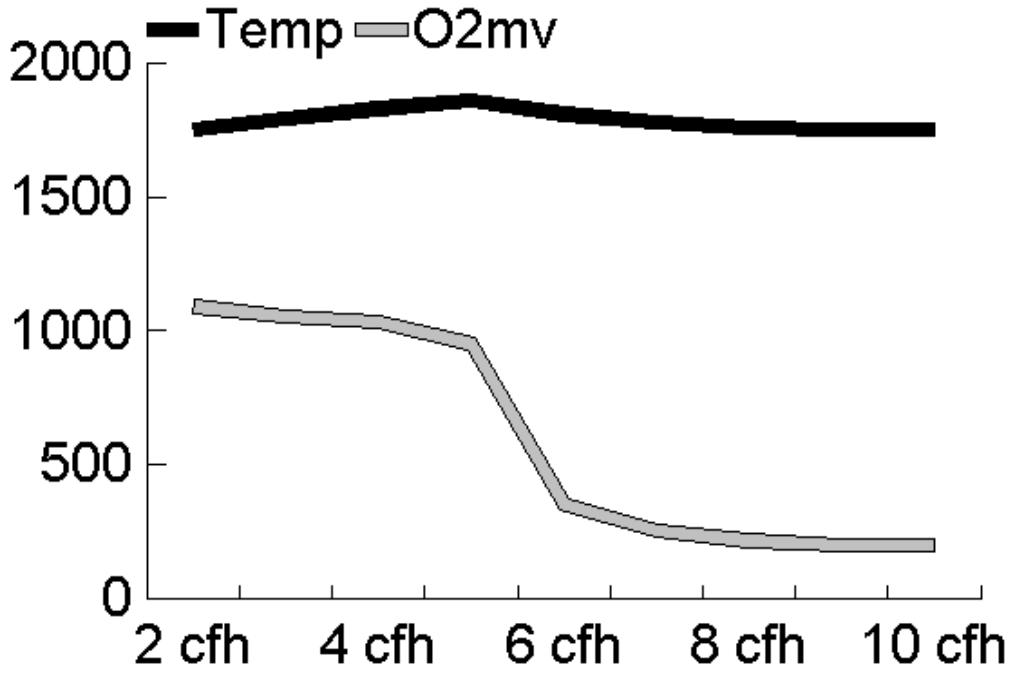
Figure 3 CORRECT PROBE BURNOFF

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 (Fig. 2). If enough air is added, the combustion reaction can actually be moved completely outside of the probe (Fig. 3). 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 MV output. For example, at 1700°F, the following values apply:

O_2 MV	% O_2
1150	9.9×10^{-19}
700	3.6×10^{-11}
100	.43

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 interface out to the probe tip. One example noted that 20 CFH was not enough to overcome the atmosphere circulation, yet when the furnace fan was shut off, < 2 CFH was found to be adequate.

If the combustion reaction is centered at the probe tip, a rise of as much as 200°F might be observed in the probe thermocouple. Care must be taken to keep the probe tip below 1850°F, or permanent damage might result. Determination of CFH air flow is estimated by plotting probe burnoff air versus probe mv's. Fig. 4 (below) is a typical example of data used to determine CFH for the burnoff.



In the above situation, an air flow of 6-7 CFH would be selected, because this provides a lower temperature as well as some free oxygen at the probe tip. 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.

Probe burnoff duration is typically 3-6 minutes. The frequency of the operation depends upon the rate at which carbon is being accumulated (3 to 6 times per day is typical in continuous furnace applications). In batch applications, the burnoff should be done at the start of each cycle. To verify effectiveness, simply remove a probe after a burnoff and examine it.

APPENDIX B

Oxygen Probe Diagnostic Testing

Fact: Over 60% of all in-warranty oxygen probes returned to MARATHON for evaluation are simply cleaned, tested, found to be functional, and returned to the customer.

There is, unfortunately, no definitive test that will prove that an oxygen probe is absolutely accurate. The only way to verify that an oxygen probe is reading accurately is to compare it to a reference oxygen probe exposed to the same atmosphere. However, there are several tests that can be performed, any one of which might prove that a probe is inaccurate.

1. Reference Air Test -

A constant flow of reference air (.5-1.0 cfh) is required by all oxygen probes to maintain accuracy. If this flow is discontinued, the output of the probe will naturally drop at a rate of less than 20 MV/minute. If the rate is found to be between 20 MV/minute and 200 MV/minute, or the direction of change is up rather than down, a crack is present in the probe, which can cause inaccurate readings. If the rate exceeds 200 MV/minute, it is likely that the probe is actually broken wide open. Most fractures in oxygen probes are due to thermal shock during installation or removal from a furnace, although at least one type of probe has been known to develop cracks from its own designed-in stresses.

2. Electrode Impedance Test -

The output impedance of an oxygen probe is a function of the electrode contact surface area, the particular materials involved, and temperature. The lower the output impedance, the more surface area is in active contact in the electrode assembly. A value below 50K ohms at temperatures above 1500°F (816°C) is considered acceptable, while higher values indicate trouble. New probes almost always read lower than probes that have been in service a while, and results measured at high temperatures are always lower than results measured at lower temperatures. This test is not valid below 1400°F (760°C).

3. Electrode Response Time Test -

When an oxygen probe is short circuited, it is converted from an oxygen measuring device into an oxygen pump. Oxygen is transported from the reference air side of the electrode to the furnace atmosphere side. A shorted electrode will actually build up a small amount of free oxygen around the outer electrode. When the short

is removed, the amount of time required to completely dissipate the oxygen and return the gas at the electrode interface to the original composition is an important parameter.

To run this test, it is necessary to short the probe for 15 seconds, remove the short, and measure the amount of time required to recover to 99% of the original millivolt reading. If this time exceeds 60 seconds at temperatures above 1500°F (816°C), the probe is responding sluggishly and the accuracy of the probe is in question.

If a probe is able to pass all of the above tests, but is still in question, the next step is to remove the probe and examine it for obvious physical damage or solid carbon (soot) contamination, either of which could cause accuracy problems. If the mystery persists, return the probe to Marathon for evaluation.

APPENDIX C

PASSWORD FEATURE

NOTE

You may wish to remove this appendix and store it in another location if your goal in using the Password feature is to limit access. The following procedure will allow you to bypass any password or disable the function entirely.

During normal operation the current password must be entered in order to change the password to a new code. If the password has been forgotten or you would like to disable the password function totally follow the procedures below:

1)Locate Dipswitch 8 of bank 1 { Inside of the top cover, bank 1 is the closest to the front of the instrument}.

2) Turn dipswitch on { 8 of bank 1}

3) The Password function is now disabled. If you do not want to use the password capability stop here. If you need to reset the password continue to the next step.

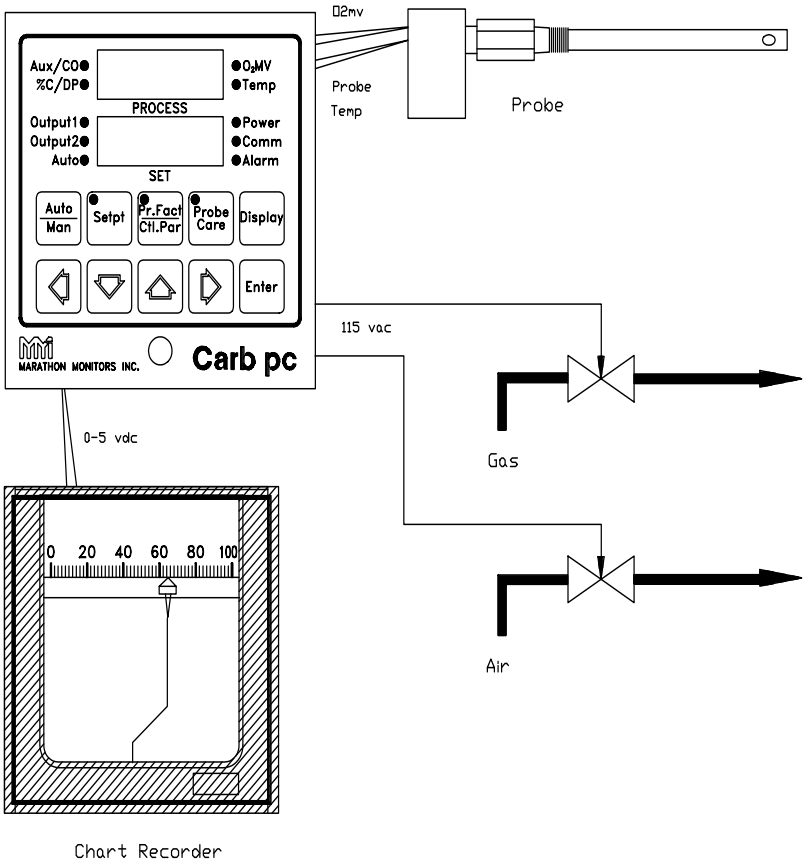
4) Go to the front panel and access the password by pressing **[Pr.Fact/Ctl.Par]** and **[Display]** together. This two key command places the CarbPC in the password entry mode. The upper display will show 'PSEn' for password entry. The lower display will show 'PSSd' for password. The old password must be entered first followed by the **[Enter]** key. The lower display changes to a ' 0'. This is a count of the key presses to form the new password. The password may consist of any combination of single keys except the **[Enter]** or **[Display]** keys. The combination may be up to 10 key presses long. When the desired sequence is entered, press **[Enter]** to save the sequence. The lower display will show 'OK'. Press **[Enter]** again to return to normal operation.

5) Relocate Dipswitch 8 of bank 1 and turn it back to the off position. Your new password is as entered in step 4.

APPENDIX D

CARBPC APPLICATIONS

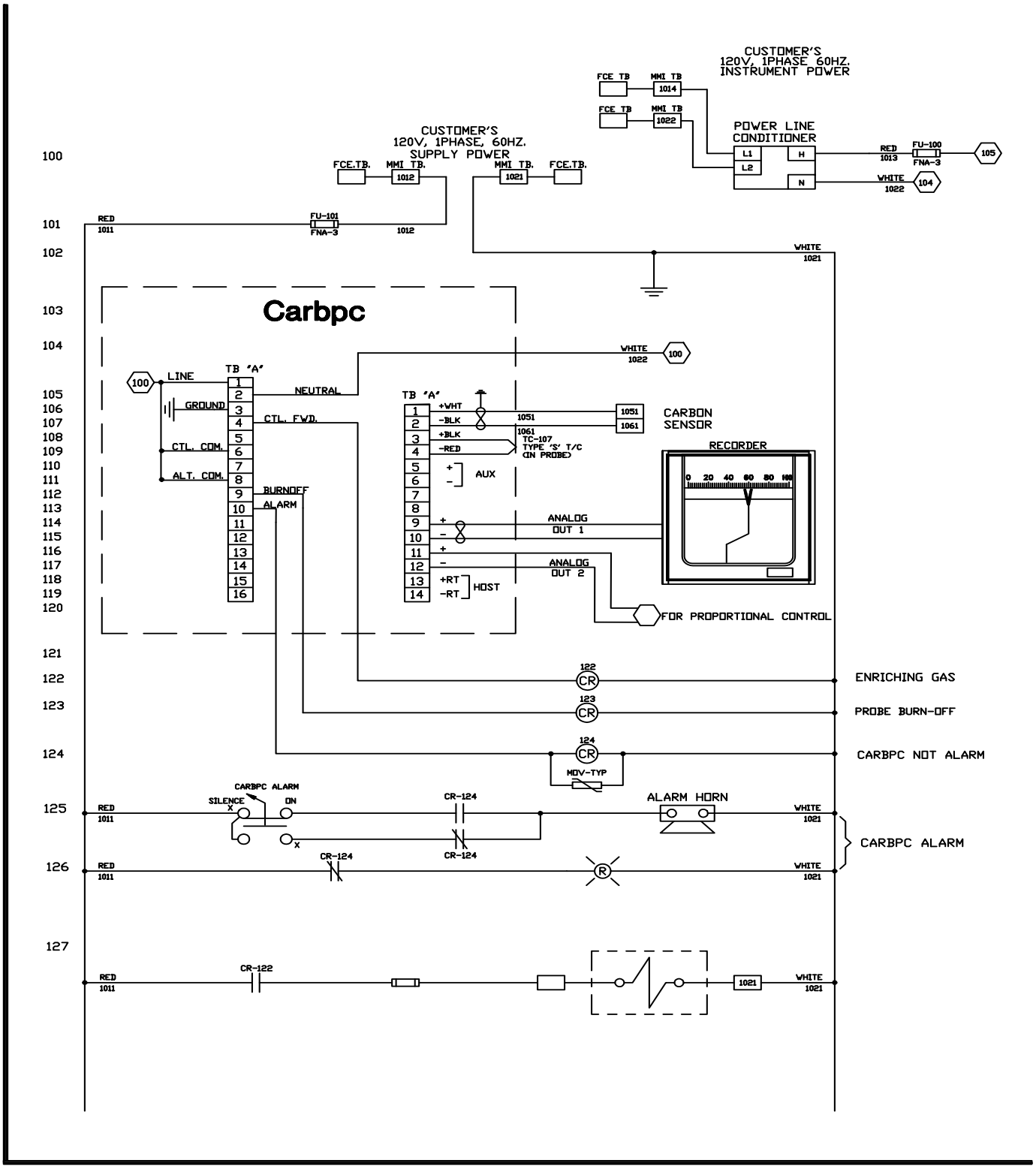
The drawing below shows a typical application for the CarbPC. This application utilizes two solenoids to control air and gas additions. In this manner percent carbon or dewpoint may be effectively controlled. A chart recorder is also being used to record the process values. The following drawings depict common control methods and typical connections to the CarbPC.



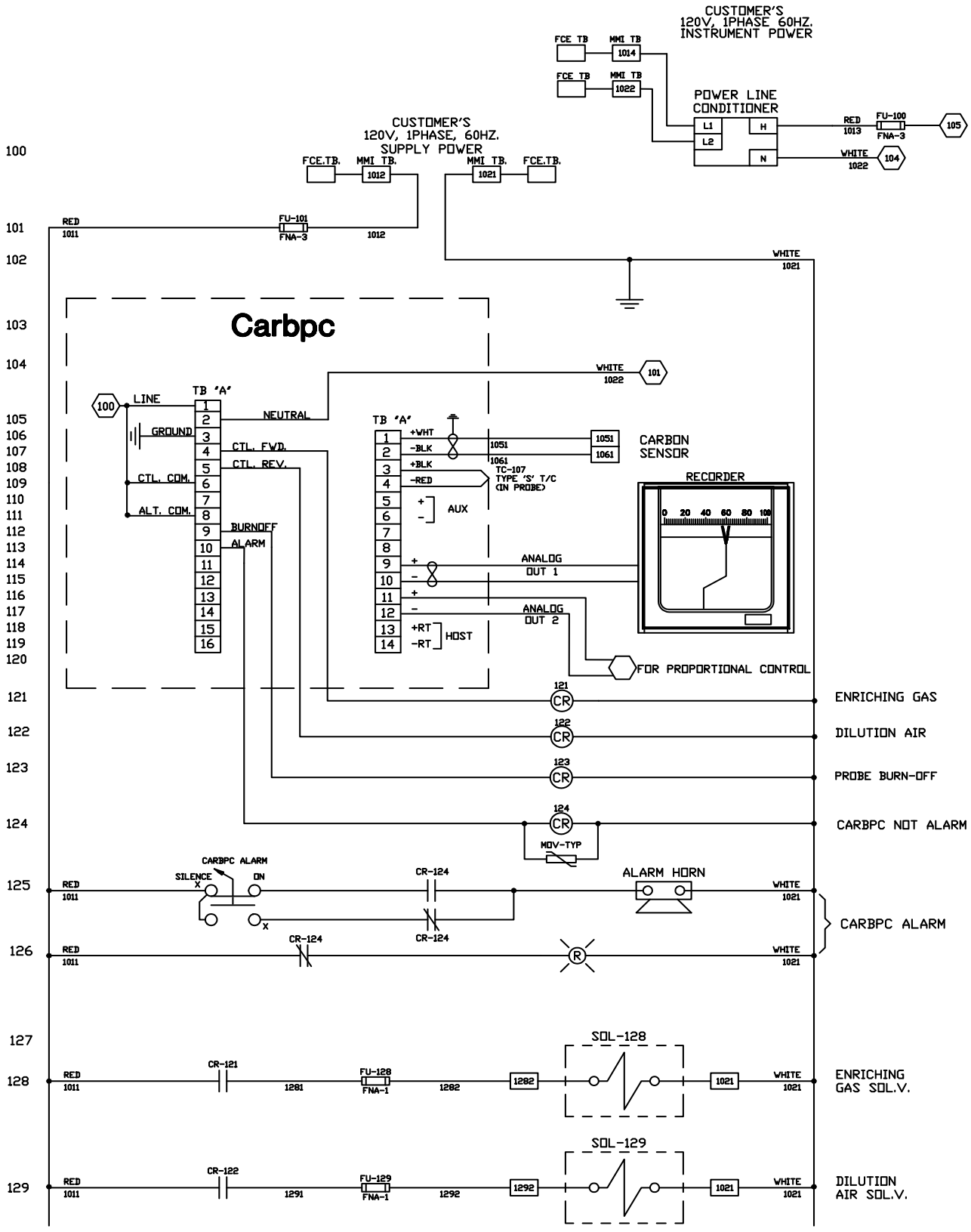
NOTE

On the following pages you will notice the use of isolation relays on all 115vac connections to the CarbPC. Marathon **STRONGLY RECOMMENDS** this practice be followed if you will be making the electrical connections to the CarbPC.

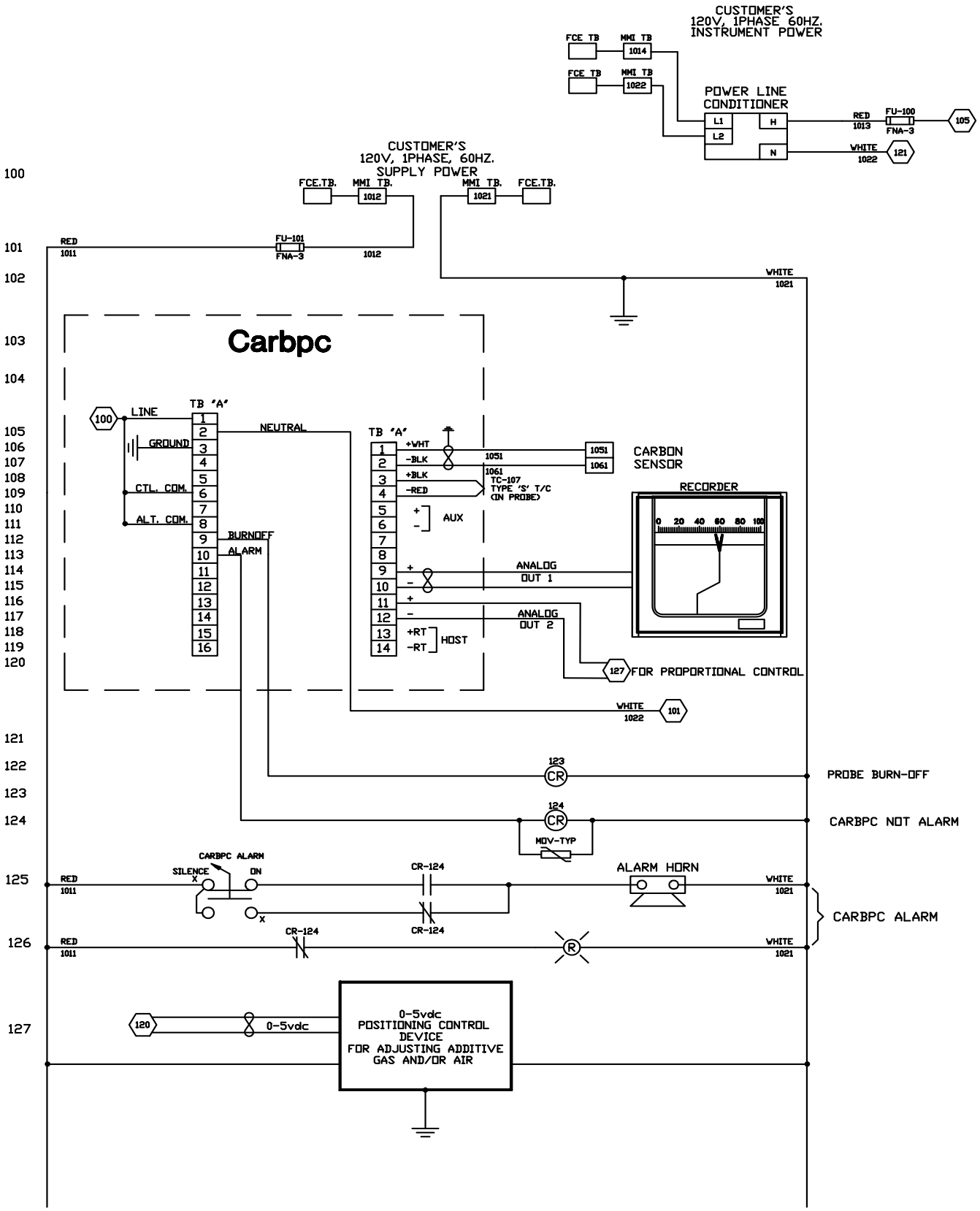
Single Solenoid Control



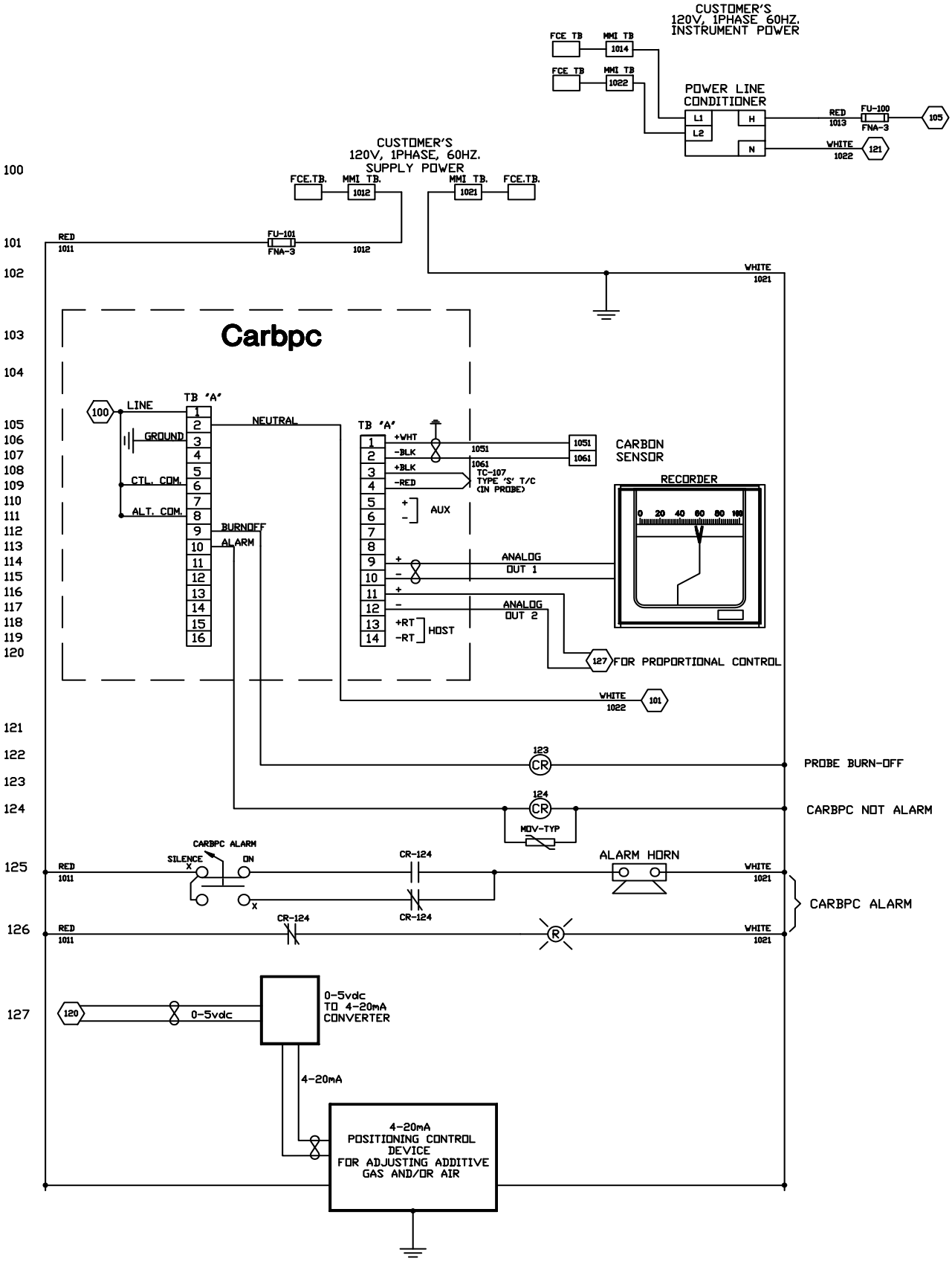
Dual Solenoid Control



0 to 5vdc Positioning Control



4 to 20Ma Positioning Control



APPENDIX E

CarbPC		Unit 1	Unit 2	Unit 3	Unit 4
Parameter	**Description**				
Setpt Key					
Stpt	Set Point				
rEF	Reference #				
AL	Alarm Value				
A tn	Alm Time On				
A tf	Alm Time Off				
Aout	N.O. / N.C.				
Pr Fact Key					
Pb	Prop Band				
reS	Reset				
rAt	Rate				
CyC	Cycle Time				
HIPO	HI % Output				
LOPO	LO % Output				
LdLn	Load Line				
PFC	Carbon Process Factor				
Pfd	Dewpt Proces Factor				
Con	Process Type				
Cont	Contact Type				
TC	T/C Type				
CjC	Cold Junction Comp				
deGC	Deg C YES / NO				
dP	Dewpt deg C or deg F				
AO 1	Analog Out 1 Process				
AO 2	Analog Out 2 Process				
AO2O	Analog 2 Offset				
AO2r	Analog 2 Range				
LOCK	Lock Level				
CO C	CO Compensation				
O2of	Oxygen mV Offset				
Probe Care Key					
Strt	Start Probe Burnoff				
Strt	Start Probe Test				
PrES	Measured Probe Kohms				
Prt	Measured Probe Recv				
Ptrt	Probe Recv Time (sec)				
Pt 1	Max Kohms Setting				
Pttc	Min Probe Temp				
Pt t	Test Interval (Hrs)				
Pbt	Burnoff Interval (Hrs)				
Pb d	Burnoff Delay (sec)				

Pbrt	Burnoff Recovery (sec)				
PbO2	Min Probe mV for Burn				
PbtC	Min Probe Temp for Burn				
Pbtr	Allowed Burnoff Temp Limit				
hthr	Hrs above Temp Limit				
ht L	High Temp Limit				

APPENDIX F

Communication

Among the capabilities of the CarbPC is the ability to communicate with a host computer.

Software designed to interrogate the CarbPC and draw out needed information must follow the Marathon Monitors Protocol described in this section. This information is the used for realtime displays (current status), datalogging (the process history), and can be used to control the instrument from the computer.

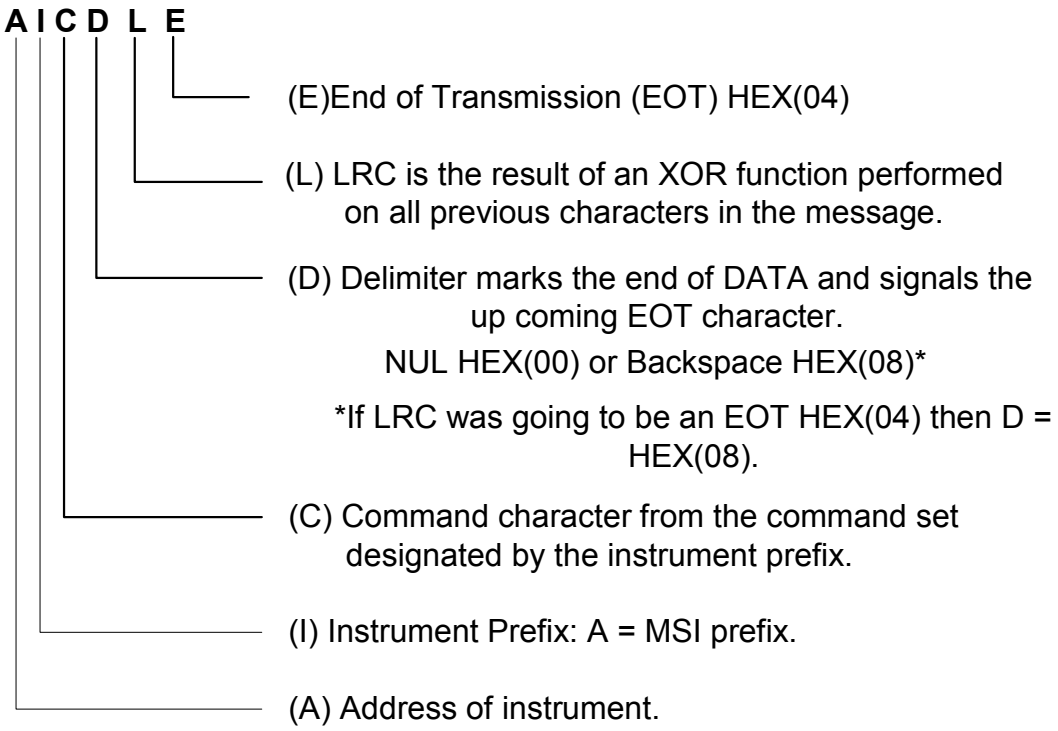
The CarbPC can be used to communicate by itself, with a group of CarbPCs, or with a group of other types of instruments.

The CarbPc must have an address that the computer can use as identification for that instrument. When a group of instruments are used each one must have a unique address to distinguish it from all others. This address is set using the dip switches inside the CarbPC top cover. (See section 3.11 for more information). The valid address range is 1 to 15.

For the CarbPC to properly communicate with the host computer connection have to be made from the CarbPC HOST port. This port is RS-422 half duplex. Other setting are fixed to 1200 Baud Even Parity only.

MSI Message Protocol

The Marathon Monitors message protocol is determined by the source of the transmission. The following format is used by the HOST to request data from the instrument. NOTE: no data field is required.



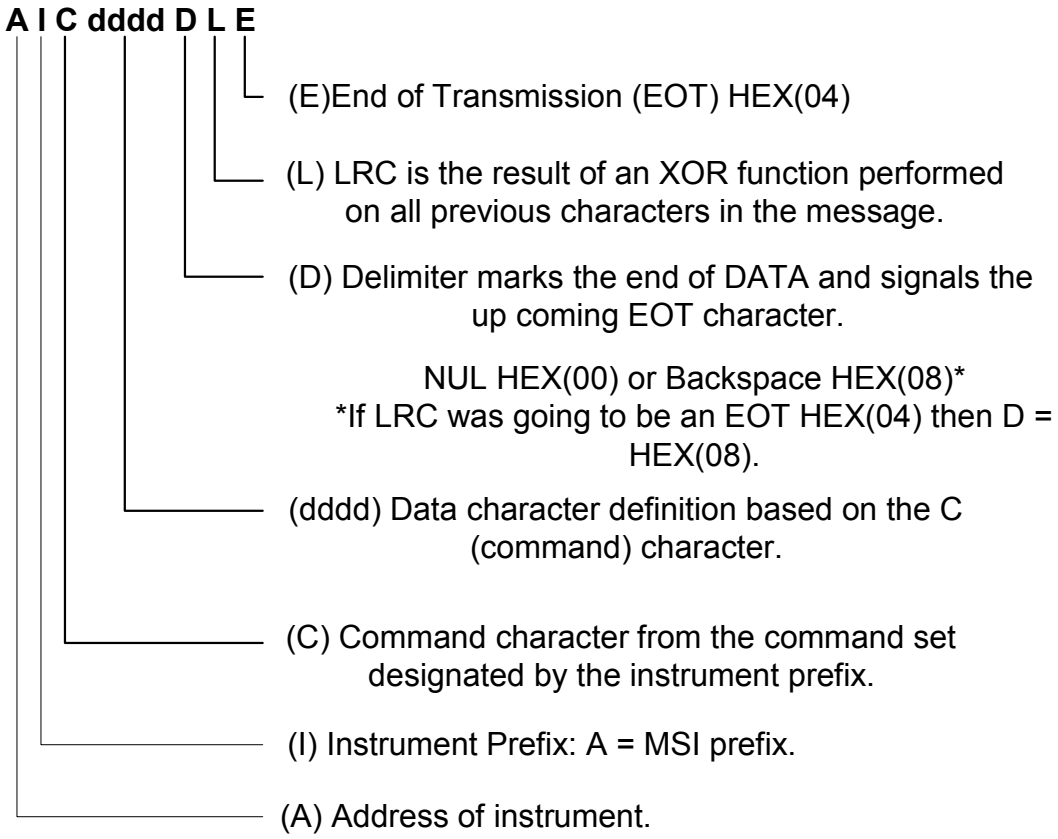
Instrument Address Range

ASCII	or	BROADCAST MODE
0 – F (15)	? character	
		or
		@ character

If an error free and valid message is received by the VersaPro, it will respond with the first character being an (ACK) HEX(06). It then echoes the message received, inserting any requested data. If an error was detected or an invalid request made, the first character sent is a (NAK) HEX(15).

Note that the Versapro will respond to both types of instrument prefix. The 'A' prefix is used to address a simple slave instrument such as a 10Pro temperature controller. This protocol is based on a series of individual commands and responses. The 'U' prefix is typically used for more advanced protocols such as the Marathon Version 4 protocol. This protocol allows for block transfers and is used by instruments such as the Marathon Monitors Version 4 Dualpro, AACC controllers, and 10Pro-E. The Versapro responses to either prefix in order to be compatible with either the 10Pro or with instruments using the more advanced block transfers.

The following format is generated by the HOST when parameters are changed in the instrument or when the instrument in responding to the HOST request. Any change commands from the HOST are echoed by the instrument in the same format as the data that was sent.



The MSI (Marathon Monitors Inc.) command set supports the extensive capabilities of the MSI line of instruments. The command set consists of the typical characters shown in the following table. These commands are used when the master instrument or server issues an ‘A’ prefix with the command when requesting a single parameter. This command structure is used with other slave instruments such as the 10Pro-T. The typical commands that are issued are p, o, i, h, l, and m. The master issues updates to the Versapro when required.

MSI Command Set for 'A' Type Instruments

COMMAND LETTER	Process (oxygen, carbon, temp, etc.)	Timer	Returned Value
p (low case)	Read Auto / Manual mode	Same	'A' = auto or remote 'B' = manual
o (low case)	Read Remote / Local	Same	'A' = auto or manual 'B' = remote
i (low case)	Read Remote Process Setpoint	Read Remote Time Setpoint	4 digit ASCII number
h (low case)	Read Auto Process Setpoint	Read Auto Time Setpoint	4 digit ASCII number
l (lower case as in limits)	Read Actual Process	Read Remaining Time	4 digit ASCII number
m (low case)	Read % Output	Read Time control byte	4 digit ASCII number
P (upper case)	Update Auto / Manual mode	Same	'A' = forces a remote 'B' = forces a manual

Note that the CarbPC does not have a remote setpoint capability. It will return the local setpoint value if it receives a remote setpoint request.

Here is an example of a typical data exchange between a host or master and the Versapro using the 'A' prefix. The hexadecimal values of the command and response messages are shown in the second line to illustrate the actual values used to calculate the LRC. The LRC is calculated by doing an exclusive OR on all of the hexadecimal values in the message up to the delimiter.

This is the command and response for reading the actual process value of the Versapro. In this example the instrument address is 2 and the return value is 0071. Typically this would be 00.71% carbon. Other parameters and scaling are available if the linear inputs are selected. In general the number that is returned is the number displayed on the instrument. No decimal point information is available.

Transmit from Host or Master

Add	Prefix	Cmd	Delim	LRC	
2	A	1	<NULL>	<HEX 1F >	<EOT>
0x32	0x41	0x6C	0x00	0x1F	0x04

Response from CarbPC

	Add	Prefix	Cmd	D1	D2	D3	D4	Delim	LRC	
<ACK>	2	A	l	0	0	7	1	<NULL>	<HEX 1F >	<EOT>
0x06	0x32	0x41	0x6C	0x30	0x30	0x37	0x31	0x00	0x1F	0x04

Here is an example of a request and response for the local setpoint of the instrument in Automatic mode. The response indicates that the instrument's address is 2 and the local setpoint is 1500.

Transmit from Host or Master

Add	Prefix	Cmd	Delim	LRC	
2	A	h	<NULL>	<HEX 1B >	<EOT>
0x32	0x41	0x68	0x00	0x1B	0x04

Response from CarbPC

	Add	Prefix	Cmd	D1	D2	D3	D4	Delim	LRC	
<ACK>	2	A	h	1	5	0	0	<NULL>	<HEX 19 >	<EOT>
0x06	0x32	0x41	0x68	0x31	0x35	0x30	0x30	0x00	0x19	0x04

Here is an example that shows how the HOST changes the instrument's remote set point. The instrument's address is 15. The HOST has sent a command to update the remote setpoint with 1450. The instrument responds by echoing the command.

Transmit from Host or Master

Add	Prefix	Cmd	D1	D2	D3	D4	Delim	LRC	
F	A	I	1	4	5	0	<NULL>	N	<EOT>
0x46	0x41	0x49	0x31	0x34	0x35	0x30	0x00	0x4E	0x04

Response from CarbPC

	Add	Prefix	Cmd	D1	D2	D3	D4	Delim	LRC	
<ACK>	F	A	I	1	5	0	0	<NULL>	H	<EOT>
0x06	0x46	0x41	0x49	0x31	0x34	0x35	0x30	0x00	0x48	0x04

1. "X" Protocol

The "X" protocol allows almost unlimited access to all Carbpc parameters. The "X" protocol software involves the Parameter Table.

a. To WRITE a "data" value to a "parameter number" in the instrument, use the format: **AUXparameternumber$data**.

b. To READ a data value from a "parameter number" in the instrument, use the following format: **AUxparameternumber**.

Therefore, to write a value to the instrument for a specific parameter (in hexadecimal), use the uppercase X. To read a specific parameter from the instrument, use the lowercase x.

The parameters supported by the instrument are listed in Appendix A. The listing includes the parameter name, number, and a short description that includes bit and byte mapping.

A few example commands follow:

To read the temperature from the Carbpro, issue the following command is transmitted to the Carbpc;

1Ux0011<00><1C><04>

Where 1 is the instrument address, U is the instrument type, x is read command, 0011 is the hexadecimal parameter number or the temperature, and <1C> is the LCR.

The return message from the instrument in this example is;

<06>1Ux0011$22CB <00><3F><04>

Where <06> is the ACK, 1 is the instrument address, U is the instrument type, x is read command, 0011 is the hexadecimal parameter number or the temperature, $ is the data delimiter, 22CB is the temperature in scaled hexadecimal, and <3F> is the LCR.

The actual temperature can be obtained by converting 22CB to decimal (8907) and dividing 8907 by 8 thus;

8907/8 = 1113.37

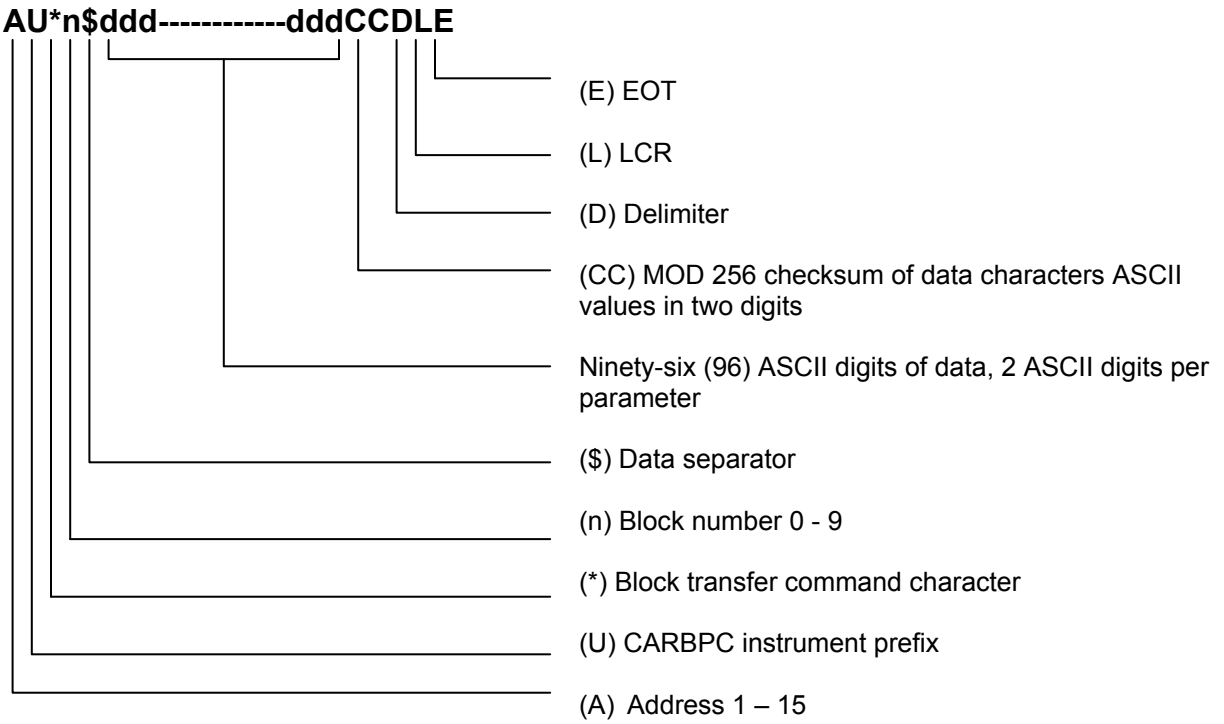
Where 1113.37 is the actual temperature in degrees F.

Note

Any character that is shown without <> is represented in these examples as an ASCII character. All numbers that are returned as data by the instrument are returned as ASCII characters that must be converted to the actual hexadecimal number they represent.

2. Block Transfer

A block transfer is used to read the values of twenty-four (24) parameters per block. The Block transfer is the most efficient method or reading all the parameters from the instrument. The reply to a Block transfer request is shown below.



Block Transfer Reply

Here is an example of the command format for block zero assuming the instrument address is 1:

Add	Prefix	Cmd	Block #	Delim	LRC	
1	U	*	00	<NULL>	d	<EOT>
0x32	0x41	0x6C	0x30 0x30	0x00	0x64	0x04

The instrument reply would start with <06>6U*00$. 96 bytes follow the '$' data symbol. Each pair of bytes represent 48 words where 24 words make up one block. So the command request for block 0 actually returns blocks 0 and 1, or 48 words.

The block command response differs slightly from the other command structures because a MODULO 256 calculation follows the last block character. For example, all of the hexadecimal values returned by the instrument as block data are added up to the hexadecimal value 0x13AE. The modulo 0x100 result of this value would be 0xAE. The actual characters that would be transmitted by the instrument would be 'AE' or hexadecimal values 0x41 0x45, which are the ASCII values for the letters AE.

A complete example of a command request and the instrument response follows;

Command request: 6U*00<00>I<04>

Response: <06>6U*00$C51C90E2000000960096000000960000F00000

000001E000A00520000000140000002D1B650962FFF203D1

FFE100630000AE<00><13><04>

Here are the hexadecimal numbers for the hex / ASCII response shown above:

ACK, Address, Block command, etc.: 06 36 55 2A 30 30 24

Data block values: 43 35 31 43 39 30 45 32 30 30 30 30 30 30 39 36

30 30 39 36 30 30 30 30 30 30 39 36 30 30 30 46

30 30 30 30 30 30 30 30 30 30 31 45 30 30 30 41

30 30 35 32 30 30 30 30 30 30 31 34 30 30 30 30

30 30 32 44 31 42 36 35 30 39 36 32 46 46 46 32

30 33 44 31 46 46 45 31 30 30 36 33 30 30 30 30

Modulo 256 value: 41 45

Delimiter: 00

LRC: 13

EOT: 04

All of the parameters used in a CarbPC reside in blocks 0 through 2. Block 0 contains all the measured and clauclated values: whereas, the other blocks contain only setup parameters. Block 9 contains the temperature, O2 millivolts, auxiliary input, percent carbon, and dewpoint scaled to integer values. Block 5 is the same as block 0. Only blocks 0, 1, 2, 5, and 9 are transmitted. All other block numbers are invalid.

CarbPC Parameter List

Number Dec	Hex	PM Slot	Name	Description
BLOCK 0				
0	00	0	chstat	Channel status bit 0 = calibrate mode bit 1 = calibrate in operation bits 2-3 = reserved for block xfr bit 4 = auto/man bit 5 = nu bit 6 = comms light flash bit 7 = comms light bits 8-11 tc type input a bit 12 = cj comp input a bit 13 = co comp of % carbon bits 14-15 = lock level
1	01	1	conmd1	Control mode and configuation bits 0-2 = controlled variable bit 3 = inhibit calculation bits 4-6 = mode 000 = time prop 001 = time prop w/ complement 010 = time prop, dual 011 = nu 100 = on/off 101 = on/off w/ complement 110 = on/off,dual 111 = pos prop w/o feedback bit 7 = direct(0) or reverse(1) acting bit 8-10 = analog out 1 source 00 = %c, 01 = dewpt1 (0-200) 10 = dewpt2 (0-100) 11 = dewpt3 (-100 to 100) bit 11= dewpoint display, 0 = deg F, 1 = deg C bit 12-14 = analog out 2 source 00 = temp, 01 = O2 mv 10 = aux, 11 = po bit 15 = degree C
2	02	2	pcarex	Probe care status bits 0-3 non zero indicate probe test bits 4-7 non zero indicate probe burnoff bits 8-15 stage of probe care 1-5

Number		PM	Name	Description
Dec	Hex	Slot		
3	03	3	pf1	process factor, percent carbon
4	04	4	pf2	process factor, dewpoint
5	05	5,24	refnum	reference number
6	06	6,28	setpt	setpoint
7	07	7	tnxpb	time to next probe burnoff (minutes)
8	08	8	tnxpt	time to next probe test (minutes)
9	09	9	prbdat	probe test data (1/10 kohms)
10	0A	10	prbrec	probe recovery time (seconds)
11	0B	11	alarm1	alarm value
12	0C	12	alrmmd	alarm mode
			bit 0 => 0=direct, 1=reverse	
			bits 1-3 variable	
			000 pv	
			001 band	
			010 dev	
			011 p o	
			100 o2 mv	
			101 aux	
			110 off	
			111 nu	
			bit 4 = output (delayed by timer)	
			bit 5 = timer set	
			Bit 6 = condition	
			bit 7 = contact polarity; 0 = n.O. , 1 = N.C.	
			bit 8 = fault	
			bit 9 = probe care impedence alarm	
			bit 10 = probe care recovery time alarm	
			bits 11-15 = not used	
13	0D	13	alrmt1	alarm 1 on/off times (seconds)
				on time In low byte, off in high
14	0E	14	phttmin	probe high temp time (minutes total)
15	0F	15	N.A.	
16	10	16	coldjct	cold junction
17	11	17,25	temp	temperature (1/8 degree)
18	12	18,26	oxygen	O2 millivolts (1/2 mv)
19	13	19	aux	aux input (4x value displayed)
20	14	20,27	pcarb	percent carbon (400x ie, 200 = 0.50)
21	15	21	Dewpt	dewpoint (4x)

Number Dec	PM Hex	Name Slot	Name	Description
22	16	22	perout	percent output (-100 to +100)
23	17	23	N.A.	
BLOCK 1				
24	18		pb1	prop band
25	19		reset1	reset (100x)
26	1A		rate1	rate (100x)
27	1B		cyctim1	cycle time (seconds)
28	1C		hipo1	hi limit
29	1D		lopo1	low limit
30	1E		ldln1	load line
31	1F		fault	input faults
			bits 0-3 = temperature input	
			bits 4-7 = oxygen input	
			bits 8-11 = aux input	
			bits 12-15 = nu	
32	20		apttime	auto probe test time (1/100 hours)
33	21		aptmint	probe test min temp
34	22		aptmaxi	probe test max impedence (1/10 kohms)
35	23		aptmrt	probe test max recovery time (seconds)
36	24		pbtime	auto probe burnoff time (1/100 hours)
37	25		pbmint	probe burnoff min temp
38	26		pbmino2	probe burnoff min O2 mv
39	27		pbmtr	probe burnoff max temp rise
40	28		pbtfb	time of burnoff (seconds)
41	29		pbrt	burnoff recovery time (seconds)
42	2A		manstrt	manual start
			bit 0 = probe test	
			bit 1 = auto probe test	
			bit 2-3 = unspecified, will start test	
			bit 4 = probe burnoff	
			bit 5 = auto probe burnoff	
			bit 6-7 = unspecified, will start burnoff	
43	2B		phtval	probe high temp value
44	2C		phtmin	probe high temp minutes counter (lo byte)
45	2D		phthrs	probe high temp hours counter
46	2E		N.A.	
47	2F		mvoffset	millivolt offset for probe calulations

Number Dec	PM Hex		Name Slot	Description
BLOCK 2				
48	30		N.A.	
49	31		N.A.	
50	32		N.A.	
51	33		aoutof2	analog output 2 offset
52	34		aoutrn2	analog output 2 range
53	35		N.A.	
54	36		N.A.	
55	37		N.A.	
56	38		passcode	password codes
60	3C			
61	3D		N.A.	
62	3E		N.A.	
63	3F		N.A.	
64	40		conval1	control value
65	41		N.A.	
66	42		dacv1	analog output 1 value
67	43		dacv2	analog output 2 value
68	44		N.A.	
69	45		N.A.	
70	46		N.A.	
71	47		dipsw	dip switches
			Bank 0	
			bits 0-6 not assigned	
			bit 7 = service	
			Bank 1	
			bits 8-11 = host comms addr	
			bits 12-15 not assigned	
BLOCK 9				
72	48		N.A.	
73	49		N.A.	
74	D9	55	inttemp	integer temperature
75	DA	56	into2	integer O2 mv
76	DB	57	intaux	Integer aux
77	DC	58	intpc	integer percent carbon
78	DE	59	intdew	integer dewpoint

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