WIRING BASE WITH CONTROLLER
and ACTUATOR MODULE INSTALLED

ACTUATOR

SCANNER

INSTALLATION MANUAL
FIREYE® FOCUS™
COMBUSTION EFFICIENCY SYSTEM

IMPORTANT NOTICE: THE SUCCESSFUL OPERATION OF THIS PRODUCT DEPENDS ON PROPER INSTALLATION. OPTIMAL PERFORMANCE REQUIRES UNDERSTANDING THE PROCEDURES IN THIS DOCUMENT. IT IS HIGHLY RECOMMENDED THAT YOU READ THIS MANUAL BEFORE ANY HARDWARE INSTALLATION!

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NOTICE

When Fireye products are combined with equipment manufactured by others and/or integrated into systems designed or manufactured by others, the Fireye warranty, as stated in its General Terms and Conditions of Sale, pertains only to the Fireye products and not to any other equipment or to the combined system or its overall performance.

DESCRIPTION

The function of the Fireye FOCUS™ Combustion Efficiency System (Patent Pending) is to maintain preset combustion efficiency levels on commercial and industrial gas burners. The system provides these benefits by optically monitoring combustion **at the flame**, rather than at the stack. The system learns the optimal performance parameters and constantly monitors and adjusts the fuel/air ratio to maintain it for the life of the burner. Long term savings both in fuel and maintenance can be expected.

The FOCUS system consists of three major components: The Combustion Efficiency Scanner, the Controller, and the Actuator. The Fireye CS200 scanner monitors the ratio of two constituents (OH AND CH) in the targeted flame to maintain the efficiency ratio. The Fireye CES1000 controller receives this information from the CS200 and automatically adjusts the fuel/air mixture by positioning the Fireye CA202 actuator. The CES1000 Controller is housed in the 60-2555 Wiring Rack, along with the AM300 Actuator Module which powers the CA202 Actuator itself.

The control action, speed of response, and range within the burner firing rate may be configured in the CES1000 controller to optimize burner performance. When used as both an efficiency controller and flame supervision system, an output from the 60-2555 wiring rack (S1,S2) may be wired to the input (S1,S2) of a Fireye Flame-Monitor™ as the flame signal, eliminating the need for a second sight port and flame scanner. When this option is selected, the Fireye Flame-Monitor must use an E1R1 flame amplifier to process the input signal.

The 60-2555 wiring rack accepts inputs from various accessories. Inputs available are for an analog 4-20 mA DC signal, a type K thermocouple, and a digital input. Outputs are provided and include an analog 4-20 mA DC and a RS485 for data transfer to a proprietary Fireye software program. A configurable SPDT relay contact can also function as an alarm or flame relay.

CAUTION: Installation of the Fireye FOCUS combustion efficiency system should only be performed by a qualified combustion control technician.

MAIN COMPONENTS OF FOCUS SYSTEM (See Component Picture Next Page)

PART NUMBER	DESCRIPTION	ITEM	USE WITH
60-2555	Wiring Rack	3	—
CES1000	FOCUS Controller	5	60-2555
AM300	FOCUS Actuator Module	4	60-2555
CS200	FOCUS Scanner	9	CES1000
CA202	FOCUS Actuator	2	AM300

ACCESSORIES FOR FOCUS SYSTEM (See Component Picture Next Page)

PART NUMBER	DESCRIPTION	ITEM	USE WITH
ACC-59-10FF*	10 ft. metal flex, 1 female straight connector, flying leads	12	Actuator and JB100
ACC-59-10FM*	10 ft. metal flex, 7 pins male straight connector, flying leads	NS	Controller and JB100
ACC-59-10F90*	10 ft. metal flex, 1 female right angle connector, flying leads	10	Actuator and JB100
ACC-59-10D*	10 ft. metal flex., 2 straight connectors male and female	NS	Actuator and Controller
ACC-59-10D90ST*	10 ft. metal flex, 1 right female and 1 straight male connectors	NS	Actuator and Controller
AC-59-10	10 ft. cable with two connectors	11	Actuator and Controller
AC-59-25	25 ft. cable with two connectors	NS	Actuator and Controller
AC-59-50	50 ft. cable with two connectors	NS	Actuator and Controller
AC-59-75	75ft. cable with two connectors	NS	Actuator and Controller
SCC-59-10FF*	10 ft. metal flex, 1 female straight connector, flying leads	12	Scanner and JB100
SCC-59-10FM*	10 ft. metal flex, 6 pins 1 male straight connector, flying leads	NS	Controller and JB100
SCC-59-10F90*	10 ft. metal flex, 1 female right angle connector, flying leads	10	Scanner and JB100
SCC-59-10D*	10 ft. metal flex, 2 straight connectors male and female	NS	Scanner and Controller
SCC-59-10D90ST*	10 ft. metal flex, 1 right female and 1 straight male connectors	NS	Scanner and Controller
SC-59-10	10 ft. cable with two connectors	NS	Scanner and Controller
SC-59-25	25 ft. cable with two connectors	NS	Scanner and Controller
SC-59-50	50 ft. cable with two connectors	NS	Scanner and Controller
SC-59-75	75 ft. cable with two connectors	NS	Scanner and Controller
59-489	FOCUS cable	NS	JB100
JB100	FOCUS cable junction box, 7 conductors terminal	6	
STS100-12A	Stack Temperature Sensor (K type)	8	CES1000
FPQ181	135 ohm Feedback Potentiometer	1	CES1000
FP1000	1000 ohm Feedback Potentiometer	NS	CES1000
FP5000	5000 ohm Feedback Potentiometer	7	CES1000
* Use when UL listing is required. ** UL Listed System NS = Not Shown in Picture			

STANDARD RETROFIT PACKAGE KITS

The FOCUS system can be purchased in the form of an FK1 or FK2 kit. (The difference is the type of prefabricated cable included).

PART NUMBER	DESCRIPTION
FK1	Includes 60-2555, CES1000, AM300, CS200, CA202, AC-59-25***, SC-59-25***
FK2 **	Includes 60-2555, CES1000, AM300, CS200, CA202, ACC-59-10F90*, ACC-59-10FM*, SCC-59-10F90*, SCC-59-10FM*, (2 each JB100)
* Use when UL listing is required. ** UL Listed System *** Cables not UL Listed	

COMPONENT PICTURE

FIGURE 1. 60-2555 WIRING RACK

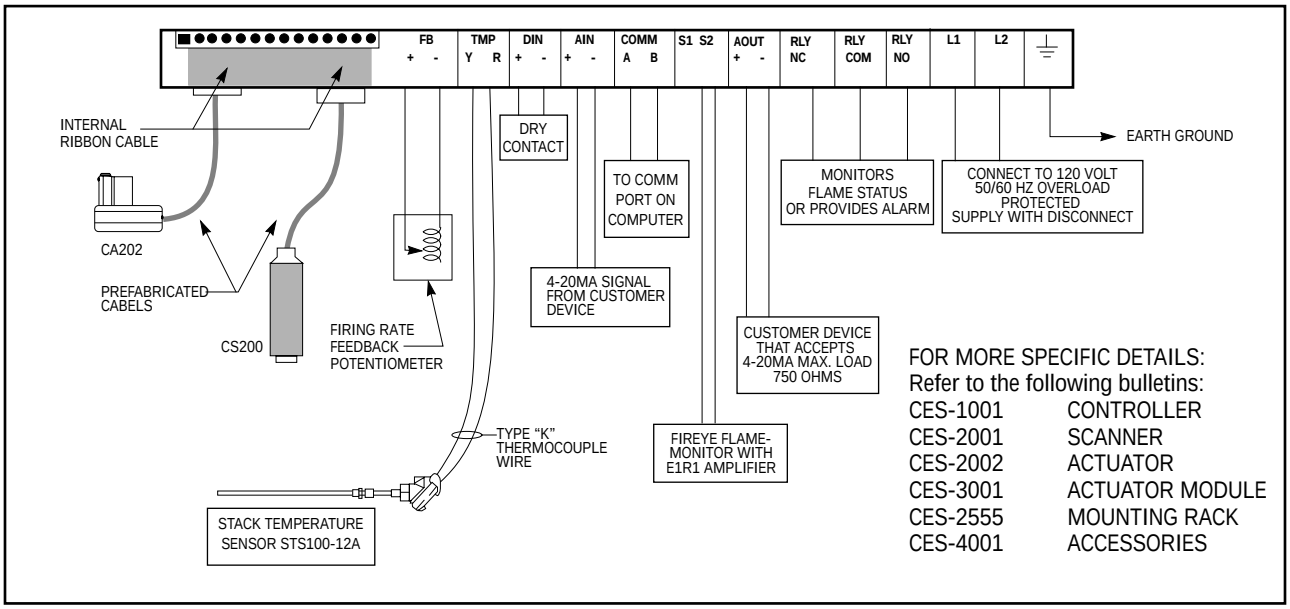


FIGURE 2. FOCUS SYSTEM INSTALLED ON A JACK SHAFT OPERATED BURNER

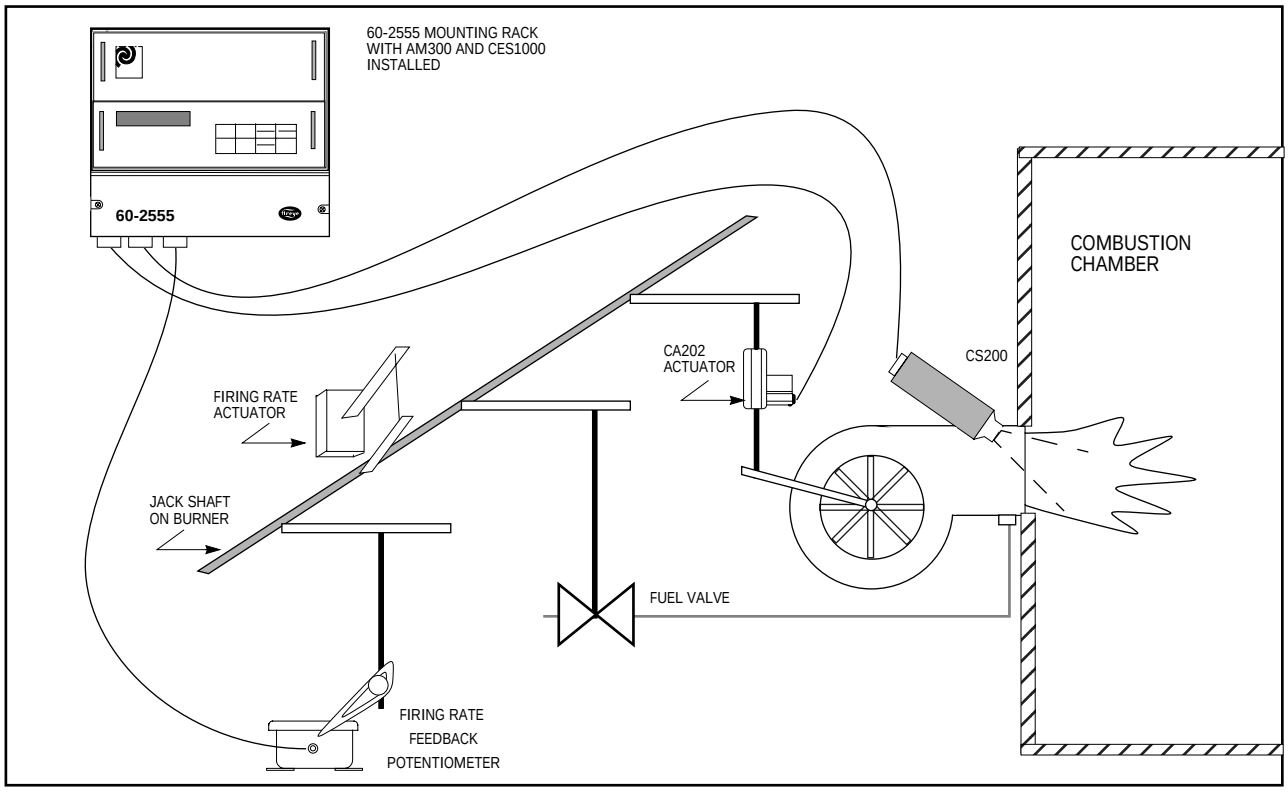
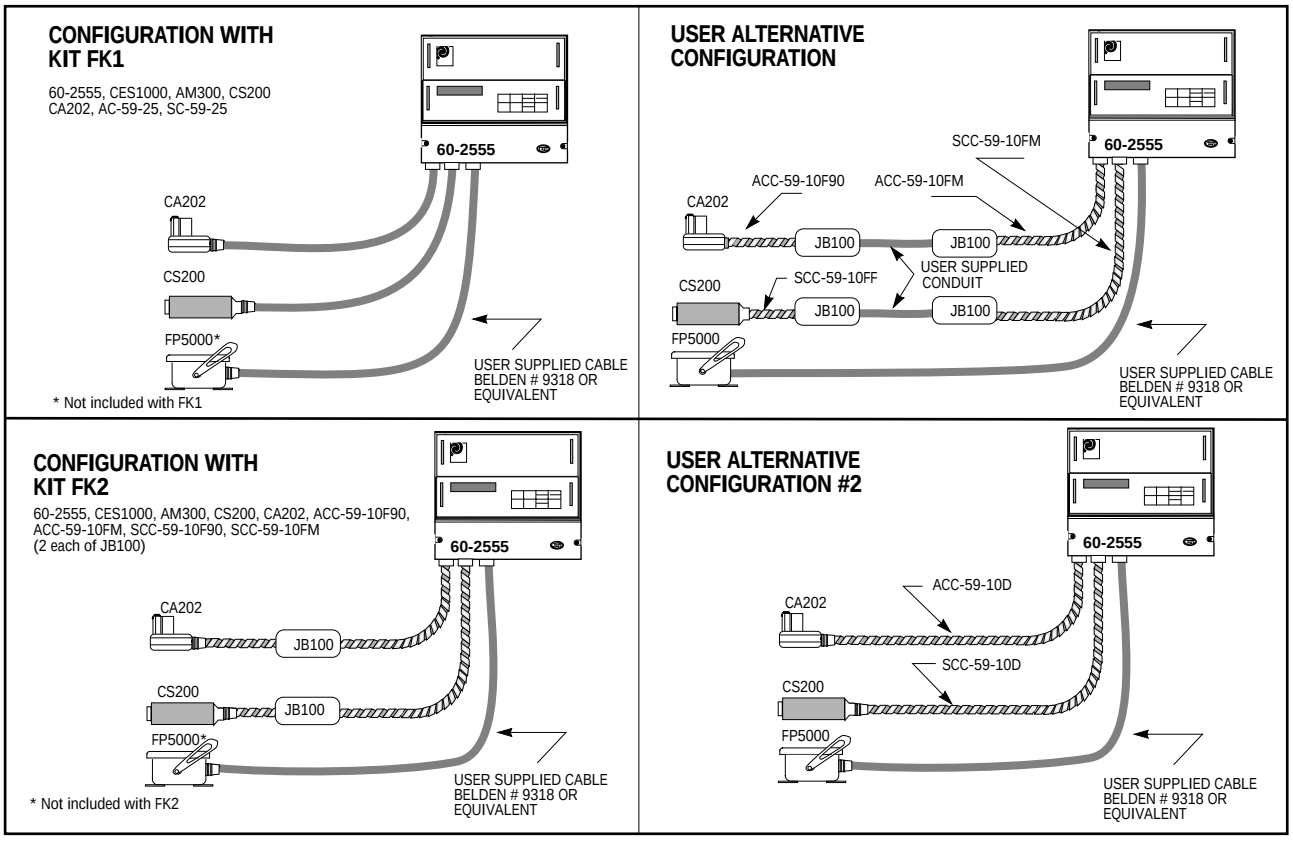


FIGURE 3. CONFIGURATIONS FOR FOCUS COMBUSTION EFFICIENCY SYSTEM

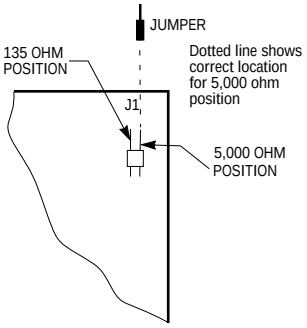


MECHANICAL INSTALLATION OF COMPONENTS

After locating a position for the 60-2555 mounting rack, the following sequence should be followed. Remember, do not locate any component where it will exceed the published ambient temperature limitations.

1. Perform the mechanical installation of the 60-2555 Mounting Rack, along with the CES1000 Controller and AM300 Actuator Module according to Technical Bulletins # CES-2555, CES-1001 and CES-3001 respectively.
2. Determine which firing rate feedback potentiometer will be used. (FP5000 mounted on the burner and actuated via a linkage assembly or FPQ181 mounted directly on the firing actuator). Once the feedback potentiometer has been determined perform the mechanical installation according to its associated Bulletin CES-4001. (See the following section entitled **SELECTION OF THE FIRING RATE FEEDBACK POTENTIOMETER** for additional information.)
3. Mount the CS200 scanner to provide an unobstructed view of the burner flame. (If used for flame detection and combustion efficiency, this sighting location must also provide an unobstructed view of the pilot burner). Install according to Technical Bulletin # CES-2001.
4. Install the CA202 trim actuator adapted correctly to the burner air linkage according to Technical Bulletin CES-2002.
5. Finally, install any accessory equipment to be used with the system according to enclosed bulletins and instructions.

SELECTION OF THE FIRING RATE FEEDBACK POTENTIOMETER



JUMPER ON CORNER OF LOWER BOARD OF CES1000 CONTROLLER (SHIPPED IN 5,000 OHM POSITION)

The FOCUS system must use one of two styles of firing rate feedback potentiometers to provide a signal to the CES1000 controller indicating the firing rate position of the burner. The CES1000 controller can take an input from a feedback potentiometer having a total resistance range of either 0 to 135 ohms or 0 to 5,000 ohms. Depending on which potentiometer is used, a range selector jumper on the CES1000 must be properly positioned. If a change to the jumper setting is required, **first** remove all power to the unit. Then remove the CES1000 module from the mounting rack, by removing the screws located on the front panel and pull it out by the two handles. See the drawing for jumper location. Reverse procedure to reinstall module.

FPQ181 mounts directly on the end of a manufacturers actuator. (See Figure 4).

The Fireye potentiometer FP5000 mounts on the burner assembly and is driven through the use of a linkage rod. The FP5000 should be linked so the rotation of the potentiometer provides the maximum resistance change when the burner is stroked from low to high fire. (See Figure 5).

After the mechanical installation is complete, the potentiometer's electrical connection should be made from the wiper and one end of the potentiometer to the terminals marked **"FB+, FB-"** (See Figure 1) in the 60-2555 mounting rack. The beginning resistance at low fire is between 10-20 ohms for the FPQ181, or between 50-150 ohms for the FP5000. The span for the FPQ181 should be a minimum of 110 ohms while the FP5000 should be a minimum of 1,000 ohms.

The resistance should increase in value as the firing rate feedback potentiometer moves from the low to the high fire position. Maximize the span to provide the highest resolution to be seen by the CES1000 controller and to allow better repeatability (a good hand-held Ohmmeter is important for this process).

FIGURE 4. FIRING RATE FEEDBACK POTENTIOMETER FPQ181

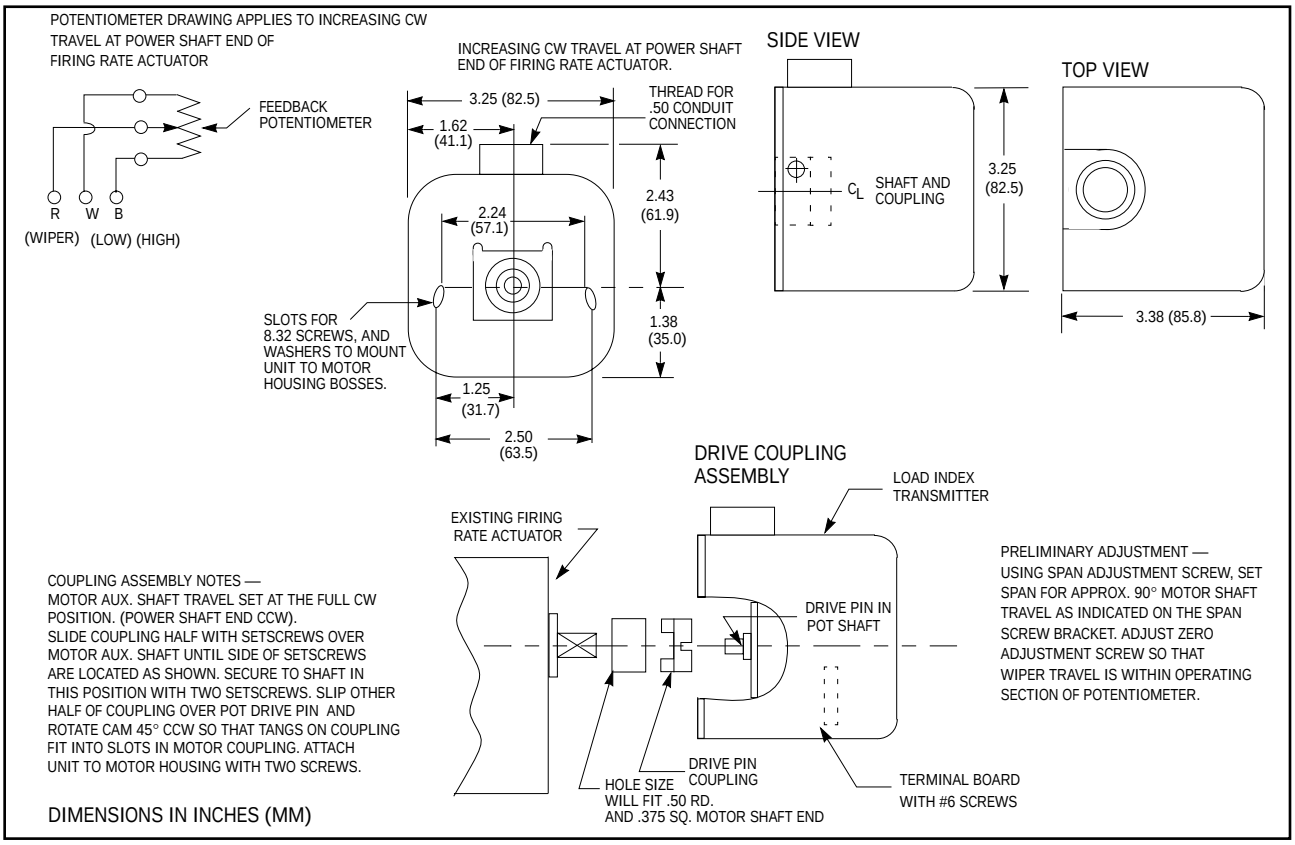
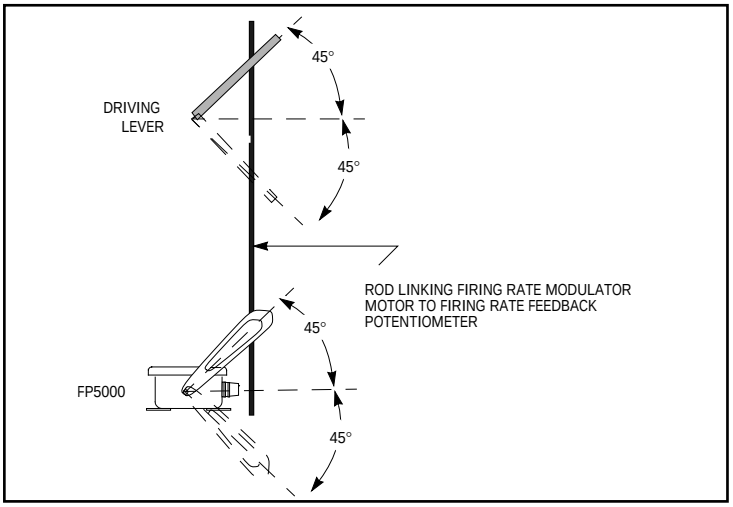


FIGURE 5. TYPICAL FIRING RATE FEEDBACK POTENTIOMETER TRAVEL (90° MINIMUM)



ELECTRICAL INSTALLATION

Refer to the previously mentioned technical bulletins and Figure 1 to determine which and how components must be connected to the 60-2555 mounting rack. Electrical connections must comply with all applicable codes. A good earth-ground must be connected to the 60-2555.

Failure to connect a continuous earth-ground could result in erratic operation. Do NOT connect or disconnect actuator or scanner cables with power applied to the controller.

FIRST APPLICATION OF POWER - OVERVIEW

The **LEARN** process is how we program the controller to operate and control the combustion process. The CES1000 **LEARNS** the various parameters associated to the trim actuator, firing rate, feedback potentiometer, the scanner, and optimal combustion parameters at various loads.

The first function to be performed after applying power to the unit is to **LEARN** the firing rate feedback potentiometer. Those instructions follow the **OVERVIEW OF CONTROLLER OPERATION** and **USING AND SETTING PASSWORDS.** Do not jump to that section until reviewing these two important sections.

When the FOCUS system is used for flame detection, the system can then be brought to and through the pilot proving position. It may be necessary to place the FLAME-MONITOR programmer in **CHECK** while the pilot flame signal values (OH/CH) are observed under the **SYSTEM VALUE** menu. At this point, it may be necessary to adjust the gain of the scanner to display an OH signal greater than 700 but less than 2500. The gain is adjusted under the SETUP menu. The value of pilot signal must be balanced against the value of main flame signal. Once a pilot signal is established, the FLAME-MONITOR programmer can be placed in the **RUN** mode and allowed to continue its sequence.

The burner should be recycled and a minimum pilot turndown test must be performed before proceeding with the configuration for the FOCUS system.

OVERVIEW OF CONTROLLER OPERATION

There are four primary programming groups which can be accessed using the keypad and viewed on the display. These groups coincide with the four keys on the left side of the keypad. These keys are marked:

SYSTEM VALUES
SYSTEM TEST
SETUP
LEARN

At any time, when you push one of these keys, you will leave the primary group you are currently viewing and enter the group corresponding to the key pushed. These groups are separate and distinct. To view, or change a parameter in that group, requires the pressing of that respective key. As we proceed with installation, we will refer to various functions in these groups.

SETTING AND USING PASSWORDS

OVERVIEW

This system is equipped with password security. It has been added to insure that once the FOCUS system is set up properly, no one can alter its operation without entering the password combination.

Before proceeding, make sure all electrical connections have been properly performed.

When the **SETUP** key is pushed, the display will read:

TRIM CONTROL DISABLED

This is the factory default value and message on the display when first received and powered.

You may proceed to review all the parameters in this group by pressing either the **UP/NEXT** key or the **DOWN/BACK** key. The parameters will be displayed in the order shown later in this bulletin. These keys will take you forward or backward through that list.

You cannot modify any of the parameters in this group until you enter the password parameters shown as **Password LV 1** and **Password LV 2** in this group.

SETTING PASSWORD

Go to the display position within the **SETUP** group which says, **Password LV 1**. When you have this on the display, push the **MDFY/ENTER** key and an "*****" will appear on the upper line of the display. This indicates that you can change the value on line 2 to the proper password. THIS IS DONE ONLY WHILE THE "*" IS ON THE DISPLAY. By pressing the **UP/NEXT** or **DOWN/BACK** keys, the second line on the display will change to allow you to find the proper password numerical value. The default value for **Password LV 1** as received from the factory is the number **2**. When it is present on the display, by pressing the **MDFY/ENTER** key, you will have selected this number and the "*****" on the upper line will disappear.

Press the **UP** key. **Password LV2** will appear.

With the **Password LV 2** display message, again, press the **MDFY/ENTER** key and the "*****" will appear on the upper line. By pressing the **UP/NEXT** or **DOWN/BACK** key, you will be able to find the proper password numerical value. The default value for **Password LV2** as received from the factory is the number **5**. When it is present on the display, by pressing the **MDFY/ENTER** key, you will have selected this number and the "*****" on the upper line will disappear.

You do have the option to program the CES1000 with personalized password codes as described in the following paragraph. Once you have entered the proper password, you can enter, store and edit data in the Controller.

After selecting the proper passwords for these two levels, the next display will show, **Set LV 1** and **Set LV 2**. This will allow you to select new passwords for either, or both of these levels, if you choose. Follow the procedure described above in order to modify, select and enter the new passwords. Remember to record your new passwords and store them in a secure location.

Please note, when the passwords are enabled, it will automatically disable if no key is pressed within 10 minutes. You will have to re-enter the password if left longer than that period.

LEARNING THE FIRING RATE FEEDBACK POTENTIOMETER POSITION

After the firing rate feedback potentiometer has been mechanically and electrically installed, continue as noted below.

Enter the **SETUP** group and enter the passwords for LV1 and LV 2

Then press the **LEARN** key

Lrn Bin Params appears on the display.

Press the **UP** key. - **Lrn ModLow Pos** appears on the display. Verify that the firing rate modulator motor and the feedback potentiometer are in the low fire position before proceeding.

Press **MDFY** key and the "*****" appears on the display in the far right of the upper line.

Press **MDFY** key again - **Mod Motor Low Learned** appears on the display for a few seconds and then, **Lrn ModLow Pos 0%** appears on the display.

Press the **UP** key - **Lrn ModHigh Pos 0%** appears on the display. Verify that the firing rate modulator motor and the feedback potentiometer are in the high fire position before proceeding.

Press the **MDFY** key and the "*****" appears on the display in the far right of the upper line.

Press the **MDFY** key again - **Mod Motor High Learned** appears on the display for a few seconds and then, **Lrn ModHigh Pos 100%** appears on the display.

The firing rate feedback potentiometer position **LEARN** is now complete.

NOTE: *Learning the firing rate feedback potentiometer will erase all previously learned bin data.*

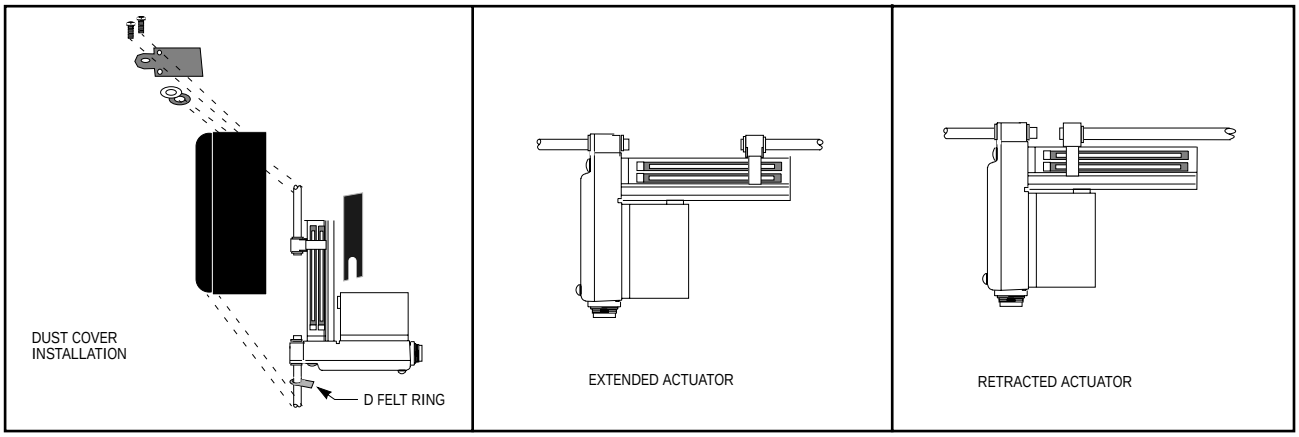
INSTALLATION OF THE CA202 ACTUATOR

An actuator **LEARN** must be performed before the rod/CA202 assembly is permanently installed. This process is how the CES1000 **LEARNS** the outer limits of travel of which the actuator is capable. It also will learn the normal operating, or, **NULL** position. If you have fixed the new assembly in place, it must be loosened to perform the following **LEARN** function.

Before proceeding, you must enter the **SETUP** group and enter the passwords for LV1 and LV 2. Having loosened the assembly (**LEARN Actuator** can be established before installing the CA202 assembly, but is most often performed as described), the trim actuator can be positioned at the **NULL**, **EXTENDED** and **RETRACTED** positions.

EXTENDED is when the nut slide is at it's maximum distance from the gear case housing and is displayed as 100%. **RETRACTED** is when the nut slide is closest to the gear case housing and is displayed at 0% (See Figure 6).

FIGURE 6. CA202 TRIM ACTUATOR



TO LEARN THE ACTUATOR

Enter the **SETUP** group and enter the passwords for LV1 and LV 2

Press the **LEARN** key — **Lrn Bin Params** appears on the display.

Press the **UP** key three times until **Lrn Act Retrac** appears.

Press the **MDFY** key and the "*****" will appear on the display in the far right of the upper line.

Press **MDFY** - **Lrn Act Retract** appears on the display and then **Actuator Ret Learned** appears on the display for a few seconds. You will observe during this procedure that the actuator is moving to its **RETRACT** position. If it does not reach this point, an error message will be displayed. Refer to the section entitled **MESSAGES** for further instructions if this occurs. Once completed, the display will read, **Lrn Act Retract 0.0%**.

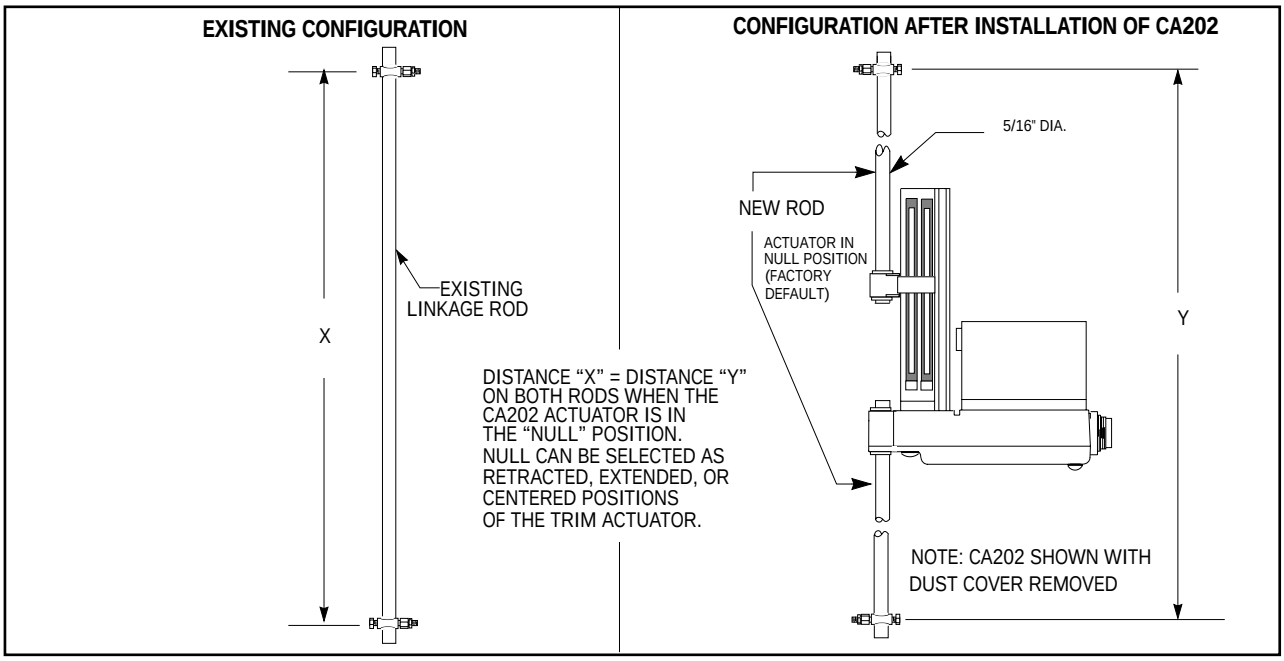
Press the **UP** key and **Lrn Act Extend** will appear on the display.

Press the **MDFY** key twice and **Lrn Act Extend 100%** will appear on the display. **Actuator Ext Learned** appears for a few seconds. You will observe during this procedure that the actuator is moving to its **EXTEND** position. If it does not reach this point, an error message will be displayed. Refer to the section entitled **MESSAGES** for further instructions if this occurs. Once completed, the display will read **Lrn Act Extend 100%**.

Press the **SYSTEM VALUES** key once. The CA202 actuator will drive to the **NULL** position.

The CA202 Actuator Assembly is now assumed to be installed according to Technical Bulletin CES-2002. As a reminder, make sure the new rod/CA202 assembly is exactly the same length as the original rod. (See Figure 7).

FIGURE 7. LINKAGE ROD CONFIGURATIONS



Re-install the CA202 actuator and associated linkage on to the burner. The Learn Actuator position is now complete.

After the Actuator Learn is complete there are two additional features that can be configured for the CA202 actuator. First is the **NULL Position** and the second is the **CONTROL ACTION**.

The choices for the **NULL Position** are, **Retracted, Center** or **Extended.** The factory default for **NULL Position** is **Center.**

The choices for the **CONTROL ACTION** are **Direct** or **Inverse.** The factory default for **CONTROL ACTION** is **DIRECT. Direct** means that the actuator will move to the **Extended** position to trim the air or close the air damper. It will move to the **Retracted** position to add air or open the air damper. Conversely, **Inverse** means that the actuator will move to the **Extended** position to add air or open the air damper and move to the **Retracted** position to trim air or close the air damper.

THESE ARE FACTORY SET AND NEED NOT BE ADJUSTED UNLESS A SPECIAL REQUIREMENT IS NECESSARY. THE FOLLOWING PROCEDURE IS FOR INFORMATION PURPOSES.

SELECTING ACTUATOR NULL POSITION

The factory default value for the **NULL Position** may be changed as follows.

Note; If the null position is changed, the mechanical installation of the CA202 actuator must be done again.

Enter the **SETUP** group and enter the passwords for LV1 and LV2.

After the proper passwords have been entered Press the **SETUP** key once.

Trim Control is displayed,

xxxxx

Depending in what mode the control is, the "xxx" may display as **Disabled** or **Enabled.**

Press the **UP** key twice.

NULL POSITION
CENTER

Press the **MDFY** key once and the "*****" will appear on the display in the far right of the upper line.
Press the **UP** key until the desired selection is displayed.
Press the **MDFY** key once and the "*****" will disappear on the display in the far right of the upper line while the actuator drives to the selected position.

SELECTING ACTUATOR CONTROL ACTION

The factory default value for the **CONTROL ACTION** may be changed as follows.
Enter the **SETUP** group and enter the passwords for LV1 and LV2.
After the proper passwords have been entered press the **SETUP** key once. - **TRIM CONTROL** is displayed,

xxxxx

Depending on what mode the control is in the "xxx" may display as **Disabled** or **Enabled**
Press the **UP** key three times.

```
CONTROL ACTION
     DIRECT
```

Press the **MDFY** key once and the "*****" will appear on the display in the far right of the upper line.
Press the **UP** key until the desired selection is displayed.
Press the **MDFY** key once and the "*****" will disappear on the display in the far right of the upper line, the **CONTROL ACTION** has been selected.

CAUTION: When the actuator is at its NULL position and the mod motor is traveling through its firing range, the actuator must not be forced against any mechanical stops.

TRIM ACTUATOR ADJUSTMENT

When learning bin data, (described later in **LEARNING THE BIN LOCATIONS AND BIN DATA) the** CA202 trimming actuator may be used as a fine tuning adjustment. This happens in the setup menu under the **LEARN BIN** mode. The screen will display the OH/CH ratio and the actuator trim position in percentages. The **UP/NEXT, DOWN/BACK** keys can be used to extend or retract the trimming actuator. This change in position is represented by an increase or decrease in the actuator position percentage on the display. This feature is NOT intended to be used to tune the burner. Variances greater than 5 percent result in excessive trim actuator movement as the burner modulates between bins and may result in unsatisfactory control.

SCANNER (CS200) SETUP

It is assumed the CS200 Scanner has now been installed and wired as per Bulletin CES-2001. The CS200 must now be optimally "fixed" in position. This is done by rotating the scanner, by 90 degree increments and logging OH and CH values at both pilot and low fire as displayed on the Controller at each position. Once you determine which orientation provides the highest value for OH and CH, lock (or "fix") the scanner in this position. Note in the space provided in the **SCANNER ORIENTATION LOG** (Figure 8) which position was used.

To view the OH and CH values:

Press the **SYSTEM VALUES** key

Press the **MDFY** key ten times until the following screen is visible.

```
FLAME ON
OH = xxxx      CH=yyy
```

Using this screen of information, rotate the scanner inurement, find the optimal position and lock it in that place.

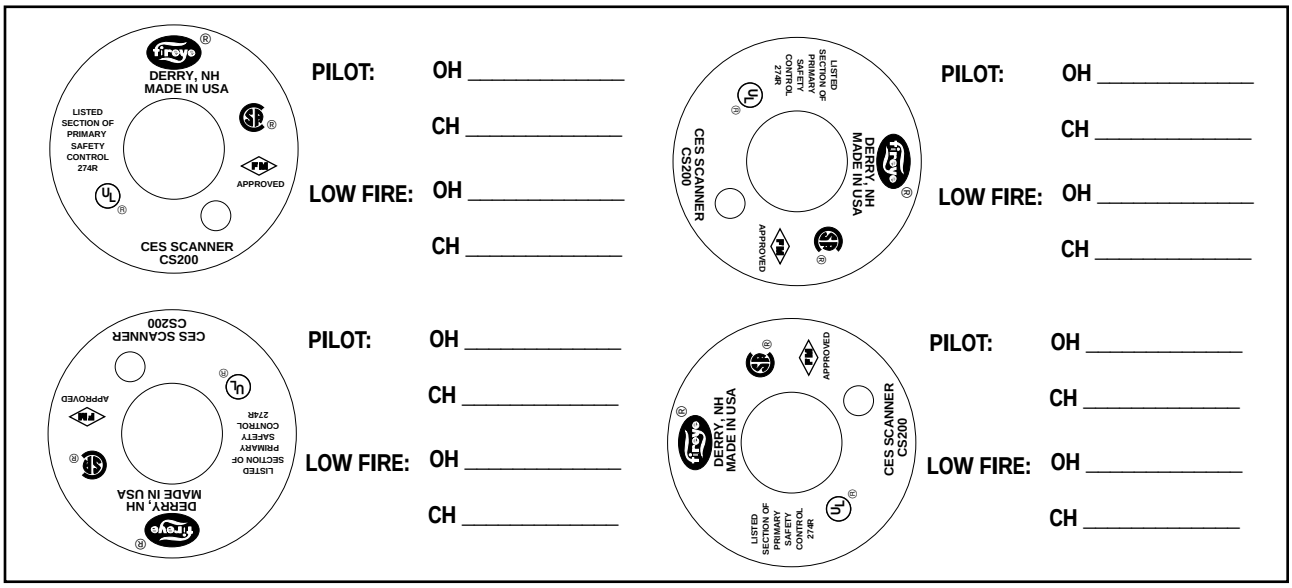
Once the scanner has been "fixed," it should not be rotated from that position. Rotating will require all **LEARN** sequences associated with **BIN DATA** (discussed later in this document) to be performed again. The scanner contains a detector assembly consisting of two adjacent detectors. Rotating the scanner changes the field of view and flame signal levels seen by each detector. It also effects the value of the resultant OH/CH ratio.

SCANNER OPERATION

Flame On OH and CH values can be read from the CES1000 controller display in the **SYSTEM VALUES** group. (These are described in the **KEYPAD DISPLAY INTERACTION** section later in this document). The FOCUS system references the OH value and uses it to determine flame on and flame off. For the purposes of flame on, the OH value must exceed 500 for a minimum of one second. Should the OH value drop below 200, the FOCUS system will interpret it as a flame off condition. Under the flame off condition, the trimming actuator will return to the **NULL** position and the flame signal output from terminal **S1** and **S2** is terminated. The FOCUS system will function in a trimming mode once the trim control feature has been **enabled**, the flame is on, the OH/CH ratio is below 9.99 and the firing rate feedback potentiometer is within the trim limits. The burner should be tuned and the scanner oriented to provide an OH/CH ratio with values between 1.2 and 7.5. OH/CH ratios less than 1.2 and greater than 7.5 should be avoided. If values less than 1.2 or greater than 7.5 are being observed on a continuous basis, the burner should be readjusted and/or the scanner orientation/sighting angle should be reassessed. (See the **SETUP OF THE SCANNER** section).

Note: Any action taken to change either the burner tuning, or scanner alignment, requires relearning all bin information.

FIGURE 8. SCANNER ORIENTATION LOG



LEARNING THE BIN LOCATIONS AND BIN DATA

The CES controller allows up to 10 firing rate locations to be learned and the data saved within the associated bins. For bins not learned, the controller will determine and display the theoretical values at the mid-point of each bin. This is noted by an asterisk (*) following the bin number. *You must **LEARN** a minimum of four bins with at least two bins above and two bins below the 50% firing rate point.* It is recommended to **LEARN** all bins as the control will be more accurate with more bins learned.

Using a combustion flue gas analyzer (such as the Fireye Firetron® Analyzer), the boiler technician should first tune the burner (with the CA202 trim actuator in the **NULL** position) to its optimum performance. After tuning is complete, all pertinent data should be logged for future reference. A sample troubleshooting log is provided in this manual.

The CES1000 controller provides up to 10 bin locations to maintain optimum burner performance data between low and high fire. After analyzing the data log from the burner tune-up:

Enter the **SETUP** group and enter the passwords for **LV1** and **LV2**.

Press the **LEARN** key and continue.

The controller display reads **LRN BIN PARAMS**,

Press the **MDFY** key once, again. The display will show the present bin number and modulator position in percentages.

Press **MDFY** key again. **Act Pos** and **Ratio** will appear on the display.

Manually, set the burner to a desired firing rate position at some point above the **LOW TRIM START** point. Typically this should be in the 15% - 18% region.

Pressing the **UP** or **DOWN** key will force the CA202 actuator to move **UP** toward the extended end and **DOWN** toward the retracted end; as such, the CA202 is being used as a fine tuning adjustment for the burner. When used with an analyzer (such as the **Firetron Analyzer**), and when an actuator position is found yielding the lowest value O2 with no generation of CO and the burner has stabilized, press the **MDFY**/enter key once and the displayed information will be entered into controller memory.

Repeat this process to learn additional bins.

Bins may be learned in any order, at any time. Should it be determined that a previously learned bin is not correct, the technician can proceed to that bin and relearn it. If the next position is within the same bin range of any previously learned bin, that data will then be overwritten with the new data.

A minimum of four learned bins are required in order to place the control in **ENABLED** mode; however, it is recommended the maximum number of bins be learned. The more bins learned, the better the control over the entire firing range. Any bins that are not learned by the technician, will be calculated by the controller.

After the controller is placed in a **ENABLED** mode, the processor references the learned bins and calculates a set point for OH/CH ratio along a line connecting the learned bins.

When sufficient bin data has been accumulated, modifying the **TRIM CONTROL** to **ENABLED** will now allow the FOCUS system to control the burner/boiler environment. The system will not allow you to enable unless at least four (4) bins must be learned (two below 50% and two above 50%).

Enter the **SETUP** group and enter the passwords for **LV1** and **LV2**.

Press the **SETUP** key again. **TRIM CONTROL, disabled** will appear on the screen.

Press the **MDFY** key once and the "*****" will appear on the display in the far right of the upper line.

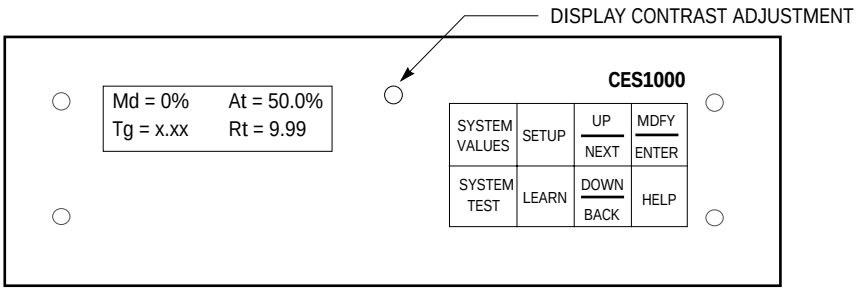
Press the **UP** key until the **ENABLED** is displayed.

1. In the chart above, log the OH and CH values at both pilot and low fire with the CS200 scanner oriented at 90° increments. The OH/CH values can be read under the SYSTEM VALUES GROUP section later in this document.
2. Determine which orientation provides the highest levels of OH and CH.
3. Lock the scanner in this position and note in the spaces above which position was used.

Note: A change in the orientation of the CS200 scanner after the system has been enabled will require recalibrating the system. If not recalibrated, the system will no longer function optimally.

KEYPAD AND DISPLAY INTERACTION

FIGURE 9. FOCUS CES1000 MODULE DISPLAY



SYSTEM VALUES

Pressing the **SYSTEM VALUES** key will allow you to step through the parameters listed in this group. You will move in sequence through the various parameters by using the **UP/NEXT** or **DOWN/BACK** keys. One will take you through the listing forward, the other in the reverse order. When in this group, you will not be able to change any setting of the parameters.

(Note that these parameters are not modifiable and information can only be reviewed on the display) (If there are no key entries within 10 minutes, the display on the Controller will move back into this group automatically)* = Factory Default.

Md=xxx% At=yyy.a%, (.a=0 or 5) Tg=z.zz Rt=r.rr	"Md" is the Mod Motor position in %."At" is the firing rate Actuator Position in %. "Tg" is the "OH/CH" Target Ratio that the control will attempt to maintain. "Rt" is the "OH/CH" Actual Ratio Value that the CS200 scanner is monitoring.

Bn Md At Ratio
# xx% yyy% z.zz 	
	Learn values, max of 10 bins. Unlearned bins are not displayed if number of learned bins is less than 2. A minimum of 4 bins must be learned before the control will become functional. Two of the bins must fall below 50% and two of the bins must fall above 50% of the firing rate feedback potentiometer value.
	Bn =Bin # 0 to 9, An "*" after the # denotes calculated learn values.
	Md =Firing Rate Feedback Potentiometer position in %.
	At = Trimming Actuator position in %.
	Ratio ="OH/CH" Actual Ratio Value that the CS200 scanner is monitoring.

Scanner Ambient xxx°F	Displays the Ambient Temperature as read in the CS200. Proper Units, as selected under "Temp. Units" in Setup Group.
Detector Temp xx°F	Displays the temperature of the detector as read in the CS200. Proper Units, as selected under "Temp. Units" in Setup Group.
Scanner Gain xx	Value displayed will be within 0-100
Scanner F/W Ver x.x	Displays the version of firmware that is in the CS200 Scanner

DelayStartIntlk xxxxx	Where **"xxxx"** is as noted below. **Unused**, Feature is Inactive. **Time**, Number of minutes before the system will begin to trim on initial startup.**Stack Temp**, Measured temperature must equal or exceed the value entered in the **SETUP** group before the system will begin to trim on initial startup.("Enabled" must be selected in the **SETUP** group to use this function)
Stack Temp xxx° F	Proper Units, as selected under "Temp. Units" in Setup Group.
Digital Input xxxxx xxxx	Where **"xxxx"** is as noted below. **Unused**, Feature is Inactive. **Trim Enabled**, Trim disabled (as selected under "Digital Input" in Setup Group)
xxxxxxx AuxAO yyy% zz ma	Where xxxxxxx is the selection made in the **SETUP GROUP**. "AuxAO," Analog Output. "yyy%," numeric value of selected variable in %. "zz ma," milliampere output that equates to the numeric value of selected variable.
xxxxxxx AuxAI yyy% zz ma	Where xxxxxxx is the selection made in the **SETUP GROUP**. "AuxAI," Analog Input. "yyy%," numeric value of selected variable in %. "zz ma," milliampere input that equates to the numeric value of selected variable.
FLAME OFF (or ON) OH=xxxx CH=yyy	**FLAME ON** or **FLAME OFF** displays the present flame status. **OH**=xxxx, OH Averaged Raw Counts. **CH**=yyy, CH Averaged Raw Counts.
3-20-97 12:42 pm	Actual Date and Time.
FIREYE * CES VER X:Y *	Displays the version of firmware that is in the CES1000. Where X denotes major version and Y denotes minor version.

SYSTEM TEST

SYSTEM TEST GROUP

Before entering this group the password MUST be enabled. (See SETTING PASSWORD).

Pressing the **SYSTEM TEST** key will allow you to access a number of system parameters found in the group. Some of these parameters allow you to alter the setting and some are for viewing only. Select the parameter you want to view by pressing the **UP/NEXT** or **DOWN/BACK** key to choose the number of the **SYSTEM TEST** you want. A listing is shown later in this bulletin. Holding the key down will allow you to scroll through the numbers faster. You can chose a number from 0 to 255.

When you wish to change a variable within a parameter, you must go to the **MDFY/ENTER** key and when you see the "*"symbol select the value using the **UP/NEXT** or **DOWN/BACK** keys. Then press **MDFY/ENTER** and the "*" symbol will disappear and the setting is saved.

SET DATE AND TIME

For example, if you want to view and change the date and time of the controller, you would go through the following steps:

Press the **SYSTEM TEST** key and the following will appear:

```
SYS TEST #0
```

The Set Date and Time parameter is System Test #7 from the chart shown on the following pages. Therefore, you press the **UP/NEXT** key seven times until the number 7 appears on the screen. Then press **MDFY/ENTER** and the following appears on the display:

```
SYS TEST #7   *
 MONTH = 07
```

Because the "*" symbol is on the upper line of the display, the lower line can be adjusted using the **UP/NEXT** or **DOWN/BACK** keys. Once the proper month is selected, press the **MDFY/ENTER** key. If you press the **MDFY/ENTER** key again will move you to the next step in selecting the date and time. In this case, it is the "day" and it appears on the display with the "*" symbol which again allows you to change the value using the **UP/NEXT** or **DOWN/BACK** keys.

Pressing the **UP/NEXT** or **DOWN/BACK** key when the "*" is not present will advance you to the **SYS TEST # X** display position and allow you to chose another System Test parameter number.

All tests except #8 are password protected. See SETTING PASSWORD.

2	Forced Time Out of Password	
3	OH and CH Instantaneous Values	OH=YYYY CH=ZZZZ
7	Set the Date and Time	Month = XX, Day = XX, Year = XX, Hrs = XX PM or AM, Min = XX
8	Restore All Factory Settings	Clears all data
9	Forced Actuator	Takes control of actuator, allows manual movement when in trim mode with time out.
12	Clear Comm Errors	Clear scanner's comm errors.
17	View Lockout History	View last 10 Lockouts, Type, Date/Time, Detected, and Date/Time Resolved
27	Clear All Lockouts	
70	Bin Learn Parameters Edit	
75	Delete all Learned Bin Data	
161	Set Count Averaging Filter in %	NewAvg=(OldAvg * (100-Filter) + (CurReading * Filter)) /100, default is 4%
248	Set Ratio Control Integral Multiplier	Setpoint range from 1 to 1000, higher numbers result in larger corrections, 0=Disabled, default = 80
249	Additional Ratio Control Integral	If Firing Rate <=30% AND this Flag Divider Flag Multiplier of Test248 is halved. default is "Disabled"
252	Feed Forward Hold Timer	Setpoint range 0 to 300 sec, default = 0
255	View Communication Errors	View scanner's communications errors. To clear use Test #12.

SETUP

SETUP GROUP

When the **SETUP** key is pushed, the display will read:

Trim Control Disabled

This is the factory default value and message on the display when first received and powered.

You may proceed to review all the parameters in this group by pressing either the **UP/NEXT** key or the **DOWN/BACK** key. The parameters will be displayed in the order shown later in this bulletin.These keys will take you forward or backward through that list.

You cannot modify any of the parameters in this group until you enter the password parameters shown as **Password LV 1** and **Password LV 2** in this group.

(Note that these parameters are all modifiable)* = Factory Default

MESSAGE	DESCRIPTION
Trim Control xxxxx	Disabled*, Enabled (This selection determines if FOCUS will act as a trimming system).
Actuator Type xxxxx	**Fireye***, configures the controller to work with the Fireye CA202 trim actuator. **Other**, This selection has no function in FIRMWARE VERSION 1.2 or 1.3
Null Position xxxxxx	**Retracted**, sets the CA202 actuator in (0%) position. **Center***, sets the CA202 actuator in (50%) position. **Extended**, sets the CA202 actuator in (100%) position.
Control Action xxxxxx	**Direct***, the actuator moves toward the Extended (100%) position to reduce excess air. **Inverse**, the actuator moves toward the Extended (100%) position to add excess air.
CA202 Trim Limit xxxxx%	Range dependent upon Null Position. For **Retracted** "100%- 0%" default = 100%. For **Center*** "+/- 50%," default = 50%. For **Extended** "0%-100%," default = 0%.
Mod Trim Start xx%	0% - 30% (position of mod motor below which trimming will cease - zero bias position), default = 10%.
Mod Trim End xx%	70% - 100% (position of mod motor above which trimming will cease - zero bias position), Default = 90%.
Delay Start Intlk xxxx	**Unused**, Feature is Inactive. Time, Minutes before the system will begin to trim on initial startup. default = 0. Stack Temp, Temperature at which trim action will begin. Default = 200°F.
Relay Option xxxx	**Flame Relay***, Flame failure response (FFRT) time is selectable, 1 or 3 sec. Default = 1 sec. Relay is de-energized during a flame-our condition. **Alarm Relay**, Output from "S1" and "S2" is terminated when an alarm condition occurs. (See LOCKOUT MESSAGES for exact conditions).

Digital Input xxxxx	**Disabled**.* **Enabled**, a dry contact closure across terminals (Din +) and (Din -) on the 60-2555 mounting rack will cause the "Trim Control" to switch from **ENABLED** to **DISABLED**.
Analog Input xxxx	**Unused***, Feature is Inactive. **Mod FeedBack**, uses a 4 -20 mA DC signal in place of the firing rate Feedback Potentiometer.
Analog Output xxxx	**Unused***, Feature is Inactive. The output from the 60-2555 Mounting Rack is 4 -20 mA DC. The maximum load that can be connected to the terminals (AOUT +) and (AOUT -) is 750 Ohms. **Act Feedback,** transmits the position of the CA202 actuator as a function of %. 4 mA DC = 0% 20 mA DC = 100% **OH Counts,** transmits the numerical value of the actual "OH" in real time. 4 mA DC = 0% or 0 counts 20 mA DC = 100% or 4095 counts **CH Counts,** transmits the numerical value of the actual "CH" in real time. 4 mA DC = 0% or 0 counts 20 mA DC = 100% or 4095 counts. **Ratio,** transmits the numerical value of the actual "OH/CH" Ratio in real time. 4 mA DC = 0% or 0 20 mA DC = 100% or 9.99 **Mod Feedback,** transmits firing rate actuator position of as a function of %. 4 mA DC = 0 % 20 mA DC = 100%
Temp. Units xxxx	Fahrenheit*, Centigrade.
Scanner Gain xx	1-100, default=40.
Detector Temp xx° C	-20° C - + 10° C (or proper units), default = -10° C.
Deadband Type xxxxxxxx	**Symmetrical***, The value selected for "Deadband" is applied to both sides of the "Target Ratio." **Single Sided,** The value selected for "Deadband" is applied to the upper side of the "Target Ratio."
Deadband x.x	0.1-3.0, The value is in "OH/CH" ratio units. default = 0.1.
Sample Size xxx	Scanner Sample Size 62*, 125, 250.
Password LV1 x	If password not enabled, default = 2.
Password LV2 x	If password not enabled, default = 5.

Set LV1	If password enabled user can set a new value.
Set LV2	If password enabled user can set a new value.

LEARN

LEARN GROUP

This group will allow you to program the needed values of OH/CH ratio at various firing rates. It also allows the controller to learn the firing rate potentiometer values at low and high fire positions, to learn the trim actuator retract and extend positions.

Before you proceed to make changes to the parameters in this group, you must move to the **SETUP** group and enter the password LV 1 and LV 2 commands. After successfully entering these passwords, you can press the **LEARN** key and by pressing the **MDFY/ENTER** key in any of these parameters, you will be able to modify the data. Remember that the "*" symbol must be on the upper line of the display before you will be allowed to change the information in the parameter.

Lrn Bin Params	Learn Bin Parameters: 10 bins available based on Mod Motor Positions. Bin 0: 0% to 9%, Bin 1: 10% to 19%, Bin 3: 20% to 29%, . . . , Bin 9:90% to 100%. Parameters saved are OH, CH, Mod Motor Position and Actuator Position. At least four bins must be learned (two below 50% and two above 50%).
Lrn ModLow Pos xx%	User sets mod motor to low position, hit modify, then hit enter to capture current value. Display **ModMotor Low Learned**.
Lrn ModHigh Pos xx%	User sets mod motor to high position, hit modify, then hit enter to capture current value. Display **Mod Motor High Learned**.
Lrn Act. Retract xx.x%	Hit modify, then hit enter. Actuator travels toward fully retracted position until no further movement detected. Display **Actuator Ret Learned**.
Lrn Act. Extend xx.x%	Hit modify, then hit enter. Actuator travels toward fully extended position until no further movement detected. Display **Actuator Ext Learned**.

MESSAGES

MESSAGE RULES

- Timed messages are for the specified time.
- If a timed message occurs while another timed message is currently being displayed, the second message will be ignored.
- Message priority is Normal (lowest), Solid, Lockout (highest).
  If a new message has a higher priority than the current one, then the new message will overwrite the current message. If a new message has a lower priority than the current message, then the new message will be ignored.

- Lockout messages are date/time stamped and saved within battery backed-up RAM in the Lockout log. Should the lockout condition be resolved, the lockout log can be reviewed within System Test #17.
- Pressing any key when the displayed message is Solid or Lockout message will inhibit that display message for 2 minutes.

TYPICAL NORMAL MESSAGE

Pressing ENTER Will Erase Bin Data	Mod Motor learn selected with Bin data present. If ENTER pressed, Mod Motor learn will be initiated. This invalidates the learned bin data. Bin data automatically erased.

TIMED MESSAGES

FIREYE *CES VER X.Y*	At Power Up. Where X denotes major version and Y denotes minor version.
Control Error Out of Adjust	While in "Trim" mode, the actuator has been adjusted to the actuator trim limits. After this occurs, the actuator will be repositioned to the "Feed Forward" position and "Trim" will restart.
Mod Motor Low Learned	After a successful Mod Motor Low Learn.
Mod Motor High Learned	After a successful Mod Motor High Learn
Actuator Ret Learned	After a successful Actuator Retract Learn.
Actuator Ext Learned	After a successful Actuator Extend Learn.
Flame is OFF Learn Denied	Bin learn denied as no flame present.
Mod Range Error ReLearn Mod	The difference between the Mod Motor High and Low learn values is less than 120 counts. Tested after a Mod Motor learn. Mod Motor learn defaults are reloaded.
Mod Align Error ReLearn Mod	The Mod Motor High learn value is NOT greater than the Mod Motor low learn value. Tested after a Mod Motor learn. Mod Motor learn defaults are reloaded.
Act Range Error ReLearn Mod	The difference between the Actuator High and Low learn values is less than 700 counts. Tested after an Actuator learn. Actuator learn defaults are reloaded.

Mod Out of Range Act Learn Denied	Actuator learn denied, as the Mod Motor is NOT between the Mod Trim Start and End settings.
Mod Out of Range Test 9 Denied	System Test 9 (manual actuator control) denied, as the Mod Motor is NOT between the Mod Trim Start and End settings.
Flame is ON Act Learn Denied	Actuator Learn denied, as the Flame is ON. Flame must be OFF for actuator learn.
Mod Out of Range Test 9 Aborted	System Test 9 (manual actuator control) aborted, as the Mod Motor is NOT between the Mod Trim Start and End settings.
Mod Out of Range Learn Denied	Bin learn denied, as the Mod Motor is NOT between the Mod Trim start and end settings.
Mod Motor Active Learn Aborted	During the final stages of a Bin Learn the Bin # being learned has changed causing an abort of the bin learn.
Flame is OFF Learned Aborted	Flame OFF detected during a Bin learn causing an abort of the Bin learn.
Mod Out of Range Learn Aborted	Bin learn aborted, as the Mod Motor is NOT between the Mod Trim Start and End settings.
Flame is ON Act Learn Aborted	Actuator Learn aborted, as the Flame is ON. Flame must be OFF for Actuator learn.
Actuator Unsafe Mod Learn Denied	Mod Motor learn denied as the actuator is “Unsafe.” Unsafe is defined as greater than 2.5% of Full Scale from Null.
Actuator Unsafe Mod Learn Aborted	Mod Motor learn denied as the actuator is “Unsafe.” Unsafe is defined as greater than 2.5% of Full Scale from Null.
No Bin Data to Edit	Attempting to edit nonexisting Bin data within System Test 70.
Refer to Bltn: CES-5001	Help message that is displayed whenever the HELP key is pressed.
Mod Not Learned Relearn Mod	Bin learn denied, as the actuator has NOT been learned. Relearn the Mod Motor.

Mod Not Learned Relearn Act	Bin learn denied, as the actuator has NOT been learned. Relearn the actuator.
Cannot Change Null Relearn Act	Changing Actuator Null position denied, as the Actuator has NOT been learned. Relearn the Actuator.

SOLID MESSAGES

Cannot Trim LearnProperBins	Attempted to start Trim (Trim Control set to Enabled) but the proper bins have NOT been learned. Need minimum of four bins, two below 50% and two above 50% firing rate.
Cannot Trim ReLearn Act	Attempted to start Trim (Trim Control set to Enabled) but the Actuator has NOT been learned. Relearn the Actuator.
Cannot Trim ReLearn Mod	Attempted to start Trim Control. (Trim Control set to Enabled) but the Mod Motor has NOT been learned. Relearn the Mod Motor.

LOCKOUT MESSAGES

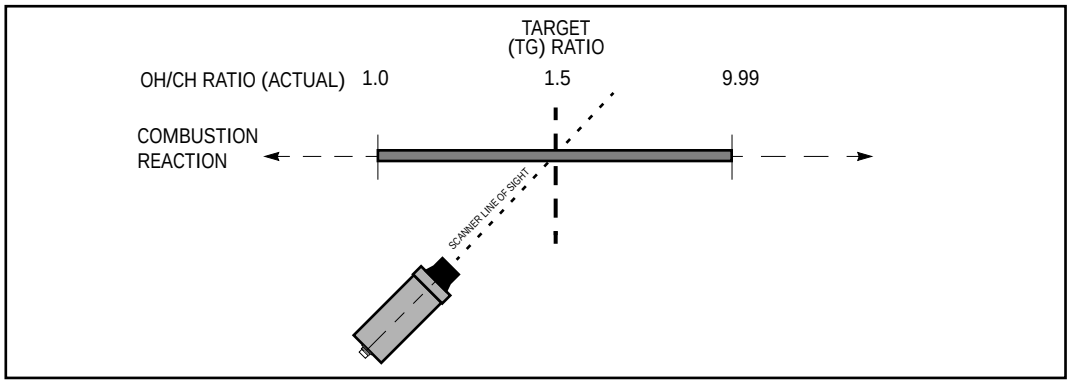
Actuator Error Stalled	Five consecutive attempts to move the actuator have all failed.
Scanner Error Communications	Continual consecutive scanner communication errors have persisted for 10 sec.
Actuator Error Open	Actuator feedback is less than 50% of Actuator Low learn value. Causes all actuator signals to be disabled.
Programmer Error	External RAM test failed.
Interlock	Internal software handshake failure.

THEORY OF OPERATION

The Fireye FOCUS system optically monitor's the burner's combustion performance. The CS200 scanner contains two independent detectors that continuously monitor the ratio between the OH (water vapor) and CH (carbon hydrogen bonded molecule) in the flame. Because combustion is a chemical reaction taking place over time, a snapshot of the reaction at any particular firing rate can be viewed. This snapshot will show that the OH/CH ratio being monitored varies with a change in the burner fuel/air ratio.

To explain this phenomena in greater depth, refer to Figure 10. In Figure 10, a dashed horizontal line signifies the combustion reaction. Extending from the scanner in this figure is a dotted line that represents the scanner line of sight. The Target (TG) OH/CH ratio depicted in the following figures is a set point value that is stored in one of the ten (10) **BINS** of the CES1000 controller. The Target (TG) OH/CH ratio is read at the intersection of these two lines. As long as the combustion reaction remains in a steady-state condition and the scanner Line of sight remains constant, the Target Ratio will remain the same. If a change is made to the fuel/air ratio, the combustion reaction will move along the horizontal line. The Combustion Reaction moves to the left or to the right depending on the change in fuel/air ratio. The most common cause for a change in fuel/air ratio is an increase or decrease in the combustion air supplied to the burner.

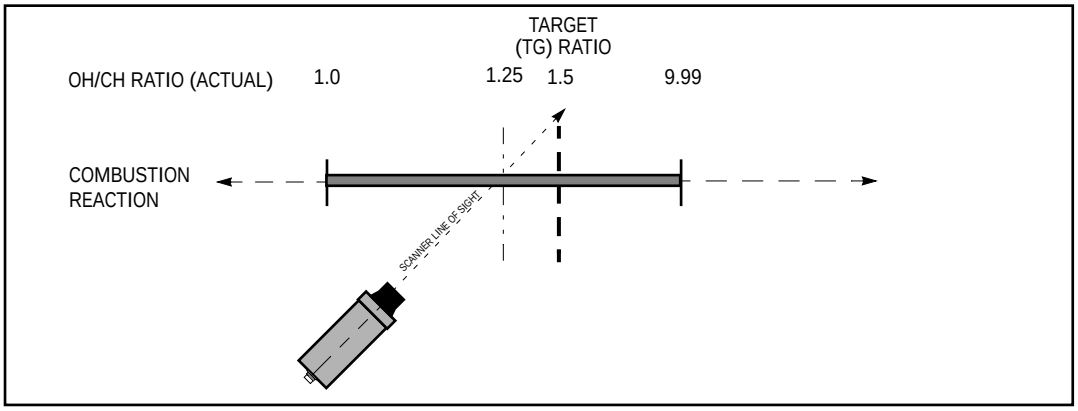
FIGURE 10. EXAMPLE OF LEARNED TARGET RATIO



In Figure 11, Target Ratio (TG) of the combustion reaction has moved to the right causing the scanner to view a lower ratio. This shift was caused by the fuel/air ratio becoming richer. To correct for this change in fuel/air ratio, the trimming actuator needs to open the air damper, increasing the air supply. This increase in air causes the combustion reaction to move left, repositioning the original OH/CH TARGET RATIO (TG) in front of the scanner.

Note: The scanner line of sight remains fixed.

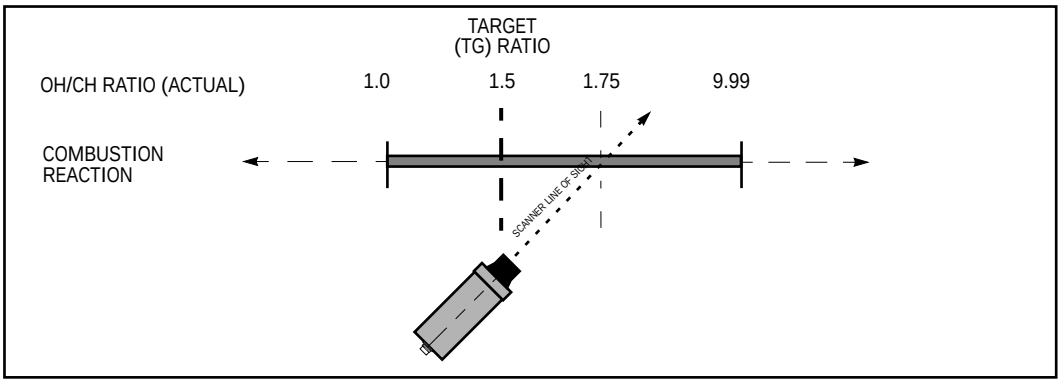
FIGURE 11. COMBUSTION REACTION MOVED TO RIGHT DUE TO RICH FUEL-AIR RATIO



In Figure 12, the Target Ratio (TG) of the combustion reaction has moved to the left causing the scanner to view a higher ratio. This shift was caused by the fuel/air ratio becoming leaner. To correct for this change in fuel/air ratio, the trimming actuator needs to close the air damper, decreasing the air supply. This decrease in air causes the combustion reaction to move right, repositioning the original OH/CH TARGET RATIO (TG) in front of the scanner.

Note: The scanner line of sight remains fixed.

FIGURE 12. COMBUSTION REACTION MOVED TO LEFT DUE TO LEAN FUEL-AIR RATIO



The changes in the OH/CH ratio is sensed by the scanner and transmitted to the controller. The controller compares the actual OH/CH ratio to the TARGET RATIO (TG) for that specific firing rate. (Refer to the **LEARN OPERATION** under the **LEARN GROUP** section of this bulletin.). When the controller sees a difference between the TG and the actual OH/CH ratio, it generates an output to the CA202 trimming actuator to reposition the burner air damper.

Since the Scanner Line of Sight can be drawn to intersect at any point along the horizontal line in this snapshot of the combustion reaction no direct correlation can be drawn between the OH/CH ratio and the traditional excess oxygen in the flue gas. Therefore, the qualified burner technician must first tune the burner to its optimum combustion efficiency with the use of a combustion analyzer (such as the FIRETRON® analyzer). The data obtained when tuning the burner should be logged by the burner technician. This data can then be used for future reference if the burner needs readjusting. Refer to the MECHANICS OF COMBUSTION section later in this document for more details on the combustion process.

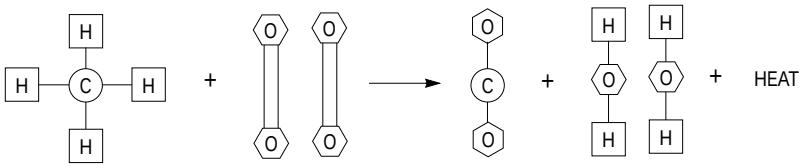
MECHANICS OF COMBUSTION — GASEOUS FUELS*

Gas molecules are constantly in motion in straight line paths. Their rate of motion is determined by temperature. The higher the temperature, the faster a molecule moves; and conversely, the lower the temperature, the slower it moves.

There are very large numbers of molecules in any gas stream and during their random movements may collide with each other, bounce off and change direction. With increased temperature and energy levels of the gas, these collisions become more frequent and violent.

In a complete mixture of oxygen and methane (natural gas) one molecule of methane would be colliding with two molecules of oxygen even at room temperature. The momentum of the collision would not be sufficient to break the bonds of the hydrogen and carbon or oxygen molecules, and allow the oxygen to be added to the carbon or hydrogen. As the temperature of the molecules is raised, the velocity of the molecules increase and more energy is liberated upon impact.

The Chemical Reaction of Methane and Oxygen



At about 1200°F enough velocity and energy has been imparted to molecules so that the collision occurs with enough force to break the double oxygen bond and hydrogen linking to the carbon center of the methane molecule. At this time, the situation is very unstable. The carbon has a high affinity for oxygen and so does hydrogen. Combustion begins.

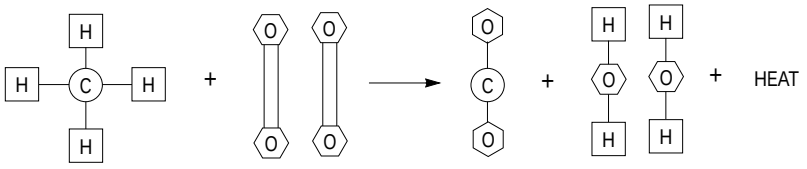
As soon as this reaction takes place, heat is released in the immediate vicinity of the collision and the molecule is at a temperature approaching 5200°F. This heat is radiated to the next adjoining molecules and a chain reaction begins. The initial 1200°F can be provided by a match, pilot flame, or spark from an ignition transformer.

If air is substituted for oxygen, the chain reaction will continue but nitrogen absorbs part of energy and impedes the progress. If the ratio of air to methane is increased, a point will be reached where the energy required to bring the mixture of 1200°F exceeds the heat released by the molecules ignited by the ignition source. At this point the flame will go out.

This point is known as the LEL or low explosive limit. At room temperature the lower explosive limit is approximately 4 percent methane in the air. There is also an upper limit of 15 percent methane that is too rich to support combustion.

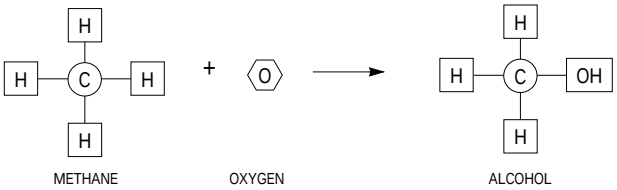
GAS COMBUSTION PHASES

Referring back to the natural gas combustion reaction, that is the mechanical and chemical reaction of methane and oxygen, further investigation shows that the reaction passes through several intermediate stages before the reaction is completed. The initial and final reactants and products are:

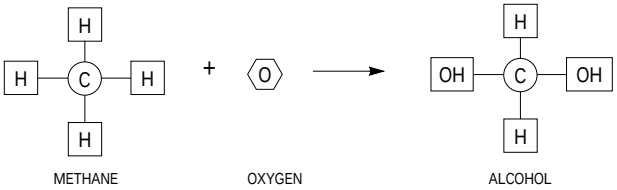


* The information contained in this section (pages 26-28) is from *Combustion Technology Manual* (5th edition, 1994) published by IHEA (Industrial Heating Equipment Association). Reprinted with permission of the publisher.

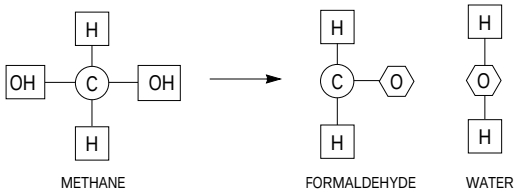
But actually, the first action taking place is:



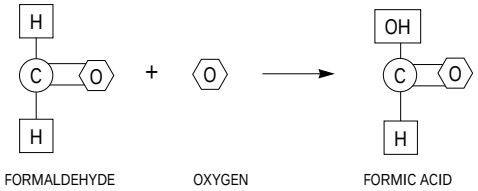
Or, methane plus oxygen equals an alcohol. The collision force actually drives the oxygen atom into a methane molecule. The opening of the chemical linkages holding the atoms releases the energy of these linkages, raising the temperature of the molecule. The second phase is:



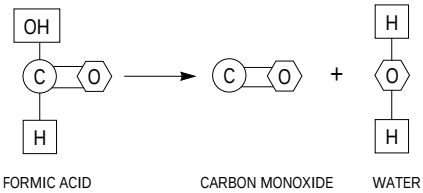
The alcohol unites with another oxygen to form a secondary alcohol. This alcohol is very unstable and beaks down almost immediately to formaldehyde and water vapor:



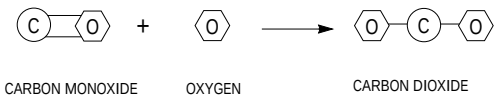
The formaldehyde has a high affinity for oxygen and when another oxygen is added an acid is formed:



The step-by-step reaction is proceeding with increasing releases of energy and a constantly rising temperature level. In this high-energy state, formic acid is unstable and breaks down with the oxygen to form carbon monoxide and the second water molecule is released.



The carbon monoxide then combines with the last oxygen atom available to form carbon dioxide, and complete the reaction

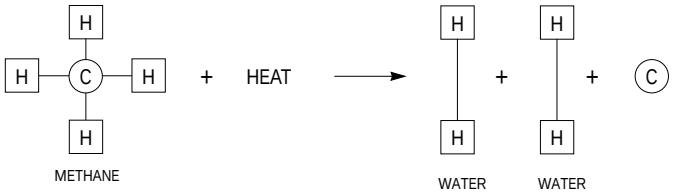


These reactions all take place at extremely high-energy levels, progress almost instantaneously and at very high temperatures, approaching 5000°F internal molecular temperature.

The combustion phases indicated occur with a characteristic blue flame, when oxygen is intimately mixed with the gas, and readily available to add to the methane molecule.

LUMINOUS GAS FLAMES

If insufficient oxygen is present at the beginning of the combustion reaction some of the gas molecules will combust and raise the temperature of the remaining gas stream above the 1200° F linkage-bond fracture point. The high-velocity movement of the methane molecules colliding with each other causes the shearing off of the hydrogen atoms, leaving the carbon as free atoms or linked molecules.



At these temperatures the carbon atoms are incandescent and they impart a yellow glow to the flame. Some luminous flame nozzle mixing burners deliberately control the rate of air addition to moving gas stream to produce maximum flame color.

The combustion phases for thermally disassociated molecules then becomes a simple two-step process with the addition of oxygen:

$C + O \rightarrow C = O$	CARBON MONOXIDE
$C = O + O \rightarrow O = C = O$	CARBON DIOXIDE
$2\ H—H + O = O \rightarrow 2\ H—O—H$	WATER VAPOR

FLAME QUENCHING

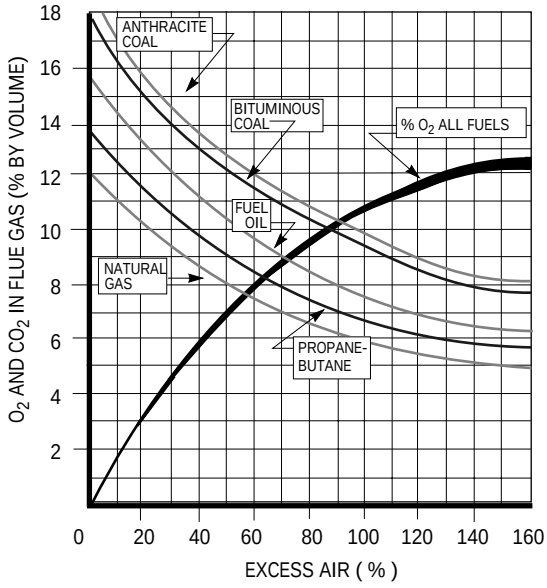
If during the multiphase reaction the temperature of the molecules dropped drastically from some external causes, the reaction would cease and the reactants would be isolated in their various stages of formation. When this occurs the flame is quenched. A burning gas flame contains all of the partially reacted compounds at the time in their various states of transformation. Should a refrigerating medium be brought in contact with any part of the flame and reduce the temperature of that part below 1200°F, the flame will be arrested or quenched and combustion will be halted in any stage of completion. When this occurs, there are alcohols, aldehydes, formic acid, higher order acids, and carbon monoxide present as well as carbon dioxide and water vapor.

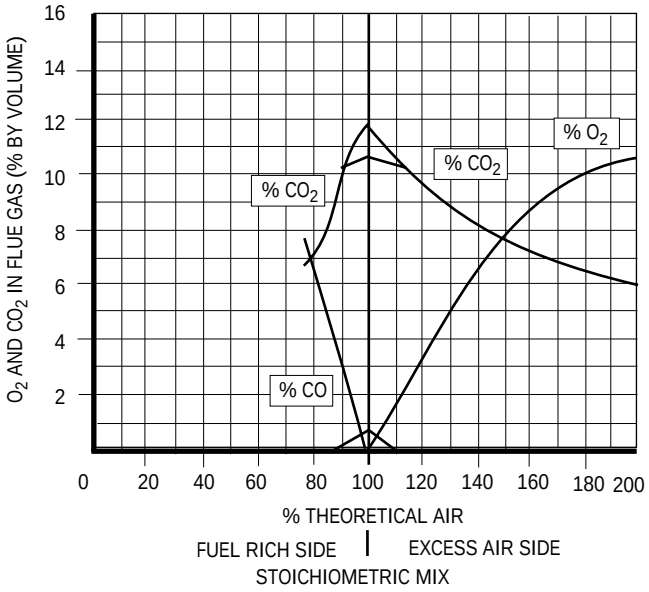
FLAME QUENCHENING OF AN UNPROTECTED FLAME

In actual practice, flame quenching is a possibility on lower temperature industrial processes, especially air heaters. In a case where recirculated air is being heated by mixing with hot flue gases, the air itself might become the refrigerating medium if it impinged into the flame. Long, unprotected flames from a burner firing into a high velocity air stream may permit the air to quench the edge of the flame and produce the aldehydes and the other undesirable flue products. Arrested or quenched combustion conditions can be detected, even in small quantities, by the acrid odor of the products.

In this particular process, the arrested aldehyde formation can be prevented by protecting the flame from the cooling effects of the air with an air shield, and thereby controlling the rate of introduction of secondary air into the flame.

FIGURE 13. TYPICAL COMBUSTION CURVES





CONVERTING BETWEEN WET % O2, DRY % Ox, AND % EXCESS AIR

% Oxygen Dry	% Oxygen Wet	% Excess Air
0	0	0
1.00	0.82	4.53
1.10	0.90	5.00
1.22	1.00	5.57
2.00	1.66	9.54
2.09	1.73	10.00
2.41	2.00	11.70
2.98	2.49	15.00
3.00	2.51	15.10
3.57	3.00	18.60
3.80	3.20	20.00
4.00	3.38	21.40
4.54	3.85	25.00
4.71	4.00	26.20
5.00	4.26	28.40
5.22	5.02	30.00
5.83	5.00	34.80
5.85	5.02	35.00
6.00	5.16	36.30
6.43	5.55	40.00
6.92	6.00	44.60
7.46	6.50	50.00
8.00	7.01	55.90
8.38	7.35	60.00
9.04	8.00	68.70
9.83	8.77	80.00
10.00	8.93	82.60
11.00	9.92	100.00
11.10	10.00	102.00

TROUBLESHOOTING LOG

The information below is required for effective troubleshooting. Fill in all the values to find the best solution to your problem.

Boiler Manufacturer	_____	hp _____
Burner Type	_____	
Hot Water	_____ Steam _____	psi _____
MAX Input	Millions of BTU/HR _____	
Minimum Input	Millions of BTU/HR _____	
Feedback Jumper (J1) position,	135 _____ 5000 _____	
Feedback Potentiometer span	span _____ ohms	
Scanner Amb.	_____ ° F	
Detector Temp.	_____ ° F	
Scanner Gain	_____	
Scanner F/W Ver	_____	
OH/CH Burner off OH	OH_____ CH _____	
OH/CH Pilot	OH_____ CH _____	
OH/CH Low Fire	OH_____ CH _____	
Style of Air Damper	Single Blade Butterfly _____	Inlet Vane _____ Other _____
CA202 null position	Extend _____	Center _____ Retract _____
CA202 operation Direct	Direct _____	Inverse _____
Lo trim start	0-30_____	
Hi trim end	70-100 _____	
Controller F/W Version	_____	

LEARNED BINS (Indicate bins that display an (*) after the BIN number. Example, 3*	**0**	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**
FEEDBACK POSITION ALLOWABLE RANGE (%)	**0-9**	**0-19**	**20-29**	**30-39**	**40-49**	**50-59**	**60-69**	**70-79**	**80-89**	**90-99**
Feedback Potentiometer Position % (md)										
CA202 Position, % (At)										
OH/CH Ratio (Tg)										
OH/CH Ratio (Rt)										
OH VALUE										
CH VALUE										
% Excess Oxygen										
NET Stack Temperature										
% Combustion Efficiency										
PPM Carbon Monoxide										

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