Series 6200
CA-CALC™
Combustion Analyzers

Operation and Service Manual

1980431 Rev. F
January 2004

TSI®

Series CA-6200

CA-CALC™
Combustion Analyzers

Operation and Service Manual

January 2004
P/N 1980431 Rev. F

U.S. AND CANADA
Sales & Customer Service:
(800) 874-2811/(651) 490-2811
Fax:
(651) 490-3824

OTHER COUNTRIES
Sales & Customer Service:
(001 651) 490-2811
Fax:
(001 651) 490-3824

MAIL/SHIP TO:
TSI Incorporated
ATTN: Customer Service
500 Cardigan Road
Shoreview, MN 55126
USA

E-Mail
answers@tsi.com

WEB SITE
www.tsi.com

Part Number

1980431 / Revision 5

Address

TSI Incorporated / 500 Cardigan Road / Shoreview, MN 55126 / USA

Fax No.

(651) 490-3824

LIMITATION OF WARRANTY AND LIABILITY (effective July 2000)

Seller warrants the goods sold hereunder, under normal use and service as described in the operator's manual, shall be free from defects in workmanship and material for twenty-four (24) months, or the length of time specified in the operator's manual, from the date of shipment to the customer. This warranty period is inclusive of any statutory warranty. This limited warranty is subject to the following exclusions:

a. Batteries are warranted for 90 days from the date of shipment to the customer. Electrochemical gas sensors are warranted for a period of twelve (12) months from the date of shipment to the customer.
b. Parts repaired or replaced as a result of repair services are warranted to be free from defects in workmanship and material, under normal use, for 90 days from the date of shipment.
c. Seller does not provide any warranty on finished goods manufactured by others or on any fuses, batteries or other consumable materials. Only the original manufacturer's warranty applies.
d. Unless specifically authorized in a separate writing by Seller, Seller makes no warranty with respect to, and shall have no liability in connection with, goods which are incorporated into other products or equipment, or which are modified by any person other than Seller.

The foregoing is IN LIEU OF all other warranties and is subject to the LIMITATIONS stated herein. **NO OTHER EXPRESS OR IMPLIED WARRANTY OF FITNESS FOR PARTICULAR PURPOSE OR MERCHANTABILITY IS MADE**.

TO THE EXTENT PERMITTED BY LAW, THE EXCLUSIVE REMEDY OF THE USER OR BUYER, AND THE LIMIT OF SELLER'S LIABILITY FOR ANY AND ALL LOSSES, INJURIES, OR DAMAGES CONCERNING THE GOODS (INCLUDING CLAIMS BASED ON CONTRACT, NEGLIGENCE, TORT, STRICT LIABILITY OR OTHERWISE) SHALL BE THE RETURN OF GOODS TO SELLER AND THE REFUND OF THE PURCHASE PRICE, OR, AT THE OPTION OF SELLER, THE REPAIR OR REPLACEMENT OF THE GOODS. IN NO EVENT SHALL SELLER BE LIABLE FOR ANY SPECIAL, CONSEQUENTIAL OR INCIDENTAL DAMAGES. SELLER SHALL NOT BE RESPONSIBLE FOR INSTALLATION, DISMANTLING OR REINSTALLATION COSTS OR CHARGES. No Action, regardless of form, may be brought against Seller more than 12 months after a cause of action has accrued. The goods returned under warranty to Seller's factory shall be at Buyer's risk of loss, and will be returned, if at all, at Seller's risk of loss.

Buyer and all users are deemed to have accepted this LIMITATION OF WARRANTY AND LIABILITY, which contains the complete and exclusive limited warranty of Seller. This LIMITATION OF WARRANTY AND LIABILITY may not be amended, modified or its terms waived, except by writing signed by an Officer of Seller.

Service Policy

Knowing that inoperative or defective instruments are as detrimental to TSI as they are to our customers, our service policy is designed to give prompt attention to any problems. If any malfunction is discovered, please contact your nearest sales office or representative, or call TSI's Customer Service department at (800) 874-2811.

CONTENTS

TÜV Reg. No. 213 *

** Instruments supplied with the Model 801940, 41 Sampling Probe have been approved for measurements of O_2, temperature, CO and NO. Instruments supplied with the Model 80151,52 Emission probe do not meet the temperature response requirement.*

.

Introduction

Manual Purpose

This manual describes the operation and maintenance of TSI Series CA-6200 CA-CALC™ portable combustion analyzers (Models 6210, 6211, 6212, 6213, 6214, 6215 and 6216).

Using This Manual

Before using the CA-CALC combustion analyzer for the first time, review this manual in its entirety.

The manual assumes that you have a basic understanding of combustion analysis and are thoroughly familiar with your fuel burning equipment. When performing equipment adjustments, rely on good judgment and experience along with the measured data. This is especially important where safety issues are of concern. Equipment adjustments must always coincide with the fuel burning equipment manufacturer's recommendations.

Warnings and Cautions

!	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 combustion analysis instrumentation for the purpose of making equipment adjustments.

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

!	Caution
	Always use the water trap when sampling. Check the trap frequently during operation to prevent overfilling with condensed water. Empty often.

!	WARNING
	This device is not intended for use as a continuous monitor or as a safety indicator.

Note: 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

The CA-CALC™ combustion analyzer is a portable instrument measuring combustion gases, combustion gas and supply air temperatures and draft pressure for evaluating the performance of burners in boilers, furnaces, and hot water tanks. From the measured data, the CA-CALC combustion analyzer calculates a variety of combustion parameters including excess air, CO_2 level, and combustion efficiency. When fitted with NO, NO_2, and SO_2 gas sensors, emission rates and NOX are calculated. Combustion data is presented on a large display screen, making it possible to display multiple parameters simultaneously. This data can be saved or printed with the press of a button.

The basic CA-CALC analyzer Model 6210 comes standard with two electrochemical gas sensors for stack gas measurements, one sensor for measuring oxygen (O_2), and one for measuring carbon monoxide (CO). Depending on the model ordered, your CA-CALC may have one or two additional electrochemical gas sensors. The table below shows the available models and sensor combinations. It is also possible to add additional gas sensors later to upgrade your CA-CALC combustion analyzer.

Model	**Gas Sensors**
CA-6210	O_2, CO
CA-6211	O_2, CO, NO
CA-6212	O_2, CO, CO(high concentration)
CA-6213	O_2, CO, NO, SO_2
CA-6214	O_2, CO, NO, CO(high concentration)
CA-6215	O_2, CO, NO, NO_2
CA-6216	O_2, CO, SO_2 , NO_2

Gas Sampling Probes

One of two basic gas sampling probe types is provided with the CA-CALC, depending on the model chosen. For instruments measuring O_2, CO, and NO, the standard *Sampling Probe* is provided. This probe has an unlined sampling tube, and has an exposed thermocouple tip for fast-response temperature measurements. For instruments supplied with NO_2 or SO_2 gas sensors, the *Emission Probe* is supplied. This probe has a non-reactive “lined” sample tube to limit loss of the reactive gases. The Emission Probe also has a sintered metal filter on the probe tip to reduce soot buildup in the sample line.

Chapter 2. Unpacking

Carefully unpack the CA-CALC™ combustion analyzer and accessories from the carrying case. 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

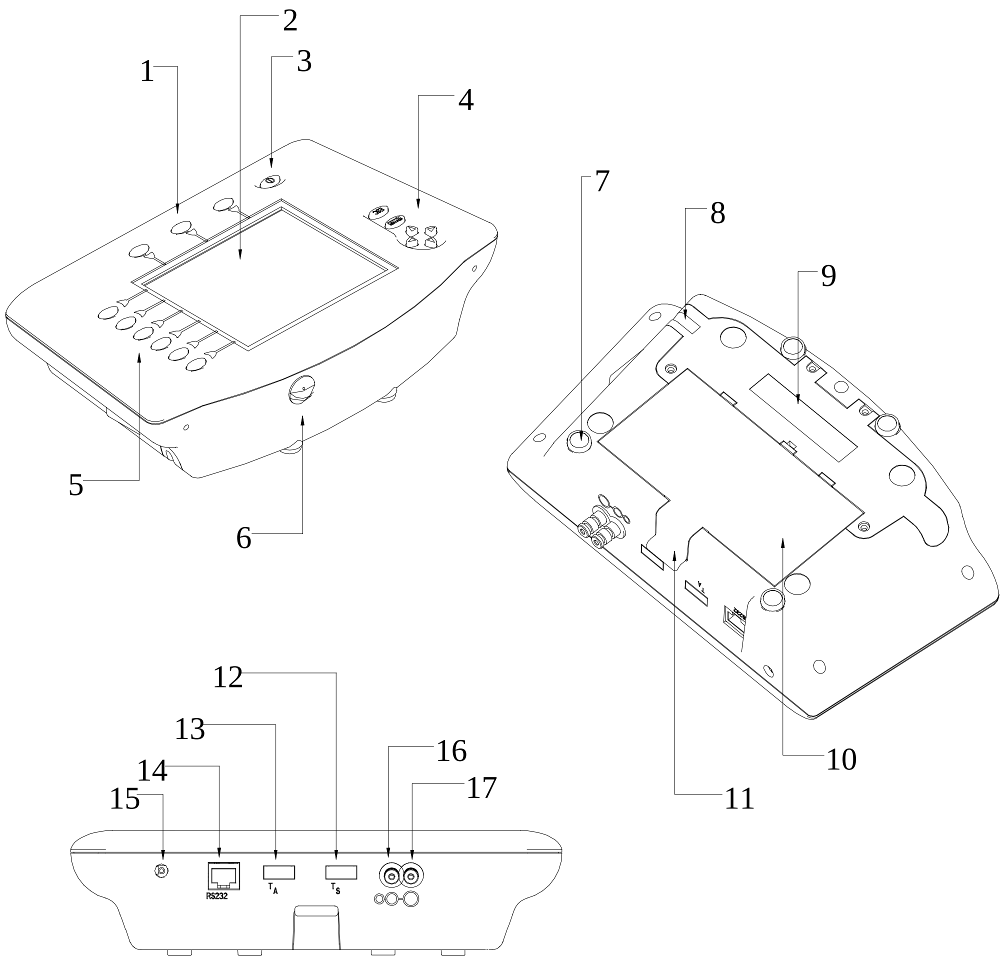
Qty.	Item	Part/Model
1	Series CA-6200 CA-CALC combustion analyzer	CA-62XX *(XX = 10-16)*
1	Carrying case	1319319
1	Standard probe 12" with water trap *or* Emission probe 12" with water trap *or* Other probe and hose lengths available (24" probe, 25' hose)	801940 801951 Consult factory
1	Power supply 7.2V 120V *or* 230V European, *or* 230V Great Britain, *or* 240V Australian	 2613033 2613078 800169 2613106
1	Calibration certification	
4	C cell alkaline batteries	
1	Operation and Service manual	1980431

Optional Accessories

	Item	Part/Model
	Combustion supply air thermocouple, *Type K*	3013003
	Portable printer	801994
	Carrying strap tether	2913011
	Computer cable	8940
	NO sensor	802266
	NO_2 sensor	802267
	CO sensor (high concentration)	802265
	O_2 replacement sensor	802263
	CO (hydrogen compensated) replacement sensor	802264
	SO_2 sensor	802268
	Water trap filters	801947
	Replacement kit, emission probe filter	801944
	Gas Calibration kits *(U.S. only)* CO (hydrogen compensated) NO NO_2 SO_2 O_2 zero calibration kit (N_2)	 801923 801937 801938 801936 801939
	Probe adapter kit	801970
	Probe heat shield	801969
	Replacement filter kit	801944
	Water trap replacement	802215
	Lithium battery	1208028

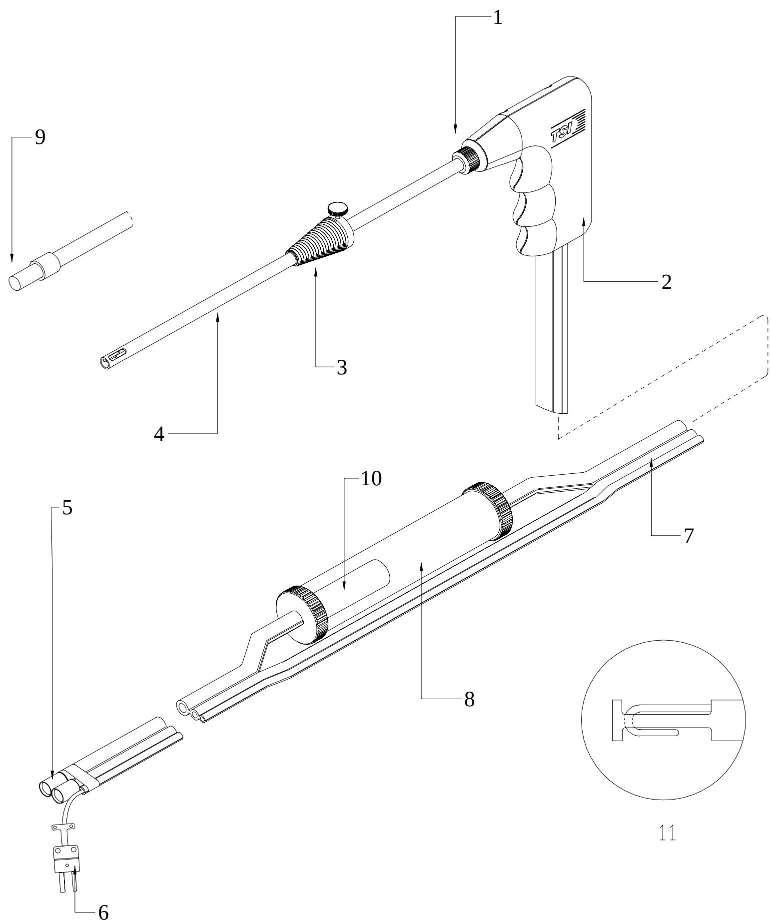
Chapter 3. Component Identification

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. Label buttons
2. LCD display
3. On-Off button
4. Control buttons
5. Icon buttons
6. CO diversion valve
7. Magnets
8. Vent
9. Sensor cover
10. Battery cover
11. Battery cover tab
12. Port for *stack gas* thermocouple probe
13. Port for *combustion supply air* thermocouple, *type K*
14. RS232 serial port
15. Power connection
16. Draft sample port
17. Gas sample port

Figure 1: CA-CALC Combustion Analyzer Components



1. Sample tube retaining fitting
2. Probe handle
3. Position collar
4. SS sampling tube
5. Sample and Draft connectors
6. Thermocouple connector
7. Tri-plex tubing
8. Water trap
9. *Emission Probe* for NO2, SO2, with SS filter
10. Plastic filter
11. Detail of standard probe tip

Figure 2: CA-CALC Sampling Probe Components

The Gas Sensors

The CA-CALC analyzer holds up to four electrochemical gas sensors. Oxygen (O_2) and hydrogen compensated carbon monoxide [$CO(H_2)$] sensors are standard, included with all Series CA-6200 CA-CALC combustion analyzers. Two of the following sensors can also be added: nitric oxide (NO), nitrogen dioxide (NO_2), sulfur dioxide (SO_2) and high concentration carbon monoxide (COhi). The gas sensors are found under the sensor cover identified in Figure 1 above.

Optional Combustion Supply Air Thermocouple Probe

A measurement of the *Combustion Supply air* temperature is made using an optional thermocouple accessory probe (TSI PN 3013003). This probe is connected to the supply air temperature port.

Combustion supply air temperature is an important value used in the determination of flue losses and efficiency.

On-Board Temperature Measurement

The CA-CALC analyzer uses an on-board resistance temperature detector (RTD) to provide the combustion supply air 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 long-life diaphragm sampling pump.

Draft Sensor

A differential pressure transducer in the CA-CALC analyzer is used to measure draft pressure. The transducer has a measurement range of ±30” of H_2O (7.47 kPa).

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. Water must be prevented from entering the instrument through the sample port. The water trap uses two chambers and a *hydrophobic* coalescing filter to maximize water removal.

Stack Probe Thermocouple

The type K thermocouple probe extends through the SS sampling tube to its tip, where stack temperatures are measured. The thermocouple probe measures temperatures up to 1800 degrees F.

The yellow thermocouple connector plugs into the *stack thermocouple* port (see Figure 1).

Emission Probe (Supplied with Models CA-6213 and CA-6215)

An “*Emission” gas sample probe* (Model 801951) is required when NO_2 and SO_2 gases are measured. This gas sampling probe has an internal liner (TFE), which does not absorb NO_2 and SO_2 gases. The *Emission Probe* also has a sintered stainless steel filter at the probe tip to reduce soot buildup in the sampling lines. Soot, combined with moisture from condensation, readily absorbs NO_2 and SO_2. Note that the sintered metal filter on the tip of the *Emission probe* slows the response of the temperature sensor.

Note: When making temperature measurements, maintain the position of the probe in the flue until the temperature reading has stabilized. For faster temperature measurement, when determining combustion efficiency, a Model 801940 Sampling Probe is recommended.

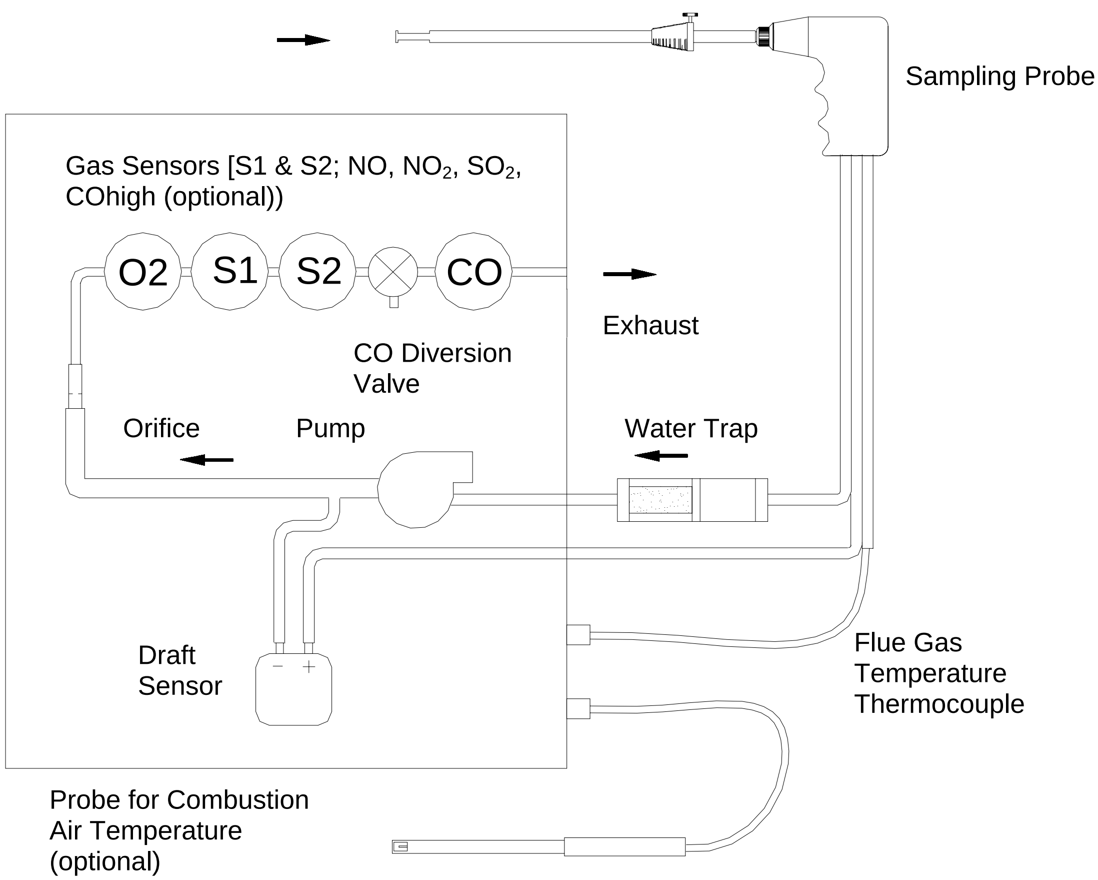
CO Diversion Valve

The CO diversion valve is used to divert high concentrations of carbon monoxide (>5000 ppm) away from the hydrogen compensated CO sensor. High CO concentrations cause the sensor baseline value to shift upward. Although the effect is temporary, it may take ten minutes or longer for the sensor to recover. A shift upward in the sensor baseline means the CO sensor indicates a concentration that is higher than the true concentration.

Mounting Magnets

The CA-CALC combustion analyzer can be adhered to a flat metal surface using the magnets on the case bottom. This orients the instrument for convenient viewing and button operation. When mounted in this way it is advisable to use the optional strap/tether (see optional accessories) as a safety harness in case the instrument is pulled away from the metal surface. Metal surface must ***not*** be hot.

Schematic Representation of CA-CALC

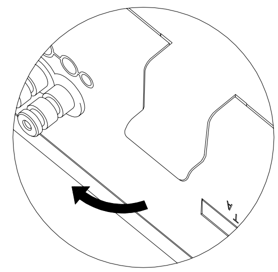


Chapter 4. Getting Started

Supplying Power

The CA-CALC™ portable combustion analyzer operates using 4 C-cell batteries or using the AC adapter provided. Quality alkaline batteries enable the instrument to operate for 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 to the right. 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 AC Adapter

Find the supplied 7.2-volt AC Adapter included with the instrument. Connect the corresponding connector plugs to the AC wall source and instrument power connection located on case bottom (see Figure 2). When using the power supply, the batteries are bypassed.

Note: The CA-CALC analyzer does not charge rechargeable batteries.

Connecting the Sampling Probe

The sampling probe depicted in Figure 2 is connected to the instrument by pushing the sample and draft connectors over the bulkhead ports on the instrument. Refer to Figure 3 below showing the probe connection. Make sure the connectors are pushed fully over the bulkhead ports. Finish the connection by plugging the yellow thermocouple connector into the *Stack* temperature thermocouple port. The thermocouple plugs in only one way. *Don't force the connector.*

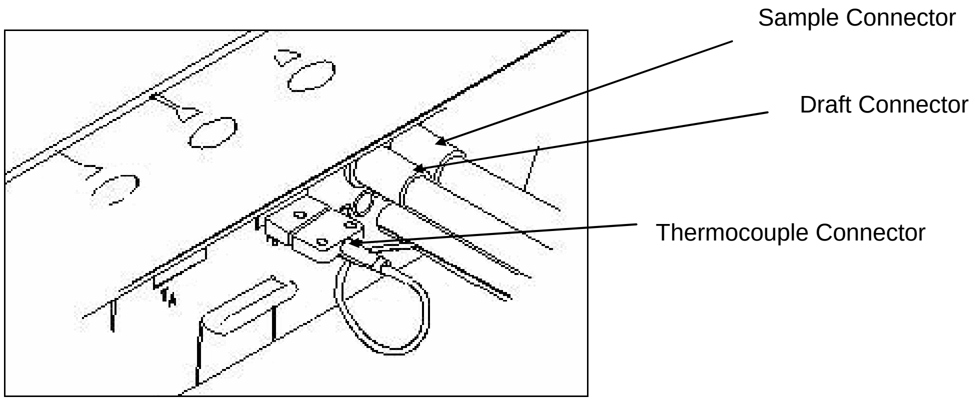


Figure 3: Sampling Probe Connection

Setting CO Diversion Valve

Set the CO diversion in the orientation shown in the figure below. In this position, the valve is open, allowing gas to flow to the CO sensor. Only under conditions where the CO level is very high (above 5000 ppm), should the valve be closed. To close the valve, turn it 90 degrees counterclockwise.

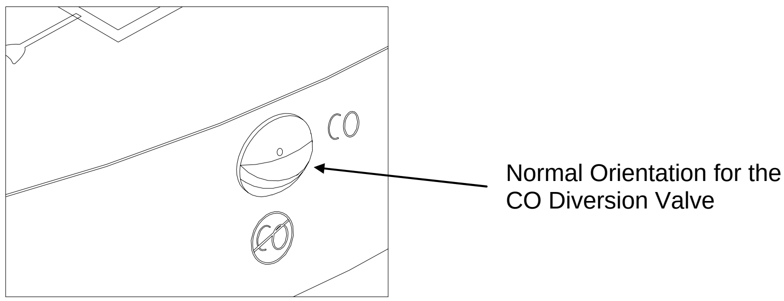


Figure 4: Normal CO Diversion Valve Orientation

Connecting the Optional Combustion Supply Air Temperature Probe

An optional type K thermocouple probe (TSI PN 3013003) is used to measure the temperature of the air supplied to the burner; the *Combustion Supply air*. When a probe is not used, the supply air temperature is measured using the on-board resistance temperature detector (RTD). Connect the optional supply air thermocouple (see "Optional Accessories") to the supply air thermocouple port depicted in Figure 1. The thermocouple plugs in only one way. *Do **not** force the connector.*

Connecting the Optional Portable Printer

Find the printer interface cable included with the Model 8925 portable printer. Connect the large 9-pin connector on the cable to mating connector on the printer. Connect the opposite end to the instrument's RS232 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 different, 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. You will also need to set the **RS232 Device** setting to **Printer**. To set the CA-CALC baud rate and device settings, refer to Chapter 6, "MENU Selections and Menu Items."

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. 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 RS232 communications and printer port. See Figure 1 for port location.

You will need to do two things before you can successfully communicate with a computer. First make sure the baud rate of the CA-CALC analyzer matches that of the computer. Second, make sure the **RS232 Device** setting is set to **Computer** and not **Printer**. To set the Device, refer to “Instrument Setup” in Chapter 6, “MENU Selections and Menu Items.”

Default Instrument Settings

The CA-CALC combustion analyzer uses a number of standard settings for presenting the data, performing calculations, and controlling instrument operation. These include the units displayed, the fuel used, the baud rate and so on. When shipped, these have factory pre-set *Default* settings. The default settings are listed below. Default settings can be changed as described in Chapter 6, “MENU Selections and Menu Items.”

Factory Defaults (U.S.)

Gas Concentrations	PPM (parts per million), applicable for CO, NO, NO_2, SO_2 sensors
Temperature	Degrees F
Fuel*	Natural Gas
O_2REF	OFF (do not incorporate O_2 reference in calculation of gas concentration)
O_2	Reference level: 3% (not used if OFF selected above)
Draft:	Inches H_2O
Excess Air:	%EA
Effc./Loss	Net Efficiency
Fuel Heat	High heating value used in calculations, units are BTU
Auto Draft Meas.	OFF
Baud Rate	1200
RS232 Device	Printer, configured for output to printer rather than to computer
CO Shutoff level	2000 ppm. Turns the pump off if the CO level exceeds this set level
NO Shutoff level	1000 ppm. Turns the pump off if the NO level exceeds this set level

*Defaults extend to include factory set fuel parameter values for eight fuels. These fuels are; natural gas, propane, #2 fuel oil, #6 fuel oil, coal, wood, baggasse, coke.

Factory Defaults (Non-U.S.)

Instruments sold outside the U.S. are often set up with *default* units and settings different than those identified in the table above. The defaults installed depend upon the letter designation present in the instrument’s Model number. For example a -D in Model number CA-6210–D indicates that Germany is the destination country and has appropriate units and settings installed. Other letter designations have the following meanings: -EU European, -M metric units, -UK United Kingdom, -AU Australia. The following table shows *defaults* relating to the instrument designations. Remember it is always possible to change the default settings.

Default Settings For Different Model Letter Designations

Instrument Model number	O2 ref.	O2 ref. Level	Draft	Temp	Excess Air	Effc / Loss Basis	Effc / Loss	Fuel heat	Gas Conc.	Decimals	Fuel Setup
CA-621X	off	3%	" H20	F	%EA	ASME/heat loss	Net Efficiency	BTU HHV	PPM	periods	fuel composition parameters
CA-621X – D	off	0%	mbar	C	lambda	Siegert	qA	NA	PPM	commas	Siegert fuel parameters
CA-621X - EU	off	0%	mbar	C	lambda	Siegert	qA	NA	PPM	commas	Siegert fuel parameters
CA-621X - M	off	0%	kPa	C	%EA	ASME/heat loss	Net Efficiency	kJ/kg HHV	PPM	periods	fuel composition parameters
CA-621X - UK	off	0%	kPa	C	%EA	ASME/heat loss	Gross Efficiency	kJ/kg LHV	PPM	periods	fuel composition parameters
CA-621X - AU	off	0%	kPa	C	%EA	ASME/heat loss	Gross Efficiency	kJ/kg LHV	PPM	periods	fuel composition parameters

Chapter 5. Basic Operation

Quick Start

This chapter describes the steps needed to start making basic measurements. When used for the first time, the CA-CALC™ combustion analyzer parameter settings match the *Defaults* listed in the previous chapter. To select different instrument parameter settings refer to "Instrument Setup" in Chapter 6, "MENU Selections and Menu Items."

Steps to Quick Startup

1. Review Chapter 4, "Getting Started." Perform the necessary hardware setups.
2. Turn the instrument on using the red **ON-OFF** button identified in Figure 1.
3. Verify that you have adequate battery life for your measurement needs. A 50% reading for example, indicates 8 to 12 hours of additional operating life.
4. Press the **ENTER** button. A brief initialization follows.
   If the **Error** screen appears, refer to Chapter 9, "Maintenance and Troubleshooting."
5. Review the **Pre-Test** screen. The O_2 sensor should indicate approximately 20.9% and other gas sensors indicate near 0 ppm. The draft reading should be 0.
6. Press **ESC** to bypass the baseline calibration.

Baseline Calibration

To perform a baseline calibration press **ENTER** from the **Pre-Test** screen. A baseline calibration reestablishes baseline levels for the electrochemical sensors and draft sensor. When performing a new baseline calibration, make sure the probe is in air free of exhaust gases (or disconnected). The baseline calibration takes about 40 seconds. To abort the baseline calibration, press **ESC.** The data display screen appears when the baseline calibration is complete or bypassed.

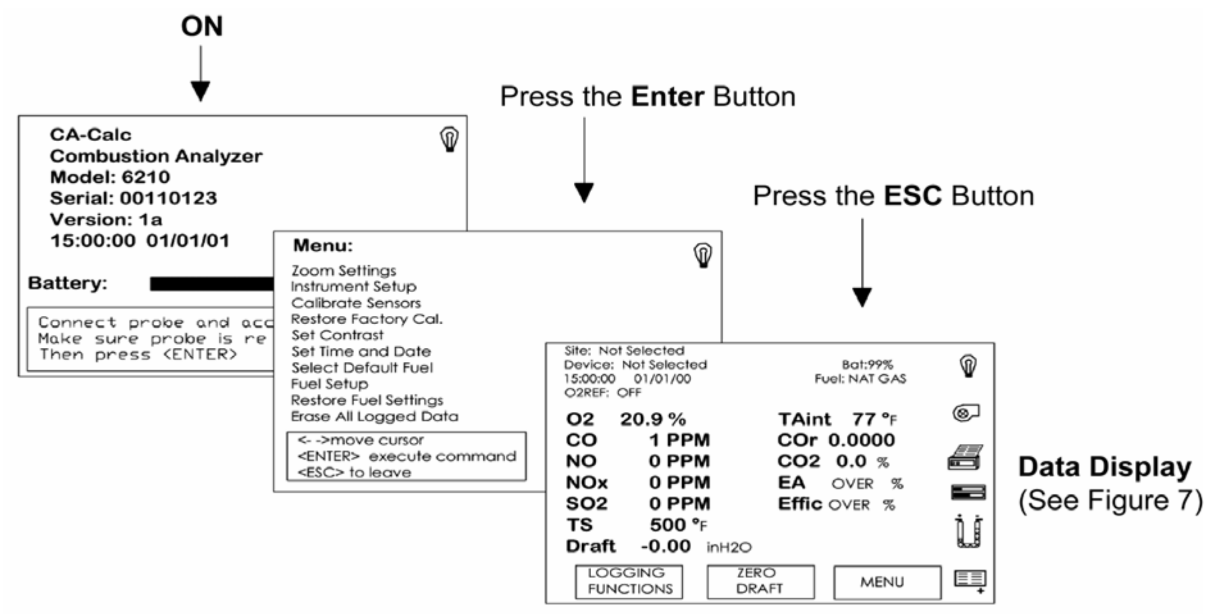


Figure 5: Schematic Illustration of Quick Start Process

The Data Display Screen

Refer to the figure below to identify the key components of the main Data Display screen.

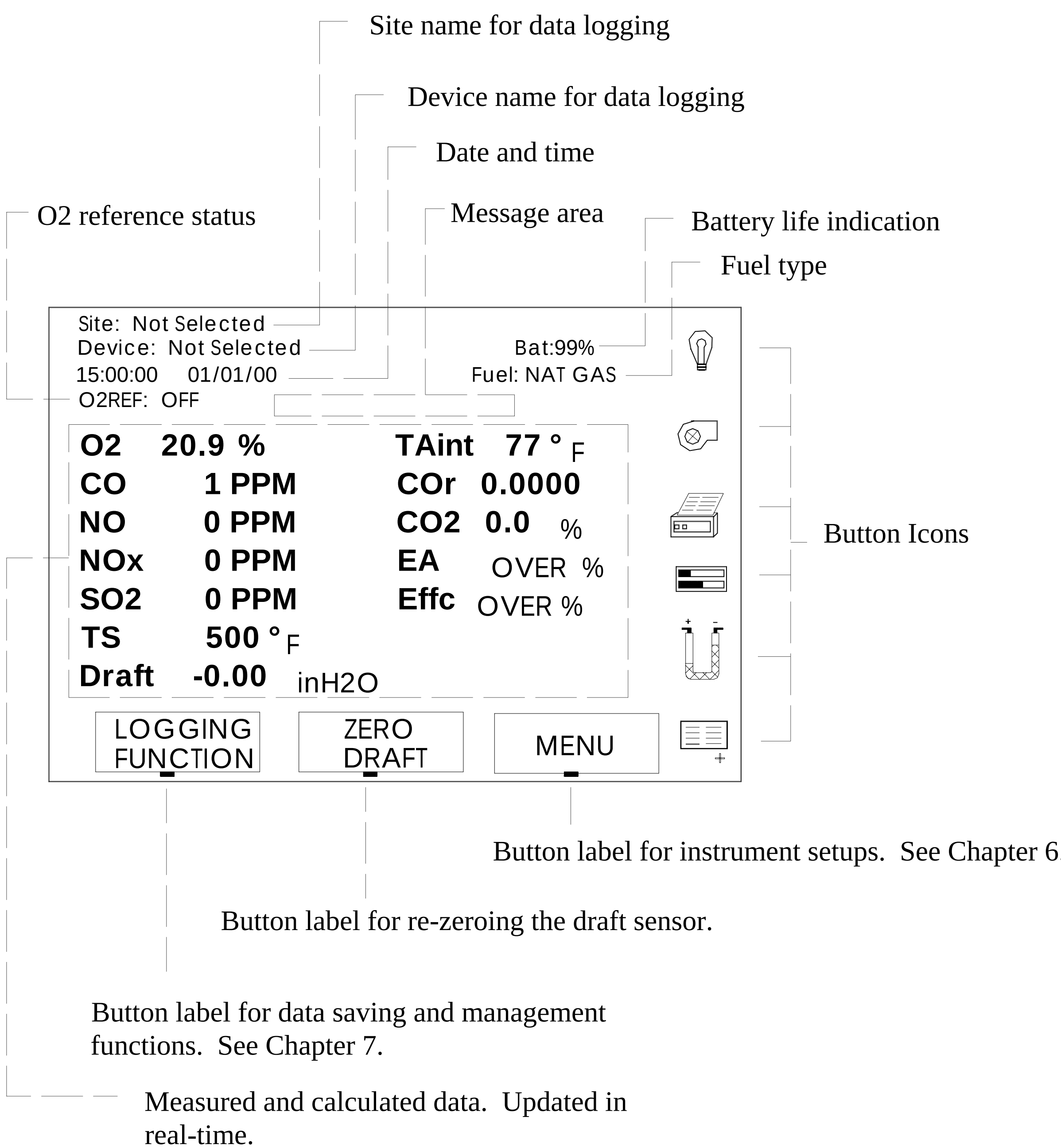


Figure 6: The Main Data Display Screen

Available Measurements

The CA-CALC analyzer automatically detects the sensors installed. Only measurements for detected sensors appear on the display. For example, if no carbon monoxide sensor is present, **CO** will not appear on the display. For values that are calculated, such as efficiency **(Effc)**, sensors that provide data for the calculation must be present. If the O_2 sensor data or stack temperature data is missing, efficiency will not be calculated and **Effc** will not be displayed on the Data Display.

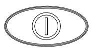
The following table presents a list of the measurements and calculations made by the CA-CALC analyzer. These will appear on the Data Display if the appropriate sensors are present.

O_2	Oxygen concentration. 0–25%
CO	Carbon monoxide concentration measurement made using the hydrogen compensated CO sensor. 0–5000 ppm
NO (optional)	Nitric oxide concentration 0–4000 ppm
NO_2 (optional)	Nitrogen dioxide concentration. 0–500 ppm
NO_X (optional)	Concentration combining NO and NO_2 concentrations. When a NO_2 sensor is not present, the NO_X concentration is assumed to be 5% of the NO concentration. No NO_X is displayed if the NO_2 sensor alone is present
SO_2 (optional)*	Sulfur dioxide concentration. 0–4000 ppm
COhi (optional)	Measurement of carbon monoxide made using the high concentration CO sensor. 0–20000 ppm
TA (optional)	The *combustion supply air* temperature. Only present when the accessory probe is used. –20–392 °F (0–200°C)
TAint	The temperature measured using the on-board RTD.
TS	Stack temperature. Displayed when thermocouple is plugged in. 32–1800°F (0–1000°C)
Draft	The Draft measurement. Only updated when the pump is off. ±30” H_2O (80 mbar)
CO_2	The carbon dioxide concentration in %. Based upon the O_2 measurement and fuel CO_2 Max parameter.
COr	The ratio of CO to CO_2. ppm CO/(%CO_2 x 10000)
EA%	% Excess air.
Lambda (λ)	Alternative excess air representation to %.
Effc	Combustion Efficiency, Net or Gross and (100 – qA)
Loss	Dry gas loss and Siegert (qA).

Special note: The SO_2 sensor has a negative response to NO_2 gas which is proportional to the NO_2 concentration. The CA-CALC analyzer corrects for the effect of NO_2 on the SO_2 sensor if an NO_2 sensor is present. A correction is also performed for the effects of NO_2 when a NO sensor is installed. In this case, the NO_2 concentration is assumed to be 5% of the NO measured concentration. The response of each SO_2 sensor to NO_2 is determined at the factory as part of the SO_2 sensor calibration.

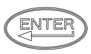
Buttons and Button Operations

ON-OFF Control Button (red)



Turns the instrument **on** and **off**. Pressing this button is accompanied by a beep.

The ENTER Control Button



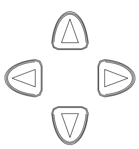
Press the **ENTER** button to execute a command, such as selecting a menu item. Most instrument display screens have a message indicating the **ENTER** button function.

Note: Pressing **ENTER** does not cause entered values to be saved to the instrument memory. Buttons with display labels such as **SAVE & EXIT** or **ACCEPT** are designed for saving.

The ESC Control Button

Press the **ESC** button to exit the current screen and operation, in most cases returning to the previous screen.

Arrow Control Buttons



The arrow buttons are used for three purposes:

Purpose 1. To move the *display cursor* to a menu item for selection using the **ENTER** key. The display cursor appears as a dark background over light characters. Example: Instrument Setup

Purpose 2. To move the *character cursor* to a character or character space.

Example:

Name: NAT GAS Character cursor on letter T.

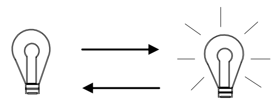
Purpose 3. To increment a numerical value or select a character from the character menu.

When a blinking cursor box is present, the arrow keys cause the value in the box to change; ON toggles to OFF, a *Name* character steps through a set of characters, or a number value increases or decreases.

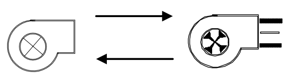
Icon Buttons

Button Icons appear on the right side of the display and are connected to an *Icon button* by an indicator line. The button icons correspond to the button functions described below. You will see that some icons change when the button is pressed, indicating a change in a current status (e.g., pump on/off), or indicate that a new operation will be performed when the button is pressed again. This is true of the Display button that changes from the *graph icon* to the *zoom icon* to the *un-zoom* icon.

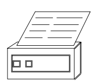
Icons **Icon Description**



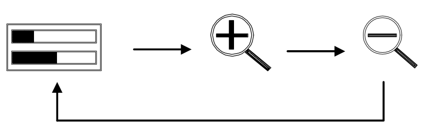
Back Light button icon. Left icon indicates light off, right icon indicates light on.



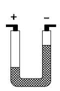
Pump On-Off button icon. Left icon indicates pump off, right icon indicates pump on.



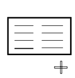
Print a Sample. Press the button to the right of this icon to output the current data displayed on the Data Display screen through the serial port to the portable printer or a computer.



Display Icons. Button to the right toggles from the Graph display to the Zoom display to the Un-zoomed, standard Data Display.



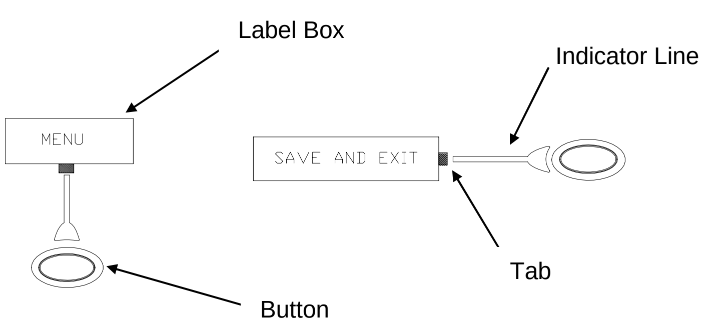
Draft Measurement. Press this key to take a draft measurement. This causes the pump to stop. A countdown begins during which time the draft reading is stabilized and taken.



Save Data. Save (log) current data on the Data Display screen.

Labeled Buttons

Button labels appear in boxes such as those shown below. The labels have tabs that connect to a button, performing the labeled function, by an *indicator line*. Examples are shown in the illustration below.



If no tab is present on a box, it is not linked to a button and is a *message box*. A good example of a message box is shown below.

```
 <--> move cursor
<ENTER> to restore
```

Message Box

Selecting Menu Items

Menus are lists of items or options you select to perform a needed operation. Selection of a menu item begins by moving the display cursor to the item and pressing the **ENTER** button. The display cursor is moved using the **Arrow** buttons.

Example: Display Cursor

Display Cursor

Zoom Settings
Instrument Setup
Calibrate Sensors
Restore Factory Cal
Set Contrast
.
.

Once the **ENTER** button is pressed, a new menu may appear with a new list of option items, or you may see a blinking cursor indicating that a number value, or unit value can be changed. If you want to back-out of a selection, simply press the **ESC** button.

Changing a Number Value

The CA-CALC combustion analyzer has a variety of number values that are changeable. Examples are the Contrast level, Time and Date, O_2 Reference, and so on. Press the **ENTER** button on the list item to initiate a change. A value becomes *changeable* when a blinking cursor box surrounds it.

Example: Changeable number value.

Contrast: 50

Blinking cursor indicates value can be changed using the **Arrow** buttons.

Use the **Arrow** buttons to increase or decrease the indicated value. Note—there are upper and lower limits on values. When an upper or lower limit is reached, the numbers wrap around.

Use the **SAVE & EXIT** button to install the new value.

Changing Units

Data displayed by the CA-CALC analyzer can be presented in different units. To change units, first select **Instrument Setup** from the main **MENU**. Use the **Arrow** buttons to select from the list of available units. Press **ENTER** to make a selection. A blinking cursor box over the selected unit indicates that it is *changeable.* Use the **Arrow** buttons to change between available units. Press **ENTER** once the desired units are shown, then use the **SAVE & EXIT** button to install the new unit.

Refer to "Instrument Setup" in Chapter 6, "MENU Selections and Menu Items," for specific information on unit types.

Entering and Changing Names

Names include the fuel types and data saving identifications: **Site**s, **Device**s and **Sample**s. To create or edit a name, use the **Arrow** buttons to move the cursor to the desired character space and press the **ENTER** button (see the example below). The blinking cursor indicates that a character can be changed or added if none exists.

Note: A character table is displayed when **ENTER** is pressed. Use the Arrow buttons to choose any character in the table. Press **ENTER** to install the selected character. Repeat this process to enter all your required characters.

When the entries are complete, press the **SAVE & EXIT** button to install the name.

Example: Name entry

Move character cursor with **Arrow** buttons. Select using the **ENTER** button.

Name: A B C D

Blinking cursor after **ENTER.** Change character with the **Arrow** buttons. Use **ENTER** to accept character.

Name: A B C D

Finish by pressing the **SAVE & EXIT** button to install new name.

To select an item from a menu list use the **Arrow** buttons to highlight the item, then press **ENTER**.

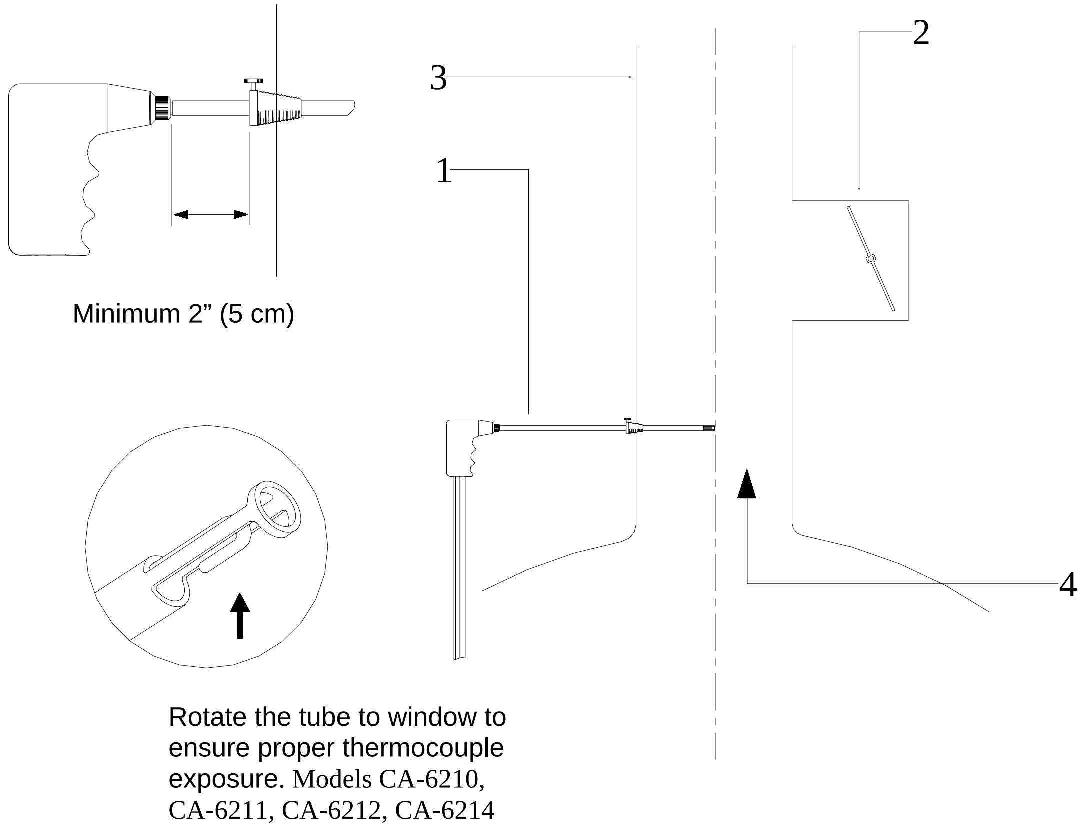
Using the Sampling Probe

Gas and Temperature Measurements

Connect the sampling probe to the CA-Calc 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 7. 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. **Important:** Twist sampling tube to ensure that the thermocouple tip is exposed directly to exhaust flow (see figure below).



1. Sampling probe
2. Draft regulator
3. Exhaust flue
4. Hot exhaust gases

Figure 7: Sampling Probe Location

Stack temperature measurement is extremely important to establish the heat loss from the exhaust gases and determine combustion efficiency. The S*ampling Probe* with its integral thermocouple measures temperature at the probe tip. The tip should be placed at the point of highest exhaust gas temperature when determining efficiency. This means at the base of the flue, before heat is lost to the flue side-walls, and towards the center, especially for small ducts. If the stack gas temperature is underestimated, the operating efficiency will be overstated. When an economizer or air heater is used, the stack temperature is measured after these devices.

Note: When an Emission Probe is used, allow adequate time for the temperature to stabilize before accepting the combustion efficiency measurement (5–10 minutes).

Cautions

Hot probe! 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.

Empty Water Trap! Watch the water trap and empty it frequently to prevent the possibility of flooding the instrument. See Chapter 9 for instructions.

Making a Draft Measurement

Before making a draft measurement, zero the draft pressure transducer by pressing the **ZERO DRAFT** option button in the Data Display. For zeroing, make sure the sampling probe is out of the flue, or that the draft and sample fittings are disconnected from the instrument. Once zeroed, reinsert the sample probe and press the **Draft Measurement** icon button to initiate a draft measurement.

During the draft measurement, the sampling pump is automatically turned off.

When the draft measurement is complete, the pump turns on again.

Note: Draft readings are also taken continuously whenever the pump is turned off. When the pump is turned on again, the current draft reading is captured, and remains displayed until the next time the pump is turned off or the **Draft Measurement** icon button is pressed.

Auto Draft Meas. Feature

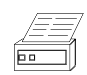
The **Auto Draft Meas.** feature is used so that a draft reading is automatically taken whenever a sample is saved using the **Save Data** icon button. To activate automatic draft saving, set the **Auto Draft Meas.** item to **On** from the **Instrument Setup** menu.

Printing to the Portable Printer and to a Computer

Printing

Instrument data can be output through the RS232 serial port to the optional Model 8925 portable printer. First refer to “Connecting the Optional Portable Printer” in Chapter 4, “Getting Started.” Make sure the baud rate is set correctly.

To print the information on the Data Display, press the **Print a Sample** icon button.



The printer responds immediately once the button is pressed, producing a printout. Example printouts are shown in Figure 8.

Data is also printed using the logging functions accessed by pressing the **LOGGING FUNCTIONS** option button. The logging functions enable you to print saved data as a single **Sample**, or as many **Samples** saved under a **Site** or **Device** name. Chapter 7, “Saving Data and LOGGING FUNCTIONS,” identifies the buttons used to perform these printing operations.

When data is printed from **LOGGING FUNCTIONS**, the **Site** and **Device** names are presented as well as the **Sample** name. In addition, fuel parameters used in the calculations are also printed. An example of a **Sample** printout from **LOGGING FUNCTIONS** is shown on the right in Figure 8.

Printing to a Computer

Use the print buttons and print functions to output data to a computer as well as to the portable printer. First refer to “Connecting a Computer” in Chapter 4, “Getting Started.” Make sure the **RS232 Device** is properly set to **Computer**, and that the baud rate is set correctly.

Data transferred to a computer is the same as that output to a printer (see Figure 8); however, it is formatted differently and uses the Windows® character set rather than DOS characters. Setting the **RS232 Device** tells the CA-CALC combustion analyzer how to output the data. Data transferred to a computer is t*ab-delimited* so it can be more conveniently *parsed* when using spreadsheet applications such as Microsoft Excel®.

®Windows and Excel are a registered trademarks of Microsoft Corporation.

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.

Communications Protocol

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

```
DATE: 01/01/99
TIME: 15:00:18
Fuel: Nat Gas
O2REF: Off

O2          6.0
CO          5 PPM
NO          0 PPM
NO2         0 PPM
NOx         0 PPM
TA          70 °F
TS          300 °F
Draft       0.01 inH2O
CO2         8.4 %
Lambda      OVER
Effc        84%
```

Printout using the **Icon** button.

```
Site: 1( site name
Device: 1( device name
Sample: 1(sample name)
DATE: 01/01/99
TIME: 15:00:18
O2REF: Off
Fuel: Nat Gas

Fuel Parameters:
Carbon wt.:  79.9%
CO2 max vol.: 11.8%
Sulfur wt. 0.0%
Moisture. 0.0%
HHV(BTU/lb): 21869

O2          6.0
CO          5 PPM
NO          0 PPM
NO2         0 PPM
NOx         0 PPM
TA          70 °F
TS          300 °F
Draft       0.01 inH2O
CO2         8.4 %
Lambda      OVER
Effc        83.8 %
```

Printout from **LOGGING FUNCTIONS**.

Figure 8: Example Printouts

Chapter 6. MENU Selections and Menu Items

Select from items in the *main menu* to perform setup operations. Access the main menu by pressing the button labeled **MENU**. Following is a list of the main menu items and the underlying menus. In this chapter, main menu items are described in sections in the order they appear in the menu, beginning with the **Zoom Settings** followed by **Instrument Setup** and so on.

It will be useful to review sections of the previous chapter dealing with selecting menu items, changing number values, units and names before proceeding. Recognize that for most operations, the procedure is as follows: use the **Arrow** buttons to highlight a menu item, use the **ENTER** button to select the menu item, use the **Arrow** buttons make modifications, and finally use **SAVE & EXIT** to implement the change.

(**MENU** main menu)
Zoom Settings
Instrument Setup
Calibrate Sensors
Restore Factory Cal
Set Contrast
Set Time and Date
Select Default Fuel
Fuel Setup
Restore Fuel Settings
Erase All logged Data

ZOOM SETTINGS
O2
CO
NO
NO2
NOX
SO2
TS
TA
Draft
CO2
EA

INSTRUMENT SETUP
O2REF
O2REF Level
Temp:
Draft:
Excess Air
Effc./Loss
Fuel Heat
Gas Conc.
Decimals:
Auto Draft Meas:
Baud rate:
RS232 Device
CO Alarm Level
NO Alarm Level:
Effc/Loss Basis

CALIBRATE SENSORS
O2
CO
NO
NO2
SO2
TS
TA
Draft

RESTORE FACTORY CAL
O2
CO
NO
NO2
SO2
TA
TS
Draft

SET DATE AND TIME
Date:
Time:

SELECT FUEL TYPE
Nat GAS
Propane
Oil #2
Oil #6
Coal
Wood(dry)
Bagasse
Coke
User Type
User Type
User Type
User Type
User Type

FUEL SETUP
Nat GAS
Propane
Oil #2
Oil #6
Coal
Wood (dry)
Bagasse
Coke
User Type
User Type
User Type
User Type
User Type

Zoom Settings

In the Zoom Settings screen you can select two parameters to be displayed in large characters. The large character display appears when the Zoom Display Icon button is pressed.

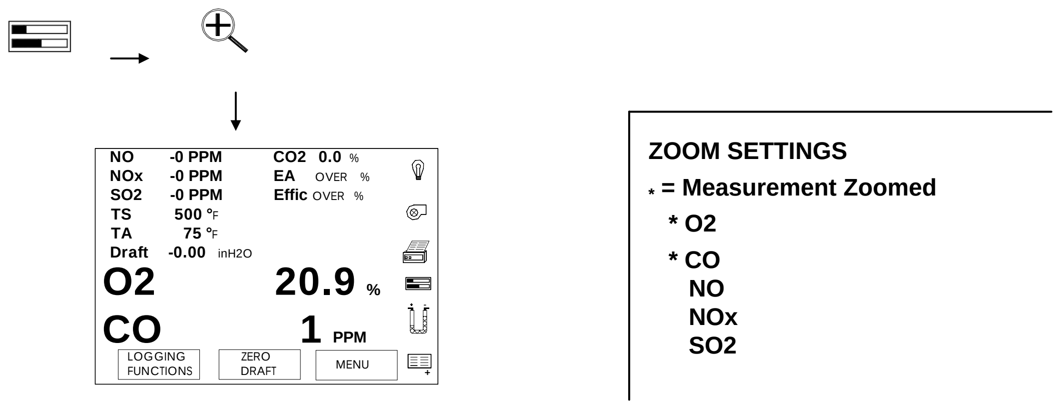


Figure 9: Example Zoom Display and Zoom Settings Screen

To set the parameters for large display select **Zoom Settings** from the **MENU** items.

Choose a parameter from the list in the **Zoom Settings** menu by moving the cursor to a list item using the **Arrow** buttons, and pressing **ENTER**. An asterisk appears by the selected parameter. Two parameters can be chosen.

Instrument Setup

Below is a list of **Instrument Setup** options. These are discussed on the following pages. Some of the items below are calculated. Refer to Appendix A, "Calculations," later in this manual for information.

O_2REF
O_2REF Level
Temp:
Draft:
Excess Air
Effc./Loss
Fuel Heat
Gas Conc.
Decimals:

….more….

This indicates additional items are available beyond those currently displayed. Use the down **Arrow** button to access these items.

Auto Draft Meas:
Baud rate:
RS232 Device
CO Alarm Level
NO Alarm Level:
Effc/Loss Basis

Instrument Setup

Item Description	Options
O_2REF: Enable or disable the O_2 reference calculation. The O_2 reference applies to the CO, NO, NO_2 and SO_2 measurements. Refer to the next item below.	Select between: On Off
O_2REF Level: This option is used to set a value for the O_2 reference level used in the reference calculation. Refer to Appendix A, "Calculations," at the back of this manual.	The O_2 reference level can be adjusted between 0 and 18%.
Temp: This option is used to select temperature units for display.	Temperature units are: Degrees Fahrenheit, °F Degrees centigrade, °C
Draft: This option is used to select draft units for display.	Optional Draft units are: inH_2O kPa mbar hPa
Excess Air: This option is used to select between options for the display of excess air.	Options for displaying excess air are: %EA Lambda,(λ)
Effc./Loss: Choose to display Net Efficiency, Gross Efficiency Loss *or* qA and Effic. for the Data Display. Options for display will depend upon the **Effc/Loss Basis** selected (ASME or Siegert). Refer to the Fuel Setup section and Appendix A, "Calculations," later in this manual. To change the **Effc/Loss Basis**, refer to the item description found later in this section.	The options for the display of fuel combustion efficiency are: **ASME** Effc. Net, Effc Gross, Loss **Siegert** qA Effic. = 100 – qA
Fuel Heat: This option allows you to select whether the high heating value (HHV) of the fuel, or the low heating value (LHV) of the fuel. Fuel heating value is used when calculating combustion efficiency or loss. Units for fuel heat are also selectable between BTUs/lb. and kJ/kg. **Note**: Emission factors will change to metric units when kJ/kg fuel heat units selected (see Appendix A).	Fuel heat options: BTU/lb HHV BTU/lb LHV kJ/kg HHV kJ/kg LHV

Instrument Setup *(continued)*

Item Description	Options
Gas Conc.: Change gas concentration units for display gas concentration using this option. The selections of units applies to all gases accept the O_2 and CO_2. These are expressed as percent only. Units relating the weight of the gas to the fuel energy input use the conversion factors, **FNOx**, **FSO_2**, **FCO** displayed in the **Fuel Parameters** screen.	Select units for concentration display from the following: PPM parts per million g/MWh grams per megawatt hour mg/MJ milligrams per mega-joule ng/J nanogram per Joule mg/kJ milligrams per kilo-joule #/Mbu pounds per million Btus mg/m3 milligrams per cubic meter g/bhph grams per brake horsepower hour mg/kWh milligrams per kilowatt hour g/kWh grams per kilowatt hour
Decimals: Select between periods or comas to use when expressing decimal notation.	Select from: Commas Periods
Auto Draft Meas: When On is selected, this option causes the instrument to automatically take a new draft measurement each time the **Save Data** icon button is pressed.	Chose between: On Off
Baud Rate: This option is used to select the baud rate for the serial output to an attached computer or printer. The default baud rate is 1200, which matches the default printer setting. If the baud rate is changed in the instrument, make sure it is also changed for your computer or printer.	Select from the following baud rates. 1200 2400 4800 9600 19200
RS232 Device: Select the **Device** (printer or computer) receiving the serial data. Sending data to the wrong **Device** results in the presence of bad characters.	Choose device to receive serial data: Printer Computer
CO Shutoff Level: Extended CO sensor exposures above the stated maximum overload concentration of 4000 PPM can cause temporary shifts in the CO readings. To help avoid this, the instrument automatically turns the pump off and displays a warning when the **Shutoff level** is exceeded for three seconds**.**	The CO shutoff level can be set over the range: 1000-5000 PPM: The default level is set to 2000 PPM. See Chapter 9, "High Concentration Overload"..
NO Shutoff Level: Extended NO sensor exposures to NO concentrations above the recommended maximum overload concentration (5000 PPM) can cause temporary shifts in NO sensor measurements. To avoid this, the instrument turns the pump off when concentrations remain over the **Shutoff level** for three seconds.	The NO shutoff level can be set over the range: 1000-5000 PPM: The default shutoff level is 1000 PPM See Chapter 9, "High Concentration Overload".

Instrument Setup *(continued)*

Item Description	Options
Effc/Loss Basis: Efficiency and loss are calculated based upon *heat-loss* (ASME) or Siegert calculations. Select between ASME or Siegert using the **Effc/Loss Basis** instrument setup option. In the U.S. select the ASME calculation to determine Net Efficiency. Use the high fuel heating value (HHV). Use the Siegert formula in Europe. Refer to the **Default Instrument Setting** section in Chapter 2. **Note:** Depending upon the basis selected for the efficiency and loss calculations, default fuels and fuel parameters in the **Fuel Setup** menu change. Refer to the **Fuel Setup** section later in this chapter and Appendix A for more information. **Note**: If you use this option to change the basis of your efficiency/loss calculations, it is necessary to use the **Restore Fuel Setting** following the change. Select **YES** for both factory and user fuels.	Select from the following options: ASME Siegert

Calibrate Sensors

Calibrate Sensors is the third selection in the main **MENU**. This is used when performing calibrations of the on-board sensors. Gas sensors, thermocouples and the draft sensor can all be calibrated. When the **Calibrate Sensors** option is selected, the display menu appears as in the example below (Figure 10). Only installed sensors are listed. Select the sensor for calibration using the **Arrow** buttons and **ENTER**.

For specific information regarding calibrations, refer to Chapter 8, “Calibrations,” found later in this manual.

Calibration:

Name	Reading	Units	Serial	Last cal
O_2	20.9	%	01020001	01/02/99
CO	-1	PPM	01200002	
NO	-1	PPM	01200003	01/02/99
NO_2	-1	PPM	01200004	01/02/99
SO_2	-1	PPM	01200005	01/02/99
TS	75	F		01/02/99
TA	75	F		01/02/99
Draft		inH20		01/02/99

<--> move cursor
<ENTER> to calibrate

Figure 10: Screen to Select Sensor for Calibration

Restore Factory Cal

In the event that a sensor calibration is performed in error, or the calibration(s) becomes corrupted, the initial sensor calibration performed at the factory can be re-installed. This is possible because factory calibration data is saved, either in the gas sensor electronics, or in the instrument. The initial data is never discarded. Calibrations are restored for individual sensors by selecting the appropriate sensor from the list in the **Restore Factory Cal** screen, and pressing **ENTER**.

Set Contrast

The **Set Contrast** option is used to lighten or darken the display, improving visibility. Once **Set Contrast** is selected with **ENTER**, set the contrast using the **Arrow** buttons to increase (darken), or decrease (lighten) the contrast value. The default is value is 50. Use the **SAVE & EXIT** button to save the new contrast setting.

Set Time and Date

Once selected from the main **MENU** using **ENTER**, a blinking cursor in the **Set Time and Date** screen indicates the number field is changeable. The up/down (▲ ▼) **Arrow** buttons are used to increase or decrease the indicated value. To move between entry fields use the left/right (◄ ►) **Arrow** buttons. Time and date have the following format:

Date: Month/Day/Year
Time: Hour:Min.:Sec.

Use the **SAVE & EXIT** button to save new settings.

Select Fuel Type

Use this selection from the main **MENU** to choose the type of fuel being burned. When you select a fuel type, you install *fuel parameters* for this fuel. Fuel parameters are used to perform calculations of CO_2, combustion efficiency, loss, and emission rates. These calculated values are ***not*** correct if the wrong fuel is specified! The fuel list includes eight *standard* fuel types (five when Siegert basis used), with nominal fuel parameter values, and five *User* fuels. More information on fuels is included in the next section “Fuel Setup.”

Fuel Setup

This menu selection lets you change fuel parameters for existing fuel types and add new fuel types to the fuel list. When the **Fuel Setup** is selected from the main **MENU**, the fuel list is displayed together with a table of fuel parameters. Use the **Arrow** buttons to move to a fuel in the fuel list. The fuel parameters in the table automatically update for the highlighted fuel. See the example display in Figure 11 below.

Fuel Setup

Nat Gas
Propane…..
Oil #2
Oil #6
Coal
Wood(dry)
Bagasse
Coke
User 1
User 2
User 3
User 4
User 5

Fuel parameters

Carbon wt.:	81.8 %
Hydrogen wt.:	18.2 %
CO2 max vol.:	13.8 %
Sulfur wt.:	0.00 %
HHV(BTU/lb):	21669
LHV(BTU/lb)	19693
Moisture:	0.0%
F.SO2:	0.00145
F.NOx:	0.00104
F.CO:	0.00063

Table of fuel parameters for highlighted fuel (Propane).

Figure 11: Fuel Setup Screen—Selecting Fuel to Change Parameter

To modify parameters for the highlighted fuel, Press **ENTER**. The fuel parameters screen appears as in Figure 12 below.

Use the **Arrow** buttons to move the cursor to the field to be changed. This can be a letter in the fuel name, or a fuel parameter with a number value. Press the **ENTER** button to choose the highlighted field. A *blinking* cursor appears, indicating that the field is changeable.

Use the **Arrow** buttons to increase or decrease a value in the chosen field, or select a character from the character table. The character table appears when a character in the fuel name is highlighted and **ENTER** is pressed. A fuel name can be comprised of any character in the character table.

Press the **SAVE & EXIT** to install your new entries. **ESC** will abort any changes.

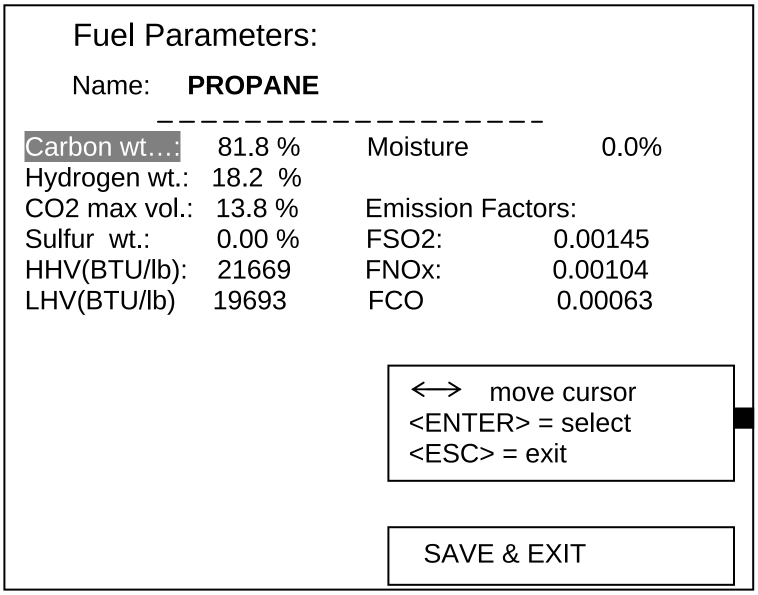


Figure 12: Fuel Parameters Screen—Select and Change Fuel Parameters

Fuel Setup When Siegert Loss Calculation Used

When **Siegert** is selected from the **Effc/Loss Basis** option, flue losses and fuel efficiency are calculated using the Siegert formula (see Appendix A). The fuel parameters are different than those identified in the section above. The Siegert formula for flue gas loss uses constants A1 and B, replacing the weight percents of C, H, S and the fuel heating values (HHV and LHV). These constants are derived from the fuel's composition and incorporate the low heating value into the loss calculation.

To change these values, or enter values for new fuel types, follow the same procedure outlined in the previous sections above. Remember to use the **SAVE & EXIT** button when complete. For information on the Siegert calculation, refer to Appendix A.

Restore Fuel Settings

Fuels one through eight (1-8) in the fuel list are set at the factory, together with their fuel parameters. These fuel values are saved in the instrument, and can be changed if desired using the **Fuel Setup** option. Fuels 1-8 can also be restored to the initial factory setting if needed. To return values to the factory settings after changes have been made, select **Restore Fuel Settings** from the main **MENU**. Choose the **YES** option button when required. **Restore Fuel Settings** does not affect the *User* fuels (9-13), however, you are given a chance to clear your user fuels by selecting **YES** when requested. Skip this process by selecting **NO** or pressing **ESC**.

Remember to use this option after changing the **Effc/Loss Basis**.

Erase Logged Data

Use the **Erase Logged Data** function to clear the instrument's logging memory. When this option is selected, press **YES** to perform the clean-up operation. Choose **NO** or **ESC** to abort the erasing process.

!	Caution
	This option permanently erases all user entered **Sites, Devices** and **Samples** from the CA-CALC combustion analyzer logging memory.

Chapter 7. Saving Data and LOGGING FUNCTIONS

A key feature of the CA-CALC™ combustion analyzer is the ability to save combustion and emission test data to memory in the instrument. This data can be retrieved later for printouts, downloaded to a computer, or used for comparison with other tests. Data is maintained by power supplied from a 2-year lithium battery on-board the instrument. There is the possibility that if the instrument is dropped, lithium battery power could be lost with subsequent loss of data. Important data stored on-board should be saved periodically to a computer or printed for a permanent record.

Overview

The CA-CALC analyzer saves data **Samples** when the **Save Data** icon button is pressed. A **Sample** is a snapshot or log of the data appearing on the Data Display screen.

The **Save Data** icon button

Data **Samples** consist of all the sensor data, units, time and date, and O_2 reference values. In addition, the saved data includes fuel type and fuel parameters. The CA-CALC analyzer saves up to 350 **Samples**.

To improve data retrieval for comparisons, printing or downloading to a computer, the CA-CALC combustion analyzer relies on structured saving environment with data management functions. The data management functions are accessed using the **LOGGING FUNCTIONS** button on the main Data Display.

LOGGING FUNCTIONS Data management functions.

The structured data environment provided by the **LOGGING FUNCTIONS** is particularly useful for the testing contractor who has numerous customers (**Sites**), who may in turn have multiple furnaces or boilers (**Devices**) requiring service.

Samples can be saved under a **Device** name. Multiple **Device**s can be saved under a **Site** name. Refer to the schematic below. This shows the data saving organization.

CA-Calc Data Management Structure

Sites (35 possible)

Devices (75 possible)

1)***Device 1***
2)***Device 2***
.
.

Samples (350 possible)

1) *sample name*
2) *sample name*
3) *sample name*
4) *sample name*
.

Before saving a Sample, it is necessary to define a **Site** and **Device**. This is discussed in the following two sections.

Saving Data When no Site or Device is Selected

It is necessary to choose a **Site** name and **Device** name before saving data **Samples**.

If a **Site** and **Device** has not been selected when the **Save Data** button is pressed, the following message is displayed:

Store Data:

A Site and Device need to be selected for logging
Press <**ENTER**> to continue

Message appears if no **Site** and/or **Device** selected.

By pressing **ENTER**, a screen appears which is similar to that displayed when the **LOGGING FUNCTION** button is pressed. You will be given a chance to select from previously created **Sites** and **Devices**, or to **ADD** a **Site** and **Device**. Other functions will be available too, giving you a chance to **DELETE** or **EDIT Site**s and **Device**s. Once a Site and Device are selected or created press <CONTINUE LOG> to proceed with data sampling. Figure 13 on the next page outlines the data saving process.

Creating or selecting **Site** and **Device** and other logging functions are described in "LOGGING FUNCTIONS," immediately following the next section.

Saving Data to Selected Site or Device

Once a **Site** and **Device** have been created and selected, **Samples** can be saved using the **Save Data** icon button. Before saving data, decide if you want a draft measurement to be taken and saved with each sample. If yes, turn **Auto Draft Meas**. *On* from the **Instruments Setup** menu option in the main **MENU**. Refer to Chapter 6, "MENU Selections and Menu Items," for more on the **Auto Draft Meas.** function.

The **Save Data** icon button

When the **Save Data** button is pressed, and once an automatic draft is completed or skipped, the instrument displays a screen allowing you to: confirm the current **Site** and **Device** selection, save to another **Site**/**Device**, or choose not to save at all. To continue, press the button under the label **YES**. You will be asked to enter a name for the sample. If you select **YES**, a name entry screen will appear. When complete, press **SAVE & EXIT** to save your data under the entered name. If you do not want to enter a name, simply press **NO**. Data will be saved under a number designation. For example, **Sample 5** appears as **5)** in the sample list, (i.e., number followed by open parentheses). The number and parentheses become the sample name.

Samples are automatically incremented so you will not overwrite previously saved sample data. The number designation preceding the name becomes part of the name itself, so the same name can be repeated.

The data saving process is presented in the schematic in Figure 13. Information introduced in the schematic regarding creating, deleting and editing **Sites** and **Devices** is provided in the next section, "**LOGGING FUNCTIONS**."

The **Save Data** icon button

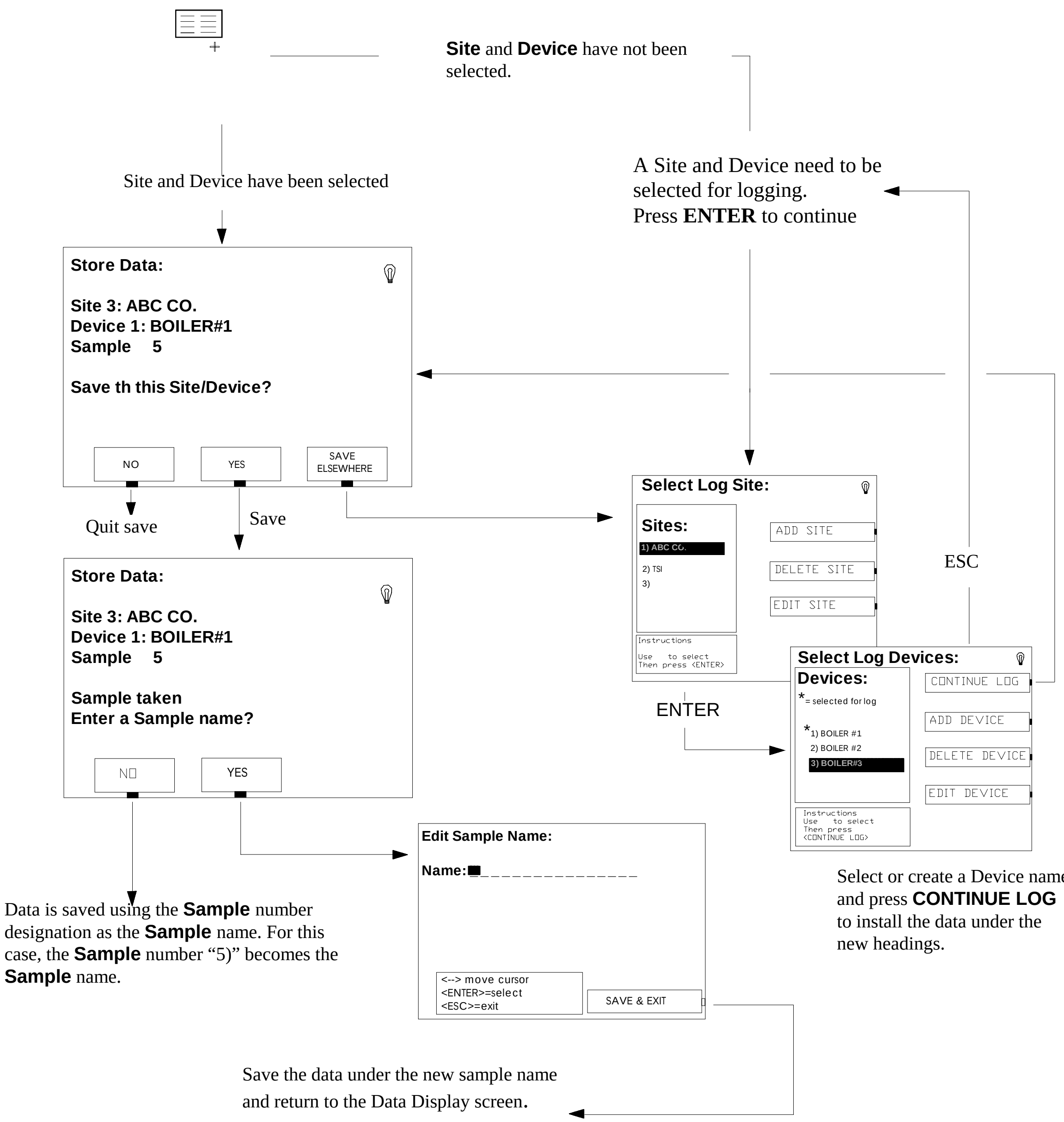


Figure 13: Schematic of the Data Saving Process

LOGGING FUNCTIONS

When using the logging routines, be sure to pay attention to all the information on the display screen, particularly in the message boxes. This will help steer you through the logging process and reduce confusion.

Note: When **ADD**ing or **EDIT**ing **Site**, **Device** or **Sample** names, follow the procedure described in “Entering and Changing Names” in Chapter 5, “Basic Operation.” Also, refer to the message box in the lower left of the display screens. These outline the steps to add or change characters.

Sites

When the **LOGGING FUNCTION** button is pressed, the **Log Functions: Sites** display screen appears. Here you are given the option to review existing site data, edit it, add new data, print the **Site** data and delete **Site** data.

To use options in the **Sites** display, shown schematically in Figure 14 below, first move the display cursor to a **Site** using the **Arrow** buttons. Next, select one of the button options on the right side of the display (e.g., **ADD**, **DELETE**...), or press **ENTER** to view **Devices** within the Site.

If no were Sites are created, you will need to add a **Site** using the **ADD SITE** button.

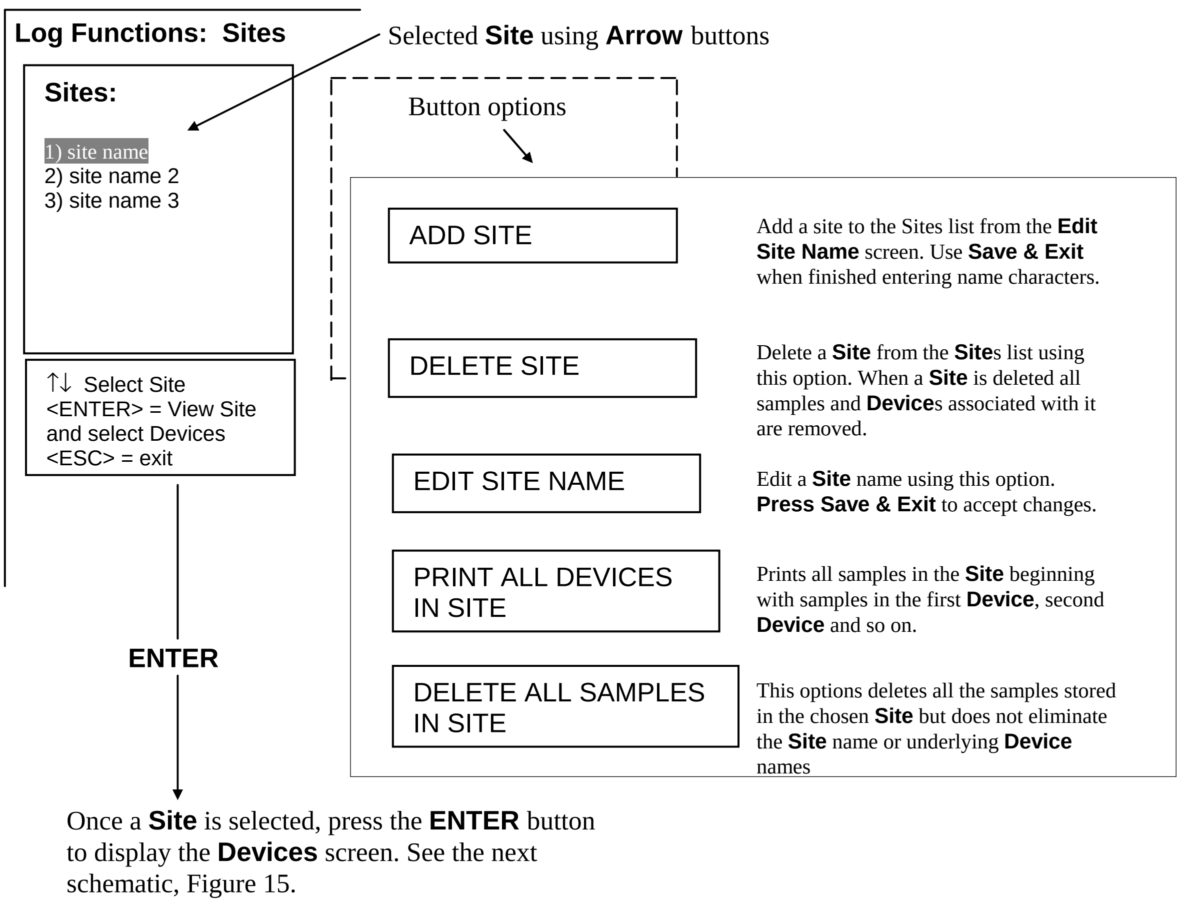


Figure 14: Schematic of the Log Functions: Sites Display Screen

Devices

From the **Log Function: Sites** display screen, a **Site** is selected using the **ENTER** key. This display screen which follows, shows the **Devices** in the **Site** and enables options for reviewing, selecting, adding, modifying **Devices**, and printing **Samples**.

Figure 15 below, provides a schematic representation of the **Devices** screen, and describes the purpose of each button option.

To use options in the **Devices** display, first move the display cursor to a **Device** with the **Arrow** buttons. Next select one of the button options on the right side of the display (e.g., **ADD**, **DELETE**...), or press **ENTER** to view **Samples** in the **Device**.

If no **Devices** were created, you will need to add a **Device** using the **ADD DEVICE** button.

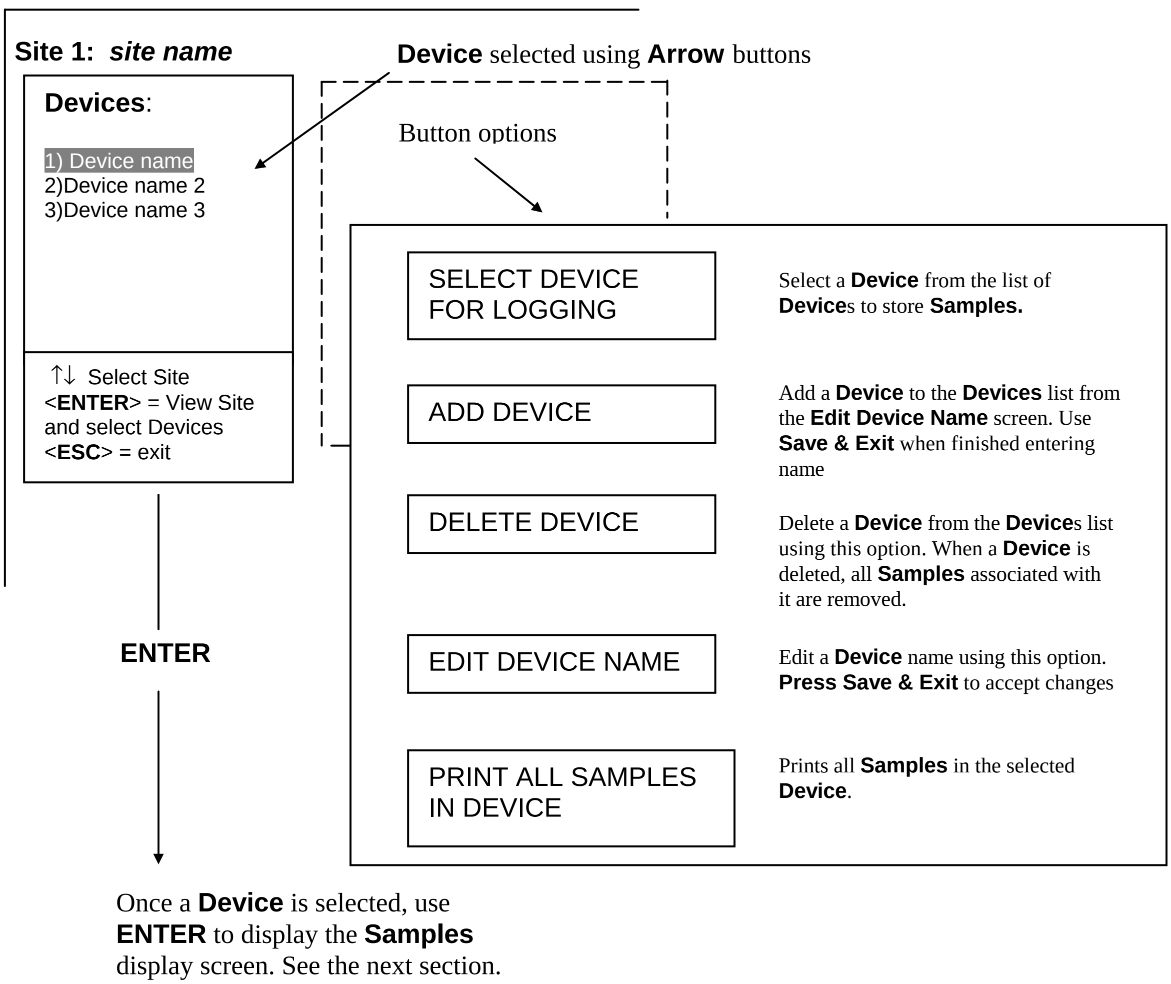


Figure 15: Schematic of the Devices Display Screen

Samples

If there are **Samples** present for a **Device**, they are displayed when a **Device** is selected from the **Devices** screen using **ENTER**. This was described in the previous section. The **Samples** display screen enables you to view your saved data, and also provides buttons letting you delete or print saved data.

Figure 16 below, provides a schematic representation of the **Samples** screen and describes the purpose of each button.

To use options in the **Samples** screen, highlight a **Sample** using the **Arrow** buttons, then select the button option. To view the highlighted **Sample**, press **ENTER**.

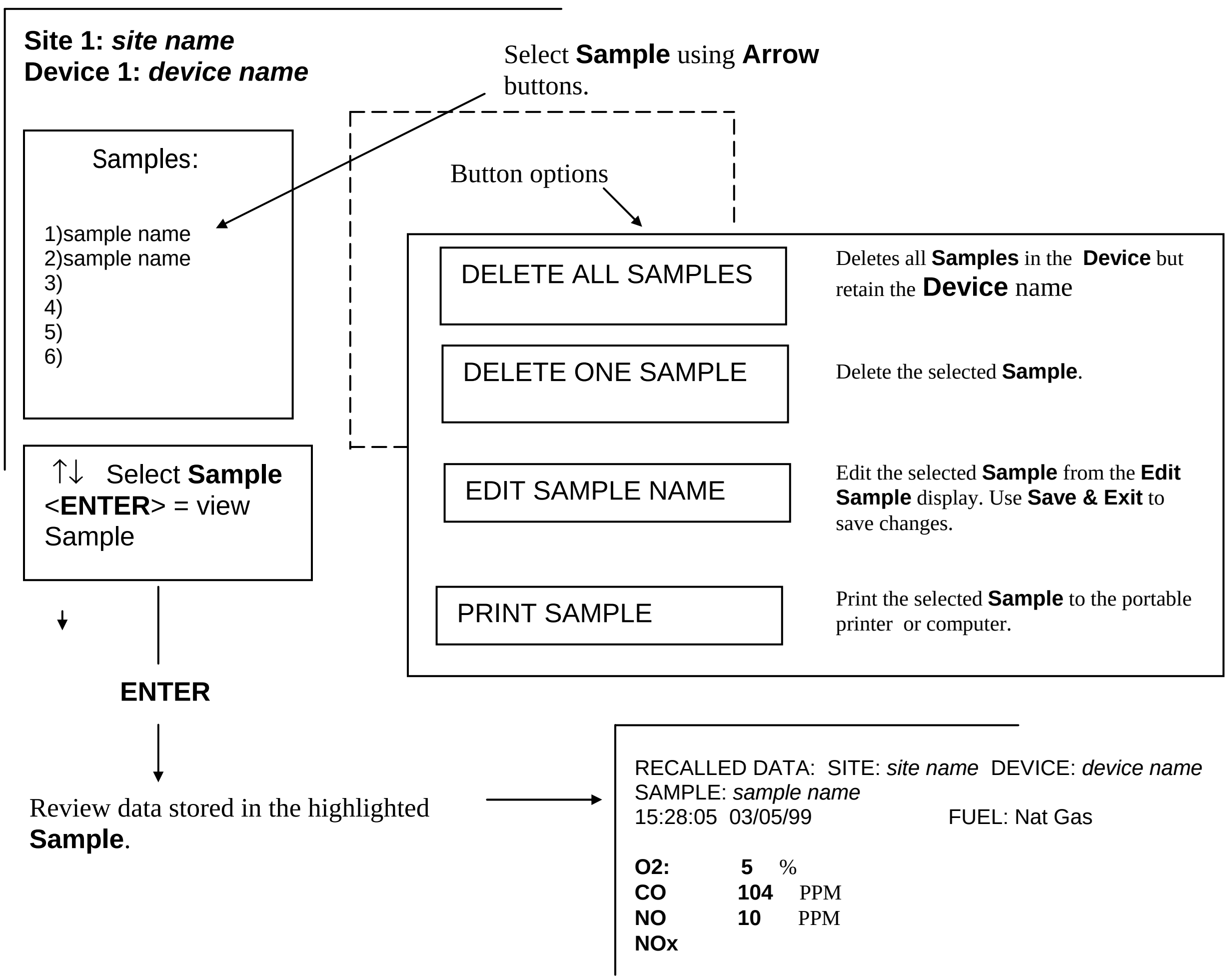


Figure 16: Schematic of Samples Display Screen

Chapter 8. Calibrations

Gas Sensors

Gas sensors can be calibrated periodically to maintain the accuracy of your gas measurements. Gas sensors do drift over time, depending upon the operating environment and gas exposure history. With the exception of the O_2 sensor, gas sensors may have a loss in signal of up to 2% per month. The O_2 sensor is subject to a possible loss of signal of 5% per year. With the proper equipment, such as that shown in the figures below, it is easy to calibrate your CA-CALC analyzer gas sensors. 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 17 and 18. A brief discussion of these calibration setups is presented in the following section.

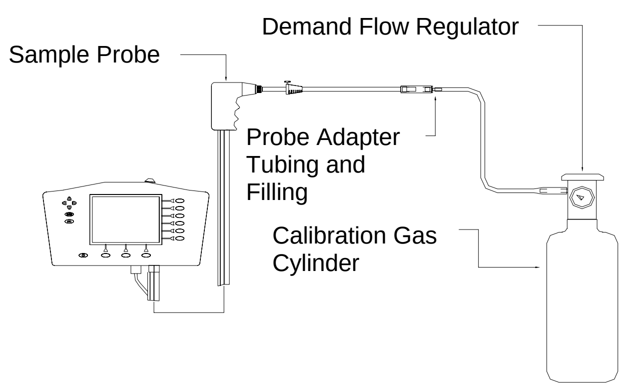


Figure 17: Calibration Setup Using TSI Calibration Kit Accessories

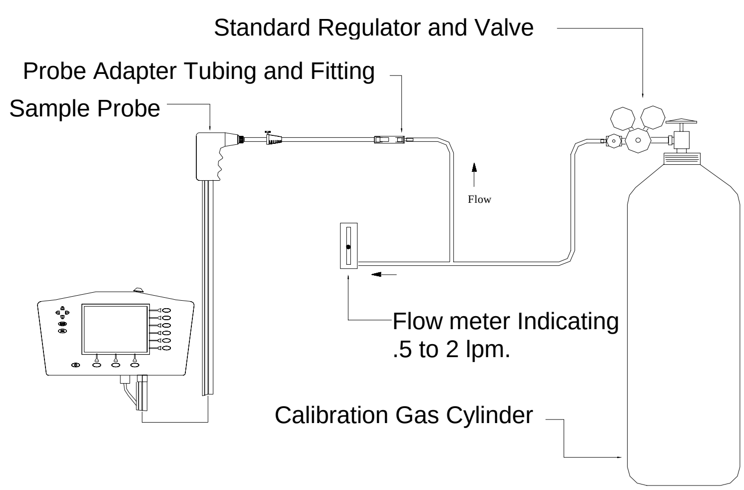


Figure 18: Alternative Calibration Setup

The Calibration Setups

A TSI supplied calibration kit (Figure 17) 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 18), the generic setup, supplies gas to the instrument using 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 LPM recommended). Extra flow is required to prevent room air from being drawn in, diluting the sample.

Calibrating the O_2 Sensor

To calibrate the O_2 sensor, ambient air (room air) is used as the *span* gas. Ambient air is almost universally 20.9% oxygen by volume. To calibrate the zero point, nitrogen (N_2) gas is used, free of O_2. The O_2 Calibration kit Model 801939 provides the zero gas, consisting of a cylinder of pure nitrogen.

Calibration Steps

From **MENU**, highlight **Calibrate Sensors**. Press **ENTER**. Highlight O_2 in the **Calibration** screen (refer back to Figure 10). Press **ENTER**. You will be given a chance to span the O_2 sensor with room air. Press **ENTER** to begin. Once the span is complete (150 sec.), accept the calibration by pressing **ACCEPT**.

Note: Leave the Actual value at 20.9 as indicated. Press **ENTER** to return.

Connect a bottle of pure nitrogen as shown in Figure 17 or 18. Start the calibration by selecting **YES.** Follow the instructions as indicated.

Special Note: Once exposed to pure nitrogen, the O_2 sensor takes time to fully recover. You will probably see a low room air concentration when returning to the main data display screen. For best accuracy, avoid performing a baseline calibration (which calibrates O_2 span) for at least fifteen minutes after zeroing the O_2 sensor.

Calibration of the CO (Hydrogen Compensated) Sensor

The hydrogen compensated carbon monoxide sensor comes standard with the CA-CALC analyzer. Although electrochemical CO sensors are sensitive to the presence of hydrogen (H_2), when calibrated properly, this specially designed sensor can be made non-sensitive to H_2. To perform a full calibration on this sensor, it is necessary to use two gas mixtures, one containing CO in air or nitrogen, and one containing a mixture of CO and H_2, also in air or nitrogen. The calibration kit, TSI Model number 801923 is recommended. This kit contains two calibration gas bottles, one containing 500 ppm CO, and one containing 500 ppm CO, 500 ppm H_2.

Calibration Steps

From **MENU**, highlight **Calibrate Sensors**. Press **ENTER**. Highlight CO in the **Calibration** screen (Figure 10) and press **ENTER**. Select **YES** when requested to re-zero the sensor. Make sure the sampling probe is in clean air and press **ENTER**. After 60 seconds, accept the new baseline reading by pressing **YES**. Follow the instructions that appear on the **CO Span Calibration** screen, and connect the CO calibration gas bottle. Refer to Figure 17 or Figure 18. Press **ENTER**. When the calibration is complete, use the **Arrow** buttons to adjust the CO concentration value in the blinking cursor box, to match the gas concentration in the CO calibration bottle. **ACCEPT** the new value. Next perform the calibration using the gas mixture of CO and H_2. Follow the instructions presented on the instrument screen, repeating the process outlined above. When finished, press **ENTER** to return.

Note: It is possible to do only the CO part of the calibration, bypassing calibration using the CO and H_2 mixture. Accuracy is not impaired if there is no hydrogen in your sampled gas.

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

Calibration of NO, NO_2, SO_2 and COhi (High Concentration) Sensors

The process of calibrating NO, NO_2, SO_2 and high concentration CO sensors are all similar. Recommended calibration kits are TSI Model 801937 for NO, Model 801938 for NO_2, Model 801936 for SO_2 and Model 801945 for CO high concentration.

Calibration Steps

From **MENU**, highlight **Calibrate Sensors**. Press **ENTER**. Highlight the gas for calibration. The **Calibration** screen is referenced in Figure 10. Press **ENTER**. Select **YES** when requested to re-zero the sensor. Make sure the sampling probe is in clean air and press **ENTER**. After 60 seconds, accept the new baseline reading by pressing **YES**. Follow the instructions that appear on the **Span Calibration** screen, and connect the gas calibration gas bottle. Refer to Figure 17 or Figure 18 for the appropriate connection method. Press **ENTER**. When the calibration is complete, use the **Arrow** buttons to adjust the gas concentration value in the blinking cursor box, to match the gas concentration in the gas calibration bottle. **ACCEPT** the new value. Press **ENTER** to return.

Draft Sensor Calibration

The draft sensor should be routinely zeroed using the **ZERO DRAFT** button on the main Data Display. This is especially important when draft pressure is below 1" of water column. A complete calibration of the draft sensor requires the use of accurate pressure standards. Your calibration will only be as good as the reference pressures used for the calibration. A calibration of the draft sensor is typically not recommended unless there is evidence that the sensor span has drifted.

Calibration Procedure

Required: An apparatus to provide stable calibration pressures of between *plus* 10-30 inches of water (2.5–7.5 kPa), and stable calibration pressures of between *minus* 10-30 inches of water (minus 12.5–7.5 kPa). Both are necessary for a calibration.

From **MENU**, highlight **Calibrate Sensors**. Press **ENTER**. Highlight the **Draft** option in the **Calibration** screen shown in Figure 10. Press **ENTER**. Disconnect any tubing from the Draft port (see Figure 2). Re-zero the Draft sensor when requested to do so by pressing **ENTER**. When the baseline calibration is complete (13 seconds), press **YES** to accept or **NO** to redo. Once the baseline is accepted, connect a positive calibration pressure of between 10 and 30 inches of water to the Draft sample port (15" is recommended). When the pressure is stable, press **ENTER** to begin the *positive* span calibration. When complete, adjust the draft reading within the *blinking* box to the exact value of your supplied calibration pressure. Then press **ACCEPT**. Next perform the *negative* pressure span calibration. This calibration is similar to that of the positive calibration just performed, with a negative pressure supplied rather then a positive pressure. Repeat the previous steps using your negative pressure calibration standard.

Note: For a calibration to be accepted by the CA-CALC combustion analyzer, the calculated calibration factor must be in the range of 14 to 17 inches of water (±) per volt. If not, an error is indicated and the calibration is not used. If this happens, it may mean there is a problem with the pressure transducer, your calibration pressure is not what you think it is, or you simply made a mistake in your calibration procedure. Redo the calibration.

Stack and Supply Air Thermocouple Calibration

Remember, your CA-CALC combustion analyzer may also be returned to the factory for this and other calibrations.

Calibration of the Stack and Supply air thermocouples is generally not recommended. The Type K thermocouples are inherently stable and repeatable. Nevertheless, a calibration is possible, and may be of value to compensate for electronic instrument drift occurring over time.

Note: Calibrations should only be performed by individuals having the proper equipment and training.

Calibration Procedure

Plug in the thermocouple to be calibrated. Select **Calibrate Sensors** from **MENU**. Highlight either **TS** or **TA**, depending upon the calibration of interest, and press **ENTER**. Place your thermocouple in an ice bath, 32 degrees Fahrenheit (0°C). Allow the probe to stabilize in the bath for 60 seconds, then press **ENTER**. When the test is complete (13 seconds), enter the true temperature as instructed, and **ACCEPT**. Perform the second part of span test at the high temperature, placing the probe in the hot reference (300 to 600°F recommended). Allow the probe to stabilize for a minimum of 60 seconds. Then begin the calibration by pressing **ENTER**. Once complete, enter the true temperature and **ACCEPT** the calibration. The instrument evaluates the calibration data and determines if it is reasonable. If not, an error message is displayed and the calibration data reverts to the previous calibration.

!	Caution
	When the sampling probe is submerged in the ice bath, the sampling pump must not be operated.

Chapter 9. Maintenance and Troubleshooting

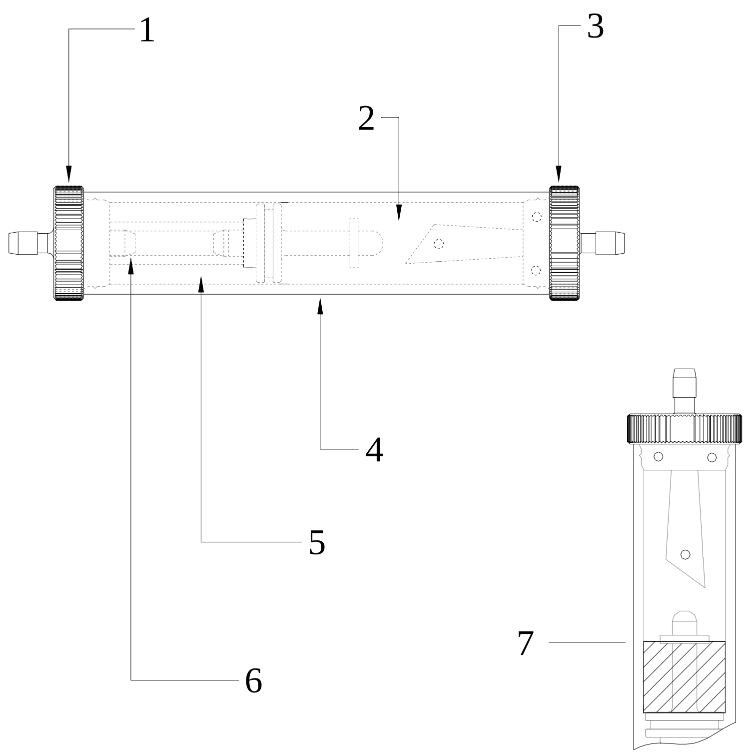
Emptying Water Trap

Refer back to Figure 2 showing the water trap in the sample line, and to Figure 19 below. 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.
4. Replace the end cap and re-install the trap.

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



1. Instrument side end-cap
2. First chamber
3. Probe side end-cap
4. Polycarbonate trap body
5. Second chamber
6. Plastic filter
7. Maximum water level

Figure 19: In-line Water Trap

Changing the Water Trap Filter

Identify the water trap filter (refer to Figure 19). 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 contaminates 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.

Cleaning the Sample Probe

Cleaning may be necessary in high-soot sampling environments. Much of the soot will probably accumulate in the SS sampling tube identified in Figure 2. The sampling tube is easily removed by loosening the sampling tube retaining fitting completely.

1. Separate the tube from the handle by pulling straight out so as not to bend the thermocouple.
2. Carefully wipe the thermocouple off and rinse the soot from the SS sampling tube.
3. Examine the interior of the probe handle. If there appears to be little build up of soot here, simply replace the sampling tube and retaining fitting. If significant buildup exists, water or isopropyl alcohol may work well to clean the tubing. Remove the water trap and pour the liquid through the elevated sample tube until it exits the probe end. Allow the tubing to dry prior to reuse.

High Concentration Overload

When the CO or NO concentration exceeds the **shutoff level**, as described in Chapter 6, “Instrument Setup,” the sample pump shuts off, preventing sensor exposure to very high gas concentrations. Before continuing use of the instrument, clean air must be supplied to reduce the gas concentration below the shutoff level. To do this, remove the probe from the sampling location then press the **Pump ON** key. The pump will run for sixty seconds. If the concentration is still above the shutoff level, the pump turns off. Turn the pump on again, and continue this process until the pump stays on. Before reusing, wait until the affected sensor reads at or near zero gas concentration.

The **shutoff level** set at the factory is low (1000 for NO, 2000 for CO). Increase the shutoff level to the maximum value of 5000 PPM to make measurements without the pump shutting off, refer to Chapter 6 “Instrument Setup.”

If the affected sensor is CO, you can close the CO diversion to prevent exposing the CO sensor to high CO gas concentrations and prevent pump shut-off.

Adding or Replacing a Gas Sensor

Gas sensors are warranted for one year, however sensors (O2 excluded) typically last two or three years.

Sensor Positions

Up to four different gas sensors can be used together with the CA-CALC analyzer. The sensors are installed in four positions identified as CO, S1, S2, O_2 (refer to Figure 20 on the following page). The standard instrument is supplied with an oxygen (O_2) sensor and a carbon monoxide (CO) sensor. The oxygen sensor **must** occupy the O_2 position, and is the only sensor that can occupy this position. The carbon monoxide sensor occupies the CO position after the CO diversion valve. Other sensors are placed in either S1 or S2.

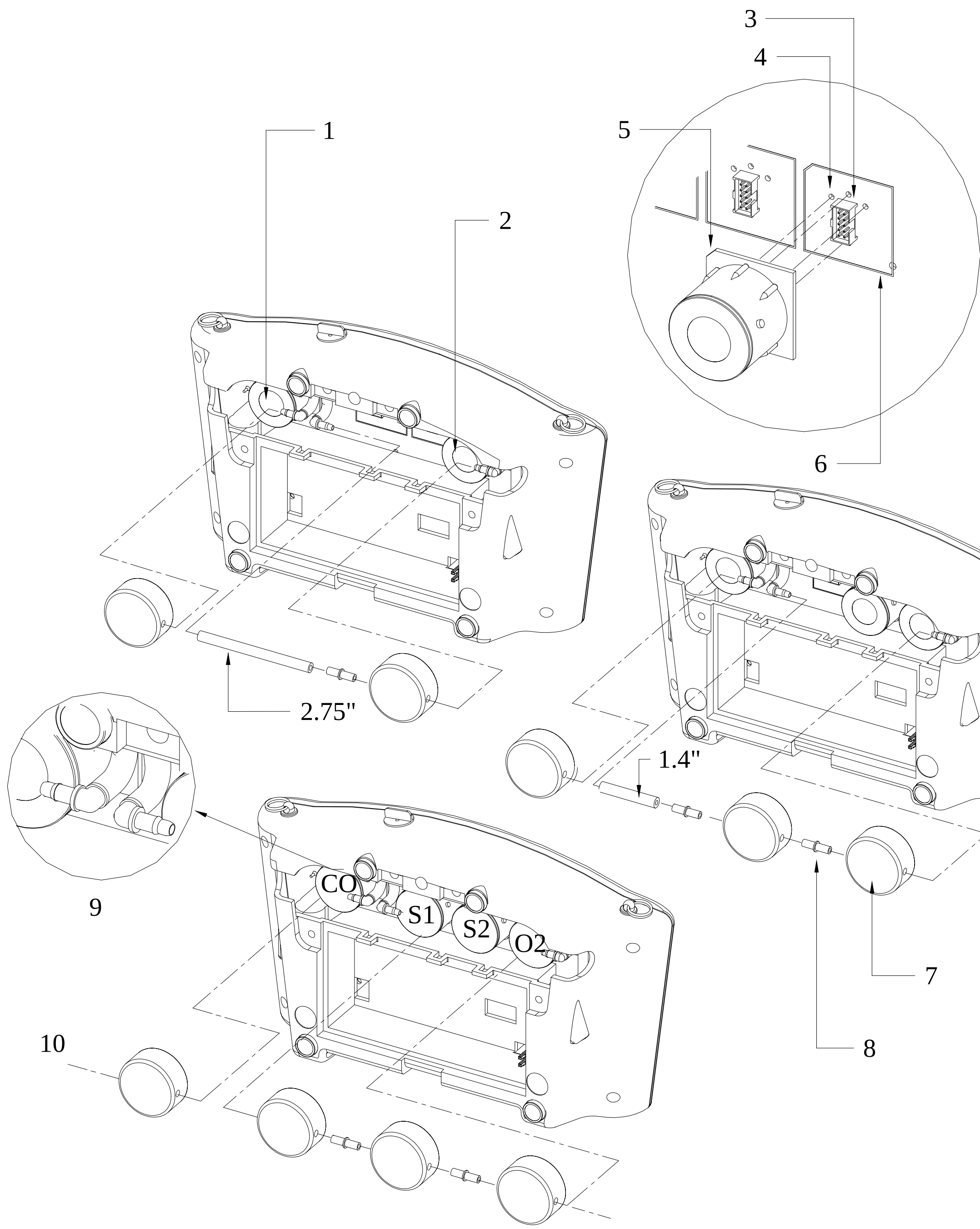
Replacing a Sensor

When a replacement sensor is received from TSI, the package may include a new sensor cup, fitting and tubing. These additional supplies are generally not needed for a replacement and may be put aside.

To replace a sensor:

1. Remove the sensor cover by removing the four cover screws.
2. Disconnect the sensor cups from the valve fittings shown in Figure 20, by pulling the fittings away from the attached sensor cups.
3. Grasp the sensor cups and pull up to separate them from the tops of the sensors. It is okay if the sensors come too. When removing the cups, keep the tube connecting the O_2 sensor cup from separating. If this tubing falls into the case it can be difficult to retrieve.
4. Note the location of the sensor being replaced. Remove it and set it aside. The replacement sensor goes in the same location.
5. When installing the replacement sensor, note the orientation of the notch on the sensor electronics board. This notch must align with the notch depicted by the outline drawn on electronics board. See the illustration in upper right corner of Figure 20.
6. Once the sensor is oriented, mate the four pins on the bottom of the sensor with the holes in the electronics board, aligning the sensor connector.
7. Push down gently to seat the sensor.
8. Replace the sensor cups. It is helpful to place a small amount of silicone vacuum grease on the inside surfaces of the sensor cups when replacing them. This will facilitate the assembly.
9. Push the cups down firmly over the sensors.
10. Before replacing the sensor cover, twist the sensor cups as necessary so the sensor cup fittings are on a common axis as shown at the bottom of Figure 20.
11. Once the sensor cover is replaced, make sure the outlet hole on the CO sensor cup is clearly visible through the sensor cover vent (see Figure 21).
12. Replace the sensor cover and cover screws. If the sensor cover does not fit readily over the sensor cups, it may mean the sensors or sensor cups are not properly installed.

(continued on next page)



1. CO (hydrogen compensated) sensor position #4
2. O_2 sensor position #1
3. Sensor matting connector
4. Holes for alignment pins
5. Alignment notch
6. Line on electronics board
7. Sensor cup
8. Sensor cup fitting
9. Valve fittings and tubing connections
10. Axis for sensor fitting alignment

Figure 20: Gas Sensor Installation

Adding a New Sensor

Sensors can be added to sensor S1 and S2 as shown in Figure 20. Positions O_2 and CO are reserved for the Oxygen (O_2) and hydrogen compensated carbon monoxide (CO) sensors, respectively. A third sensor should be added to S1, a fourth sensor to S2.

When your new sensor is received, the package will include a sensor, sensor cup, sensor cup fitting and tubing. These will be necessary for the installation.

1. Begin by removing the tube (1.4” or 2.75”) connecting the sensor to the CO diversion valve, see Figure 20. Leave the fittings intact.
2. When installing the new sensor, note the orientation of the notch on the *sensor* electronics board. This notch must align with the notch depicted by the outline drawn on *instrument* electronics board. See the illustration in upper right corner of Figure 20. Once the sensor is oriented, match the four pins on the bottom of the sensor with the holes in the instrument electronics board, aligning the sensor connector. Push down gently to seat the sensor. When seated properly, the sensor will not rock or twist.
3. Install the sensor cup fitting and tubing as shown in Figure 20. If the new sensor is in position 3, connect the 1.4” tube to the CO diversion fitting. If in position 4, push the diversion valve fitting directly into the sensor cup.
4. Replace the sensor cups. ***Note:*** *It is helpful to place a small amount of silicone vacuum grease on the inside surfaces of the sensor cups when replacing them. This will facilitate the assembly.* Push the cups down firmly over the sensors. Replace the sensor cover and cover screws. If the sensor cover does not fit readily over the sensor cups, it may mean the sensors are not properly seated. Reseat the sensors. Also, make sure the valve fittings are aligned with the sensor cup fittings.

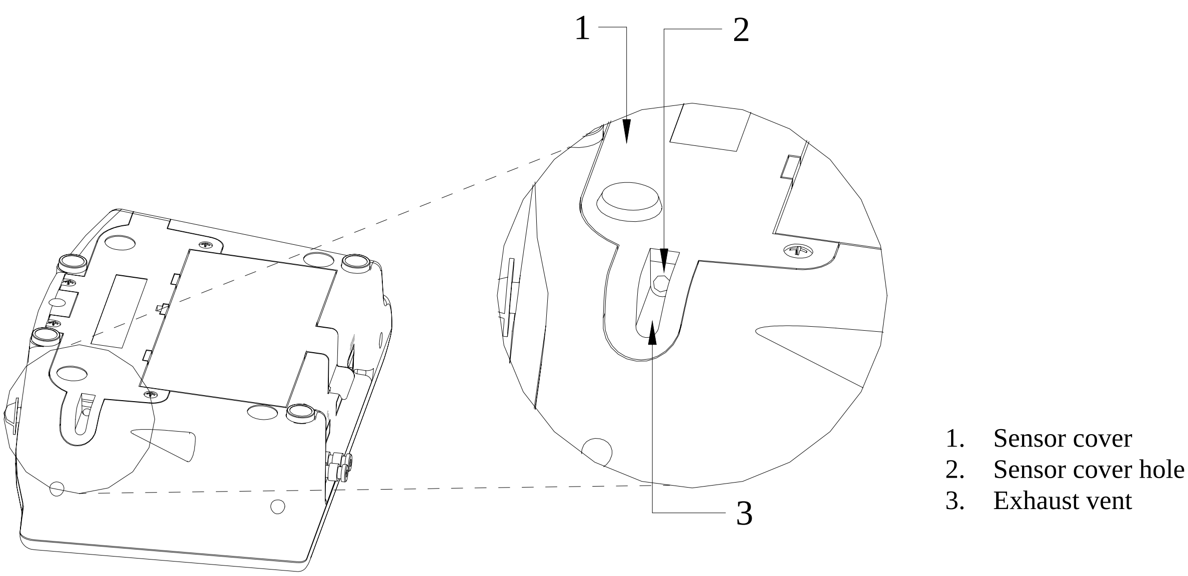


Figure 21: Alignment of Sensor Cup Hole with Sensor Cover Exhaust Vent

Troubleshooting Chart

Error message(s) after startup.	"Unrecognized sensor error" requires sensor replacement. "Ref. Voltage factor" and "A/D cal factor" errors require factory service. Other errors, regarding the chemical sensors, draft measurement or thermocouples can usually be solved by re-calibrating the affected device.
Pump vacuum out of range.	This message indicates that the sample line or probe is plugged, the pump is damaged or dirty, or ice from condensed water vapor has formed in the pump at freezing temperatures. In the latter case, allow the instrument to warm up, then dry by operating at least one hour. Consult the factory if problem persists.
Gas concentration is indicated when none is present.	If small gas concentrations are indicated when no gas is present, it means a new baseline calibration is required. Baseline calibrations should be done routinely. When exposed to very high concentrations, the CO and NO sensors may require a lengthy purge before zero concentrations are indicated correctly.
Bad characters or unexpected results when printing or saving.	The wrong **RS232 Device** is selected (Printer or Computer) or the baud rate is set incorrectly.
No display or display hard to see.	This may occur at extremes in temperature. Make sure the instrument is within its operating temperature range. Adjust the contrast setting.
Gas sensor baseline errors.	Make sure the probe is ***not*** in the flue during the baseline measurement. Remove the probe from the flue and allow the instrument to purge (operate) in clean air for 10 minutes before repeating the baseline calibration. Note: the presence of NO_2 in the flue gas may trigger a baseline error for the SO_2 sensor. Perform a baseline calibration.
"NOTE-O_2REF: correction out of range" error appears.	The probe is sampling room air and **O_2Ref** is On. Turn the **O_2Ref** correction Off or ignore the reading. Once the probe is inserted in the in the flue, and the O_2 concentration drops, this message disappears.
Span error during calibration.	Recalibrate. Make sure the correct gases are connected at the correct time. Make sure internal fittings and tubing are connected after adding or replacing a sensor. Make sure CO diversion valve is oriented to the "CO" position when calibrating the CO(H_2 compensated) sensor.
CO sensor does not respond.	Turn CO diversion valve to the "CO" position. Make sure pump is on.
Sensor installed but not indicated.	If an electrochemical sensor or thermocouple is not installed properly or is damaged, its presence may not be indicated on the data display screen. Try reseating electrochemical sensors. See Chapter 9 "Adding or Replacing a Gas Sensor."
Efficiency, %CO_2, excess air readings not indicated.	These values are calculated from measurements made by installed sensors. If these sensors are not present, the calculated values are not displayed.
Low lithium battery.	Lithium battery needs to be replaced. Find lithium battery in the opening on the right side of the battery compartment, under white foam insert. Replace with instrument ON to prevent loss of logged data. Replace foam insert when complete.
Sensor calibration factor out of range.	Properly working gas, temperature, and draft sensors have predictable voltages in response to calibration input parameters. The CA-CALC combustion analyzer checks to make sure that the calibration factors, determined from calibration, are within an acceptable range. If not, an error message is generated and the calibration is aborted. Reasons for an aborted calibration can include poor calibration procedures, bad calibration standards or damaged sensor.

Appendix A. Calculations

O_2 Reference Concentration Calculation

$$\textit{Corrected Gas Concentration (PPM)} = \textit{gas concentration (PPM)} \times \frac{20.9 - O_2 \textit{ reference}}{20.9 - O_2 \textit{ measured}}$$

O_2 reference is value entered as **O_2REF level**

Excess Air Calculation

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

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

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

Calculating Combustion Efficiency

Net combustion efficiency (Effic Net)

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

flue heat losses = heat loss from dry gas
+ heat loss due to moisture from burning hydrogen
+ heat loss due to moisture in fuel
+ heat loss from the formation of CO

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.

Gross Combustion Efficiency (Effic Gross)

In Europe combustion efficiency is often calculated without the latent heat loss from the formation of water. The dry gas alone is subtracted from 100 percent.

$$\textit{\% Combustion Efficiency (dry)} = 100 - \frac{\textit{dry losses}}{\textit{fuel heating value}}$$

Remember either heating value, (HHV) or (LHV) can be applied in this calculation.

Siegert Formula

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

$$qA = (Ts - Ta)\ x \left(\frac{A2}{(21 - O_2)} + B \right)$$

Efficiency = 100 – qA

where:
qA = dry gas losses
Ts = flue temperature
Ta = supply air temperature
O_2 = measured volumetric oxygen concentration expressed as a percent
$A2$, B = fuel dependent constants

The constants *A2* and *B* are based on the composition of combustibles in the fuels. In Germany, the following prescribed values are provided for common fuels.

Fuel Type	A2	B
Natural gas	.66	.009
Fuel oil	.68	.007
Town gas	.63	.011
Coking oven gas	.60	.011
LPG	.63	.008

Determining CO_2 Using the O_2 Concentration

$$\% CO_2\ (by\ volume) = CO_2\ max \times \frac{(20.9 - \%O_2\ measured)}{20.9}$$

CO_2max is the theoretical maximum concentration produced for the fuel used.

Emission Rate Calculations Using Emission Factors

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, NO_X, and SO_2 from PPM to pounds per million Btu of fuel.

$$E = Cg\ Ft \times \left(\frac{20.9}{20.9 - O_2\ measured} \right)$$

where:
E = Emission Rate (pounds/MBtu of fuel)
Cg = Gas Concentration (PPM)
Ft = factor from Table I (below)
$O_2\ measured$ = Oxygen concentration from flue measurement (%)

TABLE I.

Factor (Ft)	Nat. Gas	Propane	Oil #2	Oil #6	Coal	Wood (dry)	Bagasse	Coke	Methanol
SO_2	.00145	.00145	.00153	.00153	.00164	.00153	0.0016	0.00164	.00143
NO_X	.00104	.00104	.00110	.00110	.00118	.00110	0.001	0.00118	.00103
CO	.00063	.00063	.00067	.00067	.00072	.00067	0.00067	0.00072	.00062

Ft units: lb./MBtu PPM

For those familiar with Method 19, *Ft* is related to *Fd* in the following way:
Ft, in units lbs/(MBtu ppm)
Fd, in units scf/MBtu
Ft = *Fd* x lb/(scf ppm)

Important note: When the Fuel Heat option in the Instrument Setup menu is selected for kg/kJ(metric), the Ft factors F.SO2, F.NOx and F.CO are presented in units of ng/J PPM. Make sure entries or changes are made in the appropriate units.

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

$$C_xH_y + \left(\frac{4x+y}{4}\right)O_2 \Rightarrow CO_2 + \frac{y}{2}H_2O$$

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

Calculating CO_2 Max From the Carbon Content

$$\%CO_2\ max = \frac{moles\ CO_2}{(moles\ CO_2 + moles\ N2)} \times 100$$

$$moles\ CO_2 = x\ moles$$

$$moles\ N2 = \frac{(4x+y)\times 3.76}{4}$$

Calculation of Combustion Air

Pounds Air / Pound Fuel = 11.5C + 34.3(H_2 - O_2/8) + 4.3S

C, H_2, O_2 and S are the fractions, by weight, of each chemical constituent of the fuel.

Appendix B. Series CA-6200 CA-CALC Combustion Analyzers Detailed Specifications

Oxygen (O_2):

Sensor Type	Electrochemical
Range:	0–25%
Accuracy:	±0.3% O_2
Resolution:	0.1% O_2
Response Time*:	<30 seconds to 90% of step change

Carbon Monoxide (CO)– H_2 compensated[†]:

Range:	0-5000 ppm
Accuracy:	*0–400:* ±20 ppm *400–2000:* ±5% of reading *2000–5000:* ±10%
Resolution:	1 ppm
Response Time*:	<30 seconds to 90% of step change

Carbon Monoxide (CO)- High Range:

Range:	0–20000 ppm
Accuracy:	*0–500:* ±25 ppm *500–10000:* ±5% of reading *>10000–20000:* ±10%
Resolution:	5 ppm
Response Time*:	<30 seconds to 90% of step change

Nitric Oxide (NO)[†]:

Range:	0–4000 ppm
Accuracy:	*0-100:* ±5 ppm *>100–1000:* ±5% of reading *>1000–4000:* ±10% of reading
Resolution:	1 ppm
Response Time*:	<60 seconds to 90% of step change

Sulfur Dioxide (SO_2):

Range:	0–4000 ppm
Accuracy:	*0–200:* ±10 ppm *>200–1000:* ±5% of reading *>1000–4000:* ±10% of reading
Resolution:	1 ppm
Response Time*:	<40 seconds to 90% of step change.

Nitrogen Dioxide (NO_2):

Range:	0–500 ppm
Accuracy:	*0–100:* ±5 ppm *>100–200:* ±5% of reading *>200–500:* ±10% of reading
Resolution:	1 ppm
Response Time*:	<40 seconds to 90% of step change.

Carbon Dioxide (CO_2) –calculated from O_2 and fuel type:

Range:	0–CO_2 Max
Resolution:	0.1%

Excess Air (%EA):	0–1000%
Efficiency (E_{net} and E_{gr}):	
Range:	0–125%
Resolution:	0.1%
Stack Loss:	0–100%
Supply Temperature:	-22–392^{0}F (-30-200^{0}C)
Accuracy:	±2^{0}F(1^{0}C) ±.5% of reading
Flue Gas Temperature:	32–1800^{0}F (0-1000^{0}C)
Accuracy:	±2^{0}F(1^{0}C) to 390^{0}F(199^{0}C) ±0.5% of reading >390^{0}F(199^{0}C)
Draft Pressure:	±30" H_2O (±80 mBar)
Accuracy:	±1% of rdg. or 0.01" H_2O (zeroed)
Resolution:	0.01

<u>Operating Conditions:</u>

Electronics Component Temperature Range:

Operating range:	32 to 122°F (0 to 45°C)
Storage range:	-20 to 140°F (-30 to 60°C)
Maximum probe temp:	1800°F (1000°C)
Instrument Humidity Range:	
Continuous:	15 to 90% non-condensing
Intermittent:	0 to 99%

<u>General Data</u>

Pump:

Flow rate:	nominal 700 cc/min
Maximum Flue Pressure:	±30" H_2O (±80 mBar)
Sampling Probe:	
Probe type:	stainless steel/neoprene
Probe length:	12" std (30cm)
Hose length	9' std (2.75m)
Probe diameter:	5/16" (0.8cm)
External dimensions:	6x10x2½" (15x25.4x6.4cm)
Weight:	2.5 lbs/3.9 lbs w/probe (1.14/1.75 kg)
Display:	approx. ¼-VGA B/W

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.*
**With a 9'sampling tube length and water trap.*

TSI Incorporated
500 Cardigan Road, Shoreview, MN 55126 U.S.A.
Web: www.tsi.com