

FURNACE DOCTOR BASIC

USER MANUAL

Version Number 005



COPYRIGHT^(C)

No part of this publication may be reproduced, transmitted, transcribed, stored in a retrieval system, or translated into any language or computer language, in any form or by any means, electronic, mechanical, magnetic, optical, chemical, manual, or otherwise, without prior written permission of FURNACE CONTROL CORP.

DISCLAIMER:

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

For assistance please contact:

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

TABLE OF CONTENTS

SAFETY	4
EQUIPMENT RATINGS.....	5
THEORY	6
OPERATIONS	13
MENU SYSTEM.....	17
CALIBRATION	19
BATTERY CHARGER	27
RESTORE FACTORY CALIBRATION.....	28

SAFETY

Please read the instructions before operating the instrument.

This instrument complies with accepted industrial safety standards.
Do NOT operate this instrument with the internal top cover removed.



EQUIPMENT RATINGS

Supply Voltage	110-240 VAC
Supply Frequency	50/60 Hz
Power Consumption	3.2/1.8 Amps

Range	Resolution	Accuracy
CO 0-30 %	0.02 %	2% of range
CO2 0-2%	20 ppm	1% of range
CH4 0-10%	0.02 %	2% of range

Operating Temperature	40°F - 120°F
Relative Humidity	5% - 90% non-condensing

Atmospheres:

Suitable for:

Carburizing
 Carbonitriding
 Carbon Correction
 Neutral Hardening
 Austempering
 Martempering
 Precipitation Hardening
 Annealing
 Normalizing
 Stress – Relieving

call FCC if your process is not listed

****NH3 (ammonia) is strictly prohibited in the sample****

THEORY

Why Infrared?

By purchasing your new Furnace Doctor, you have obviously made the decision that your current process measurement methods require some enhancement. This may be due to customer requirements for back-up process verification to your existing oxygen probe based system or simply a matter of answering the question "is that probe really working?" You might be looking for more complete information of what is happening with respect to your furnace atmosphere.

Whatever your reasons, the use of I/R analysis, and the Furnace Doctor will satisfy these requirements.

Since most Furnace Doctor owners are either performing gas carburizing, or neutral hardening in an endothermic atmosphere, the following discussion will help to understand the meaning of the measured values:

Endothermic atmospheres in use for these applications have this basic composition:

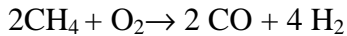
CO \cong 20%	(carbon monoxide)
H ₂ \cong 40%	(Hydrogen)
CO ₂ \cong Trace	(carbon dioxide)
CH ₄ \cong Trace	(methane, usually from natural gas)
O ₂ \cong Trace	(oxygen)
H ₂ O \cong Trace	(water vapor)
N ₂ .Balance	(nitrogen)

These ratios are typical whether you are producing gas by means of an endothermic generator, or using prepared gasses such as nitrogen and methanol. Ratios are slightly different if propane is used rather than methane for the production of carrier gas.

Obviously any increase in volume in one of the gasses means a decrease in one or more of the other gasses. We often get asked the question "Why is my generator producing 20% CO, but I am only measuring 17% at my furnace?" "It is even lower when I add ammonia!" One part of the answer to this question is simple volumetric displacement. There is only room in the furnace for 100% of the atmosphere!

How can the Furnace Doctor help me with my generator?

The basic chemical reaction taking place in an endothermic generator is as follows:



Ignoring the nitrogen

Remember you are mixing gas and air together and heating it up to produce the above described gas composition. The reaction takes place in two stages: First some of the methane burns with air and makes heat. The by-products of this combustion are H₂O (water vapor), and CO₂. In the second stage, the remaining methane reacts with the CO₂, and H₂O. It becomes obvious that we want this reaction to be as complete as possible!

This is the reason for the nickel catalyst in the generator.

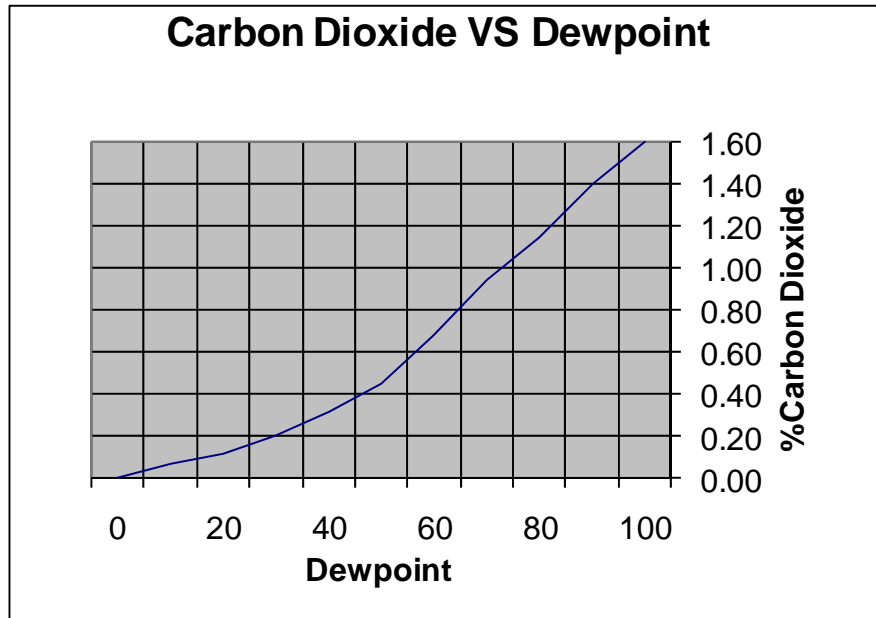
Assuming that the main air gas ratio is set somewhere between 2.7 and 2.85 parts air to 1 part gas, there are two considerations:

1. The catalyst must be clean, and free from soot. If soot is present, the efficiency of the above reactions goes down.
2. You must have adequate temperature to keep the rate of the reactions high enough.

So how can the Furnace Doctor help?

First by measuring the generator's methane content you can determine whether or not the catalyst is operating efficiently. .8% CH₄ is about the upper limit. Above this level it is possible that the catalyst is laden with soot, or the catalyst is simply spent. Another indication of this condition would be a high CO₂, or dew point. The Furnace Doctor provides a convenient way to obtain dew point, CO, CO₂, and CH₄.

Check to see that the basic gas composition is as expected. CO should be around 20%. Check the CH₄ level and be sure that it is less than .8%, observe the CO₂, and the dew point readings. Note the relationship between dew point, and CO₂.

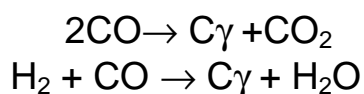


Make adjustments to either your oxygen probe control system, or the generator carburetor to obtain the desired dew point.

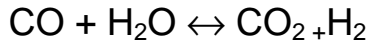
How will the Furnace Doctor help me with my Furnace atmosphere?

If you are using oxygen probes the Furnace Doctor can supply independent, traceable verification of your probes accuracy. It will also give you a much more complete picture of what is happening in your furnace atmosphere.

The primary reactions involved in carbon transfer are well understood as:



These reactions are assumed to be close to equilibrium. The theory behind this is that a reaction sometimes called the water-gas reaction, is busy keeping the H₂ and O₂ in balance:



The measurement of %Carbon in your atmosphere with an oxygen probe is based on the assumption that the above is true:



Note that it is assumed that the primary mechanism of carbon transfer is CO dependant. What is really happening is that the ratio of CO to CO₂ is much more accurate means of determining equilibrium carbon.

One problem is that we use CH₄ as enriching gas. What happens to the CH₄ once it enters the furnace? It decomposes - mostly near the hot catalytic surfaces in your furnace.

It may be replenishing depleted CO, based on equilibrium "rules" it may be making soot crumbs on your hearth, or it may be reacting directly with the surface of the material:



How much of the above reaction is happening is dependent on how much methane is present in your furnace. The reaction also happens faster at higher temperatures, but is still slow compared to the equilibrium reactions.

For example at 1600 with an equilibrium carbon potential of .4%, and methane content of .5 the theoretical carbon potential is actually .44%. In reality the effect is usually about 6/10 of what the theoretical calculations deliver making the carbon potential closer to .42%. By contrast if we were to up the methane content to 5%, the actual carbon potential might be closer to .6%, a significant difference!

Whether the work really ends up seeing this is dependent on a number of issues - temperature – governing the rate of reaction, the surface area of the work and the level of saturation at the surface, atmosphere circulation, etc.

Using the Furnace Doctor to analyze furnace atmosphere

Probe condition:

Carbon is computed using actual gas values, so it is more accurate than the assumptions made by the probe. Compare the %C calculated by the Furnace Doctor to %C displayed on the Carbon Control instrument.

Your carbon controller is set up with some assumptions about the content of the furnace atmosphere. Most controllers assume a CO to be 20% "out of the box" you may use the Furnace Doctor to correct this situation by adjusting this "factor" to the correct %CO.

Observe the probe millivolts as computed by the Furnace Doctor, and displayed by the carbon controller. These should be within 1-2 % of each other. If not, and you have entered the process temperature into the furnace doctor correctly, you probably have a problem with the probe or the controller. First check the millivolt reading at the back of the probe with a meter to eliminate any possible instrument problems.

Next be sure that the probe is free of soot by burning the probe off. If the numbers still do not agree, perform an impedance test on the probe to help determine the electrode condition. You will also want to check to see how fast the probe recovers after this test. Recovery time should be in seconds, not minutes.

Finally disconnect the probes reference air tube, and see if the millivolts reading on the controller changes, if it does you have a leak in the probe substrate.

If you change the probe or if you are sure that the probe is ok, check to be sure you are obtaining a good sample at the Furnace Doctor. Many times sample ports are the cause of the problem. A good non-metallic sample probe helps solve this. One trick is to use the probe burnoff port to obtain a sample. This has a few problems associated with it in furnaces running high methane contents. The methane will crack near the alloy surface of the probe creating a local reaction not representative of the overall furnace atmosphere.

Interpreting the gas value readings:

CO: For most atmospheres in use this number should be around 18-20%. If it is lower than 18% then observe the following:

Check generator for proper operation.

If you are using nitrogen methanol, check the ratio of nitrogen to methanol. Also be sure that the atmosphere sparger is in good condition. If you are using nitrogen to "push" the methanol into the furnace be sure that the methanol is not getting nitrogen bubbles in it.

If you are using ammonia, the ammonia additions will dilute the %CO in the furnace. Remember there is only room for 100% of the gas in the furnace. Check for leaks. This can be confirmed by a high CO₂.

If you are asking for a high carbon potential, high methane content, may also dilute atmosphere mix.

Check for leaks. Air leaks typically cause the control system to add more natural gas to the furnace.

High surface area loads will be able to draw more carbon out of the atmosphere. Typically the methane content will go up because of this.

CO₂: This number can be anywhere between .05% to 1% and is dependent on temperature, and gas composition. It tracks inversely to carbon potential. At 1600F a .4%C will be about 0.62% CO₂ (assuming 20% CO). To achieve a .4% carbon at 1750 CO₂ will be around .25

If the carbon potential is lower than expected the CO₂ should be higher than expected.

Check for air leaks.

Check for burner tube leaks.

Check for furnace fan water jacket leaks.

Check generator or nitrogen methanol system.

If the probe system is in agreement with the Furnace Doctor, be sure there is adequate carrier gas flow, and adequate enriching gas flow.

Is carbon controller turning on the natural gas when it should?

CH₄: Most batch furnaces will operate with a CH₄ content ranging from .1% to 4-5%. At the start of the cycle this number is higher than when the atmosphere and the work approach equilibrium with each other. Continuous furnaces performing carburizing will usually operate at higher methane levels. In fact in some belt furnace applications this is necessary for the process to work!

High free methane content is usually a product of the control system calling for too much natural gas due to an air leak, unusually high surface area in the load.

Check for air leaks.

Check for burner tube leaks.

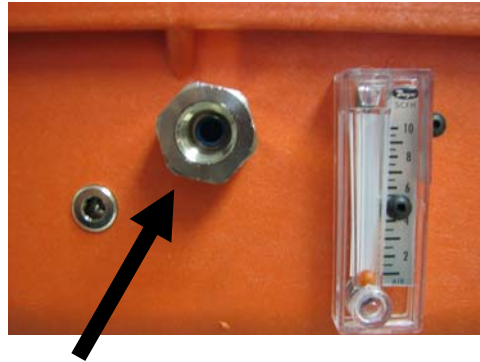
Check for furnace fan water jacket leaks.

Check generator or nitrogen methanol system

Be sure that the probe control system is working properly

OPERATIONS

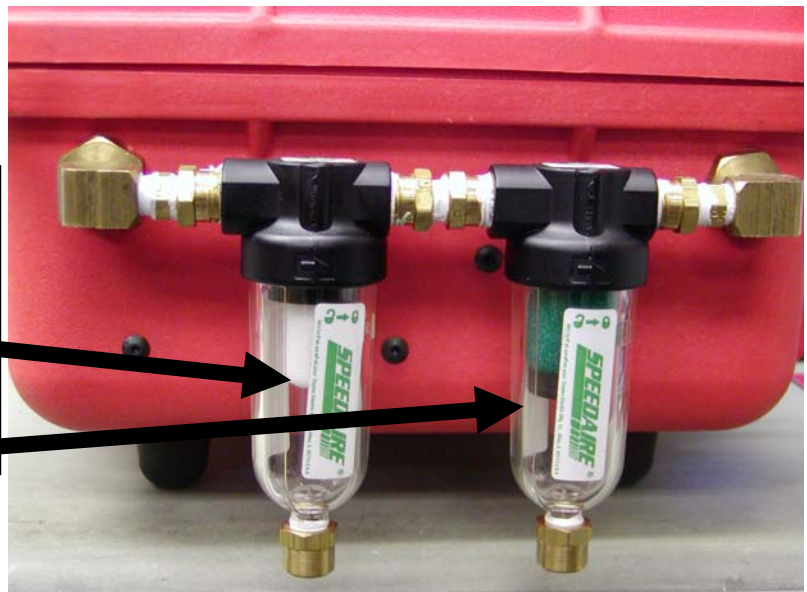
- Connect one end of the sample tube to the inlet. Connect the other end to the furnace sample port. Do not use oxygen probe burn off ports, or connect to a port with a lambs wool, or angel hair filter already installed.

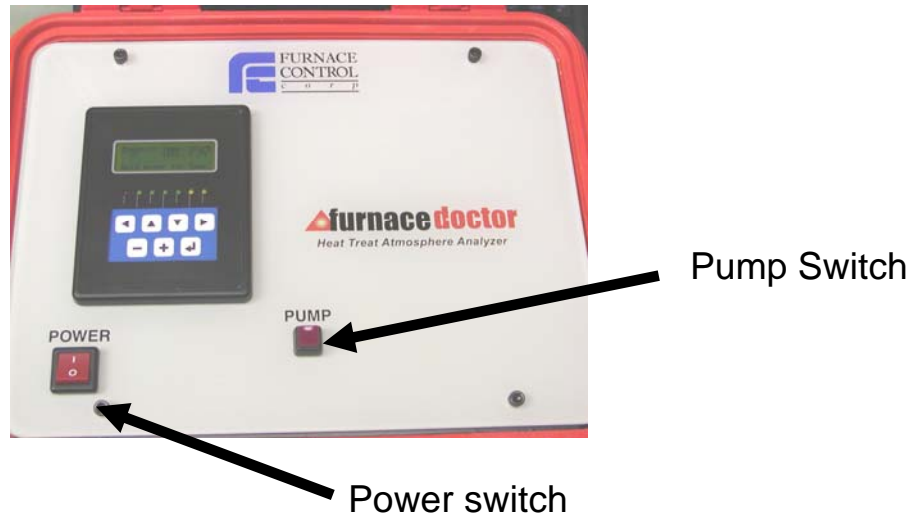


Sample inlet hookup point

Any discoloration in the white sample element requires the element to be replaced.

P/N T-FIL-01 - The .3 micron (green) filter should be changed annually P/n T-FIL-02





Power the unit on by depressing the power switch. Depress the Pump button to start sampling.

- The LCD display will illuminate, and the internal pump will begin after pump switch is depressed drawing a sample.



Allow adequate time for the sample line to purge. Moisture could be retained in the sample line. At least two minutes for each 10 feet of sample line is recommended.

- Ensure that sample flow is adequate. If you are sampling a generator with significant pressure at the sample port, it is recommended that you partially close the port valve so that the internal pump is not damaged. The pump is rated at 4 LPM @ 1 PSI.

- The following display is shown on the LCD when power is applied to the unit.

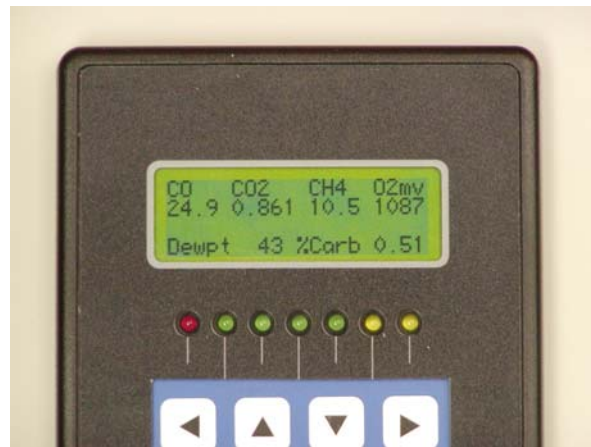


- Measurement approximately 1 min after start up and is continuous after the process temperature is entered. The unit will not correctly display O₂mv, Carbon, or Dewpoint until temperature is entered. The display includes actual CO, CO₂, CH₄ as readings, calculated theoretical carbon and dewpoint and milli-volts for the computed %Carbon and manually entered temperature
- If you desire to compute the correct %C associated with the CO, CO₂, CH₄ measured gasses – press and hold the enter button. The main menu will be displayed



- Press the enter button to access the process temperature screen. The arrow will point under the digit in the temperature number. Change the indicated digit by using the +, - keys until the desired digit appears. Use the right or left pointing arrow keys to move from digit to digit until the desired temperature is displayed. Press the enter key to store

- The instrument displays the carbon, dewpoint for the measured CO, CO₂, CH₄ gasses and entered probe temperature. Additionally, it displays calculated probe millivolts.
- The instrument will take at least 60 seconds from cold start to display any meaningful information. Ensure that sample flow is adequate!
- Look at the flow meter on the front of the instrument and make sure that it indicates at least 6 CFH.
- Meaningful process values are displayed on the LCD after initialization, and the unit has obtained a good sample from the furnace and process temperature is entered.

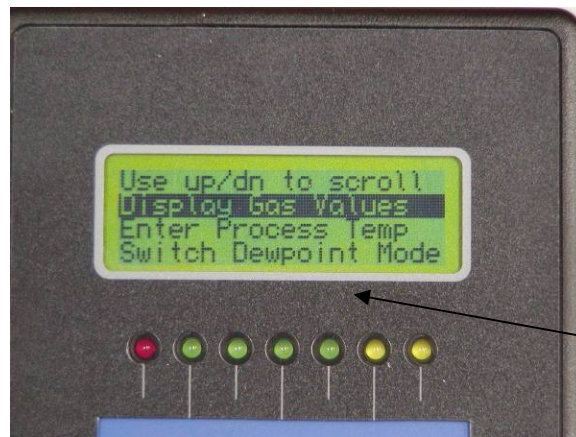


A note about sample ports:

In a large percentage heat treats we have found that the furnace sample ports are either plugged, or leaking. Even if you can look into the port, and it appears unobstructed, the port may leak somewhere behind the hot face of the refractory. This may cause the sample to be drawn from between the brick, and the furnace shell, or even outside of the furnace. If you are getting numbers do not make sense, (I.E. Extremely low CO values or high CO₂) try taking a sample from the oxygen probe burn-off port (not the reference airport). **Only use this method of no other working port is available. This method will affect the probe reading.** If the port extends for a large distance outside of the furnace wall, moisture can accumulate in the bottom of the pipe leading to incorrect readings.

You may also purchase a non- metallic sample probe that will penetrate the hot zone adequately.

MENU SYSTEM



Main Menu
Screen

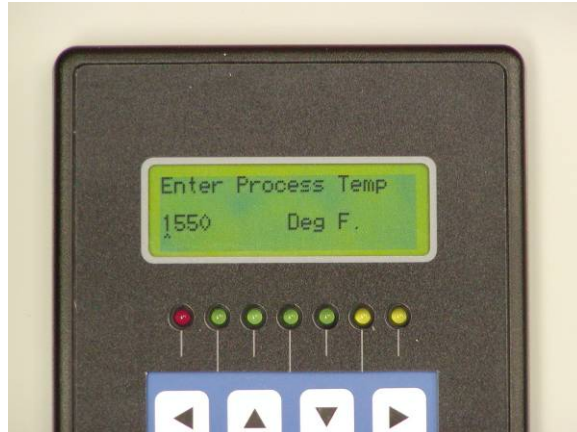
Pressing and holding down the enter button from the default gas value display will cause the main menu to be displayed. From this menu you may enter process temperatures for the computation of carbon and dew point, calibrate the instrument, choose between the endo generator calculation of dew point, and the furnace temperature dependant calculation.

Entering a process temperature:

- Hold down the Enter button until the main menu is displayed.
- Use the down arrow until Enter Process Temp is highlighted



Press the enter button, the following screen will be displayed.



Use the Left or Right arrows to move the cursor under the desired number you wish to change. Use the + or – buttons to change the number that the cursor is under until the desired value is displayed. Move the cursor to the next number and change the value in the same manner. When done push the enter button, you will return to the main menu. Display Gas Values will be highlighted. Press Enter to return to the gas values screen.

Selecting the Dew point Calculation Mode:

The instrument will compute dew point using either a temperature based calculation, used when measuring furnace atmospheres where you can identify the process temperature or a simplified table look up method based on CO₂ to be used when measuring the dew point of endothermic generators.

If you use the furnace calculation when measuring your endothermic generator, and enter a process temperature of 1900F or so, you will get meaningless values for dew point.

If you have the generator calculation selected, it is not necessary to enter a process temperature.

From the main menu, using the Down Arrow key, scroll until Switch Dewpoint Mode is highlighted.

CALIBRATION

You may calibrate your unit with certified grade span gas, and nitrogen. If you have plant nitrogen available, make sure to regulate approximately 1 PSI. Span bottle gas must have a bottle top regulator that will be capable of regulation at 1 PSI. ***Be sure that your gas supplier provides you with a certified analysis of the gas in the bottle!***

You may purchase span gas bottles from Furnace Control Corp. Please contact your local Furnace Control Corp representative.

Values for span gas should be 25.0%CO 1.0%CO₂, and 10.0% CH₄. It is recommended that you select span gas with values approximately 20% higher than typical observed process value. Span gas values may be higher, or lower, but should not exceed the ranges of the measuring cells of 30%CO, 1%CO₂, 10% or 30% CH₄ depending on the CH₄ option purchase.

Be sure to keep the second stage regulator pressure around ½ PSI. Your Furnace Doctor is equipped with good internal pressure regulation, but too much pressure may override the regulator's ability to control the pressure in the cells.

It is important to understand the I/R cells are very pressure sensitive by nature. Realize that for a given species of gas there are more molecules of that gas present in a cell with a pressure of 1.5 PSI, than in a cell with a cell pressure of 0.5 PSI will lead to measurement error if the unit is calibrated at a high pressure, and then applied to low pressure measurements.

You may observe these phenomena by closing of the exhaust of the instrument while measuring a furnace. Note the quick rise in the CO value.

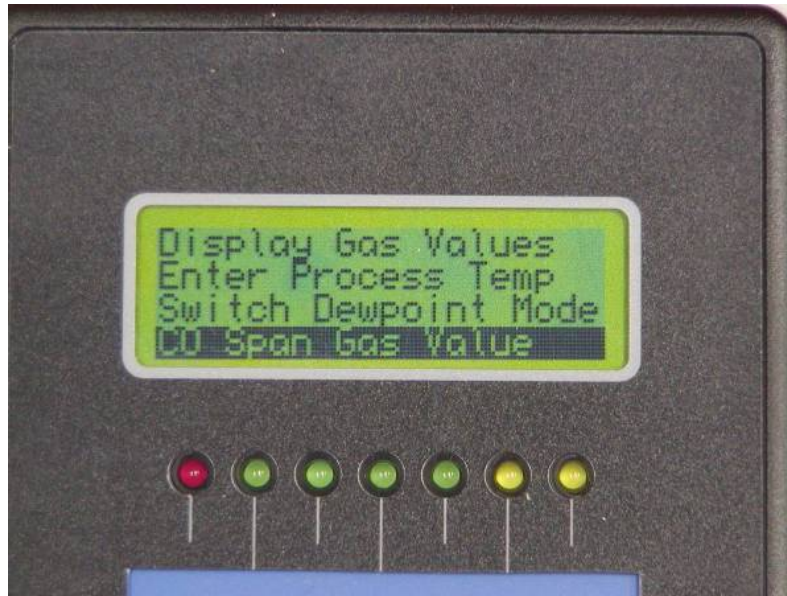
Calibration Frequency:

Furnace Control Corp recommends the following procedure:

- Connect the span bottle to the instrument and measure it on a weekly basis. If the instrument measures the span bottle within 2% of the analyzed values on the bottle it is not necessary to calibrate the instrument.
- If calibration is required do it in the environment that the instrument will be used in. If you calibrate the instrument in an office that is 70 degrees, and then go use the instrument in a 110 degree heat treat, you will probably experience some error in measurement.

To begin calibration:

- *The procedure for Span gas values only needs to be performed when a new span bottle is to be used.*
- From the default gas value display hold down the Enter button until the main menu is displayed. Scroll down the menu by using the Down Arrow key until the CO Span Gas Value is highlighted.



- Press the Enter Key and the following screen will appear.



- Enter the correct CO gas values as displayed on you Span Gas Bottle. Use the Left or Right arrows to move the cursor under the desired number you wish to change. Use the + or – buttons to change the number that the cursor is under until the desired value is displayed. Move the cursor to the next number and change the value in the same manner. When done push the enter button, you will return to the main menu. Display Gas Values will be highlighted.
- Scroll down until CO2 Span Gas Values is highlighted.

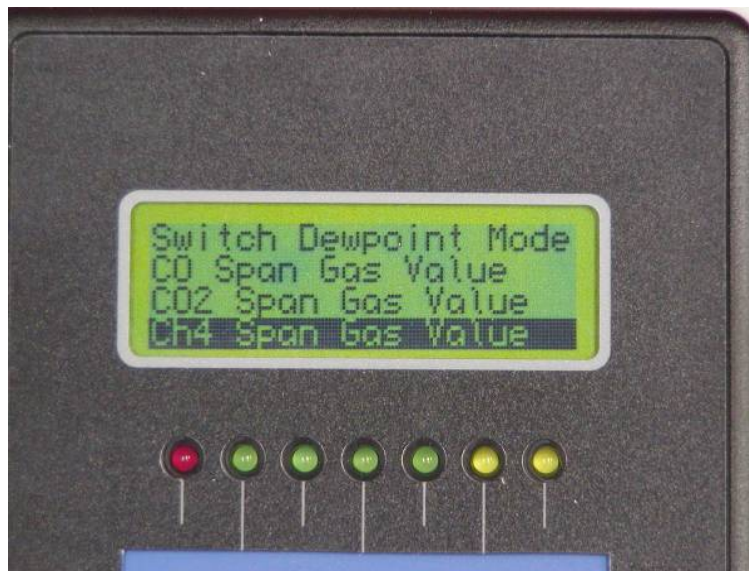


- Press the Enter Key and the following screen will appear.



Enter the correct CO₂ gas values as displayed on your Span Gas Bottle. Use the Left or Right arrows to move the cursor under the desired number you wish to change. Use the + or – buttons to change the number that the cursor is under until the desired value is displayed. Move the cursor to the next number and change the value in the same manner. When done push the enter button, you will return to the main menu. Display Gas Values will be highlighted.

Scroll down until CH₄ Span Gas Values is highlighted.



Press the Enter Key and the following screen will appear



Enter the correct CH₄ gas values as displayed on your Span Gas Bottle. Use the Left or Right arrows to move the cursor under the desired number you wish to change. Use the + or - buttons to change the number that the cursor is under until the desired value is displayed. Move the cursor to the next number and change the value in the same manner. When done push the enter button, you will return to the main menu. Display Gas Values will be highlighted.

Once the correct CO, CO₂, and CH₄ calibration gas values have to be entered from the main menu, use the down arrow until Calibrate Analyzer is highlighted.



Press the enter button and the following screen will be displayed



Select 1 to start calibration, 2 to exit and cancel the calibration by using the + or – buttons.

Once 1 has been entered the calibration will start. The following screen will be displayed.



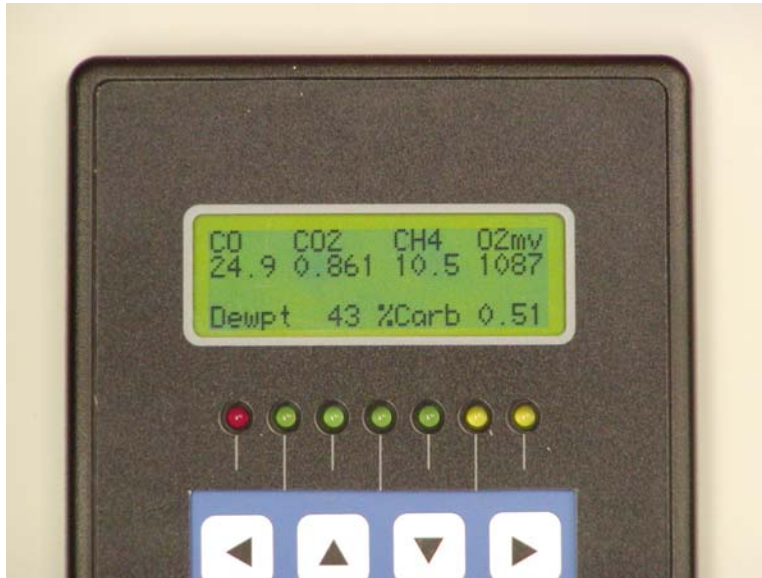
Connect and turn on the nitrogen gas, be sure that you have adequate flow, and press any key.

The unit will then start to count up to 60. When this is reached the following screen will be displayed.



Connect and turn on the span gas be sure that you have adequate flow, and press any key.

Once the unit has counted up to 60 the main menu will be displayed, Display Gas Values will be highlighted. Press the enter key to return to the main gas display screen. The instrument should read the values in the bottle within 2% of the cell range. (i.e. 30% CO should be +/- .6% CO.)



Correction Factor

This allows you to adjust the computed carbon to match shim stock analysis, or actual carbon results obtained from analysis of the work. The number has a range of 0 – 255. An entry of 0 disables the calculation. The calculated carbon is affected as follows:

$$\%C = (\text{Corr.fact}/100) \times \text{Computed \%C}$$

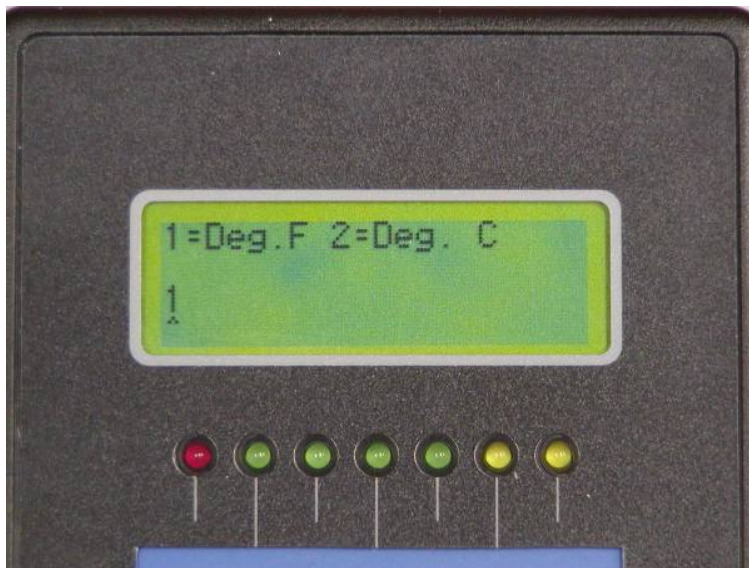
For example if the computed carbon from the gas analysis and temperature is = 1.00%C and the Corr.Fact = 90 then the displayed %C = .90

Degrees F/C

The unit has the capability of displaying the process temperature in degrees F or C. From the main menu, scroll down until Degrees F/C is highlighted.



Press the enter button the following screen will be displayed.



Choose 1 for degrees F and 2 for degrees C. Push the enter button to accept the change. The unit will then be in the main menu.

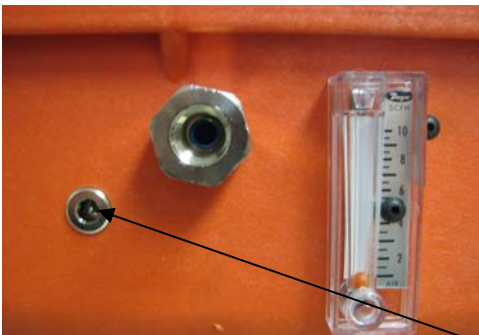
BATTERY CHARGER

Your Furnace Doctor includes a battery charger



Charging

- Unit will operate continuously for approximately 8 hours without recharging. A full charge will take approximately 8 hours to complete. It is not necessary to completely discharge the battery before charging.
- To charge the unit, turn the Furnace Doctor Power switch to the off position.
- Connect the supplied battery charger to the charging port on the side.
- Red Status Indicator Light –battery is charging
- Green Status Indicator Light- battery is charged



Note: Unit is designed to operate with a charged battery. Using the charger as an AC adapter will not allow the battery to charge properly. Eventually the battery will not be able to sustain operation of the analyzer. Please connect the charger with the unit's power off and charge only when batt low light turns on.

Charging Port

RESTORE FACTORY CALIBRATION

- You Furnace Doctor has the ability to restore to the last factory calibration if an error occurs during a user calibration.
- From the main menu scroll down until Restore Factory Calibration is highlighted.



- Press the enter button, the following screen will appear.
- This will return calibration values to the last certified factory calibration.