

**Model 6205 Series  
CA-CALC™  
Combustion Analyzer**

**Operation and Service Manual**

*P/N 1980493 Revision B  
January 2006*



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CA-CALC™  
Combustion Analyzers**

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Manual**

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P/N 1980493 Revision B

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# Introduction

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## Manual Purpose

This manual describes the operation and maintenance of TSI® CA-6205 CA-CALC™ portable combustion analyzer.

## Using This Manual

Before using your CA-CALC combustion analyzer, review this manual in its entirety.

## Warnings and Cautions

The manual assumes that you have a basic understanding of combustion safety and are thoroughly familiar with the fuel burning equipment being tested. If you are using measurements as the basis for equipment adjustments, rely on your good judgment and experience together with the measured data. This is especially important for safety. Remember when adjusting equipment, always follow the manufacturer's recommendations.



### WARNING

High temperatures and toxic gases are produced when fossil fuels are burned. Only qualified individuals, thoroughly familiar with operating and adjusting fuel-burning equipment, should use gas measurements for the purpose of making equipment adjustments.



### Note

The CA-CALC combustion analyzer is **not** intended for use as a continuous monitor.

**Notes:** *Best results are obtained if the CA-CALC combustion analyzer is allowed to stabilize at the temperature of the test environment before using.*

*To reduce sensor exposure to gas and to reduce build up of water vapor in the sampling lines and water trap, turn the pump off when not making measurements.*



# Chapter 1

## Instrument Description

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The CA-6205 CA-CALC™ combustion analyzer is used to evaluate the performance of burners in boilers, furnaces, and hot water tanks, specifically where fuels contain sulfur. The Model CA-6205 has sensors for the direct measurement of combustion gases; O<sub>2</sub>, CO, SO<sub>2</sub>, combustion gas temperatures and draft pressure. The Model CA-6205 performs a complete list of combustion and emission parameters for a variety of system performance evaluations. Different units and different fuel types are readily selectable.

### CA-6205 CA-CALC™ Combustion Analyzer Measurements and Calculations

Measurement	Sensor
Oxygen concentration	O <sub>2</sub> , electrochemical
Carbon monoxide	CO, electrochemical
Sulfur dioxide	SO <sub>2</sub> electrochemical
Flue temperature	Thermocouple
Supply air temperature	On-board sensor or Thermocouple probe
Draft pressure	Pressure transducer, internal solid state
<b>Calculations</b>	
CO <sub>2</sub> , Carbon Dioxide	
Excess air / $\lambda$	
Stack/Flue loss / qA	
Combustion efficiency	
Differential temperature	
SO <sub>2</sub> undiluted	
CO undiluted	
CO <sub>r</sub> index	
Emission Rates CO, SO <sub>2</sub>	

The Model CA-6205 is supplied with a sampling probe having a metal filter at the tip of the sampling tube to remove soot, an inert plastic liner in the sampling line to prevent loss of SO<sub>2</sub> gas and an in-line water trap with internal particulate filter to protect the instrument from contamination.

The Model CA-6205 operates using either an AC power supply or 4 x C-size batteries.

The Model CA-6205 stores individual data samples (up to 100), and prints the data to a portable printer or computer. Stored data can be saved over a user-defined interval and averaged.

The Model CA-6205 provides parameters for a variety of standard fuels, and enables you to modify the fuel parameters, or install your own *user*-defined fuels for use in combustion related calculations.

Loss and efficiency are calculated from standard ASME heat-loss calculations or using the Siegert formula (see [Appendix B](#)).

## Chapter 2

### Unpacking

---

Carefully unpack your CA-6205 CA-CALC™ combustion analyzer and accessories. Check the individual parts against the list of components in the table below. If items are missing or damaged, notify TSI immediately.

#### List of Standard Components

Qty	Item Component	Part/ Model
1	Series CA-6205 CA-CALC combustion analyzer	1083618
1	Sample probe with water trap, draft line and temperature	801951
1	Universal Power supply 7.2 V with assorted plug types	2182003
4	C cell alkaline batteries	
1	Operation and Service manual	1980493

#### Accessories and Replacement Parts (*Cal. Gas US only*)

	Item	Part/Model
	Combustion Supply Air thermocouple <i>Type K</i>	3013003
	Portable printer kit	801994
	Computer cable	8940
	Hard side Carrying case	1319319
	CO replacement sensor	802014
	O <sub>2</sub> replacement sensor	802012
	SO <sub>2</sub> replacement sensor	802009
	Water trap filters	801947
	Calibration Kit O <sub>2</sub> (N <sub>2</sub> gas) and CO	802003
	Calibration Kit CO	801999
	Calibration Kit SO <sub>2</sub>	801936
	Replacement bottled gas, CO (requires Cal. Kit)	801941
	Replacement bottled gas, SO <sub>2</sub> (requires Cal. Kit)	801929
	Replacement bottled gas, N <sub>2</sub> (requires Cal. Kit)	801980
	Bottled gas, CO with H <sub>2</sub> (requires Cal. Kit)	801942
	Probe Adapter kit	801970
	Replacement metal filter	801944
	Probe heat shield	801969

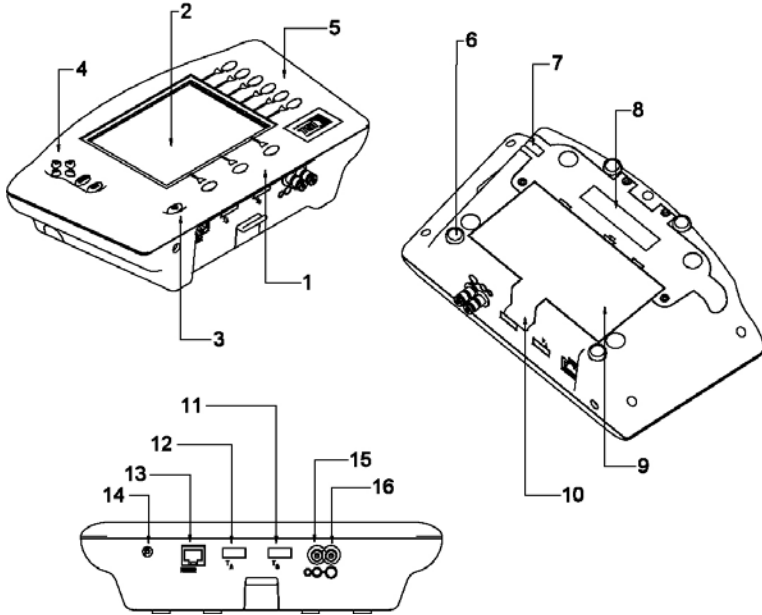


# Chapter 3

## Component Identification

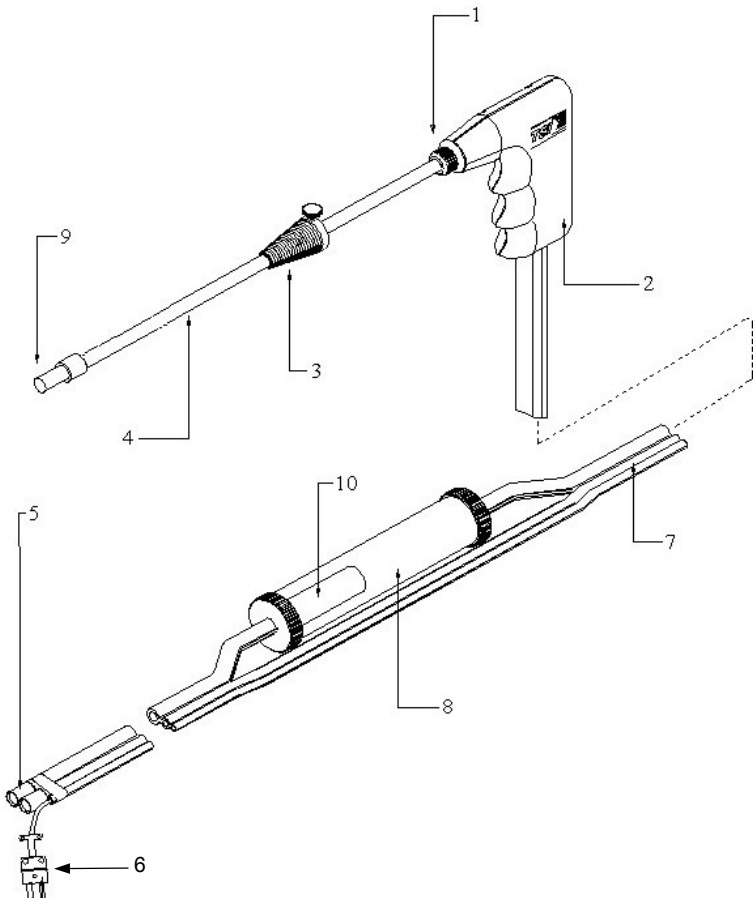
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Key components of the CA-CALC™ combustion analyzer and sampling probe are identified in Figures 1 and 2, and under section headings in the text that follows.



- |                    |   |
|--------------------|---|
| 1. Data buttons    | 9. Battery cover                            |
| 2. LCD display     | 10. Battery cover tab                       |
| 3. On-Off button   | 11. Port for <i>flue gas</i> thermocouple   |
| 4. Control buttons | 12. Port for <i>supply air</i> thermocouple |
| 5. Icon buttons    | 13. RS-232 serial port                      |
| 6. Magnets         | 14. AC adapter connection                   |
| 7. Vent            | 15. Draft sample port                       |
| 8. Sensor cover    | 16. Gas sample port                         |

**Figure 1: CA-6205 CA-CALC™ Combustion Analyzer**



- |                                |                                    |
|--------------------------------|------------------------------------|
| 1. Tube retaining fitting      | 6. Thermocouple connector          |
| 2. Probe handle                | 7. Flexible sample line with liner |
| 3. Position collar             | 8. Water Trap                      |
| 4. Sample tube                 | 9. Metal filter                    |
| 5. Sample and draft connectors | 10. Plastic filter                 |

**Figure 2: CA-CALC Sampling Probe Components**

### The Gas Sensors

The CA-6205 CA-CALC combustion analyzer uses three gas sensors for measuring oxygen (O<sub>2</sub>), carbon monoxide (CO) and sulfur dioxide (SO<sub>2</sub>). CO and SO<sub>2</sub> sensors are capable of operating from two to three years. The O<sub>2</sub> sensor typically lasts one year. Best accuracy is obtained by routine user



calibration (automatic for the O<sub>2</sub> sensor). Calibrated replacement CO and SO<sub>2</sub> sensors are also available from the factory.

## **The Sampling Probe**

Your combustion analyzer comes equipped with a sampling probe, depicted in Figure 2. A thermocouple extends to the end of the sampling tube for making flue temperature measurements. Two flexible sampling lines are used for gas sampling and draft measurement. The sampling tube is removable for cleaning.

## **Flue Probe Thermocouple**

The flue temperature (TS) is measured using a Type K probe, which extends through the sampling tube to the probe tip. The thermocouple probe measures temperatures up to 1000 degrees C (1800 degrees F).

## **On-Board Temperature Measurement**

Your CA-CALC analyzer uses an on-board temperature detector to provide the *Combustion Supply Air* (TA) temperature when no supply-air accessory probe is present.

## **Diaphragm Pump**

The CA-CALC analyzer samples exhaust gases from the flue and delivers them to the electrochemical sensors using a diaphragm sampling pump. Typical pump life is 5000 hours.

## **Draft Sensor**

A differential pressure transducer in the CA-CALC analyzer is used to measure draft pressure.

## **Water Trap**

The water trap, shown in Figure 2, is used to remove moisture that collects in the sample tubing when combustion gases are sampled. The water trap has a two-chamber design with a particulate filter.

## **Optional Combustion Supply Air Thermocouple Probe**

A measurement of the *Combustion Supply Air* (TA) temperature at the source can be made using an optional thermocouple accessory probe (TSI PN 3013003). This probe is connected to the supply air temperature port shown in Figure 1.

When a Supply Air temperature probe is not used, the supply air temperature is determined from the on-board temperature sensor.

### Schematic Representation of CA-CALC Analyzer

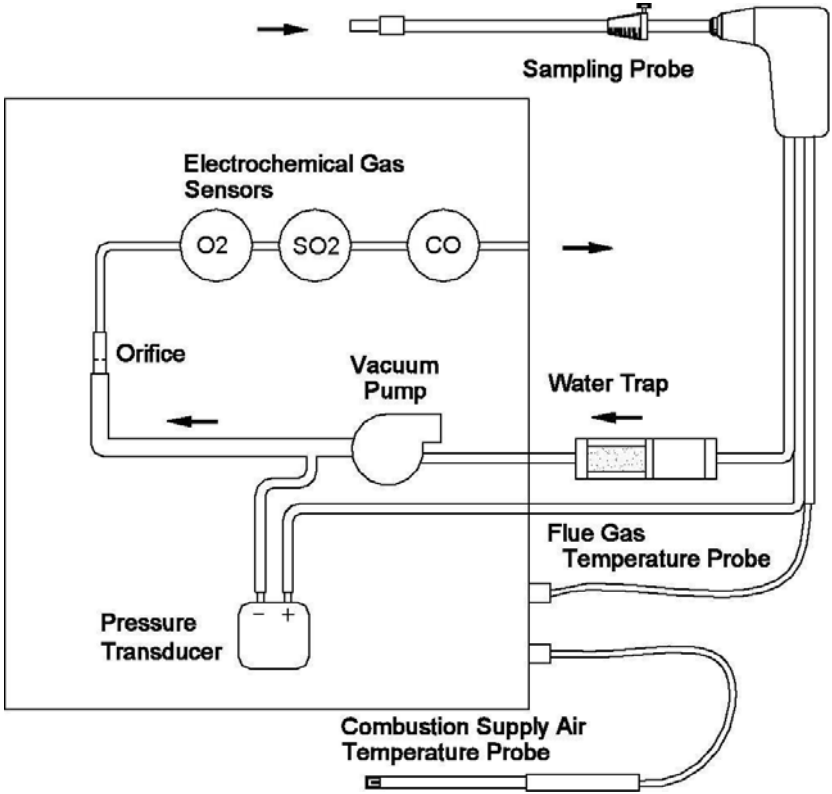


Figure 3. Schematic Representation of CA-CALC Analyzer

# Chapter 4

## Getting Started

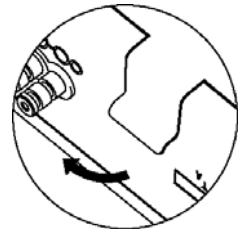
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### Supplying Power

The CA-CALC™ portable combustion analyzer operates using 4 C batteries or an AC adapter. Quality alkaline batteries enable the instrument to operate for at least 24 hours. Use of the plug-in AC adapter conserves battery life, and can be substituted for batteries.

### Installing Batteries

Turn the combustion analyzer over and remove the battery cover by lifting up and out on the battery cover tab shown below. Remove the old batteries.

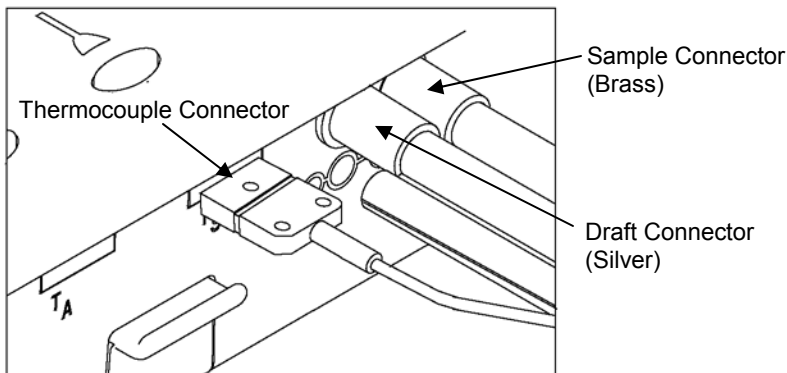


**Note:** It is not necessary to remove the battery holder when removing or installing batteries. Best results are obtained if the batteries opposite the contact springs are removed first.

Install four new C-cell batteries, noting the battery orientation depicted on the base of the battery holder. Install spring-side batteries first.

### Connecting the Sampling Probe

The sampling probe depicted in Figure 2, is connected to the instrument by pushing the *brass* sample and *silver* draft connectors over the ports on the instrument. Refer to the figures below showing the proper connection of the probe tubes to the instrument sample ports. Note that the thermocouple connector can be inserted only one way. The thermocouple connector is oriented with the large spade to the right. ***Do not force the connector.***



**Figure 4: Sampling Probe Connections**

### Connecting the Optional Combustion Supply Air Temperature Probe

A type K thermocouple probe may be used to measure the temperature of the air supplied to the burner. Connect the optional supply air thermocouple (see [“Accessories and Replacement Parts”](#)) to the supply air thermocouple port depicted in Figure 1. The thermocouple connector can be inserted only one way—large spade to the right. ***Do not force the connector.***

When the optional Supply Air Temperature Probe is not used, supplied combustion air temperature is determined from the instrument temperature using an on-board sensor.

### Connecting the Optional Portable Printer

Find the printer interface cable included with the optional portable printer. For the serial printer, connect the large 9-pin connector on the cable to mating connector on the printer. Connect the opposite end to the instrument’s RS-232 communications and printer port. See Figure 1 for port location.

The printer and CA-CALC combustion analyzer have both been factory set for a baud rate of 1200. If baud rates are not matched, the printer will print random characters, question marks or asterisks. Printer settings are described in the printer manual, along with illustrations identifying the correct DIP-switch configuration. To set the CA-CALC baud rate and device settings, refer to Chapter 6, [“MENU Options.”](#)

### Connecting to a Computer

Use the *optional* computer interface cable, Model 8940, to transfer (download) data serially from the CA-CALC analyzer to a computer. Your printer cable will not work for downloading to the computer. Connect the

large 9-pin connector on the computer interface cable to the 9-pin serial connector on your computer. Connect the opposite end to the instrument's RS-232 communications and printer port. See Figure 1 for port location. Set the baud rate of the CA-CALC analyzer to that of your computer, as described in Chapter 6, "[MENU Options](#)." The factory preset baud rate is 1200. Set the COMM option to COMP so serial data is formatted for output to the computer. The alternative is PRNTR, indicating output formatted for printer output. Press the PRINT button to send data to the computer.

## Default Instrument Settings

The CA-CALC combustion analyzer uses a number of parameter settings for presenting measured data, performing calculations, and controlling instrument operation. These include the measurement units, the fuel used, the baud rate, and so on. When shipped, your instrument has factory preset parameter settings and the selection of E (English) as the *Default* language. When another language is chosen from the language MENU option, different settings are automatically installed. These are indicated in the table below. Specific settings are easily changed as described in Chapter 6, "[MENU Options](#)," however, settings are reset to those listed below if the language is changed.

## Factory Defaults and Language Selection

Language Selection	E ( <i>Default</i> )	D, FI, S, N, I
O <sub>2</sub>	%	%
CO	PPM (parts per million)	PPM
Draft units	Inches H <sub>2</sub> O	mbar
Temp units	Degrees Fahrenheit	Degrees Centigrade
Excess Air	%EA	$\lambda = \%EA/100 + 1$
Effc./Loss basis	ASME	Siegert formula
Effc./loss units	% (net)	% qA
Fuel parameters	C, H, H <sub>2</sub> O, HHV, CO <sub>2</sub> max	A2 B
Fuel list	U.S. Fuels	Siegert Fuels
Fuel	Natural Gas	Natural Gas
Baud Rate	1200	1200
Sampling interval	1 second	1 second
Communications	Printer format	Printer format
Time	MM / DD / YY	DD / MM / YY







# Chapter 5

## Basic Operation

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### Buttons and Button Operations

	<b>ON-OFF</b> Control Button Turns the instrument <b>on</b> and <b>off</b> .
	The <b>ENTER</b> Control Button Press the <b>ENTER</b> button to execute a command, such as selecting a menu item.
	The <b>ESC</b> Control Button Used to return to the previous screen or cancel a process.
	<b>ARROW</b> Control Buttons Use the Left and Right arrow buttons to step between options. Use the Up and Down arrow buttons to change number values.

### Button Indicators



Back Light ON/OFF



Pump ON/OFF



Print



Make draft measurement



Zero draft transducer



Select fuel

## Data Buttons



Clear stored data



Review stored data



Save data

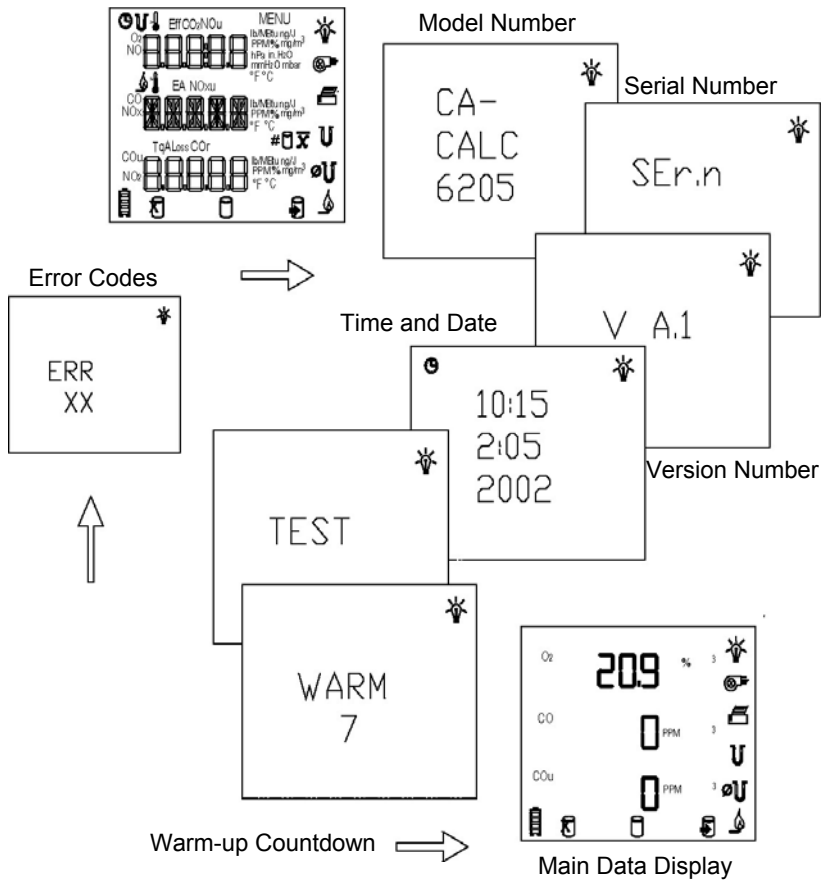
## Startup

Remove the sampling probe from the flue or disconnect the sample tubing from the sampling port. Press the ON-OFF button. Refer to Figure 5 showing screens displayed during the *start up* sequence. If no errors are detected, the Main Data Display screen appears when the sequence is complete. Error codes are presented in [Appendix A](#). ESC will bypass the error messages.

While the WARM screen is displayed, the O<sub>2</sub> sensor is automatically calibrated using ambient air, and the CO and SO<sub>2</sub> sensors are zeroed. At the end of the WARM sequence (45 seconds), the pump stops and the draft sensor is zeroed.

The WARM sequence can be bypassed by pressing the ESC button. Do this if a new O<sub>2</sub> calibration and new zeros are not desired.





**Figure 5. Startup Sequence**

## Characters and Display Icons

Refer to Figures 6 and 7 that follow. These identify the icons and characters found on the Model 6205 display. The display icons indicate measurements made, units, or functions performed. Some icons are not used with the Model CA-6205.

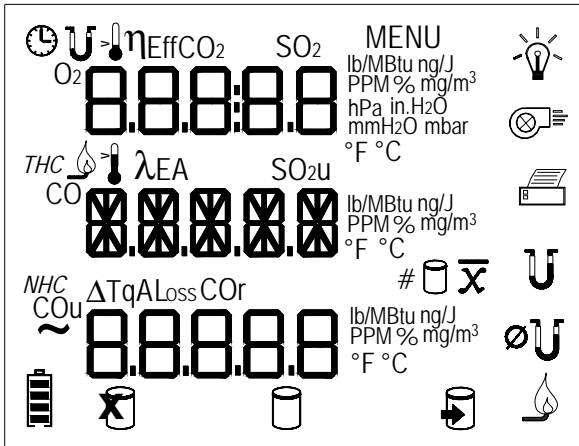













Figure 6. LCD Display Showing Icons

O <sub>2</sub>	Oxygen	$\bar{x}$	Average of samples
CO	Carbon monoxide	#	Sample number
U	Draft	SO <sub>2</sub> u	SO <sub>2</sub> undiluted
	Supply air temperature	COu	CO undiluted
$\eta$	Efficiency (Siegert)	lb/MBtu	Pounds / million Btu
Eff	Efficiency (ASME)	ng/J	Nano grams / Joule
CO <sub>2</sub>	Carbon Dioxide	PPM	Parts per million
MENU	Menu	mg/m <sup>3</sup>	Milligrams / M <sup>3</sup>
	Fuel	hPA	Hecto Pascals
	Flue Temperature	inH <sub>2</sub> O	Inches of water
$\lambda$	Lambda (excess air)	%	Percent
EA	Excess air %	mmH <sub>2</sub> O	Millimeters of water
°F	Degrees F.	Eff	Efficiency
°C	Degrees C.		Battery life
SO <sub>2</sub>	SO <sub>2</sub>		Clear data
$\Delta T$	Differential temp.		Review data
qA	Loss (Siegert)		Save data
LOSS	Loss (ASME)		Light on/off
CO <sub>R</sub>	CO ratio		Pump on/off
			Printer
			Zero draft sensor

**Figure 7. LCD Display and Description of Icons**

## Measurements and Calculations

### Oxygen Measurement

An O<sub>2</sub> electrochemical sensor measures oxygen concentration in the range of 0 to 25%. The O<sub>2</sub> measurement is also used to calculate the concentration of carbon dioxide (CO<sub>2</sub>) in the exhaust, and is used in calculations of combustion efficiency and undiluted CO and SO<sub>2</sub> concentrations.

### Carbon Monoxide Measurement

Carbon monoxide is measured in the range of 0 to 5000 PPM.

### CO<sub>2</sub> Measurement

%CO<sub>2</sub> calculated from the O<sub>2</sub> concentration in the flue. Refer to Appendix B for a description of the calculation.

### SO<sub>2</sub> Measurement

Sulfur dioxide is measured in the range of 0 to 4000 PPM.

### Flue/stack Temperature, TS

Flue temperature is measured with sampling probe.

### Combustion Air Temperature, TA

Measurement of combustion air temperature is determined using the temperature probe accessory, TSI PN 3013003. In the absence of this probe, the combustion air temperature is assumed to be the instrument temperature, and determined from a temperature sensor in the instrument case.

### ΔT, Temperature Difference

The flue/stack temperature minus the combustion air temperature.

### Excess Air or Lambda (λ)

Calculations of these values are found in [Appendix B](#).

### Loss

ASME based heat loss from the hot gases exiting the flue/stack. Includes latent heat loss from the formation of water vapor. See [Appendix B](#).

### qA

Heat loss using the Siegert formula (see [Appendix B](#)).

## **Efficiency**

Combustion efficiency, expressed as a percent. Calculated as 100 percent minus ASME heat loss (LOSS) described earlier (see [Appendix B](#)).

## **$\eta$ Siegert Efficiency**

Combustion efficiency, expressed as a percentage. Calculated as 100 percent minus  $qA$  (see [Appendix B](#)).

## **CO<sub>u</sub>, Undiluted Carbon Monoxide Concentration**

Calculation of the CO concentration, undiluted by excess air. This calculation uses a measurement of the O<sub>2</sub> concentration together with the CO measurement (see [Appendix B](#)).

## **CO<sub>r</sub>, CO Ratio**

Ratio of CO to CO<sub>2</sub> (see [Appendix B](#)).

## **SO<sub>2u</sub>, Undiluted Sulfur Dioxide Concentration**

Calculation of the SO<sub>2</sub> concentration, undiluted by excess air. This calculation requires a measurement of the O<sub>2</sub> concentration together with the SO<sub>2</sub> measurement (see [Appendix B](#)).

## **Draft**

Draft pressure is measured with the sampling probe inserted in the flue. The draft measurement is referenced to room pressure.

## **Data Display, Viewing Measurements and Calculations**

Measurements and calculations are presented in the Data Display screens. The Data Displays appear once the Startup sequence is complete (illustrated earlier in Figure 5).

Data appears on three lines, with an icon indicating the measurement or calculation presented above or to the left of the data. Units are presented on the right side.

Data are viewed using the ARROW buttons, in groups of two or three. The table below shows the order of the data displayed together in vertical columns. Use the right ARROW button to scroll through the data as shown below.

Order of displayed measurements and calculations.

ARROW button →

O <sub>2</sub>	Draft	Combustion Air Temperature	Efficiency	CO <sub>2</sub>	SO <sub>2</sub>
CO	Fuel Type	Flue Temperature	Excess Air	CO	SO <sub>2U</sub>
CO <sub>u</sub>		Differential Temperature	Loss	CO <sub>r</sub>	

## Error Indications

A series of ERR (error) codes indicate a problem with instrument operation. Often the problem has a simple remedy. If the ERR code persists, contact the factory. Press ESC to bypass the error message.

Error codes are described in [Appendix A](#).

## Using the Sampling Probe

### Gas and Temperature Measurements

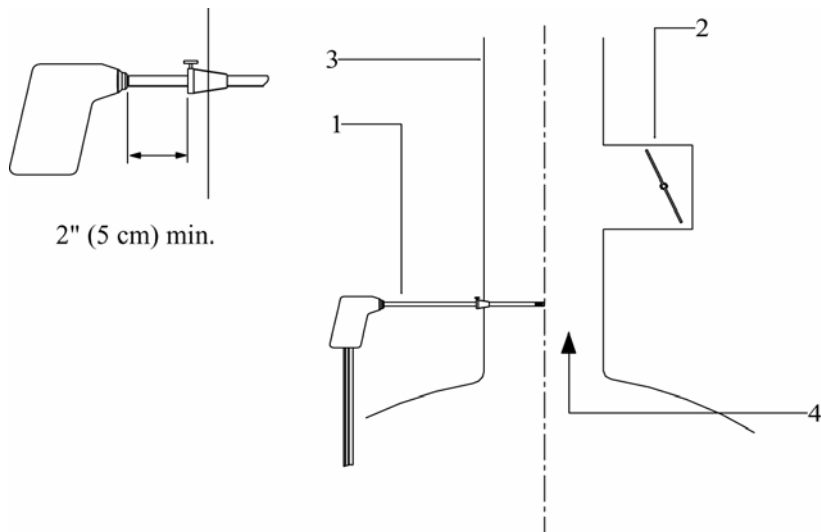
Connect the sampling probe to the CA-CALC portable combustion analyzer as described in [Chapter 4](#).

Place the Sampling probe through a hole in the exhaust flue, following recommendations presented below. Placement of the probe is important and certain considerations must be given when choosing a sampling location.

To ensure that the gas measurements are not diluted or cooled by outside air, place the probe before any draft damper or regulator as illustrated in Figure 8. Tilt the probe tip up slightly so vapor condensing in the sampling tube does not run back to the probe tip and cool the thermocouple tip.

The sampling probe tip should be placed at the point of highest exhaust gas temperature. This means at the base of the flue, before heat is lost to the flue sidewalls, and towards the center, especially for small ducts. If the flue/stack gas temperature is underestimated, the operating efficiency will be overstated. When an economizer or air heater is used, the flue/stack temperature is measured after these devices


**Important:** Orient the sampling tube to ensure that the thermocouple tip is exposed directly to exhaust flow (see Figure 8 below).



- 1. Sampling probe
- 2. Draft regulator

- 3. Exhaust flue
- 4. Hot exhaust gases

**Figure 8: Sampling Probe Location**

	<h2>Cautions</h2>
	<p><b>Hot probe!</b> When removed, the sampling probe will be extremely hot. Avoid touching the probe tip, and avoid placing the probe on or near plastic materials such as the instrument case. These will melt. Maintain a minimum 2” (5 cm) clearance between the probe handle and position collar when the probe is mounted in flue.</p> <p><b>Empty Water Trap!</b> Watch the water trap and empty it frequently to prevent the possibility of flooding the instrument. See Chapter 8 for instructions.</p>

## Making a Draft Measurement

Use the DRAFT button to the right of the DRAFT button indicator to make draft measurements. When the DRAFT button is pressed, the sampling pump turns off and the draft measurement is displayed and updated each second.

### Zeroing the Draft Sensor

For the most accurate draft reading, the draft sensor must be zeroed prior to the draft measurement. To zero the draft sensor, remove the sampling probe from the flue, or separate the sampling tube from the draft port. Press the ZERO draft button. When ZERO is displayed, the draft sensor is zeroed.

### Saving Draft

Whenever a sample is saved using the SAVE DATA button, a draft reading is taken. For this to occur, the pump is automatically turned off and a few seconds are allowed for the draft reading to stabilize. Draft is recorded at the end of the data-sampling interval.

## Printing to the Portable Printer and to a Computer



### Printing to the Portable Printer

Instrument data can be output to the optional portable printer through the RS-232 serial port. Refer to [“Connecting the Optional Portable Printer”](#) in Chapter 4.



To print the information on the Data Display, press the PRINT button, to the right of the print button icon. The printer responds immediately, producing a printout of the current data. An example of this printout is shown in Figure 9.

Saved data can be printed too. Hold the Print button down until a countdown from three (3) begins. Release the button at zero (0), and **all** saved data is printed.

Printing individual saved data samples is described in the next section, "[Handling Data](#)."

### Printing to a Computer

Use the PRINT button to output data to a computer as well as to the portable printer. Refer to "[Connecting to a Computer](#)" in Chapter 4.

Data transferred to a computer is the same as that output to a printer (see Figure 9); however, it is formatted differently and uses the Windows® character set rather than DOS characters. You will need to set appropriate COMM MENU option before sending data to the computer. Refer to the Chapter 6, "[MENU Options](#)."

Data can be downloaded to a terminal emulator program such as the **HyperTerminal**, which accompanies the Windows® operating system program. Look for **HyperTerminal** in the **Accessories** folder. In **HyperTerminal**, use the **Capture Text** option from the **Transfer** menu for recording instrument data.

Your instrument comes configured with the following communications protocol.

#### Communications Protocol

Baud rate	1200 (default)
Data bits	8
Parity	None
Stop bit	1
Flow	None

---

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```
-----  
MODEL: 6205  
SERIAL:  
-----  
Current Data  
-----  
DATE: 01/01/06  
TIME: 15:00:18  
Fuel: Nat Gas  
  
Fuel Parameters:  
C: 75  
H: 25  
CO2MX: 11.8  
KBTU: 23.8  
H2O: 0  
O2      6.0  
CO      5 PPM  
SO2     25 PPM  
COu     7 PPM  
COr     NA  
SO2u    35 PPM  
TA      70 °F  
TS      300 °F  
Draft   0.01 inH2O  
CO2     8.4 %  
Lambda  OVER  
Effc    84%  
LOSS    16%
```

**Figure 9: Example Printout**

## Handling Data

### Saving Data



Up to one hundred (100) separate measurements can be made and saved to the instrument memory as data *Samples*. Press the SAVE DATA button located below the SAVE DATA icon at the bottom of the display. When SAVE DATA is pressed, measurements are sampled and averaged over the interval set in the INT.SA MENU option described in [Chapter 6](#). As data is sampled, the sample number is displayed, and the save data icon blinks.

*Note: The pump turns off while the draft is measured and saved.*

### CLEAR Data



While in the Data Display screen, press and hold the CLEAR DATA button for three (3) seconds to erase all saved data from the instrument memory. The button must be released when zero is displayed. If the button is held longer than three (3) seconds, nothing is cleared.

**To clear the last Sample only**, release the CLEAR data button before the end of the countdown, during 3, 2, or 1.

### REVIEW Data Samples



Press the REVIEW DATA button briefly to recall saved Samples. The number of the last Sample appears. Select the specific data Sample you wish to view using the ARROW buttons and press ENTER. When the Sample number (#) is displayed, use the ARROW buttons to review the different measurements.

### Printing

To print individual saved Samples, press the PRINT button while the saved Sample is shown. To print **all** saved Samples, hold the PRINT button down until a countdown from three (3) begins. Release the button at zero, (0) and all saved Samples are printed.

### Averaging Saved Samples



To average the last three (3) saved Samples, press and **hold** the REVIEW DATA for a couple of seconds. The screen blanks during this interval. When averaged, the X-bar icon appears indicating that the data presented is an average of the Samples. Data averaging works only from the main Data Display screen.



# Chapter 6

## MENU Options

The Model 6205 CA-CALC instrument has a variety of user selectable parameters, available as MENU options. The user-selectable MENU options are shown in the schematic below. Press ENTER to access the MENU options from the Main Data Display screen. View the MENU options by using the ARROW buttons. Once the screen of interest is displayed, press the ENTER button again to choose the MENU option. Refer to Figure 10, which shows the MENU options.

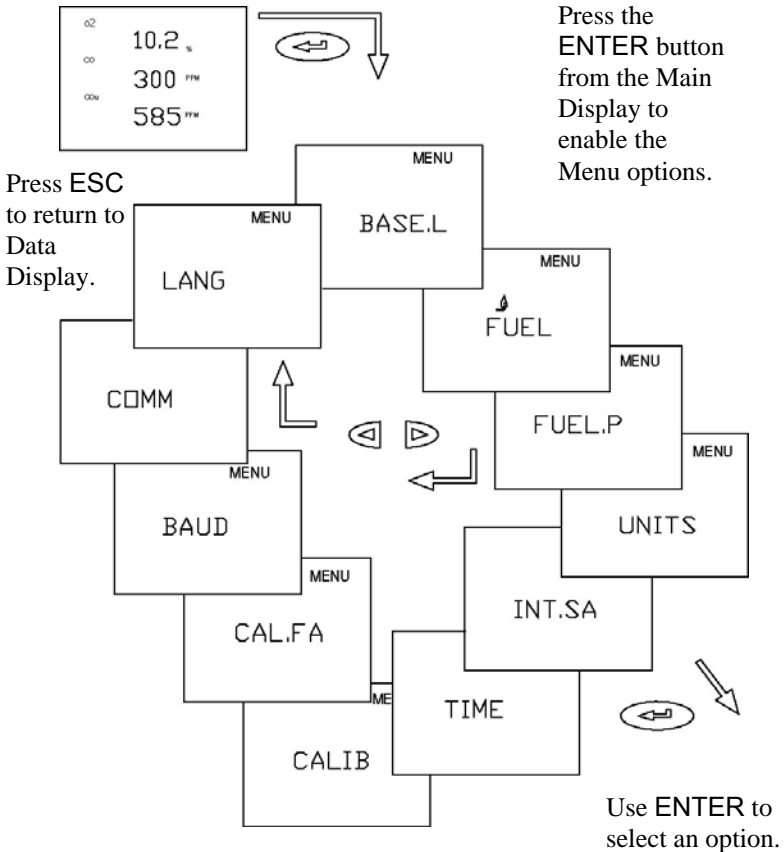


Figure 10. Menu Option

## BASE.L MENU—Option Update Sensor Baselines

Use the BASE.L MENU option to update the zero concentration baselines for your electrochemical sensors. Make sure the sampling probe is removed from the flue or disconnected from the instrument during zeroing. If ESC is pressed before zeroing is complete, previous baseline values are restored.

## FUEL MENU Option—Select Fuel

Use the FUEL option to select from seven preset U.S. fuels or six Siegert fuels, or select the USER fuel. The fuels parameter list presented (U.S. or Siegert), is determined by the selection, LOSS or  $qA$ , respectively, made from the UNITS MENU option (see Figure 11).

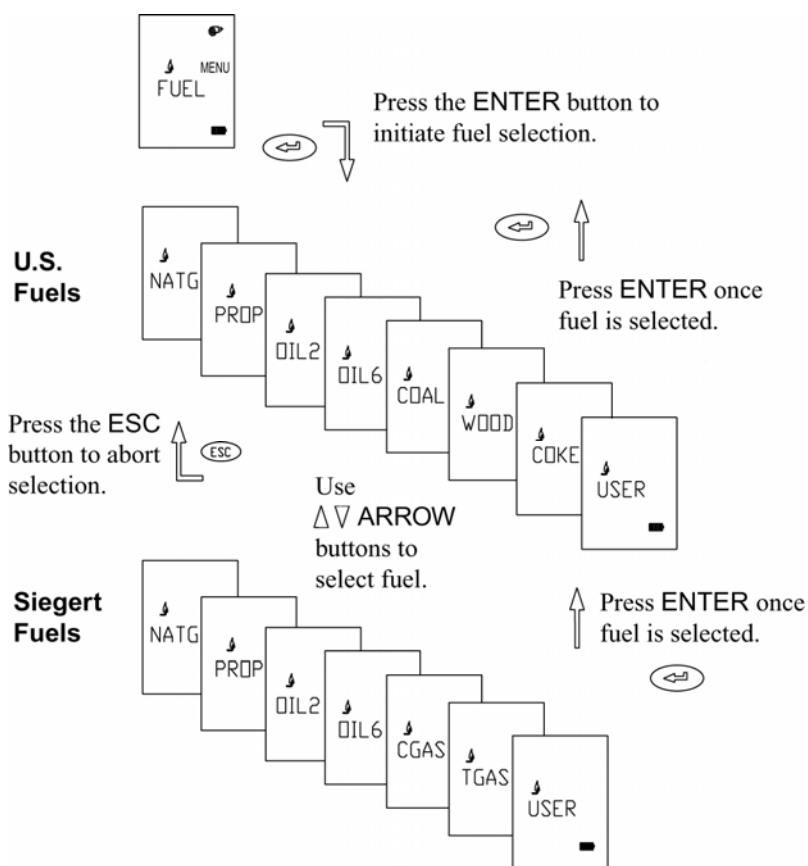


Figure 11. FUEL Options

## FP MENU Option—Fuel Parameters

See later.

## UNITS MENU Option (changing units)

It is possible to display data in different measurement units as indicated in the table below.

### Optional Units

Measurement	UNIT Options
TEMP (temperature)	Degrees F, Degrees C
GAS (for CO, SO <sub>2</sub> , SO <sub>2u</sub> concentrations)	PPM, mg/m <sup>3</sup> , lb/Mbtu, ng/J
PRESS (draft)	In.H <sub>2</sub> O, mbar, hPa, mmH <sub>2</sub> O
LOSS (flue gas heat loss)	Loss (ASME), qA (Siegert)
Excess Air	% (EA), λ (Lambda)
DECIMI	Periods or commas for printing
DATE	Date format, MM/DD or DD/MM for printing

To change units, press the ENTER button from the Data Display screen.

Using the ARROW buttons, find UNITS from the MENU options and press ENTER. Continue using the ARROW buttons to find the measurement for which units are to be changed. Use the up and down ARROW buttons to select the desired unit and press ENTER.

Use ESC when complete to return to the Data Display screen.

## INT.SA MENU Option—Sampling Interval for Saving Data

This option enables you to change the sampling interval over which data is averaged and saved. Select this option using the ENTER button. Use the up and down ARROW buttons to choose the sampling interval from the following: 1, 5, 10, 15, 20, 25, and 30 seconds. Press ENTER to select the interval.

Use the SAVE DATA button to save data over the sampling interval.

## TIME MENU Option—Set Time and Date for Printout

Press the ENTER button when the TIME MENU item is displayed. Use the ARROW buttons to select the field to be changed. The field will blink as it is changed with the right and left ARROW button. To change the value, use the up and down ARROW buttons. Press ENTER to install the new value. Press ESC to abort and return to the previous screen. Use the DATE option in UNITS to change the month/day presentation.

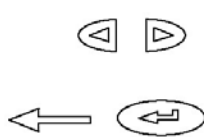
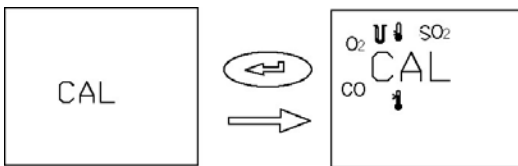


## CALIB MENU Option (select sensor for calibration)

The CALIB MENU option is used for performing calibrations of the on-board sensors. When this option is chosen using the ENTER button, characters and icons associated with the installed sensor will be displayed, one at a time. Press an ARROW button and scroll through the options until the desired sensor for calibration appears. Press ENTER to begin the calibration process.

Example, Draft calibration initiated.

Icons below appear one at a time. See Chapter 5 for a description of icons.



Use ARROW buttons to choose sensor for calibration. Press ENTER to initiate the calibration.



## O<sub>2</sub> Gas Sensor Calibration

The Oxygen (O<sub>2</sub>) sensor is *SPAN* calibrated in room air whenever the instrument is turned on and allowed to complete the Startup sequence. Using the **BASE.L MENU** option also spans the O<sub>2</sub> sensor. Additional calibration is generally not required.

Calibrating the O<sub>2</sub> sensor is done to determine a new *zero* value (no O<sub>2</sub> present) for the sensor. This is done if a drift in the sensor zero value is suspected.

Select **CALIB** from the **MENU** options using the **ENTER** button. Select the O<sub>2</sub> icon from the icons displayed using an **ARROW** button, and press **ENTER**. Attach the zero gas (nitrogen, N<sub>2</sub>) to the sampling probe as described in Chapter 7, "[Setup for Gas Calibration](#)." When ready, press **ENTER** to begin the zero calibration. Once complete, the *SPAN* calibration screen appears. The O<sub>2</sub> concentration can be adjusted using the **ARROW** buttons. If room air is used as the calibration gas, use the value displayed initially, 20.9%. Press the **ENTER** button to begin the *SPAN* calibration. Once complete, use the **ESC** button to return to the Data Display screen.

## Calibration of the CO (hydrogen compensated) Sensor

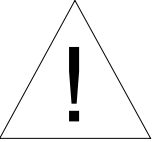
The presence of hydrogen gas (H<sub>2</sub>) produces a false signal on electrochemical CO sensors. The CO sensor in your **CA-CALC** has a second internal sensor that detects the H<sub>2</sub> concentration and enables the instrument software to subtract the error caused by the presence of hydrogen gas.

You can elect to calibrate using both the CO and H<sub>2</sub> or calibrate with CO only. In the second case the sensor retains the previous correction for H<sub>2</sub>.

## Calibration Steps

From the **MENU** screen select the **CALIB** option. Press **ENTER**. Use the **ARROW** buttons to select the CO icon and press **ENTER**. Sampling from the room air, press **ENTER** to perform the **ZERO** calibration. When complete, connect your CO calibration gas as depicted in Chapter 7, "[Setup for Gas Calibration](#)." Use the **ARROW** buttons and adjust the CO gas calibration number to match the concentration of your gas bottle. Press **ENTER** to initiate the CO calibration. Once complete, connect your calibration gas bottle containing both carbon monoxide and hydrogen (see note below). Use the **ARROW** buttons to adjust to the CO bottle concentration under the **SPAN.CO** heading, then press **ENTER**. Under the **SPAN.H<sub>2</sub>** heading adjust the number using the **ARROW** buttons to match the hydrogen concentration. Press **ENTER** to start the calibration.

**Note:** It is possible to do only the CO part of the calibration. To bypass the calibration using the combined CO and H<sub>2</sub> bottle, press the ESC button after the CO portion of the calibration is complete.

	<b>CAUTION</b>
	<b>Toxic Gases!</b> Familiarize yourself with the toxic properties of the calibration gases by reading the supplied Material Safety Data Sheets (MSDS) accompanying the gas cylinders. Do <b>not</b> perform calibrations in a confined space. Make sure calibrations are performed in an area with proper ventilation, or under an exhaust hood.

### SO<sub>2</sub> Gas Sensor Calibration

From the MENU screen select the CALIB option. Press ENTER. Use the ARROW buttons to select the SO<sub>2</sub> icon and press ENTER. Sampling from the room air, press ENTER to perform the ZERO calibration. When complete, connect your SO<sub>2</sub> calibration gas as depicted in Chapter 7, "[Setup for Gas Calibration](#)." Use the ARROW buttons and adjust the SO<sub>2</sub> gas calibration number to match the concentration of your gas bottle. Press ENTER to initiate the SO<sub>2</sub> calibration.

### Draft Calibration

Span calibration of the draft sensor is normally not required. The draft sensor should be routinely zeroed, however, using the DRAFT ZERO button. This is especially important prior to making measurements at low draft pressures. When zeroing, make sure the sample probe is disconnected or that the probe is not in the flue.

### Calibration Procedure

**Required:** An apparatus to provide stable calibration pressures of between *plus* 10–30 inches of water (25–75 hPa), and stable calibration pressures of between *minus* 10–30 inches of water (minus 25–75 hPa).

From the Main Data Display screen, press the ENTER button. Select CALIB from the MENU options presented using the ENTER button. Select the draft icon from the icons displayed using an ARROW button and press ENTER. Begin the calibration by pressing the ENTER button to perform a ZERO calibration. When the zero is complete, use the arrow buttons to adjust your positive supply reference pressure. Connect

your positive pressure to the draft port and press ENTER. Once the positive calibration is complete, connect your negative pressure reference to the draft port. Adjust the negative calibration pressure value using the ARROW buttons and press ENTER. Once the calibration is complete, use the ESC button to return to the main Data Display screen.

## Temperature Calibration

Calibration of the flue and ambient thermocouple sensors is not recommended. Thermocouples are very repeatable, and even if replacement of a sampling probe is required, or a combustion air temperature probe is purchased as an accessory, it is unnecessary to calibrate it.

Thermocouple accuracy can be improved for a specific temperature range if a calibration is performed in that range. You will need to provide an accurate temperature reference. Refer to the steps below if calibration of a thermocouple is desired.

### Calibration Procedure

Select the CALIB MENU option. Select the appropriate thermometer icon in the CALIB screen using the ARROW buttons. Install your sampling probe thermocouple or accessory thermocouple at the appropriate TS or TA connector. Press ENTER and set the calibration temperature to that of your supplied standard. Bring your thermocouple to the entered temperature and initiate the calibration by pressing ENTER.

## CAL.FA MENU Option—Setting the Calibration Factor for a Replacement Gas Sensor

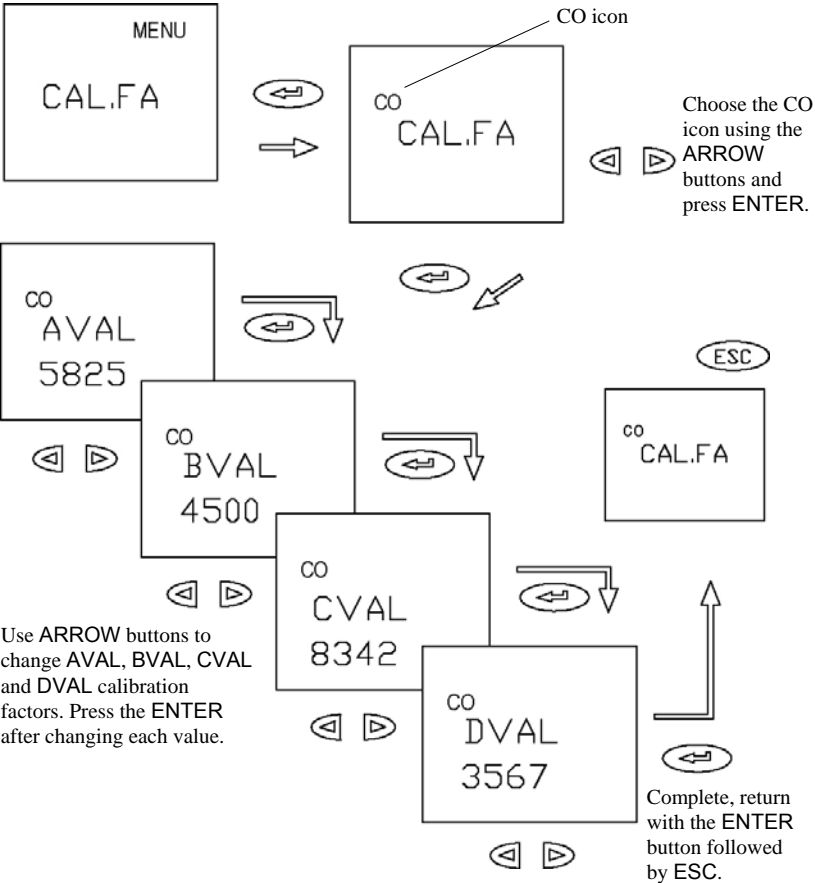
Install your new sensor as described in Chapter 8, “[Maintenance and Troubleshooting](#).”

### CO Sensor

Find the *Calibration Factor* sheet. Use the MENU option CAL.FA and press ENTER. Change the AVAL, BVAL, CVAL and DVAL to values on the calibration sheet using the up and down ARROW buttons. Follow each change by pressing the ENTER button. Figure 12 shows the steps. Pressing ESC takes you out of the entry sequence but keeps values which were saved with the ENTER button.

Once complete, review entered values by stepping through the calibration factor screens using ENTER.

Use the ARROW buttons to find the CAL.FA MENU option.  
 Press the ENTER button.



**Figure 12. Setting the Calibration Factor**

**SO<sub>2</sub> Sensor**

After installing your new sensor, as described in Chapter 8, "[Maintenance and Troubleshooting](#)," find the SO<sub>2</sub> calibration factor sheet. Use the ARROW buttons in the MENU option and find CAL.FA. Press ENTER. Use the ARROW buttons and select the SO<sub>2</sub> sensor icon, press ENTER. Adjust the number displayed to match the value on the calibration sheet. Press ENTER to finish. Press the ESC button to return to the Data Display.

## BAUD Rate MENU Option

Baud rate can be set to match your computer or portable printer. Your instrument is delivered with a default baud rate of 1200 to match the printer.

Baud rate values are displayed in the BAUD rate MENU option divided by 1000. The following baud rates can be set. 1.2 (1200), 2.4 (2400), 4.8 (4800), 9.6 (9600), 19.2 (19200).

To set the baud rate, select BAUD from the MENU option using the ENTER button. Step through the BAUD rates using the ARROW buttons and choose the desired value with the ENTER button. Use the ESC button to return.

## COMM MENU Option—Set the Output Communications Device

Your CA-CALC transfers current or saved data to a serial printer or computer. The COMM MENU option is used to select the device that you want to communicate with. Failure to select the correct device may cause incorrect characters to appear on your printout or computer file.

COMM options are COMP and PRNTR, for computer and printer, respectively. Set the device COMM from the MENU options using the ENTER button. Use the ARROW buttons and choose the desired option followed by pressing the ENTER button. Use the ESC button to return.

## FP MENU Option—Fuel Parameters

### U.S. Fuel Parameters

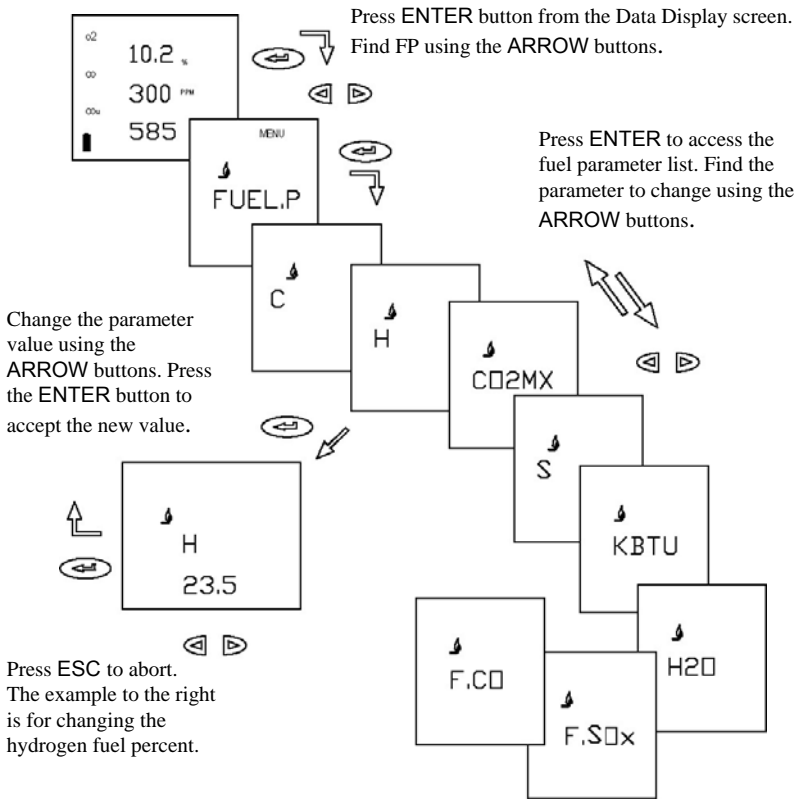
**Note:** For U.S. fuels and fuel parameters to be displayed, the fuel heat LOSS selection must be set to Loss, not qA. Refer to the section "[UNITS MENU Option \(changing units\)](#)" in this chapter.

For calculations of flue losses, maximum %CO<sub>2</sub>, fuel composition and fuel heat content are used. These are the Fuel Parameters. In your CA-CALC, U.S. fuel parameters are the carbon and hydrogen content, moisture content, sulfur content, and maximum %CO<sub>2</sub>, CO<sub>2</sub>MX.

Refer to the diagrams below (Figures 13 and 14), for information on viewing and changing fuel parameters.

Your CA-CALC analyzer has parameters for seven common U.S. fuels in instrument memory. Fuel parameters for these fuels can be changed, if you know, for example, that your fuel has a different composition than

that stored. The instrument fuel parameters values are presented in [Appendix B](#), with additional technical information.



**Figure 13. Fuel Parameters for U.S. Fuels.**

Fuel Parameter	Description
C	% carbon by weight
H	% hydrogen by weight
H <sub>2</sub> O	% moisture content by weight
S	% sulfur by weight
CO <sub>2</sub> MX	CO <sub>2</sub> maximum %
KBTU	Heating value in kiloBTUs, (BTU/1000)
F.CO F.SO <sub>2</sub>	Emission Factors

## FP Fuel Parameters for Siegert Calculation—Siegert Fuel Parameters

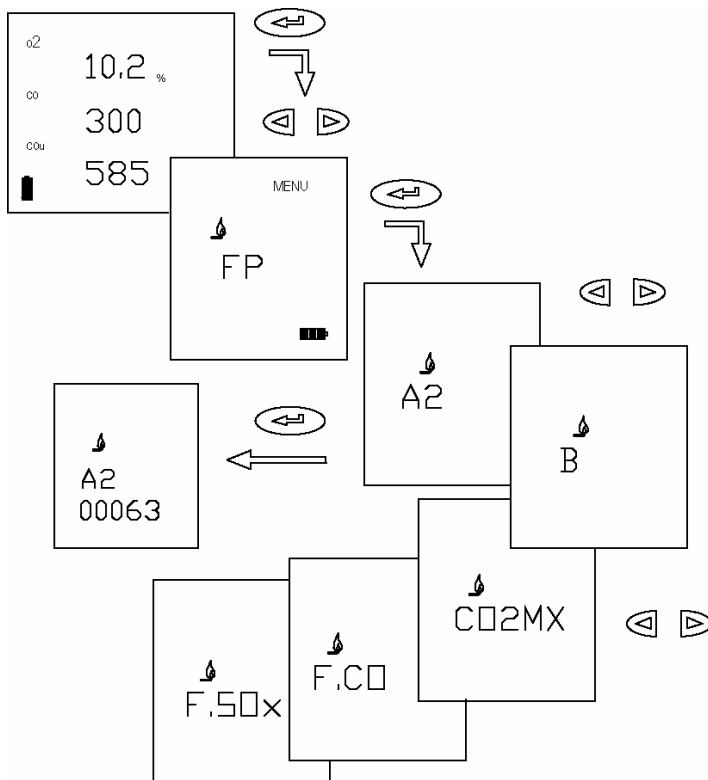
**Note:** For Siegert fuels and fuel parameters to be displayed, the fuel heat LOSS selection must be set to qA not LOSS. Refer to the section “[UNITS MENU Option \(changing units\)](#)” in this chapter.

The Siegert value for flue loss, given the designation qA, is used widely in Europe. Two coefficients are used in the Siegert formula for flue loss, derived from typical fuel compositions. These are given the designations, A2 and B.

Fuel Parameter	Description
A2	Siegert factor, fuel specific
B	Siegert factor, fuel specific
CO2MX	CO <sub>2</sub> maximum %
F.CO F.SO2	Emission Factors

The default Siegert coefficient values in your CA-CALC combustion analyzer, are those used in Germany. Siegert coefficients used in other countries may be different, reflecting differences in local fuel compositions.

Figure 14 diagrams the steps in changing the Siegert fuel parameters.



**Figure 14. Changing Fuel Parameters for Siegert Fuels**

### **LANG MENU Option**

Use this option to select between the following languages: **E** English, **D** German, **N** Dutch, **FI** Finnish, **I** Italian or **S** Swedish. English is the language (*Default*) initially installed on the instrument.

When the language is changed, instrument settings are automatically changed too. Refer to Chapter 4 "[Default Instrument Settings](#)" for more information on this feature.



# Chapter 7

## Setup for Gas Calibration

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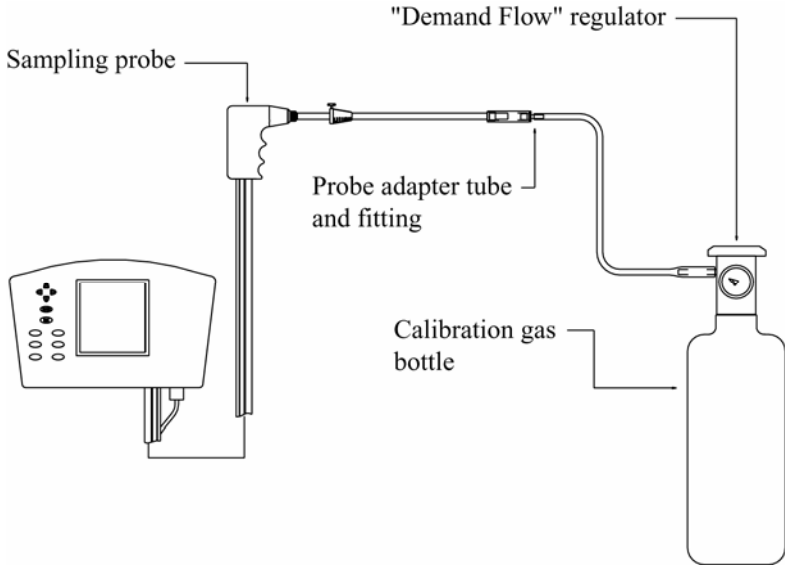
### The Calibration Setups

**Note:** To perform your gas sensor calibration, you will also need to refer back to Chapter 6, and the section "[CALIB MENU Option.](#)"

CO, SO<sub>2</sub> and O<sub>2</sub> gas sensors can be calibrated periodically to maintain the best accuracy. Gas sensors do drift over time, depending upon the operating environment and gas exposure history. CO and SO<sub>2</sub> gas sensors can lose sensitivity by as much as by 10% per year. Since O<sub>2</sub> sensors are calibrated in room air, loss in sensitivity poses no real problem. However, a drift in the *zero* (no O<sub>2</sub> present) can occur, impacting the accuracy when measuring low O<sub>2</sub> concentrations.

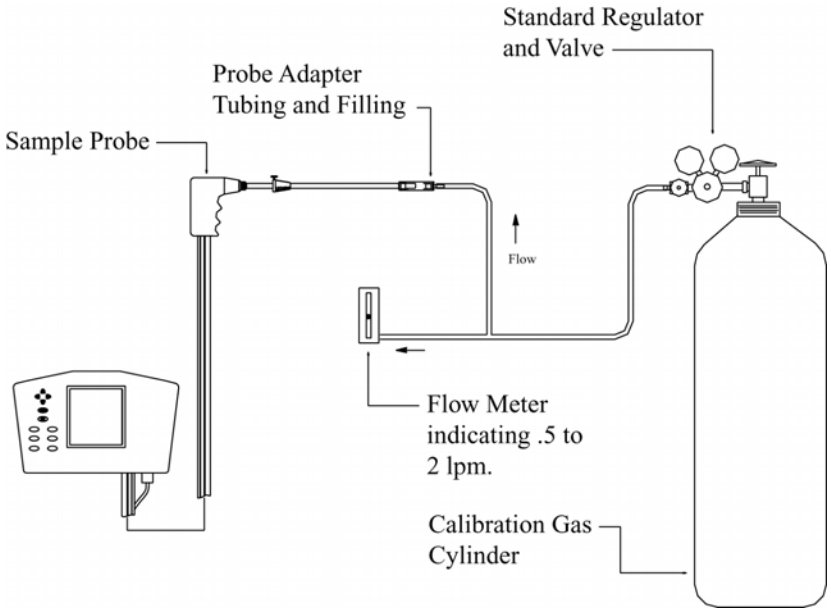
With the proper equipment, such as that shown in the figures below, it is easy to calibrate your CA-CALC™ analyzer gas sensors. However, if you wish, you may also return your instrument to TSI for a new *factory* calibration.

The equipment needed to calibrate individual gas sensors can be purchased from TSI as calibration kits. Model numbers for these kits are found in Chapter 2, "[Unpacking.](#)" You may also elect to put together your own calibration system. Two calibration setups are presented in Figures 15 and 16. A brief discussion of these calibration setups is presented in the following section.



**Figure 15. Calibration with TSI Calibration Kit**

A TSI supplied calibration kit (Figure 15) uses a *demand flow* regulator to supply gas to the CA-CALC analyzer in response to the draw of the instrument sampling the pump. If a conventional regulator and valve are used (Figure 16), the setup requires a tee to a bleed-off extra gas. This prevents a forced flow at the instrument inlet. The bead-type flow meter depicted in the figure is used to verify there is extra flow (.5 to 2 L/min recommended). Extra flow is required to prevent room air from being drawn in, diluting the sample.



**Figure 16. Alternative Calibration Setup**



## Chapter 8

# Maintenance and Troubleshooting

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For additional troubleshooting information, please visit TSI's website <http://combustion.tsi.com>.

### Emptying Water Trap

Refer back to Figure 2 showing the water trap in the sample line and to Figure 17. Liquid water forms in the first chamber of the water trap as gases are sampled from the flue. The water trap is designed so even when shaken, or when its orientation is changed, water does not pass to the second chamber. The water level must remain below the level depicted in the figure, however.

To empty the water trap:

1. First separate it from the sampling tube by pulling the tube ends off the barbs on the end caps.
2. Remove the probe side end cap by pulling outward with a twisting motion.
3. Pour out the water and replace the end cap. Re-install the trap.

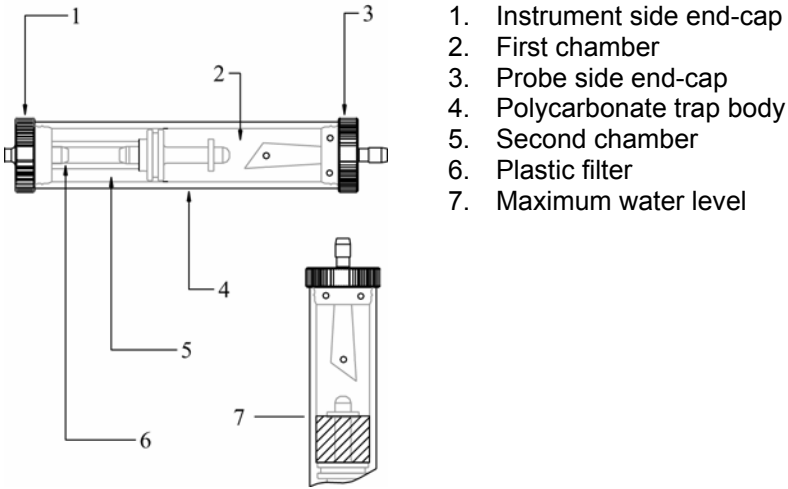
**Important:** Make sure the water trap is oriented so that end-cap 1 below is toward the instrument.

### Changing the Water Trap Filter

Identify the water trap filter (see Figure 17). This filter is designed to remove soot particles before they contaminate the instrument. The filter can be removed for cleaning or replacement by following these steps:

1. Remove the instrument side end cap by pulling it out with a twisting motion.
2. Grasp the filter using a needle-nose pliers and pull it out.
3. To clean the filter, remove the bulk of the soot by tapping the filter. The soot may be removed by rinsing with water or isopropyl alcohol. The effectiveness of the rinse depends on the soot composition—is it dry or oily. Avoid rubbing, which may drive contaminants into the filter causing permanent plugging.

4. Whether cleaned or replaced, install the filter by pushing it over the stub in the filter body, then replace the end cap.



**Figure 17: In-line Water Trap**

### **Cleaning the Sample Probe**

Cleaning may be necessary in high-soot environments. Soot accumulates in the steel sampling tube and sampling line and over time may contribute to a blocked flow path.

1. Remove the water trap by separating the sample tube from the tube stub on each end of the trap.
2. Rinse the tubing, allowing the water to drain from the probe end. When the water is clear, discontinue the rinse. Orient the probe and tubing so excess water drains from the sample lines.
3. Allow adequate time for the interior of the probe to dry. Replace the water trap making sure the water trap is oriented properly. The filter must be toward the instrument.

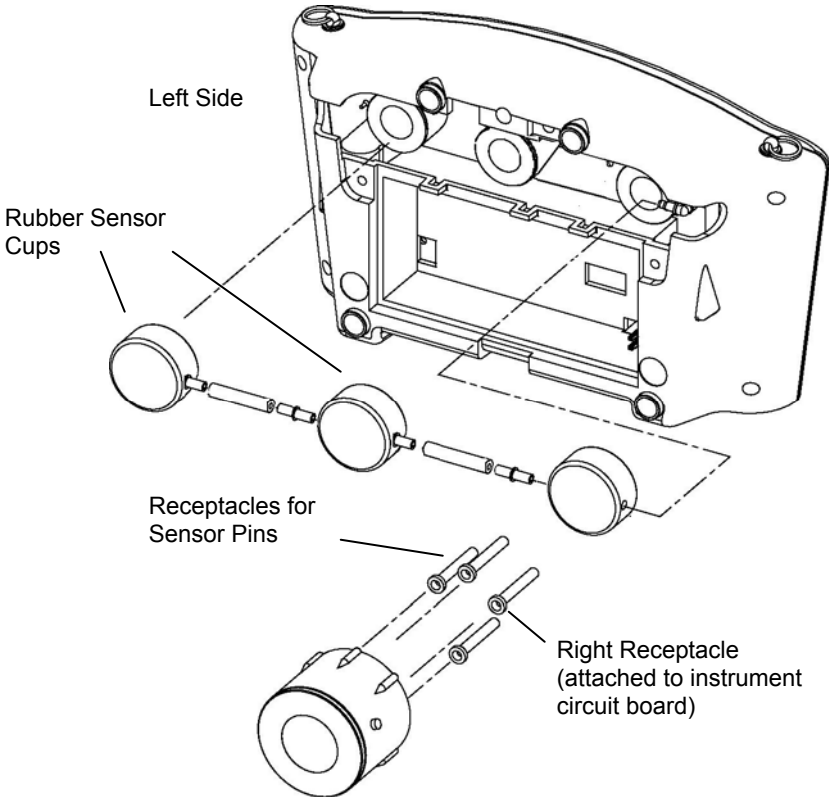
### **Lithium Battery Replacement**

The lithium battery supports measurement data saved in memory. Typical battery life is three years. An ERR code 63 indicates a low lithium battery. To replace the battery open the battery compartment and remove the C-cell battery holder. Find the  $\frac{1}{2}$  AA lithium battery after removing the white foam battery retainer. Replace the battery in the correct plus/minus orientation. Replace the white foam retainer, C-cell holder and battery cover.

## Replacing a Gas Sensor

Remove the sensor cover identified earlier in Figure 1 (item 8). From the left side, pry back the black rubber sensor cups to expose the gas sensors. Do **not** separate any fittings connected to the rubber cups. To remove a sensor, grasp the sensor and lift straight up. When installing a sensor, note the orientation of the sensor pins at the bottom of the sensor and the orientation of the receptacles in the instrument. Tilt the sensor, aligning the bottom pin (see Figure 18) with the base receptacle and the right pin with the right receptacle. Once aligned, stand the sensor up and push in. When installed properly, the sensor will not twist.

*Calibration factor:* when installing a replacement CO or SO<sub>2</sub> sensor from TSI, enter the calibration factor or factors for the sensor as described in Chapter 6, "[CAL.FA MENU Option.](#)"



**Figure 18. Sensor and Sensor Cup Assembly**





# Appendix A

## Error Codes

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*Note: An Error Code can be bypassed using the ESC button.*

- 7) Error in logged data.
- 9) Can't save data to EEPROM.
- 10) Fuel type changed to Natural Gas (fuel and LOSS type mismatch)
- 11) An invalid fuel parameter was corrected.
- 12) Model number checksum error.
- 13) TA thermocouple checksum error.
- 14) TS thermocouple checksum error.
- 15) Draft sensor checksum error.
- 16) A/D calibration checksum error.
- 17) CO sensor checksum error.
- 18) O2 sensor checksum error.
- 20) SO2 sensor checksum error.
- 50) O2 zero voltage out of range.
- 51) CO zero voltage out of range.
- 52) COAUX zero voltage out of range.
- 54) TA sensor zero voltage out of range.
- 55) TS sensor zero voltage out of range.
- 56) Instrument temperature out of range.
- 57) Draft zero voltage out of range.
- 58) Draft gain calibration out of range.
- 59) O2 span (baseline) voltage out of range.
- 60) Error in CO sensor-present test.
- 61) Error in COAUX sensor-present test.
- 63) Lithium battery voltage is low.
- 64) TA sensor gain factor out of range.
- 65) TS sensor gain factor out of range.
- 67) CO sensor A\_VALUE out of range.
- 68) CO sensor B\_VALUE out of range.
- 69) CO sensor C\_VALUE out of range.
- 70) CO sensor D\_VALUE out of range.
- 71) Instrument temperature sensor offset factor out of range.
- 72) AtoD converter gain factor out of range.
- 73) Pump vacuum out of range.
- 77) or higher: Internal program error-contact TSI.
- 74) SO2 zero voltage out of range.
- 75) Error in SO2 sensor-present test.
- 76) SO2 sensor gain factor out of range.



## Appendix B

### Calculations

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#### Undiluted Gas Concentration Calculation ( $\text{CO}_u$ , $\text{SO}_{2u}$ )

$$GAS_{undiluted} = GAS_{measured} (PPM) \times \frac{20.9}{20.9 - O_2 \text{ measured}}$$

#### Excess Air Calculation

$$\% \text{ Excess Air} = \frac{\%O_2 - \%CO/2}{20.9 - (\%O_2 - \%CO/2)} \times 100$$

Another expression of excess is  $\lambda$  (Greek letter Lambda) also used. The relationship between % EA and Lambda is shown below:

$$\lambda = \frac{\%EA}{100} + 1$$

#### Calculating Combustion Efficiency for U.S. Fuels

##### Net Combustion Efficiency (Effic Net)

$$\% \text{ Combustion Efficiency} = 100 - \frac{\text{flue heat losses}}{\text{fuel heating value}} \times 100$$

$$\begin{aligned} \text{flue heat losses} = & \text{heat loss from dry gas} \\ & + \text{heat loss due to moisture from burning} \\ \text{hydrogen} & \\ & + \text{heat loss due to moisture in fuel} \\ & + \text{heat loss from the formation of CO} \end{aligned}$$

Heat losses are per unit weight of fuel

Fuel heating value: HHV or LHV (high heating and low heating, respectively).

This basic method is described in the ASME (American Society of Mechanical Engineers) Power Test Code 4.1. Note, however, the calculation of *Combustion Efficiency* considers only flue losses. In ASME PTC 4.1 losses from other sources (e.g., radiation, convection) are also considered.

## Fuel Parameters for U.S. Fuels

Fuel Parameters	NATG, Methane	PROP, Propane	OIL2, Oil #2	OIL6, Oil #6	COAL	WOOD	COKE
%C (carbon)	75	81.8	85.84	87.49	94.5	51.8	98.2
%H (hydrogen)	25	18.18	12.46	9.92	5.2	6.3	1.5
KBTU/lb HHV	23800	21600	19500	18300	13400	9100	16393
CO <sub>2</sub> max	11.8	13.8	15.6	16.5	17	19.1	20.1
%S (sulfur)	0	0	1.6	1.40	0.034	0	0
%H <sub>2</sub> O (moisture)	0	0	0	0	0.12	0	.5

## Siebert Formula

This formula is widely used in Europe to determine flue gas losses ( $qA$ ) and efficiency.

$$qA = (T_s - T_a) \times \left( \frac{A_2}{(21 - O_2)} + B \right)$$

$$\text{Efficiency} = 100 - qA$$

where:

$qA$  = dry gas losses

$T_s$  = flue temperature

$T_a$  = supply air temperature

$O_2$  = measured volumetric oxygen concentration expressed as a percent

$A_2, B$  = fuel dependent constants

The constants  $A_2$  and  $B$  are based on the composition of combustibles in the fuels. In Germany, the following prescribed values are provided for common fuels.

## Fuel Parameters for Siebert Fuels

Fuel Type	A <sub>2</sub>	B
NATG, Natural gas	.66	.009
OIL2, light fuel oil	.68	.007
OIL6, heavy oil	.68	.007
TGAS, Town gas	.63	.011
CGAS, Coking oven gas	.60	.011
PROP, propane	.63	.008

## Determining CO<sub>2</sub> Using the O<sub>2</sub> Concentration

$$\% \text{CO}_2 \text{ (by volume)} = \text{CO}_2 \text{ max} \times \frac{(20.9 - \% \text{O}_2 \text{ measured})}{20.9}$$

CO<sub>2</sub>max is the theoretical maximum concentration produced for the fuel used.

## Emission Rate Calculations Using Emission Factors

Emission rate expresses the CO and SO<sub>2</sub> concentrations in units of mass of effluent per amount of energy (fuel) consumed (lb./Mbtu or ng/J). Since fuel energy differs from fuel to fuel, emissions, expressed in PPM for example, must be converted using a fuel specific parameters. This is where the *Emission Factors* F.CO and F.SO<sub>2</sub> are used.

The emission rate calculation presented below is described in EPA Method 19. This uses the dry gas factor Fd. Dry factors are incorporated into the values found in the Table I, below. The table values (Ft), convert the measured concentrations of emission gases, CO and SO<sub>2</sub> from PPM to pounds per million Btu of fuel. Note: The bracketed quantity converts the emission rate to the *undiluted* value.

$$E = C_g \text{ Ft} \times \left( \frac{20.9}{20.9 - \text{O}_2 \text{ measured}} \right)$$

where:

- E* = Emission Rate (pounds/MBtu of fuel, ng/J)
- C<sub>g</sub>* = Gas Concentration (PPM)
- F<sub>t</sub>* = factor from Table I (below)
- O<sub>2</sub> measured* = Oxygen concentration from flue measurement (%)

## Emission Rate Factors

Factor (Ft)	Nat. Gas	Propane	Oil #2	Oil #6	Coal	Wood (dry)	Bagasse	Coke
F.SO2	.00145	.00145	.00153	.00153	.00164	.00153	0.0016	0.00164
F.CO	.00063	.00063	.00067	.00067	.00072	.00067	0.00067	0.00072

Ft units: lb./MBtu PPM

For those familiar with Method 19, *F<sub>t</sub>* is related to *F<sub>d</sub>* in the following way:

*F<sub>t</sub>*, in units lbs/(MBtu ppm)

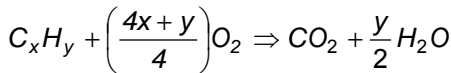
*F<sub>d</sub>*, in units scf/MBtu

$F_t = F_d \times \text{lb}/(\text{scf ppm})$

### Important Note

The Emission Rate factors shown in the table above are always expressed in units of lb./MBtu PPM regardless of whether the instrument is configured to display lb./MBtu or ng/J. This is important to recognize if entering your own factors.

### A General Equation for the Combustion of a Simple Hydrocarbon in Air



*x and y are the number of atoms of carbon and hydrogen in the fuel.*

### Calculating CO<sub>2</sub> Max From the Carbon Content

$$\%CO_2 \text{ max} = \frac{\text{moles } CO_2}{(\text{moles } CO_2 + \text{moles } N_2)} \times 100$$

$$\text{moles } CO_2 = x \text{ moles}$$

$$\text{moles } N_2 = \frac{(4x + y) \times 3.76}{4}$$

### Calculation of Combustion Air Requirement

$$\text{Pounds Air / Pound Fuel} = 11.5C + 34.3(H_2 - O_2/8) + 4.3S$$

*C, H<sub>2</sub>, O<sub>2</sub> and S are the fractions, by weight, of each chemical constituent of the fuel.*

## Appendix C

# Series CA-6205 CA-CALC™ Combustion Analyzer Specifications\*

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### **Oxygen (O<sub>2</sub>)**

Sensor Type	Electrochemical
Range:	0–25%
Accuracy:	±0.3% O <sub>2</sub>
Resolution:	0.1% O <sub>2</sub>
Response Time:	<30 seconds to 90% of step change

### **Carbon Monoxide (CO)**

Sensor Type	Electrochemical
Range:	0–5000 ppm
Accuracy:	0–100 ppm ±5 ppm or 10% of reading 100–5000: ±10 ppm or 5% of reading
Resolution:	1 ppm
Response Time:	<30 seconds to 90% of step change

### **Sulfur Dioxide(SO<sub>2</sub>)**

Sensor Type	Electrochemical
Range:	0–4000 ppm
Accuracy:	0–200 ppm ±10 ppm 200–4000: ±10 ppm or 5%
Resolution:	1 ppm
Response Time:	<30 seconds to 90% of step change

### **Sampling Probe**

Hose length	9' std (2.8 m)
Probe diameter:	½" max (1.3 cm)
Length	24" (61 cm)

### **Flue/stack Temperature**

Range	0–1000°C.
Resolution	1°C
Accuracy	±2°C, or .5% of reading

### **Supply Air Temperature Probe**

Range	-40–150°C
Resolution	1°C
Accuracy	±1°C or 1%

### **Draft**

Range	±30" H <sub>2</sub> O (±80 mbar)
Resolution	±0.01" H <sub>2</sub> O
Accuracy	±1%rdg or .01" H <sub>2</sub> O (zeroed)

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\*Specifications are subject to change without notice. Specification giving lowest accuracy is applied.

**External Dimensions:** ..... 6" x 10" x 2.5"

**Communication Interface:**

Type: ..... Serial

Baud rate: ..... 1200–19200 selectable

**Power Requirements:**

Batteries: ..... 4 C cell alkaline batteries

Battery life: ..... >24 hours (pump on)

AC Adapter: ..... Use only TSI-supplied adapter

Backup battery: ..... Lithium

Backup battery life: ..... 3 yrs

*Note: These specifications assume the instrument is allowed to stabilize at the operating temperature before being turned on.*



# Appendix D

## Default Settings

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<b>Defaults</b>	<b>O<sub>2</sub></b>	<b>CO</b>	<b>Draft Units</b>	<b>Temp Units</b>	<b>Excess Air</b>	<b>Effic/Loss Basis</b>
CA- 6205	%	PPM	"H <sub>2</sub> O	°F	%EA	ASME/heat loss
CA- 6205-D	%	PPM	hPa	°C	<b>Baud</b>	<b>COM</b>
CA-6205	Eff/Net effic	C,H,H <sub>2</sub> O,S, HV,CO2M X F.CO, F.SO2	U.S.	Nat gas	1200	PRN





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