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GUIDELINES FOR RESIDENTIAL OIL-BURNER ADJUSTMENTS

Oil-Burner Adjustment Procedures to Minimize Air Pollution and to Achieve Efficient Use of Fuel

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Guidelines intended for use

- by skilled service technicians in adjustment of residential oil burners.
- as a training guide for advanced burner service courses.
- as a supplement to manufacturers' service instructions.

EPA, Office of Research and Development
Industrial Environmental Research Laboratory
Research Triangle Park, NC 27711

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- Air Pollution Control Association
- American Petroleum Institute
- National Association of Oil Heat Service Managers
- National Oil Fuel Institute.

GUIDELINES FOR RESIDENTIAL OIL-BURNER ADJUSTMENTS

In the past, the most important reason for adjustment of oil burners has been to ensure reliable automatic operation. A second important reason has been to provide efficient fuel utilization. Common good practice of adjusting a burner for minimum air setting, consistent with acceptable smoke levels, is an effective way of meeting both objectives.

Recently, a third objective has been added, that of minimizing air pollution. It is important to recognize that any burner adjustments for this purpose must also meet the former requirements. Fortunately, adjustments for low air-pollutant emissions can still meet the objectives of reliable and efficient operation.

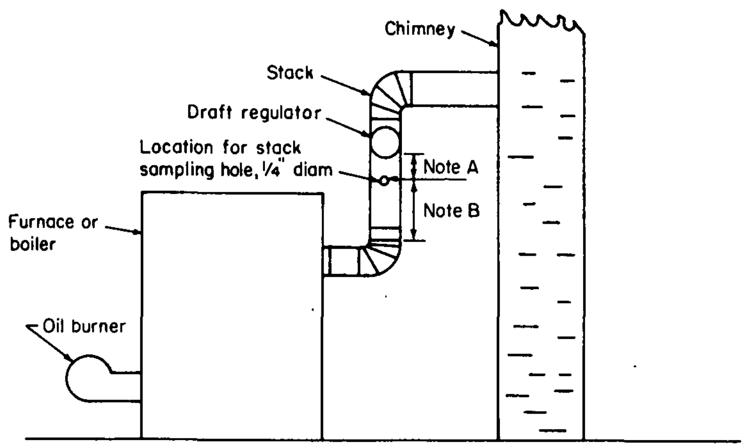
PURPOSE OF THESE GUIDELINES

These Guidelines have been prepared for use by service managers for service training and by skilled service technicians in their oil burner service work. By following these Guidelines, the skilled oil-burner service technician will be able to adjust residential oil burners to minimize air pollution and get the most useful heat from the fuel fired.

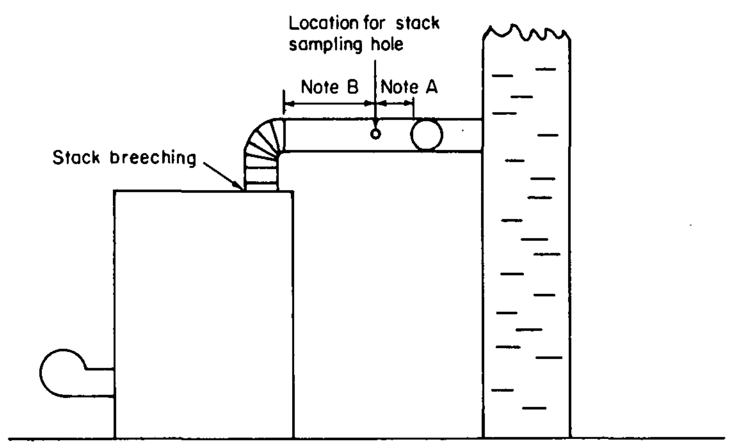
Adjustment procedures recommended here apply to automatic oil burners used for heating of homes, ranging from single-family dwellings to three-family dwellings. They apply generally to a capacity range up to approximately 400,000 Btu/hr output. Apartment buildings are covered in separate Guidelines being issued by EPA for commercial oil-fired boilers.

These Guidelines should be used as a supplement to the equipment manufacturers' installation and service instructions, plus the handbooks and manuals on good service practice developed by oil-heating industry specialists.

> Burner service organizations may wish to develop their own short-form recommendations that tie in with overall company policy, service training doctrine, abilities of the service technicians, and local regulations. Included at the back of these Guidelines in Appendix D is an example of such a short form prepared by the National Association of Oil Heat Service Managers.



Horizonial Stack Connection



Vertical Stack Connection

Figure 1. Desirable Location for 1/4" Stack Sampling Hole for Typical Stack Connections

A. Locate hole at least one stack diameter on the furnace or boiler side of the draft control.

B. Ideally, hole should be at least 2 stack diameters from breeching or elbow.

RECOMMENDED ADJUSTMENT PROCEDURES FOR RESIDENTIAL OIL BURNERS

These procedures are intended for adjustment of gun-type oil burners for residential heating systems and are supplemental to manufacturers' installation instructions or other service handbooks.[1,2,3]

The following steps are emphasized from the viewpoint of minimizing air-pollutant emissions:

PREPARATION STEPS

1. CLEAN & SEAL — Make sure the burner blast tube, fan housing, and blower wheel are clean of dirt and lint. Seal any air leaks into the combustion chamber, especially joints between sections of cast-iron boilers (and around fire door).

2. NOZZLE — Annual replacement of nozzle is recommended. The nozzle size should match the design load. DO NOT OVERSIZE. Short cycles and low percent "on" time result in higher overall pollutant emissions and lower thermal efficiency. An in-line oil filter will reduce service problems due to nozzle clogging.

   Select the nozzle and spray pattern to match the air pattern produced by the mixing head and, for matched units, follow the manufacturer's instructions.

3. SAMPLING HOLE — Drill a 1/4" hole in the stack or flue duct between the unit and the barometric draft regulator (if not already drilled by the installer). This is for taking smoke and CO_2 samples. It can also be used to insert a stack thermometer.

   [See Figure 1.] If space permits, the hole should be located in a straight section of the stack, at least 2 stack diameters from the unit breeching and at least one diameter from the unit side of the draft regulator.

4. ADJUST ELECTRODES — Adjust ignition electrodes to assure prompt ignition.

5. OPERATE BURNER — Operate burner, adjust air setting for good flame by visual observation, and run for at least 10 minutes or until operation has stabilized.

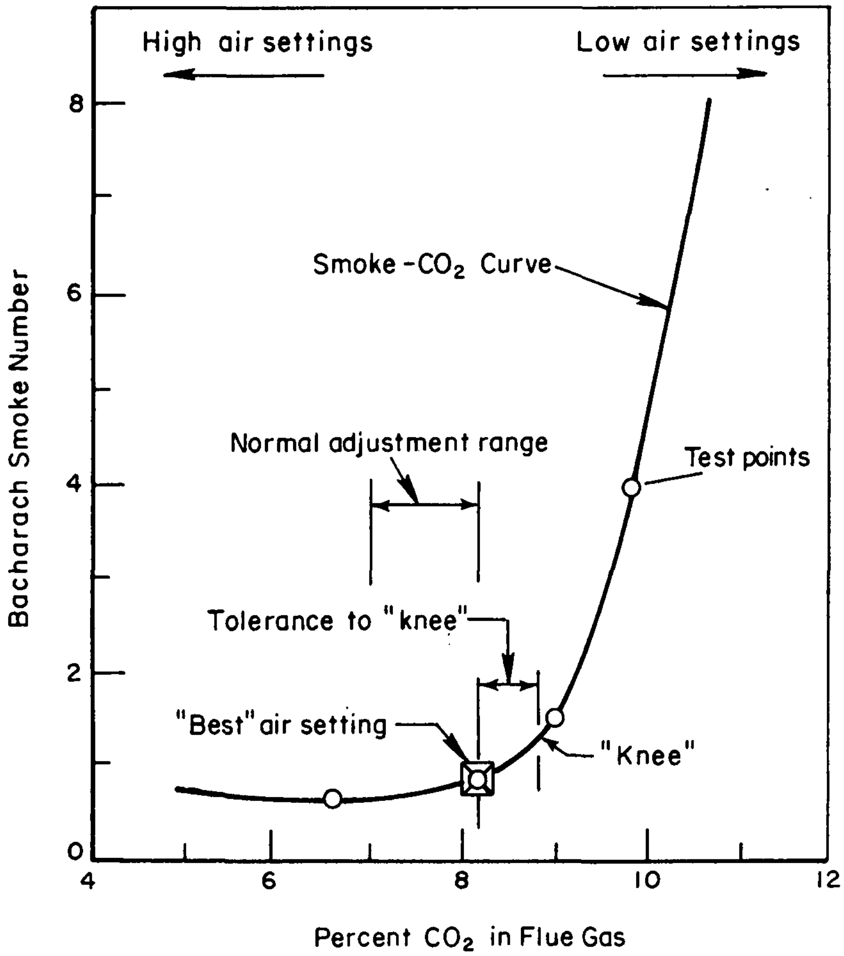


Figure 2. Typical Smoke-CO_2 Characteristic for a Residential Oil Burner – With Recommended Air Adjustment

6. **CHECK BURNER** — Bleed air from pump and nozzle piping. Check pump pressure and adjust to 100 psi, if necessary (or to manufacturer's recommendation).

COMBUSTION ADJUSTMENT STEPS

7. **SET DRAFT** — Check the draft reading over the fire with a draft gage through a 1/4" hole drilled in the fire door or inspection door. [This hole should be in the inspection door for oil-fired-matched units, or in the fire door for conversion installations. If possible, the hole should be above the flame level.]

   Adjust the barometric draft regulator on the stack to give the overfire draft recommended by the manufacturer. If no such recommendations are available, set overfire draft to assure a negative pressure within the combustion chamber (usually 0.02 inches water column).

   With some equipment, it will not be possible to take draft readings over the fire. In this case, adjust the draft regulator to give a stack draft reading between 0.04 and 0.06 inches water column (taken at the stack sampling hole.)

   Seal draft or sampling hole in inspection or fire door after these tests have been made, using a plug, bolt, or high-temperature sealant. (It is not necessary to seal the stack sampling hole).

8. **CHECK SMOKE** — After burner has been operating 5 or 10 minutes, make a smoke measurement in the stack, following the smoke tester instructions.(2) Pump the tester slowly for 10 full strokes. On pull stroke, use a steady motion such that a full stroke is obtained in 3 or 4 seconds. Allow a 2-second pause between pump strokes to insure a full sample.

   Oily or yellow smoke spots on the filter paper are usually a sign of unburned fuel, indicating very poor combustion (and likely high emissions of carbon monoxide and unburned hydrocarbons). This condition can sometimes be caused by too much air, or by factors mentioned in the diagnosis section. If this condition cannot be corrected, major renovation or even burner replacement may be necessary.

9. **SMOKE-CO_2 CURVE** — Record measurements of smoke and CO_2 from the stack. (When making CO_2 readings, follow the instrument manufacturer's instructions.) Then establish the smoke-CO_2 curve by taking readings over a range of air settings, as shown in Figure 2.

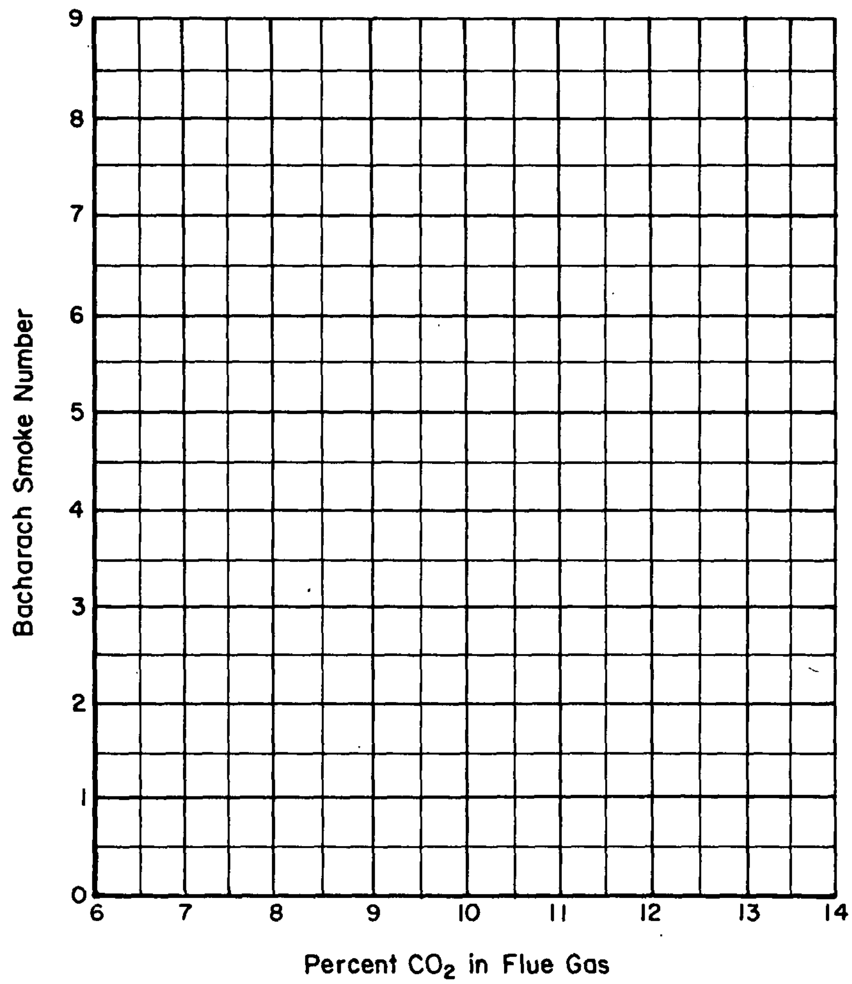


Figure 3. Sample Graph Paper for Service Technician's Plot of Smoke-CO_2 Characteristic

To do this, start with the air gate set at nearly full open and then take smoke and CO_2 readings at progressively lower air settings, as necessary to visualize the general shape of the curve. (The CO_2 readings will increase as the air setting is decreased, unless combustion is incomplete.) Do not set air gate to give smoke reading above No. 4 or No. 5. Plot the points on graph paper, as in Figure 3. Usually 3 or 4 readings are enough to establish the curve.

In adjusting each air setting, it is helpful to mark the various positions of the air gate at which measurements are made so that the final setting can be located quickly.

10. SET AIR — Examine the smoke-CO_2 plot and, keeping in mind the curve of Figure 2, note the location of the "knee" where the smoke number begins to rise sharply. Noting the air gate position marks, adjust the air setting to a CO_2 level 1/2 to 1 percent lower than the CO_2 level at the "knee". (This provides a tolerance against possible shifts in the setting over a period of time.) Do not increase the air setting any more than necessary on the lower portion of the curve below the "knee".

(The characteristic curve for some burners may not yield a distinct "knee" in the curve. Burner A in Figure 5 of the Appendix has no distinct "knee". In such cases, the setting should be made near the minimum smoke, (using judgment).

Lock the air adjustment and repeat draft, CO_2, and smoke measurements to make sure the setting has not shifted.

COMBUSTION DIAGNOSIS

11. CHECK PERFORMANCE — A well-matched and well-tuned burner should be capable of operation with smoke not greater than No. 2 and at a CO_2 level not less than listed in Table 1. If this cannot be reached, check the following:

A. Air leaks into the combustion chamber or heat exchanger can dilute the combustion gases and prevent normal CO_2 readings. Such leaks should be sealed with furnace cement or other high-temperature sealant.

To check for dilution by leakage, measure the CO_2 at as high a point as possible over the fire, using a stainless steel tube inserted through the fire door sample hole (as described earlier for overfire draft measurements), and

TABLE 1. TYPICAL AIR ADJUSTMENTS FOR DIFFERENT TYPES OF RESIDENTIAL BURNERS

OIL-BURNER TYPE	Typical CO_2 in Flue Gas When Tuned*
HIGH-PRESSURE GUN-TYPE BURNERS	
• Old-Style Gun Burners	8 %
- No internal air-handling parts other than an end cone and stabilizer	
• Newer-Style Gun Burners	9 %
- special internal air-handling parts	
• Flame-Retention Gun Burners	10 %
- flame-retention heads	
OTHER TYPES OF BURNERS	
• Atomizing Rotary Burners	8 %
- ABC, Hayward, etc.	
• Rotary Wall-Flame Burners	12 %
- Timken, Fluid-Heat, Torridheet, etc.	
• Miscellaneous Low-Pressure Burners	**

* Based on acceptable Bacharach smoke -- generally No. 1 or trace, but not exceeding No. 2.

Caution should be used in leaving burners with CO_2 level higher than 13%.

** See manufacturer's instructions.

compare this with the CO_2 measured in the stack. A difference of more than 1 percent CO_2 between the stack and overfire readings usually indicates air entry through leaks that have not been properly sealed.

Seal between the probe and fire door sample hole during test (for example, with asbestos rope). The fire door hole should be sealed when not being used to avoid leakage of air through it. [See Step 7.]

B. If the CO_2 level in Table 1 still cannot be reached without exceeding No. 2 smoke, poor mixing of air and fuel is likely.

This could be caused by a combustion head (blast tube nose piece) with too large a throat for good mixing, or an improper match between air pattern and nozzle spray pattern. Frequently, replacement of the nozzle with one having different spray angle and pattern will improve performance.

It may be necessary to replace the combustion head or try different settings if the burner is equipped with an adjustable head or mixing devices. Modern flame-retention heads can be adapted to fit most blast tubes.

C. The combustion chamber must be matched in size and shape to the nozzle spray and the burner air pattern. Oversize chambers do not insure adequate mixing. Undersize chambers may allow flame impingement on the chamber walls or heat exchanger.

FINAL CHECKS

12. STACK TEMPERATURE

Operating the unit at excessive firing rate will generate more heat than the heat exchanger can utilize and result in unnecessary heat loss up the stack. Other causes of excessive heat loss are badly sooted heat-exchanger surfaces and excessive draft. The temperature of the flue gas provides an indication of these heat losses.

Measure stack temperature after at least 5 minutes of operation. Determine the net stack temperature by subtracting the room air temperature from the thermometer reading. Excessive stack loss is indicated if the net stack temperature during steady operation exceeds 400° to 600° F for matched-package units, or 600° to 700° F for conversion burners.

13. IGNITION — Check operation over repeated cycles to insure prompt ignition on starting.

14. PUMP CUTOFF — Slow pump cutoff at the end of a firing cycle can cause smoke and other pollutant emissions. Check for prompt pump cutoff by observing flame or by testing smoke at shutdown. If poor cutoff is observed, make sure air is purged from the pump and nozzle line. Air trapped in the pump or nozzle line will expand when heated, thus causing oil to drip into the combustion chamber after shutdown. If poor cutoff persists, repair or replace pump. (A solenoid valve in the nozzle line should insure prompt cutoff. If it does not, replace or repair solenoid.)

15. CONTROLS — Check settings of all operating and limit controls before leaving the installation.

16. ANNUAL CLEANUP — An overall burner checkup and cleanup is recommended annually.

Experienced service technicians will observe that these procedures are essentially the same as they have followed in normal good practice. The added aspect of specific visualization of the smoke-CO_2 curve helps in adjusting for good performance and in diagnosing problems.

Adjustment of residential oil burners by these procedures will minimize emissions and provide efficient fuel utilization.

APPENDIX: BACKGROUND INFORMATION

Information on the air-pollutant effects of different burner adjustment procedures have been developed in recent field and laboratory investigations[4,5,6,7], including those conducted cooperatively by the U.S. Environmental Protection Agency and the American Petroleum Institute.[6,7] The findings of these investigations, combined with good field practice, are the basis for the Guidelines.

This Appendix contains additional background information as follows:

A. POLLUTANTS OF MAIN CONCERN

B. FIELD-TYPE INSTRUMENTS AND SIGNIFICANCE OF MEASUREMENTS

C. TYPICAL EMISSION CHARACTERISTICS OF RESIDENTIAL OIL BURNERS

D. EXAMPLE SHORT-FORM ADJUSTMENT PROCEDURE

E. REFERENCES

APPENDIX: BACKGROUND INFORMATION

A. POLLUTANTS OF MAIN CONCERN

Pollutants and Their Measurement

The air pollutants of main concern for the purposes of these Guidelines can be divided into three broad classes, depending upon how much the serviceman can control them by his adjustments. These classes are:

Class 1. Pollutants that may result from incomplete combustion and are generally strongly affected by burner adjustment procedures:

- Smoke and particulate*
- Carbon monoxide, CO
- Hydrocarbons, HC

Class 2. Pollutants only partially affected by burner adjustment procedures (and not recommended as adjustment criteria).

- Nitrogen oxides: NO and NO_2 (usually considered together and identified as NO_x)

Class 3. Pollutants not affected by burner adjustment procedures but depending only on sulfur content of the fuel.

- Sulfur oxides (SO_2 and SO_3)

The following comments describe each of the Class 1 pollutants from the viewpoints of definition, hazards associated with the pollutant, how it is detected or measured, and how emissions of the pollutant are affected by service adjustments. (The Class 2 and Class 3 pollutants are not discussed further here, because the serviceman has little or no control over them by adjustment.)

Smoke and Particulate

Smoke consists mainly of tiny unburned particles of carbon. Smoke has long been an important factor in the adjustment of oil-burning equipment to avoid fouling of heat-transfer

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* Particulate that is formed from the ash content of the fuel oil is not affected by burner adjustment. However, the carbon or soot portion of particulate, usually the larger portion, can be strongly affected by burner adjustments.

passages with soot, to achieve efficient fuel utilization, and to avoid general complaints resulting from visible smoke and fallout of large particles.

Over the past 25 years, the development and the use of the filter-paper method of smoke measurement (as used, for example, in the Bacharach Smoke Tester) has allowed a much more sensitive measurement than by visual means such as the Ringlemann Scale.[1,2,8] The method is now an accepted ASTM standard[9] and is widely used in the oil-burning industry to assist in field adjustments.

Particulate is the usual scientific term applied to air-pollution measurements in terms of weight of solid and liquid materials being emitted to the atmosphere. "Particulate" is defined by the U.S. Environmental Protection Agency as "any finely divided solid or liquid material, other than uncombined water, as measured by EPA Method 5".[10,11]

Particulate is composed of unburned fuel, carbon or soot, ash constituents in the fuel*, and noncombustible-airborne dust that enters with the combustion air.

Coarse particles do not carry far in the atmosphere and usually fall out near the stack. Fine particles, the predominent portion of particulate from oil burning, can remain in the atmosphere for long periods and can obscure long-range visibility. In addition, particulate can deposit on lung tissues and, therefore, result in respiratory impairment if present in high concentrations. These are the reasons particulate is of concern to air-pollution control.

Smoke and CO_2 measurements provide a simple and relatively reliable means to avoid high emissions of pollutants (including particulates associated with incomplete combustion). The service technician can exert considerable control over particulates by ensuring that the fuel pump and safety shut-off valve has good cutoff characteristics and by the burner adjustments he chooses.

For steady operation, smoke measurements by the filter-paper method are the most practical method to warn of high particulate levels, as discussed in Appendix C.[7] Particulate measurements by EPA standard measuring techniques require special equipment and techniques, plus long sampling periods -- which are not practical for most residential burner adjustments.

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* Ash is extremely low for No. 2 heating oil, usually below 0.005 percent.

Carbon Monoxide, CO

CO is a toxic gas formed by incomplete combustion. When oil-burning equipment is in good adjustment, the CO level is very low. But with improper combustion, CO can reach levels which can be dangerous if gases should leak into living spaces. When the low levels of CO that are emitted by properly operating residential-oil heating equipment are diluted in the atmosphere, CO is not considered dangerous and is depleted with time in the atmosphere.

For field adjustment of most conventional oil-fired residential equipment by methods suggested in these Guidelines, it is seldom necessary to measure CO. Smoke measurement can be used as a detector of poor combustion that could lead to the onset of CO at low excess-air levels (high CO_2 levels). However, if the serviceman increases the air setting too far, CO levels occasionally will increase rapidly without smoke; therefore, the air setting should not be increased beyond that necessary to obtain a satisfactory smoke reading below the "knee" on Figure 2.

Hydrocarbons, HC

Emissions of hydrocarbons from oil-burning equipment occur when combustion is incomplete; they can consist of unburned or partially burned fuel vapors.

Although hydrocarbons are generally not toxic to the same extent as CO [or NO_x], they can be accompanied by unpleasant odors and can contribute to photochemical smog in the atmosphere. Essentially, no hydrocarbons are emitted when equipment is properly adjusted.

If large amounts of unburned oil vapor should be emitted from an improperly operating installation, this can be detected as oily or yellow deposits on the filter paper during smoke measurements. At lower levels of hydrocarbon emissions, the emissions generally follow trends of smoke or CO emissions and, hence, these measurements are usually a good indicator of whether hydrocarbon emissions are high or low (except at extremely high air settings where smoke readings may fail to indicate a rise in hydrocarbons).

For routine adjustment of residential oil burners, it is not necessary to measure hydrocarbons by chemical or analytical means. If the service technician detects hydrocarbon odors (unburned oil vapor) near the burner or near the barometric draft control, he should check for flame impingement, improper nozzle size, improper adjustment of the combustion head, or improper pump cutoff. [See page 10].

B. FIELD-TYPE INSTRUMENTS AND SIGNIFICANCE OF MEASUREMENTS

For the adjustment procedures outlined in these Guidelines, it is assumed that the oil-burner service technician is accustomed to using field-type instruments.(2) A typical kit includes the following:

- CO_2 tester for stack-gas analysis
  - a simple wet-chemical absorbent-type analyzer (for example, Fyrite or Orsat apparatus)
  - CO_2 readings are used to provide an indication of the combustion air setting.
- Smoke tester and shade scale
  - hand-pump version of the ASTM filter-paper method for smoke determination.(9)
  - includes a shade scale for evaluating smoke spots from 0 to 9 (Bacharach or ASTM Scale). (This is not a Ringlemann scale. Smoke levels below about 5 on the Bacharach scale are generally not visible from a residential-size stack against the sky.)
- Thermometer for measuring stack temperature
  - usually a dial type, but liquid thermometers are more accurate.
- Draft Gauge
  - for draft measurements in the stack or overfire.
- CO detector for dual-fuel commercial boilers
  - usually color-sensitive chemical in tubes.

Instruments which combine several of these readings in one device are being introduced on the market and offer convenience in use.

The Significance of CO_2 Measurements

CO_2 readings are used to identify how much combustion air is being supplied to the burner, compared to the theoretical amount required for combustion. It is seldom possible to burn a fuel completely and cleanly unless air in excess of the theoretical amount is provided. The following values will illustrate the relationship between excess air supplied for combustion and the CO_2 concentration in the flue gas for residential oil burners firing No. 2 heating oil.

Air/Fuel Mixture Settings	Excess-Air Supply (percent above theoretical)	CO_2 in flue gas,	Comments on Combustion Performance (assuming satisfactory smoke levels)
Theoretical or "Chemically Correct"	0	15 %	"Stoichiometric mixture" (cannot be achieved for reliable operation in practice)
Typical for Residential Equipment	35 %	11 %	Excellent performance
	70 %	9 %	Average performance
	150 %	6 %	Poor performance

The overall efficiency of fuel utilization is lowest at the low levels of CO_2 (high excess air), because the products of combustion are diluted by the excess combustion air and carry more heat up the stack.

The Significance of Smoke Measurements

The filter-paper method of smoke measurement is useful in assessing the sooting characteristics of a combustion process.[(2)] In this method, a measured sample is drawn through a filter paper and smoke spots are compared to a standard shade scale[(9)] (commonly known in the oil-heating trade as the "Bacharach shade scale".) The method offers a practical and sensitive means of judging the combustion of fuel oils[(12)] and can be used as a rough indicator of particulate emissions during steady-state operation.[(7)] [See comments below on smoke scale.]

Bacharach Smoke	Comments on Combustion Performance (assuming satisfactory CO_2 level)	Comments on Sooting of Heating Surfaces Anticipated[(2)]
No. 0	Excellent	None
No. 1	Excellent	Extremely light if at all
No. 2	Good	Slight sooting which will not increase stack temperature appreciably
No. 3	Average for untuned burners	May be some sooting but will rarely require cleaning more than once a year
No. 4	Poor	Borderline condition. Some units will require cleaning more than once a year
No. 5 or higher	Very Poor	Potential for rapid and heavy soot buildup

For reliable smoke readings, it is important that the manufacturer's instructions with the smoke tester be followed carefully. For example, the sample should be pumped slowly from the stack with full strokes, with several seconds pause at the end of the pullstroke to allow a full sample.[(2)]

The Significance of Stack Temperature: Its Effect on Efficiency

Stack temperature is significant in determining the effectiveness of fuel utilization because it is an indicator of the amount of heat lost up the stack.

Stack temperature can be considered abnormally high if the net stack temperature (stack temperature minus room air temperature) should exceed:

400° - 600° F for matched package units, or

600° - 700° F for conversion units.

A high stack temperature may indicate one of the following conditions:

1. Excessive firing rate for furnace or boiler size
2. Dirty or soot-covered heating surfaces
3. Need for effective baffling of flue passes
4. Improper adjustment of the draft regulator, usually excessive draft through the unit.

These points should be checked and remedied if stack temperature is abnormally high.

"Overall thermal efficiency" is defined as the proportion of the heat energy in fuel that is actually available for heating the dwelling during continuous burner operation. Two factors can be used to determine the heat lost up the stack and, therefore, the overall thermal efficiency. These factors are:

- Net stack temperature (actual stack temperature reading minus the room temperature)
- Percent CO_2 in the flue gases.

Figure 4 shows the combined effects of these two factors on overall thermal efficiency.[13] This figure is based on continuous operation and use of No. 2 heating oil. It also assumes that heat from the unit jacket is available for heating some portion of the dwelling; otherwise, the overall thermal efficiency will be reduced by this jacket loss (usually only a few percent).

The overall thermal efficiency is sometimes referred to as "combustion efficiency"; however, it is also dependent on the effectiveness of the heat transfer surfaces in the boiler or furnace.

Seasonal thermal efficiency is less than the continuous thermal efficiency in Figure 4, because of lower efficiency during cyclic operation (e.g., additional losses up the stack from the unit during off-periods). Seasonal efficiency will be highest for units that:

1. Have high overall thermal efficiency during continuous operation
2. Have good starting and shutdown characteristics
3. Have firing rates matched to the design load. (Overfiring results in excessively long shut-down periods.)

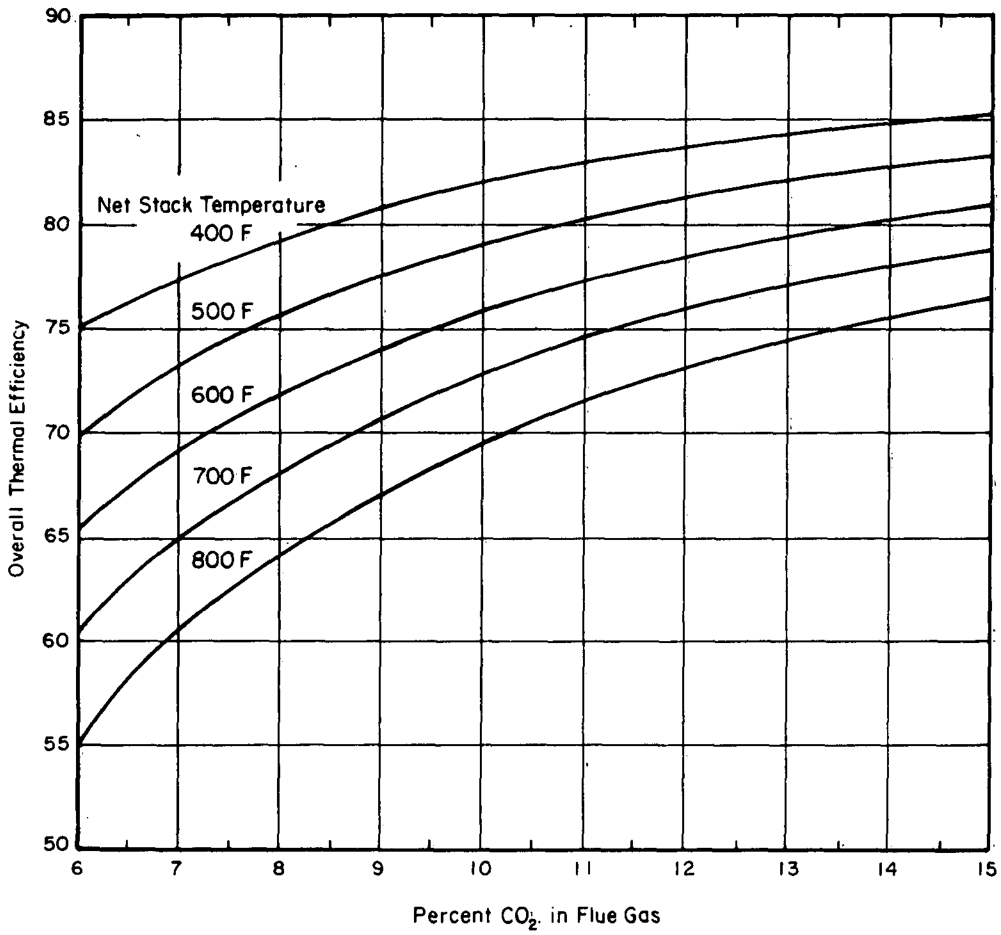

Figure 4. Effect of Stack Temperature and CO_2 on Overall Thermal Efficiency

Basis:
- Continuous operation
- No. 2 heating oil
- Heat from unit jacket contributes to heating dwelling, so only loss is stack heat loss.

C. TYPICAL EMISSION CHARACTERISTICS OF RESIDENTIAL OIL BURNERS

Figure 5 illustrates the performance characteristics of three different but typical gun-type oil burners. This figure shows the relationship between smoke and carbon dioxide (CO_2), as measured with field-type measurements.

The three burners represent different and unique characteristics. Burner C has superior operating characteristics, in that the combustion air can be set to a higher CO_2 level and still maintain a low smoke level. Other burners could have still other characteristics, but these are typical. It is possible to shift from one characteristic curve to another in "tuning", such as by a nozzle change or by burner cleaning.

Low CO_2 levels indicate excess combustion air; high CO_2 levels indicate an approach to the theoretical air requirement for combustion. (See Appendix B.) It is important that the service technician visualize this curve as he changes the air setting and makes measurements of CO_2 and smoke. During steady operation, particulate emissions would be expected to follow the same general trends as smoke.[7]

Particulate matter is also formed during burner starting and shutdown. Poor starting performance by ignition delay or resulting from shifts in nozzle delivery rates can result in high levels of smoke and particulate over a period of cyclic operation.[7] Poor pump cutoff can also result in increased smoke and particulate generation at the end of a cycle.

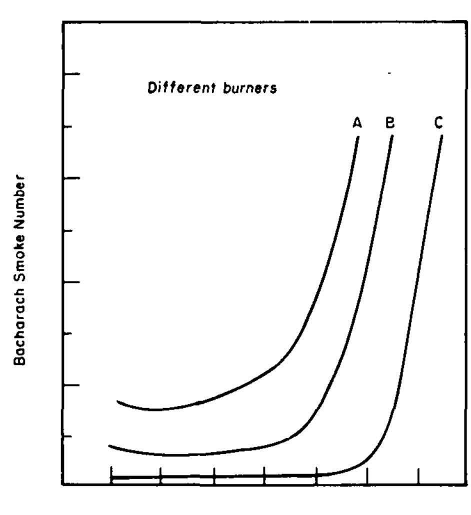

Figure 5. Different Burners have different Smoke-CO_2 Curves

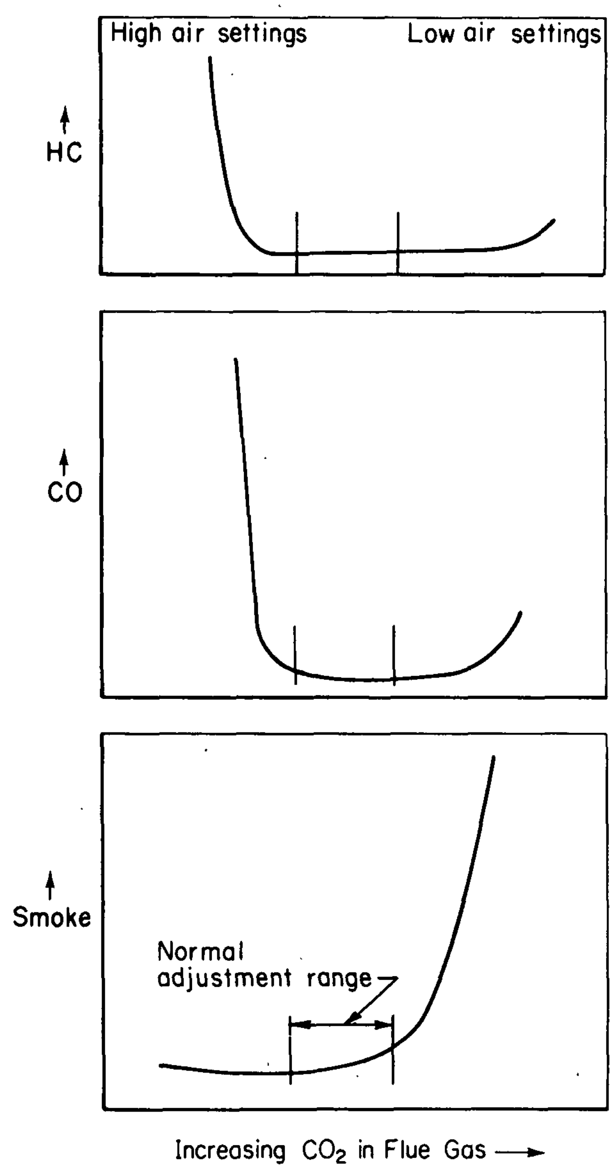

Figure 6. Typical Relationships of Carbon Monoxide and Hydrocarbon Emissions to Smoke when Changing the CO_2 Setting for Residential Oil Burners

Figure 6 illustrates typical trends of CO and HC in relation to smoke as the CO_2 setting is varied. Note the following trends:

1. As CO_2 is increased (by closing the combustion air setting)

   a. Smoke rises sharply beyond the normal operating CO_2 range.

   b. CO and HC begin to rise. Here smoke has served as an indicator to forewarn of this increase.

2. As CO_2 is decreased (by opening the combustion air setting)

   a. CO starts to rise sharply below the normal operating CO range.

   b. HC begins to rise after CO rises.

   c. Smoke usually remains low, so that smoke is no longer a good indicator of high CO and HC emissions.

Not all burners will perform in this way. In some, the "normal operating" range will be wider, in others narrower, and in some poor units nonexistant.[4-7] However, Figure 6 provides a picture of general relationships.

The service technician should visualize the interaction of the various pollutants to develop an appreciation for the fact that the smoke-CO_2 characteristic is basic to setting an oil burner for minimum emissions by use of field-type instruments. Note that adjustments made with only a smoke limitation in mind could result in high CO and HC at the low CO_2 end of the adjustment range (high excess air). This can be avoided in most cases by adjusting the CO_2 setting closer to, but still below the "knee" of the smoke-CO_2 curve.

D. SHORT-FORM ADJUSTMENT PROCEDURE

Burner service organizations may wish to develop short-form recommendations that tie in with overall Company policy, service training doctrine, experience of service technicians and local regulations. The following is an example of such a short form prepared by the National Association of Oil Heat Service Managers.(14)

STEP #1. Service & Clean Burner

Follow Company procedure to complete the cleaning and servicing. Operate burner for ten minutes while tools are gathered and area cleaned.

STEP #2. Check Draft

Set draft regulator, if necessary. If no manufacturer's recommendations are available, a minus draft over the fire of 0.02 to 0.04 inches of water is acceptable. Draft readings in the breeching will be higher depending on the flue passages of the boiler. The more restricted and lengthy the flue, the higher the draft necessary to obtain the accepted over-fire conditions.

STEP #3. Smoke Test

Follow the instructions of the manufacturer of the smoke tester and take a smoke test. Adjust the air to obtain a preliminary reading of about No. 3 spot. Then readjust the air to obtain the lowest possible reading, but do not open the air adjustment more than absolutely necessary to obtain a trace or No. 0 spot.

STEP #4. CO_2 Test

Follow the instruction of the manufacturer of the CO_2 gas analyzer, take a CO_2 test. The following results should be obtained:

a. Old-Style Gun Burners (burners with no special air-handling parts other than an end cone and stabilizer). A CO_2 reading of 7% to 9% should be obtained. If the reading is less, reduce the air until a satisfactory CO_2 reading is reached. In no case should the air be reduced to a point where the smoke reading exceeds a No. 3 spot. If a No. 2 smoke or less cannot be obtained with the above CO_2 reading, proceed as directed by the Company.

b. Newer Style Gun Burners (burners with special air-handling parts.) Follow the same procedures as above except that CO_2 readings should be in the 9% and 11% range.

c. Flame-Retention Gun Burners. Follow the same procedures as above except the CO_2 readings should be in the 10% to 12% range.

d. Rotary Burners (Hayward, ABC, etc.) Follow the same procedure as outlined under old-style gun burners.

e. Rotary Wall-Flame Burners (Timken, Fluid-Heat, Torridheet, etc.) Follow the procedures as outlined above, with the exception that the appearance of the flame is important and the draft settings critical. Higher CO_2 readings are obtainable, as much as 13.5% is common. The best procedures for adjusting these burners are to be found in the manufacturer's service manuals.

f. Miscellaneous Low Pressure Burners. As mentioned in the previous paragraph, in most cases the manufacturer's service manual contains the best adjustment procedures. In the absence of such specific instructions, follow the procedure as outlined under Steps 4a, b, or c.

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** Available from American Petroleum Institute, 1801 K Street, N.W., Washington, D.C. 20006.

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16. ABSTRACT These guidelines contain recommended procedures for adjusting residential oil burners to minimize air pollution and for efficient fuel use. They are intended for use by skilled service technicians in adjusting burners, and as an aid to service managers engaged in training service technicians. In addition to recommended steps for burner adjustment, the guidelines also include appendixes of background material on pollutants of main concern, field-type instruments and significance of measurements, and emission characteristics of residential oil burners.

17. KEY WORDS AND DOCUMENT ANALYSIS

a. DESCRIPTORS		b. IDENTIFIERS/OPEN ENDED TERMS	c. COSATI Field/Group	
Air Pollution	Carbon Monoxide	Air Pollution Control	13B	
Space Heating	Hydrocarbons	Stationary Sources	13A	07C
Combustion	Fuel Oil	Particulate	21B	21D
Nitrogen Oxides	Residential Buildings	Emission Factors	07B	13M
Nitrogen Oxide (NO)	Heating	Distillate Fuel Oil		
Nitrogen Dioxide	Burners	No. 2 Oil		
Smoke	Boilers			

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