FUEL OIL COMBUSTION PROCESS, ANALYSIS AND TESTING OF OIL FIRED AND NATURAL GAS BURNERS

CONTENTS PAGE

1. GENERAL

1.01 This section is issued to serve as a guide for personnel engaged in oil and gas burner maintenance, to assist them in understanding the basic requirements for good fuel combustion, and to improve the results obtained from incomplete combustion.

1.02 This practice is general in design, and specific data concerning particular combustion equipment should be made by consulting manufacturers' service manuals. When this section is reissued, the reason(s) for reissue will be given in this paragraph.

1.03 Additional information concerning boilers, oil burners, and associated equipment may be obtained by referring to the following sections:

SECTION	TITLE
770-210-300	Low Pressure Heating Basic Fundamentals and Bell System Standards
770-210-301	Hot Water Heating Boilers—Operation and Maintenance
770-210-302	Steam Heating Boilers—Operation and Maintenance

2. PRECAUTIONS

2.01 Safety should be foremost in the minds of the craft personnel performing the heating equipment tests outlined in this practice. Only trained and qualified personnel should be assigned these tests, and they must observe the following precautions:

(a) Safety glasses must be worn at all times.

(b) Avoid hot surfaces in and around the boilers.

(c) Never stand in front of combustion chamber doors when burner is lighting off.

(d) Make sure all associated electrical control switches are turned off and tagged when performing the check outlined in paragraph 6.01.

(e) Always keep hands off and away from working motor parts when burner is operating.

(f) Be alert for carbon monoxide as it is a by-product of incomplete combustion.

3. FUEL OILS

3.01 Fuel oils are classified by divisions (grades from 1 through 6), and oil burners are designed accordingly for use of each. There are limiting properties within these grades which are specified in the Americal Society Testing Materials specifications for fuel oil.

3.02 The two common methods employed in preparing fuel oils for combustion are high pressure atomization and centrifugal atomization. The following is a brief description of each method:

(a) With high pressure atomization used by high pressure gun-type burners, the oil pressure is built up to approximately 100 to 300 psi by a pump and delivered through an oil line to a nozzle from which a vaporous cloud of tiny droplets or globules is sprayed into the combustion chamber. With the aid of ignition and a proper air ratio, combustion is established.

(b) In centrifugal atomization, the oil is fed to a rapidly rotating cup (3450 rpm or faster). The oil spreads throughout this cup in a fine film and then flies off the outer edge at a high speed into finely divided parts. Again, with aid of ignition and air, combustion is established.

3.03 Natural gas is also used for firing heating boilers. This fuel is easy to control, and its clean combustion characteristics make it desirable for heating. Two types of burners are used for heating boilers with natural gas; they are:

(a) The atmospheric gas burner is used primarily on domestic and small commercial-type boilers and employs the bunsen burner or injection principle in their operation.

(b) There are two types of power burners used; the pressure and forced draft. The pressure type is used for small commercial operation usually with natural draft or induced draft. Forced draft burners are used for the larger commercial installations and industrial application.

4. COMBUSTION PROCESS

4.01 Combustion may be defined as the combination of a substance with oxygen resulting in the release of heat, gases, and light. The rate of combustion depends upon the rate of reaction of the substance with oxygen, the rate of which the oxygen is supplied, and the temperature obtained due to surrounding conditions. Complete combustion is obtained when the combustible elements in a fuel are oxidized by all of the oxygen with which they will combine. All of the oxygen or air supply is generally not utilized; this excess portion is commonly referred to as excess oxygen or excess air. Excess air is usually expressed as a percentage of the air required for best possible combustion.

4.02 Incomplete combustion is obtained when any of the combustible elements are not completely oxidized in the combustion reaction. This condition not only represents inefficient use of the fuel, but also presents a hazard because carbon monoxide is usually one of the by-products of incomplete combustion. For example, when a hydrocarbon does not oxidize completely to form carbon dioxide and water, it forms by-products depending on where and how the reaction process is interrupted. Too low a temperature, such as may be caused by flame impingement on a cold surface, improper air to fuel ratio caused by a poor oxygen supply to the flames, and/or insufficient mixing of the air and fuel, is the primary cause of incomplete combustion.

4.03 Fuel oil is prepared for burning by the oil burner. To burn properly, the oil must be atomized or broken up into minute particles and combined with air. The oil must be combined in suspension, and the environment in which the combustion takes place must furnish enough heat to the burning oil to assist vaporization and maintain a high temperature to prevent any oil from escaping unburned.

4.04 Burning oil in suspension means that the oil must burn in free space and must not impinge on any cold surfaces. To obtain complete combustion, the particles of oil must be constantly exposed to high temperatures.

4.05 In order to burn oil properly in suspension, the combustion process must be confined to an environment that will provide it with the required space to prevent impingement of the oil on the surrounding surfaces and will also provide it with intense heat that is reflected, radiated, and reradiated back on the fire itself. This atmosphere will permit the oil particles to vaporize freely and completely without interference.

4.06 The environment in which this combustion takes place, a combustion chamber or fire box, must be of the proper size, design, and shape for the burner and boiler (or furnace).

4.07 In lighting an oil burner, the initial heat required to raise the temperature of the fuel to the firing point (ignition point) is supplied by the ignitor. There are three types of ignition employed in oil and gas burners:

(a) ***Constant (standing):*** Ignition that is present in the combustion chamber at all times whether the burner is operating or not.

(b) ***Intermittent:*** Ignition that is introduced at the start of a burner operation and continues until the end of the burner cycle.

(c) ***Interrupted:*** Ignition that is introduced at the start of a burner operation, remains on for a timed interval, and then cuts off while the burner operation continues.

4.08 Based on the design of the burner, the ignitor may be an electric spark, a gas flame, an electric spark ignited gas flame, or electric spark ignited oil flame. After ignition, the temperature of the environment required for combustion is maintained by the heat from the flame. Where burning gases, which make up a fuel flame, come in contact with low temperature surfaces on a boiler (or furnace) or are prematurely cooled in any other manner, combustion may be retarded or quenched. It is the function of the combustion chamber or fire box to offset any such undesirable effects. The combustion chamber design will depend on the type of oil burner and boiler (or furnace) used.

5. COMBUSTION ANALYSIS

5.01 An analysis of the burner combustion process is required to determine the efficiency of the existing flame and how well the heat produced by this flame is being absorbed by the boiler (or furnace).

5.02 Analysis of CO_2 or oxygen, stack temperature, smoke emergency, and draft utilizing combustion efficiency measurement instruments, such as those manufactured by the Bacharach Company, Lynn Products Company, and others, may be used to obtain a scientific approach to good combustion. Adjustments made without the use of these instruments based on the judgment of the individual can be erratic, costly in fuel oil consumption, and may cause smoke problems.

5.03 Many state and local codes have ordinances pertinent to smoke control which have been developed in the interest of health and safety, and effort shall be directed to meeting these standards.

6. COMBUSTION TESTING PROCEDURES AND EQUIPMENT

6.01 Prior to making the required combustion tests of a burner, the following should be performed:

(a) With the main burner switch off, check the following:

(1) Inspect combustion equipment for loose hardware and obvious maladjustment.

(2) Inspect combustion chamber for loose brick or other defects and repair as required.

(3) Check concentration of soot deposits or carbon formation on flue passages, combustion chamber, and smoke pipe. Clean, if necessary, before conducting combustion tests.

(4) Verify whether combustion chamber is of the proper size. (Refer to manufacturer's specifications or use ratio of approximately 100 square inches per gallon per hour firing rate.)

(5) Remove ignition assembly. Check nozzle for proper size and type. Check for proper adjustments of electrodes. Adjust and clean as required.

(6) Check and clean, as required, the burner fan, fan housing, and other air handling parts.

(7) Clean or replace oil filter and/or fuel pump strainer.

(8) Seal all leaks in boiler (or furnace), smoke pipe, around doors, and blast tube.

6.02 With the main burner switch on and burner firing, observe or determine the following:

(a) Flame ignition.

(b) Flame color and shape.

(c) If there is any flame impingement on combustion chamber surfaces.

(d) Evidence of odors near burner or barometric regulator.

(e) Starting, running, post fire, and noise conditions.

(f) Flame cut-off when burner is shut down.

(g) Measurement of oil pressure delivered by pump and vacuum measurement of fuel oil suction line.

(h) Verify fuel pump pressure and adjust for correct pressure as required.

(i) Lubricate burner parts as directed in the manufacturer's maintenance instructions.

6.03 The term "combustion efficiency test" refers to the process of evaluating the effectiveness with which a heating plant is using fuel.

6.04 The ideal situation would be where the fuel was completely burned in the correct amount of air, thus releasing its full heat potential and where this heat in the hot gases was completely absorbed by the heating medium. In practice, it is impossible to achieve these two results.

6.05 In a combustion efficiency test, the degree to which each of these objectives is attained is separately assessed. The two results then being jointly compared with certain yardstick figures which are known to represent good practice.

6.06 Test results disagreeing widely from the yardstick figures would probably mean that the plant was operating at less than maximum effectiveness; the manner of divergence perhaps indicating the type of adjustments required in order that performance might be improved.

6.07 A number of reliable combustion efficiency testing devices are currently available for analyzing heating plant effectiveness. Two of the more widely used devices are described below:

(a) The Bacharach combustion efficiency testing kit for oil and gas burner heating plants contains the items illustrated in Fig. 1.

CO_2 Indicator

Smoke Tester

Draft Gauge

Carbon Monoxide Tester

Stack Thermometer

Combustion Efficiency Calculator (Fire Finder)

Smoke Scale

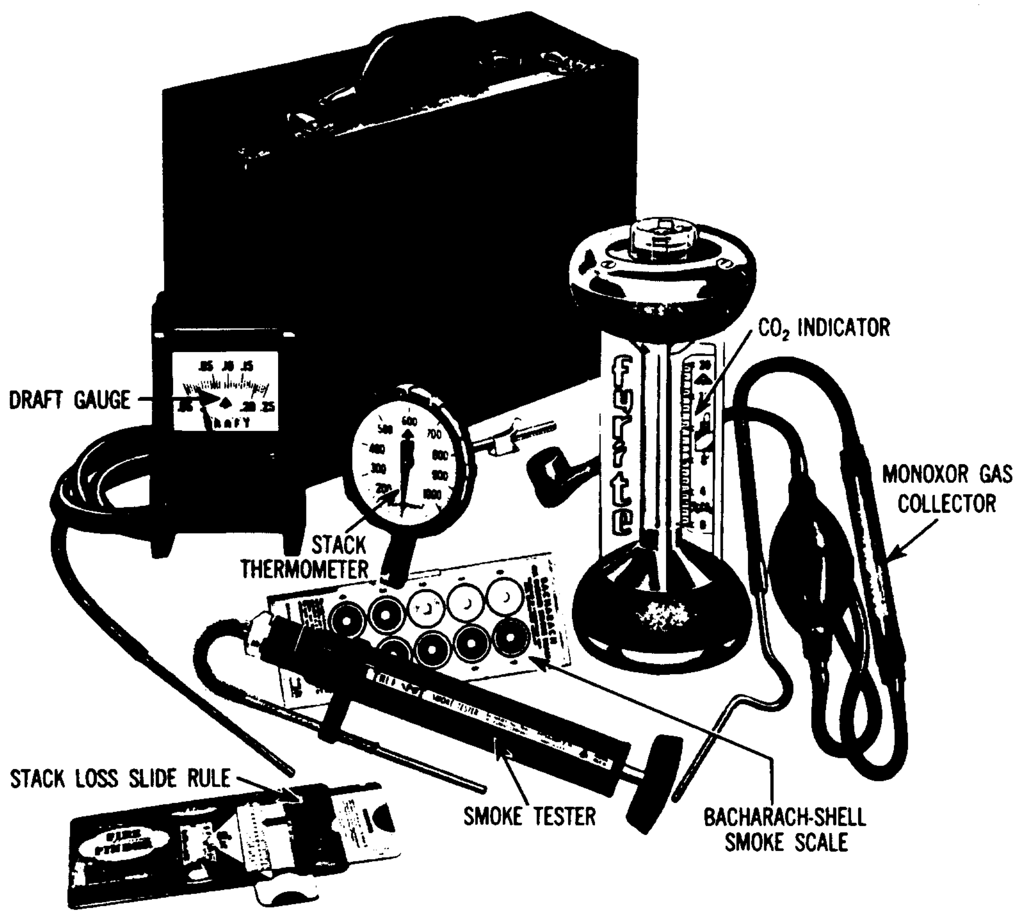


Fig. 1—Combustion Efficiency Testing Kit

(b) The Lynn Combustion Efficiency Analyzer for oil and gas heating plants is an electrically powered, solid-state analyzer manufactured in two models measuring CO_2 or O_2. Additionally, it measures the stack temperature, draft, and smoke test. All tests are measured through a single probe inserted into the stack. The probe samples gases for CO_2 or O_2 measurement; it has an internal thermocouple for stack temperature and a slot for smoke test. The probe also serves as the connector for breech draft measurement. Testing procedures to measure the heating plants performance consist of pressing the appropriate test button on the face of the instrument. The instrument responds quickly, indicating the results on a meter. This procedure permits the technician to make an adjustment to the burner while watching the meter respond. The Lynn Combustion Efficiency Analyzer for oil and gas heating plants is illustrated in Fig. 2.

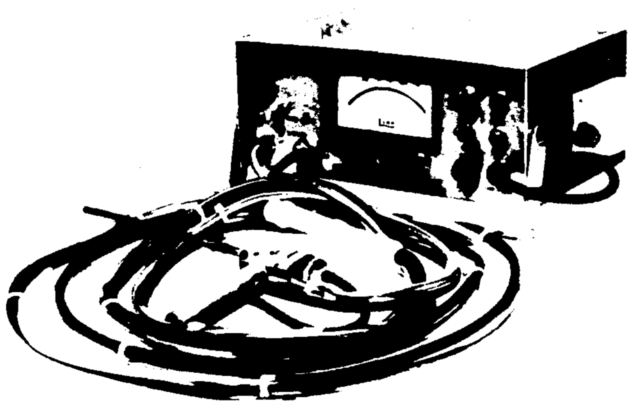


Fig. 2—Lynn Combustion Efficiency Analyzer for Oil and Gas Heating Plants

A. Combustion Efficiency and Smoke Test of Oil Fired Plants

6.08 The combustion efficiency of an oil fired plant is determined by means of the following tests conducted in the order given:

(1) Stack Temperature Test

(2) Draft Test

(3) CO_2 or O_2 Test

(4) Smoke Test.

Instrument readings and the combustion efficiency that they indicate should be recorded as soon as they have been determined and before any adjustment to the heating plant are made.

6.09 If test holes do not exist in the heating plant, it will be necessary to drill a 1/4-inch hole through the fire door and also through the breeching within 12 inches of the boiler (between the boiler and the automatic draft regulator). If desired, an additional hole may be drilled at the breeching location so that the stack thermometer may be inserted and left in place throughout the various tests. The test holes should be sealed with furnace cement when not in use, and any insulation removed when drilling the breeching holes should be replaced.

Stack Temperature Test

6.10 Insert the thermometer stem or sensing element into the breeching test hole as shown in Fig. 3. The stack temperature should be read when the following conditions are satisfied:

(1) The burner is operating.

(2) All movement of the thermometer has ceased.

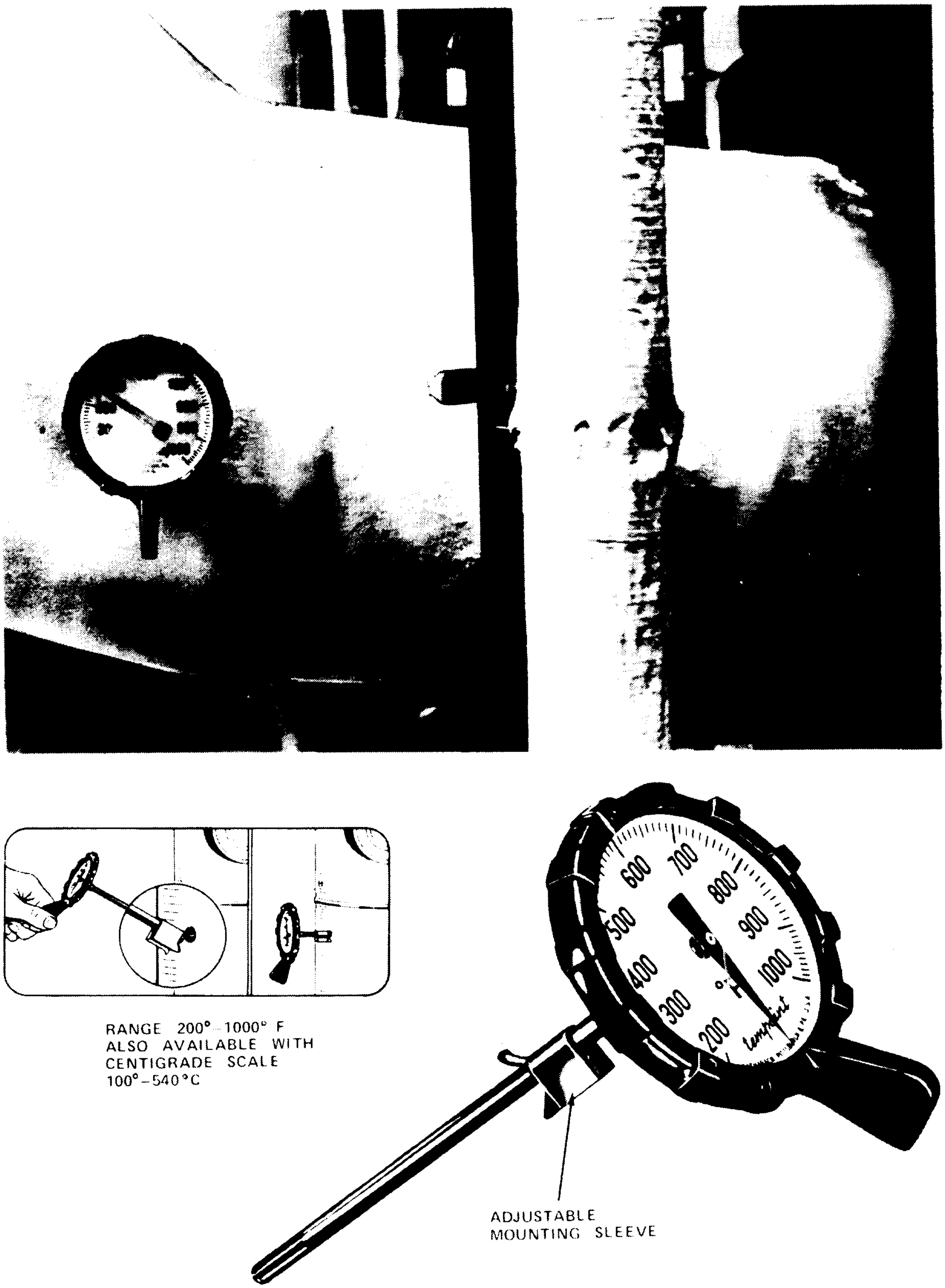


Fig. 3—Testing Stack Temperature

6.11 To determine the net stack temperature, subtract the room temperature from the actual stack reading.

Example:

Actual stack reading	420° F
Room Temperature	70° F
Net Stack Temperature	350° F

6.12 As a rule, the net stack temperature should be approximately 100 to 150°F over media temperature (steam or hot water.) It is desirable to keep the stack temperature as low as possible which means that the greatest amount of heat is being absorbed by the heat exchanger. Stack deterioration may begin when the border line temperature is 260° F. Units converted from coal to oil will run somewhat higher.

Example:

Steam temperature (at 6 psi)	230° F
Temperature above media	120° F
Stack Temperature	350° F

Draft Test

6.13 The draft test on natural draft systems is performed as follows: Place the draft gauge on any convenient level surface near the boiler for ease of interpretation. (For forced draft units, review the manufacturer's specifications.)

6.14 Adjust the draft gauge to "zero." (See manufacturer's specifications for individual styles of gauges.)

6.15 After allowing the heating plant to reach a normal operating temperature, as indicated by a constant reading on the stack thermometer, insert the draft gauge sampling tube through the hole in the fire door as illustrated in Fig. 4 and observe the gauge reading. This reading should be as low as possible with a minimum 0.02 inch of water negative.

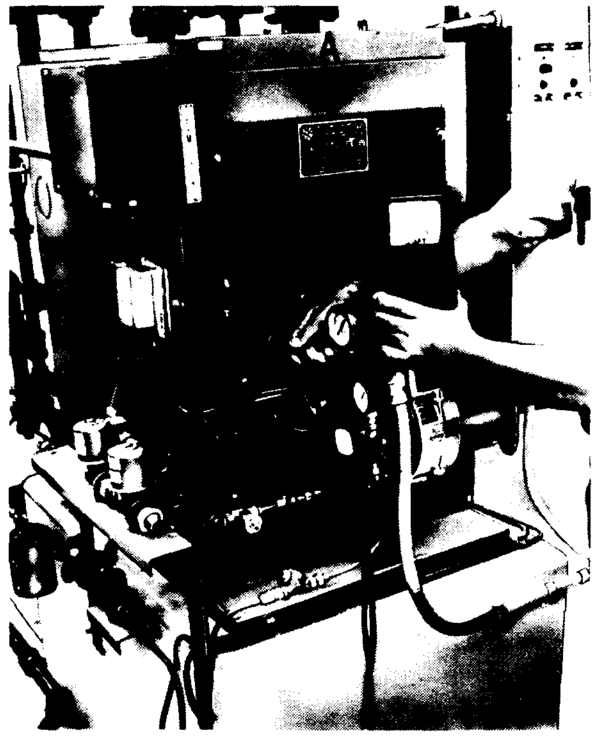
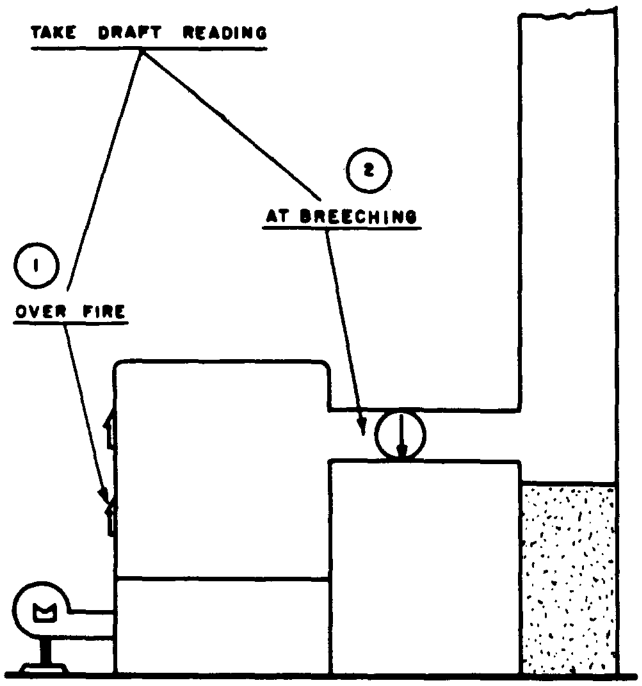


Fig. 4—Testing the Draft

6.16 Insert the draft gauge sampling tube through the test hole in the breeching and observe the gauge reading. This reading should be greater than the reading taken over the fire.

6.17 The draft loss through the boiler can now be calculated as illustrated in Fig. 5 by subtracting the reading over the fire from the reading at the breeching. Draft loss through the boiler should not equal or exceed draft at the breeching.



DRAFT AT BREECHING - 0.04
DRAFT OVER FIRE - NONE
DRAFT LOSS THROUGH BOILER - 0.04

NO GOOD !!

DRAFT AT BREECHING - 0.05
DRAFT OVER FIRE - 0.02
DRAFT LOSS THROUGH BOILER - 0.03

GOOD !!

DRAFT LOSS THROUGH BOILER SHOULD NOT EQUAL OR EXCEED DRAFT AT BREECHING

Fig. 5—Calculating Draft Loss

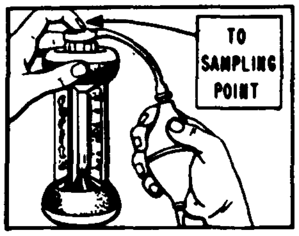
6.18 The CO_2 test indicator must be replaced on a level surface, vented to atmosphere by depressing the top plunger, then set to "zero" on its scale. The instrument must be at room temperature before starting the test.

6.19 Turn the heating plant on and allow the normal operating stack temperature to be reached, then insert the metal sampling tube into the breeching test hole as illustrated in Fig. 6. The cap end of the sampling tube is then placed on the plunger valve of the CO_2 indicator and held in a depressed position.

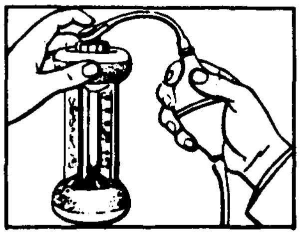
Fig. 6—Taking a Flue Gas Sample

6.20 Next, the rubber bulb is squeezed 18 times in order to obtain a flue gas sample. On the final squeeze, the depressed plunger valve is released; then release the squeeze bulb.

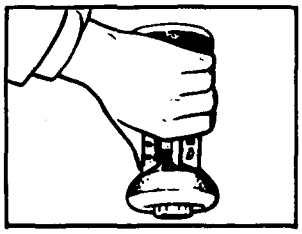
6.21 The CO_2 indicator is now turned over one or more times, permitting the test fluid to run back and forth inside to absorb the gas sample. The indicator is next held upright at a 45-degree angle to permit the test fluid to drain to the bottom of the instrument. The tester is then placed upright on a level surface and the percent CO_2 is read directly from the scale as shown in Fig. 7.



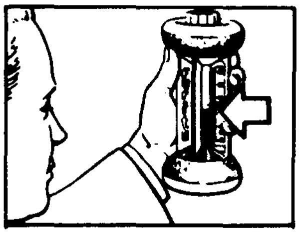
Push rubber connector down-then squeeze bulb 18 times.



Lift finger from rubber connector-this seals FYRITE



Turn bottom side up and back again



Read fluid level on CO_2 scale

Fig. 7—Taking a CO_2 Reading

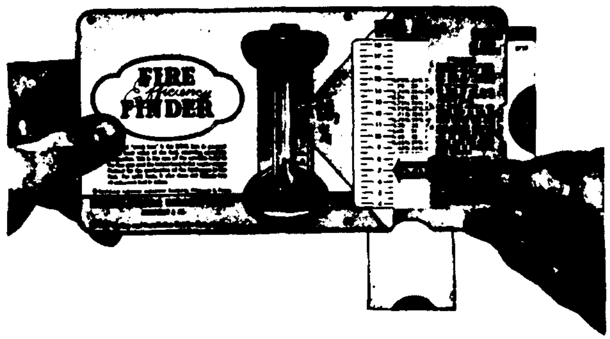
Combustion Efficiency

6.22 The calculation of combustion efficiency is made as follows:

(1) Set the horizontal slide of the "Fire Finder" at the net stack temperature.

(2) Align the vertical slide with the percent CO_2 reading.

(3) Read combustion efficiency directly from indicator window as shown in Fig. 8.



Note: Combustion efficiency slide rule saves time in figuring combustion efficiency and fuel savings.

Fig. 8—*Fire Finder*

6.23 If a low CO_2 reading is observed at the breeching, a further test can be made to determine if air is leaking into the heating plant. In this case, an extra long sampling tube is inserted through the test hole in the fire door. The percent CO_2 indicated at this point should agree with the sample taken at the breeching.

6.24 The highest possible CO_2 reading and/or the lowest oxygen reading should always be the goal as indicated in Fig. 9. A CO_2 or oxygen reading of about 10 and 8 percent, respectively, with No. 2 smoke, and low stack temperature may be considered satisfactory. The perfect excess air for various CO_2 and oxygen readings are show in Fig. 9. The method to calculating excess air leakage is outlined in Fig. 10.

PERCENT CO_2		PERCENT EXCESS AIR	PERCENT OXYGEN O_2
	3	400	16
	4	280	15
	5	200	14
A low CO_2	6	155	13
	7	120	12
	8	86	11
A fair CO_2	9	66	9
A good operating CO_2	10	51	8
	11	37	6
A high CO_2	12	26	5
	13	17	3
An excellent but critical CO_2	14	9	2
	15	0	0

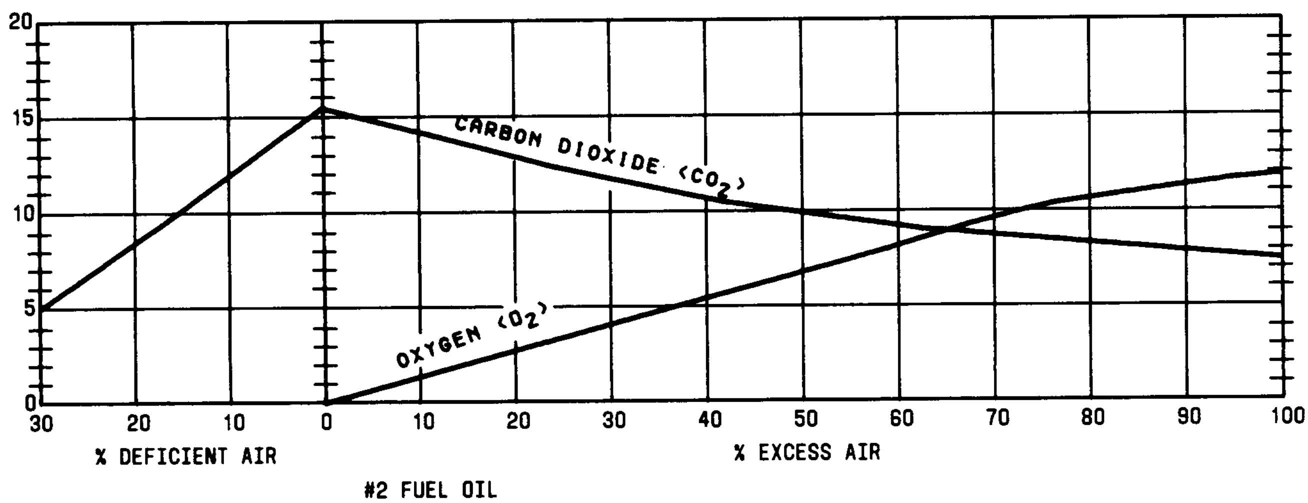
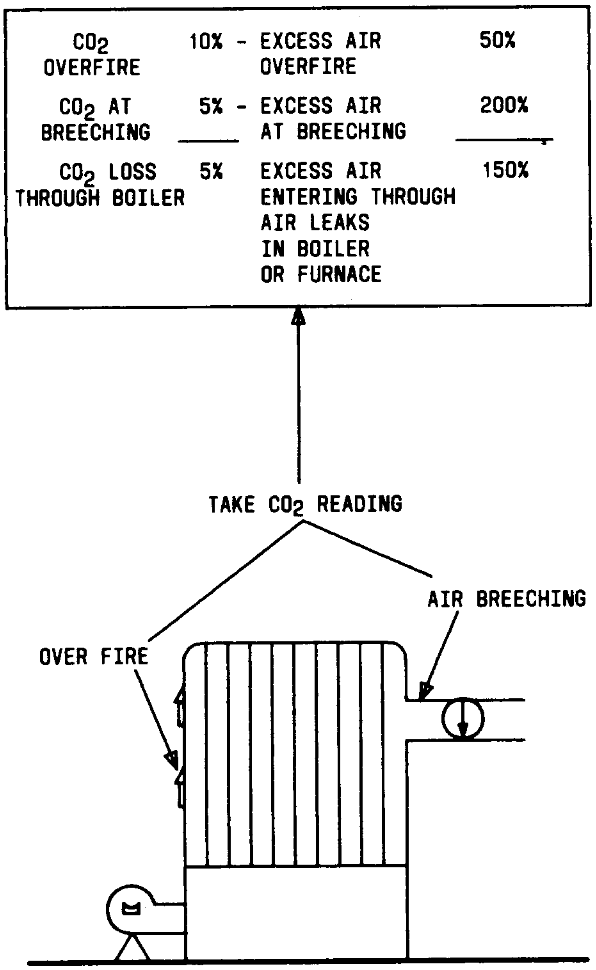


Fig. 9—Percent of Excess Air for Various CO_2 and Oxygen Readings



CO_2 READING (%)	PERCENT EXCESS AIR	CO_2 OXYGEN READING (%)
4	275	15
5	200	14
6	155	13
7	120	12
8	90	11
9	65	9
10	50	8
11	35	6
12	25	5
13	15	3
14	7	2
15	0	0

Fig. 10—Calculating Percentage of Excess Air

Smoke Test

6.25 The objective of this test is to measure the smoke content of the flue gas, and then, in conjunction with other combustion test results, to set the burner operation according to readings on an indicated smoke scale. This scale consists of a card containing approximately ten color-graded spots. Each spot is coded from (0) pure white to (9) the darkest maximum smoke color obtainable on a heating plant.

6.26 While the heating plant is operating at normal temperature, insert the metal sampling tube of the smoke tester into the test hole in the breeching as illustrated in Fig. 11. Place a clean piece of standard grade filter paper into the holding slot of the instrument. Operate the sampling pump or squeeze bulb ten times, waiting for several seconds between each suction stroke.

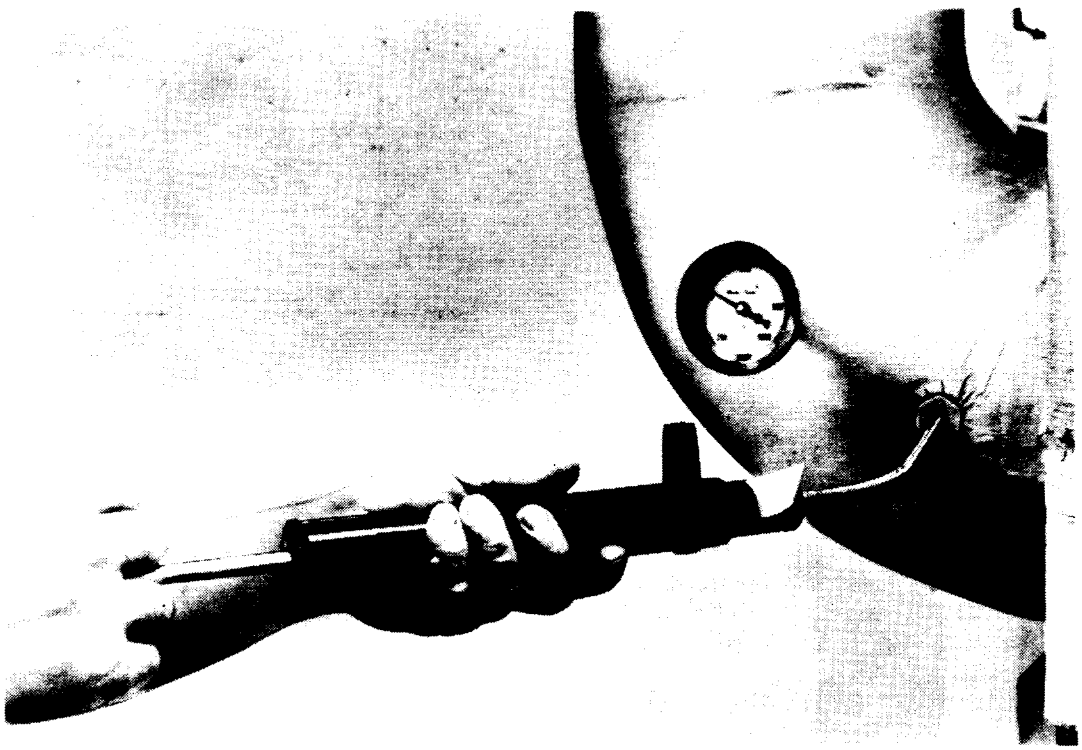


Fig. 11—Taking a Smoke Sample

6.27 Remove the sample paper from the instrument holding slot and compare it with the smoke scale indicator. It is recommended that the comparison of the sample to the standard scale be made in natural light as artificial light tends to distort the comparison.

B. Adjustment to Improve Efficiency

Stack Temperature

6.28 A high stack temperature reading may be the result of any of the following conditions:

(a) Excessively high draft; baffling needed.

(b) Heating surfaces dirty; boiler tubes and surface coated with scale or soot.

(c) Furnace undersize; burner overfired.

(d) Poor combustion chamber; repair or replace.

(e) Burning equipment needs expert tuning.

6.29 ***Draft:*** For efficient operation of the burner using natural draft, it is necessary to have a negative draft (updraft) over the fire. This negative draft is necessary to move the flue gas up the stack and to draw air into the firebox for combustion.

6.30 On forced draft systems, the firebox and breeching are subjected to a pressure higher than that of normal atmospheric pressure; this is called positive draft. The manufacturer's specifications should be reviewed before attempting any testing or adjustment of these systems.

6.31 A low draft condition over the fire can possibly cause boiler pulsations, odors, noise, loose soot, and an overall reduction in efficiency.

6.32 An excessive draft condition over the fire will affect the efficiency of the heating plant and will cause a greater suction or pull through the boiler or breeching, resulting in a considerable amount of excess air being drawn into the boiler. This immediately lowers the CO_2 reading and increases the stack temperature as shown in Fig. 12.

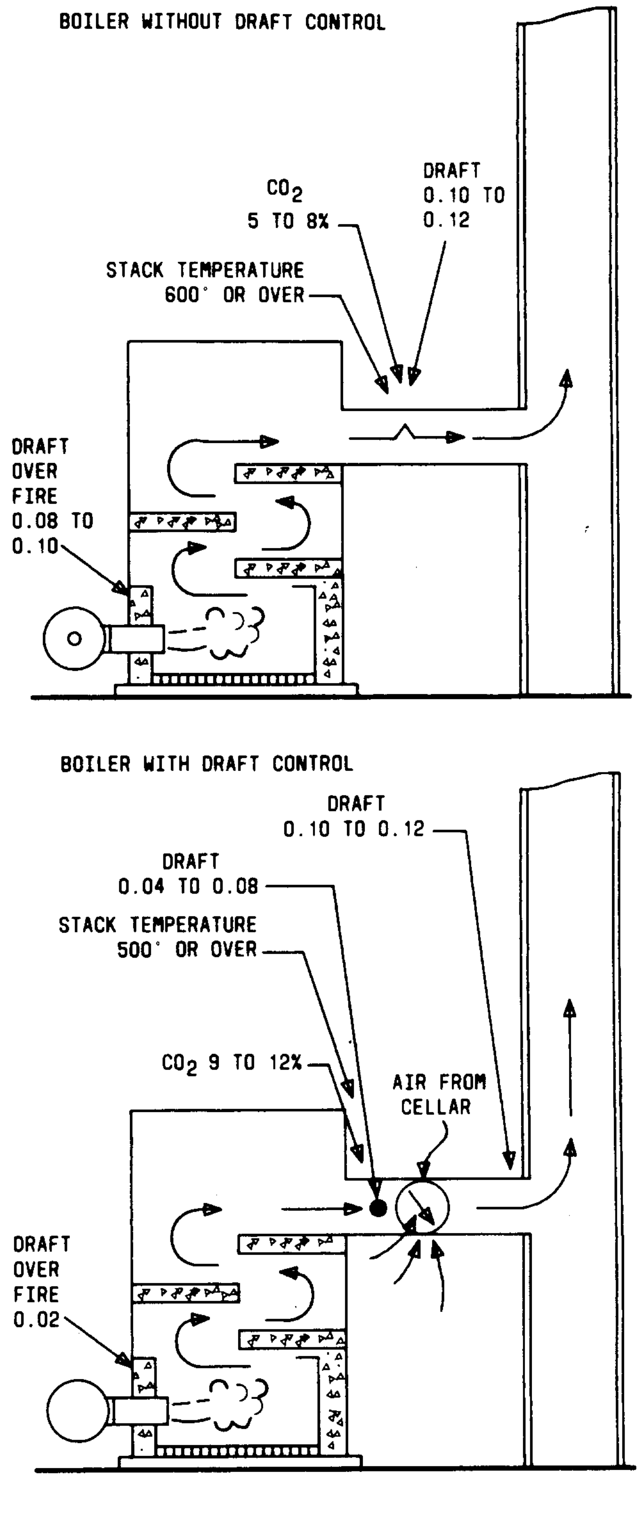


Fig. 12—Draft Control Can Increase Operating Efficiency

6.33 If the draft over the fire is in excess of 0.02, flame roar may occur due to the large quantities of air that will readily flow into the low-pressure area.

6.34 The draft over the fire can be adjusted to the recommended minimum of 0.02 inch of water by repositioning the counterweight on the barometric damper as illustrated in Fig. 13. After adjustments have been made, the counterweight should be locked securely to the shaft.

Fig. 13—Adjusting the Draft

6.35 A low CO_2 and high oxygen reading can be caused by any of the following conditions:

(a) Air shutter open too wide.

(b) Excessive air leaks into furnace.

(c) Excessively high draft through furnace.

(d) Nozzle worn, plugged, or unsuitable for oil burner.

(e) Air handling parts incorrectly adjusted.

6.36 If the CO_2 reading over the fire is higher than the reading at the breeching, excess air is leaking into the heating plant and the cause should be found and corrected. This may be done by lighting a candle and presenting the flame to the suspected areas of leakage, in which case the candle flame will be drawn towards the leak. This test is performed while the burner is operating.

Smoke

6.37 Some of the causes of smoky combustion are as follows:

(a) Air inlet to boiler room sealed.

(b) Unit overfired, chamber too small or wrong shape, liquid oil inpinging on chamber wall.

(c) No draft over fire.

(d) Air cone diameter too large for gpm rating.

(e) Motor not up to speed; coupling slipping.

(f) Clogged air opening; improper adjustment.

(g) Oil pressure too low.

(h) Oil too heavy and poor grade oil.

6.38 The following are some examples of what the smoke scale numbers will indicate about the performance of the heating plant:

No. 1 – Excellent—Little if any sooting of furnace or boiler surfaces.

No. 2 – Good—May be slight sooting of furnace or boiler.

No. 3 – Fair—Substantial sooting with some types of furnaces or boilers.

No. 4 – Poor—This is a borderline smoke. Some units may soot only moderately; others may soot rapidly.

C. Combustion Efficiency and Carbon Monoxide Test—Gas Fired Heating Plants

6.39 Company personnel should never attempt to adjust or repair the gas, utility-owned, regulating devices on a boiler. Any defects or irregularities that may be discovered by a visual inspection or a combustion efficiency test should be corrected by a thoroughly qualified gas burner mechanic.

6.40 This part of the practice outlines the accepted method of performing combustion efficiency test on gas fired heating plants, the results of which would indicate any need for adjustment or regulation of the burner.

6.41 The main objective of a combusiton efficiency test on gas burning equipment are to analyze the flue gases for safe combustion (no carbon monoxide) and to obtain maximum operating efficiency of the equipment.

6.42 Atmospheric burners are used primarily on domestic- and small commercial-type boilers and forced warm air heating plants. Large commercial heating plants may be equipped with a fan assisted or power-type burner, similar in appearance to the high pressure oil burner. The schematic diagram in Fig. 14 illustrates a typical atmospheric-type burner and how it receives air for combustion.

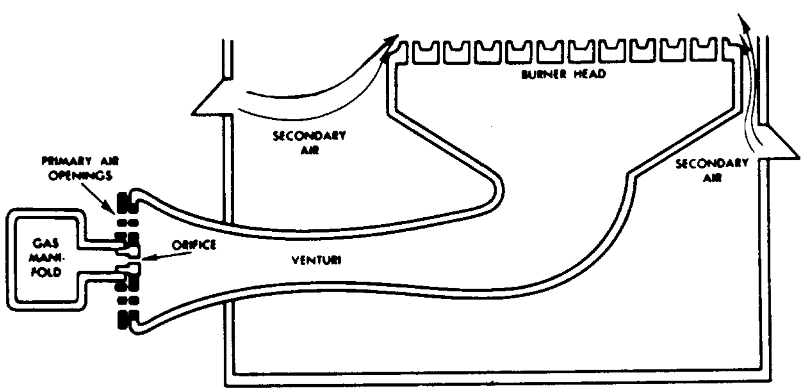


Fig. 14—Typical Atmospheric Burner

6.43 Gas burning equipment is designed to meet rigid standards of efficiency. The features necessary for maximum efficiency are built into the equipment by the manufacturer. Nevertheless, some field adjustments may be necessary to obtain good operating results under the particular conditions of each installation, and these adjustments must be verified by appropriate tests.

6.44 The combustion efficiency of an atmospheric-type burner is computed by means of the following tests:

(a) Stack temperature test.

(b) CO_2 and/or O_2 test.

(c) Carbon Monoxide (CO) test at the flue.

(d) Overfire draft test.

6.45 Instrument readings and the combustion efficiency that they indicate should be recorded as soon as they have been determined and before any adjustments to the heating plant are made.

6.46 The test sequence is similar for fan assisted or power burners except that the manufacturer's specifications should be reviewed for each type of burner.

6.47 Forced draft units should only be tested after thoroughly reviewing the manufacturer's specifications and instructions.

6.48 If test holes do not exist in the heating plant, it will be necessary to drill a 1/4-inch hole through the fire door and also through the breeching within 12 inches of the boiler, between the boiler and the automatic draft regulator (or in the case of small domestic furnaces, the draft diverter). If desired, an additional hole may be drilled at the breeching location so that the stack thermometer may be inserted and left in place throughout the various tests. The test holes should be sealed with furnace cement when not in use, and any insulation removed when drilling the breeching holes should be replaced.

Stack Temperature Test

6.49 Insert the thermometer stem or sensing element into the breeching test hole as shown in Fig. 3. The stack temperature should be read when the following conditions are satisfied:

(a) The burner is operating.

(b) All movement of the thermometer has ceased.

6.50 Turn the burner on and allow the heating plant to reach a normal operating temperature. This will be indicated when all movement of the pointer (or liquid) of the thermometer ceases. Read and record the indicated temperature.

6.51 To determine the net stack temperature, subtract the room temperature from the actual temperature reading.

Example:

Actual stack temperature	420° F
Room temperature	70° F
Net stack temperature	350° F

6.52 As a rule, the net stack temperature should be approximately 100° to 150°F over media temperature (steam or hot water). It is desirable to keep the stack temperature as low as possible, which means that the greatest amount of heat is being absorbed by the heat exchanger. Stack deterioration may begin when the borderline temperature is 260° F.

CO_2 Test

6.53 The CO_2 indicator must be placed on a level surface, vented to atmosphere by depressing the top plunger, then set to "zero" on its scale. The instrument must be at room temperature before starting the test.

6.54 Turn the heating plant on and allow the normal operating stack temperature to be reached. Then, insert the metal sampling tube into the breeching test hole (at the same location used for obtaining stack temperature) as illustrated in Fig. 6. The cap end of the sampling tube is then placed on the plunger valve of the CO_2 indicator and held in a depressed position.

6.55 Next, the rubber bulb is squeezed 18 or 20 times (according to manufacturer's instructions) in order to obtain a flue gas sample. On the final squeeze, the depressed plunger valve is released; then release the squeeze bulb.

6.56 The CO_2 indicator is now turned over one or more times (as directed by the manufacturer), permitting the test fluid to run back and forth inside to absorb the gas sample. The indicator is next held upright at a 45-degree angle to permit the test fluid to drain to the bottom of the instrument. The tester is then placed upright on a level surface and the percent CO_2 is read directly from the scale as illustrated in Fig. 7.

6.57 The addition of some excess air is required with all fuel gases to ensure safe and complete combustion. In general, plants are so adjusted that the flue gases contain 8-1/4 to 9-1/2 percent of CO_2.

Combustion Efficiency

6.58 To calculate combustion efficiency on natural gas heating plants, use the chart in Fig. 15.

Carbon Monoxide Test

6.59 Since carbon monoxide is an extremely dangerous gas, the basic requirement for installing and servicing any gas burning appliance is that no unit shall be left showing any carbon monoxide in the flue products.

6.60 The Monoxor Detector is an instrument designed to indicate whether the flue gas is monoxide-free within the defined limitations. It is not an instrument which measures the percentage of monoxide gas in the sample.

6.61 If the detector tube shows a discoloration indicating excessive carbon monoxide, a qualified gas burner repairer should be notified immediately in order to take corrective action.

Draft Test

6.62 Place the draft gauge on any convenient level surface near the heating plant (for ease of interpretation) and adjust the draft gauge to "zero." (See manufacturer's specifications for various types of gauges.)

6.63 With the burner operating and the stack at normal operating temperature, insert the draft gauge sampling tube into the combustion chamber and observe the gauge reading.

6.64 On atmospheric burners, the draft reading at this point should never be less than 0.01 inch of water. For fan assisted units, review the manufacturer's specifications.

6.65 Any proposed change in the regulation of the draft or firebox pressures should first be discussed with local gas company authorities or qualified repairer representing the type of equipment involved.

D. Adjustments to Improve Efficiency—Gas Fired Plants

6.66 As adjustments to gas burning equipment should only be performed by qualified repairers, the adjustment detail has not been included in this section.

6.67 The causes of low CO_2 readings, etc, are the same as those listed in paragraph 6.35 of this practice.

7. FREQUENCY OF TESTING

7.01 Complete combustion tests should be performed on all oil-fired boilers or burners upon start-up of heating plant and at least once during the heating season. Test should also be made subsequent to any modifications of a burner or boiler. Combustion tests which do not meet acceptable standards should be repeated at shorter intervals until satisfactory test are reached. The final results of each combustion efficiency test should be individually posted in the boiler room log, ie, efficiency 82-1/4 percent, 9 percent smoke No. 2, stack temperature 350 degrees overfire draft 0.02 inch, and stack draft 0.05 inch. Boilers or furnaces that appear to have design problems should be referred to the engineering department for correction.

8. COMBUSTION AIR REQUIREMENTS FOR BOILER ROOMS

8.01 Figure 16 indicates the minimum sized louvered opening to be provided in each boiler room for gravity or natural air entrance. These sizes are based on the total fuel firing rate for each boiler. Any combustion air opening that does not conform to this attachment should be referred to the engineering department for proper action. No opening shall be less than one gross square foot in area.

8.02 In those boiler rooms where combustion air is supplied by means of a mechanically operated fan, the ratio of air to fuel should be 12 cubic feet or per 1,000 BTU of fuel burned.

EFFICIENCY CHART FOR NATURAL GAS

% CARBON DIOXIDE CO_2	% OXYGEN O_2	NET STACK TEMPERATURE (DEGREES F)										
		100	150	200	250	300	350	400	450	500	550	600
4.0	14	84 ¾	82 ¼	79 ½	77	74 ½	71 ½	69	66	63 ½	61	58
4.5	13	85 ½	83 ¼	81	78 ½	76 ½	74	71 ½	69	67	64 ½	62
5.0	12	86	83 ¾	81 ¾	79 ½	77 ½	75 ½	73	71	69	67	65
5.5	11	86 ¼	84 ½	82 ½	79 ¾	78 ¾	76 ¾	74 ¾	72 ¾	71	69	67
6.25	10	86 ¾	85	83 ¼	81 ½	79 ½	78	76	74 ¼	72 ½	70 ¾	69
6.75	9	87	85 ½	83 ¾	82	80 ½	79	77 ½	75 ½	74 ¼	72	70 ½
7.5	8	87 ¼	85 ¾	84 ¼	82 ¾	81 ¼	79 ½	78	76 ½	75	73 ½	72
8.0	7	87 ¼	86	84 ½	83	81 ¾	80 ¼	79	77 ¼	76	74 ½	73
8.25	6	87 ½	86 ¼	84 ¾	83 ½	82 ¼	81	79 ½	78	76 ¾	75 ¼	74
9	5	87 ½	86 ¼	85	83 ¾	82 ½	81 ¼	80	78 ¾	77 ¼	76	74 ¾
9.75	4	87 ½	86 ½	85 ¼	84 ¼	83	81 ¾	80 ½	79 ½	78	76 ¾	75 ½
10.25	3	87 ¾	86 ¾	85 ½	84 ½	83 ¼	82	81	79 ¾	78 ½	77	76
10.75	2	88	86 ¾	85 ¾	84 ¾	83 ½	82 ½	81 ¼	80	79	77 ¾	76 ¾
11.5	1	88 ¼	87	86	85	83 ¾	82 ¾	81 ¾	80 ½	79 ½	78 ¼	77 ¼

A—Locate Net Stack Temperature on chart. Read down to where Net Stack Temperature column intersects with Percent Oxygen and/or CO_2 Column. That figure will be the combustion efficiency percentage.

EXAMPLE:

Gross Stack Temperature	=420°
Room Air Temperature	= 70°
Net Stack Temperature	=350°
Percent Oxygen Reading	= 4%
Percent Carbon Dioxide Reading	=9.75%

B—Read the Net Stack Temperature column 350° down to where it intersects with the Oxygen column 4% and/or Carbon Dioxide column 9.75%. This figure at that point is 81¾, which is the combustion efficiency of the heating plant.

C—Calculate percent flue loss = 100 minus combustion efficiency.

EXAMPLE:

	100%
Combustion Efficiency	= 81¾ %
Percent Flue Loss	= 18¼ %

Fig. 15—Efficiency Chart for Natural Gas

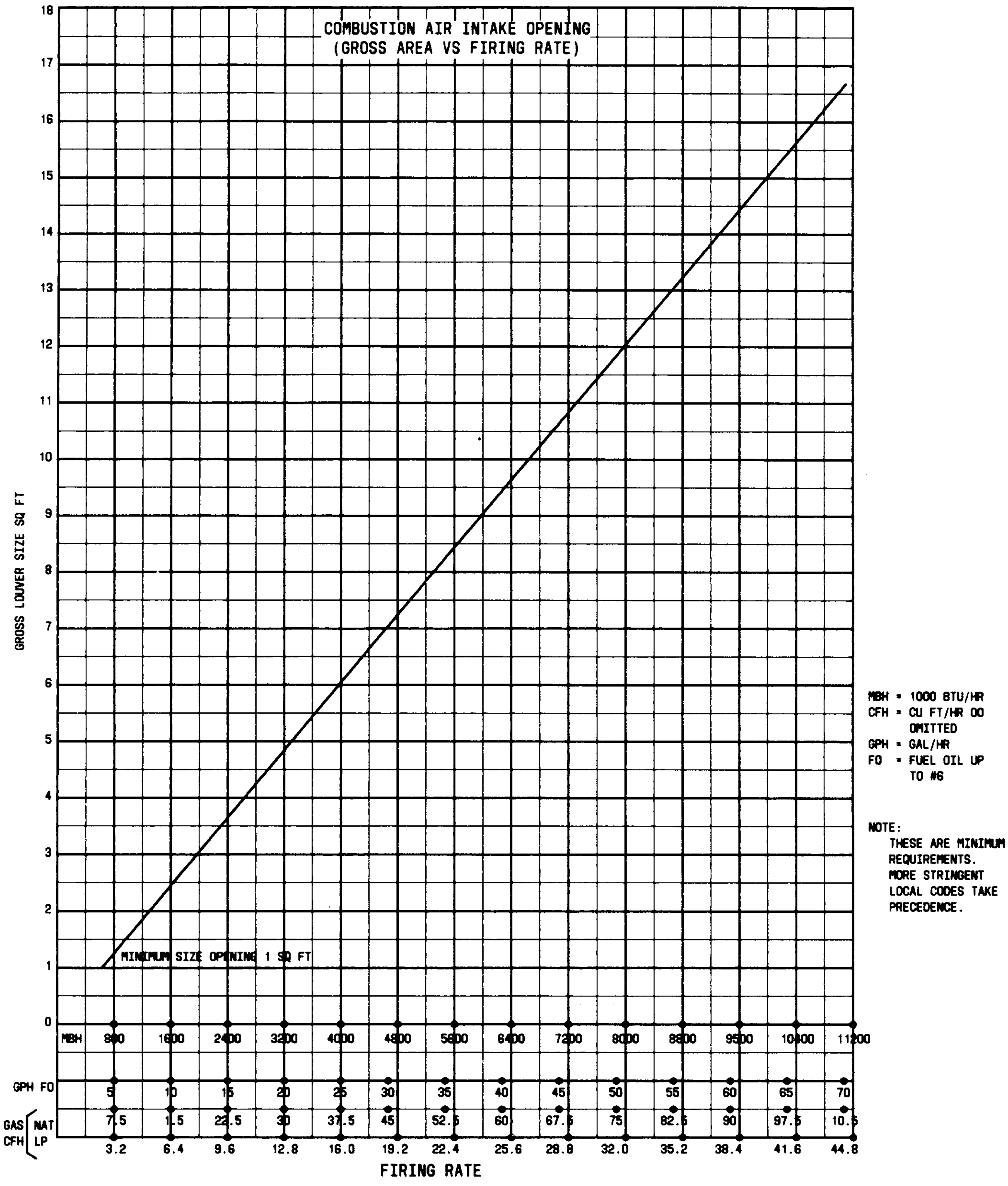


Fig. 16—Combustion Air Intake Opening (Gross Area Versus Firing Rate)