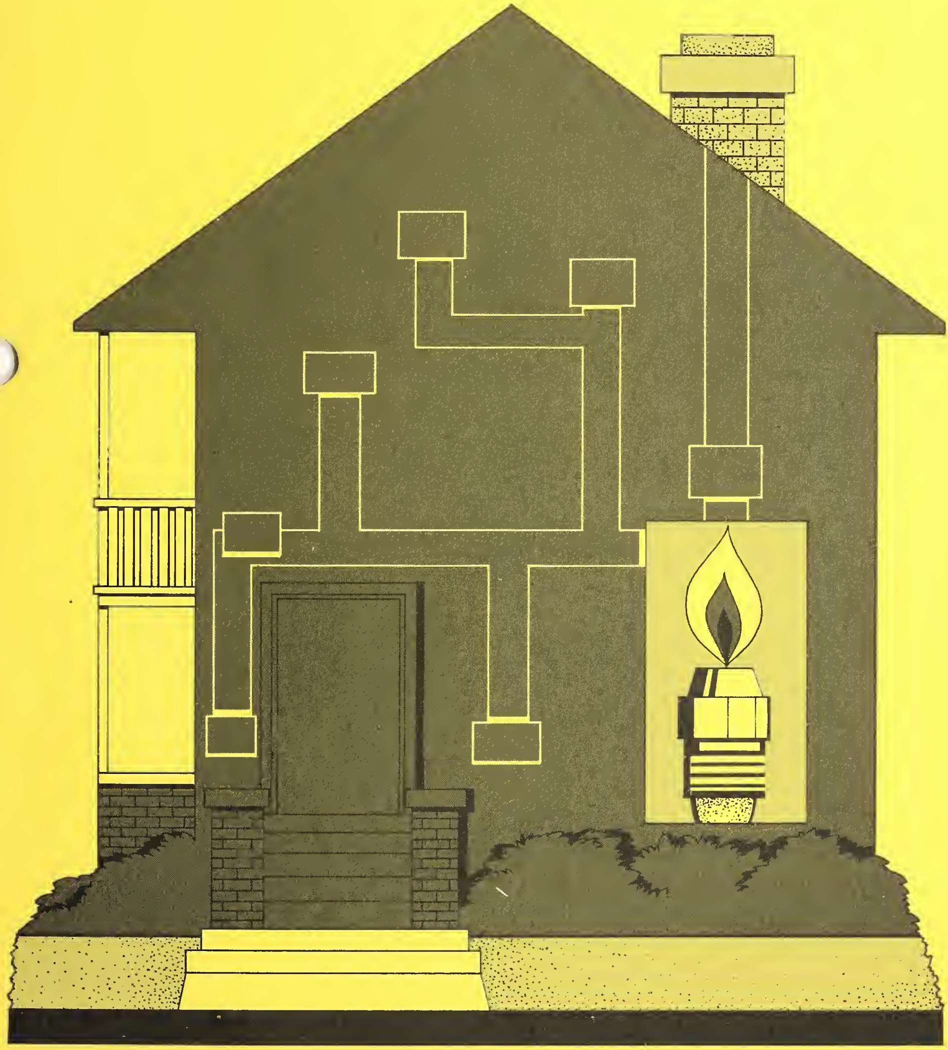
A Service Manager's Guide to **Saving Energy in Residential Oil Burners**

Optimizing Nozzle Size



U.S. DEPARTMENT
OF COMMERCE

National Bureau
of Standards

June 1977

FEDERAL ENERGY
ADMINISTRATION

LC 1082

Introduction

This guide is intended to help you, the trained oil-burner service manager, conserve fuel oil in residential oil burners. This can be accomplished by optimizing the nozzle size on high-pressure oil burners that are overfired with respect to a building's heating requirements at the outdoor design temperature. By following the instructions in this guide and by using your training, knowledge, and skills, you can help homeowners save energy and money on their home heating bills. Bear in mind that this guide is not intended for use by the general public or by untrained persons, since such use may be unsafe or result in damaged equipment.

Note: Data on potential fuel savings in this pamphlet are based on a field study conducted by the Walden Research Division of ABCOR for the National Bureau of Standards under the sponsorship of the Federal Energy Administration. Actual savings will depend upon the particular type of furnace and the accuracy in carrying out the recommended adjustment procedures.

Background

Recent tests make it apparent that greater attention should be given to the seasonal performance of a heating system, rather than its steady state efficiency. One approach to better seasonal performance is proper adjustment of the firing rate.

The fuel savings that result from reducing the firing rate on overfired heating systems come from (1) an increase in heat exchanger efficiency and (2) a reduction in the off-cycle loss. The former results from having more heat exchanger surface available per unit of energy input. The off-cycle loss, which is due to the flow of air through the combustion chamber and heat exchanger during off periods (by natural convection), is decreased because the air shutter opening is reduced and because a burner with a reduced firing rate operates for longer periods of time.

A recent study of 429 oil burners found that 416 (97 percent) were overfired with respect to the design heating load. In many cases, oil burners were found to be overfired by 100 to 200 percent. The study showed that the seasonal performance of a large fraction of the oversized units could be improved by having their nozzle size reduced. It also predicted fuel savings of 4.3 percent and 2.4 percent on forced warm air and hot water systems respectively. The study also indicated that an even greater savings was likely if the average included only oil burners suitable for nozzle size reduction and excluded some units with tankless coils and burners which could not maintain the same carbon dioxide (CO_2) concentrations at the reduced firing rates.

The maximum reduction in firing rate that should be made on an over-fired oil burner is limited by the need to:

- meet heating requirements of the residence at the outdoor design temperature of the region
- maintain dependable domestic hot water service
- assure proper combustion and correct operation of the heating system
- maximize the seasonal energy savings.

In order to achieve maximum energy savings, the percentage of excess air after the firing rate is reduced should be nearly equal to or smaller than the percentage before the rate is adjusted. This is because the amount of excess air required by the burner for good combustion is one factor that determines combustion efficiency. Stack temperature is the other factor. Thus, after placing a smaller nozzle in an oil burner, you will have to close the air shutter on the burner until the percentage of CO_2 measured in the flue gas is close to or greater than the percentage before the nozzle change.

At the same time the smoke should be kept equal to or below #1 on the Bacharach Smoke Scale. If the nozzle size is reduced too far, the turbulence of the air leaving the gun may be reduced so much that good atomization will not occur. This will result in a smoky fire which is unacceptable. The amount by which a nozzle may be reduced will depend upon the type and size of the devices used to create turbulence in the air leaving the gun. Most burners are approved for a specific range of firing rates and these data are usually shown on the nameplate. Reduction in firing rate should not go below this minimum listed input. In addition, the burner manufacturer may recommend specific modifications to nozzle spray angle and pattern as well as blast tube or retention head changes for specific firing rates.

Procedure

The procedure outlined below is recommended for use on forced warm air systems and forced hot water systems. For forced hot water systems, special consideration is given to those systems supplying domestic hot water by means of tankless coils. This procedure is NOT recommended for use on steam heating systems.

Step 1

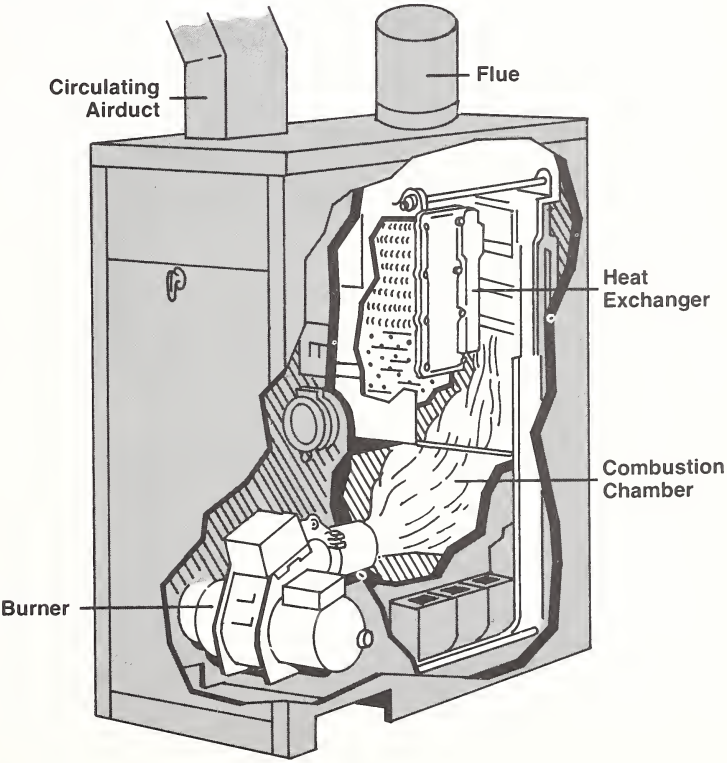
Repair and Tune-Up the Heating System

Thoroughly check the heating system and make all necessary repairs prior to optimizing the nozzle size. All air leaks into the combustion chamber should be sealed and the oil burner given a regular tune-up. OPTIMIZING THE NOZZLE SIZE SHOULD BE DONE IN ADDITION TO REGULAR SERVICING, NOT AS A SUBSTITUTE FOR REGULAR SERVICING.

Step 2

Measure the Steady-State Efficiency and Smoke

Measure flue gas temperature, the percentage of CO_2 in the flue gas, along with the smoke concentration (*smoke number on a Bacharach Smoke Scale of 0 through* 9). Determine the steady-state efficiency. It is usually necessary to wait at least 15 minutes after start-up for a unit to reach a steady-state operating condition. Units should operate with steady-state efficiencies at or above 75%. If the steady-state efficiency is less, or the smoke number is greater than #2, Step #1 has not been satisfactorily carried out or the burner or heat exchanger is in need of replacement.



Step 3

Determine First Trial Nozzle Size

Using the local outdoor design temperature for the area * and the winter K-factor for the residence ** (degree days per gallon) determine the "minimum nozzle size" by using either:

(1) the graph displayed on the enclosed card;

(2) a calculating slide rule such as in [2]; or

(3) the formula:

$$\text{minimum nozzle size} = \frac{(65 - T_D)}{(\text{K-factor})(24)}$$

where T_D is the local outdoor design temperature in °F and the K-factor is in degree days per gallon of oil.

This nozzle size should be at least:

0.5 gph for warm air systems;

0.65 gph for hot water systems not supplying domestic hot water;

0.85 gph for hot water systems with aquaboosters; or

1.20 gph for hot water systems using only tankless coils.

The first trial nozzle should be selected to give the same spray pattern and angle as the nozzle presently installed in the unit and should never be larger than the present nozzle.

Step 4

Install Trial Nozzle and Make Required Adjustments

Install the trial nozzle and see if the flame fits the combustion chamber. If it does not, a nozzle with a different spray pattern and angle may have to be tried. Using a smoke measuring device, adjust the oil burner to the "best" operating condition using either the "eyeball" inspection approach or the procedure outlined in reference [3]. This "best" condition will in general correspond to the smallest opening in the air shutter (least amount of excess air) which will allow the burner to operate with an oil-free (non-yellowed) smoke spot having a smoke number of #1 or less on the Bacharach Smoke Scale. Check the draft and readjust the draft regulator if necessary. The fire should be uniformly distributed in the combustion chamber and must not touch any metal surfaces. There should be no delayed ignition, visible flame instability or pulsation noise.

---

* If this is not known, refer to Chapter 33 of the ASHRAE Handbook of Fundamentals, Reference [1]. Use the 97.5 percent values for the nearest weather station listed.

** The winter K-factor should be the average value derived over one or more complete heating seasons. The K-factor for a residence is defined as the number of degree days occurring in a time period divided by the total number of gallons of oil used during the same period to maintain a house at its normal thermostat setting.

Step 5

Remeasure the Percentage of CO_2 and the Flue Gas Temperature

Remeasure the percentage of CO_2 and the flue gas temperature. The percentage of CO_2 in the flue gas should be equal to or higher than the reading obtained with the original nozzle. As a general rule, the final CO_2 reading should not be allowed to fall below the reading obtained with the original nozzle by more than 0.2 percentage points for each 10% reduction in firing rate.

In addition, the smoke number must be less than or equal to #1 on the Bacharach Smoke Scale. The temperature of the combustion gases prior to their entering the draft regulator should be above 370 °F in order to avoid the possibility of corrosion.

Satisfying the above conditions should result in a steady-state efficiency not significantly lower than with the original nozzle. As a check, recalculate the new steady-state efficiency and compare it with the original. If the new efficiency is not below the original efficiency by more than 2 or 3 percentage points, the new nozzle is the proper one and you may skip Step #6. If this is not the case, one or more additional nozzles should be tried. This is discussed in Step #6.

Step 6

Trying Additional Nozzles

If the conditions discussed in Step #5 have not been met, repeat Steps #4 and #5 using other nozzle sizes. It is not possible to give a hard and fast rule for selecting the successive nozzles. It may be desirable to try one or more additional nozzles of the same size but with different spray patterns or angles or it may be necessary to go to a larger size nozzle. The only generalization which can be made is that if after installing a trial nozzle, the flame pattern looks good but the excess air has to be increased considerably in order to keep the smoke equal to or below #1 on the Bacharach Smoke Scale, the next nozzle size should probably be half way between the newly installed nozzle size and the original nozzle size. Experience will be the best guide in selecting the successive trial nozzles.

Step 7

Record Results

Carefully record the following information and leave a copy with the owner or place a tag on the equipment:

- date of servicing
- the original nozzle size and type
- the final nozzle size, type, and spray angle
- the number and size of each nozzle tried (include the final nozzle in this count)
- the initial and final CO_2, stack temperature, and smoke readings.

This information will be helpful for future servicing of the unit and could be invaluable in trouble shooting any problems which might arise immediately after a reduction in firing rate.

References

1. ASHRAE Handbook of Fundamentals, 1972.
2. Exxon's "Guide for Optimizing Firing Rates."
3. Guidelines for Residential Oil-Burner Adjustments, US Environmental Protection Agency, Report No. EPA-600/2-75-069-a (October 1975).

Step 8

Repeat Nozzle Optimization Procedure

If the procedure in Step #3 resulted in the proper nozzle size in Step #5, the nozzle size should be re-evaluated after one heating season. The reason for this is that the K-factor used in Step #3 to calculate the minimum nozzle size is dependent upon the seasonal efficiency of the heating system. Reducing the firing rate should increase the seasonal efficiency, leading to a larger K-factor. This new K-factor should be used to find a new minimum nozzle size.

☆ U. S. GOVERNMENT PRINTING OFFICE : 1977 O - 239-912

Field Checklist for Optimizing Nozzle Size

1. Repair and tune-up heating system.

2. Measure steady state efficiency and smoke. If steady state efficiency is less than 75% or smoke greater than #2 on the Bacharach Smoke Scale, repeat Step #1 or replace burner and/or heat exchanger.

3. Determine the minimum nozzle size by using the chart on the back of this card. This nozzle size should be at least:

   0.5 gph for warm air systems,

   0.65 gph for hot water systems not supplying domestic hot water,

   0.85 gph for hot water systems with aquaboosters,

   1.20 gph for hot water systems using only tankless coils.

4. Install trial nozzle and adjust oil burner to best operating condition. Check and readjust draft regulator, if necessary.

5. Remeasure CO_2 and flue gas temperature. The CO_2 reading should not be allowed to drop below the reading obtained with the original nozzle by more than 0.2 percentage points for each 10% reduction in firing rate. The smoke should be less than or equal to #1 and the stack temperature should be greater than 370 °F. The steady state efficiency recalculated with the new nozzle should not be more than 2 or 3 percentage points below the steady state efficiency with the original nozzle.

6. If the criteria in Step #5 are not met, Steps #4 and #5 should be repeated using additional nozzles having different spray patterns, angles and/or sizes.

7. Record results and leave a copy with the owner and/or tag equipment.

8. On heating systems for which the first trial nozzle met the criteria in Step #5, the procedures outlined in Steps #1 through #7 may be repeated after one complete heating season has passed using the new winter K-factor derived from a full heating season of operation with the new nozzle.

Figure 1 Minimum Nozzle Size