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INTERIM GUIDANCE FOR OIL HEATING EQUIPMENT SELECTION

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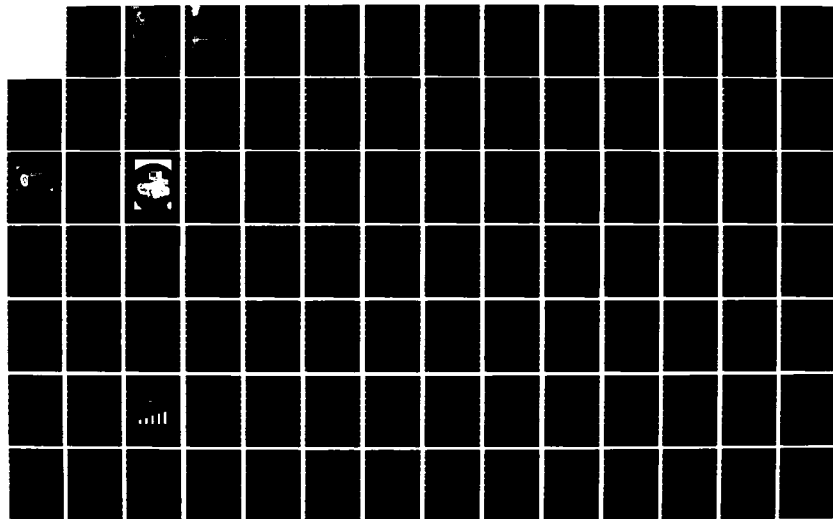
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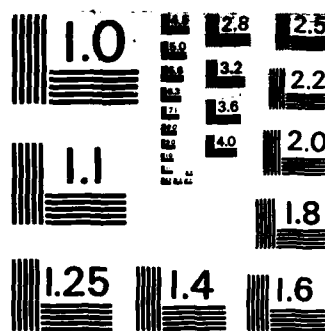
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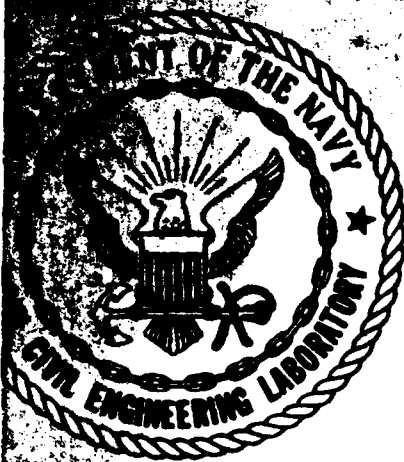
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NAVAL CIVIL ENGINEERING LABORATORY
Port Hueneme, California

Sponsored by
NAVAL FACILITIES ENGINEERING COMMAND

INTERIM GUIDANCE FOR OIL HEATING EQUIPMENT SELECTION FOR
NAVAL RESIDENTIAL HOUSING

January 1984

An Investigation Conducted by
Brookhaven National Laboratory
Department of Applied Science
Upton, Long Island, N.Y. 11973

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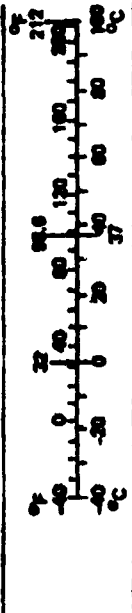
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From Unit	To Unit	Factor	From Unit	To Unit	Factor
LENGTH					
in	inches	1	mm	millimeters	25.4
ft	feet	12	cm	centimeters	30.48
yd	yards	3	m	meters	36
mi	miles	1760	km	kilometers	1609.34
AREA					
sq in	square inches	1	sq cm	square centimeters	6.45
sq ft	square feet	144	sq m	square meters	10.76
sq yd	square yards	9	sq km	square kilometers	1076390
sq mi	square miles	270869	ha	hectares	247105
ac	acres	43560			
MASS (weight)					
oz	ounces	16	g	grams	28.35
lb	pounds	16	kg	kilograms	2.205
st	short tons (2000 lb)	2000	t	tonnes	2204.62
VOLUME					
ts	teaspoons	3	ml	milliliters	0.061
Tsp	tablespoons	3	l	liters	1.057
fl oz	fluid ounces	8	m ³	cubic meters	35.23
c	cups	8			
pt	pints	2			
qt	quarts	2			
gal	gallons	4			
cu ft	cubic feet	7.46			
cu yd	cubic yards	27			
TEMPERATURE (exact)					
F	Fahrenheit temperature	5/9 (after subtracting 32)	C	Celsius temperature	1.8

* 1 in. = 2.54 exactly. For other exact conversions and more detailed tables, see NBS Mon. Publ. 288, Units of Weight and Measure, Price \$2.35, SD Catalog No. C13.16-288.



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settings, pipe or duct insulation, turbulators for steel tube boilers, and heating system tune-up. Each suggested equipment and modification is described in detail with pros and cons of its implementation, when to consider modification or replacement, possible cost savings, and the expected payback period.

This report is prepared in the form of a guide for use by Public Works personnel charged with the responsibility of procuring, installing, operating and maintaining oil-based heating systems for Navy housing. Consequently, detailed methods and techniques of efficiency measurement in the field, basic combustion theory, and copies of six manufacturer's installation manuals for widely used retention head oil burner designs sized for small (single or two-family) residential applications have also been included.

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FOREWARD

This interim guide was prepared by Brookhaven National Laboratory with the assistance of equipment manufacturers and the residential oil heating industry at large, and the wealth of information developed during the last six years under the U.S. Department of Energy. The effort was funded by the Naval Civil Engineering Laboratory, Port Hueneme, CA. and conducted under the auspices of the U.S. Department of Energy.

The information contained in this interim guide is intended for experienced oil burner service personnel. While the general thrust of the guide is directed at retention head burner technology, other equipment options are discussed. An attempt is made to explain how the various parts of the heating system function together and how various options can be selected to improve performance.

The material in section 1.0 essentially summarizes the subject of improved efficiency in residential oil-fired heating systems. Section 2.0 discusses in some detail the function of the high pressure atomizing oil burner and describes the retention head burner technology. Section 3.0 outlines the theory behind heating equipment efficiency and discusses the adjustment of oil-fired heating equipment in the field. In section 4.0 a reasonably comprehensive discussion of parameters effecting heating equipment performance is presented. Finally in section 5.0 various retrofit options are discussed in detail together with specifics regarding oil firing rate optimization. The appendices at the back of the guide contain detailed discussion of combustion theory, flue gas measurements, some selected burner installation instructions provided by manufacturers, as well as cautionary comments on some energy conservation devices not covered elsewhere in the report.

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1.0 INTRODUCTION

1.1 Purpose of Interim Guide

In simple terms the purpose of this Interim Guide is to assist Navy personnel in making good choices in planning the replacement of oil burners and the servicing of equipment used in the heating of Naval buildings and residential housing.

The information in the guide is intended to assist the user in the following general areas; 1) retention head oil burners and how they can improve the efficiency of heating equipment when they are correctly selected, installed and maintained over their service life, 2) other energy saving devices or techniques and how well they work, 3) how and why the various parts of the heating system work together.

With this information the user will be better able to maintain the performance of the existing equipment, to accurately judge manufacturer claims about performance or savings and to correctly select replacement equipment.

This guide contains information which is applicable to a wide range of oil-fired heating equipment and does not attempt to deal with issues or subjects which are specific to Naval shore applications. These specific issues and subjects will be covered in a user data package which will be prepared later in the project. A summary of the current report is given below.

1.2 Summary

1.2.1 Improved Efficiency and Consumption

Some manufacturers of modern oil burners claim large efficiency improvements with the use of their product. Some of the claimed improvement is due to improved combustion and this is true of many modern burner designs which use air swirling vanes in the burner tip. Another part of the improvement is due to a reduction in losses from the furnace or boiler when the burner is off. This is due to smaller required air inlet shutter settings and the complex air vanes in the burner tip. These features help to reduce the free movement of cool air through the furnace or boiler during the off period reducing the amount of heat lost up the flue. At the time of installation other improvements may be made which do not involve the burner specifically but for which the manufacturers take credit in making their claim. Some of these improvements relate to improvements in the general condition of the furnace or boiler before the installation of the new burner. Performance of the heating system is reduced by such things as poor adjustment, the buildup of soot on heat exchange surfaces, missing flue gas baffles, air leaks into the combustion chamber, and high heat exchanger operating temperatures. Correction of these problems at the time of the burner replacement can add greatly to the improvement due to the burner alone and when taken in total may result in a substantial reduction of fuel consumption over the heating season. It is important to understand how the correction of each problem contributes to overall savings and this will be discussed later in the report.

At this point, it may be useful to discuss the relationship between improved heating efficiency and fuel consumption. Basically, the total annual fuel consumption of heating equipment in buildings is equal to the total amount of heat required for the year divided by the product of the average efficiency of the heating equipment over the year and the higher heating value of the fuel.

$$\text{Annual Fuel Consumption} = \frac{\text{Total Heat Required (Btu)}}{\text{Average Efficiency} \times \text{Fuel Heating Value (Btu/Gal)}} \\ \text{(Gallons)}$$

The total amount of heat required for a building can be estimated from calculations of its heating needs for human comfort and hot water.

Estimating the average efficiency of the heating system is much more difficult. The efficiency of heating equipment varies depending on how frequently it is required to deliver heat. Generally speaking the more frequently the system delivers heat the higher its efficiency. Maximum system efficiency occurs when the system is continuously delivering heat. This is called steady state operation and the resulting efficiency of heat delivery is called steady state efficiency. Unfortunately heating systems rarely operate at steady state conditions. This is due to the fact that the building heating needs vary hour to hour and are almost always very much smaller than the maximum output of the heating system. For this reason the average efficiency of heating equipment over the year will be less than its steady state efficiency. How much less depends on the heating equipment and its application.

Fortunately most changes in annual fuel consumption can be estimated by using measurements commonly taken in the field by heating system service people. These measurements involve a simple stack gas analysis of the heating system under forced steady state operation. These measurements can be translated into what is called a steady state stack gas efficiency. It is interesting that these efficiency measurements, if carefully taken, are higher than the true steady state heat delivery efficiency by a constant amount for the same heating system. Because of this, changes in the steady state stack gas efficiency can be used to estimate changes in the true steady state heat delivery efficiency. From these conservative estimates of the savings in annual fuel consumption due to heating system modification or servicing can be made. The following formula can be used for estimating savings:

$$\text{Annual Fuel Savings (\%)} = \frac{\text{New Stack Efficiency} - \text{Old Stack Efficiency}}{\text{New Stack Efficiency}} \times 100$$

1.2.2 Cost Effectiveness

The cost effectiveness of a particular energy conservation measure may be evaluated under actual operating conditions if sufficient information about fuel consumption and delivered heat energy is available. This information is sometimes difficult to obtain and it becomes necessary to make estimates without the benefit of extensive tests. The procedure outlined above can be used

to make such estimates. The effectiveness of replacing conventional burners with retention head burners can be evaluated in the following example.

Based on stack gas measurements taken in the field the average as-found steady state stack gas efficiency of 161 steel boilers using conventional burners was found to be 72.5%. The installation of retention head burners together with careful adjustment could be expected to result in a new stack gas efficiency of 83%. Calculation of the expected annual savings can be written as:

$$\text{Annual Fuel Savings (\%)} = \frac{83.0 - 72.5}{83.0} \times 100 = 12.7\%$$

Assuming a previous annual consumption of 1200 gallons the expected savings is:

$$\begin{aligned} \text{Annual Fuel Savings (Gal.)} &= \frac{\text{Prev. Consumption (Gal.)} \times \% \text{ Savings}}{100} \\ &= \frac{1200 \text{ Gal.} \times 12.7\%}{100} = 152 \text{ Gallons} \end{aligned}$$

The installed cost for a retention head burner is about \$325. Assuming a per gallon fuel cost of \$1.12 (\$8.10 per 10⁶ Btu) the simple payback is:

$$\begin{aligned} \text{Simple Payback} &= \frac{\text{Installed Cost (\$)}}{\text{Cost of Fuel (\$/gal)} \times \text{Savings Per Year (gal/yr)}} \\ \text{Simple Payback} &= \frac{325 \$}{1.12 \text{ \$/gal} \times 152 \text{ gal/yr}} = 1.9 \text{ years} = 23 \text{ months} \end{aligned}$$

It should be noted that these savings represent improvements in the combustion process only. Some additional savings in boilers can be expected due to reduction of losses in the burner off period.

1.2.3 Recommendations

Later sections in this guide will focus on heating equipment design and operation, and on heat loss and efficiency. Clearly, heat losses from equipment can reduce system efficiency, and the performance of many boilers and furnaces can be improved in this area. The purpose of this section is to introduce a wide range of energy-saving equipment modifications and indicate both expected fuel savings and possible adverse effects. This information must be supplied to users so that they can decide on the best conservation approach for their specific application. Heating system improvement often reduces excessive fuel cost more than many other home energy conservation measures at less expense to the user.

The adverse effects that can result from some modifications are included, so that equipment users are aware of both positive and negative results. While variability in heating equipment and retrofit designs prevent the development of a general and simplified installation approach, the experienced service person using manufacturers instructions can adapt heating equipment to operate more efficiently while assuring safe and reliable operation.

Many heating unit modifications exist that will reduce heat loss and improve efficiency. These range from simple control adjustments of boilers and furnaces to the replacement of the entire heating system. The low-cost approaches should be considered for all heating units. Higher cost modifications must not be automatically rejected, however, because in the long term they offer the greatest energy savings, and they are often economically attractive. The specific heating unit modifications included here represent two groups which are:

1. Relatively High Cost Modifications

- o Flame retention head burners.
- o Replacement boilers or furnaces.
- o Flue heat reclaimers.
- o Vent dampers.

2. Relatively Low Cost Modifications

- o Reduced fuel firing rates (smaller fuel nozzles).
- o Reduced temperature settings for boilers and furnaces.
- o Pipe or duct insulation.
- o Turbulator (baffle) replacement for steel tube boilers.
- o Heating system tune-up.

1.2.3.1 Relatively High-Cost Modifications

A. Retention Head Burners. Installation of flame retention head burners as replacements for older units is an effective and economic means for conserving heating oil. Flame retention burners represent an important advance in burner performance and the technology has been proven by many years of field experience. Few problems are anticipated by widespread use of newer burners, but careful installation and adjustment practices are required to assure safe and efficient performance.

Extensive laboratory and field investigations indicate that replacement of older burners with flame retention units will reduce fuel use by an average of 15%. Savings measured in the laboratory range from about 5 to 25%, while field investigations show larger variations. It is possible in some field installations to save up to 40% by burner replacement.

Flame retention head burners do not present the reliability problems that are sometimes associated with new energy saving add-ons because these burners have been available for more than a decade. Many burner components are the same as older oil units that have been used for several decades, therefore,

few problems are expected by wider use of retention head burners. One area that must be considered by installers, however is the possible incompatibility with some older heating units. These boilers and furnaces may not have been designed for the higher flame temperatures produced by new burners, and modification of the combustion chamber may be required.

Generally, flame retention burners reduce annual fuel use by an average of 15%, and the installed cost assumed here can range from less than \$300 to above \$500. If we assume a typical fuel useage of 1200 gallons per year and a fuel cost of \$1.00 per gallon, then the annual fuel savings is \$180. In this case the burner pays for itself in about two years, and this payback period is shorter for homes with higher fuel consumption or less efficient heating units. Table 5.1 gives examples of payback periods for different values of equipment costs, annual fuel uses, and efficiency improvements.

B. Replacement of Boilers and Furnaces. Replacement of obsolete boilers and furnaces with modern highly efficient models can reduce fuel cost more than any other option available to homeowners. A government efficiency labeling program is in place which can identify high efficiency units. Older boilers and furnaces with outdated design features should be replaced. High equipment costs may deter investment, but planning should focus on the substantial savings that are available. Remember that paybacks become shorter as the price of fuel rises.

Fuel savings that result from boiler or furnace replacement depend on the original and final efficiency of the heating system. These efficiencies are difficult to evaluate, but laboratory and field studies show that fuel savings of 25% or more are common. Nine out of ten units are expected to save between 20 and 35 percent.

New boilers and furnaces are not expected to present adverse effects when compared to the older units they replace. Service requirements should be reduced, and occupant satisfaction improved. Properly installed replacement boilers and furnaces provide many years of economical thermal comfort.

A basis for evaluating the value of boiler or furnace replacement is the payback period (discussed earlier). The payback period is the number of years required to pay for the new equipment with fuel savings. Payback periods vary with:

- o Original system efficiency.
- o Final system efficiency.
- o Cost of equipment.
- o Fuel consumption.
- o Price of fuel per gallon

Fuel cost reduction and payback period are calculated in the example below:

- o Fuel savings of 25%.
- o Installed cost of \$2000 for the new equipment.
- o Fuel consumption of 1500 gallons per year.
- o Fuel price of \$1.00 per gallon

(Installed costs vary widely and can be considerably less than or greater than this example).

- o Annual fuel savings = 375 gallons
- o Payback period = 5.33 years

Table 5.5 gives examples of payback periods for different values of equipment costs, annual fuel uses and savings percentages.

C. Heat Reclaimers. Flue heat reclaimers reduce on-cycle heat loss. Some flue heat loss cannot be avoided, but many heating units have excessive losses. Reclaimers that heat boiler water reduce fuel use from about 6 to 20%. Fuel savings are estimated by measuring on-cycle heat loss, and heating units with high flue temperature save the most. Adverse conditions including reduced chimney draft and heating unit corrosion are possible and reclaimers must be installed carefully.

Flue heat reclaimers are not the best option for many heating units. They are add-ons that increase the complexity of the heating system, and, therefore, can cause operational problems. Replacement of old boilers and furnaces is a better option for many users. Also, other equipment modifications including new flame retention burners reduce on-cycle heat loss. Flue heat reclaimers are useful in some cases particularly where flue gas temperatures are high and boiler or furnace replacement cannot be considered.

Heat reclaimer performance depends on its design and the on-cycle flue gas temperature of the heating unit. Tests of water type reclaimers on boilers at Brookhaven National Laboratory show fuel savings that range from 6 to 20% for typical heating units with high flue temperatures. The difference reflects design variations of the heat reclaimers. Measurement of the actual heat output is necessary to compare the performance of different reclaimers.

Two adverse conditions can result from the use of flue heat reclaimers:

- o Reduced chimney draft.
- o Heating unit corrosion.

Heat reclaimers often contain heat transfer surfaces that reduce the total free area of the flue pipe. These restrictions limit the ability of the chimney to remove combustion exhaust gases. Insufficient chimney draft is a problem for some heating systems and flue heat reclaimers can make the problem worse. Also, heat reclaimer flue passages tend to collect soot, and this further aggravates the problem. The soot deposits reduce the effectiveness of

the reclaimer and periodic cleaning is required. Consider the ease of servicing and cleaning when selectig a reclaimer.

Heat reclaimers reduce chimney draft in another way. The reclaimer lowers exhaust temperature and draft is directly related to this temperature. Better reclaimers create lower exhaust temperatures and less chimney draft. Some heating units continue to operate properly with lower draft, but others do not. Equipment installers must be certain that there is sufficient chimney draft after heat reclaimer installation.

Heating unit corrosion is another adverse effect of flue heat reclaimers. The cooler exhaust gases approach the point at which water vapor condenses. The water vapor combines with other flue gases to form a corrosive liquid. If the water vapor condenses on heating unit or flue surfaces, then corrosion damage may result. Equipment lifetime is shortened by corrosion. Typically, a final flue (after the heat reclaimer) temperature of about 350°F is considered safe for oil-fired heating units. Systems with lower flue temperatures or long exhaust pipes are more likely to have flue gas condensation problems.

A typical fuel saving is 12% for a flue heat reclaimer, and installed costs range from less than \$400 to above \$700. The fuel saving and installed cost for an example case are:

- o Percent Savings: 12%
- o Annual Fuel Use: 1500 gallons
- o Fuel Cost: \$1.00 per gallon
- o Annual Savings: \$180
- o Installed Cost: \$550
- o Payback Period: 3 years

The reclaimer in the example above saves \$180 per year and costs \$550, with a payback period of 3 years. Other examples are shown in Table 5.4.

D. Vent Dampers. Vent dampers reduce off-cycle and air infiltration heat losses. Average savings are about 8%, but installed on some older heating units they may save more. Off-cycle loss cannot be measured in the field, however, and accurate prediction of savings is difficult. Vent dampers that close tightly save more fuel than dampers with cut-outs that permit off-cycle air flow. Many factors affect heat loss and vent damper effectiveness, and dampers should be used on systems with larger off-cycle heat losses. While savings are less than those for burner replacement, vent dampers can be economically attractive for many homes.

Laboratory and field studies show that vent dampers reduce fuel use on the average by 2% to more than 14%. The actual reduction depends on existing off-cycle and infiltration heat losses. Field studies indicate average fuel savings are about 8% for oil-fired heating units.

Laboratory tests show that tight-closing dampers are better than units with cutouts. Tight dampers often include a time delay before closure to

allow purging of combustion gases from the heating unit. This short delay does not reduce fuel savings, but cut-outs reduce fuel savings significantly. For example, Brookhaven National Laboratory tests show that one boiler saved 11% with a tightly closing damper. The same boiler with damper blade cut-outs saved only 5%. This shows that cut-outs can reduce savings by 50% compared to tightly closing units. Clearly, vent dampers that close tightly save more fuel than other designs.

Two areas of concern exist for vent dampers:

- o Operating the burner while the damper is closed.
- o Off-cycle odors.

Operating the burner while the damper is closed is an obvious safety problem, but most dampers have control features to prevent it. Careful installation is essential to be sure that all safety devices are operative. Manufacturer instructions must be followed explicitly!

Payback periods are shown in Table 5.2. Generally, the payback periods for vent dampers are longer because fuel savings are less than for new burners. A typical example may be represented by:

- o Installed cost: \$350
- o Annual fuel use: 1500 gallons
- o Percent savings: 8 percent
- o Fuel cost: \$1.00 per gallon

The payback period for this case is about 3 years with an annual savings of \$120. This is not the best payback or annual cost saving measure, but it does represent an attractive investment for many homes. Heating systems with design features that tend toward high off-cycle and infiltration losses are certainly candidates for vent dampers.

1.2.3.2 Relatively Low Cost Modifications

A. Reduced Fuel Firing Rate. Reduced fuel firing rate is a low cost modification that can become part of periodic burner servicing. Fuel savings average about 8% for boilers and furnaces. Smaller nozzles are not suitable for all heating units and several adverse effects must be considered before modification. Standard procedures are available for choosing the appropriate nozzle size, and these can become part of standard burner adjustment procedures.

Laboratory measurements, field investigations and computer simulations show that lowered firing rates reduce fuel use by about 8%. Savings for warm air furnaces average 7.5% while boilers average 8.5%. It is difficult to separate on-cycle and off-cycle savings, but laboratory tests on boilers show that a large part of the savings occurs during the burner off-cycle.

Reduced nozzle size is not appropriate for all heating units, and several undesired effects are possible. These include:

- o Insufficient heat during peak heating requirements.
- o Slow response to changing heat loads.
- o Burner on-cycle flue loss may increase.
- o Inadequate domestic hot water supply.

Reduced fuel firing rate is a low cost option with important benefits. If it becomes part of a periodic service procedure, then the added cost is minimized. Typical fuel savings are 8%. The economics are very favorable as seen in the example below:

- o Percent savings: 8%
- o Annual fuel use: 1500 gallons
- o Annual fuel savings: \$120
- o Installed cost: \$30
- o Payback period: 0.25 years

The cost of reduced firing rate pays for itself in about three months in this case.

B. Reduced Temperature Settings for Boilers and Furnaces. The efficiency of many heating systems improves with reduced boiler water or fan shut-off temperatures. Manual adjustment of controls can be part of annual tune-up procedures at low cost. First, advise each occupant of expected savings and possible adverse effects. Automatic controllers change boiler temperature continuously during the heating season, but compare their installed cost to expected savings. Systems with large off-cycle heat loss and high off-cycle temperature can save the most. Payback periods and annual fuel savings for automatic boiler controls are worthwhile in some cases.

Laboratory tests on hot water boilers show a direct relationship between boiler temperature and off-cycle loss. Tests show that off-cycle heat loss doubles when the water temperature increases from 140°F to 200°F. These test results are for one specific boiler-burner combination, but other units show a similar effect. Less test data is available for warm air furnaces, but losses are effected by higher temperature also. Clearly, off-cycle heat loss increases with the temperature of the boiler or furnace.

Actual fuel saving depends on the initial off-cycle heat loss and the degree by which boiler (or furnace) temperature is reduced. Typical savings of about 10% are expected for older burner-boilers with large losses when automatic controls are applied. Manual adjustment is less effective and savings are less predictable.

Typical fuel savings for warm air furnaces are expected to be lower than for boilers, but in some cases substantial fuel savings are possible.

Some heating systems require high boiler water temperatures. Two conditions that restrict boiler temperature reductions are:

- o Inadequate radiator area within the house.
- o Tankless coils for domestic hot water.

Furnace temperature settings are set high for two reasons:

- o To provide adequate air temperature at the registers while the unit is "on."
- o To prevent cool drafts during the furnace cool down (burner-off) period.

Savings and cost are considered in two groups:

- o Manual adjustment of boilers and furnaces by service personnel.
- o Automatic temperature controllers for hot water boilers.

The cost in the first case is low because temperature adjustment can be part of periodic equipment servicing. The savings expected are small but it can be worth the effort.

Automatic temperature controls are expensive but the savings are usually higher. Estimates of boiler temperature controls show typical costs of about \$350, but this varies. The actual saving depends on initial off-cycle heat loss and the percentage improvement. Expected savings range from less than 5 to above 10 percent. For these values we find a payback period below:

- o Typical Fuel Use: 1500 gallons
- o Percent Savings: 7.5
- o Annual Savings: \$112 (at \$1.00 per gallon)
- o Installed Cost: \$350 (Installed costs vary widely and can be less than the example shown above)
- o Payback Period: 3.1 years

C. Pipe or Duct Insulation. Heat loss from hot water pipes or warm air ducts reduces system efficiency and increases fuel use. Uninsulated piping wastes heat while water circulates and during idle periods. Warm air systems lose heat through inadequate insulation and through leaky duct connections. All of these situations reflect improper installation practices. Distribution losses are not necessary, and must be eliminated whenever possible. Seal air ducts and insulate ducts and hot water pipes, particularly when they pass through unheated areas of the house. Actual savings vary, but the improvement is a worthwhile investment.

It is impossible to estimate savings for "average" cases, because each heating system is different. The size of the piping system, the temperature of air surrounding the pipes, and the degree of insulation vary from house to house. Typical savings, however, of 5 to 10 percent should be expected for insulating an originally uninsulated system.

For warm air ducts the prediction of average savings is not possible for the reasons discussed above. Savings can range from small values up to 40 percent depending on original heat losses. Seal and insulate all warm air ducts, particularly those in unheated spaces.

Few adverse effects are expected from reducing pipe and duct heat loss. Supply temperatures increase and this may cause air temperatures at the supply registers to become too hot. Increase the fan speed or reduce the firing rate if this is a problem. Also, some basements and other "unheated" areas of the house may become colder. Additional radiators or warm air registers solve this problem.

D. Turbulator (Baffle) Replacement for Steel Boilers. Turbulator replacement reduces on-cycle heat loss in some steel tube boilers. Choose the correct size and design for each boiler. Expected savings are about 5 percent, and this normally justifies material and installation costs in many cases. Turbulators are simple devices that present few problems for most boilers and reduce excessive fuel use.

Turbulators reduce flue gas temperature and reduce flue heat loss. Typically, flue temperatures drop about 150°F after turbulator installation, and this corresponds to a fuel saving of about 5 percent. Actual savings depend on initial flue temperatures.

Flue gas turbulators add restriction to the boiler passages and reduce the effect of chimney draft. In most boiler installations this is not a problem. Some units have marginal or poor draft conditions, however, and turbulators could be a problem for these systems. Be sure that there is adequate chimney draft before installing turbulators.

E. Heating System Tune-Up. Periodic cleaning and adjustment of heating units is necessary to maintain good performance. Tune-up procedures should be thorough and include combustion efficiency testing. Good service procedures reduce wasted time and reduce unnecessary service calls.

Typical savings for tune-up are about 3 percent for systems that are regulatory adjusted. Fuel savings are greater for heating systems that are tuned infrequently and for units that are out of adjustment because of equipment malfunction. For example, the efficiency of a boiler or furnace with a partially plugged fuel nozzle improves significantly after a tune-up. Adjust burners for less than a "number one" smoke on the Bacharach scale to prevent soot buildup and a gradual loss of efficiency. Fuel is saved and vacuum cleaning of the heating unit is required less frequently. This reduces service time and permits the service department to operate more effectively.

The savings resulting from heating system tune-up vary widely. If fuel savings are about three percent, then the homeowner saves about \$40 per year, and that figure, of course, will go up as the cost of energy rises. Annual tune-up is recommended, but if a system is adjusted properly, then it may not need to be readjusted each year. A simple inspection and efficiency test may be sufficient. Invested time in the initial tune-up pays for itself later, if done properly.

1.2.3.3 Retrofit Summary

The summary in Table 5.6 relates each retrofit modification to the system heat losses that are effected most. Typical savings and brief comments are included. The heat losses decrease from left to right for most heating systems. That is, on-cycle loss is greater than off-cycle loss and so on. It is not surprising that most of the modifications affect heat losses in the first two columns, because this yields the greatest savings. The chart points out another important fact. The savings for combined modifications are not additive. For example, if a vent damper (8%) is combined with reduced firing rate (8%), then fuel saving is less than 16 percent, because each heat loss is reduced only once. A more detailed retrofit summary and explanation of Table 5.6 is presented in section 5.4.

The costs of modification vary widely from tune-up to complete replacement of the heating unit. Four options in this guide involve considerable cost, while the other five are often less expensive. This factors into the final decision. Be aware of the long term advantages of some of the higher cost equipment modifications, because these are often the best choices.

Deciding on which efficiency improvements to recommend is not always easy, because fuel savings is difficult to predict for a specific house. The savings shown in this guide represent average values and individual cases vary. In order to predict fuel savings, all heat losses (on-cycle, off-cycle jacket, distribution, and air infiltration) must be measured. Unfortunately, this is not possible in most cases. On-cycle heat loss is known through combustion efficiency testing, but the other losses cannot be evaluated in the field. Therefore, it is difficult to accurately predict savings for each retrofit in order to identify options for a specific system.

Combustion efficiency testing shows burner on-cycle heat loss and is vital for heating system evaluation. Combustion testing is useful for deciding if new burners, flue heat reclaimers or turbulators should be recommended, because on-cycle flue loss is the main loss affected. The other options involve other heat losses and prediction is more difficult. In these cases heating system inspection gives valuable insight into the importance of these losses.

Heating system inspection is important because it identifies burner, boiler and furnace design and installation characteristics that effect system efficiency. The combination of combustion efficiency testing and system inspection supply the information needed to formulate decisions.

The specific retrofit option(s) recommended depends on the results of combustion efficiency testing and system inspection.

1.2.3.4 Retrofit Combinations

When more than one modification is used, the expected fuel savings is difficult to estimate. The savings cannot be determined by adding together

the savings for each individual modification because some retrofits effect the same heat loss. For example, flame retention burners and flue heat reclaimers both reduce on-cycle flue heat loss. This combination saves less than 28 percent (15 plus 13, average values for the respective options) when applied to typical boilers. In general, savings are not additive. The best retrofit is the one that saves the most energy and has the lowest installed cost. Additional modifications cost more and achievable fuel savings often are less.

Some combinations are sensible because different heat losses are affected. The chart in Table 5.7 shows various retrofit combinations and identifies some worthwhile combinations. The primary modifications include equipment installations that are costly to perform, while the secondary modifications include equipment installation and lower cost adjustments (i.e., reduced firing rates, reduced temperature, duct and pipe insulation, turbulator replacement, and system tune-up). In all cases Duct and Pipe Insulation and Heating System Tune-up are worthwhile (represented by a G in the chart).

For example, consider combining secondary retrofits with a flame retention burner. A separate vent damper is often unnecessary because the burner reduces off-cycle heat loss. An exception is a heating system with very high off-cycle losses. A flue heat reclaimer is questionable because the new burner reduces on-cycle heat loss and flue gas temperature. Reduced firing rate, reduced boiler or furnace temperature, duct or pipe insulation, turbulator replacement and heating system tune-up are considered good combinations. Some of these can become part of the new burner installation and adjustment routine.

Use the information in the chart to develop a list of single and multiple choices for each building. In some cases multiple retrofits are sensible depending on the final installed cost. In other cases replacement of the boiler or furnace with a highly efficient model is better for the total costs that are involved. A detailed explanation of the chart is presented in section 5.5 of this report.

2.0 OIL BURNER DESIGN AND SELECTION

The burner used in oil-fired boilers and furnaces performs several functions. It prepares the oil for combustion by converting it to very small droplets or a vapor; it mixes the oil with a suitable amount of combustion air; and it provides a source for ignition of the mixture.

The high pressure gun-type burner has emerged as the most common burner in the U.S., for use in residential heating systems. In this type of burner, the oil is atomized by being forced through a nozzle of very small size (typically five to twenty thousandths of an inch in diameter) at a pressure of about 100 pounds per square inch. The nozzle tip is centered at the end of a tube through which combustion air is forced by a squirrel cage blower. An electric motor operating at 1725 or 3450 RPM drives both the oil pump and the blower. Ignition is accomplished by a spark between two electrodes located near the tip of the nozzle.

2.1 Oil Burner Component Parts and Their Function

An oil burner serves four important functions:

- o Atomizes fuel at the required flow rate.
- o Supplies combustion air at a controlled flow rate.
- o Mixes air and fuel to permit complete combustion.
- o Ignites the fuel-air mixture and stabilizes the flame.

Each of the above tasks must be accomplished successfully to provide a safe, reliable and efficient burning process.

The main parts of a typical residential oil burner necessary to accomplish the tasks above are: an electric motor, a fuel pump, a fuel atomizing nozzle, a combustion air fan, air control damper, air turbulators and/or mixing head, and an ignition transformer and electrodes. Electric controls are used to assure safe burner operation. This description is true of older conventional units as well as new retention head burners.

The electric burner motor drives the combustion air fan and fuel oil pump. Typically these motors rotate at 1725 (low speed) or 3450 RPM (high speed), with a small electrical power consumption of approximately 1/6 of a horsepower (about 100 watts).

Heating oil is drawn into the fuel pump, pressured to about 100 pounds per square inch and conveyed to the atomizing nozzle. The fuel nozzle uses this pressure to break the oil into a mist of small droplets. These small droplets enable the rapid evaporation of fuel that is required for combustion. By this process the exposed surface area of one gallon of oil is increased 3800 times to approximately 690,000 square inches.

The air fan supplies combustion air which travels down to the air tube to the burner head where fuel air mixing begins. (See Figure 2.1). The amount

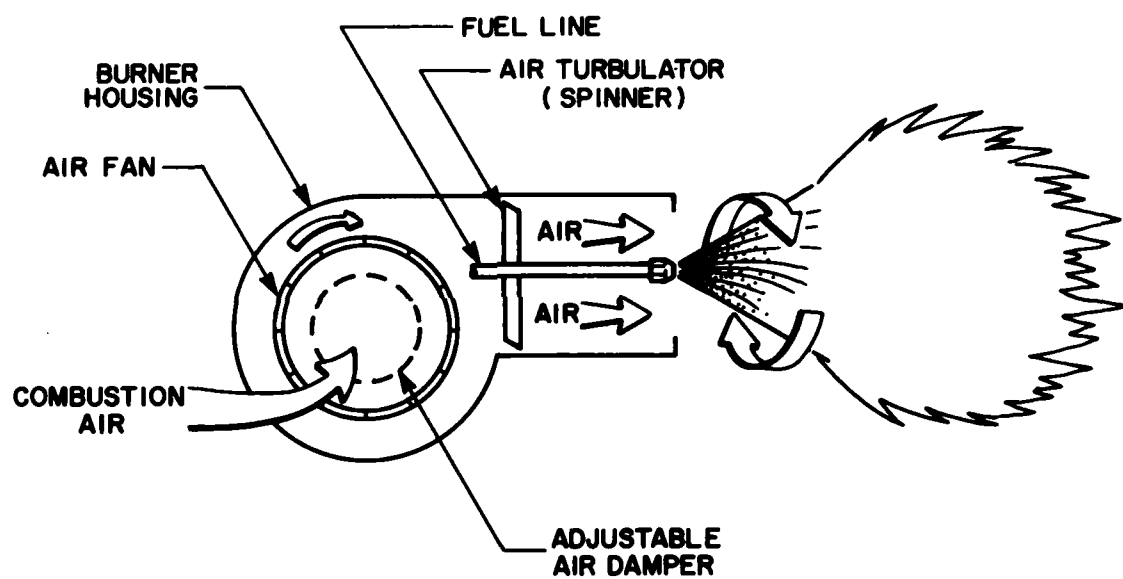


FIGURE 2.1 DRAWING OF OIL BURNER OPERATION

of air entering the burner is controlled by an inlet damper. The adjustment of this damper controls the amount of air the fan delivers for combustion.

The velocity transferred to the combustion air by the burner fan is used to swirl the air to improve mixing with the fuel oil droplets for an efficient, stable flame. Air swirl is created in some burners by spinners located within the air tube.

Ignition of the fuel-air mixture is provided by an electric spark. An ignition transformer amplifies standard house voltage to 10,000 volts, and ignition electrodes are located above the burner nozzle. Once ignition is completed, the flame is selfsustaining and the transformer is often deenergized.

2.2 Fuel Air Mixing and Combustion in Oil Burners

An adequate supply of combustion air and thorough fuel-air mixing are essential ingredients for clean and efficient oil flames. The air flow pattern delivered by a burner is formed by flow control mechanisms located within the burner air tube. Conventional burner designs include stabilizers and chokes. A stabilizer (or spinner) is shaped like a fixed propeller, and it imparts a swirling motion to the air that improves mixing of fuel droplet and vapors with the combustion air stream. Chokes (or end cones) are restrictions located at the end of the air tube that increase the air velocity at the burner outlet and affect the shape of the air pattern. A stabilizer and choke combination is shown in Figure 2.2. The stabilizer and choke combination is typical for older burners. The proper matching of fuel nozzle spray characteristics and the air flow patterns in older burners is difficult and frequently results in fuel-air mixing problems.

The existence of fuel-air mixing problems is best seen by the excess combustion air required by older burners. Most of these use from 50 to 100 percent excess air over the chemically correct value to achieve acceptable smoke numbers. Efficiency loss from excess air is discussed in more detail later. It is important to keep in mind that excess air requirements depend on specific burner design details, and that modern burners have improved fuel-air mixing and require less excess air.

To a great extent the efficiency of a heating system fired by an oil burner is a function of the amount of air that is needed to obtain complete combustion of the oil. All burners succeed in burning virtually all of the oil (well over 99 percent), but some require more air than others to accomplish complete burning without producing noticeable smoke in the chimney.

The amount of air theoretically required to convert the carbon and hydrogen in fuel oil to carbon dioxide, water vapor and heat is about 14.4 pounds of air for each pound of fuel (or 1350 cu. ft. of air for each gallon of oil). In practice, however, most burners need a lot more air than that to achieve complete combustion. Very poor burners need up to one and one half times more than the theoretical amount, average conventional burners need about 70% more than the theoretical amount, but flame retention burners,

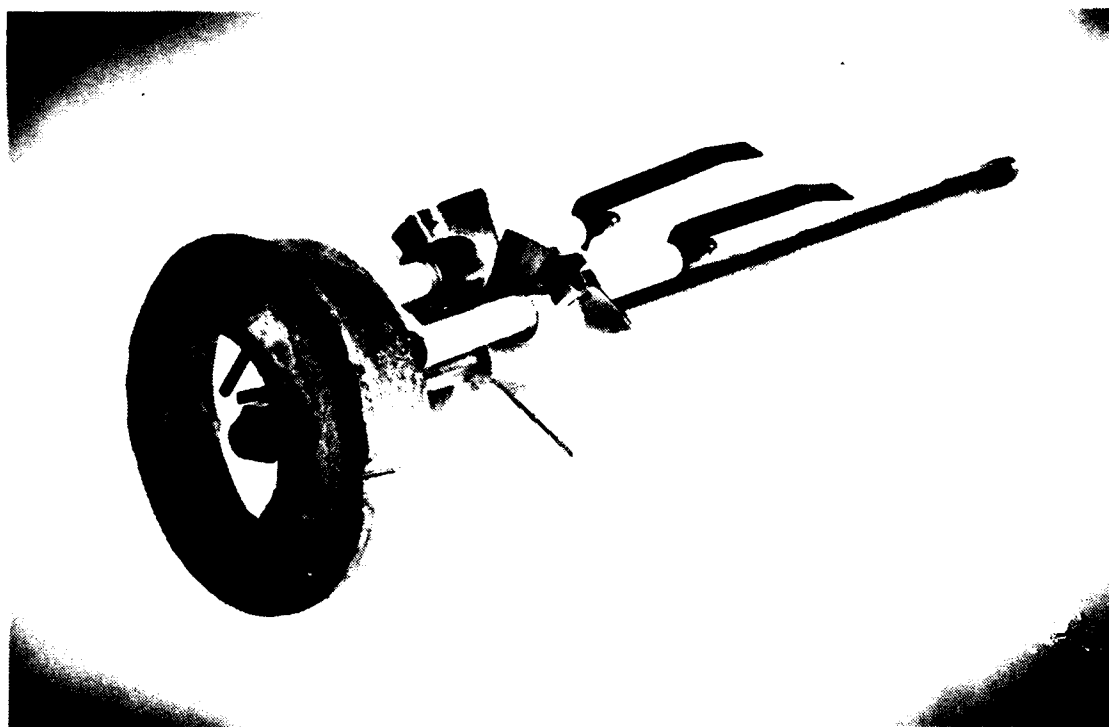


Figure 2.2. A Stabilizer and Choke combination.

properly adjusted, need only about 30% more than the theoretical requirements. High excess air is wasteful because most of the heat of combustion that goes into heating the excess air is lost up the chimney.

An advancement in burner design that has evolved within the past fifteen years is the flame retention head. The flame retention head end cone provides a modified air flow pattern and improved burner performance. A picture of one type of flame retention head is shown in Figure 2.3. Note that the end design is quite different from older style burners. The improved design produces a swirling air pattern with some recirculation of combustion products for improved fuel-air mixing. The flame stabilizes near the burner head and that is where the name "flame-retention" originates.

Several companies manufacture these burners and some of the design details differ slightly. The general flame retention concept is similar, however, and it represents a significant improvement over earlier burner designs.

The intensity of fuel and air mixing is largely dependent upon the velocity and swirl of the combustion air. Modern burners that use the flame retention principle produce high intensity mixing that provide very stable well-defined flames. In contrast to this, some burners of older design do not produce intense mixing but operate instead with lazy, diffuse flames. A comparative illustration is shown in Figure 2.4.

The improvement in fuel air mixing provided by flame retention head burners is evident from performance i.e.; low smoke numbers and high levels of CO_2 in the combustion product gases. Typical retention head burners can produce an 11 to 13 percent CO_2 with a zero to number one smoke. Older burners using stabilizers and end cones reach only seven to nine percent CO_2 with marginal smoke levels (see Table 2.1).

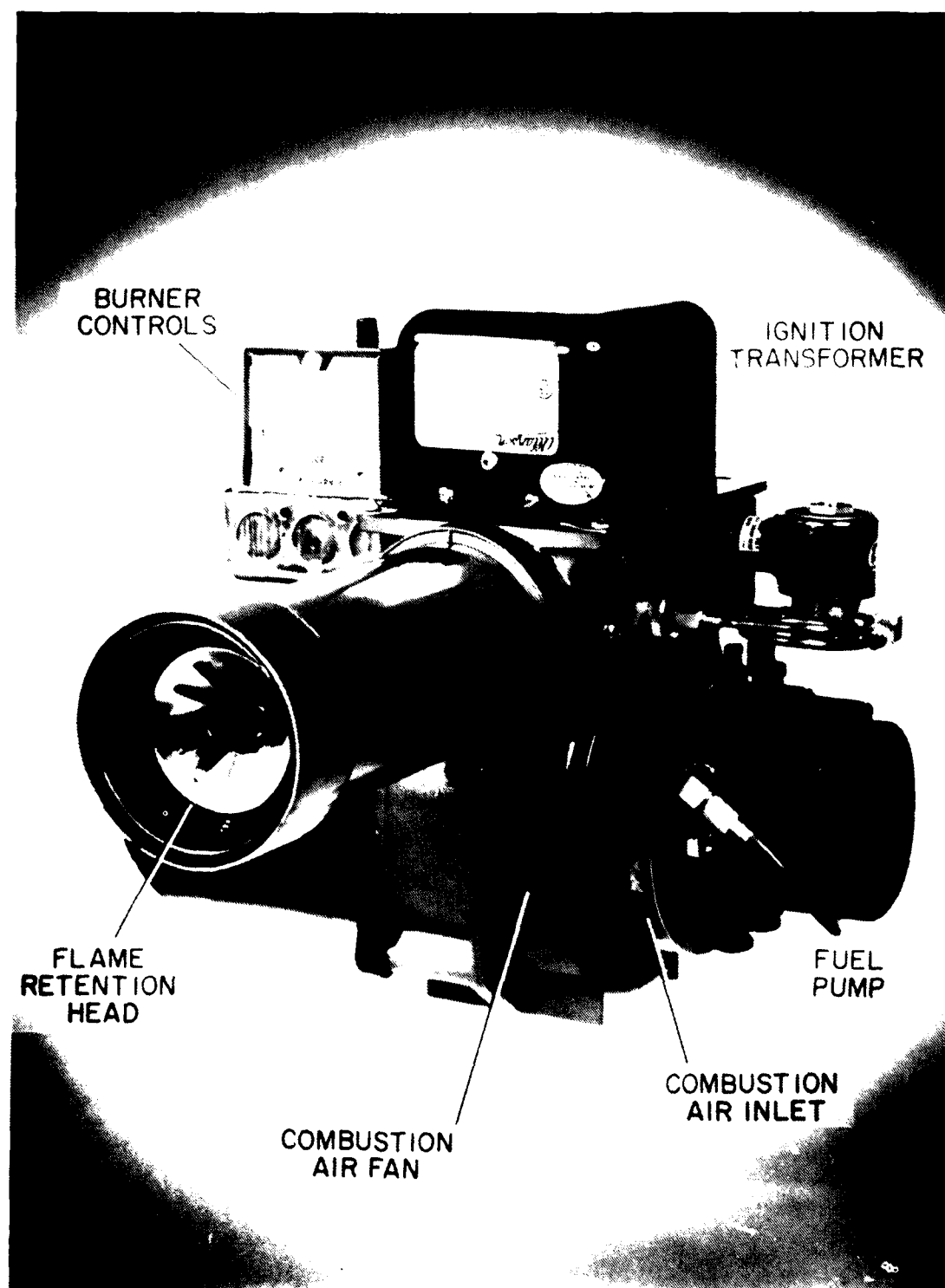
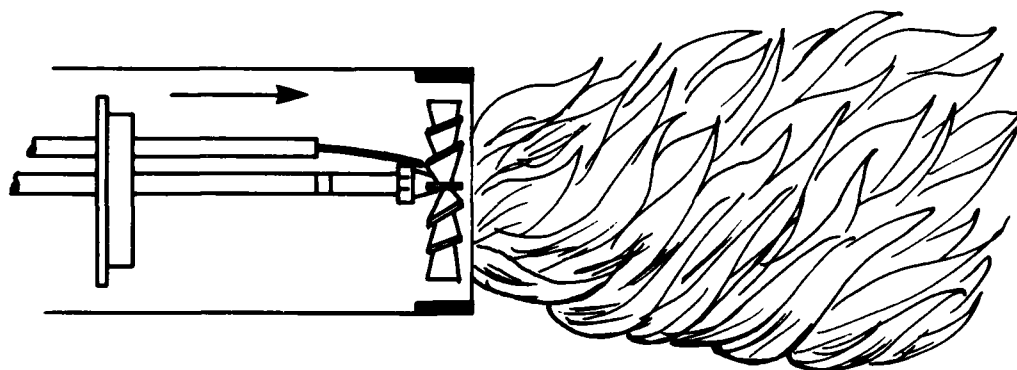
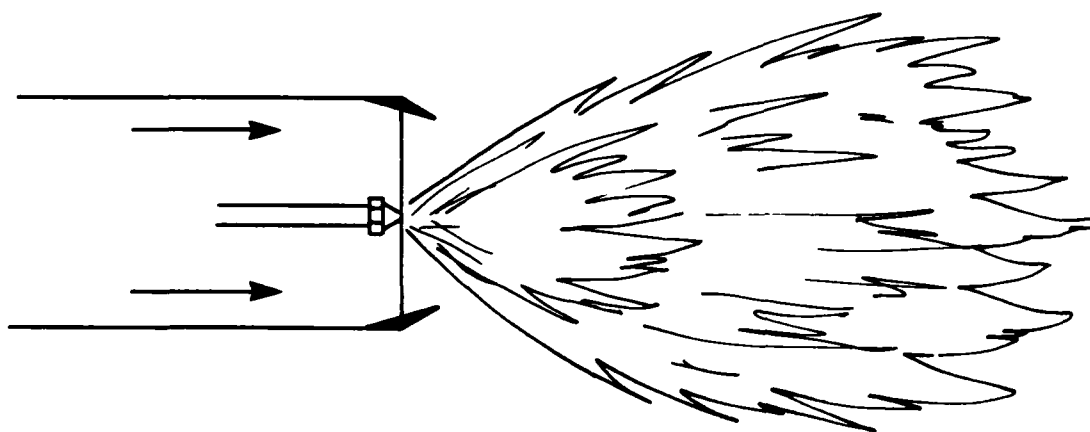


Figure 2.3. Flame retention oil burner.



FLAME RETENTION



CONVENTIONAL

FIGURE 2.4 CONVENTIONAL AND RETENTION
HEAD FLAMES

Table 2.1 Comparison of Burner Performance
(Typical Burner Performance)

	Olders Burners (Turbulator & Choke)	Flame Retention Head Burners
Percent CO ₂	7 - 9	11 - 13
Percent Excess Combustion Air	50 - 100	20 - 30
Bacharach Smoke Number	1 - 3	0 - 1
Percent Flue Heat Loss (on-cycle)	30	20

3.0 EFFICIENCY EVALUATION AND RECORD KEEPING

3.1 Efficiency and Record Keeping

3.1.1 Flue Loss Efficiency

Also known as:

Steady state efficiency
Combustion efficiency
Absorption efficiency
Flue gas efficiency
Running efficiency

This efficiency is equal to 100% minus the percentage of flue heat loss during burner operation. Flue heat loss is that portion of the heat released in the combustion process that is lost up the chimney in the form of hot exhaust gases including water vapor, carbon dioxide (CO_2), nitrogen (N_2) and excess air. An example of a typical value for the flue loss might be 28%. The corresponding flue loss efficiency would be 100-28 or 72%. The efficiency does not include off-cycle, jacket, distribution, or infiltration losses.

The term steady state efficiency refers to the fact that this efficiency is measured during continuous burner operation when the system is in a "steady operating state."

The term combustion efficiency is misleading because this efficiency involves both the combustion and heat transfer processes. In fact, the combustion efficiency, or conversion of fuel droplets to combustion gases, is nearly 100%. The smoke number reaches unacceptable levels (above Bacharach number 9) when less than 1% of fuel is not completely burned. "Heat transfer efficiency" would be a better name, because it reflects the fraction of heat that escapes as hot combustion exhaust gases.

The term absorption efficiency indicates that this efficiency describes the percentage of heat that is transferred to (absorbed by) the boiler or furnace.

Flue loss is important because it is usually the only efficiency that can be measured in the field. It provides useful insight into burner-boiler or burner-furnace performance, allows calculation of possible fuel savings, and provides a scientific basis for equipment trouble-shooting and diagnosis.

3.1.2 Cycle Efficiency

Cycle Efficiency is a term of limited use, but it should be defined. Off-cycle heat loss varies with the burner off-period, and the off-time varies in length throughout the heating season. Both off-cycle loss and cycle efficiency are a function of the burner operating cycle, and cycle efficiency is defined as 100% minus off-cycle heat loss. It is that lost fraction of useful

heat produced and absorbed by the heating unit but not distributed to the heated living spaces.

$$\text{Cycle Efficiency(\%)} = 100\% - \text{Off-Cycle Heat Loss(\%)}$$

The utility of this information is limited because the average on-off ratio is usually not known, and an average off-cycle loss cannot be determined easily. Note that the cycle efficiency is 100% for continuous burner operation, and decreases as the burner off-time gets longer. The importance of cycle efficiency is that it can be combined with flue loss efficiency and other information to calculate the annual fuel utilization efficiency.

3.1.3 On-Cycle Efficiency

This is called overall efficiency by the Hydronics Institute, an agency that rates boiler performance.

This efficiency includes both flue and jacket heat loss during continuous burner operation but it does not include off-cycle and other losses. It is defined as:

$$\text{On-Cycle Efficiency(\%)} = 100\% - \text{Flue Heat Loss(\%)} - \text{Jacket Heat Loss(\%)}$$

For example, if the flue loss is 25% and the jacket loss is 5%, then the on-cycle efficiency is:

$$100 - 25 - 5 = 70 \text{ Percent}$$

This efficiency represents heating unit performance in cases where the jacket loss does not contribute significantly to useful space heating.

3.1.4 Annual Fuel Utilization Efficiency

(AFUE) is the most useful of all efficiencies because it relates more directly to the annual fuel consumption by a heating system. It combines all heat losses together and represents average annual efficiency. AFUE is the fraction of the fuel's energy that is transported to the house as useful heat.

Note: The AFUE definition that is used in the DOE/FTC Labelling Program is slightly different.

AFUE = 100 %	-	Flue Heat Loss (%)	-	Jacket Heat Loss (%)	-	Average Annual Off-Cycle Loss (%)	-	Other Important Losses (%)
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For example, if the stack heat loss is 22%, jacket loss is 3%, and average off-cycle loss is 10%, then the AFUE is:

$$100 - 22 - 3 - 10 = 65\%$$

Other losses may include infiltration heat loss, distribution system losses, or other heat losses that may be important for a particular installation. These losses are difficult to estimate and for the purpose of this example were disregarded.

The annual fuel utilization efficiency is important because it can predict annual fuel use. An old heating unit might typically have an annual fuel utilization efficiency of 60% while a new heating unit might typically have an annual fuel utilization efficiency of 76%. Fuel savings for replacing the older system with the new one can be calculated from the AFUE values:

Percentage Reduction in Annual Fuel use =

$$\frac{\text{New Efficiency} - \text{Old Efficiency}}{\text{New Efficiency}} \times 100$$

Percentage Reduction in Annual Fuel Use is:

$$\frac{76 - 60}{76} \times 100 = 21\%.$$

AFUE values can be used to accurately predict fuel savings provided that the original and final efficiencies are known.

Unfortunately, annual fuel utilization efficiencies are usually unknown. A Federal labeling program for heating units provides AFUE's for new heating appliances, but older field-installed units are difficult to evaluate. Many heat losses and operational factors that change the actual in-place efficiency are discussed in this report. Flue loss efficiency is the only measurement that can be performed in the field.

The steady state or flue loss (combustion efficiency) measurement indicates the highest efficiency that a system can attain, because it includes only operating flue heat loss. However, in most cases this is the single largest source of inefficiency, and it provides valuable information for prediction of annual fuel use. It is the only scientific basis normally available for estimating fuel savings in the field.

If we go back to the above example of the old and new heating, we find that the change in flue heat loss accounts for about half of the actual fuel savings (by comparing AFUE).

Clearly, comparison of AFUE's provides the most accurate fuel savings predictions, but the change in flue loss efficiency often accounts for a large part of the savings. The advantage of flue loss is that it can be measured before and after equipment modification to provide an estimate of savings. Also, the difference between AFUE and flue loss predictions are smaller for other modifications including replacement burners. In any case the flue loss method gives a conservative estimate and will not overstate fuel savings.

Flue loss efficiency measurement (combustion efficiency tests) should be performed before and after all equipment replacements or retrofits. It is the only quantitative evaluation available at this time. As research continues, correlation factors may become available for relating the flue loss to AFUE for different types of heating units. There is at least one heating system efficiency computer available that makes such a comparison. An important input to any present or future efficiency computer, however, will be accurate measurement of heating system performance in terms of flue heat loss during burner operation. It is essential that the standard combustion efficiency tests (flue loss tests) be performed whenever possible, particularly when prediction of fuel savings are required.

As stated there are many methods of measuring and monitoring heating system efficiencies. Except for the FLUE LOSS EFFICIENCY method most cannot be used in the field due to the high cost and skill levels required. The FLUE LOSS EFFICIENCY method is however a very good method which is reliable, accurate, repeatable, and easy to perform in a relatively short period of time. With the availability of micro-processor based test equipment these methods have almost been made fool proof.

The traditional equipment used to perform FLUE LOSS EFFICIENCY tests has been commercially available for over 40 years, described in Appendix B; currently, the kit costs about \$250. The newer micro-processor based units cost up to \$1500, but are somewhat faster, easier to use, and more reliable. The question of which unit to use is based on the frequency and amount of use. Each system when properly used will provide very useful results of comparable accuracy and repeatability. The new automatic test units are expensive, but can be justified on the basis of reductions in labor costs and improved results in heating equipment adjustments when the housing inventory it is used for is sufficiently large.

All the efficiency testing in the world is of little benefit if the results are not recorded. The efficiency test results should be recorded for future reference both at the boiler site and in an energy conservation data file for use by the housing area office and plant engineering offices. The heating plant site records will be useful in future service calls and can be used to verify past performance in comparison to current or future performance data. This will help a service technician to determine what service is required and in cases of "no-heat" calls may help to indicate what part of the heating unit has caused the failure.

The centralized records found in an energy conservation data file will assist housing office and plant engineering personnel to determine what the current levels of efficiencies are in residential housing. This information would then be used to determine what steps should be taken to conserve additional energy and perform the costs/benefits analysis of various options.

It is vital that records be kept on file so that this information is available to those who will need it.

Examples of forms to be used for the above mentioned purposes are presented in figures 3.1 through 3.3.

3.2 Oil Burner Efficiency Adjustment

Oil burner adjustment for peak efficiency can be separated into four main tasks:

- o Clean and service the burner before adjustment;
- o Adjust the burner air supply for low smoke number and high efficiency;
- o Measure efficiency and diagnose performance problems;
- o Perform final checks.

STEP 1. Clean and Service the Burner

A number of steps must be completed before the burner can be adjusted for peak efficiency. These include:

- o Clean all parts of the burner that are contaminated by dirt or soot build up. Open the burner, remove the nozzle-electrode assembly and clean the parts listed below:
 - Air blower wheel
 - Blower housing
 - Air tube
 - Burner head (end cone)

NOTE: If the nozzle assembly position is adjustable, mark the burner housing before removing the assemble.

- o Inspect the fuel nozzle and replace it as required. Annual replacement is recommended because good fuel atomization is vital for high system efficiency. Always use the correct nozzle size (see Section V), spray angle, and pattern. (See the equipment manufacturers suggestions for spray angles and patterns in the equipment instruction literature.) Replace the nozzle adaptor as required.
- o Inspect condition of ignition electrodes. Remove soot or oil deposits and replace if insulators are cracked. Adjust electrode spacing according to manufacturer specifications.
- o Reinstall nozzle-electrode assemble and close the burner.
- o Open furnace inspection door and observe condition of the combustion chamber. Badly worn or degraded chambers should be replaced or relined (especially when a new burner is installed). Close the inspection door.

FIGURE 3.1
EXAMPLE 1 - SHORT FORM

RESIDENTIAL HOUSING HEATING SYSTEM EFFICIENCY TEST REPORT FORM

The following test results are based upon measurements
of the heating system performed on _____.
(date)

Located at: _____
(address)

Efficiency

Poor	Fair	Good	Excellent
60	70	80	90

Smoke number
(Bacharach scale) _____

Acceptable	Unacceptable
0	2 4 6

CO₂(%) _____

Poor	Fair	Good	Excellent
6	8	10	12 14

OR

O₂(%) _____

Excellent	Good	Fair	Poor
2	4	6	8 10 12

Net Stack
Temperature (°F) _____

Excellent	Good	Fair	Poor
300	400	500	600 700 800

Overfire Draft _____ "H₂O

Breech Draft _____ "H₂O

Heating Technician _____

SITE HOUSING OFFICE
5XX-6YYY

FIGURE 3.2
EXAMPLE 2 - LONG FORM

RESIDENTIAL HOUSING HEATING SYSTEM EFFICIENCY TEST REPORT FORM	
NAME: _____	ACCOUNT NO. _____
ADDRESS: _____	PHONE NO. _____
_____	DATE _____

Part I: Heating Plant/Hot Water
BOILER/FURNACE:

MANUFACTURER: _____ MODEL NO. _____ AGE _____ years

NAMEPLATE RATING: Btu INPUT _____ Btu OUTPUT _____

SO. FEET RADIATION _____

TYPE: (Circle all that apply)

Gravity Forced Hot Water Steam Warm Air

Is Unit Coal Converted? Yes No

Is there an adequate supply of air for combustion? Yes No

Is there an adequate return air from basement or from living quarters? Yes No

OIL BURNER:

MANUFACTURER _____ MODEL NO. _____ AGE _____ years

TYPE: (Circle One)

Flame Retention Conventional Low Pressure Rotary
 Shell Head Other _____

OIL TANK:

CAPACITY _____ gals. (Circle One): Above
 Below Ground

COMBUSTION TEST:

Smoke Number _____ CO₂ _____ Room Temp. _____ °F
Overfire Draft _____ "H₂O O₂ _____ Net Stack Temp. _____ °F
Breeching Draft _____ "H₂O Stack Temp. _____ °F

STEADY-STATE EFFICIENCY _____

FIGURE 3.2
SHEET 2

OIL CONSUMPTION:

Winter K-factor _____ Summer Consumption _____ gal./day

Annual Consumption _____ gal./year (19 ____)

angle _____° Pattern: (Circle one)

Present Nozzle Size _____ hollow

Optimum Nozzle Size _____ semi-hollow

solid

COMBUSTION CHAMBER:

Type of Material _____

Condition _____

DOMESTIC HOT WATER:

Type: (Circle all that apply)

Electric

Separate Oil-Fired Water Heater

Gas

Tankless without storage

Solar

Tankless with _____ gallon storage

Does boiler maintain temperature year round? Yes No

Is there an automatic tempering valve? Yes No

If the system is Separate:

Tank size _____ gallons

Model No. _____

Btu Input _____

Age _____ years

Manufacturer _____

Aquastat Setting _____°F

MISCELLANEOUS:

Heating Zones? Yes No

How Many? _____

Heating Unit Improvements in Last 5 Years _____

FIGURE 3.2
SHEET 3

Part II: Supplemental Information

HOUSE:

TYPE: (Circle one)

Ranch Cape 3-Decker
Garrison Duplex Other _____

Number of Families: _____

Number of Permanent Residents: _____ Number of Floors: _____

Construction: (circle one)

Brick
Wood Age _____
Other _____

Exterior House Dimensions: Length _____ ft. Width _____ ft.

Is there a basement? Yes No

Are there fireplaces? Yes No How many? _____

Do dampers close securely? Yes No

Insulation: (Check appropriate spaces)

	Walls	Ceiling	Floors
NONE			
LIGHT (less than 3")			
MODERATE (3-5")			
HEAVY (6" or more)			

HUMIDIFICATION? Yes No

NATURAL GAS SERVICE IN HOUSE? Yes No

STORM WINDOWS OR THERMOPANE? Yes No

FIGURE 3.2
SHEET 4

ARE THERE ANY DRAFTS?

Yes

No

Comments _____

IS HEAT EVENLY DISTRUBUTED?

Yes

No

Comments _____

ARE ANY ROOMS KEPT UNHEATED?

Yes

No

Comments _____

CAN HEAT BE SHUT OFF IN ANY ROOMS?

Yes

No

Comments _____

IS THERMOSTAT LOCATED PROPERTY?

Yes

No

FORMAL THERMOSTAT SETTING: Day _____ °F Night _____ °F

IS THERMOSTAT SET-BACK AUTOMATIC OR MANUAL? (Circle one)

ARE ANY CODES UPDATES REQUIRED? _____

OTHER PROBLEMS _____

FIGURE 3.3 - FIELD FORM

HEATING SYSTEM EVALUATION

Name _____

Street _____ City _____

Combustion Test

Date

Gross Stack Temp.

Net Stack Temp.

CO₂/O₂%(circle one)

Smoke

Breech Draft

Overfire Draft

Efficiency

Rating

- ☐ Excellent
☐ Good
☐ Fair
☐ Poor

Winter K-Factor

Aquastat Setting

Equipment

Heating Plant

Manufacturer _____

Model _____

- ☐ F. Warm Air ☐ G. Warm Air
☐ F. Hot Water ☐ G. Hot Water
☐ Steam ☐ Coal Converted

No. of Zones _____

Burner

Manufacturer _____

Model _____

Nozzle (GPH, Angle, Spray) _____

Domestic Hot Water

- ☐ Tankless ☐ Gas
☐ Electric ☐ Oil
☐ Tankless with Booster Tank
Temperature Setting _____
Tankless size _____ gpm

Other

Combustion Chamber

- ☐ Replace ☐ Repair
☐ No Action

Oil Tank Size _____ Gals.

Work done by _____

Cert. of Competency No. _____

Company _____

- o Seal air leaks into the combustion chamber with furnace cement. Inspect in particular;
 - around the burner air tube
 - joints between cast iron sections
 - points where the combustion chamber meet the heat exchanger (particularly in dry base units).
 - around loose-fitting inspection doors.
- o Remove and inspect the fuel oil filter. Replace as needed.
- o Tighten all fittings on the fuel oil line between the fuel tank and the burner.
- o Open the bleed valve on the fuel pump and remove all air from the fuel line.
- o Install an oil pressure gauge in a high pressure port of the fuel pump. Operate the burner momentarily and adjust oil pressure to 100 PSIG or to manufactures specifications as required. Remove the gauge and replace the port plug.
- o Again bleed all air from the fuel system.
- o Drill two 1/4-inch holes in the flue pipe between the heating unit and the barometric draft damper (if not already present).

STEP 2. Adjust the Burner Air Supply for Low Smoke and High Efficiency.

NOTE: See Appendix B for proper use of instruments for measuring smoke, CO₂, and temperature.

- o Operate the burner and adjust the air band for a good flame by visual inspection. Allow burner to operate for ten minutes before final adjustments.
- o Insert the stack gas thermometer in one sample hole and leave for later reading.
- o Measure the overfire draft through a 1/4-inch hole in the fire door or inspection door. (If possible, the hole should be above the flame level).
- o Adjust the barometric draft regulator to give the overfire draft recommended by the heating unit manufacturer. Usually a negative 0.02 inches of water column over the fire is adequate.

- o If overfire draft cannot be measured, adjust the barometric regulator for a flue draft of negative 0.04 to 0.06 inches water column (or as specified by the manufacturer).
- o Seal the overfire sample hole with a screw or high temperature cement.
- o Measure the smoke content of flue gases. Adjust the air band (or shutter) to produce between "zero and number one" smoke. Generally, if the original smoke number is above one, open the air band, and if it is less than one, close the air band. Remember that small changes in the air setting can change the smoke content dramatically.

NOTE: Too much excess air can also produce higher smoke numbers. Smoke spots with a yellow tinge indicate too much excess air.

- o Lock the air band in place and again measure the smoke to be sure it is at the correct level.

STEP 3. Measure Efficiency and Diagnose Performance Problems

Measure Efficiency:

- o Measure the CO₂ content of the flue gases through the second sample hole. Repeat this test if time permits. Generally, a CO₂ reading of 13% is the highest recommended setting (unless otherwise specified by the equipment manufacturer).
- o Allow the stack thermometer sufficient time to level off, and then read the flue gas temperature.
- o Subtract the furnace room temperature from the flue gas temperature to arrive at the net flue gas temperature. Use the percent CO₂ and net flue gas temperature to determine the burner on-cycle efficiency. Many convenient slide rules and charts are available for this purpose.

DIAGNOSE PROBLEMS:

- o An efficiency of 75 or better is considered good for most heating units. (Some new models are capable of operating into the middle to high 80% range.)
- o Poor efficiency can be caused by:
 - o Low CO₂ percent
 - o High flue gas temperature
- o Causes of low CO₂ (typical values are 8% for older burners and 10-13% for newer burners).

- Air leaks into the combustion chamber or heat exchanger. Compare the overfire CO_2 to flue CO_2 to determine if dilution is taking place. If the CO_2 values are substantially different, locate and seal air leaks with furnace cement.
- Poor fuel-air mixing can also cause low CO_2 levels. This can be caused by many conditions including:
 - (i) Improper or maladjusted burner head. Vary the position of the burner head if it is adjustable.
 - (ii) Damaged or worn fuel nozzles. Try replacing the existing nozzle.
 - (iii) Improper nozzle spray pattern or angle. Try different nozzles.
 - (iv) Fuel nozzles that are too small - Try increasing the firing rate by one size - but never above the design rate of the boiler or furnace. Remember, larger nozzles increase burner off-cycle heat loss.
 - (v) Incorrect combustion chamber size. A chamber that is too small will allow flame impingement that produces smoke and requires excessive air. Observe the fire to be sure that the flame does not touch the combustion chamber or any burner parts. A chamber that is too large can also cause problems.
 - (vi) Defective burner parts including end cone, air tube, fan, motor coupling, or fuel pump. Check all burner parts for damage.
 - (vii) Excessively cold fuel oil. Check the storage temperature.
- o Causes of high flue gas temperature;
 - Heating surfaces of boiler or furnace need cleaning to remove soot deposits. Inspect internal surfaces, and vacuum clean as needed.
 - Firing rate too high, compare nozzle size to boiler or furnace rating.
 - Boiler tubes require turbulators. Inspect tubes for turbulators.
 - Excessive combustion air (see causes of low CO_2).
- o If a heating unit with low efficiency cannot be improved by service and adjustment procedures, it is a candidate for equipment upgrading ranging from a new burner to heating system replacement.

STEP 4. Perform Final Checks

- o Check operation of ignition system over several cycles.
- o Check pump cut-off at the end of the firing cycle. If cut-off is poor, check fuel line for air leaks, and if none is found, the fuel pump may need to be replaced.
- o Check the operation of the high limit safety controls for proper operation.
- o Check flame safety controls for normal operation.
- o Check that all forms are completed and test results are properly recorded. Record the date, adjustments made, fuel nozzle size and test results on a record form or label near the furnace or boiler. This will improve the effectiveness of future servicing.
- o Notify the housing office of the test and service results as prescribed by site policy.

NOTE: This section is based on: Guidelines for Residential Oil Burner Adjustments, U.S. Environmental Protection Agency, Report EPA600/2-75-069-a, Oct. 1976.

4.0 OIL-FIRED FURNACES AND BOILERS

The oil burner flame releases the energy stored within the fuel and transfers it to combustion gases that have a temperature between 2000° and 3000°F for most burners. The purpose of the boiler or furnace is to extract most of this heat and distribute it to the house. The most common central heating systems use either warm air or hot water (or steam) to distribute heat to the home. Systems that use heated water or steam are usually referred to as boilers, while heating systems that use warmed air are called furnaces. There are approximately an equal number of furnaces and boilers used in oil heated homes in this country.

4.1 Performance Factors

A hot water boiler or furnace transfers heat from the flame to the boiler water or furnace air and efficiency varies with its design and operating controls. Some boilers and furnaces are more efficient than others, but proper installation, adjustment and maintenance is required to obtain the highest possible efficiency. The principles of how heat is transferred are similar between boilers and furnaces.

A diagram of boiler operation is shown in Figure 4.1. High temperature combustion gases are cooled as they pass through the boiler, and in the case shown the temperature drops from 2500°F to 500°F. In the diagram the water flowing through the boiler increases in temperature from 160 to 180 degrees Fahrenheit. For furnaces the air side increases from about 70 to 140 degrees Fahrenheit.

Heat transfer occurs when a difference in temperature exists between substances. In the case of a boiler, the water is cooler than the combustion gases, and heat flows to the cooler water. The boiler serves as the means by which heat is transferred without direct contact between the water and flue gas. Figure 4.2 is a crosssectional schematic of a residential boiler showing the heat transfer processes (both useful heat flows and losses) which occur during burner operation.

Heat is transferred by a combination of two methods called Radiation and Convection. Radiative heat transfer occurs as a result of heat energy being transported from a body at high temperature to surroundings at lower temperature without direct physical contact. If a body can "see" (line of sight) a colder body, then energy will be transferred. An example of radiation transfer is solar heating of the earth. Heat is radiated from the sun to all other planets without physical contact and without a flow of matter. Radiation transfer is one method by which heat is transferred that is the flame emits energy that is absorbed by some of the heat exchanger surfaces and transferred to the water or air. Convection heat transfer results from the flow of a liquid or gas over a surface at a different temperature. In the case of a boiler or furnace the heated combustion gases flow over the cooler heat exchange surfaces and heat is transferred to the boiler water or furnace air. For example, the boiler shown in Figure 4.2 performs two important functions. First, the combustion chamber at the base accepts the fuel air mixture and

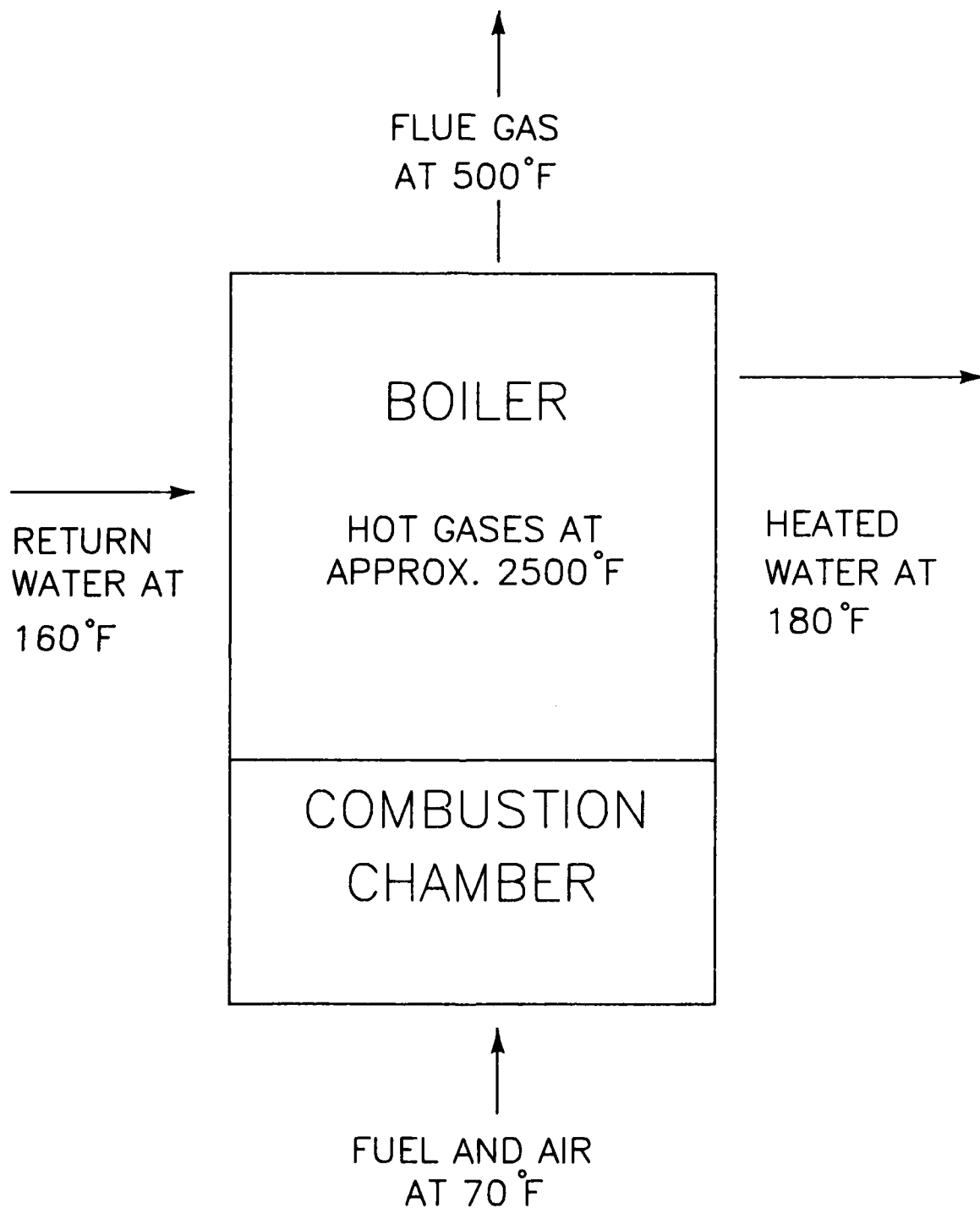


FIGURE 4.1 TYPICAL HOT WATER BOILER OPERATION

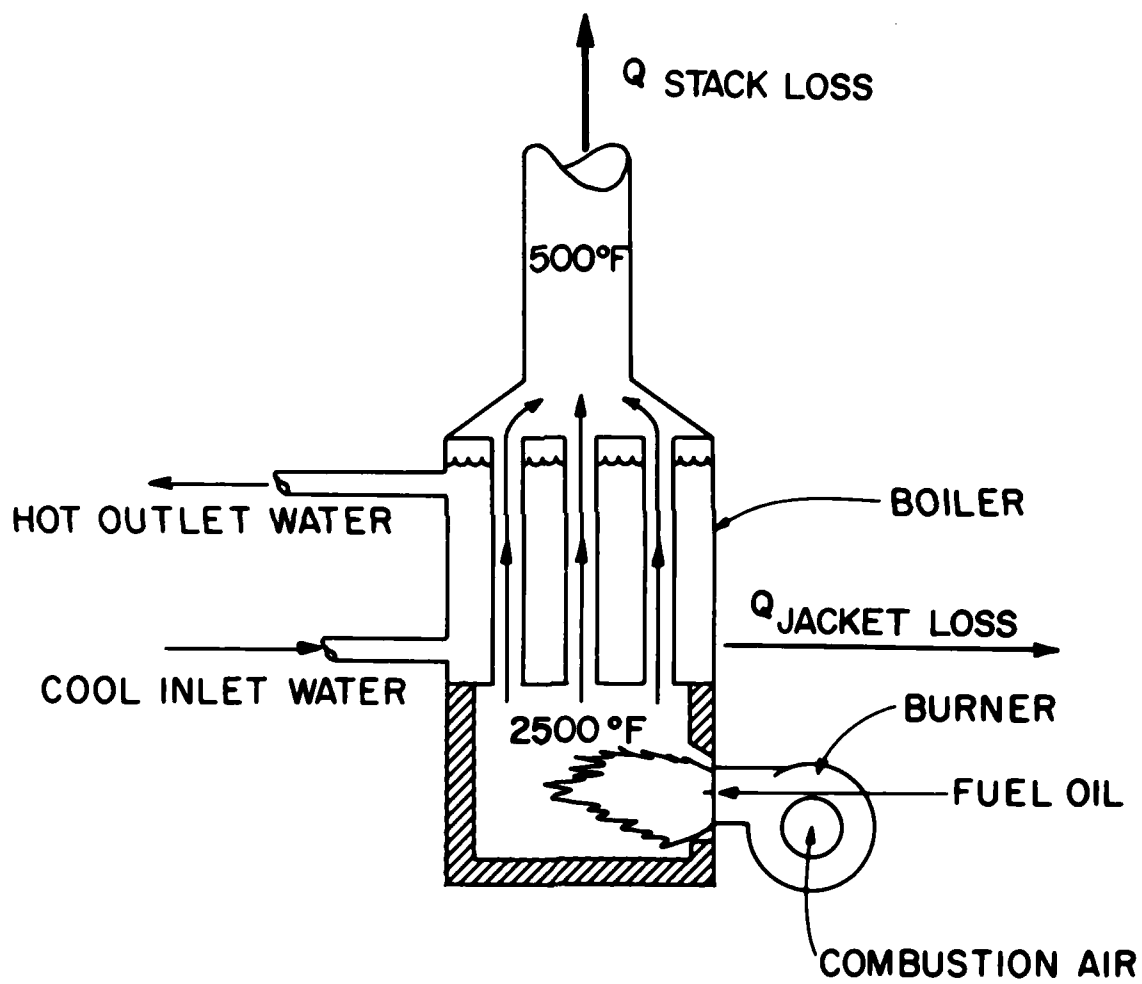


FIGURE 4.2 HOT WATER BOILER SCHEMATIC

assists the formation of a stable flame. The heat from the flame radiates to the combustion chamber walls and they heat up. As the chamber temperature increases, energy is radiated back to fuel and air, and this can improve burner performance. This assistance is most important for older burner designs that form soot, and require considerable excess combustion air. Many modern burners operate satisfactorily with less radiative energy feedback from the combustion chamber.

The second function of the boiler is to extract as much heat as possible from the flame gases. This takes place by a combination of radiation and convection. Radiation from the flame carries heat energy to all the surfaces of the boiler that are in direct view. The heat transfer depends on the temperature of the hot gases and the total area of boiler surfaces. One means of improving radiative heating is to raise the flame temperature and this can be accomplished by reducing the amount of excess combustion air.

Convective heat transfer takes place as the hot gases pass through the boiler tubes shown in Figure 4.2. Heat travels from the combustion gases through the boiler walls and into the boiler water. In cast iron section boilers, heat is removed from the flue gases as they pass between boiler sections. In both cases, the boiler water temperature increases and combustion gas temperature drops as a result of the energy transfer. As the hot gases travel up through the boiler tubes (or between cast sections) their temperature decreases until they reach the end of the tubes. At that point the combustion gases have reached the flue gas temperature.

There are many factors that affect heat transfer in boilers. Four of these are:

- o Flame temperature
- o Boiler surface area
- o Combustion gas turbulence
- o Fouling of heat exchange surfaces

4.1.1 Flame Temperature

Heat transfer rates depend on the temperature difference between the cold and hot bodies. It is improved by raising the flame temperature which increases the temperature difference between the boiler water and flame gases. Less excess combustion air increases flame temperature, and improves the heat transfer in boilers.

4.1.2 Heat Exchange Surface Area

Heat transfer also depends on the total heat exchange surface area of the boiler or furnace. As surface area enlarges, the heat exchange improves. Unfortunately, the effectiveness of additional surface area diminishes as area is added. This diminishing return is explained in Figure 4.3. For example, high temperature gas enters the bottom of the boiler tube and the heat transfer rate is very high. As the gases flow up the tube they are cooled as heat is transported to the boiler water. Therefore, near the top of the boiler

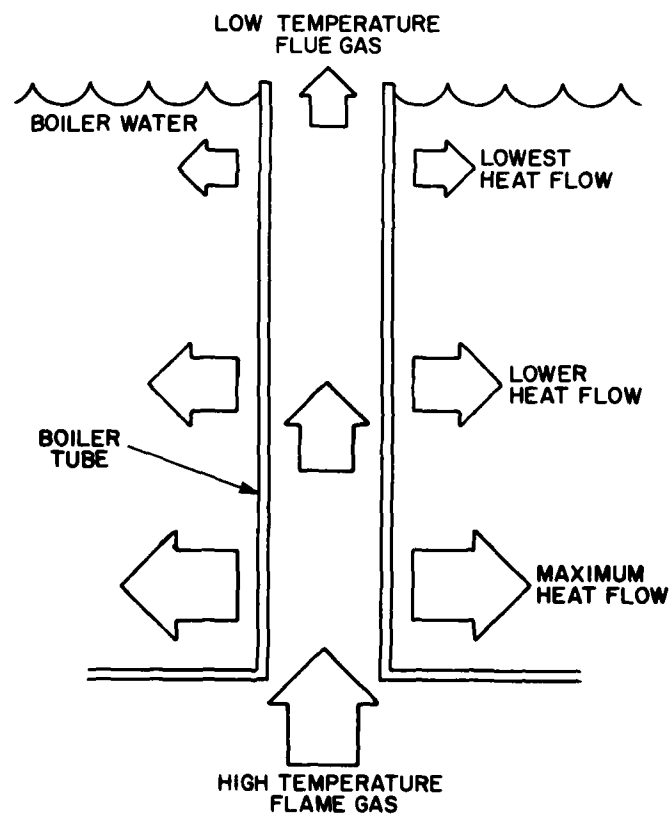


FIGURE 4.3 HEAT TRANSFER IN A SINGLE TUBE BOILER

tubes the combustion gases are much cooler than near the bottom of the tube, and the heat transfer rate is lower. The size of the arrows in Figure 4.3 represent gas temperature and heat transfer, and these arrows become smaller as the gases flow up the boiler tube.

The addition of heat exchange surface area can be viewed as extending the length of the tubes. As tube length increases, more heat will be removed but combustion gas temperature continues to drop, until extremely large tube lengths are required to improve the performance further. Boiler and furnace design involves a balance between high efficiency and construction cost. High efficiency requires good heat transfer and large surface areas, while minimum construction costs require small surface areas. Obviously, the boiler/furnace designer must balance these conflicting requirements.

4.1.3 Combustion Gas Turbulence

Another factor that affects the rate of heat transfer is the flow condition of the hot gases passing through the heat exchanger. Turbulent flow in which the gas is well mixed as it flows improves heat transfer. Boilers often use "turbulators" to swirl the gas stream as it flows through the boiler.

Baffles and turbulators are placed in boiler tubes to improve heat transfer. A baffle may be constructed from a long, thin piece of sheet metal that is twisted to form a spiral. The turbulator improves contact between the hot gases and the walls of boiler tubes, and without it, a central core of hot combustion gases can travel up through the tube without direct contact with the tube walls.

4.1.4 Fouling of Heat Exchange Surfaces

Heat transfer can be reduced by accumulation of corrosion and soot on heat exchange surfaces. Clean heat exchange surfaces give the highest efficiency which drops as the surfaces become fouled. Soot fouling is particularly troublesome and consists predominately of carbon deposits that thermally insulate heat exchange surfaces.

A small layer of soot reduces heat transfer rates significantly, and this effect is shown in Figure 4.4. A one-sixteenth ($1/16$) inch soot layer typically reduces the efficiency of a residential boiler or furnace by 4 percent, and a $1/8$ inch layer by 8 percent. It is clear, however, that soot accumulation must be avoided, because it adversely affects performance. Annual cleaning of surfaces is necessary to keep the efficiency high.

4.2 Boilers

Steam boilers are seldom used for residential heating today, except as replacements in existing systems. Water boilers, however, are in common use. Residential boilers have outputs from about 60,000 Btu/hr to over 300,000 Btu/hr.

SOOT DEPOSITS WASTE FUEL

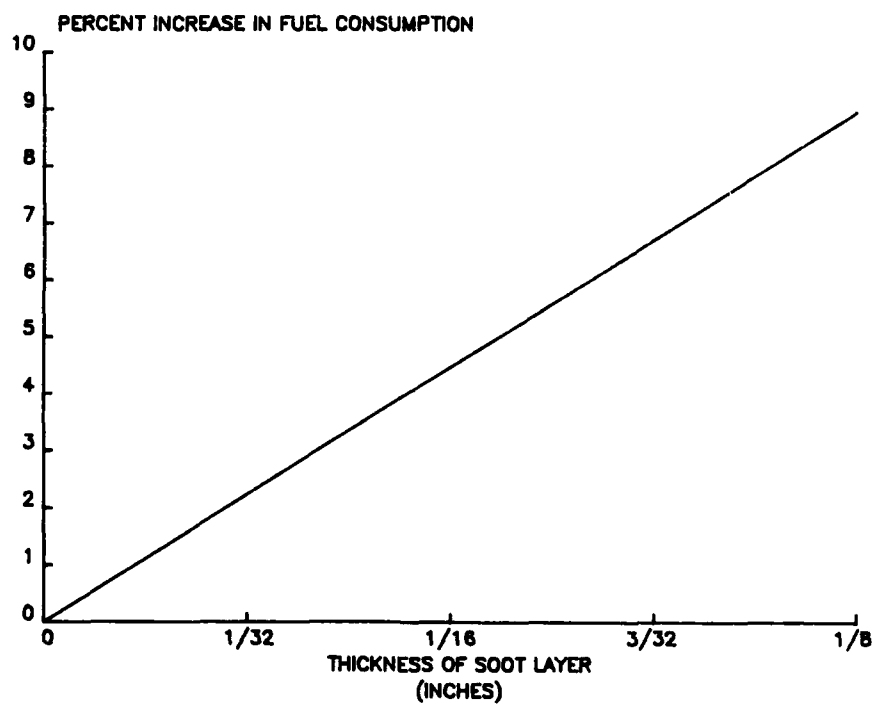


FIGURE 4.4 SOOT DEPOSITS WASTE FUEL

Boilers are classified by the heating industry on the basis of three distinguishing characteristics: their construction material (steel or cast iron), the presence or absence of circulating water around the combustion chamber, and the number of times the hot combustion gases go through the heat exchanger on their path to the chimney (single or multiple pass). Testing has shown that, contrary to popular belief, cast iron construction does not necessarily offer superior performance. There are some well-fabriated steel units that compare favorably to those made of cast iron in their thermal properties. A boiler whose combustion chamber is surrounded by water, circulating into the heat exchanger, is a wet-base type. One without this feature is a dry-base boiler; its combustion chamber is separated from the heat exchanger, which cuts down efficiency since the heat generated has less chance to reach the working fluid before some is lost through the jacket. A multiple-pass boiler, more complicated to make than a single-pass unit, gives greater efficiency by placing combustion gases in longer contact with the heat exchanger. Dry-base boilers are typically of single-pass design.

Residential boilers are made of steel or cast iron in various designs. One feature that impacts thermal efficiency is the location of the combustion chamber relative to heat exchange surfaces. A dry-based boiler has a combustion chamber that is separated from the heat transfer area. The schematic diagram of Figure 4.2 shows such a design where the combustion chamber is located in the lower part of the unit and all the water is in the upper part of the boiler. A wet base boiler is shown in Figure 4.5 in which the combustion chamber is surrounded by boiler water and heat flow through the chamber is absorbed by boiler water. Some boilers fall between these two classifications including wet-leg and wet back units where the combustion chamber is partially water enclosed.

Residential steel boilers often are built with boiler tubes through which the combustion produce gases flow. These tubes may be either vertical as in Figure 4.2 or horizontal as in Figure 4.5. The number of tubes, tube diameter and length, boiler tube placement, the use of hot gas baffles ("turbulators") and combustion chamber design vary from unit to unit. Some boilers, particularly those of dry-base design, require refractory combustion chambers, while some wet base units may be operated without refractory chambers. An acceptable burner must be selected for these boilers. For example, older nonretention-head type burners often do not operate satisfactorily in a combustion chamber without a refractory lining.

4.3 Warm Air Furnaces

The function of a warm air furnace is to transfer heat released by the combustion of fuel to air and to distribute the warmed air to heat the building. Combustion takes place in a metal walled heat exchanger where circulating air passes over the outside surfaces of the heat exchanger. Heat transfer from the combustion products to the circulating air takes place through the heat exchanger so that circulating air does not come in contact with products of combustion.

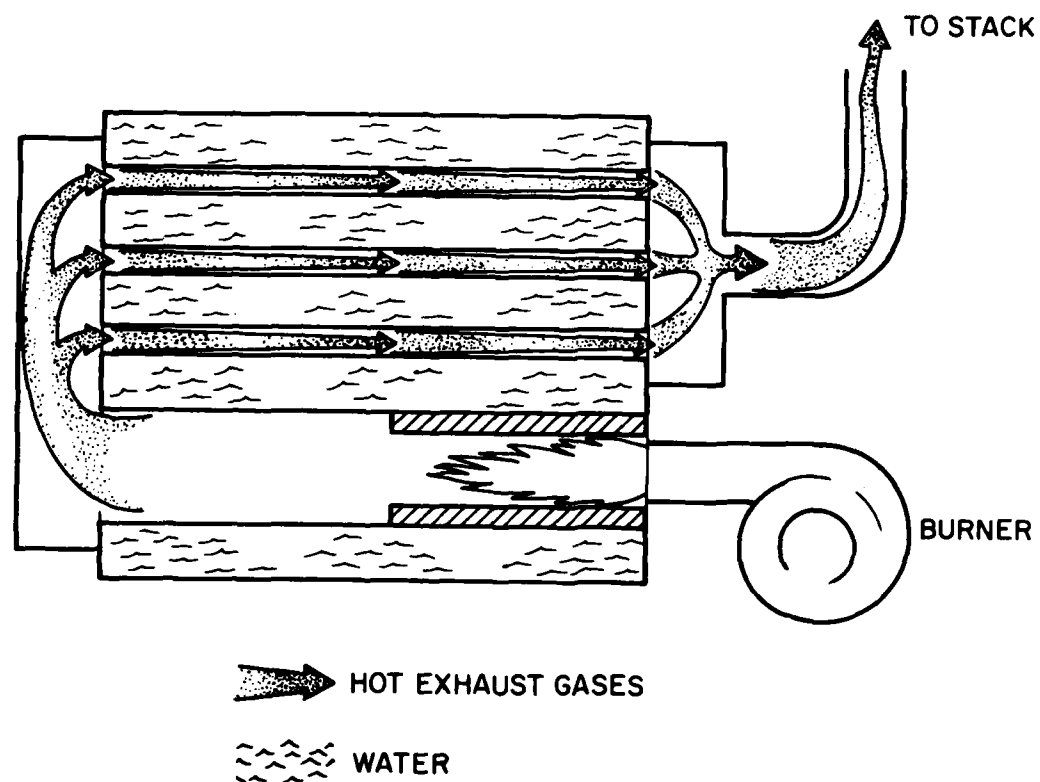


FIGURE 4.5 A SCHEMATIC OF A WET
BASE BOILER

Modern oil fired furnaces utilize forced air circulation incorporating a direct drive blower or a belt driven blower. The blower function is to circulate air over the heat exchanger and through the air distribution system. Various building constructions and air ducting systems require the use of four basic furnace configurations described below:

The Upflow or High-Boy Furnace is the most common type of furnace configuration. The blower is positioned below the heat exchanger and circulating air is directed upward over the heat exchanger and into a supply plenum as illustrated in Figure 4.6. The return air ducting is connected to either the left or right side of the furnace blower compartment.

The Counterflow Furnace has the blower positioned above the heat exchanger and circulating air is directed downward as illustrated in Figure 4.7. This furnace is typically used in houses with perimeter ducting systems where there is no basement.

The Horizontal Furnace has the blower positioned to the side of the heat exchanger. Circulating air moves horizontally over the heat exchanger either to the left or right and is discarded out the opposite end as illustrated in Figure 4.8. Horizontal furnaces are used where overhead room is limited in such spaces as attics, crawl spaces, or are sometimes suspended from ceilings.

The Low-Boy Furnace has the blower positioned on the side of the heat exchanger. Air is discharged over the heat exchanger discharging upward similar to the High-Boy furnace. Return air is directed downward as illustrated in Figure 4.9. This furnace configuration is used where overhead room is limited.

Warm air furnace heat exchangers are typically made of mild steel with welded seams. Areas that are subject to high temperatures are protected with refractory linings or utilize aluminum or ceramic coated steel alloys compatible with higher temperatures. Many conventional furnace heat exchangers use ceramic liners in the combustion chamber area to promote rapid vaporization of the oil and to protect the heat exchanger from excessive temperatures.

Heat exchangers are designed to effect the greatest overall heat transfer rates for the lowest materials cost. The heat exchanger should have provisions for accessibility to all fireside surfaces for inspection and cleaning. Flue passages are designed to be compatible with the type of fuel and type of burner.

Warm air furnaces are enclosed in rectangular cabinets that provide a passage way for air over the heat exchanger. Cabinets are usually insulated with aluminum faced mineral wool and are finished with a baked enamel coating. Various access doors are provided for required servicing.

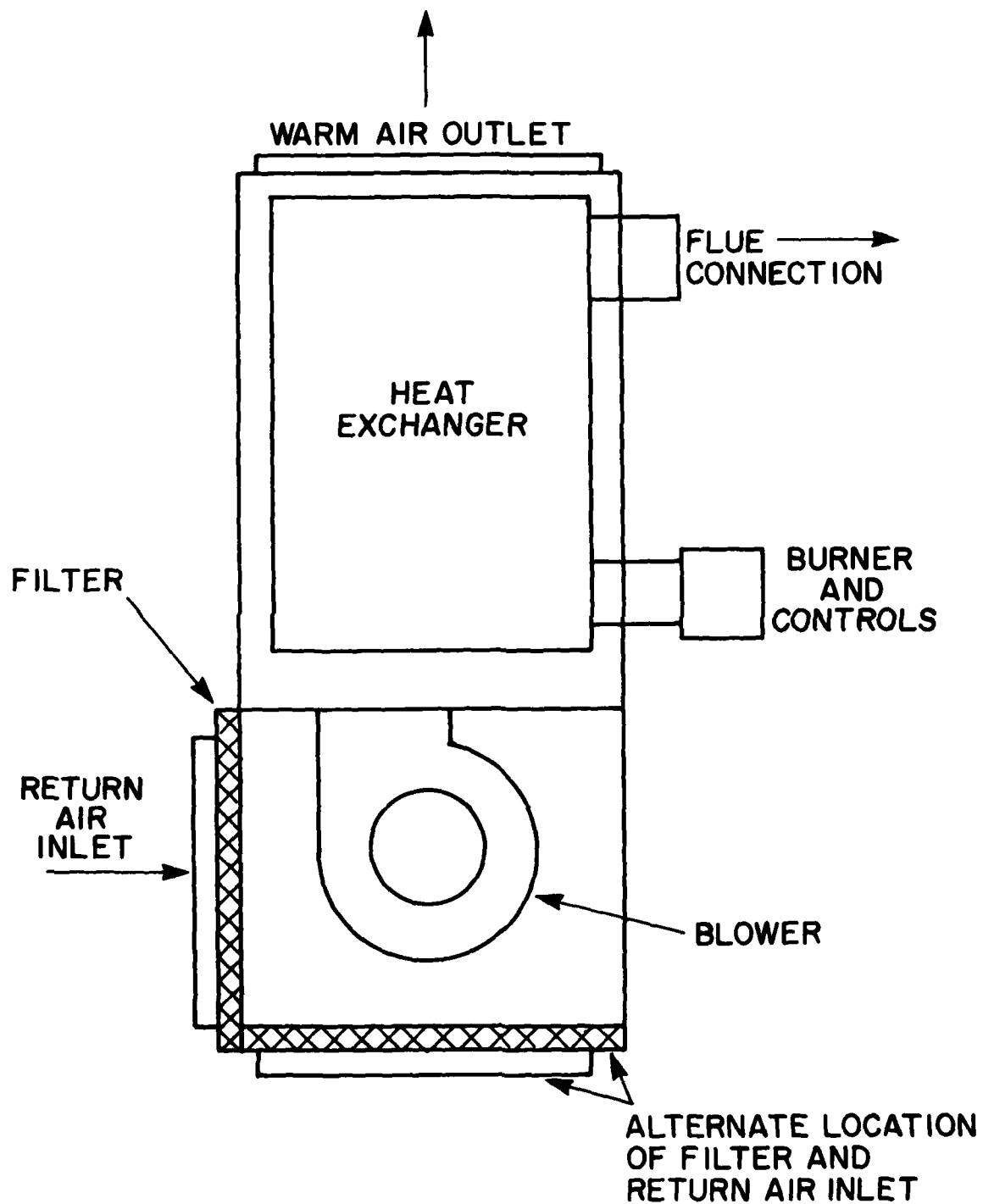


FIGURE 4.6 UPFLOW OR HIGH-BOY FURNACE

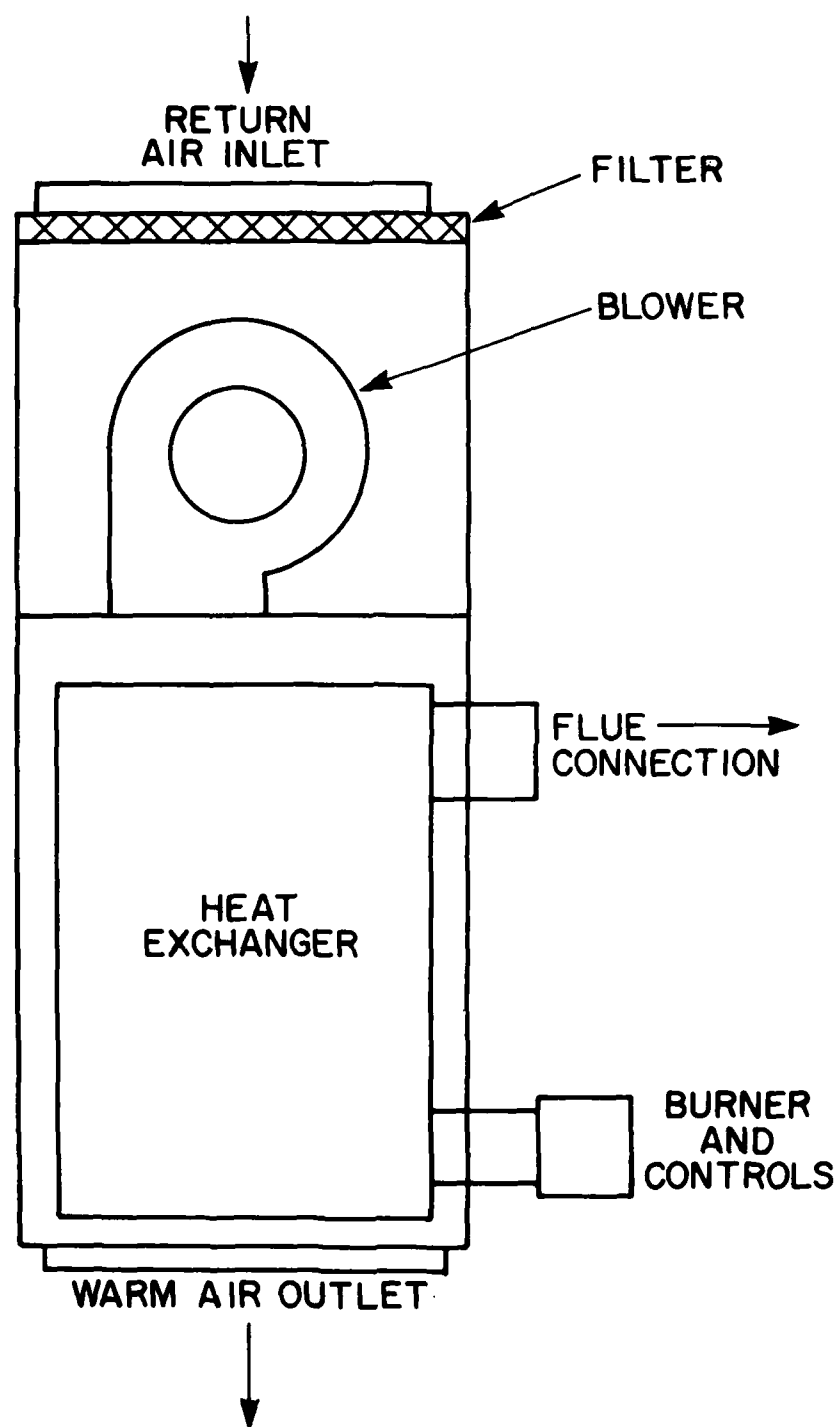


FIGURE 4.7 COUNTERFLOW FURNACE

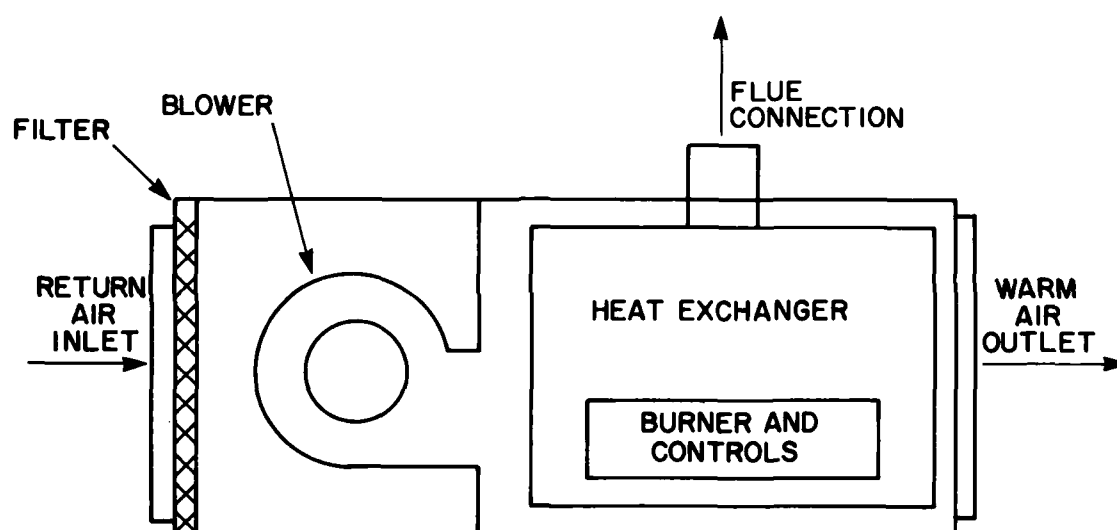


FIGURE 4.8 HORIZONTAL FURNACE

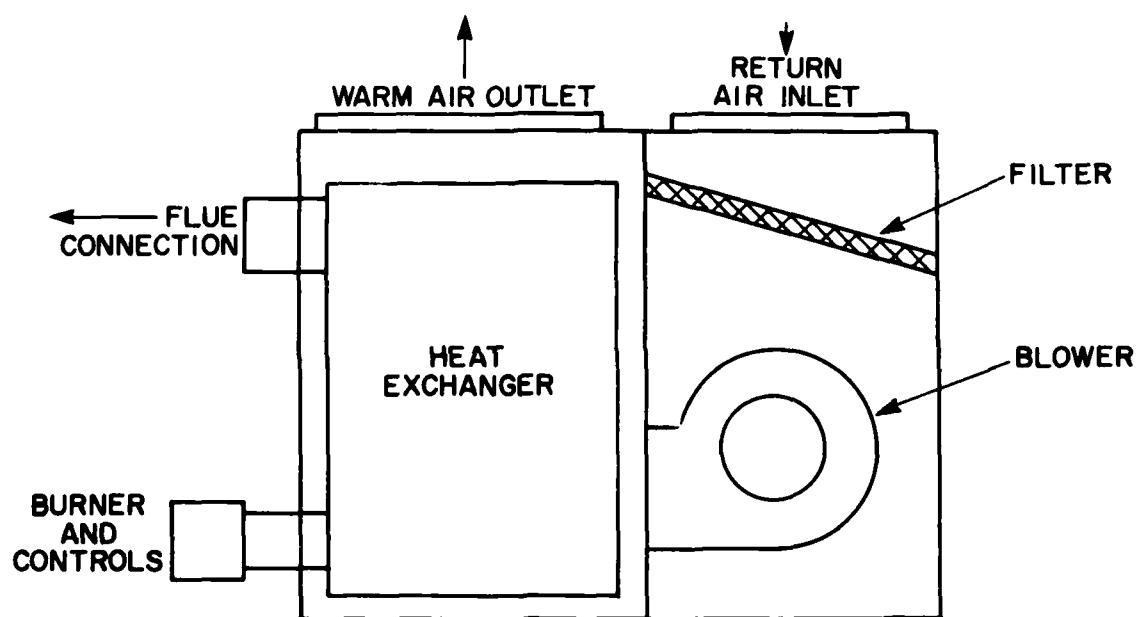


FIGURE 4.9 LOW-BOY FURNACE

Double inlet centrifugal blowers are used in conjunction with blower motors mounted directly on the blower shaft or mounted remotely with a belt and pulley assembly. The adjustment of fan speed for a direct drive assembly is made by switching motor leads electrically as would be done with an air conditioning relay. Fan speed adjustments for a belt driven blower are accomplished by adjusting the V-belt in the variable pitch drive pulley on the motor. Belt tension is then adjusted by shifting the motor position. Blower performance data is usually specified by the manufacturer to aid in selection of the air handling capacities for various duct system static pressures.

Warm air furnace controls usually consist of a low voltage room thermostat which starts and stops the burner in response to room temperature changes. The burner is interlocked with combustion controls that permit the burner to operate only under safe conditions. The blower is controlled by a fan and limit control which starts the blower when a predetermined temperature near the heat exchanger is reached. This control keeps the blower running until the heat in the furnace has been dissipated. The fan and limit control operates independently of the burner controls and also functions as a limit control that will shut the burner off if the temperature in the furnace exceeds a predetermined level. On some furnaces, including most counterflow furnaces, an auxiliary temperature limit control is fitted in the furnace. Residential furnaces are sold as complete packages completely assembled and wired at the factory.

Filters supplied with a forced air furnace are often the throw-away type. Permanent filters that may be washed and reinstalled are also used. The air filter is always located in the circulating air stream ahead of the blower and heat exchanger.

Humidifiers are sold as accessory equipment and are not included as a standard part of the furnace package. However, one of the advantages of a forced air heating system is that it offers the opportunity to control the relative humidity of the heated space at a comfortable level.

Electronic air cleaners are available as an accessory to the forced air furnace. These air cleaners are much more efficient than the air filter provided with the furnace and filter out much finer particles, including smoke. They create an electric field in which dust particles are given a charge and consequently collect on a plate having the opposite charge. The collected material is then cleaned from the collector plate periodically by the homeowner. Electronic air cleaners are mounted in the air stream entering the furnace.

4.4 Ancillary Equipment and Controls

4.4.1 Tankless Domestic Hot Water

Many oil-fired boilers are equipped to provide domestic hot water as well as space heating, through use of a "tankless coil" which is immersed in the boiler water. When hot water is demanded (by opening a sink faucet, for example), cold water flows through the coil, which is usually a serpentine

length of finned copper tubing. When the water leaves the coil and flows to the faucet, it has been heated to a temperature around 120-140°F. Initially, the hot water draw causes the boiler water temperature to fall. This causes the burner to come on in order to maintain the boiler water at the pre-selected temperature.

As with storage hot water heaters, the rate at which the tankless coil can supply hot water is limited. In practice, the coil is designed to have a sufficiently large surface area, the boiler is sized to contain a sufficient amount of hot water, the burner is provided with a sufficiently high firing rate (usually a higher rate than needed to meet the space heating needs of the house), and the boiler water temperature control is kept high enough, to provide hot water continuously at a reasonable flow rate.

The tankless coil is used widely in houses in the Northeast that are heated by oil-fired boilers. It has a considerably lower first cost than would be incurred to install a separate storage type water heater with its own oil burner.

The simplicity and low cost of the tankless coil can be combined with a separate glass-lined storage tank which increases the availability of domestic hot water by maintaining a standby supply for use at all times. This permits use of a smaller boiler. Water is circulated by a small auxiliary pump through the tankless coil to the storage tank and back to the coil. A thermostat on the tank permits simple adjustment of the stored water temperature over a range of about 120-160°F.

4.4.2 Barometric Damper

The construction of the furnace chimney system is designed to obtain adequate draft to eliminate the products of combustion. As mentioned before, seasonal temperature variations must be considered when designing and adjusting for chimney draft. Accordingly, under maximum draft conditions (i.e., cold and windy conditions) the driving force pulling the exhaust gases becomes greater than necessary, and the combustion gases can be vented too rapidly, reducing heat transfer. Excess heat is, therefore, lost up the chimney. This conditioning of overpowering draft must be controlled to insure optimum performance of the heating system. This is accomplished by using a barometric damper. The barometric damper is a movable door on a hinge that opens and closes in response to pressure differentials that exist in the chimney. The rear side of this damper is exposed to the negative pressure of the chimney while the front side is exposed to the ambient or atmospheric pressure. During periods where the draft is just adequate to eliminate combustion products, the barometric damper remains closed. When there is more draft than necessary, the excessive negative pressure in the chimney opens the damper, allowing air to flow into and up the chimney reducing the negative pressure of the chimney.

The barometric damper is adjusted by a weight found on the damper which allows proper settings for each individual installation. Usually the setting is made so that it produces the desired draft reading measured over the fire or in the flue pipe. This setting insures that the amount of air through the burner remains constant as chimney draft varies.

The barometric damper for all its energy saving qualities has one inherent drawback; it can increase air infiltration into the house. The growing use of flame retention head burners has brought about some discussion of the need for barometric dampers in modern residential installations. Newer burners are less strongly affected by draft variation. No definitive conclusions are available at this time, but some of the more knowledgeable individuals in the industry have suggested the elimination of barometric dampers may conserve energy. The adverse effects of this action must be evaluated before any recommendations can be decided upon.

It is common knowledge that every system cannot operate in perfect adjustment all the time, and a certain amount of lee-way must be given. The factors that usually will cause draft variations are:

- o excessive wind
- o inadequate chimney construction or system installation
- o inadequate system maintenance

The first problem, excessive wind, is more a function of geographic location rather than heating system construction. It is important to maintain the overfire draft in the proper range under windy conditions. If the overfire draft is too large even when the barometric damper is fully open, it may be necessary to install a second damper in series with the first one. This will help maintain regulated air flow through the heating system at all times.

When installing a barometric control damper it is important to recognize that there is a optimum location for each installation. Oil-fired units use barometric controls best when they are located in the direct flow of combustion gases such as the illustration in Figure 4.10.

The proper installation and adjustment of a heating system is important for trouble-free operation of the unit during its life time. The construction of chimneys is usually standard today in the residential housing market, and it is governed by various state and local codes. Problem areas usually occur when existing solid fuel heaters are retrofitted with oil-fired units. The diameters of the flue and the height of the chimney in relation to surrounding structures are the two important considerations that must be examined when installing a heating unit. Diameters that are too restrictive may not allow proper evacuation of combustion products and flue gases can flow back into the living space. If the diameter of the flue is too large the chimney is never given a chance to completely warm because of the large surface area of the inside of the flue. This situation may cause poor draft and flue gas condensation which can corrode both the chimney and the heating system. In either case adjustments must be made to maintain proper draft before the heating system is installed and as it continues to run.

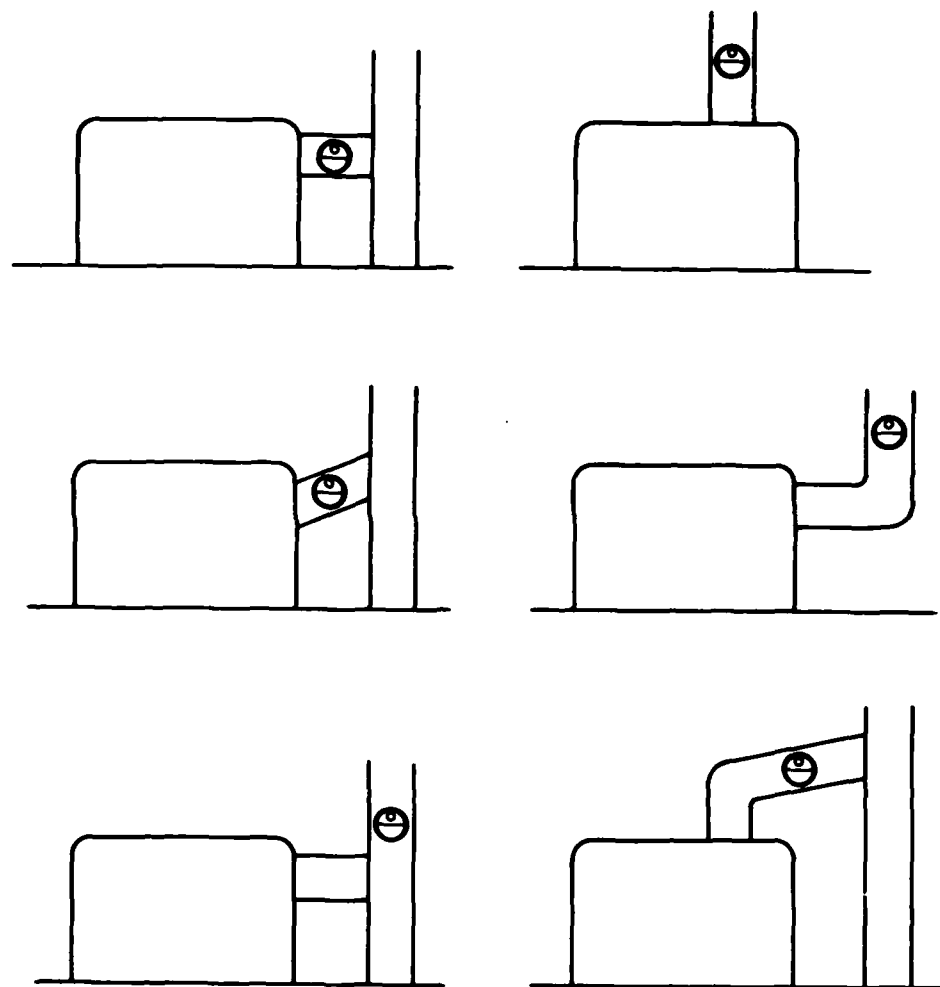


FIGURE 4.10 RECOMMENDED LOCATIONS
FOR BAROMETRIC DRAFT DAMPERS
USED IN OIL FIRED HEATERS

Another difficulty that can be encountered with lack of proper maintenance is burner sooting. If left unattended for long periods of time, the flue passages can become restricted and draft is reduced. Modern oil burners are capable of soot-free operation, and they should be used to replace poorly operating, outdated equipment.

4.5 Automatic Control Devices

Modern automatic home heating equipment has come about and progressed with the evolution of automatic control devices. These controls vary in complexity from simple bimetallic wall thermostats to completely integrated energy control systems that vary room temperature with time of day and vary heating system operating temperature with outdoor weather conditions. All control systems regardless of their complexity are installed to insure safe and efficient operation while maintaining comfort.

The basic control scheme that is utilized in the typical oil-fired system (regardless of heating medium air, water, or steam) encompasses four basic components:

- o Thermostat
- o Limit Switch
- o Primary Control
- o Operating Controls

4.5.1 Thermostat

In simplistic terms a thermostat is nothing more than an on-off switch that is heat sensitive. When heat is needed, the contacts close and the boiler or furnace is activated and responds with the necessary amount of heat. The thermostat responds by breaking its electrical contact when the heat requirement is fulfilled.

Lowering the thermostat is the most popular and cost effective way to reduce fuel bills. In the past few years the standard setting on a thermostat has dropped from 72° to 68°F. This lowering of the thermostat setting has reduced fuel consumption without seriously sacrificing comfort. Further reduction in temperature settings will be helpful, but caution must be taken to avoid health hazards with the elderly, the very young, or the sick.

In today's very mobile society many households are left empty for the entire day which means that large amounts of energy are being wasted. Paralleling this situation is the evening period when the occupants are sleeping, and less heat is needed than during more active periods. For this reason the clock thermostat was developed. The clock thermostat regulates the temperature setting with the time of day. The highest temperature settings are only delivered during active periods such as morning and evening hours when the occupants are at home and awake. During periods when the occupants are not at home or the need for heating is reduced the thermostat will "set back" the temperature to a lower setting. This type of operation can give fuel savings from 8-30% depending on lifestyles and the geographical location. Some estimates were made by Honeywell corporation for heating as shown in Table 4.1.

Table 4.1 Fuel Savings by Set-Back Thermostats

Location	Percent Fuel Savings For 10°F Setback once a day (70° to 60°F 8 hr/day)	Percent Fuel Savings for 10°F Setback twice a day (70° to 60°F 15 hr/day) (% fuel savings)
Bismarck, ND	9	17
Boston, MA	11	22
Buffalo, NY	10	20
Charlotte, NC	14	26
Chicago, IL	11	21
Cincinnati, OH	12	24
Cleveland, OH	10	21
Denver, CO	11	22
Des Moines, IA	11	22
Detroit, MI	11	21
Milwaukee, WI	10	19
Minneapolis, MN	9	18
New York, NY	12	23
Philadelphia, PA	12	24
Pittsburgh, PA	11	22
Portland, OR	13	24
Richmond, VA	13	25
St. Louis, MO	12	23
Seattle, WA	12	24
Washington, DC	13	25

Fuel savings can also be realized through daily manual adjustment of existing thermostats. The cost, convenience and large opportunity for fuel savings make the clock thermostat a very worthwhile investment for the consumer.

4.5.2 Limit Switch

The limit switch is used as a safety mechanism to prevent the heating system from reaching a high temperature that would compromise safety. The limit switch monitors the temperature of the heating medium usually water or air. Steam system limit controls monitor steam pressure. The limit control has override over the entire system. If the limit condition is reached, power to the burner is interrupted until the water or air temperature drops to an acceptable level.

4.5.3 Primary Control

The primary control is the brain center of oil-fired heating systems. It responds to signals given by both the thermostat and the limit control. The primary is also responsible for the proving flame presence, controlling the burner and ignition, and shutting down on malfunction of the system.

The primary operates in either the start mode or run mode. On a call for heat (i.e. thermostat contacts close) the start mode circuit of the controller is activated. This circuit involves the thermostat, the safety switch, the safety switch heater and a flame detection mechanism. At such time that a flame is proven, a mechanism of the flame detector removes the safety switch heater from the powered circuit. This arrangement of the circuit allows two checks. First, the safety switch heater is checked to make sure it is working. Second, it proves that there is a flame. If either of these criteria are not met the safety switch will lock out. Locking out will cause the system to shut down immediately and prevent further operation. In some instances the circuit will recycle and try to start the burner. If this attempt fails, then the system will lock out permanently and servicing is necessary. In all oil-fired systems, primary controls use a flame detector to insure the presence of flame and avoid an unsafe condition. Automatic oil burning systems use either a thermally activated sensor called a stack relay or an optically activated sensor called a cad cell. Compactness, quick response and reliability usually make the cad cell detector the most popular choice for new equipment. Stack detectors are still very popular on existing equipment.

4.5.4 Operating Controls

4.5.4.1. Furnaces. Warm air furnace operating controls are quite simple. The operating control regulates the operation of the fan as a function of the air temperature in the exit side of the furnace. On a call for heat by the thermostat, the burner will switch on, heating the air in the plenum to the prescribed setting of the fan "on" switch. This temperature should be set at about 120-130°F to insure the initial blast of air through the duct will not be cool. The burner shuts off once the limit control

temperature has been reached or the thermostat satisfied. The fan remains "on" until the temperature of the plenum falls to the fan shut-off setting which should be in the 100°F range. To review the furnace operating controls, there are three temperature settings on forced air systems. First the high limit control is a safety check to insure that the furnace does not overheat. Second a fan "on" setting activates the fan at the proper time to maintain comfort and maximize energy utilization. And third, a fan "off" setting is used to purge excess heat from the system and stops the fan when the heat supply is exhausted.

4.5.4.2 Boilers. The boiler operating control system is a bit more complex than furnace controls. Most boilers contain a reservoir of water that is maintained warm at all times. This serves two purposes. First, it allows a quick response on a call for heat from the thermostat, and second, the reservoir can supply heat for domestic hot water.

The typical boiler has low limit and high limit temperature controllers. The low limit controller maintains the reservoir at a specified temperature. Once the temperature of the reservoir falls below this lower limit, the controller activates the burner until the temperature of the reservoir rises to the upper limit. The circulating pump brings the boiler water into radiators in the house when there is a call for heat. In most installations the circulation is not activated until the reservoir temperature is above the lower limit.

Typically the hot water radiator system are designed for peak operation when the circulator water is at about 180°F. This high temperature is only necessary under the coldest conditions. During non-peak operation, which probably represents more than 90% of operation, lower boiler water temperature is adequate to meet the needs while using less fuel. This is the principle of the indoor-outdoor boiler water control devices. As the outside temperature varies, so too does the boiler water temperature. The reduction of boiler temperature lowers heat loss during the off-cycle reducing fuel consumption. This will be discussed in detail later.

5.0 EFFECTS OF EQUIPMENT MODIFICATION

5.1 Equipment Modification Options to Improve Efficiency

The purpose of this section is to present a range of energy-savings equipment modifications and indicate both the expected fuel savings and possible problems associated with using this equipment. Heating system improvement can often reduce excessive fuel cost more than other energy conservation options. If a careful analysis of options is not performed the results of investing in any given single conservation effort may not be the most cost effective path to follow. The reader should have a clear understanding of the information contained in Appendix A:- Combustion Theory - included in the back of this report prior to analyzing the options presented in this section.

Some adverse effects that can result from some modifications are included, so that equipment installers are aware of both positive and negative results. General installation, adjustment and service recommendations are included to assist effective use of retrofit changes, but these do not provide a step-by-step installation procedure. Variability in heating equipment and retrofit designs prevent the development of a general and simplified installation approach. The serviceman with field experience must adapt heating equipment to operate more efficiently while assuring safe and reliable operation. Finally, a discussion of retrofit costs demonstrates the advantage offered by these conservation measures for typical installations.

The information that is included is briefly summarized below:

- o Function of each retrofit.
- o Expected energy savings.
- o Adverse effects.
- o General installation requirements.
- o Typical cost-benefit evaluation for each modification.
- o Conclusions.

Many heating unit modifications exist that will reduce heat loss and improve efficiency. These range from simple control adjustments of boilers and furnaces to replacement of the entire heating system.. The low-cost approaches should be considered for all heating units. Higher cost modifications must not be automatically rejected, however, because in the long term they offer the greatest energy savings, and they are often economically attractive. The specific heating unit modifications included here are:

- o Flame retention head burners.
- o Replacement of boilers or furnaces.
- o Vent dampers.
- o Reduced fuel firing rates (smaller fuel nozzles).
- o Flue heat reclaimers.
- o Reduced temperature settings for boilers and furnaces.
- o Pipe or duct insulation.
- o Turbulator replacement for steel tube boilers.
- o Heating system tune-up.

5.1.1 Flame Retention Burners

5.1.1.1 Function. The basic design of a flame retention burner is similar to other pressure atomizing burners. The main difference is the way in which fuel and combustion air are mixed, and this is controlled through careful design of the burner end cone (burner head). The flame retention head has a smaller area through which air can flow and the resulting flow pattern allows more efficient operation. The other components of flame retention burners (fuel pump, nozzle, electrodes, transformer) often are the same as non-flame retention types. One other difference is frequent use of 3450 RPM motors instead of 1725 RPM to overcome the pressure drop through the retention head, but this is not a requirement for flame retention.

Flame retention burners can improve boiler or furnace efficiency in two ways. Flue heat loss during burner operation can be lowered, and off-cycle heat loss may be reduced.

Excess air reduces efficiency, and flame retention burners usually operate with less excess air than older burner designs. Flame retention types require 20 to 30% excess air, while older burners need 50 to 100% or more to achieve low smoke numbers. The difference in flue heat loss for these burners is about 10 percentage points. This translates into a fuel savings of more than 10%.

The second advantage of flame retention burners is their tendency to reduce off-cycle heat loss while the burner is idle. The flow of off-cycle air through the heating unit is reduced by the restrictive design of the flame retention head, and off-period heat loss is less. This improves the annual fuel utilization efficiency. The magnitude of on-cycle and off-cycle savings depend on the design of the burner and boiler or furnace combination.

5.1.1.2 Expected Energy Savings. Extensive laboratory and field investigations indicate that replacement of older burners with flame retention units will reduce fuel use by an average of 15%. Savings measured in the laboratory range from about 5 to 25%, while field investigations show larger variations. It is possible in some installations to save up to 40% by burner replacement.

Actual savings are related to the efficiency before burner replacement. Combustion testing is an effective method for estimating expected savings and Figure 5.1 shows some flue gas efficiency results. The field data shown are flue gas (combustion test) efficiencies before and after burner replacement for 160 boilers in the New York area collected by Brookhaven National Laboratory. Note that the final efficiencies fall close to 80% for all the cases shown.

This information demonstrates that a lower initial efficiency corresponds to larger savings. For original efficiencies of about 72% the estimated savings is 10%, while a system at 60% can save more than 23%. Remember, these estimated savings represent only improvements during burner operation. Additional fuel savings can result from reduced off-cycle losses. These

EFFICIENCY BEFORE & AFTER BURNER REPLACEMENT
FOR 160 HOMES IN THE NEW YORK AREA

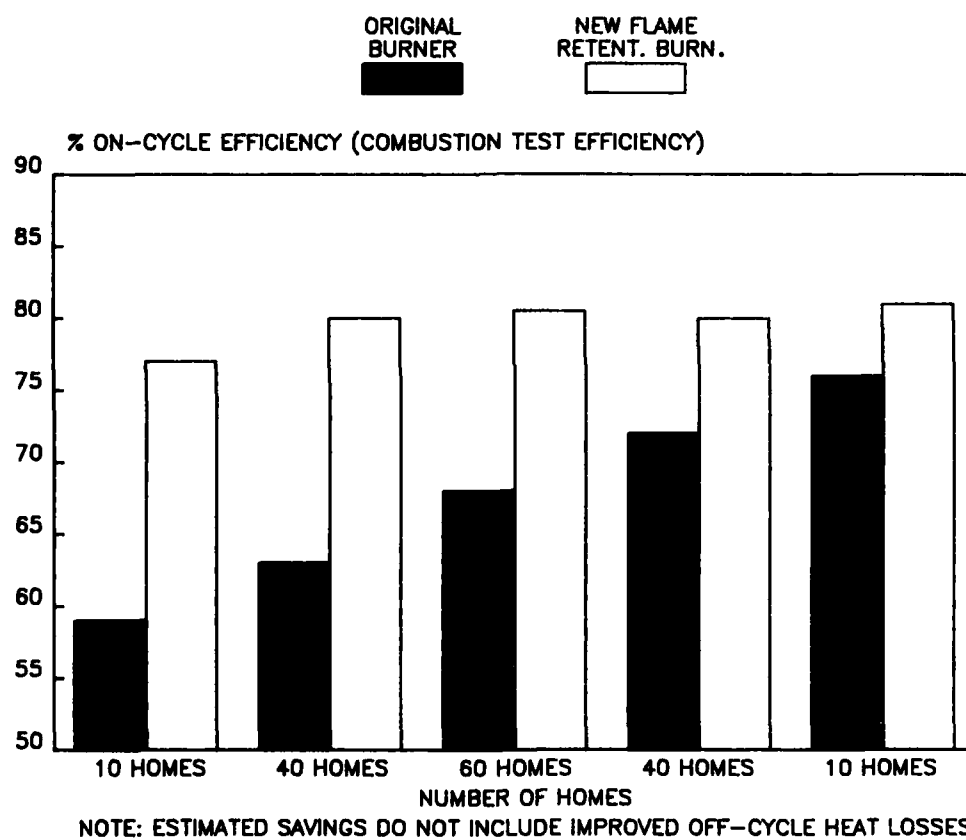


FIGURE 5.1

estimates, therefore, represent the lower limits on the improvement provided by flame retention head burners, and actual savings can be higher.

5.1.1.3 Adverse Effects. Flame retention head burners do not present the reliability problems that are sometimes associated with new energy saving add-ons because these burners have been available for more than a decade. Many burner components are the same as older oil units that have been used for several decades. Therefore, few problems are expected by wider use of retention head burners. One area that must be considered by installers, however, is the possible incompatibility with some older heating units. These boilers and furnaces may not have been designed for the higher flame temperatures produced by new burners, and modification of the combustion chamber may be required.

Retention head burners operate with higher flame temperatures that can be 600°F hotter than older burners. The higher temperature is caused by reduced excess air and contributes to higher system efficiency. Higher temperature combustion gases transfer their heat more rapidly to the boiler water increasing thermal efficiency. Remember too, that reducing excess combustion air (producing higher flame temperature) causes flue heat loss to drop. From an efficiency point of view, high combustion gas temperatures are desirable.

Most new boilers and furnaces can accommodate higher combustion temperatures, and flame retention burners are used in almost all of them. Unfortunately, this is not true for all older heating units. Raising the temperature of combustion can pose problems including burn-out of combustion chambers or heat exchangers in extreme cases. The judgement of experienced service personnel is important to eliminate safety hazards.

Several precautions should be considered whenever older heating units are retrofitted with new burners. The best decision from an efficiency viewpoint is to replace the entire heating unit, with a new burner-boiler or burner-furnace. This will provide maximum fuel savings and the fewest problems.

Another solution is to reline older combustion chambers with high temperature refractory inserts. These are available in moldable (Wet-Pak) form or similar combustion chamber liners which can be installed in the field and reduce the chance of chamber problems. Also, reducing the firing rate (fuel nozzle size) may lessen the undesired effects of high combustion temperatures.

Finally, increasing excess combustion air reduces flame temperatures, but also reduces fuel savings. Dry-base boilers and older warm air furnaces are prime candidates for this approach. For those cases a maximum CO₂ concentration of about 10% (or about 50% excess air) may be acceptable. Fuel savings will be lowered by increasing excess air, so this is not a general recommendation for all systems.

Careful attention by experienced servicemen is required for proper use of all retrofit improvements, and safety is the primary consideration in all cases. Safe operation must never be compromised for gains in efficiency.

5.1.1.4 General Burner Installation and Adjustment Requirements.

Replacing an oil burner is not a simple task, and careful attention to detail is required to assure safe and efficient operation. Important questions to consider are:

- o Is a new burner needed?
 - Can the efficiency of the existing burner be improved?
 - Should other modifications be considered first?
 - Can the existing boiler or furnace handle higher flame temperature?
 - Are there other important considerations?
- o What installation procedure will be followed for burner replacement?
- o How will the burner be adjusted to peak efficiency?

5.1.1.5 Is a New Burner Needed? The efficiency of the existing heating unit must be measured to determine possible fuel savings with the new burner. The original system should be adjusted to peak efficiency (and acceptable smoke number) before the fuel saving is estimated. Setting the draft damper, replacing fuel nozzles, adjusting combustion air, eliminating air leaks and cleaning heat exchange surfaces are some of the measures that can improve the performance of the existing burner-boiler or burner-furnace. If the flue loss efficiency of the tuned heating unit is less than 75%, then a flame retention burner is advisable in many cases.

Inspection of the combustion chamber and heat exchanger is necessary to determine if the unit can tolerate higher temperature. Remedial steps may be required. Any other specific factors that may affect the choice of a flame retention burner should be considered.

5.1.1.6 Installation Procedures. A standard step-by-step installation procedure should be used by each burner installer to assure uniform quality. Some important items in an installation procedure include:

- o Selection of correct burner for combustion chamber shape and size.
- o Upgrading procedure for combustion chambers.
- o Assembly of burner components (air tube, nozzle assembly, main housing).
- o Procedure for mounting burner on boiler or furnace including air tube insertion depth.
- o Elimination of air leaks around burner air tube and elsewhere.
- o Elimination of air leaks in the fuel line.
- o Burner electrical wiring procedure.
- o FINAL INSPECTION.

Step-by-step installation procedures are available from burner manufacturers which discuss specific details of their equipment. Equipment installers must be familiar with the recommendations of burner manufacturers, and these should be incorporated into a detailed installation plan.

5.1.1.7 Burner Adjustment. An oil burner must be adjusted carefully so that the peak efficiency is obtained. Even a highly efficient burner wastes fuel if the firing rate is too large or if the combustion air setting is incorrect. Several steps must be included in any burner adjustment procedures. These are:

- 1) Use combustion test equipment for all burner adjustments. The advantages of this step must not be ignored. Appendix B describes combustion efficiency testing procedures.
- 2) Use the smallest fuel nozzle capable of supplying sufficient heat. Many heating units are over-fired and therefore operate at lowered efficiency. Reduced firing rates will be discussed later, but selection of proper firing rate is an important part of burner adjustment. Remember that flame retention burners operate at higher efficiency and the fuel firing rate can be reduced after burner replacement because of the improved performance. Never install a nozzle that is larger than the boiler or furnace design input rate listed on the label.
- 3) Use the correct fuel spray angle and pattern for the burner and combustion chamber. Burner manufacturers generally recommend the spray patterns and angles that produce the best performance with their equipment. These guidelines should be followed, and the size and shape of the combustion chamber must be considered to avoid flame impingement and unnecessary soot production.
- 4) If the combustion head position is variable, set it for the appropriate firing rate. This is usually accomplished by loosening the nozzle assembly and sliding it forward or backward until the desired point on a scale is reached.
- 5) Adjust the combustion air shutter to produce a zero to number one smoke (Bacharach scale). Carbon dioxide concentration in the flue gas should be in the range of 11 to 13%. The correct balance between too little and too much air must be selected for best efficiency.

More detailed burner adjustment criteria are included in Section 3.2 of this guide.

5.1.1.8 Saving and Cost Comparison. Many complex formulas and equations are used to evaluate the economic advantage of investments in new equipment. The simpler ideas of initial equipment costs and annual fuel cost reduction can be used. This uncomplicated analysis shows why flame retention burners are a worthwhile investment for homeowners, and that their value increases as fuel costs rise.

Table 5.1. Payback Period in Years Necessary to Recover
Cost of New Burner

Installed Cost of New Burner	Annual Fuel Use (Gallons)	Percent Fuel Savings from Burner Replacement			
		10	15	20	25
\$300	1000	3	2	1.5	1.2
	1200	2.5	1.67	1.25	1.0
	1500	2.0	1.33	1.0	0.8
	2000	1.5	1.0	0.75	0.6
\$400	1000	4.0	2.67	2.0	1.6
	1200	3.33	2.22	1.67	1.33
	1500	2.67	1.78	1.33	1.07
	2000	2.0	1.33	1.0	0.8
\$500	1000	5	3.33	2.5	2.0
	1200	4.17	2.78	2.08	1.6
	1500	3.33	2.22	1.67	1.3
	2000	2.5	1.67	1.25	1.0

Note: For purposes of example, assumes fuel is \$1.00 per gallon. For other fuel costs divide payback period by actual cost in dollars/gallon. Installed costs, assumed here for purposes of example, vary widely and can be below \$300 or above \$500.

Generally, flame retention burners reduce annual fuel use by an average of 15%, and the installed cost assumed here can range from less than \$300 to above \$500. If we assume a typical fuel useage of 1200 gallons per year and a fuel cost of \$1.00 per gallon, then the annual fuel savings is \$180. In this case the burner pays for itself in about two years, and this payback period is shorter for homes with higher fuel consumption or less efficient heating units. Table 5.1 gives examples of payback periods for different values of equipment costs, annual fuel uses, and efficiency improvements.

The shortest payback period (0.6 years) corresponds to the lowest equipment cost shown (\$300), the largest fuel use (2000 gallons per year) and the largest efficiency improvement (25%). This means that the burner will pay for itself in about a half year. In contrast, the longest payback occurs for the highest burner cost, the lowest annual fuel use and the lowest percent fuel savings.

Table 5.1 is not exact, but the information can be useful to assist in estimating savings. The cost of the burner is known, and the average annual fuel use is available from delivery records. The only unknown is the percent fuel savings for burner replacement. This can be estimated, however, by measuring the combustion efficiency (flue heat loss) of the unmodified heating unit. Earlier, fuel savings for burner retrofit was discussed and Figure 5.1 showed that the average efficiency after burner replacement was about 80%. A conservative estimate of fuel savings (neglecting off-cycle savings produced by the new burner) can be obtained by comparing the original efficiency to 80% as shown:

$$\text{Estimated Savings (\%)} = \frac{80\% - \text{Original Efficiency(\%)}}{80\%} \times 100$$

For example, if the as-found efficiency of the heating unit is 68%, then the approximate savings is:

$$\text{Estimated Savings (\%)} = \frac{80\% - 68\%}{80\%} \times 100 = 15\%.$$

Remember that the estimated savings does not account for off-cycle improvement, and actual fuel savings will be higher in most cases.

5.1.1.9 Conclusion. Installation of flame retention head burners as replacements for older units is an effective and economic means for conserving heating oil. Flame retention burners represent an important advance in burner performance and the technology has been proven by many years of field experience. Few problems are anticipated by widespread use of newer burners, but careful installation and adjustment practices are required to assure safe and efficient performance.

Most homes with older oil burners can have substantially reduced fuel costs, with savings averaging 15% and ranging up to 40%. The combination of low burner cost and high fuel savings make retention head burners one of the best conservation investments available.

5.1.2 Vent Damper

5.1.2.1 Function. A vent damper is a mechanical device that is installed in the flue pipe to reduce off-cycle heat loss from the boiler or furnace. The damper is open during burner operation and exhaust gases are vented normally through the chimney. After completion of the burner firing cycle, the vent damper closes to reduce off-cycle heat loss through the flue. A diagram of damper operation is presented in Figure 5.2. The vent damper traps heat within the boiler or furnace and improves system efficiency.

Most vent dampers for oil fueled systems use electric motors to open and close the damper blade, and there are two types of blade design. One is a tight closing blade while the other has cutouts that allow substantial off-cycle air flow. These cut-outs help to reduce odor problems that exist in some installations, but also reduce fuel savings.

Most vent dampers are designed to fail in the "open" position. That is, if electrical power to the damper is interrupted, then the damper opens automatically. Also, some dampers have safety switches that require a full-open position before the burner can operate. These features prevent unsafe damper operation, but proper installation by specially trained service personnel is necessary to assure safe and reliable performance.

5.1.2.2 Expected Energy Savings. Laboratory and field studies show that vent dampers reduce fuel use on the average by 2% to more than 14%. The actual reduction depends on existing off-cycle and infiltration heat losses. Field studies indicate average fuel savings are about 8% for oil-fired heating units.

Laboratory tests show that tight-closing dampers are better than units with cut-outs. Tight dampers often include a time delay before closure to allow purging of combustion gases from the heating unit. This short delay does not reduce fuel savings, but cut-outs reduce fuel savings significantly. For example, Brookhaven National Laboratory tests show that one boiler saved 11% with a tightly closing damper. The same boiler with damper blade cut-outs saved only 5%. This shows that cut-outs can reduce savings by 50% compared to tightly closing units. Clearly, vent dampers that close tightly save more fuel than other designs.

Burner design is another factor that affects vent damper fuel savings. Vent damper savings are lowest for units with flame retention burners. Recall that flame retention head burners reduce off-cycle heat loss. It is not surprising, therefore, that vent dampers save more energy when they are installed on units with burners of older design. Typical savings are 2 to 4% for heating units with flame retention burners.

Some burner manufacturers have developed flame retention models with a built-in air damper that closes during the off-cycle. These new designs have the potential for superior performance and very high efficiency.

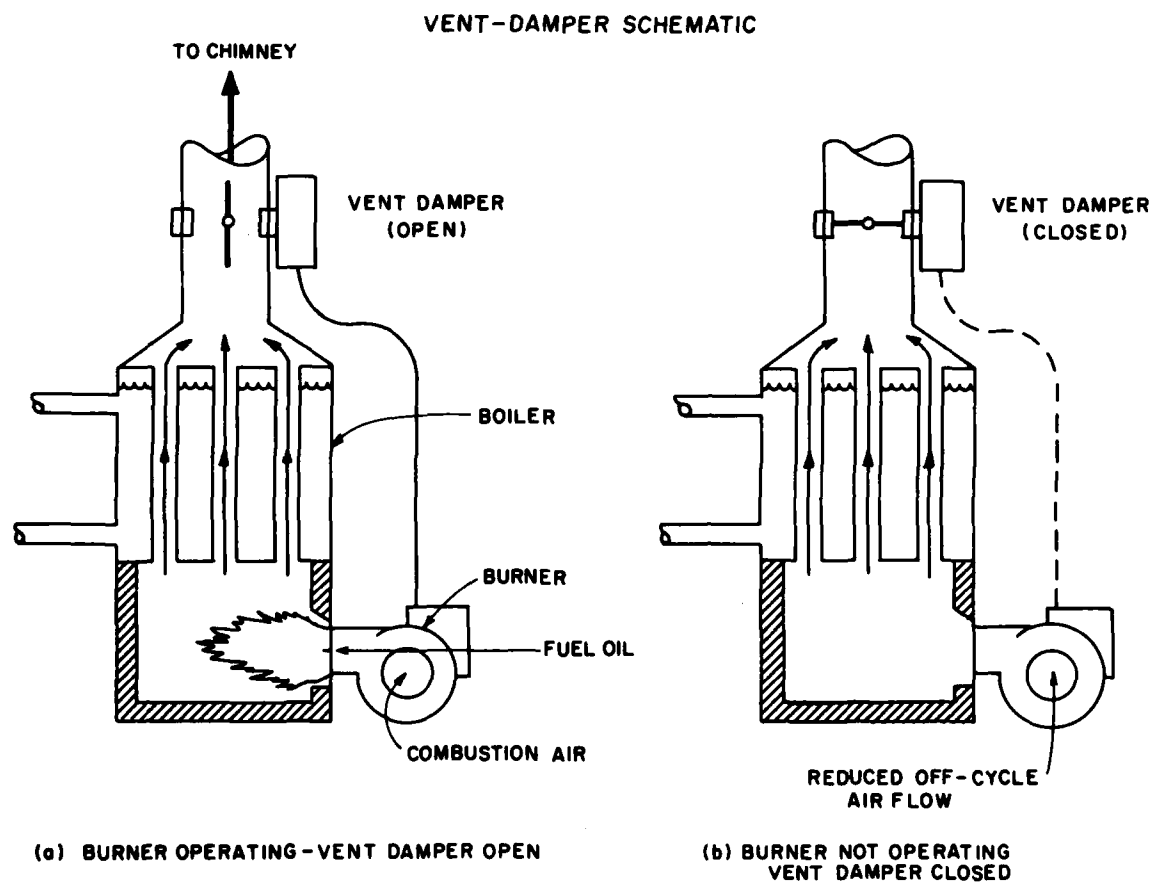


FIGURE 5.2 VENT DAMPER OPERATION

Off-cycle and infiltration losses cannot be measured in the field and fuel savings are expected to vary with the size of these losses. They represent the maximum savings for vent dampers use. Off-cycle loss varies from 5 to 15%. Air infiltration accounts for about 2% of fuel consumption, but it can be larger for specific building, heating unit and chimney designs. Factors that can contribute to large losses and higher vent damper savings are summarized below:

- o Heating systems with high operating temperature.
 - Steam boilers
 - Hot water boilers with tankless coils.
 - Boilers and furnaces with high operating temperature settings.
- o Heating units with large heat storage capacity.
 - Units with large combustion chambers of heavy brick.
 - Massive boilers and furnaces - coal converted units.
- o Heating units with large off-cycle air flows.
 - Older burner designs (non-flame retention).
 - Many air leaks.
- o Boilers or furnaces located near the heated space - infiltration loss can be significant.
- o Grossly oversized heating units with long off-cycles.
- o Heating systems with very high chimneys - inducing high off-cycle air flows.

No exact method exists for estimating vent damper savings, because off-cycle and infiltration losses are not known. The list of factors shown above indicates systems that may be suited to vent damper use. A system with several of these factors is prime candidate for a vent damper.

5.1.2.3 Adverse Effects. Two areas of concern exist for vent dampers:

- o Operating the burner while the damper is closed.
- o Off-cycle odors.

Operating the burner while the damper is closed is an obvious safety problem, but many dampers have control features to prevent it. Careful installation is essential to be sure that all safety devices are operative. Manufacturer instructions must be followed explicitly!

Off-cycle combustion odor is not a problem created by the vent damper. The damper merely reveals that a problem exists. Odors are often produced when fuel oil is injected into a hot combustion chamber at the end of the

burner "on" cycle. The oil enters the chamber because of improper pump cut-off or air in the fuel line. A hard combustion chamber sustains high temperature and contributes to the problem by heating the fuel nozzle during the off-period. The injected oil vaporizes on hot surfaces and partially oxidizes forming the undesired vapors. Normally, off-cycle draft will remove these fumes from the heating unit, but a vent damper can trap them inside. The damper does not create the odor, but it allows the problem to be noticed.

The best solution is to eliminate the source of fumes. This can be achieved by the methods below:

- o Eliminate air leads in the fuel line. Air trapped in the fuel line expands when the nozzle is heated and injects fuel into the hot chamber.
- o Use a fuel pump with a better low pressure cut-off.
- o Install a fuel solenoid valve for instantaneous fuel shut off. (Air leaks in fuel lines and fittings must be eliminated also.)
- o Install a low mass combustion chamber liner. This will lower off-cycle temperature and reduce off-cycle nozzle heating.

Using a vent damper with cut-outs or by-pass area is not the best choice. This will not eliminate the odor problem. It can only make it less noticeable, and fuel saving will be reduced.

5.1.2.4 General Installation Requirements. The instructions of each vent damper manufacturer must be followed exactly to assure safe operation. Several installation concerns are listed below:

- o Electrical wiring must follow manufacturer recommendations.
- o A specified clearance from combustible materials must be maintained.
- o The damper must serve only one appliance.
- o Qualified service agency must install damper in accordance with local, state and federal codes.
- o Deviation from instructions can cause a dangerous situation.

5.1.2.5 Saving and Cost Comparison. Payback periods are shown in Figure 5.2. Generally, the payback periods for vent dampers are longer because fuel savings are less than for new burners. A typical example may be represented by:

- o Installed cost: \$350
- o Annual fuel use: 1500 gallons
- o Percent savings: 8 percent
- o Fuel cost: \$1.00 per gallon

Table 5.2 Vent Damper Payback Periods

Installed Cost of Vent Damper	Annual Fuel Use (Gallons)	Percent Fuel Savings for Vent Damper		
		4	8	12
\$250	1000	6.2	3.1	2.1
	1500	4.2	2.1	1.4
	2000	3.1	1.6	1.0
\$350	1000	8.8	4.4	2.9
	1500	5.8	2.9	1.9
	2000	4.4	2.2	1.4
\$450	1000	11.2	5.6	3.8
	1500	7.5	3.8	2.5
	2000	5.6	2.8	1.9

Note: For purposes of example, assumes fuel is \$1.00 per gallon. Installed costs, assumed here for purposes of example, may be less than or greater than the range shown in this chart.

The payback period for this case is about 3 years with an annual savings of \$120. This is not the best payback or annual cost saving measure, but it does represent an attractive investment for many homes. Heating systems with design features that tend toward high off-cycle and infiltration losses are certainly candidates for vent dampers.

5.1.2.6 Conclusions. Vent dampers reduce off-cycle and air infiltration heat losses. Average savings are about 8%, but some older heating units may save more. Off-cycle loss cannot be measured in the field, however, and accurate prediction of savings is difficult. More field data is required. Vent dampers that close tightly save more fuel than dampers with cut-outs that permit off-cycle air flow. Many factors affect heat loss and vent damper effectiveness, and dampers should be used on systems with larger off-cycle heat losses. While savings are less than those for burner replacement, vent dampers can be economically attractive for many homeowners.

5.1.3 Reduced Fuel Firing Rate (Smaller Fuel Nozzles)

5.1.3.1 Function. Reducing the firing rate of boilers and furnaces is an effective and inexpensive method for reducing excessive fuel use. All too many heating units have fuel nozzles that are too large for their heating requirement. This is particularly true in older heating units. Some studies show typical oversizing of 100% or more. Replacement with a smaller fuel nozzle and readjustment of the combustion air improves the system efficiency. Fuel savings usually come from lower flue heat loss during both burner on - and off-cycles.

Burner on-cycle flue loss is often reduced when a smaller nozzle is installed. This is reflected in a lower flue gas temperature. A larger fraction of the available heat is removed from the combustion gases as they pass through the boiler or furnace. This results from a smaller volume of combustion gases passing over the original heat transfer surface. In effect, there is more heat transfer area for each unit volume of combustion gas.

Off-cycle heat loss is also reduced when a smaller fuel nozzle is used. The variation in off-cycle loss and efficiency for different burner off-periods is shown for a hot water boiler in Figure 5.3 (from Brookhaven National Laboratory test results). The best efficiency is obtained for continuous burner operation when off-cycle loss is zero. The efficiency drops as the burner "on" percentage gets smaller because off-cycle losses grow larger. Obviously, higher efficiency occurs at the right hand side of the curve for large burner "on" percentages. Using a smaller fuel nozzle shifts burner operation to the right side of the curve and improves efficiency by reducing off-cycle heat loss.

The highest efficiency would be reached by operating the burner continuously. This is not possible because the outdoor temperature changes during the heating season and less heat often is required. The next best option is to use the smallest nozzle that will satisfy the peak heating requirement. This will produce the shortest burner off-periods and the highest efficiency.

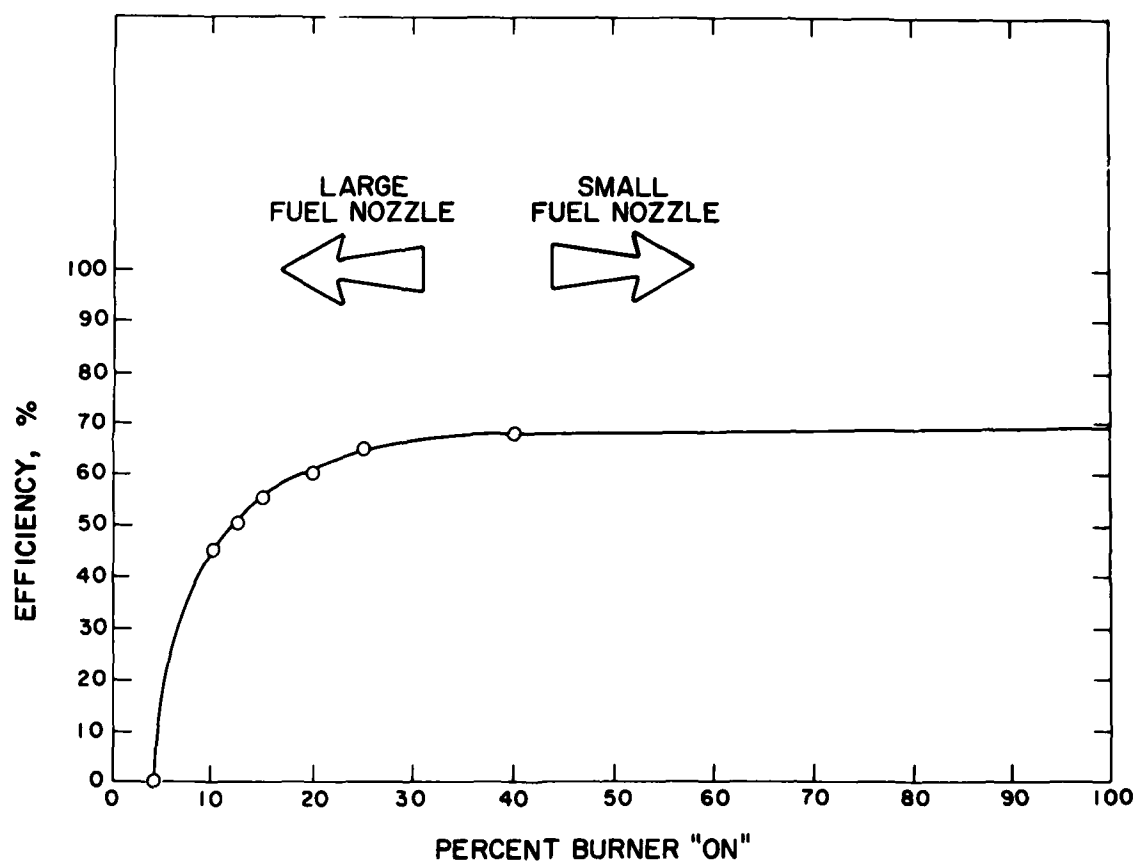


FIGURE 5.3 BURNER OFF-CYCLE
LOSSES ARE LOWER WITH A
SMALLER FIRING RATE

Similarly, warm air furnaces also benefit from smaller firing rates that are more closely matched to the heating requirement of the house.

5.1.3.2 Expected Energy Savings. Laboratory measurements, field investigations and computer simulations show that lowered firing rates reduce fuel use by about 8%. Savings for warm air furnaces average 7.5% while boilers average 8.5%. It is difficult to separate on-cycle and off-cycle savings, but laboratory tests on boilers show that a large part of the savings occurs during the burner off-cycle.

Expected fuel savings for specific heating units depends on:

- o Initial overfiring rate.
- o Degree by which overfiring is reduced.
- o Off-cycle heat losses for the burner-boiler or burner-furnace unit.
- o Burner design and ability to reduce firing rate effectively.

Many heating units are overfired by 100% when compared to the design heating requirement. For example if a firing rate of 0.75 gallons per hour is needed, then a fuel nozzle rated at 1.50 gph is often used. The field studies that show an 8% savings from reducing the firing rate by about 30%. For the example above, this means a final firing rate of about 1.05 gph. This is larger than the minimum fuel nozzle size (0.75), but it is much closer than the original firing rate.

The off-cycle heat loss of a particular heating unit cannot be determined in the field. Fuel savings for average units can be used to estimate expected savings.

5.1.3.3 Adverse Effects. Reduced nozzle size is not appropriate for all heating units, and several undesired effects are possible. These include:

- o Insufficient heat during peak heating requirements.
- o Slow response to changing heat loads.
- o Burner on-cycle flue loss increases.
- o Inadequate domestic hot water supply.
- o Poor steam generation in steam boilers.

If the firing rate is lowered too much, then the heating unit will be unable to supply peak heating requirements. This is unlikely in most cases, but care must be used not to reduce fuel input too much.

The response time of the boiler or furnace will be increased by reduced fuel firing rate. For example, longer time periods are required from a "cool" start to reach satisfactory heat output. If the house uses a set-back thermostat, then more time may be required to raise the house temperature from a low to high temperature. Readjustment of automatic time controllers may be necessary. Reduced nozzle sizes are not recommended for steam boilers.

Flue heat loss during burner operation increases for some heating units because of reduced nozzle size. This depends on burner design. Some older

burners require more excess combustion air as the firing rate is reduced because of poorer fuel-air mixing. The air control parts of these burners are not effective at lower firing rates. Replacement of burner parts could improve performance, but this is not practical in most cases. If excess combustion air is needed because of poor fuel-air mixing with the smaller nozzle, then on-cycle losses will increase and counteract savings during the off-period. Smaller nozzles should be installed only when the on-cycle flue heat loss remains the same or decreases.

Reduced firing rate can reduce the supply of domestic hot water for a boiler that uses a tankless coil. Generally, minimum firing rates of about 1.0 to 1.25 are recommended to assure sufficient domestic hot water. This severely restricts the degree by which a boiler firing rate can be lowered. The use of a separate domestic water heater or a hot water storage tank can eliminate this restriction, but the additional cost must be considered.

5.1.3.4 General Installation and Adjustment Requirements. Reduced fuel nozzle size can be included in annual burner tune-up procedures. Fuel nozzles are frequently changed during periodic burner servicing, and lower firing rates should be used whenever possible. The adverse effects discussed earlier must be considered, but a standard service procedure should include evaluation of reduced input. One such procedure is shown in Section 5.2 of this guide.

Combustion efficiency testing to determine flue gas heat loss is an important part of good burner service, and it is essential for selection of the correct fuel nozzle. Combustion testing shows which nozzle is best for the particular burner, and permits correct adjustment of combustion air. Nozzle replacement should not be attempted without combustion test equipment.

5.1.3.5 Saving and Cost Comparison. Reduced fuel firing rate is a low cost option with important benefits. If it becomes part of a periodic service procedure, then the added cost to a homeowner is minimized. Typical fuel savings are 8%. The economics are very favorable as seen in the example below:

- o Percent savings: 8%
- o Annual fuel use: 1500 gallons
- o Annual fuel savings: \$120
- o Installed cost: \$30
- o Payback period: 0.25 years.

The cost of reduced firing rate pays for itself in about three months in this case.

5.1.3.6 Conclusions. Reduced fuel firing rate is a low cost modification that can become part of periodic burner servicing. Fuel savings average about 8% for boilers and furnaces. Smaller nozzles are not suitable for all heating units and several adverse effects must be considered before modification. Standard procedures are available for choosing the appropriate nozzle size, and these can become part of the standard burner adjustment procedures.

5.1.4 Flue Heat Reclaimers

5.1.4.1 Function. A flue heat reclaimer is a secondary heat exchanger that fits in the flue pipe of a boiler or furnace and absorbs heat from the combustion exhaust gases. Reclaimers reduce on-cycle flue heat loss and improve heating unit efficiency. Actual fuel savings depend on initial flue gas temperature and the design of the heat reclaimer.

Flue heat reclaimers reduce excessive flue temperatures, but some flue loss is necessary to supply chimney draft for removal of combustion exhaust gases. Also, most systems must operate with flue temperatures of at least 350°F to avoid condensation of water vapor in the flue gases. Many heating units operate with high temperatures and these are candidates for heat reclaimers.

Two types of reclaimers are available:

- o Water heaters
- o Air heaters

The first type transport boiler water to a heat exchanger in the flue. The water recovers heat from the flue gases and flows back to the boiler for distribution to the house. Reclaimed heat is distributed directly to the heated space through boiler pipes. Some water heat reclaimers are effective fuel savers.

Air type heat reclaimers are similar but air is heated by the flue gases instead of water. This heated air can be used directly by connecting the reclaimer outlet to warm air furnace supply ducts. In this case the heat is distributed to air registers in the house. Many air type heat reclaimers, however, are not designed this way, and their heat is available only in the areas near the heating unit. These units use a small blower to force boiler/furnace room air through the flue reclaimer and fuel saving is reduced because the reclaimed heat is not distributed effectively to the heated space.

5.1.4.2 Expected Energy Savings. Heat reclaimer performance depends on its design and the on-cycle flue gas temperature of the heating unit. Tests of water type reclaimers on boilers at Brookhaven National Laboratory show fuel savings that range from 6 to 20% for typical heating units with high flue temperatures. The difference reflects design variations of the heat reclaimers. Measurement of the actual heat output is necessary to compare the performance of different reclaimers.

Potential savings are estimated by comparing existing on-cycle heat loss to the best case. Recall that 15% on-cycle flue loss is considered unavoidable for conventional systems and represents the best case. Measurement of on-cycle flue loss supplies the information required to predict possible savings. For example, consider a boiler with a flue gas temperature of 700°F and a CO₂ content of 8%. On-cycle heat loss for this case is about 30%. A good heat reclaimer can reduce flue loss by half (from 30 to 15%). Actual fuel savings will depend on final system efficiency.

Note that:

- o If the annual fuel utilization (AFUE) is lower, then fuel savings will be higher.
- o Actual fuel savings is larger than the percentage change in heat loss (because (AFUE) is always less than 100%).

The example below illustrates potential savings for a heat reclaimer under ideal conditions. Many reclaimers cannot operate as effectively, and many flue temperatures are well below 700°F. The sample does show that fuel savings can be estimated by calculating the change in on-cycle heat loss.

Table 5.3 shows the change in on-cycle heat loss for different flue gas temperatures with a CO₂ content of 8%. These illustrate approximate fuel savings for the conditions shown. They are rough guidelines because variations in heat reclaimer designs can change savings substantially as indicated by laboratory tests. Unfortunately, there is no standard testing requirements for heat reclaimers and accurate comparison of various designs is not available for all units.

Table 5.3 shows that fuel savings increase for higher flue gas temperature before reclaimer installation. Similarly fuel savings increase for lower flue gas temperature after the reclaimer. The savings shown range from 4 to 17%. The lowest saving corresponds to low initial flue temperature and poor reclaimer design. The highest values (lower right hand corner) represent high initial flue temperatures and better heat reclaimer design (lower final flue temperature).

If the annual fuel utilization is 75%, then fuel savings will be 20%.

That is:

$$\begin{aligned}\text{Fuel Savings(\%)} &= \frac{\text{Percentage Change in Heat Loss}}{\text{AFUE}} \times 100 \\ &= \frac{30 - 15}{75} \times 100 = 20\%.\end{aligned}$$

Combustion efficiency charts or slide rules supply the information necessary to estimate fuel savings for specific cases. A simple procedure is outlined below:

- 1). Measure flue heat loss of heating unit before heat reclaimer.
 - o Measure flue gas temperature.
 - o Measure CO₂ (or O₂) content of flue gas.

Table 5.3 Approximate Fuel Savings (Percent) for Flue Heat Reclaimers
(CO₂ Content: 8 Percent)

Flue Temperature after Heat Reclaimer	Flue Gas Temperature Before Heat Reclaimer			
	600	650	700	750
500	4	6	8	10
450	6	8	9	11
400	7	9	11	13
350	9	11	13	17
300	11	13	15	17

NOTES:

1. Assumes ambient air temperature of 50°F.
2. Represents change in flue heat loss. Actual fuel savings obtained by dividing by final annual fuel utilization efficiency.
3. Heat loss from jacket of heat reclaimer may reduce fuel savings.
4. Savings are lower when flue gas CO₂ content is higher than 8 percent.

- 2). Use the combustion efficiency chart to determine heat loss before heat reclaimer.
- 3). Measure (or estimate from experience) heat loss after flue heat reclaimer is installed.
- 4). Use the equation below to determine approximate savings.

Actual fuel savings will vary as discussed earlier, but this procedure can be used to estimate the benefit of heat reclaimers for specific cases.

$$\% \text{ Saving} = \frac{\text{Flue Heat Loss Before Reclaimer} - \text{Flue Heat Loss After Reclaimer}}{100 - \text{Final Flue Heat Loss}} \times 100$$

For example, if the initial flue heat loss is 30%, and the final loss is 20%, then the percent savings is:

$$\frac{30 - 20}{100 - 20} \times 100 = 12.5\%.$$

5.1.4.3 Energy Saving for Heat Reclaimers that do not use a Central Distribution System. Estimating fuel savings is more difficult for reclaimers that supply heat to areas nearby the boiler or furnace. Most of this heat will not reach the heated space in many cases. These units may increase the useful heated volume of the structure, but this will not reduce fuel use significantly. Further evaluation of house - heating unit interaction is necessary to estimate savings. General, fuel savings are expected to be lower than the central distribution case discussed earlier.

5.1.4.4 Adverse Effects. Two adverse conditions can result from the use of flue heat reclaimers:

- o Reduced chimney draft.
- o Heating unit corrosion.

Heat reclaimers often contain heat transfer surfaces that reduce the total free area of the flue pipe. These restrictions limit the ability of the chimney to remove combustion exhaust gases. Insufficient chimney draft is a problem for some heating systems and flue heat reclaimers can make the problem worse. Also, heat reclaimer flue passages tend to collect soot, and this further aggravates the problem. The soot deposits reduce the effectiveness of the reclaimer and periodic cleaning is required. Consider the ease of servicing and cleaning when selecting a reclaimer. Many units are almost impossible to clean.

Heat reclaimers reduce chimney draft in another way. The reclaimer lowers exhaust temperature and draft is directly related to this temperature.

Better reclaimers create lower exhaust temperatures and less chimney draft. Some heating units continue to operate properly with lower draft, but others do not. Equipment installers must be certain that there is sufficient chimney draft after heat reclaimer installation.

Heating unit corrosion is another adverse effect of flue heat reclaimers. The cooler exhaust gases approach the point at which water vapor condenses. The water vapor combines with other flue gases to form a corrosive liquid. If the water vapor condenses on heating unit or flue surfaces, then corrosion damage may result. Equipment lifetime is shortened by corrosion. Typically, a temperature of about 350°F is considered safe for oil-fired heating units. Systems with lower flue temperatures or long exhaust pipes are more likely to have flue gas condensation problems.

5.1.4.5 General Installation Requirements. Many different designs exist for flue heat reclaimers and general installation procedures are not available. The procedures outlined by each manufacturer must be followed carefully. Water-type reclaimers are fitted to each boiler differently, because plumbing varies from unit to unit. Several general installation practices are:

- o Locate reclaimer in flue pipe before barometric damper.
- o Allow sufficient access for cleaning reclaimer internal passages.
- o Install safety relief valves as required by manufacturer.
- o Install air vents as required in hot water or steam units.
- o Check plumbing and wiring carefully to be sure manufacturer recommendations are followed.
- o Adjust burner to zero smoke (Bacharach scale).
- o Check flue and overfire draft following reclaimer installation. Be sure there is sufficient chimney draft available. An induced draft fan may be necessary.

Before a reclaimer is installed, the on-cycle flue heat loss should be measured to predict probable savings. Boiler or furnace heat transfer passages should be clean, and the burner should be adjusted to peak efficiency. This procedure will help to determine if a heat reclaimer is the best choice.

5.1.4.6 Saving and Cost Comparison. A typical fuel saving is 12% for a flue heat reclaimer, and installed costs range from less than \$400 to above \$700. The fuel saving and installed cost for an example case are:

- o Percent Savings: 12%
- o Annual Fuel Use: 1500 gallons
- o Fuel Cost: \$1.00 per gallon
- o Annual Savings: \$180
- o Installed Cost: \$550
- o Payback Period: 3 years

The reclaimer in the example above saves \$180 per year and costs \$550, with a payback period of 3 years.

A chart of payback periods for various installed costs, annual fuel uses, and percentage savings are shown in Table 5.4. The minimum payback is about one year ranging up to 14 years for high installed cost and low percentage savings. Heating units with high flue temperatures have large percentage fuel savings and flue heat reclaimers may be a good investment for these units. The flue gas temperature is a reliable measure for selecting heating units for heat reclaimers.

5.1.4.7 Conclusions. Flue heat reclaimers reduce on-cycle heat loss. Some flue heat loss cannot be avoided, but many heating units have excessive losses. Reclaimers that heat boiler water reduce fuel use from about 6 to 20%. Fuel savings are estimated by measuring on-cycle heat loss, and heating units with high flue temperature save the most. Adverse conditions including reduced chimney draft and heating unit corrosion are possible and reclaimers must be installed carefully.

Flue heat reclaimers are not the best option for many heating units. They are add-ons that increase the complexity of the heating system, and, therefore, can cause operational problems. Replacement of old boilers and furnaces is a better option for many homes. Also, other equipment modifications including new flame retention burners reduce on-cycle heat loss. Flue heat reclaimers are useful in some cases particularly where flue gas temperatures are high and boiler or furnace replacement cannot be considered.

5.1.5 Reduced Temperature Settings for Boilers and Furnaces

5.1.5.1 Function. Lowering boiler or furnace temperature is another modification that saves fuel without a loss of comfort level to the occupant. Less heat is stored in a heating unit when the temperature is reduced, and off-cycle heat loss decreases. For example, hot water boilers are often set to supply water at 200°F. In many cases the aquastat (temperature control) can be reduced to 180°F in the winter time and 140°F in the summer for domestic hot water. Similarly, the fan shut-off temperature of a warm air furnace often can be lowered from 140°F to less than 100°F. In both cases off-cycle heat loss decreases.

5.1.5.2 Hot Water Boilers. Temperature controls are adjusted in the field by oil burner service personnel, and it is important to select low settings. The temperature chosen must supply sufficient heat during the coldest months, but it must be low to avoid unnecessary heat loss. Selecting the best setting is not easy. The size of the house and total radiator area

Table 5.4 Flue Heat Reclaimer Payback Periods

Installed Cost of Heat Reclaimer	Annual Fuel Use (Gallons)	Percent Fuel Savings			
		5	10	15	20
\$400	1000	8	4	2.7	2
	1500	5.3	2.7	1.8	1.3
	2000	4	2	1.4	1
\$550	1000	11	5.5	3.7	2.8
	1500	7.3	3.7	2.4	2
	2000	5.5	2.8	1.8	1.4
\$700	1000	14	7	4.7	3.5
	1500	9.3	4.7	3.11	2.3
	2000	7	3.5	2.3	1.8

Note: Installed costs, assumed here for purposes of example, can be lower or higher than shown. Percent fuel savings vary widely and may not be between 5 and 20 percent in all cases.

effect minimum boiler temperatures. Some systems have small radiators and require higher boiler temperature.

The best efficiency occurs if the boiler temperature is adjusted several times during the heating season. Use high temperatures in the coldest winter months, lower temperatures for the milder months, and the lowest settings for summer domestic hot water. Unfortunately, a serviceman usually cannot adjust each heating unit several times each year. There are other solutions to this problem:

- o Teach occupants to adjust the temperature.
- o Use automatic temperature controllers.
- o Operate the boiler for "heat purging".

The least expensive approach is to teach occupants how to adjust boiler temperature. Careful instruction is needed to be sure that the system operates properly. Occupants should be discouraged from making other adjustments that affect safe operation. It may not be possible to impliment this option in Naval housing.

Automatic temperature control units are a more reliable solution. They change the boiler temperatue in response to the outdoor temperature, and low temperatures are maintained throughout the heating season to minimize off-cycle heat loss.

Off-cycle heat loss is also reduced by operating the boiler so that there is no heat stored during the burner off-period. This is called "heat purging." Boiler water continues to circulate after the burner stops, most of the available heat. This requires rewiring of some controls, and it is not acceptable in all cases. Boilers that supply domestic hot water cannot operate in this way. Also, some boilers may leak when the water temperature is too low and these units cannot be completely purged of heat. New low mass boilers are being developed that are designed for purgeable operation.

5.1.5.3 Warm Air Furnaces. The temperature controls for warm air furnaces are also adjusted in the field. Allow the circulating air fan to operate after burner shut-off so that residual heat is removed from the furnace. The fan shut-off temperature is adjustable and should be set for a low temperature. Efficiency improves because of lowered off-cycle heat loss.

5.1.5.4 Expected Energy Savings. Laboratory tests on hot water boilers show a direct relationship between boiler temperature and off-cycle loss. Figure 5.4 shows that off-cycle heat loss doubles when the water temperature increases from 140°F to 200°F. These test results are for one specific burner-boiler combination, but other units show a similar effect. Less test data is available for warm air furnaces, but losses are effected by higher temperature also. Clearly, off-cycle heat loss increases with the temperature of the boiler or furnace.

Actual fuel saving depends on the initial off-cycle heat loss and the degree by which boiler (or furnace) temperatue is reduced. Typical savings

BOILER OFF-CYCLE HEAT LOSS INCREASES
WITH BOILER WATER TEMPERATURE

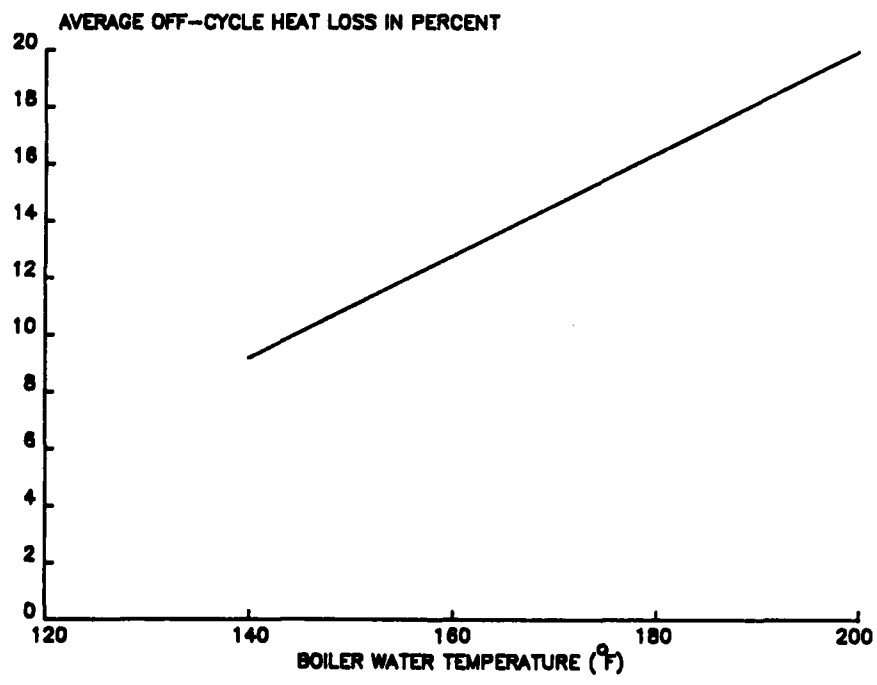


FIGURE 5.4 BOILER OFF-CYCLE HEAT
LOSS INCREASES WITH BOILER
WATER TEMPERATURE

of about 10% are expected for older burner-boilers with large losses when automatic controls are applied. Manual adjustment is less effective and savings are less predictable. Laboratory tests indicate that purgeable boiler operation eliminates most off-cycle heat loss. The annual fuel utilization efficiency is very near the steady state efficiency, and high overall efficiency is possible. Typical fuel savings for warm air furnaces are expected to be lower than for boilers, but in some cases substantial fuel savings are possible.

5.1.5.5 Adverse Effects Hot Water Boilers. Some heating systems require high boiler water temperatures. Two conditions that restrict boiler temperature reductions are:

- o Inadequate radiator area within the house.
- o Tankless coils for domestic hot water.

If the number of radiators or their total surface area is too small, then high boiler temperature is necessary. Otherwise, insufficient heat is supplied to the house on the coldest days. When a system needs boiler water at 200°F or hotter, advise the homeowner to consider adding additional radiators. This enables lower water temperature and reduced heat loss.

High temperature water often is required by boilers with domestic hot water coils (tankless coils). These coils transfer heat from the boiler to the domestic water used in the house. If the boiler temperature is too low, then there is insufficient hot water for showers and other domestic uses. This limitation is avoided by:

- o Using a separate domestic hot water unit.
- o Installing a hot water storage tank.

5.1.5.6 Adverse Effects Warm Air Furnaces. Furnace temperature settings are high for two reasons:

- o To provide adequate air temperature at the registers while the burner is "on".
- o To prevent cool drafts during the furnace cool down (burner-off) period.

In the first case high furnace temperatures assure adequate heat supply to air registers after duct heat losses. It is better to insulate air distribution ducts and reduce the temperature of the furnace supply air.

The second case limits the furnace cool-down time. The temperature of the furnace air drops as stored heat is removed and this cooler air can cause discomfort. The fan shut-off temperature can be set without causing this problem, and a low temperature of 90 to 100°F is often satisfactory.

5.1.5.7 General Installation Requirements. Resetting temperature controls of boilers and furnaces can be included in periodic burner tune-up

procedures. A standard method for selecting the correct setting should be part of a service policy. The best setting reduces fuel use without sacrificing thermal comfort in the home.

5.1.5.8 Savings and Cost Comparison. Savings and cost are considered in two groups:

- o Manual adjustment of boilers and furnaces by service personnel (or occupants).
- o Automatic temperature controllers for hot water boilers.

The cost in the first case is low because temperature adjustment can be part of periodic equipment servicing. The savings expected are small but it is worth the effort. A saving of 3 to 4% is significant and it is well worth the effort since costs are minimal.

Automatic temperature controls are expensive but the savings are usually higher. Estimates of boiler temperature controls show typical costs of about \$350, but this varies. The actual saving depends on initial off-cycle heat loss and the percentage improvement. Expected savings range from less than 5 to above 10%. For these values we find a payback period below:

- o Typical Fuel Use: 1500 gallons
- o Percent Savings: 7.5
- o Annual Savings: (at \$1.00 per gallon) \$112
- o Installed Cost: \$350
- o Payback Period: 3.1 years

5.1.5.9 Conclusions. The efficiency of many heating systems improves with reduced boiler water or fan shut-off temperatures. Manual adjustment of controls can be part of annual tune-up procedures at low cost. Automatic controllers change boiler temperature continuously during the heating season, but compare their installed cost to expected savings. Systems with large off-cycle heat loss and high off-cycle temperature can save the most. Payback periods and annual fuel savings for automatic boiler controls are worthwhile in some cases.

5.1.6. Pipe and Duct Insulation

5.1.6.1 Function. Hot water pipes and warm air ducts waste substantial amounts of energy when they are not insulated, and these losses reduce system efficiency and increase fuel consumption. Pipe and duct loss is avoidable and good installation practice requires the use of thermal insulation to prevent unnecessary heat loss. All heating system distribution lines should be adequately protected against heat loss.

5.1.6.2 Boiler Pipes. Hot water boilers distribute heat to radiators within the house through hot water pipes. The heat loss from this piping system depends on several factors:

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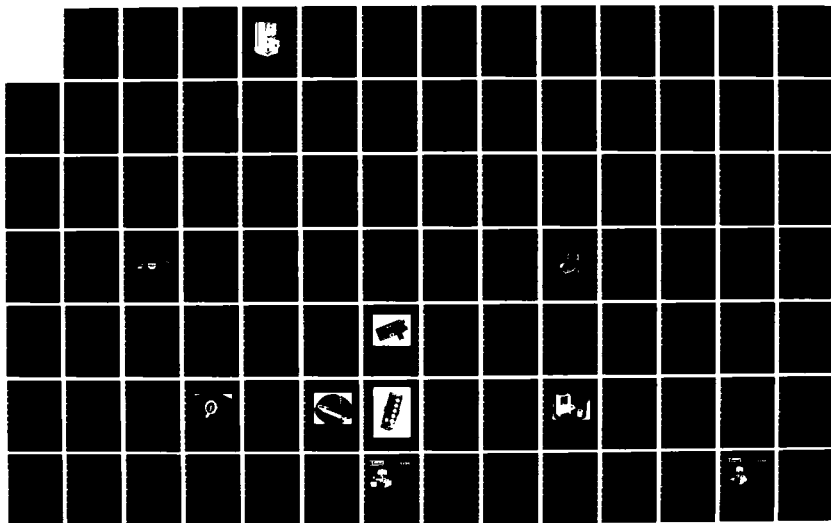
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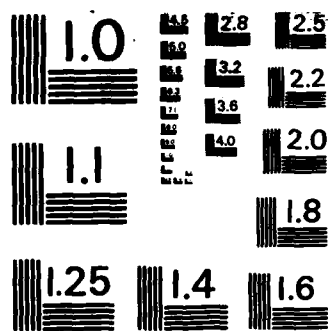
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MICROCOPY RESOLUTION TEST CHART
NATIONAL BUREAU OF STANDARDS-1963-A

- o Temperature of the hot water pipes.
- o Length of piping system.
- o Degree of thermal insulation.
- o Temperature of the air (or other media) surrounding the pipes.

The average percentage of heat loss attributed to uninsulated piping can be 10% or higher. Additional heat loss occurs through hot water pipes during cyclic operation of the heating unit. The 10% value is for heat loss while the burner and hot water circulating pump are both "on" continuously. Heat is also lost from the volume of hot water stored in the pipe during idle periods. This is similar to off-cycle boiler heat loss. An estimate of the off-cycle heat stored in pipes is calculated below for the following assumptions:

- o Total length of hot water piping is 150 feet.
- o Diameter of piping is 1 inch.
- o Temperature of water is 170°F at the start of the off-cycle.
- o Ambient (basement air) temperature is 70°F.

The total volume of water within the pipes is about 6 gallons, and the water cools from 170°F to 70°F, then 5000 Btu's are lost. This represents the maximum loss and it adds to on-cycle distribution loss. The actual loss varies during the heating season as the idle period changes, and the total heat loss from boiler piping is the sum of on-cycle and off-cycle periods.

The typical burner operates about 15% of the time and is idle the rest of the time. Hot water circulating pumps operate more frequently, but on-times vary. In the coldest months water circulates more often, and distribution losses during the on-cycle dominate. *Off-cycle heat pipe loss dominates during milder times when circulator off-times are longer.* Precise estimation of piping heat loss is difficult because system dynamics must be included.

As a general rule, higher water temperature increases heat loss and larger piping systems increase on-cycle loss and heat storage (contributing to off-cycle loss). The air temperature surrounding the pipes affects the rate of heat loss and colder air increases loss and thermal insulation reduces heat loss in all cases.

5.1.6.3 Warm Air Ducts. Ducts that distribute heated air to the house lose heat in two ways.

- o Heat flows from the heated air to colder surroundings (as discussed for boiler pipes).
- o Heated air escapes from leaky duct joints.

Both of these losses reduce the useful heat delivered to the house, and increase fuel consumption. Warm air is lower in temperature than hot water, but duct surface area is much larger. The large duct area and air leaks contribute to relatively high distribution system losses for warm air systems.

Many warm air ducts pass through unheated areas such as attics or crawl spaces. Heat loss into these areas are large because of the cooler surroundings. Inspect all warm air ducts to determine if heat loss is excessive.

Off-cycle heat losses from warm air ducts are expected to be smaller than from hot water piping systems. Heat storage is limited in the warm air systems, and off-cycle loss is small. The significant losses occur while the burner and air circulating fan are operating.

5.1.6.4 Expected Energy Savings - Hot Water Boiler Systems. It is impossible to estimate savings for "average" cases, because each heating system is different. The size of the piping system, the temperature of air surrounding the pipes, and the degree of insulation vary from house to house. Typical savings, however, of 5 to 10% should be expected for originally uninsulated piping.

5.1.6.5 Warm Air Ducts. Prediction of average savings is not possible for the reasons discussed earlier. Savings can range from small values up to 40% depending on original heat losses. Seal and insulate all warm air ducts, particularly those in unheated spaces.

5.1.6.6 Adverse Effects. Few adverse effects are expected from reducing pipe and duct heat loss. Supply temperatures increase and this may cause air temperatures at the supply registers to become too hot. Increase the fan speed or reduce the firing rate if this is a problem. Also, some basements and other "unheated" areas of the house may become colder. Additional radiators or warm air registers can solve these problems.

5.1.6.7 Conclusion. Heat loss from hot water pipes or warm air ducts reduces system efficiency and increases fuel use. Uninsulated piping wastes heat while water circulates and during idle periods. Warm air systems lose heat through inadequate insulation and through leaky duct connections. All of these situations reflect improper installation practices. Distribution losses are not necessary, and must be eliminated whenever possible. Seal air ducts and insulate ducts and hot water pipes, particularly when they pass through unheated areas of the house. Actual savings vary, but the improvement is a worthwhile investment.

5.1.7 Turbulator Replacement in Steel Tube Boilers

5.1.7.1 Function. Turbulators (or baffles) fit into steel boiler tubes to improve heat transfer and reduce flue heat loss. Figure 5.5 shows a typical turbulator in a steel tube boiler. Turbulators increase the rate of heat transfer to the boiler water, and reduce exhaust gas temperature (improving boiler efficiency). The turbulator is a simple device that is included in many steel boilers.

Frequently, turbulators need replacement because of:

- o Partial destruction after many years of service.
- o Removal during boiler cleaning without replacement.

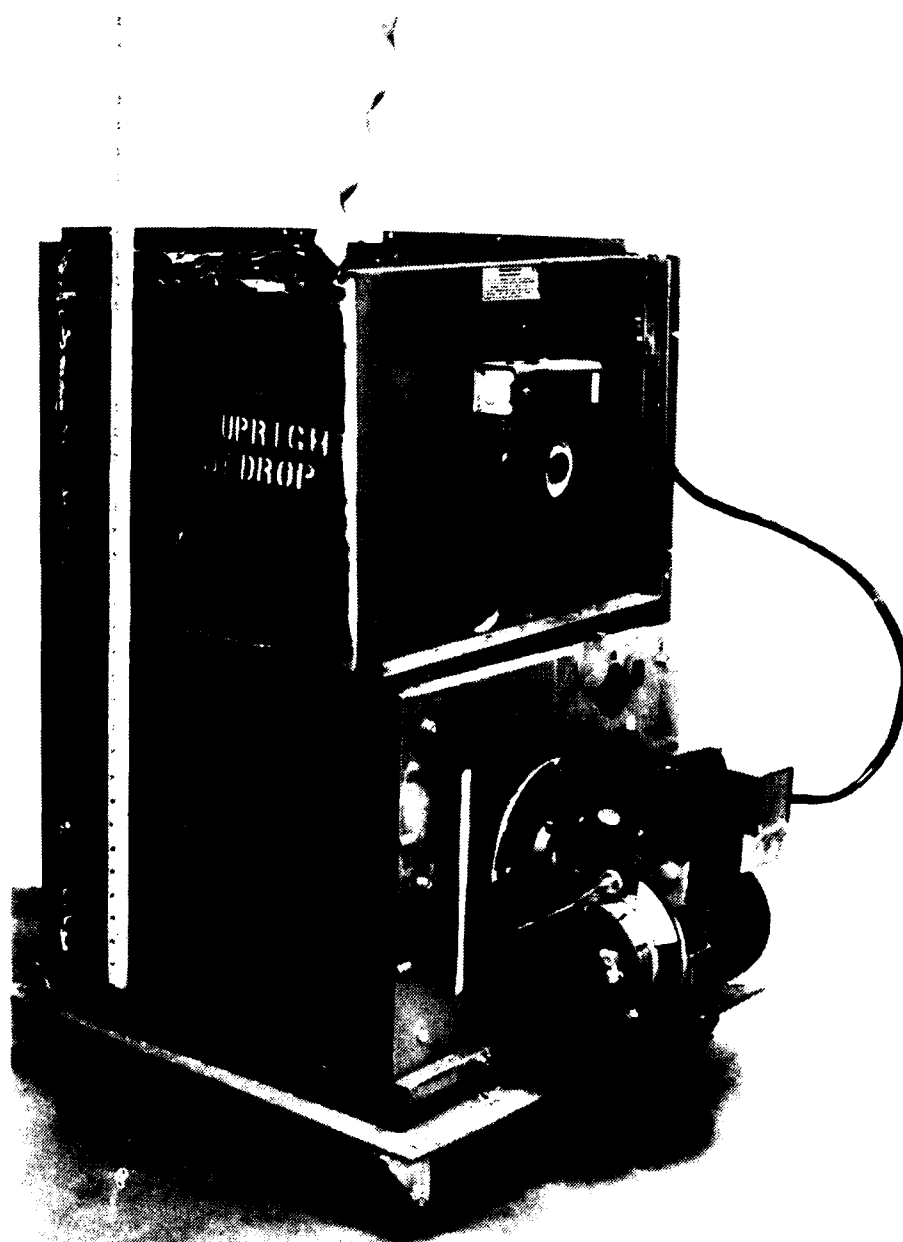


Figure 5.5. A Turbulator partially removed from the boiler.

Unfortunately, turbulators vary in length and width, and the correct size must be used.

5.1.7.2 Expected Energy Savings. Turbulators reduce flue gas temperature and reduce flue heat loss. Typically, flue temperatures drop about 150°F after turbulator installation, and this corresponds to a fuel saving of about 5%. Actual savings depend on initial flue temperatures and the reduction in temperature after installation. Consider installing turbulators in steel boilers with high flue temperature and steel tubes.

5.1.7.3 Adverse Effects. Flue gas turbulators add restriction to the boiler passages and reduce the effect of chimney draft. In most boiler installations this is not a problem. Some units have marginal to poor draft conditions, however, and turbulators could be a problem for these systems. Be sure that there is adequate chimney draft before installing turbulators.

One other problem is excessive reduction of exhaust temperature. If flue temperatures are high initially, then turbulators should not create a condensation problem.

5.1.7.4 General Installation Requirements. Measure boiler flue temperature after system cleaning and burner adjustment. If flue gas temperature is high, determine if turbulators are present. If they are missing or damaged, then install new ones. Measure boiler tube length, diameter, and the number of tubes. Turbulators can be purchased from boiler manufactures or fabricated by sheet metal shops.

5.1.7.5 Conclusions. Turbulator replacement reduces on-cycle heat loss in some steel tube boilers. Choose the correct size and design for each boiler. Expected savings are about 5%, and this normally justifies material and installation costs in most cases. Turbulators are simple devices that present few problems for most boilers and reduce excessive fuel use.

5.1.8 Heating System Tune-Up

5.1.8.1 Function. Periodic cleaning and adjustment of all heating systems assures the highest efficiency and fewest service calls. All combustion systems operate best when they are serviced on a regular basis. Periodic service routines save fuel and prevent equipment breakdowns that are a nuisance to both occupants and service personnel. Good service procedures eliminate many late night emergency service calls and improve occupant satisfaction with oil heat.

Good service procedures include several steps:

- o Visually inspect the entire heating system.
- o Vacuum clean all heating system components including the flue system and boiler or furnace flue passages.

- o Clean all burner parts including the air blower and housing, ignition electrodes, and burner head.
- o Replace fuel and air filters.
- o Seal air leaks around the burner and heat exchanger.
- o Adjust the burner for high efficiency and low smoke number.
- o Use combustion test equipment to measure efficiency.
- o Modify system and readjust until peak efficiency is obtained.
- o Record final combustion efficiency for tuned system.
- o Check all combustion safety controls.

Heating system tuning reduces on-cycle flue heat loss and assures good long term efficiency. Reduced excess combustion air lowers flue heat loss, and low smoke settings avoid soot accumulation and gradual efficiency degradation. In addition, the combustion tests give a sound basis for recommending various efficiency modifications. The information gathered during a system tune-up indicates the peak efficiency that the existing heating unit can reach.

5.1.8.2 Expected Energy Savings. Typical savings for tune-up are about 3% for systems that are regularly adjusted. Fuel savings are more for heating systems that are tuned infrequently and for units that are out of adjustment because of equipment malfunction. For example, the efficiency of a boiler or furnace with a partially plugged fuel nozzle improves significantly after a tune-up. Adjust burners for about a "number one" smoke on the Bacharach scale to prevent soot buildup and a gradual loss of efficiency. Fuel is saved and vacuum cleaning of the heating unit is required less frequently. This reduces service time and permits the service department to operate more effectively.

5.1.8.3 Savings and Cost Comparison. The savings resulting from heating system tune-up vary widely. If fuel savings are about 3%, then the homeowner saves about \$40 per year, and that figure, of course, will go up as the cost of energy rises. Annual tune-up is recommended, but if a system is adjusted properly, then it may not need to be readjusted each year. A simple inspection and efficiency test may be sufficient. Invested time in the initial tune-up pays for itself later, if done properly. A new burner or other retrofit is often advisable once the efficiency of the "tuned" heating unit is known.

5.1.8.4 Conclusions. Periodic cleaning and adjustment of heating units is necessary to maintain good performance. Tune-up procedures should be thorough and include combustion efficiency testing. Good service procedures reduce wasted time and reduce unnecessary service calls.

5.1.9 Replacement of Boilers or Furnaces

5.1.9.1 Function. Some older heating units are inefficient and replacement with new oil-fired boilers and furnaces is better than retrofit modification. A good many of the oil heat units in homes today were designed when both fuel and heating equipment costs were very low. Some were designed to burn coal and were later converted to burn oil. Typical efficiencies are much lower than models currently available. New high efficiency oil boilers and furnaces have efficiencies (AFUE's) of about 76% and go as high as 88%. This has been verified by a federal labeling program for consumer products. Clearly, replacing old and outdated heating units will save fuel.

5.1.9.2 Expected Energy Savings. Fuel savings that result from boiler or furnace replacement depend on the original and final efficiency of the heating system. These efficiencies are difficult to evaluate, but laboratory and field studies show that fuel savings of 21% or more are common. One field investigation by Walden Division of Abcor under contract to the Department of Energy shows an average saving of 28%. Nine out of ten units are expected to save between 18 and 37%.

In some outdated heating units, excessive flue, jacket, off-cycle or distribution heat loss can reduce original system efficiency below typical values and new heating units will save more than 25%. Also, the use of other retrofit techniques at the time of heating unit replacement may add to total fuel savings. These other retrofits are discussed in this section, and one example is duct or pipe insulation. If the pipes or ducts are insulated as part of the installation procedure, then fuel savings will improve.

A government testing and labeling program for home appliances estimates the efficiency of new heating units operating under "typical" conditions. These test procedures do not account for all installation, adjustment and service factors, but they can be used to select efficient new boilers or furnaces. The problem is that the labeling program applies only to new units, and it cannot be used to evaluate the annual fuel utilization efficiency of older heating units.

In fact, no simple method is available to evaluate these units because it is not possible to measure jacket, off-cycle, and distribution heat losses accurately and determine yearly averaged values. This prevents accurate prediction of fuel savings for specific boiler or furnace replacements.

Some design features of older systems tend to increase heat loss and lower efficiency. These characteristics can form the basis of a check list for likely replacement candidates. Some of these are listed below:

- o Designs that allow substantial jacket heat loss by;
 - Large jacket area around the combustion chamber
 - Dry-base combustion chamber
 - High density combustion chamber materials (fire brick)
 - Poor jacket insulation

Some converted coal units have very large combustion chambers and jackets that permit substantial heat loss. In contrast, many newer units are more compact and they use insulating chamber materials.

- o Massive combustion chambers constructed of heavy firebrick store energy that can be lost through the jacket and flue during the off-cycle. Some old boilers and furnaces have heavy chambers.
- o Some burner designs use "open" end cones that cannot restrict off-cycle air flow. Also, secondary air openings or other design leaks can increase off-cycle heat loss and reduce efficiency.
- o High stack temperatures will increase on-cycle heat loss, and this may be caused by insufficient heat exchange area or poor heat exchange because of wide flue passages without baffling. High stack temperatures also are caused by improper service and adjustments including soot accumulation or overfiring. If the stack temperature is excessive for a clean unit with the correct firing rate and burner adjustment, then the design of the boiler or furnace may be the problem.

The items discussed above do not provide a fixed set of rules for replacing burners or furnaces. They can assist identification of heating systems that will benefit most by boiler or furnace replacement.

5.1.9.3 Adverse Effects. New boilers and furnaces are not expected to present adverse effects when compared to the older units they replace. Service requirements should be reduced, and occupant satisfaction improved. Properly installed replacement boilers and furnaces provide many years of economical thermal comfort.

5.1.9.4 General Installation Requirements. The discussion of burner installation applies also to burner-boiler and burner-furnace units. Additional considerations include adjustment of temperature controls, pipe or duct insulation and some other recommendations included in previous parts of this section. Proper installation and adjustment is as important for boilers and furnaces as it is for burners. Installation procedures should follow manufacturer recommendations, and other manuals on boiler or furnace installation.

5.1.9.5 Saving and Cost Comparison. A basis for evaluating the value of boiler or furnace replacement is the payback period (discussed earlier). The payback period is the number of years required to pay for the new equipment with fuel savings. Payback periods vary with:

- o Original system efficiency.
- o Final system efficiency.
- o Cost of equipment.
- o Fuel consumption.
- o Price of fuel per gallon.

Fuel cost reduction and payback period are calculated in the example below:

- o Fuel savings of 25 percent.
- o Installed cost of \$1,800 for the new equipment.
- o Fuel consumption of 1500 gallons per year.
- o Fuel price of \$1.00 per gallon.

(Installed costs vary widely and can be considerably less than or greater than this example).

$$\begin{aligned}\text{Annual Savings}(\$) &= (\% \text{ Fuel Savings}) \times (\text{Fuel Use Gal.}) \times (\text{Price per gal.}(\$)) \\ &= (25\%) \times (1,500 \text{ gal}) \times (\$1.00/\text{gal}).\end{aligned}$$

$$\text{Annual Savings} = \$375 \text{ per year}$$

$$\text{Payback Period} = \frac{\text{Equipment Cost}(\$)}{\text{Annual Savings}(\$/\text{yr})}$$

$$\text{Payback Period} = \frac{\$1,800}{375/\text{yr.}} = 4.8 \text{ years.}$$

This payback period is longer than those calculated earlier for flame retention head burners. See table 5.5 for other examples. Annual savings for new heating systems is much higher than new burners, however, and this is \$375 for the case shown. Burner replacement will save about \$225 under similar conditions.

Estimates of probable fuel savings are a powerful tool when trying to justify a new heating unit. Equipment installations should focus on outdated systems characterized earlier so that the units with poorest efficiency are replaced before the others. Combustion testing should be used to evaluate burner on-cycle loss which often accounts for half of the total losses. the government ratings required for all new heating appliances should be used to select the replacement boiler or furnace with the highest efficiency.

5.1.9.6 Conclusions. Replacement of obsolete boilers and furnaces with modern highly efficient models can reduce fuel cost more than any other option available to homeowners. Typical savings are about 25%, but this will vary from system to system. Field data shows that most units will save between 18 and 37%, giving payback periods from 7.5 to 3.6 years. Information gained from the government labeling program can identify new high efficiency units, and older boilers and furnaces with outdated design features should be replaced. High equipment costs may deter user investment, but paybacks become shorter as the price of fuel rises.

**Table 5.5 Payback Period in Years Necessary to Recover Cost of
New Boiler or Furnace**

Installed Cost of New Furnace or Boiler	Annual Fuel Use (Gallons)	Percent Fuel Savings from Boiler or Furnace Replacement			
		20	25	30	35
\$1500	1000	7.5	6	5	4.28
	1500	5	4	3.33	2.86
	2000	3.75	3	2.5	2.14
\$2000	1000	10	8	6.67	5.71
	1500	6.67	5.33	4.44	3.81
	2000	5	4	3.33	2.86
\$2500	1000	12.5	10	8.33	7.14
	1500	8.33	6.67	5.56	4.76
	2000	6.25	5	4.17	3.57

Note: For purposes of example, assumes fuel is \$1.00 per gallon. For other fuel costs divide payback period by actual cost in dollars/gallon. Installed costs varies widely.

5.2 Procedure for Selecting the Correct Fuel Nozzle

Fuel nozzle sizes that are too large are found in many warm air furnaces and hot water boilers. Excessive firing rates increase burner on-cycle and off-cycle heat losses, reducing system efficiency. The fuel nozzle size must be small in order to reduce unnecessary heat loss, yet it must be large enough to:

- Heat the house adequately when outdoor temperatures drop to their lowest level.
- Supply sufficient domestic hot water.
- Produce a clean and efficient flame.

Many heating systems are overfired because sizing procedures in the past included a number of "sizing factors" such as "piping" and "pick-up" factors to assure adequate heat delivery. Unfortunately, these sizing practices can reduce system efficiency and waste fuel. Reducing the firing rate and readjusting the combustion air supply often improves the efficiency of heating units. The following steps show some of the important considerations with respect to selecting and installing the correct fuel nozzle size.

5.2.1 Selecting the Correct Size Nozzle

A relatively simple but reliable method for selecting the fuel firing rate uses the Winter K-factor. The K-factor is a measure of fuel consumption by a house in terms of degree-days per gallon and it is often used by fuel dealers to schedule oil deliveries.

A degree-day is a measure of "coldness," and more degree-days indicate colder weather.

Degree Days = Average Daily Temperature

For example, if the average temperature outside is 30°F. ($65 - 30 = 35$ degree days.) Each winter day adds more degree-days to the winter total.

The K-factor equals degree-days required to consume one gallon of fuel oil in a particular home. It is similar in nature to the miles per gallon rating for automobiles. The K-factor can be used to estimate the correct fuel nozzle size.

NOTE: This section is based on: "A Service Manager's Guide to Saving Energy in Residential Oil Burners - Optimizing Nozzle Size," Federal Energy Administration, June 1977.

STEP 1. Obtain the average winter K-factor for the house.

- a.) Fuel dealer records often show a K-factor for each delivery. Average the K-factor for three or more recent winter deliveries to obtain the average winter K-factor.
- b.) If K-factors for a house are not available, they can be calculated from fuel delivery and degree day records. Add up the total gallons of fuel delivered and the total number of degree-days during the delivery interval. Divide the degree-day total by the number of gallons to obtain the K-factor.

$$\text{K-factor} = \frac{\text{Total number of degree-days}}{\text{Gallons of fuel delivered}}$$

NOTE; Be sure to leave out the gallonage delivered on the starting date because this fuel "filled" the tank.

For example, calculate the K-factor from the fuel delivery records shown below:

<u>DATE</u>	<u>GALLONS OF FUEL DELIVERED</u>	<u>DEGREE-DAYS BETWEEN DELIVERIES</u>
11/25	180	
12/19	175	510
1/5	205	615
1/30	180	555
TOTAL	560	1,680

$$\text{K-factor} = \frac{1680}{560} = 3.0 \frac{\text{Degree-days}}{\text{Gallons}}$$

STEP 2. Determine the winter outdoor design temperature in degrees F for the geographic region.* The design temperatures for several cities are shown below:

*can be found in: ASHRAE Handbook - Fundamentals, The American Society of Heating, Refrigeration and Air Conditioning Engineers, 1981, Chapter 24, Table 1.

<u>City</u>	<u>Design Temperature (°F)</u>
Augusta, Maine	-7
Boston, Massachussets	6
Buffalo, New York	2
New York, New York	11
Philadelphia, Pennsylvania	10
Pittsburg, Pennsylvania	1
Columbus, Ohio	0
Chicago, Illinois	-8
Minneapolis, Minnesota	-16
Des Moines, Iowa	-10
Washington, D.C.	14
Raleigh, North Carolina	16
Spokane, Washington	-6
Portland, Oregon	17

STEP 3. Determine the minimum fuel nozzle size by:

a.) Using the Minimum Nozzle Size Chart shown on the next page (Figure 5.6).

- Find the K-factor along the bottom of the graph.
- Move upward parallel to the verticle lines until the correct diagonal "Design Temperature Line" T_D is reached.
- Move to the left (parallel to the horizontal lines) to find the minimum nozzle size.

For example, for the conditions below:

K-factor: 3.0

Design Temperature: 0

The Minimum Nozzle Size is 0.9 Gallons per hour.

b.) The equation below can be used instead of the chart to determine the minimum fuel nozzle size.

$$\text{MINIMUM NOZZLE SIZE} = \frac{65 - 0}{(3.0)(24)} = 0.9 \text{ gallons per hour}$$

NOTE: 1) the FEA/NBS report used as the basis for this section states that the nozzle size should be at least:

- 0.5 gph for warm air systems
- 0.65 gph for hot water boilers not supplying domestic hot water
- 0.85 gph for hot water boilers with separate storage tanks for domestic hot water
- 1.20 gph for hot water boilers with "tankless coils" for domestic hot water.

T_D = local outdoor design temperature in °F

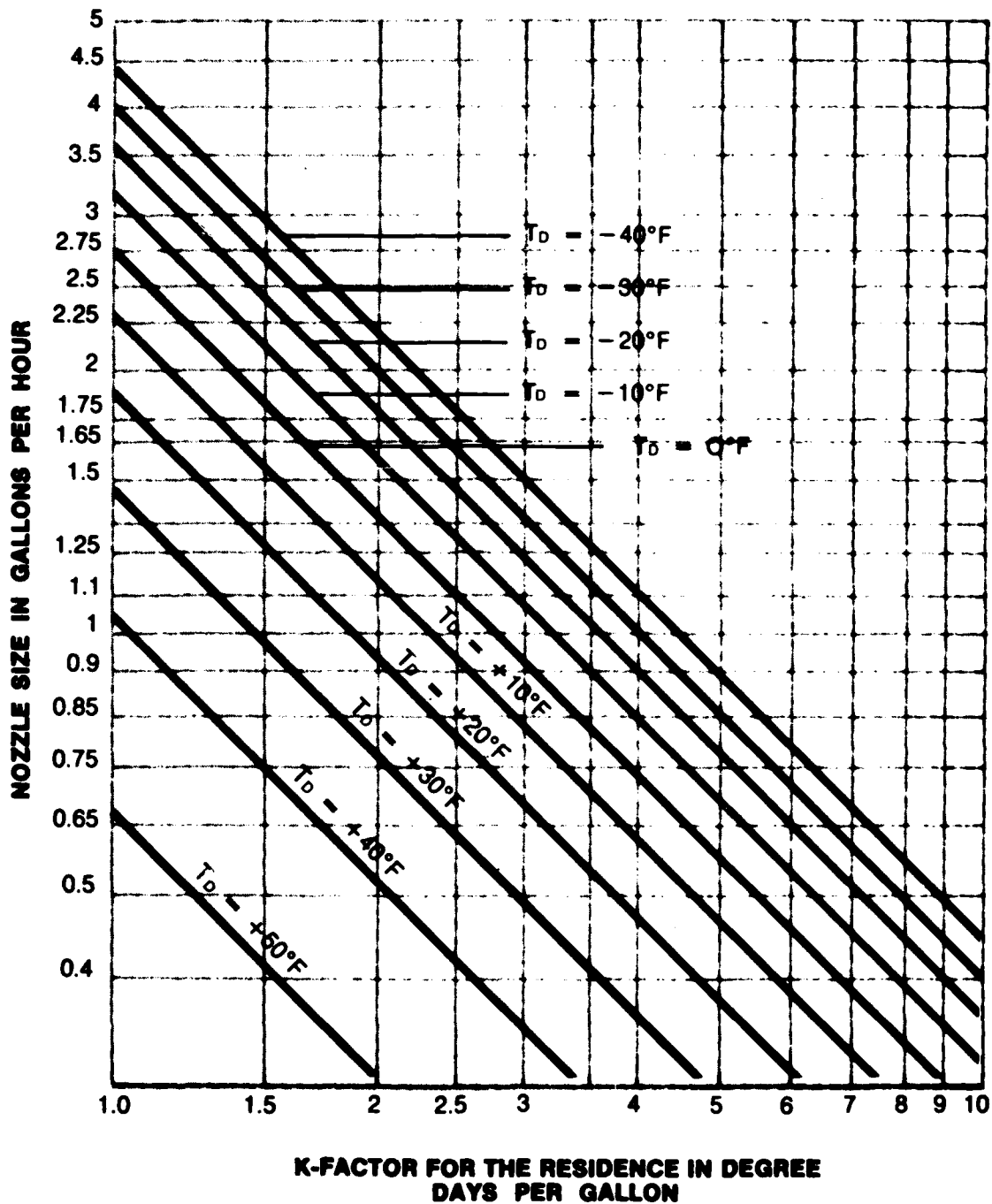


FIGURE 5.6 MINIMUM NOZZLE SIZE

These limits may be too conservative (for single family residential structures), and smaller nozzles may be advisable in some cases. Consult equipment manufacturers for recommendations concerning new equipment designed for smaller fuel nozzle sizes.

- ii) The minimum nozzle size is a lower limit and final nozzle selection depends on performance tests of the heating unit after installation.
- iii) The procedure for selecting the minimum fuel nozzle size can be performed in the office prior to the service call.

5.3 Installing the Correct Fuel Nozzle Size

The minimum nozzle size calculation is a starting point for choosing the best fuel nozzle, but it is a theoretical value. The nozzle size of some heating units cannot be reduced because of equipment limitations such as out-dated burner designs that produce smoke at reduced inputs, and boilers with tankless coils. Installing the correct nozzle includes measuring heating unit performance so that the smallest nozzle capable of good performance is used. The procedure shown below is one method for reducing the firing rate that includes many important steps.

STEP 1. Determine First Trial Nozzle Size

- o Obtain minimum nozzle size (see previous section).
- o Inspect heating unit to determine rated input of the boiler or furnace and firing rate range of the burner. Consult manufacturer specifications or rating books if necessary.
 - Never use a nozzle size that is less than the low input rating of the burner.
 - Do not reduce beyond manufacturer's specifications the firing rate for steam systems because this may inhibit steam production.
 - Use a nozzle that is at least 50 percent of the boiler or furnace input rating.
 - Be careful not to reduce the firing rate too much for boilers that supply domestic hot water.
- o Decide on a first trial nozzle size based on the information above.

STEP 2. Repair and Tune-Up the Heating System

- o Seal air leaks (compare flue and overfire CO₂ readings).
- o Clean heat exchange surfaces if necessary.
- o Adjust burner air for low smoke and peak efficiency (see Section 3.2).

Installing the correct nozzle size can become part of the regular service procedure.

STEP 3. Measure the Efficiency and Smoke Number

Measure the efficiency and smoke number before changing the firing rate, because these readings gave a basis for comparing changes in performance with other fuel nozzles.

STEP 4. Install Trial Nozzles and Make Required Adjustments

- o Remove the nozzle assembly.
- o Install a nozzle of the size determined in STEP 1, with a spray angle and pattern similar to the original nozzle. Also, consult burner manufacturer recommendations for spray angle and pattern.
- o Replace the nozzle-electrode assembly and check adjustments carefully.
 - Check forward-backward positioning of the nozzle and nozzle centering. Use a sheet of paper to check the position by placing a corner of the paper at the nozzle orifice. The edges of the paper should not touch the end cone of the burner.
 - Check the position of the ignition electrodes and adjust if necessary.
 - Inspect the combustion chamber and replace if seriously degraded. If the combustion chamber is oversized, install a preformed or "wetpak" chamber of the correct size.
- o Operate the burner and adjust the combustion air shutter.
 - Visually inspect the flame for stability and uniform distribution in the combustion chamber. Be sure that the flame does not impinge on any surfaces.
 - Follow the burner air adjustment procedure in Section 3.2. Adjust to a "number one" smoke (or lowest smoke number possible above "number one").

STEP 5. Remeasure the CO₂ Percent, Flue Gas Temperature and Smoke Number, and Determine the New Efficiency.

- o If all three conditions below are met:
 - The new efficiency is equal to the original value (or less than two percentage points lower.)
 - The smoke number is two or less.
 - The flue gas temperature is more than 350°F.

THEN: the correct nozzle is in place. GO TO STEP 7.

- o Otherwise continue to STEP 6.

STEP 6. Try Additional Nozzles

- o If the smoke number is above 2, try the same size nozzle with different spray angles and patterns, or try a larger nozzle size.
- o If the flue gas temperature is below 350°F, install a larger fuel nozzle size.
- o If the efficiency dropped more than 2%, try a larger nozzle size.

Go to Step 4 and continue.

Note: 1) Experience in burner servicing is the best guide for deciding on trial nozzles.

- ii) Do not increase the nozzle size above the original value.

STEP 7. Perform Final Checks and Record Test Results

- o Perform final checks on heating system (see Section 3.2).
- o Record important information gathered during the procedures above.

This includes:

- Date of service;
- Original nozzle size, CO₂, flue gas temperature, smoke and efficiency.
- Final nozzle size, CO₂, flue gas temperature, smoke and efficiency.
- The firing rates, spray angles and patterns of nozzles tested.

5.4 Retrofit Summary

The summary in Table 5.6 relates each retrofit modification to the system heat losses that are effected most. Typical savings and brief comments are included. The heat losses decrease from left to right for most heating systems. That is, on-cycle loss is greater than off-cycle loss and so on. It is not surprising that most of the modifications affect heat losses in the first two columns, because this yields the greatest savings. The chart points out another important fact. The savings for combined modifications are not additive. For example, if a vent damper (8%) is combined with reduced firing rate (8%), then fuel saving is less than 16 percent, because each heat loss is reduced only once. Combinations of retrofits are discussed in section 5.5

A. Flame Retention Burner.

Function: reduces on-cycle flue loss and off-cycle heat loss.

Average Savings: 15 percent.

Comments:

- o Inspect combustion chamber and replace or reline as required.
- o Install burner according to manufacturer specifications.
- o Reduce fuel firing rate whenever appropriate.
- o Adjust air setting using combustion test equipment.

Conclusions: one of the best modifications for improving heating system performance at a low cost.

B. Replacement Boiler or Furnace.

Function: reduces on-cycle, off-cycle and jacket heat loss (in some cases).

Average Savings: 25 percent--depends on system efficiency before and after replacement.

Comments:

- o Replace obsolete systems that have large heat losses.
- o Install high efficiency new equipment.
- o Install and adjust system properly using combustion test equipment.

Conclusions: can save the most energy, but is more expensive than a new burner.

C. Vent Damper.

Function: reduces off-cycle and outdoor air infiltration losses.

Average Savings: 8 percent.

Table 5.6 Summary of Equipment Modifications to Improve Efficiency

Retrofit	Heat Losses Effectuated					Range of Typical Savings (%)	Comment
	On-Cycle Flue Loss	Off-Cycle Loss	Jacket Loss	Pipe and Duct Loss	Outside Air Infiltration		
Flame Retention Burner	X	X				5-25	Check combustion chamber. Adjust Property.
High Efficiency Boiler or Furnace	X	X	X			20-35	Replace obsolete units with high efficiency models
Vent Damper		X			X	2-14	Use for units with large off cycle loss.
Flue Heat Reclaimer	X					6-20	Possible chimney draft problems
Reduced Fuel Firing Rate	X Increases in Some Cases	X	May Become More Significant			6-10	Not for all burners not for steam boilers
Reduced Temperature of Boiler or Furnace		X		Reduced in Some Cases		5-12	Be aware of lowered heat delivery
Pipe and Duct Insulation				X		5-10	Check all heating systems
Turbulator Replacement	X	May be Reduced Slightly				3-8	Possible draft problems
Heating System Tune-Up	X					2-4	Use combustion test equipment

Comments:

- o Proper installation is essential.
- o Dampers that close tightly (without cut-outs) are most effective.
- o Recommended for heating units with large off-cycle losses.
 - o Steam boilers.
 - o Hot water boilers with tankless coils.
 - o Boilers or furnaces that must operate at high temperature.

Conclusions: economically attractive for heating system with high off-cycle heat loss.

D. Reduced Fuel Firing Rate

Function: reduces off-cycle heat loss and on-cycle loss in some cases.

Average Savings: 8 percent--depends on existing firing rate and off-cycle losses.

Comments:

- o Not advisable for all burners, particularly older units with poor fuel-air mixing.
- o Do not reduce the firing rate of steam boilers.
- o Do not reduce the firing rate too much or space heating and domestic hot water supply will decrease.
- o Use combustion efficiency test equipment and a standard procedure for all nozzle reductions.

Conclusions: reduces fuel consumption at a small cost. Hot water boilers or furnaces that supply space heating only (no domestic hot water) are the best systems for lower firing rates. There is a possibility of slightly reduced heat output.

E. Flue Heat Reclaimer.

Function: reduces on-cycle flue heat loss by lowering flue gas temperature.

Average Savings: 12 percent--varies with initial flue gas temperature and reclaimer design.

Comments:

- o Units that use the existing heat distribution system (pipes or ducts) are recommended.
- o Reduced chimney draft and heating system corrosion are adverse effects to avoid.
- o Good installation and periodic cleaning are necessary.

Conclusions: reduces fuel use for systems with high flue gas temperature, but problems related to chimney draft, heating system corrosion and cleaning requirements are encountered. Other retrofits are often a better choice.

F. Reduced Temperature of Boiler or Furnace.

Function: reduces off-cycle heat loss. Also reduces distribution system (pipe or duct) loss.

Average Savings: 5-10 percent. Highly variable depending on off-cycle and distribution heat losses.

Comments: (For Boilers)

- o Periodic manual adjustment is inexpensive but gives limited savings.
- o Automatic temperature controllers are more effective but costly.
- o Inadequate radiator area within the house, and tankless coils for domestic hot water restrict boiler temperature reduction.
- o Rewiring boilers that supply only space heat into a purging mode of operation is effective.

(For Furnaces)

- o Adjust fan shut-off control to a low temperature.

Conclusions: reduced temperatures save fuel but some boilers or furnaces require a minimum temperature. Adjust controls to produce the lowest acceptable temperature to reduce off-cycle losses.

G. Pipe and Duct Insulation.

Function: reduces distribution system heat loss.

Average Savings: 5 percent or more.

Comments:

- o Insulate pipes in unheated spaces.
- o Seal air leaks and insulate warm air ducts.

Conclusions: insulation of pipes and ducts is an effective means for conserving fuel oil.

H. Turbulator Replacement for Steel Boilers.

Function: reduces on-cycle flue heat loss for steel tube boilers.

Average Savings: 5 percent.

Comments:

- o Turbulators add restriction to flue gas passages and may cause draft problems in systems with poor chimney draft. Check the overfire draft after turbulator installation.
- o Be sure that the final flue gas temperature is not too low after turbulator replacement. Minimum flue temperatures of 350°F are usually recommended.

Conclusions: turbulator replacement, when required, reduces heat loss and conserves heating oil at a reasonable cost. Check steel tube boilers to be sure that turbulators are present.

I. Heating System Tune-Up.

Function: reduces on-cycle heat loss by reducing excess combustion air and by cleaning heat transfer surfaces.

Average Savings: 3 percent. Savings depend on initial burner adjustment and system cleanliness.

Comments:

- o Good service procedures include all the steps necessary to achieve high efficiency.
- o Combustion efficiency testing is part of good servicing.
- o Good adjustment procedures reduce later service calls and cleaning requirements.

Conclusions: clean and adjust all heating units periodically using a standard procedure incorporating combustion efficiency testing.

The costs of modification vary widely from tune-up to complete replacement of the heating unit. The four options in this guide involve considerable cost, while the other five are often less expensive. This factors into the final decision. Be aware of the long term advantages of some of the higher cost equipment modifications, because these are often the best choices.

Deciding on which efficiency improvements to recommend is not always easy, because fuel savings is difficult to predict for a specific house. The savings shown in this section represent average values and individual cases vary. In order to predict fuel savings, all heat losses (on-cycle, off-cycle jacket, distribution, and air infiltration) must be measured. Unfortunately, this is not possible in most cases. On-cycle heat loss is known through combustion efficiency testing, but the other losses cannot be evaluated in the field. Therefore, it is difficult to accurately predict savings for each retrofit in order to identify options for a specific system.

Combustion efficiency testing shows burner on-cycle heat loss and is vital for heating system evaluation. Combustion testing is useful for

deciding if new burners, flue heat reclaimers or turbulators should be recommended, because on-cycle flue loss is the main loss affected. The other options involve other heat losses and prediction is more difficult. In these cases heating system inspection gives valuable insight into the importance of these losses.

Heating system inspection is important because it identifies burner, boiler and furnace design and installation characteristics that effect system efficiency. The combination of combustion efficiency testing and system inspection supply the information needed to formulate decisions.

The specific retrofit option(s) recommended depends on the results of combustion efficiency testing and system inspection. The information below shows conditions that favor the use of each retrofit.

1. Flame Retention Burner is advisable when:

- o Combustion test efficiency AFTER tune-up is less than 75 percent.
- o Smoke exceeds number 2 after tune-up or occurs during start-up or shut-down.
- o The basic boiler or furnace involved is potentially efficient and able to accept a new burner.

2. Boiler or Furnace Replacement is advisable when:

- o Combustion efficiency is low (below 70 percent).
- o Boiler or furnace off-cycle and jacket losses are high (see earlier discussions).

3. Vent Damper is advisable when:

- o System off-cycle and air infiltration heat losses are high.
- o Specific systems can include:
 - o Steam boilers.
 - o High temperature hot water boilers.
 - o Boilers that supply domestic hot water all year.
 - o Oversized warm air furnaces that cycle frequently.

4. Reduced Fuel Firing Rate is advisable when:

- o Fuel nozzle size is greater than the design input of the boiler or furnace.
- o An oversized fuel nozzle is suspected after inspection of the heating system or during an annual tune-up.
 - A method for estimating proper nozzle sizing by K-factor is shown in Section 5.2.
 - Do not reduce the firing rate of steam boilers.
 - Be careful with boilers that supply domestic hot water.
- o A smaller nozzle is within the rated firing rate range of the burner. Check combustion efficiency to be sure that on-cycle heat loss and smoke number do not increase.
- o A new burner is installed.

5. A Flue Heat Reclaimer is advisable when:

- o Combustion efficiency is low because of high flue gas temperature.
- o Boiler or furnace heat exchanger is clean.
- o Burner is tuned properly and CO₂ percent is at its peak value.
- o CO₂ percent (after tune-up) is low but burner replacement is not selected for some reason.
- o Boiler or furnace replacement is not selected.
- o Turbulator replacement is not appropriate.
- o A reliable heat reclaimer is available and service personnel are trained for proper installation and servicing.

6. Reduced Temperature Setting for Boiler and Furnace is advisable when:

- o Off-cycle heat loss is high.
- o Hot water boiler temperature settings are high.
 - Not for steam systems.
 - Not for all units with tankless coils.
- o Rewiring for heat purging is possible (for space heating only boilers).
- o Automatic temperature controllers are available and cost effective, or
- o Furnace air blower temperature settings are too high.

7. Pipe and Duct Insulation is advisable whenever:

- o Uninsulated hot water pipes or warm air ducts pass through unheated sections of the house.
 - o Basements
 - o Attics
 - o Crawl spaces
 - o Outside walls
 - o Garages

8. Turbulator Replacement is advisable when:

- o Steel boiler inspection shows that some or all of the turbulators are missing.
- o Flue gas temperature can be reduced.
- o Chimney draft is adequate.

9. Heating System Tune-Up is advisable when:

- o One year or more has passed since the last system tune-up.
- o Performing a heating system efficiency evaluation.
- o Soot or odor problems are encountered.
- o Servicing or replacing any parts of the heating system that effect efficiency performance.

5.5 Retrofit Combinations

When more than one modification is used, the expected fuel savings is difficult to estimate. The savings cannot be determined by adding together

the savings for each individual modification because some retrofits effect the same heat loss. For example, flame retention burners and flue heat reclaimers both reduce on-cycle flue heat loss. This combination saves less than 28 percent (16 plus 12) when applied to typical boilers. In general, savings are not additive. The best retrofit is the one that saves the most energy and has the lowest installed cost. Additional modifications cost more and achievable fuel savings often are less.

Some combinations are sensible because different heat losses are affected. The chart in Table 5.7 shows various retrofit combinations and identifies some worthwhile combinations. The primary modifications include equipment installations that are costly to perform, while the secondary modifications include equipment installation and lower cost adjustments (i.e., reduced firing rates, reduced temperature, duct and pipe insulation, turbulator replacement, and system tune-up). In all cases Duct and Pipe Insulation and Heating System Tune-up are worthwhile (represented by a G in the chart).

For example, consider combining secondary retrofits with a flame retention burner. A separate vent damper is often unnecessary because the burner reduces off-cycle heat loss. An exception is a heating system with very high off-cycle losses. A flue heat reclaimer is questionable because the new burner reduces on-cycle heat loss and flue gas temperature. Reduced firing rate, reduced boiler or furnace temperature, duct or pipe insulation, turbulator replacement and heat system tune-up are considered good combinations. Some of these can become part of the new burner installation and adjustment routine.

Use the information in the chart to develop a list of single and multiple choices for each building. In some cases multiple retrofits are sensible depending on the final installed cost. In other cases replacement of the boiler or furnace with a highly efficient model is better for the total costs that are involved.

A. Flame Retention Head Burner.

Function: reduces on-cycle flue loss and off-cycle heat loss.

The retention head burner already provides good control of off-cycle heat loss rendering the additional application of a vent damper as potentially unviable in an economic sense. In terms of adding a flue heat reclaimer, the retention heat burner may have reduced on-cycle losses to the point where the heat reclaimer is not economical or not even correctly applied if the resulting flue temperatures are too low and cause condensing to occur in the chimney. All the remaining adjustments are still appropriate because they add to rather than duplicate the savings potential of the retention head burner.

B. High Efficiency Boiler or Furnace.

Function: reduces on-cycle flue loss, off-cycle and jacket heat loss (in some cases).

Table 5.7 Equipment Modifications/Retrofit Combinations

Secondary Modification									
Primary Modification	Equipment			Adjustment					
	Flame Retention Burner	Vent Damper	Flue Heat Reclaimer	Reduced Firing Rate	Reduced Temp. Boiler or Furnace	Duct or Pipe Insulation	Turbulator Re-placement	Heating System Tune-Up	
Flame Retention Burner	NA	Q	Q	G	G	G	G	G	
High Efficiency Boiler or Furnace	NA	Q	Q	G	G	G	NA	G	
Vent Damper	Q	NA	G	Q	Q	G	G	G	
Flue Heat Reclaimer	Q	G	NA	G	G	G	Q	G	
Automatic Boiler Temp. Controller	G	Q	G	G	NA	G	G	G	

G - Good: A modification that improves the overall benefit through combination because of savings and cost.

Q - Questionable: A modification that will not provide a reasonable benefit in combination because of reduced savings or increased cost. A modification which requires some careful site specific judgement.

N/A -

Not Applicable: A modification which duplicates the function of the replaced equipment.

The savings potential for vent dampers and flue heat reclaimers are reduced for the same reasons discussed above. The economics are less favorable for the add on devices because the new boiler or furnace will operate together with the accompanying retention head burner in reducing on-cycle and off-cycle heat loss. All the remaining adjustments are appropriate because they add to rather than duplicate savings.

C. Vent Damper.

Function: reduces off-cycle and outdoor air infiltration losses.

Again the vent damper and the retention head burner each duplicate the control of off-cycle losses making the savings potential of the combination a poor economic choice. The combination of a vent damper with the flue heat reclaimer is reasonable in that heat stored in the reclaimer is not lost in the off-cycle. Both reduced firing rate and reduced boiler temperature are controlling factors in off-cycle losses and may effect all the remaining savings realized by a vent damper installation. The remaining adjustments are appropriate because they add to rather than duplicate savings potential.

D. Flue Heat Reclaimer.

Function: reduces on-cycle heat loss by lowering the flue gas temperature.

Again the flue heat reclaimer and the retention head burner each duplicate savings in on-cycle losses making the savings potential or the combination a poor economic choice. The combination of the flue heat reclaimer and turbulator replacement may not work well in that the resulting flue gas temperatures leaving the boiler heat exchanger may be too low for the heat reclaimer or that the combined flow restriction could adversely affect the flue gas draft characteristics of the system. All the remaining modifications and adjustments are appropriate because they add to rather than duplicate savings.

E. Automatic Boiler Temperature Controller

Function: to control boiler water temperature as a function of outdoor temperature.

The temperature controller and the vent damper each suppress off-cycle losses and the savings potential for the combination might not be economically viable. All of the other remaining modifications and adjustments are appropriate because they add to rather than duplicate savings.

Reference:

Upgrading Oil Home-Heating Systems, Brookhaven National Laboratory, December 1979, U.S. Government Printing Office: 1980, 617 - 319.

APPENDIX A
COMBUSTION THEORY

This appendix is provided to review basic concepts about the process of combustion. You should understand this process before tackling the other parts of this guide! It's likely that a good deal of material presented is familiar to you, but there's an even better chance that you might learn something new. It's worth the effort - this information develops the foundation from which every dependable oil service technician should work.

This appendix and appendix B are based primarily on material developed in 1978 by the Massachusetts Better Home Heat Council and was distributed by them as part of a report entitled "Oil Heat Energy Conservation Manual." This material is used with their kind permission. When and where appropriate, this material was modified and enhanced with up to date information.

The Better Home Heat Council (BHHC) received financial support for development of this material through the Massachusetts Energy Office, as part of the 1978 State Energy Conservation Plan, funded by the U.S. Department of Energy under PL94-163 and PL94-384. BHHC also received technical assistance from the Walden Division of Abcor, Inc. and from numerous individual members of BHHC's Technical Review Committee.

Fuel Oil

No. 2 distillate fuel oil (domestic heating oil) is a product of the refining of crude oil which is formed underground over millions of years through decomposition of marine organisms, fish, and vegetation. This organic matter eventually becomes liquid or gas concentrated underground in pockets or pools. All petroleum products, including natural gas, gasoline, kerosene, No. 2 fuel oil, etc., are chemical compounds that make up crude oil and they all contain carbon and hydrogen.

The process of separating these various components can be quite complex, but is commonly referred to as "refining." Eventually, one of the products of the refining process is No. 2 fuel oil which is found to have characteristics suitable for use as a fuel in residential oil burners. The designation "No. 2" is used as a specification guide that defines some physical characteristics such as flash point, ash content, viscosity, etc.

When fuel oil is burned, the chemical energy that is stored in the oil is released in another form of energy: heat. But to create this conversion of energy, an external source of heat must be applied to the oil droplets to start the reaction. The electric spark generated by the electrodes of an oil burner provides the initial heat. The heat from the electrodes causes oil droplets to become oil vapors and eventually burn continuously. This burning then heats the surrounding oil droplets causing them to burn. This process will begin to release heat faster than heat is lost to the surroundings so that the burning process will continue to ignite itself without the need for the additional spark of the electrodes. If the conditions for combustion are ideal, all oil droplets will vaporize and then burn completely and cleanly within the combustion zone. Combustion is the process of burning.

Combustion

Combustion, as we normally think of it, is generally described as "rapid oxidation" of any material which is classified as combustible matter. The term "oxidation" simply means the adding of oxygen in a chemical reaction and "combustible matter" means any substance which combines readily and rapidly with oxygen under certain favorable conditions. Since fuel oil primarily consists of carbon (85%) and hydrogen (15%), combustion of fuel oil, according to our previous definition, is the rapid combining of carbon and hydrogen with oxygen.

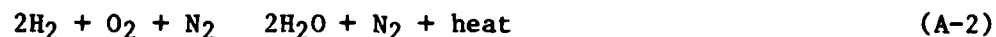
As you know, the oxygen needed for combustion comes from the air blown into the burner. Approximately twenty-one (21) percent of the air is oxygen while the remainder (79%) is nitrogen. Therefore, to supply the oxygen needed for combustion, a great deal of nitrogen goes along for a free ride. This will become an important factor in later discussions of proper oil burner adjustment!

What we see and feel from combustion - flames, smoke, heat - is a result of chemical reactions. Since we can't see carbon, hydrogen or oxygen atoms (the smallest units to combine), we symbolize the reactions with formulas that describe the process. For example:

Carbon + Air Oxygen + Nitrogen (forms) Carbon Dioxide + Nitrogen + Heat (A-1)

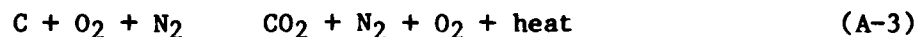
Hydrogen + Air Oxygen + Nitrogen (forms) Water Vapor + Nitrogen + Heat (A-2)

These reactions can be rewritten using symbols that represent the different chemical species in the following manner:



Both chemical reactions produce entirely new products and each reaction gives off heat. However, you may have noticed that in each reaction nitrogen (N_2) has not changed, indicating that nitrogen does not participate in the reactions. If pure oxygen rather than air were used in these reactions, the final products of each reaction would be heat plus CO_2 and H_2O , respectively. We know that flue gas does not contain 100% CO_2 and H_2O and now we can see why! Because of the large amounts of nitrogen in the air, the bulk of the flue gas is made up of unreacted nitrogen.

If exactly the right amount of air (no excess air) were supplied for complete combustion of the carbon and hydrogen in the fuel oil, the products of combustion would be as indicated in Figure A.1. However, with actual oil burner equipment, it is not possible to get a perfect mixture in which all the carbon and hydrogen are supplied with the exactly correct quantity of oxygen. To insure that all the carbon and hydrogen come into contact with enough oxygen to burn completely, excess air must be supplied. The excess air is simply air over and above the theoretical requirement for the combustion of fuel oil. With excess air needed for combustion, reaction (A-1) becomes:



Note that the only difference between reaction (A-3) and reaction (A-1) is that O_2 (oxygen) is a product of the reaction. This O_2 is the oxygen in the excess air that does not combine with carbon to make carbon dioxide. In essence, extra O_2 is provided, as a component of excess air, to guarantee that all the carbon and hydrogen come in contact with the oxygen and burn.

This excess air does not react during the combustion process but enters the heating unit at room temperature and reduces the temperature of the combustion gases so less heat is available to be transferred to the distribution medium. As a result, excess air is a source of heat loss. By introducing 50% excess air, the situation shown in Figure A.2 is created. Compare this with Figure A.1 - note that

- o the amount (weight) of H_2O , CO_2 , and N_2 formed is the same
- o the percent by volume of CO_2 and N_2 formed is less than is formed in Figure A-1.

FIGURE A.1

Amount by Weight and Volume of Combustion Products when one pound of Fuel Oil is Burned (0% excess air)

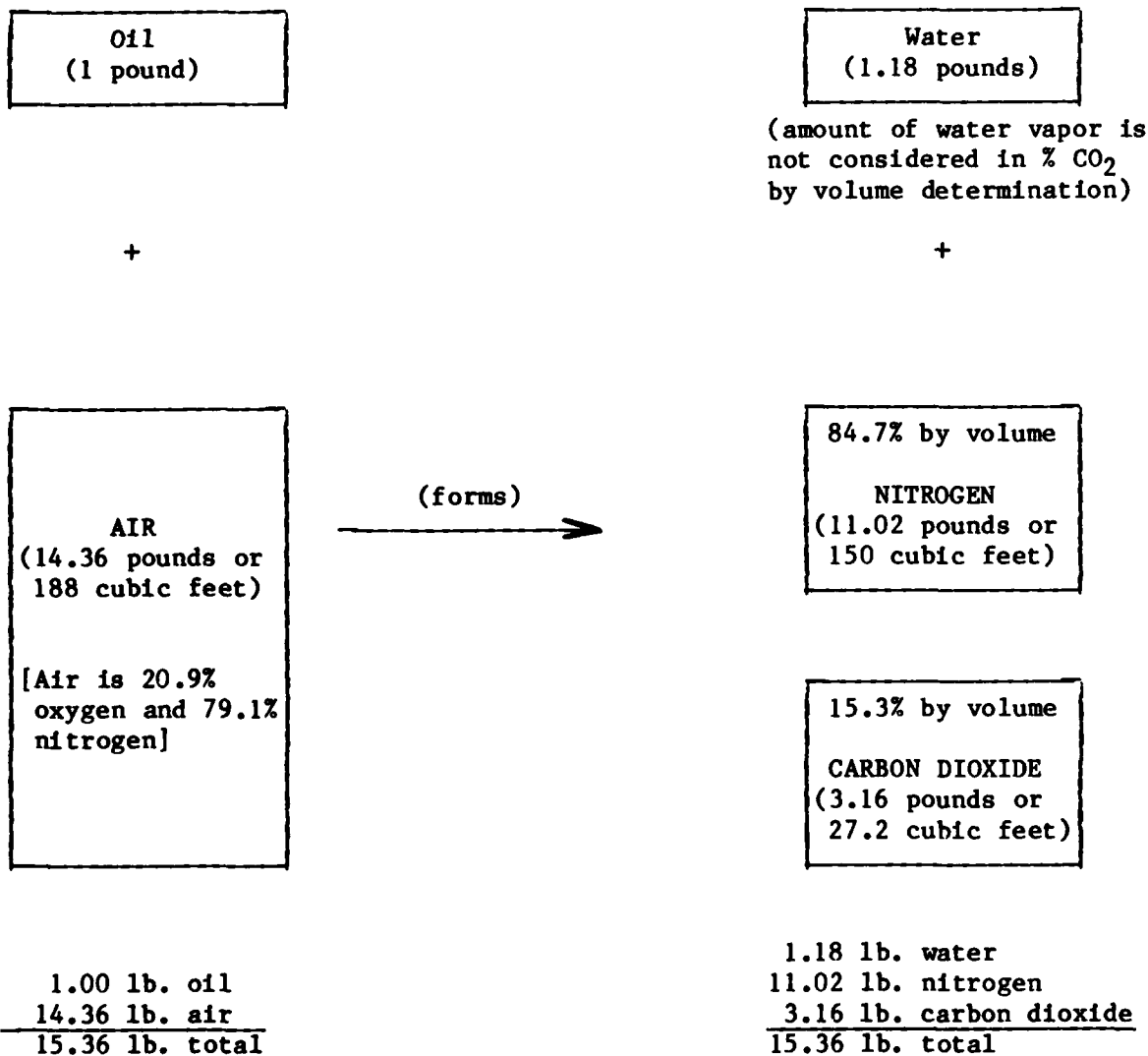
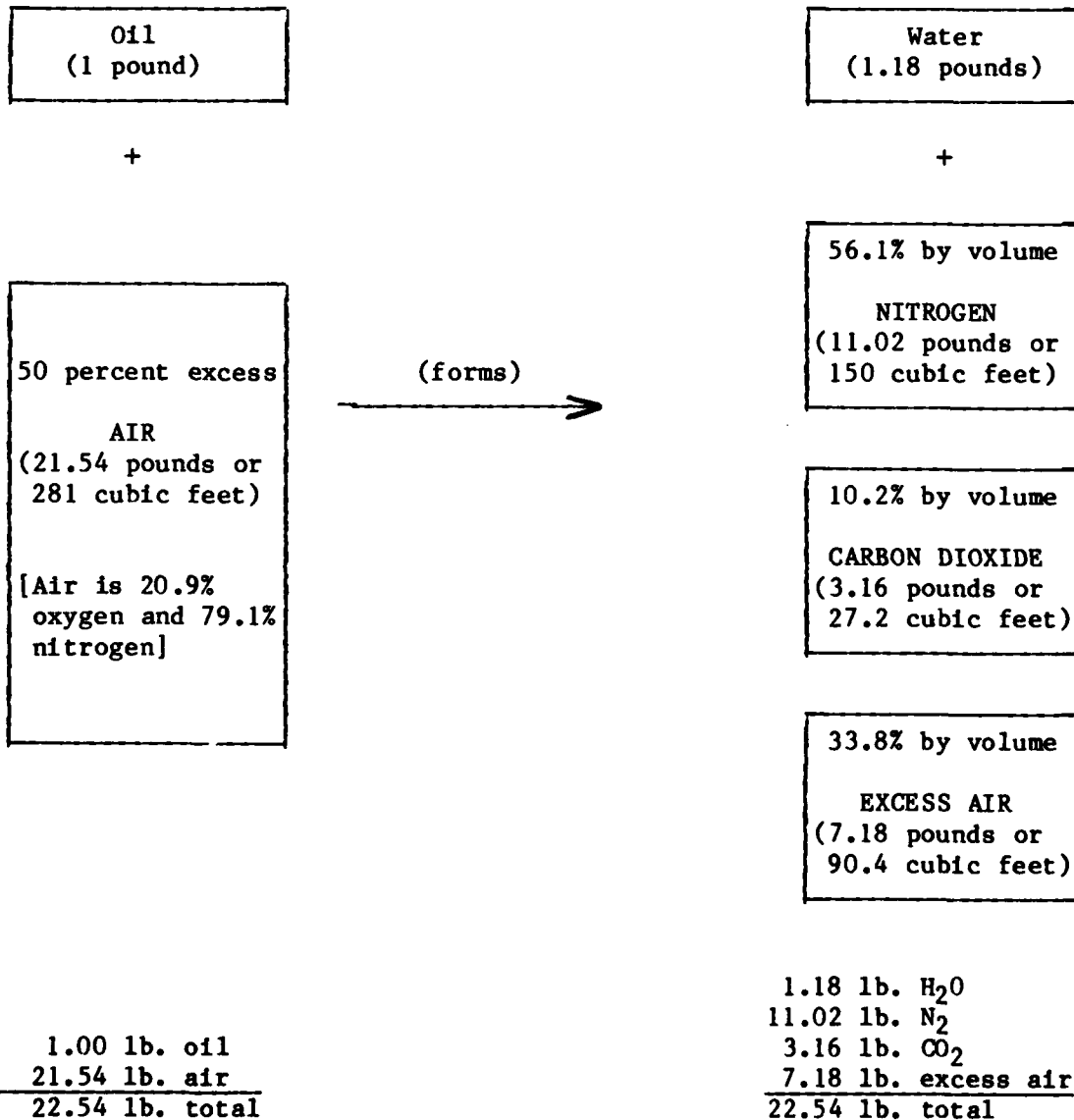


FIGURE A.2

Amount by Weight and Volume of Combustion Products when one pound of Fuel Oil is Burned (50% excess air)



- o Oxygen (as part of excess air) is a product in Figure A.2 but not in Figure A.1.

In Figure A.2, since 20.9 percent of the excess air is oxygen, 7.1 percent of all the combustion gases is oxygen. You determine this by multiplying the percent excess air (33.8%) times that portion of excess air which is oxygen (.209). This gives approximately 7.1 percent oxygen.

Note that in Figure A.2 the percentage of CO_2 or O_2 changed from Figure A.1 as a result of excess air, therefore, we can use the percent CO_2 or O_2 in the flue as a measure of excess air or vice versa - as a general rule

- o The greater the CO_2 , the less excess air
- o The greater the O_2 , the more excess air

Figure A.3 displays the relationship between CO_2 and excess air.

The above discussion is a simplification of the actual combustion process. The chemical reactions provided are only those that are important to the overall combustion process. Nevertheless, the information in this section is sufficient to support you in your oil burner service work. Make sure you understand the concepts and if necessary reread this section or ask a knowledgeable person to assist you. Don't go on without understanding the basic concepts!

Combustion Chamber

The function of the combustion chamber is to surround the flame and to radiate heat back into the flame to aid in fuel vaporization and combustion. The combustion chamber design and construction helps determine whether the fuel will be burned efficiently. The chamber must be made of the correct material, properly sized for the nozzle firing rate, shaped correctly, and of the proper height.

The chamber should be designed and built to provide the maximum space required to burn the oil needed to fire the heating plant and to meet its load. Unburned droplets of oil should not touch the chamber surface, especially a cold surface. A cold surface will reduce combustion temperatures and cause soot and carbon formation. The hotter the area around the burning zone, the easier the oil droplets will vaporize and ignite, and the hotter the flame will be. If the chamber is too small, the oil will not have enough time to complete combustion before it strikes the colder walls.

When the chamber is too large, there will be areas in the chamber which the flame will not fill. This causes cooler chamber surfaces and reduces the reflected heat from the chamber walls. As a result, the fuel droplets will not evaporate as rapidly in the cooler chamber and will be more difficult to burn completely. More air will be required to burn smoke-free and the result will be low CO_2 (high O_2) and lowered efficiency.

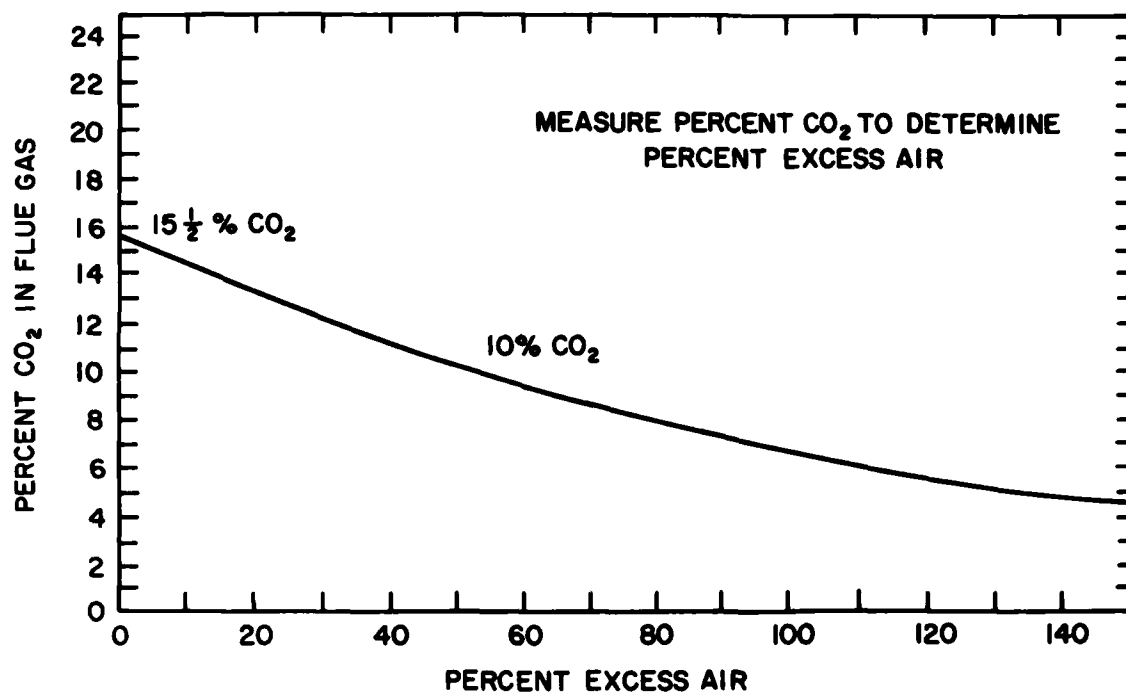


FIGURE A.3 RELATIONSHIP BETWEEN
EXCESS AIR AND CO₂

Floor Size

The size of the combustion chamber is measured in square inches of floor space. The ideal size for a home is about 80 to 90 square inches per gallon of oil. If the burner is functioning well, and the chamber has quick heating refractory material, and is properly designed, it is possible in most cases to use this formula up to 1.50 GPH. For residential use, the chamber should not normally exceed 95 square inches per gallon for a high pressure (retention head) burner.

When the combustion chamber is accurately sized to the heating plant capacity it is extremely important that the nozzle pattern and spray angle conform to the characteristics of the burner air pattern and that the oil pressure at the nozzle should normally be 100 PSI unless manufacturers instructions contain other specifications.

Shape

The majority of combustion chambers are square, rectangular or round. Curved surfaces generally produce more complete mixing of oil and air and also eliminate the pockets of air in the corners of square or rectangular chambers which reduces the reflected heat from the chamber walls to the flame. The air in these corners also does not usually become a part of the combustion process and therefore dilutes the combustion products as they flow through the heating plant. This is particularly true of the corners at the front of the chamber where the oil is sprayed in because the flame is narrow and the oil has not been heated up to maximum temperature at this point. See Figure A.4.

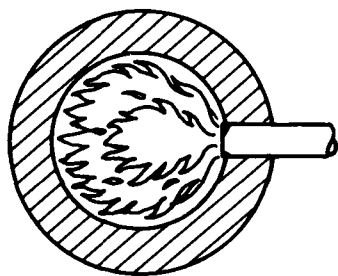
A well designed chamber will have all corners filled in and generally this should be more extensive in the front so that the wall will be closer to the desired flame pattern. It will then confine the flame and more reflected heat will enter the combustion process in its early stages. This will aid combustion and provide much smoother ignition. In making alterations in the chamber, you must keep in mind that in addition to filling in corners, you must use the nozzle spray pattern and angle to fit the chamber.

Walls

It is important that the walls of the chamber should be high enough to assist combustion, but not to interfere with the heat transfer from the combustion products to the heat exchanger. Figure A.5 shows the height to be used based on the firing rate. The chamber wall should be 2 to 2-1/4 times as high above the nozzle as it is from the floor to the nozzle.

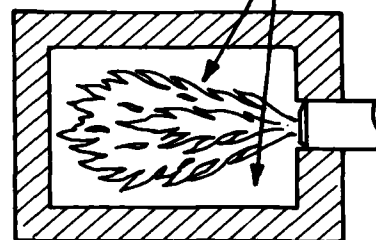
If the base of a heating plant has a tendency to overheat, the walls should be 2-1/2 to 3 times the height from floor to nozzle. This is sometimes a problem in gravity type air duct systems. Be sure to use insulation between the furnace and chamber wall up to the top of the wall.

Space between the chamber wall and the heating plant should always be filled with an insulating material, such as mica pellets. A poor grade of backfill shortens the life of the chamber, reduces the efficiency at which the oil burns, and increases combustion noise.

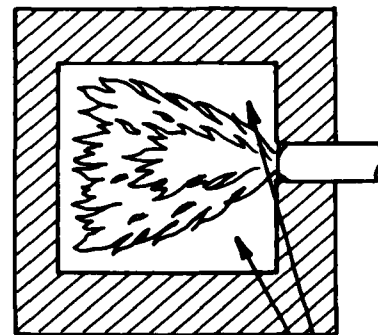
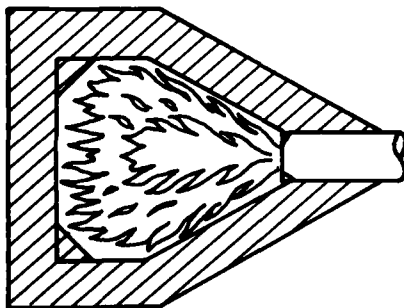


GOOD COMBINATION

EDDY CURRENT
POCKETS



CORNERS SHOULD
BE FILLED



EDDY CURRENT
POCKETS

FIGURE A.4 COMBUSTION CHAMBER
DESIGN

Figure A-5. Combustion Chamber Sizing Data

Oil Consumption G.P.H.	Sq. in. Area Combustion Chamber	Sq. Combustion Chamber in.	Dia. Round Combustion Chamber in.	Rectangular Combustion Chamber in. Wth. x lgth.	Height from Nozzle to Floor Inches			
					Convent ional Burner Single Nozzle	Convent ional Burner Twin Nozzle	Sunflower Flame Burner Single Nozzle	Sunflower Flame Burner Twin Nozzle
80 sq. in. per gal.	.75	8 x 8	9		5	x	5	x
	.85	8.5 x 8.5	9		5	x	5	x
	1.00	9 x 9	10 1/8		5	x	5	x
	1.25	10 x 10	10 1/4		5	x	5	x
	1.35	10 1/2 x 10 1/2	11 3/4		5	x	5	x
	1.50	11 x 11	12 3/8		5	x	6	x
	1.65	11 1/2 x 11 1/2	13	10 x 12	5	x	6	x
	2.00	12 5/8 x 12 5/8	14 1/4	10 x 13	5	x	7	x
	2.50	14 1/4 x 14 1/4	16	11 x 14 1/2	6	x	7.5	x
	3.00	15 1/2 x 15 1/2	17 1/2	12 x 16 1/2	6.5	x	8	x
				13 x 18 1/2	7	5		6.5
90 sq. in. per gal.	3.50	17 3/4 x 17 3/4	20	15 x 21	7.5	6	8.5	7
	4.00	19 x 19	21 1/2	16 x 22 1/2	8	6	9	7
	4.50	20 x 20		17 x 23 1/2	8.5	6.5	9.5	7.5
	5.00	21 1/4 x 21 1/4		18 x 25	9	6.5	10	8
100 sq. in. per gal.	5.50	23 1/2 x 23 1/2		20 x 27 1/2	9.5	7	10.5	8
	6.00	24 1/2 x 23 1/2		21 x 28 1/2	10	7	11	8.5
	6.50	25 1/2 x 25 1/2		22 x 29 1/2	10.5	7.5	11.5	9
	7.00	26 1/2 x 26 1/2		23 x 30 1/2	11	7.5	12	9.5
	7.50	27 1/4 x 27 1/4		24 x 31	11.5	7.5	12.5	10
	8.00	28 1/4 x 28 1/4		25 x 32	12	8	13	10
	8.50	29 1/4 x 29 1/4		25 x 34	12.5	8.5	13.5	10.5
	9.00	30 x 30		25 x 36	13	8.5	14	11
	9.50	31 x 31		26 x 36 1/2	13.5	9	14.5	11.5
	10.00	31 3/4 x 31 3/4		26 x 38 1/2	14	9	15	12

Burning Setting

The chamber must be installed so that the oil can burn clean without impinging on the floor and causing carbon to form. Figure A.6 shows the inside dimensions recommended by a burner manufacturer. The burner end cone should typically be installed 1/2" back from the inside chamber wall. Always check the individual manufacturers installation instruction manual for proper burner mounting dimensions. We recommend that you cover the end cone edges with high temperature insulating material to prevent the burnout of the end cone.

Baffles

A baffle stool or a hanging baffle installed over the combustion chamber may help increase the combustion chamber temperature. It will aid in causing the combustion products to scrub the walls of the heat exchanger which will result in more heat absorption.

A firetube boiler can often be equipped with spiral (twist) baffles in the tubes to enhance heat transfer and thus improve efficiency. These baffles should be checked and cleaned annually.

Soft Refractory

Refractories of low specific heat and low conductivity (fiberfax or Kaowool ceramic fiber types) will rise in temperature more rapidly from a cold start and maintain a higher temperature during steady operation of an oil burner. This will help produce more complete combustion and increase the heat transfer by radiation to the heat transfer surfaces of the heat exchanger.

Tests by National Bureau of Standards comparing a hard brick to a precast soft chamber in the same boiler determined that losses by radiation, conduction, convection and incomplete combustion were 13.4% for the brick and 8.6% for the precast. The difference was equal to 8300 BTU's per hour in favor of the precast. This amounts to a possible saving of 6%.

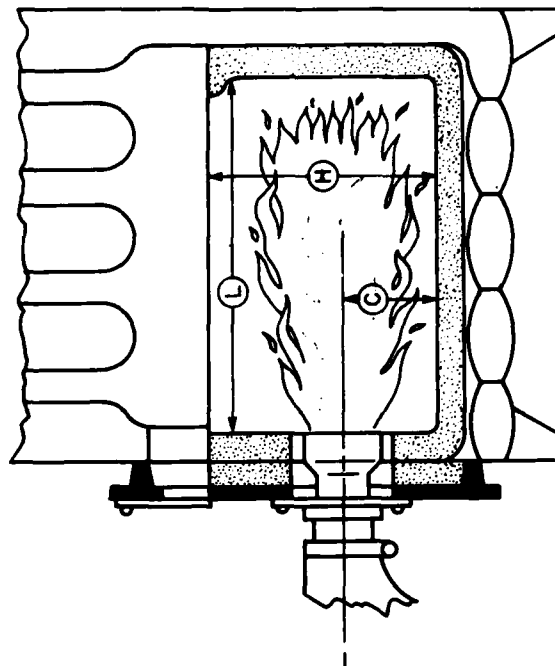
Although it is possible to obtain a relatively good fire without a chamber, you should realize that a properly sized and shaped combustion chamber will substantially improve combustion, provide a hotter flame, and reduce the amount of soot accumulation associated with start-up and shutdown. Large fire commercial burners are frequently fired without a chamber, but with small residential burners the chamber becomes extremely important. The modern materials for chamber construction become red hot within 20 seconds after starting the fire, causing heat to be reflected back into the oil spray, speeding up the conversion of liquid oil to vapor, and making the flame smaller but hotter. In general combustion temperatures of high speed flame retention head burners will be somewhat higher than older conventional burners.

FIGURE A.6 RECOMMENDED MINIMUM
INSIDE DIMENSIONS OF REFRACTORY-
TYPE COMBUSTION CHAMBERS

1 Firing Rate (GPH)	2 Length (L)	3 Width (W)	4 Dimension (C)	5 Suggested Height (H)	6 Minimum Dia. Vertical Cyl.
0.50	8	7	4	8	8
0.65	8	7	4.5	9	8
0.75	9	8	4.5	9	9
0.85	9	8	4.5	9	9
1.00	10	9	5	10	10
1.10	10	9	5	10	10
1.25	11	10	5	10	11
1.35	12	10	5	10	11
1.50	12	11	5.5	11	12
1.65	12	11	5.5	11	13
1.75	14	11	5.5	11	13
2.00	15	12	5.5	11	14
2.25	16	12	6	12	15
2.50	17	13	6	12	16
2.75	18	14	6	12	18

NOTES:

1. Flame lengths are approximately as shown in column (2). Often, tested boilers or furnaces will operate well with chambers shorter than the lengths shown in column (2).
2. As a general practice any of these dimensions can be exceeded without much effect on combustion.
3. Chambers in the form of horizontal cylinders should be at least as large in diameter as the dimension in column (3). Horizontal stainless steel cylindrical chambers should be 1 to 4 inches larger in diameter than the figures in column (3) and should be used only on wet base boilers with non-retention burners.
4. Wing walls are not recommended. Corbels are not necessary although they might be of benefit to good heat distribution in certain boiler or furnace designs, especially with non-retention burners.



While we have had much to say about the improved combustion achieved through utilization of a chamber, there are also some other benefits to be considered. Chambers act as sound absorbers and this feature is highly desirable as flame-retention burners tend to be somewhat louder than the older burners they are replacing. Another benefit obtained from combustion chambers is the protection of those portions of the dry-base boiler or furnace which could not withstand prolonged exposure to intense heat or the rapid heating-cooling of the metal.

When the correct firing rate to match the heat load has been determined, the proper size combustion chamber should be selected to match that firing rate. This will result in maximum efficiency being achieved. The relation between the size of an existing chamber and the determination of the correct firing rate to fit that chamber is important and should be considered whenever the firing rate is altered.

Heat Exchanger

The next step in the operation of the heating plant is the transfer of heat energy from the combustion gases to the air in the furnace or to the water in the boiler. This is accomplished in the heat exchanger which can be thought of as a wall which keeps gases or liquids separated and allows heat energy to flow out of the hot medium and into the cooler medium. Heat is transferred in two ways:

- o Hot combustion gases directly contact the heat exchange surfaces and transfer heat
- o Radiant energy in the combustion chamber heats the heat exchange surfaces (similar to being heated by the sun)

The selection of wall material will depend on its ability to easily pass heat, its cost, and several other factors. This is a whole area of study in and of itself.

If the heat exchanger were a perfect transfer of heat, all the energy in the combustion products would be transferred to the distribution medium. This would mean no losses of heat! With no heat losses the stack temperature would be reduced to room temperature. Of course you know this is not the actual case. Losses are caused by:

- o Temperature differences
- o Contact time
- o Insulation

The greater the temperature difference between the combustion gases and the temperature of the air or water to be heated, the more heat will be transferred in a given time. There is very little that can be done about the temperature of the air or water to be heated, but if the temperature of the combustion gases can be raised, more heat would be transferred. This is another reason why a high flame temperature from the burner is desirable.

The longer the hot combustion gases are in contact with the walls of the heat exchanger, the more heat will be transferred. The scrubbing of the heat exchanger walls by the combustion gases is essential. This means that small flue passages in the heat exchanger provide better contact than wide open flue passages. With greater heat exchange surface area per volume of combustion gas, more intimate contact of heat and walls occurs. Longer contact time can also be achieved by reducing the amount of combustion gases produced per gallon of fuel burned or per period of time. A smaller volume takes longer to flow over heat exchange surfaces. Lowering the excess air can reduce the volume of combustion gases produced per gallon of fuel burned and reducing the nozzle firing rate can reduce the volume of combustion gases produced per unit time. Figure A.7 indicates the relationship between excess air and the flame temperature and volume of combustion gases.

Insulation is any material that stops or slows down the normal rate of heat transfer. Obviously, you do not want to place an insulating material between the combustion gases and the heat exchanger walls. Smoke (often called soot) acts as an insulator! Smoke deposits from smoky combustion can collect on the heat exchange surfaces and reduce the effectiveness of the heat transfer process. Estimates have been made indicating that a 1/8 inch thick coating of soot on heat exchanger walls has the same insulating ability as a one inch thick fiberglass sheet.

It should be understood at this point that smoke caused by a poorly operating oil burner is a bad thing, not because the smoke represents unburned fuel, but because Smoke Soots up Heat Exchange Surfaces and Prevents Transfer of Heat to the Heating Load! A good burner helps the heat exchanger be more efficient by:

- o Providing combustion products at a high temperature. This means a high flame temperature.
- o Providing combustion products which have a low volume per gallon of fuel burned. This means low excess air.
- o Providing clean combustion products which contain a minimum of smoke.

Role of Excess Air in Combustion

You have seen that excess air must be supplied to insure adequate mixing of fuel and oxygen. However, excess air is one of the major causes of low efficiencies. To see how this occurs consider that excess air:

- o dilutes combustion gases
- o absorbs heat
- o drops overall temperature of combustion gases

The dilution of combustion gases occurs simply because of the presence of additional gas in the form of excess air. The excess air absorbs heat in the combustion zone and reduces the flame temperature. This in turn reduces the transfer of heat to the heat exchanger since a significant amount of heat is

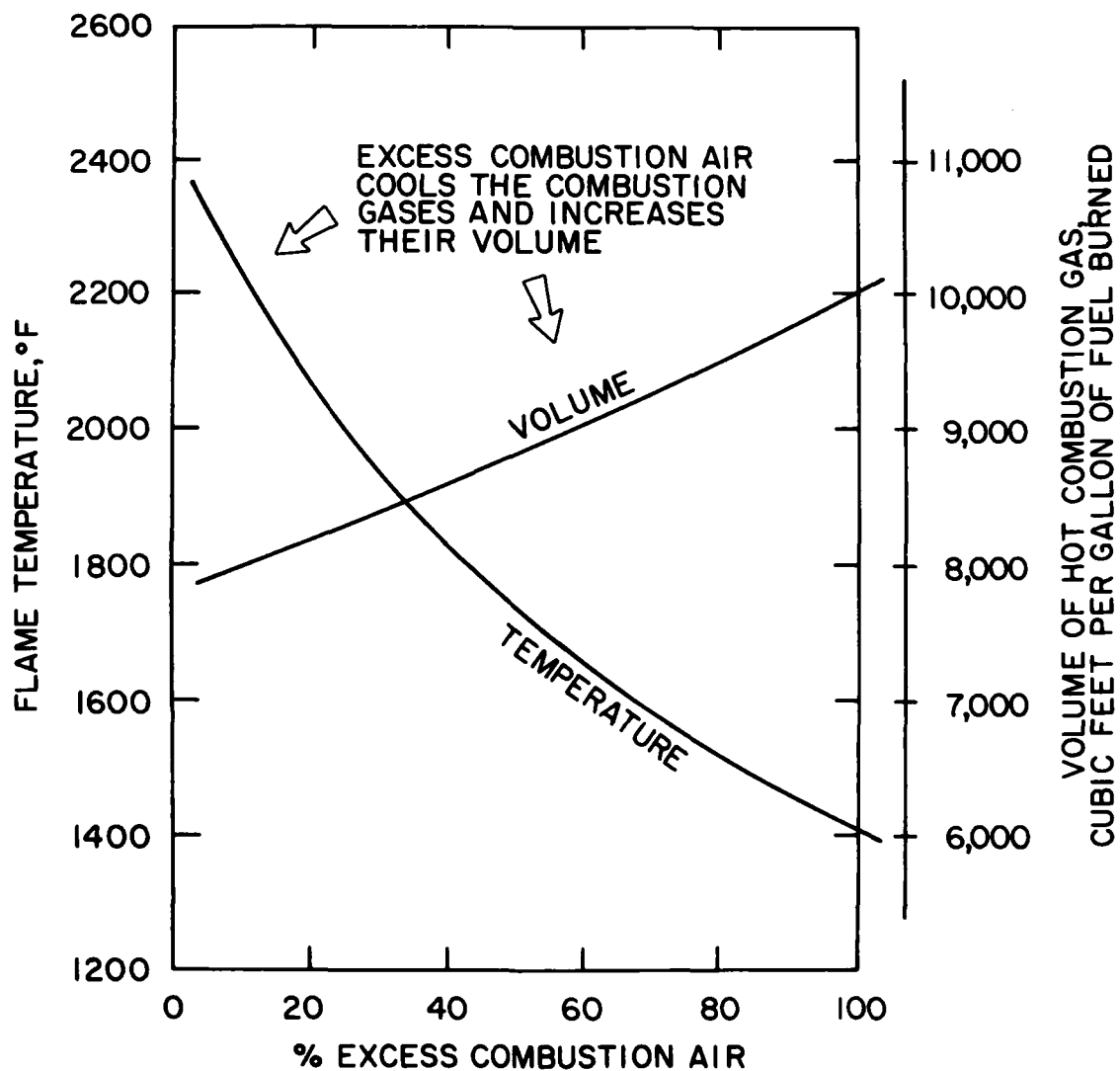


FIGURE A.7 APPROXIMATE RELATIONSHIP OF % EXCESS AIR WITH FLAME TEMPERATURE AND VOLUME OF COMBUSTION GASES

transferred by radiation. Moreover, as excess air is introduced, the overall temperature of the combustion gases drops as heat from these combustion gases is used to raise the temperature of the excess air. Think of this process as being similar to adding refrigerated cream to a cup of coffee as shown in Figure A.8. The cup of coffee is originally 160°F (high temperature) and occupies a small volume (half a cup). Adding cream at 40°F increases the volume (almost a full cup) and lowers the overall temperature to 120°F (mild temperature). Note that the temperature of the mixed coffee and cream is higher than the temperature of the cream alone and lower than the temperature of the coffee alone. Heat from the coffee went into heating the cream and the overall temperature dropped, or in other words, the cream absorbed some heat from the coffee. Do you clearly see this?

Also, by looking at Figure A.9 you can see that the coffee example illustrates the effect of excess air (shown as water) in diluting the gas (coffee) and the resulting reduction in the CO₂ percent.

Bear in mind that this temperature reduction and dilution takes place in the combustion zone not in the flue or stack. It is important to note that the effect of excess air on the temperature of the flue gas is different- with more excess air the flue gas temperature tends to rise. This happens because the volume of combustion gas per unit of fuel burned is now greater than before so that the gases pass over the heat exchange surfaces more rapidly and reduce the contact time. This reduces the heat transfer rate to the heat exchanger.

To review, remember that excess air causes the following:

- o lower flame temperature
- o lower combustion gas temperature
- o higher flue or stack gas temperature
- o poorer heat exchange to the distribution medium

All of these changes play a role in reducing the efficiency of the heating system. So minimizing excess air is essential in the proper adjustment of oil burners; however, you will find out in the next section that simply reducing excess air without concern for other factors could lead to a great deal of trouble! Keep reading, you'll see what we mean.

Excess air causes one other problem that cannot be seen in the comparison of coffee and cream. Excess air increases the volume of combustion products per unit of fuel burned so that the products pass over the heat exchange surfaces more rapidly and reduce the contact time. As was pointed out earlier, this reduces the heat transfer rate to the heat exchanger.

Excess Air - Smoke Relationship

During the combustion of oil, particularly, during burner startup and shutdown, some smoke is usually generated since some of the oil droplets do not contact enough oxygen to complete the reaction which forms carbon dioxide. This smoke consists of small particles of mainly unburned carbon.

ADDING EXCESS AIR TO A FLAME IS
LIKE ADDING CREAM TO A CUP OF
COFFEE!

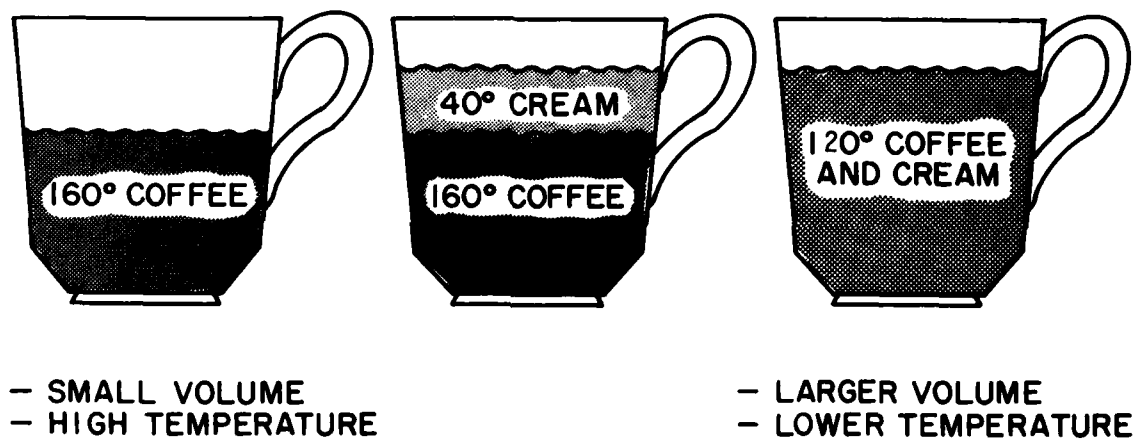
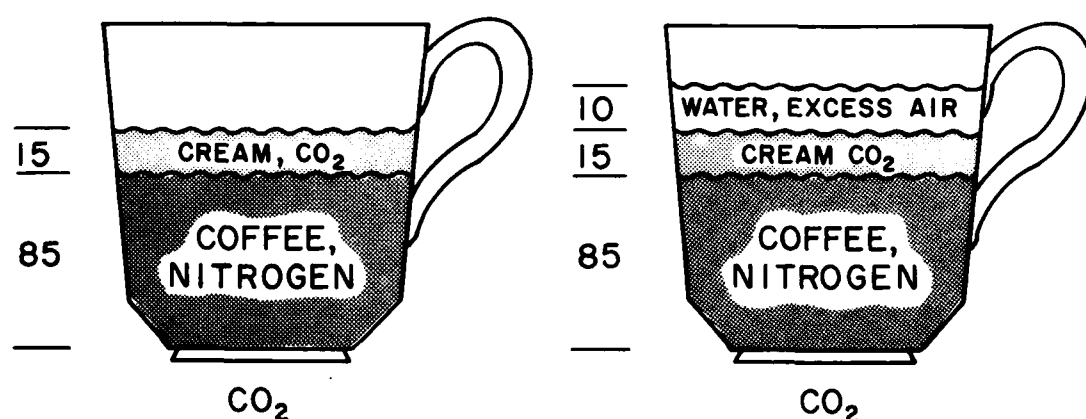


FIGURE A.8 REPRESENTATION OF THE
EFFECT OF EXCESS AIR ON COMBUS-
TION GAS TEMPERATURE



AMOUNT OF CO₂ REMAINS
THE SAME, THE PERCENT
OF CO₂ IS LESS

$$\% \text{ CREAM} = \frac{15}{85 + 15} = 15\%$$

$$\% \text{ CREAM} = \frac{15}{85 + 15 + 10} = 13.6\%$$

FIGURE A.9 THE EFFECT OF EXCESS
AIR ON CO₂

Some of these particles stick to the heat exchanger surfaces acting as insulation and can eventually clog up the flue passages while others are emitted through the stack and add to the pollution of the air.

Now you are ready for discussion of the issue that is all important to the proper adjustment of oil burners.

Excess Air-Smoke Relationship

You have learned that there must be sufficient excess air to provide good mixing of combustion air and fuel oil. Without this excess air, incomplete combustion occurs and smoke is formed. Thus, to minimize smoke, you generally add excess air. Unfortunately, as you have learned, as the amount of excess air is increased, the transfer of heat to the heat exchange medium (hot water, warm air, or steam) is reduced. A delicate balance must be achieved between smoke generation (caused by insufficient excess air) and reduced heat transfer due to reduced combustion gas temperature and an increased volume of combustion products (caused by unnecessary excess air). Figure A.10 illustrates the typical relationship between smoke and efficiency and excess air. Notice that smoke and efficiency increase as the excess air is decreased. The exact shape of this curve varies from unit to unit. Knowing this curve can pretty much give you a clear picture of where the burner air should be adjusted to. The highest efficiency occurs when you properly balance the trade-off between smoke and excess air.

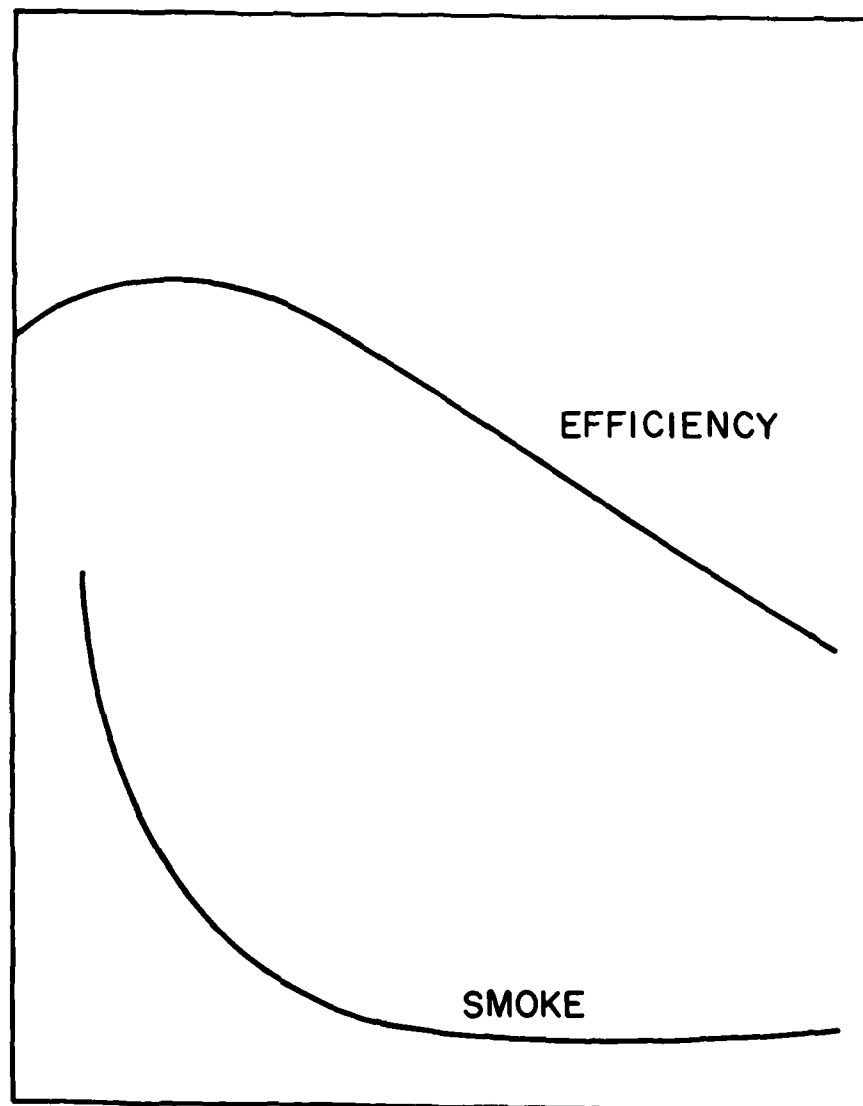
Effect of Air Leaks

Now that you understand what goes on inside the heating plant, it will be easier to follow why air leaks cause lost efficiency. Air which leaks into the combustion gases before they pass through the heat exchanger acts like excess air. The air leaks dilute the combustion gases, cooling them and increasing their volume so that they pass through the heat exchanger more quickly. However, an air leak is even worse than excess air in the combustion chamber because an air leak cannot reduce the smoke formed in the combustion zone.

Draft

In the oil heat industry, the word "draft" is used to describe the slight vacuum, or suction, which exists inside most heating plants. The amount of vacuum is called draft intensity. Draft volume, on the other hand, specifies the volume (cubic feet) of gas that a chimney can handle in a given time. Draft intensity is measured in "inches of water" - just like a mercury barometer is used to measure atmospheric pressure in inches of mercury, a draft gauge is used to measure draft intensity (which is really pressure) in inches of water.

"Natural" draft is actually thermal draft and occurs when gases that are heated expand so that a given volume of hot gas will weigh less than an equal volume of the same gas at a cool temperature. Since hot combustion gases weigh less per volume than room air or outdoor air, they tend to rise. The



% EXCESS COMBUSTION AIR

**FIGURE A.10 SMOKE AND EFFICIENCY
VS. EXCESS AIR CURVE**

**NOTE: EXCESS COMBUSTION AIR
REDUCES HEATING PLANT EFFICIENCY.
TOO MUCH SMOKE WILL EVENTUALLY
REDUCE EFFICIENCY ALSO.**

rising of these gases is contained and increased by enclosing the gases in a tall chimney. The vacuum or suction that you call "draft" is then created through this column of hot gases.

"Currential" draft occurs when high winds or air currents across the top of a chimney creat a suction in the stack and draw gasses up. "Forced mechanical" draft is the force that is exerted by the burner fan which passes gases up the chimney.

There are three factors which control how much draft a chimney can make:

- o The height of the chimeny - the higher the chimney, the greater the draft.
- o The weight per unit volume of the hot combustion products - the hotter the gases, the greater the draft.
- o The weight per unit volume of the air outside the home - the colder the outside air, the greater the draft.

Since the outside temperatures and flue gas temperature can change, the draft will not be constant. When the heating plant starts up, the chimney will be filled with cool gases. After the heating plant has operated for a while, the gases and the chimney surface will be warmer, and the draft will increase. Also, when the outside air temperature drops, the draft will increase. To indicate the size of these changes, the information in Table A.1 was determined for a 20 ft.-high chimeny. You can see that the draft produced by this chimney could be expected to vary from .011 to .136 inches of water. The high draft is over 12 times more than the low draft. This large variation cannot be tolerated for the followng reasons:

- o Too little draft can reduce the combustion air delivery of the burner and can result in an increase in the production of smoke.
- o Excessively high draft increases the air delivery of the burner fan and can increase air leakage into the heating plant, reducing CO₂ and raising stack temperature, resulting in reduced operating efficiency.
- o High draft during burner off periods increases the standby heat losses up the chimney.

To understand why varying draft causes these problems, you should bear in mind that the air presure (positive draft) caused by a burner fan averages about .25 inches of water in the air tube. If the combustion chamber has a draft of .10 inches of water and the burner fan provides a pressure of .25 inches of water, the total force causing air to flow will be .35 inches of water. If the combustion chamber draft drops to .01 inches of water, the total pressure becomes $.25 + .01 = .26$ inches of water. This is a reduction in draft of about 25% which will cause a similar reduction in the amount of air flowing into the combustion chamber. Remember what happens when the excess air is not properly adjusted? The burner will very likely smoke as a result of this change. It is for this reason that the proper draft should be obtained before the air adjustment is set.

Table A-1. Example of Draft Changes in a Chimney

Condition	Outside Temperature, °F	Chimney Temperature, °F	Draft, "H ₂ O
Winter start up	20	110	.050
Winter operation	20	400	.136
Fall start up	60	80	.011
Fall operation	60	400	.112

Because draft will not exist to any great amount during a cold startup, the burner should not depend on the additional combustion air caused by draft. The best way to be sure the burner does not depend on this air is to set the burner for smoke-free combustion with a low overfire draft (.01 to .02 inches of water). If a burner cannot produce good smoke-free combustion under low draft conditions, there is something wrong with the burner and it should be corrected. Using a high draft setting to obtain enough combustion air for clean burning is like depending on a crutch, which is not always there. A burner which gives clean combustion only with high draft will cause smoke and soot any time the chimney is not producing high draft.

In the previous section, we described the effect of air leaks and perhaps you now realize that air leaks occur because of draft inside the heating plant. It is easy to see that less draft will cause less air leakage and produce a higher efficiency. Therefore, sealing air leaks can aid in improving heating plant efficiency.

Draft Regulators

From the previous information, you should realize that a constant draft is needed and this draft should be no more than that which will just prevent escape of combustion products into the home. Since natural draft as obtained from a chimney will vary, it is necessary to have some sort of regulation. The normal draft regulator for home heating plants is the so-called by-pass, or air bleed, type as shown in Figure A.11. This type of regulator is simply a swinging door which is counterweighted so that any time the draft in the flue is higher than the regulator setting, the door is pulled in. When the door is pulled in, it allows room air to flow into the flue and mix with the combustion gases. Because the room air is much cooler than the flue gases, it cools them. Then the cooler gases fill the chimney, there is less temperature difference between the chimney gases and the outside air and less draft is produced. If the draft is less than the regulator setting, the counterweight keeps the swinging door closed and only flue gas flows into the chimney. This gives the highest draft possible under those conditions.

It is important to understand that the function of a draft regulator is to maintain a stable or fixed draft through the heating equipment within the limits of available draft of the chimney by means of an adjustable barometric damper.

Draft can be measured by using a draft gauge. It cannot be estimated or "eye balled." The draft should be checked at two different locations in the heating plant: 1) over the fire which indicates firebox draft condition and 2) draft in the breech connection.

1. Draft Over the Fire

The draft over the fire is the most important and should be measured first. The overfire draft must be constant so that the burner air delivery will not be changed. The overfire draft must be at the lowest level which will just prevent escape of combustion products into the home under all

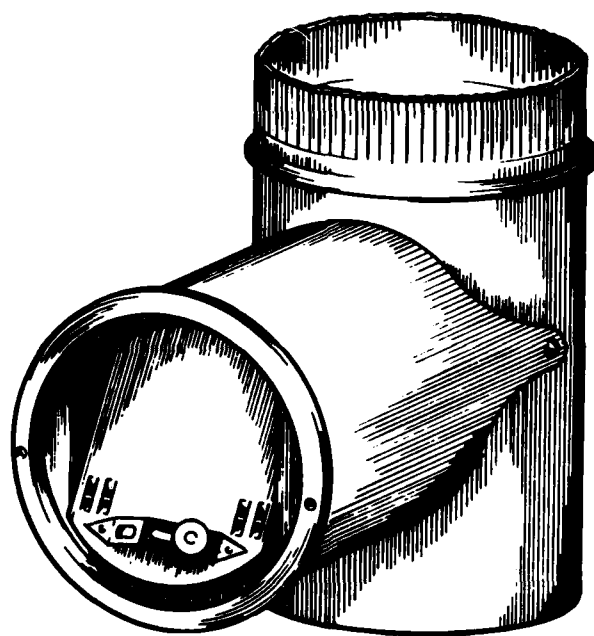


FIGURE A.11 TYPICAL DRAFT
REGULATOR

operating conditions. Normally an overfire draft of .01 to .02 inches of water will be high enough to prevent leakage of combustion products and still not cause large air leaks or standby losses.

If the overfire draft is higher than .02 inches the draft regulator weight should be adjusted to allow the regulator door to open more. If the regulator door is already wide open, a second regulator should be installed in the stack pipe and adjusted. If the draft is below .01 inch the draft regulator weight should be adjusted to just close the regulator door. Do not move the weight more than necessary to close the door. Never wire or weight a regulator so it can never open. There may be times when the outside air is colder, or the chimney hotter, and the draft needs regulation.

The overfire draft is also affected by soot buildup on heat exchange surfaces. As the soot builds up, the heat exchange passages are reduced and a greater resistance to the flow of gases is created. This causes the overfire draft to drop. As the overfire draft drops, the burner air delivery is reduced and the flame becomes even more smoky. It is a vicious cycle which gets increasingly worse.

2. Draft at the Breech Connection

After the overfire draft is set, the draft at the breech connection should be measured. The breech draft will normally be slightly more than the overfire draft because the flow of gases is restricted (slowed down) in the heat exchanger. This restriction, or lack of it, is a clue to the design and condition of the heat exchanger. A clean heat exchanger of good design will cause the breech draft to be in the range of .03 to .06 inches when the overfire draft is .01 to .02 inches.

Flue and Chimney Exhaust

1. Flue Pipe

The flue pipe should be the same size as the breech connection on the heating plant. For modern oil designed heating plants, this should cause no problem in sizing the flue pipe. The sizes generally are 6" under 1 GPH, 7" to 1.50 GPH and 8" for 1.50 to 2.00 GPH. The flue pipe should be as short as possible and installed so that it has a continuous rise from the heating plant to the chimney. Elbows should be minimized and the pipe should be joined with metal screws and straps.

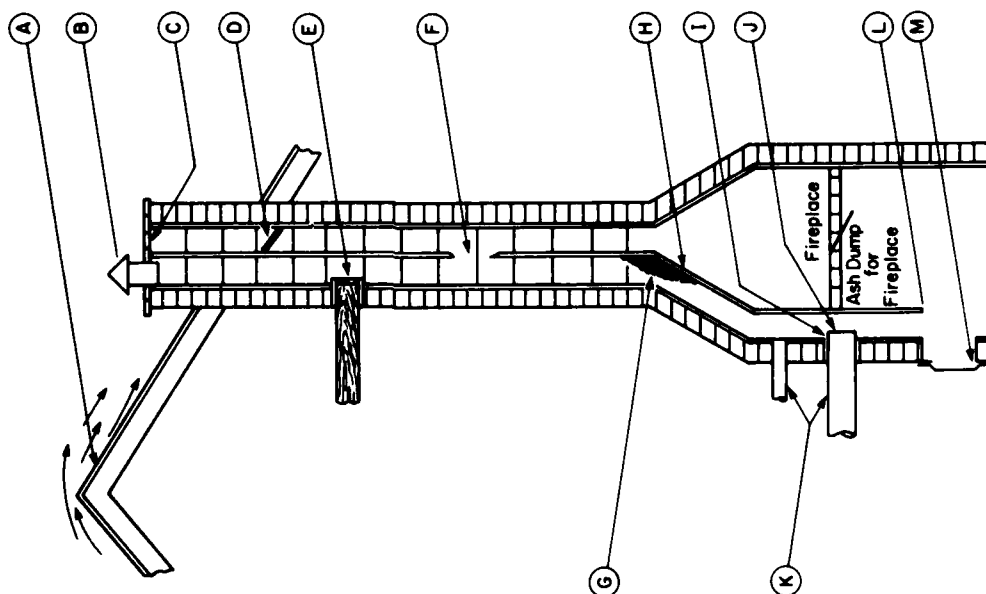
The draft regulator should be installed in the flue before the chimney and after the primary control, if one is used. Make sure the draft regulator is at least as large as the flue pipe diameter.

2. Chimney

The following table shows recommended size and height for chimneys based on BTU input (Table A.2).

Table A-2. Recommended size and height for chimneys

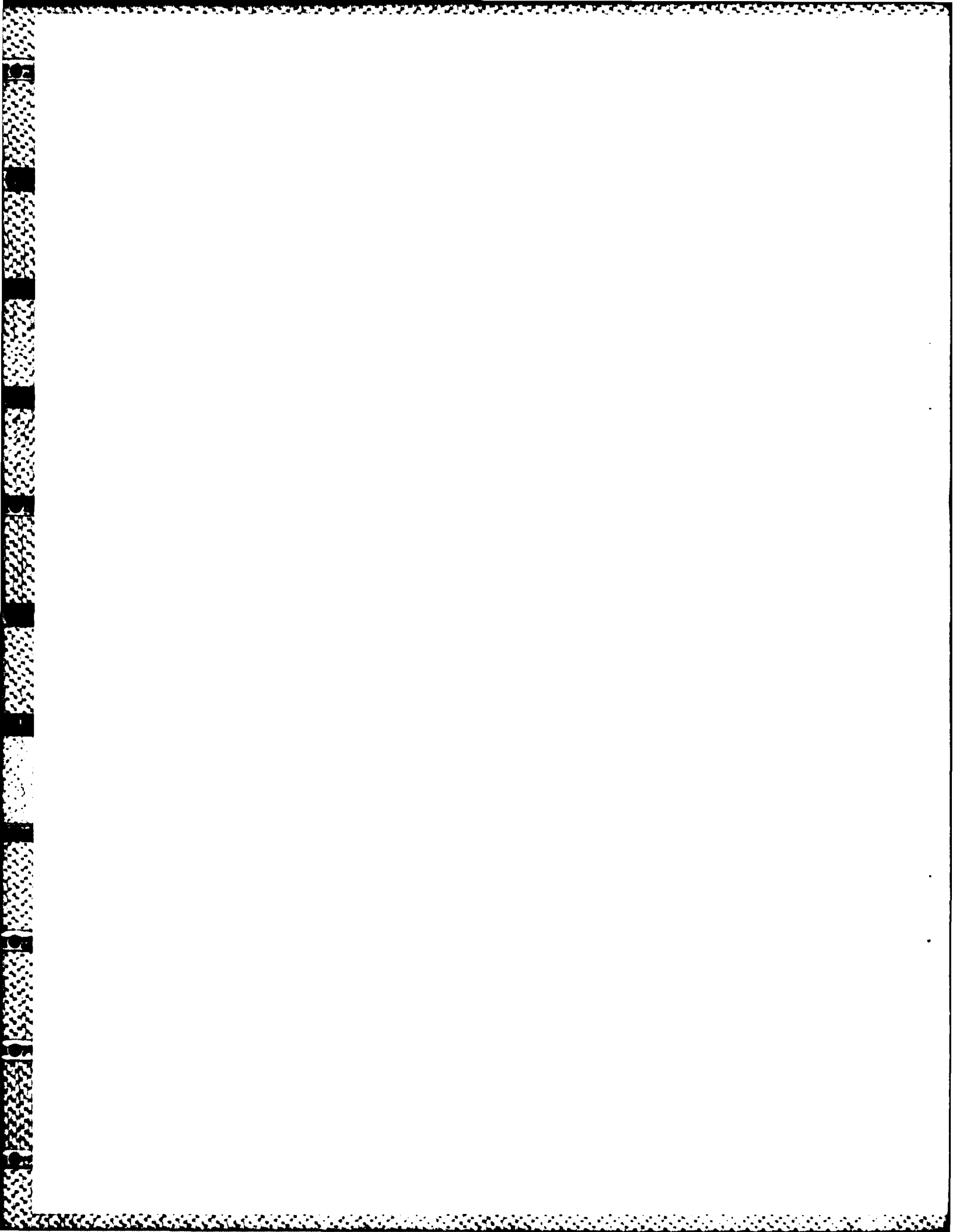
Gross Btu Input	Rectangular Tile	Round Tile	Minimum Height
144,000	8-1/2" x 8-1/2"	8"	20 feet
235,000	8-1/2" x 13"	10"	30 feet
374,000	13" x 13"	12"	35 feet
516,000	13" x 18"	14"	40 feet
612,000	-	15"	45 feet
768,000	18" x 18"	-	50 feet
960,000	20" x 20"	18"	55 feet



Common chimney troubles and their corrections.

Key	Troubles	Examination	Corrections
A	Top of chimney lower than surrounding objects.	Observation.	Extend chimney above all objects with 30 ft.
B	Chimney cap or ventilator.	Observation.	Remove.
C	Coping restricts opening.	Observation.	Make openings as large as inside of chimney.
D	Obstruction in chimney.	Can be found by light and mirror reflecting conditions in chimney.	Use weight to break and dislodge.
E	Joist projecting into chimney.	Lowering a light on extension cord.	Must be handled by a competent brick contractor.
F	Break in chimney firing.	Smoke test-build smudge fire blocking off other opening, watching for smoke to escape.	Must be handled by a competent brick contractor.
G	Collection of soot at narrow space in flue opening.	Lower light on extension cord.	Clean out with weighted brush or bag or loose gravel on end of line.
H	Offset.	Lower light on extension.	Change to straight or to long offset.
I	Loose-seated pipe in flue opening.	Smoke test.	Leaks should be eliminated by cementing all pipe openings.
J	Smoke pipe extends into chimney.	Measurement of pipe from within or observation of pipe by means of lowered light.	Length of pipe must be reduced to allow end of pipe to be flush with inside of tile.
K	Two or more openings into same chimney.	Found by inspection from basement.	The least important opening must be closed using some other chimney flue.
L	Failure to extend the length of flue partition down to the floor.	By inspection or smoke test.	Extend partition to floor level.
M	Loose-fitted clean-out door.	Smoke test.	Close all leaks with cement.

FIGURE A.12 COMMON CHIMNEY PROBLEMS AND THEIR POSSIBLE SOLUTION



APPENDIX B

FLUE GAS MEASUREMENT AND EFFICIENCY

This appendix covers the proper use of instruments to measure the steady-state efficiency of residential oil-fired heating plants. Since you should now understand what factors influence high or low efficiency, effective use of these instruments can aid you in improving the steady-state efficiency of heating plants. Perhaps you are accustomed to adjusting burners by judging the flame by eye or following a series of "rules of thumb." Certainly, using these procedures can work some of the time! But, would you stake your reputation on it? What you are doing is similar to a doctor diagnosing an illness without the use of a stethoscope or an auto mechanic tuning a car without a timing light or dwell meter. It is risky business!! Do yourself a favor, make your job easier, and assure yourself of leaving a heating plant in good operating condition by properly using the instruments discussed in this chapter.

Stack Loss Theory

The steady-state efficiency is a measure of the effectiveness of the heating unit in extracting heat from the chemical energy in the fuel and transferring it to the distribution medium. Therefore, the most straightforward approach to measuring the steady-state efficiency would be to measure the heat transferred to the distribution medium and the chemical energy in the fuel and then calculating the efficiency from these values. Unfortunately, in a residential heating plant, it would be very difficult to measure the actual amounts of heat in the fuel and the heat transferred to the air, water, or steam. As an alternate approach, a simpler method, the "stack loss" method of efficiency measurement is used.

The stack loss method is based on three assumptions:

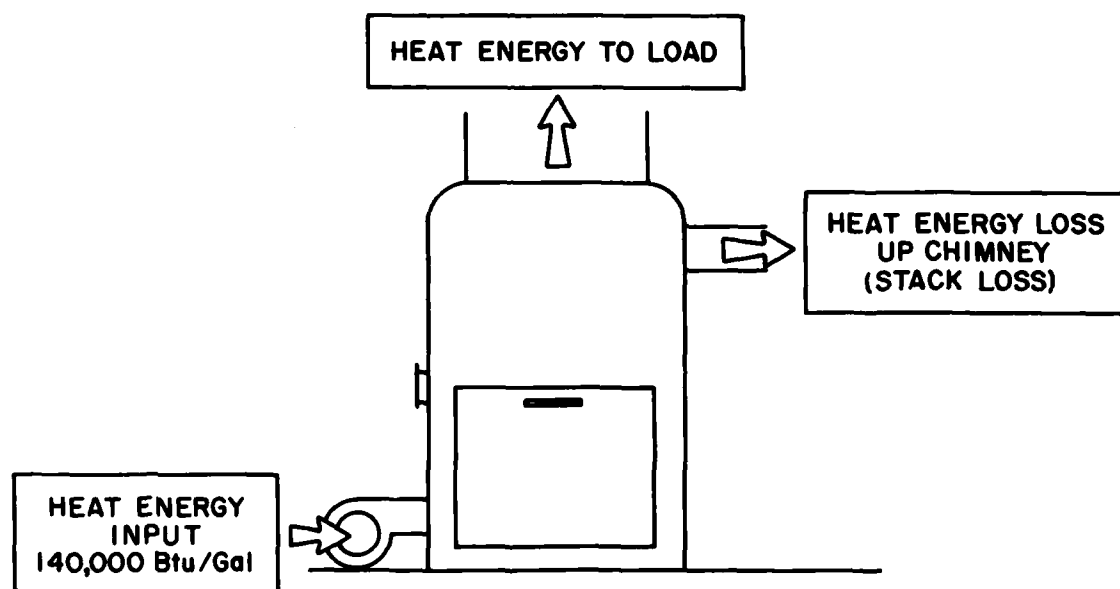
1. All the chemical energy in the fuel is converted to heat energy. This is essentially accurate for all burners as the true combustion efficiency is normally 98 to 100%.
2. The chemical energy per unit of fuel is the same - 140,000 Btu/gal. This means that from one shipment of fuel to another, variations in chemical composition that affect the chemical energy per unit of fuel oil are ignored. This can lead to small errors in the stack loss method.
3. The heat energy all goes to one of two places:
 - o the heating load or,
 - o up the chimney

These assumptions are shown in Figure B.1. From this figure, it can be seen that by measuring the heat loss up the flue and assuming an average value for the heat energy in the oil, you do not have to measure the heat transferred to the distribution medium. Fortunately, measuring the stack losses is not complicated. However, this assumes that there are no jacket losses or, in other words, no heat is transferred through the walls of the heating plant. From your experience, you should know this is inaccurate and that in older, largely uninsulated units, the jacket losses can be significant. As a result, the stack loss method tends to give higher efficiencies than those which really exist.

To measure the heat wasted up the flue and chimney you must

- o determine the amount of the combustion gases per gallon of fuel oil burned;
- o determine how much the combustion gas temperature was changed (the difference between the temperature at which the fuel and air entered the burner and the temperature of the combustion gases).

You should measure the amount and temperature of the combustion gases at an identical point in the flue pipe.



HEAT TO LOAD + STACK LOSS = HEAT ENERGY INPUT
HEAT TO LOAD = HEAT ENERGY INPUT - STACK LOSS

FIGURE B.1 DISTRIBUTION OF HEAT
AS DETERMINED BY THE STACK
LOSS METHOD

In appendix A, you learned how changes in volume of excess combustion air affect the heat exchanger efficiency. As you might imagine, these changes in volume of excess air per unit of fuel burned also affect the weight of the combustion gases formed from each gallon of fuel burned. Since knowledge of the percent excess air enables you to determine the weight of the combustion gases per gallon of fuel burned, and since the percent excess air can be determined by measuring the percent carbon dioxide or oxygen, you can determine the weight of combustion gases per gallon of fuel burned by knowing the percent carbon dioxide or oxygen.

Let's look at an example to make this more clear. In Figure A.1, Appendix A, we showed that theoretically for every pound of fuel oil exactly 14.36 pounds of air are required to completely burn the fuel. This was assuming that there was perfect mixing and that all the carbon and hydrogen in the fuel combined with the oxygen in the air to form carbon dioxide and water vapor. The figure also showed that exactly 3.16 pounds of carbon dioxide or 15.3% of the products were formed if this "perfect" situation occurred. In Figure A.2, we showed a typical case for which excess air was needed to guarantee that most of the carbon and hydrogen in the fuel would combine with oxygen to form the products. From Figure A-2, you can see that the same weight (3.16 pounds) of carbon dioxide is formed but that this represents only 10.2% by volume, of the combustion products. So, by measuring the percent carbon dioxide, you not only can determine how much excess air exists, but also you can determine the weight of combustion products flowing up the flue pipe.

Oxygen measurements can also be used to determine the amount of excess air and in turn the amount of CO_2 in the flue gas. There is a direct and fixed relationship between the amount of CO_2 and O_2 in the flue gas as shown in Figure B.2. This figure indicates that as the percent CO_2 increases, the percent O_2 decreases in the flue gas. When testing for efficiency we try to obtain a low O_2 reading or high CO_2 reading (in both cases, low excess air).

Now we have one-half of what is needed to determine the losses up the stack. The second half is much easier. This is the temperature difference between the fuel and air going into the burner and the flue gases coming out of the heat exchanger. The fuel and air will normally enter the burner at about the temperature of the room in which the furnace or boiler is located. The temperature of the gases in the flue will vary from unit to unit but can be measured with a thermometer. The difference between the flue gas temperature and the furnace/boiler room temperature is called the NET STACK TEMPERATURE.

Once you know the percent CO_2 or oxygen and the net stack temperature, you can determine the steady-state efficiency based on the stack loss method. Remember that the stack loss will be determined per gallon of fuel oil burned since this is how the weight of the combustion gases was measured. Because of this, you don't have to measure the fuel input into the burner. Since we assumed that each unit of fuel oil (a gallon) contains the same amount of chemical energy (140,000 Btu's), the stack loss calculated will be per each 140,000 Btu of input energy. If we subtract this percentage loss from 100%, what remains will be the steady-state efficiency. Rather than make you go

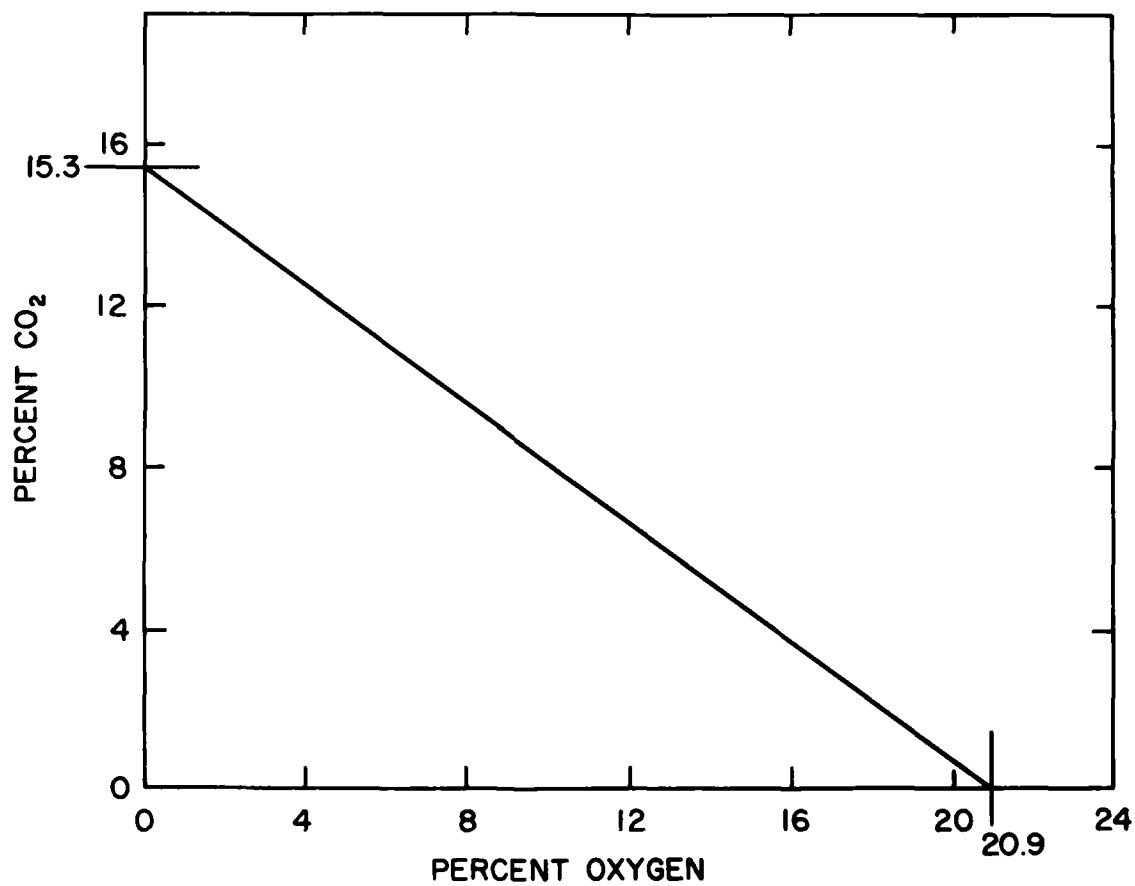


FIGURE B.2 THEORETICAL COMBUSTION
RELATIONSHIP BETWEEN CO₂ AND
O₂ FOR #2 HEATING OIL

through the calculations to determine this value, an efficiency chart or table can be used which will give you the efficiency based on the percent carbon dioxide and net stack temperature. Many of you may be familiar with the Bacharach Instrument Company's Fire Finder Efficiency Chart shown in Figure B.3. You can also use other tables or graphs to determine the steady-state efficiency. Examples are shown in Tables B.1, B.2, and Figure B.4.

Now that you know what to measure and why, let's turn our attention to how to properly measure for steady-state efficiency. As a minimum, you need to measure both the percent carbon dioxide or oxygen, and the net stack temperature, but, to get the complete picture and to do the job right, smoke and draft measurements are also required.

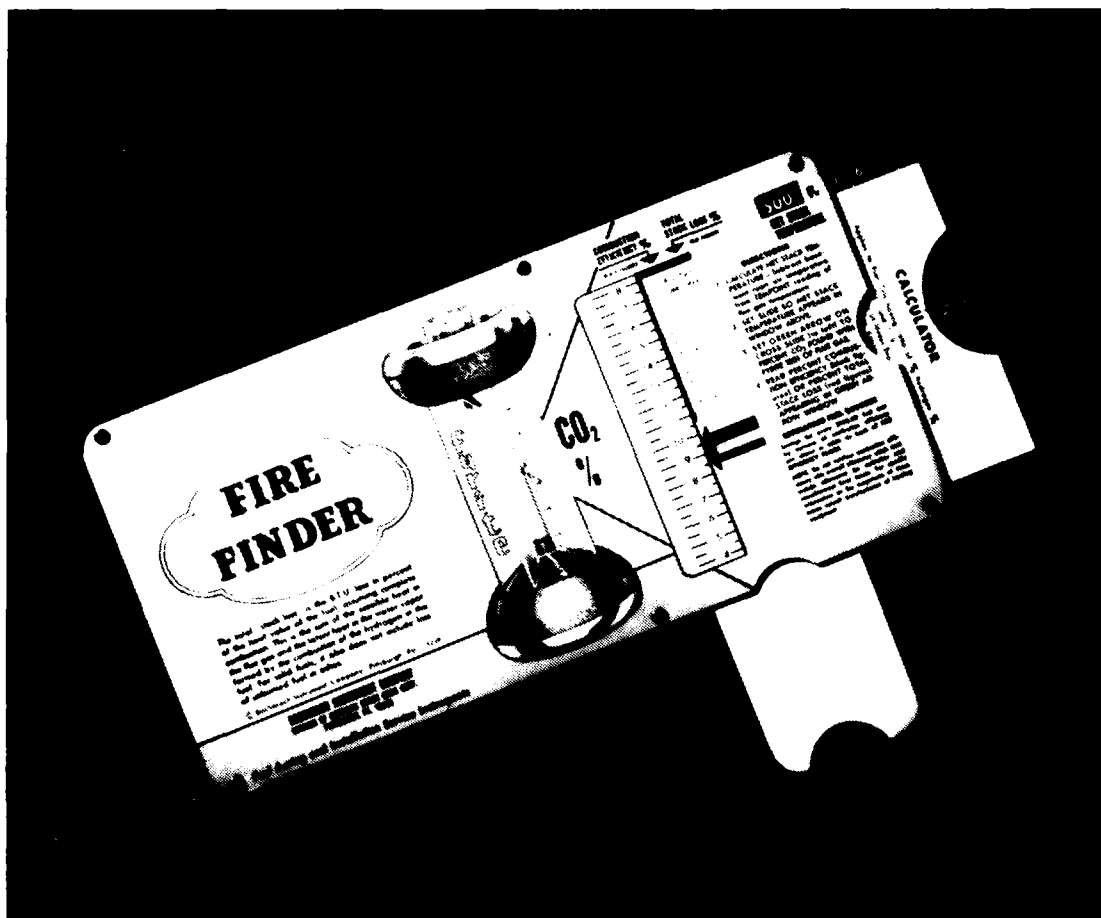


Figure B.3. Bacharach Instrument Company's Fire Finder Chart.

		Net Stack Temperature (degrees F.)													
		300°	350°	400°	450°	500°	550°	600°	650°	700°	750°	800°	850°	900°	
15		75-1/2	72-1/2	69-1/2	66-1/4	63	60	56-3/4	53-1/2	50-1/4	47	43-1/2	40-1/4	36-3/4	
14		77-1/4	74-1/2	72-3/4	70	68	64-1/4	61-1/2	58-3/4	55-3/4	52-3/4	49-1/4	47-1/4	44-1/2	
13		79-3/4	77-1/4	75	72-1/2	70	67-3/4	65-1/4	62-3/4	60-1/4	57-1/2	55	52-1/2	50	
12		80-3/4	78-1/2	76-3/4	74-3/4	72-1/2	70-1/4	68-1/4	66	63-3/4	61-1/2	59	56-3/4	54-1/4	
11		82-1/4	80-1/4	78-1/2	76-1/2	74-1/2	72-1/2	70-1/2	68-1/2	65-3/4	64-1/4	62-1/4	60	58	
10		83	81	79-3/4	77-3/4	76	74-1/4	72-1/2	70-3/4	68-3/4	67	64-3/4	63	61	
9		84	82-1/4	80-3/4	79	77-1/4	75-3/4	74	72-1/4	70-3/4	68-3/4	67	65-1/4	63-1/2	
8		84-3/4	83	81-3/4	80-1/4	78-1/2	77	75-1/2	73-3/4	72-1/4	70-1/2	69	67-1/2	65-3/4	
7		85-1/2	83-3/4	82-1/2	80-3/4	79-1/4	77-3/4	76-1/4	74-3/4	73-1/4	71-1/2	70	68-1/2	67	
6		85-3/4	84-1/2	83	81-1/2	80-1/4	78-3/4	77-1/4	75-3/4	74-1/2	73	71-1/2	70	68-1/2	
5		86	85	83-3/4	82-1/4	81	79-1/2	78-1/4	77	75-1/2	74	72-1/2	71-1/4	70	
4		86-1/2	85-1/4	84	83	81-1/2	80-1/4	79	77-3/4	76-1/2	75-1/4	73-1/2	72-3/4	71	
3		87	85-3/4	84-1/2	83-1/2	82-1/4	81	79-3/4	78-1/2	77-1/4	76	74-3/4	73-3/4	72	
2		87-1/4	86	84-3/4	83-3/4	82-3/4	81-1/2	80-1/4	79	78	76-3/4	75-1/2	74-1/2	73	
1		87-1/2	86-1/2	85	84-1/4	83-1/4	82	81	79-1/2	78-3/4	77-1/2	76-1/4	75-1/4	74	

TABLE B.1 EFFICIENCY TABLE FOR
NO. 2 FUEL OIL - O₂ VS.
TEMPERATURE

		Net Stack Temperature (degrees F.)													
		300°	350°	400°	450°	500°	550°	600°	650°	700°	750°	800°	850°	900°	
PERCENT CO ₂	15	87-1/2	86-1/2	85-1/4	84-1/4	84-1/4	82	81	79-3/4	78-3/4	77-1/2	76-1/2	75-1/2	74-1/4	
		87-1/2	86-1/4	85	84	83	81-3/4	80-3/4	79-1/4	78-1/2	77-1/4	76	75	73-3/4	
	14	87-1/4	86	84-3/4	83-3/4	82-3/4	81-1/2	80-1/4	79	78	76-3/4	75-1/2	74-1/2	73	
		87	85-3/4	84-1/2	83-1/2	82-1/2	81-1/4	80	78-3/4	77-1/2	76-1/4	75-1/4	74	72-1/4	
	13	86-3/4	85-1/2	84-1/4	83-1/4	82	80-3/4	79-1/2	78-1/4	77	75-3/4	74-1/2	73-1/2	71-3/4	
		86-1/2	85-1/4	84	83	81-1/2	80-1/4	79	77-3/4	76-1/2	75-1/4	73-3/4	72-3/4	71	
	12	86-1/4	85	83-3/4	82-1/2	81-1/4	79-3/4	78-1/2	77-1/4	75-3/4	74-1/2	73	71-1/2	70-1/4	
		86	84-3/4	83-1/2	82	80-3/4	79-1/4	78	76-1/2	75-1/4	73-3/4	72-1/4	70-3/4	69-1/2	
	11	85-3/4	84-1/2	83	81-1/2	80-1/4	78-3/4	77-1/4	75-3/4	74-1/2	73	71-1/2	70	68-1/2	
		85-1/2	84	82-1/2	81	79-1/2	78	76-1/2	75	73-3/4	72	70-1/2	69	67-1/2	
	10	85	83-1/2	82	80-1/2	78-3/4	77-1/4	75-3/4	74-1/4	72-3/4	71	69-1/2	68	66-1/4	
		84-1/2	83	81-1/2	79-3/4	78	76-1/2	75	73-1/4	71-3/4	70	68-1/4	66-3/4	65	
	9	84	82-1/4	80-3/4	79	77-1/4	75-3/4	74	72-1/4	70-3/4	68-3/4	67	65-1/4	63-1/2	
		83-1/2	81-3/4	80	78-1/4	76-1/2	74-3/4	73	71-1/4	69-1/2	67-1/2	65-1/2	63-3/4	62	
	8	83	81	79-1/4	77-1/2	75-1/2	73-3/4	71-3/4	70	68	66	64	62	60	
		82-1/4	80-1/4	78-1/2	76-1/2	74-1/2	72-1/2	70-1/2	68-1/2	66-1/2	64-1/4	62-1/4	60	58	
	7	81-1/2	79-1/2	77-1/4	75-1/4	73-1/4	71	69	67	64-3/4	62-1/2	60-1/4	57-3/4	55-1/2	
		80-3/4	78-1/2	76-1/4	74	71-3/4	69-1/2	67-1/4	65	62-3/4	60-1/4	57-3/4	55-1/2	53	
	6	79-3/4	77-1/4	75	72-1/2	70	67-3/4	65-1/4	62-3/4	60-1/4	57-1/2	55	52-1/2	50	
		78-1/2	76	73-1/2	71	68	65-1/2	63	60-1/4	57-1/2	54-1/2	51-3/4	49	46-1/2	
	5	77-1/4	74-1/2	71-3/4	69	65-3/4	63	60	57	54	51	48	45-1/2	42-1/2	
		75-1/2	72-1/2	69-1/2	66-1/4	63	60	56-3/4	53-1/2	50-1/4	47	43-1/2	40-1/4	36-3/4	
	4	73-1/4	69-3/4	66-1/4	62-3/4	59-1/4	55-3/4	52	48-1/2	45	41-3/4	37-1/2	33-3/4	30	

TABLE B.2 EFFICIENCY TABLE FOR
NO. 2 FUEL OIL - CO₂ VS.
TEMPERATURE

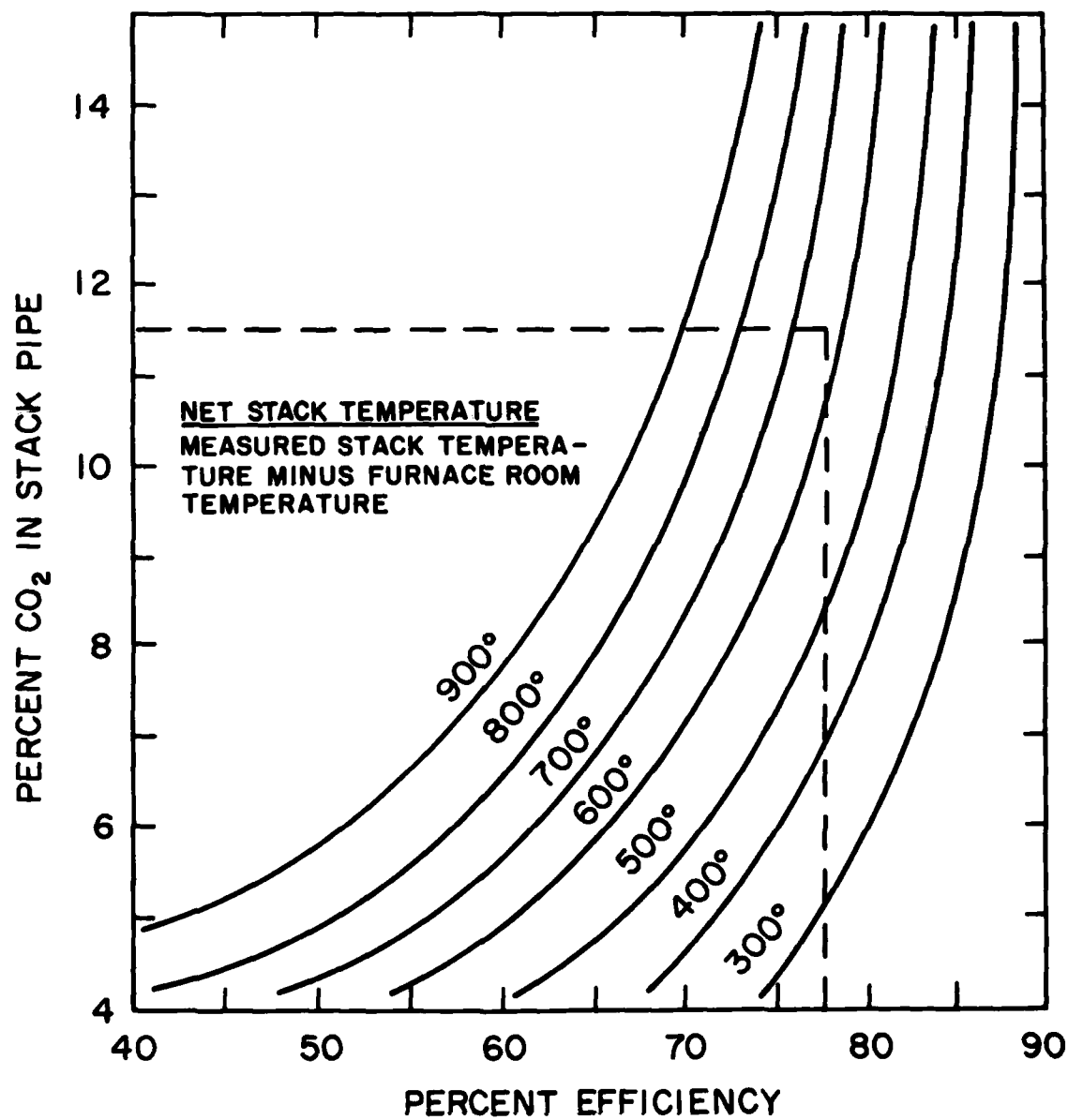


FIGURE B.4 GRAPH OF HEATING
PLANT EFFICIENCY

Measurement of Carbon Dioxide or Oxygen

Historically, to determine the weight of the combustion gases per gallon of fuel oil burned, carbon dioxide has been measured with equipment like that shown in Figure B.5. This is a rugged, inexpensive, and easy-to-operate device. However, if you recall from Appendix A, the percent oxygen also can be used to determine the weight of the combustion gases. There are devices that measure oxygen rather than carbon dioxide percent for the determination of steady-state efficiency, but let's turn our attention to the most common device first - CO₂ analyzers.

Bacharach Instrument Company manufactures a carbon dioxide analyzer called "Fyrite", which is the most well-known instrument on the market. The Fyrite, (which is diagramed in Figure B.5) and other similar instruments work on the following principles:

- o chemical adsorption of a gas sample by a liquid chemical absorbent.
- o chemical absorbing fluid is also used as indicating fluid.

The Fyrite analyzer contains potassium hydroxide, a liquid with a capacity to absorb large amounts of carbon dioxide. The Fyrite consists of two main parts - sampling pump and analyzer.

The sampling pump consists of:

- o a metal sampling tube which is inserted into the flue gases;
- o a yarn filter and water trap which stops soot and water droplets from entering the analyzer;
- o a sample pump - a rubber bulb with a suction valve and a discharge valve. These valves are rubber flapper check valves which allow flow in only one direction;
- o a rubber connector which seals the sampling pump system to the analyzer.

The analyzer is molded of clear plastic containing top and bottom reservoirs and a center tube connecting the two reservoirs. The bottom of the lower reservoir is sealed off by a flexible rubber diaphragm which rests on a perforated metal plate. The upper reservoir is covered by a molded plastic cap which contains a double-seated plunger valve. A spring holds this valve against a finished seat in the top cap providing a perfect seal which makes the instrument spillproof in any position. When the valve is fully depressed it vents the top reservoir to the atmosphere and seals the center tube beneath it. When the valve is partially depressed, the entire instrument is open to the atmosphere.

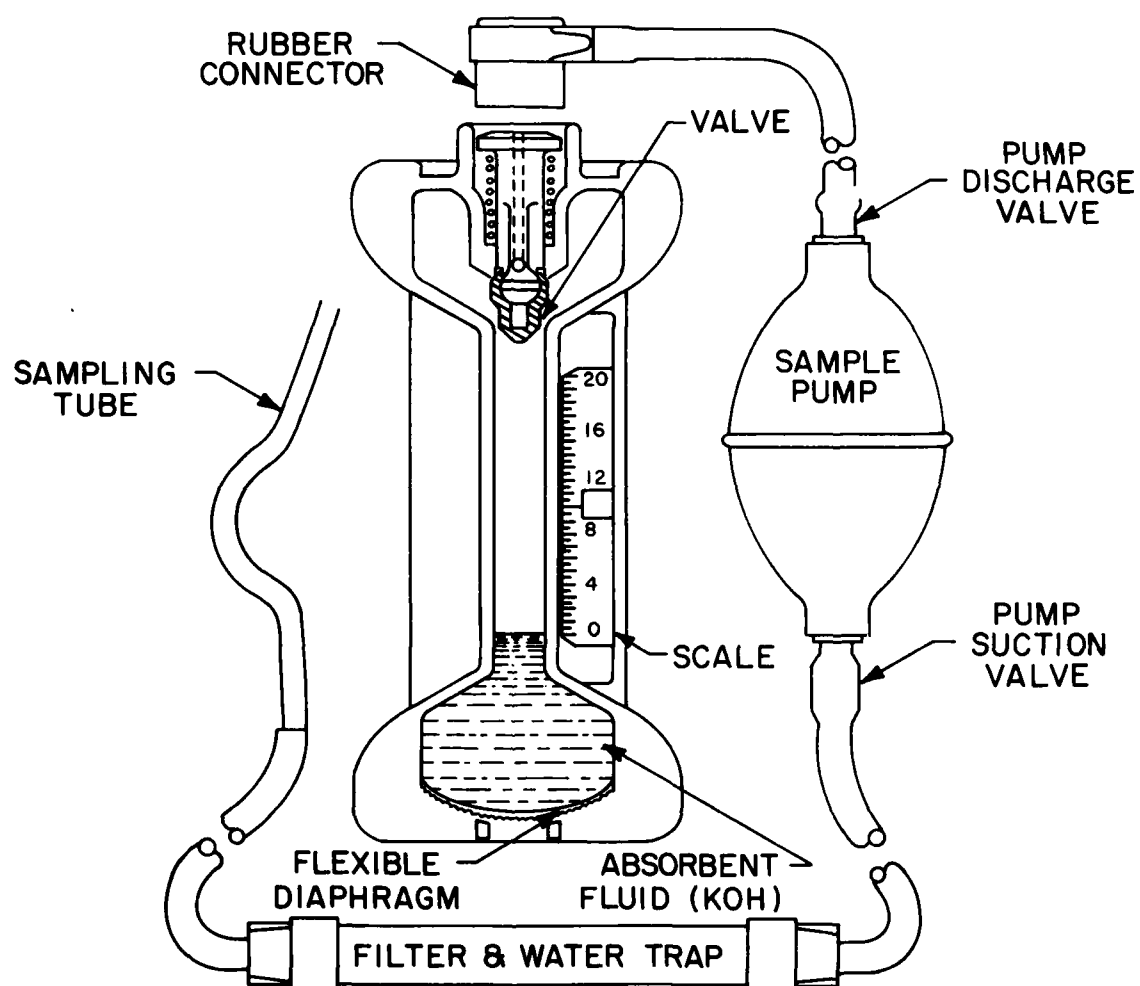


FIGURE B.5 CONSTRUCTION OF CO₂
GAS ANALYZER

The bottom reservoir is filled with the absorbing fluid which extends about 1/4 inch into the bore of the center tube when the instrument is held upright. The scale, which is mounted to one side of the center tube, is movable so that before each test the scale may be conveniently adjusted to locate the zero scale division exactly opposite the top of the fluid column in the center tube.

To measure the amount of CO₂ in a gas stream you must measure a known volume of gas, bring the gas into contact with the absorbing solution, and measure the loss in volume after the CO₂ is absorbed. To accomplish this, you must first prepare the instrument for sampling by purging the solution and adjusting the scale so that the zero mark is level with the liquid level. Be sure of the following:

- o allow instrument to reach room temperature - if you have just come in from the cold outdoors, place the Fyrite in a warm location such as near the boiler or furnace. Make sure it is not too hot and don't forget to remove the instrument.
- o make sure sufficient liquid is in the reservoir - if the liquid level is low, add water to the top of the reservoir and depress plunger valve. Repeat until scale can be adjusted to the height of the liquid level.

Zero the instrument by turning the Fyrite upside down at least twice, forcing the gas within the reservoir to bubble through the liquid; then upright and depress the plunger valve fully. After five seconds (or some other known time interval), adjust the zero mark on the scale to the liquid level. The instrument is now ready for sampling. Liquid may continue to drip down the bore of the lower reservoir causing the liquid level to rise above the zero mark on the scale. Do not readjust the scale.

To make a test with the Fyrite, the metal sampling tube at one end of the rubber hose is inserted into the gas to be analyzed. Then, the connector plug at the other end of the rubber hose is pressed down on the spring-loaded valve at the top reservoir. This seals off the center bore. Next, a sample of the gas is pumped into the top reservoir by stroking the rubber bulb. At least 18 bulb strokes should be used to assure that the rubber hose and the top reservoir are thoroughly purged of the previously analyzed sample. On the last bulb stroke the finger is lifted from the connector plug which automatically returns the plunger valve to the upper position against its top seat. With the valve in this position, 60 cubic centimeters of the gas sample are locked into the Fyrite and the top reservoir is opened to the center bore so that the gas sample can pass to the absorbing fluid. The Fyrite is then turned over, forcing the gas sample to bubble through the absorbing solution which absorbs the CO₂. This is repeated two additional times. The instrument is then turned back and held upright again. After five seconds (or the same time interval used when zeroing the instrument), read the scale adjacent to the liquid level. This is the carbon dioxide percent in the gas sample. Record this value on a data sheet.

The reason the liquid level will rise is because the absorption of CO₂ by the absorbing fluid creates a suction in the lower reservoir which causes the diaphragm at the bottom to flex up. This, in turn, permits the level of the absorbing fluid to rise in the center tube an amount equal to the CO₂ absorbed.

There is an easy check to determine if the strength of the absorbing solution is weakening and needs replacement. After you've completed a measurement and recorded the CO₂ value, turn the Fyrite over an additional two times forcing the gas sample to bubble through the absorbing solution. Return the analyzer to the upright position and read the CO₂ percent (after the same interval of time used before). If this value is greater than the recorded CO₂ percent, it is likely that the absorbing solution is weak and is not absorbing CO₂ at its normal rate. Replace the absorbing liquid before using the analyzer for further measurements. Refer to the manufacturer's instructions for the proper procedure on filling the analyzers.

Also, there is an easy check to determine if the sampling tube is leaking. Place your finger over the end of the connector plug and squeeze the bulb. If the bulb remains deflated and does not refill with air, the sampling tube is leak-free.

Bacharach Instrument Company also manufactures an oxygen Fyrite that operates on the same principle but uses a fluid that absorbs oxygen. The CO₂ analyzer is more widely used and the absorbing liquid is good for approximately 300 samples; the oxygen fluid is only good for about 100 samples. The use and operation of the O₂ analyzer is identical to the procedure followed for CO₂. The only difference is in checking the absorbing strength of the fluid. To determine the absorbing strength of the O₂ analyzer, pump a sample of room air into the analyzer and measure the O₂ content - it should read 21 percent. If it reads less, you should replace the liquid.

So you don't waste time - if you are in the process of squeezing the bulb and forget how many times you have already squeezed it, just continue squeezing until you are sure you've squeezed the bulb 18 times. It doesn't matter if you "over squeeze" just as long as you make a minimum of 18 compressions of the bulb.

Other CO₂ or O₂ Measurement Techniques

There are many other alternatives for measuring CO₂ or O₂. Several have been packaged into automatic or semi-automatic combustion analyzers. Most utilize an oxygen sensor cell which produces a small electrical current proportional to the level of oxygen in a flowing sample of combustion products which are drawn by a small suction pump through a test cell containing the oxygen sensor.

These combustion analyzers were originally sold by one firm called Lynn Products Co. of Lynn, MA. The Lynn analyzer was packaged into a portable unit which could alternately measure O₂ (or CO₂ depending on the specific model) percentage in the flue gases, net stack temperature, and provided a means to use the sample pump to provide a smoke spot check similar to that which can be performed with a Bacharach smoke spot tester. The net stack temperature and O₂ percent data was obtained by reading an indicator scale on the machine and then manually the operator would use a slide rule type device to determine the corresponding stack efficiency.

This basic configuration has been upgraded and improved upon by both Lynn Products Co. and many others. The resulting combustion analyzers available today fall into two general types, those which display temperature and O₂ (or CO₂) percent composition which still require the manual use of a slide rule type device and those which incorporate a small electronic microprocessor which automatically calculates the efficiency based on continuous measurement readings of O₂ (or CO₂) and net stack temperature and displays the efficiency on a digital readout panel on the device.

There are six companies which BNL is currently aware of who manufacture and market these devices, some of the six market both general types and some market various models and configurations. Energy Efficiency Systems Inc. for example sells five different models including a hand held unit. The following is a list of manufacturers which deal in this type of equipment:

1. United Technologies - Bacharach
Bacharach Instruments
301 Alpha Drive
Pittsburgh, PA 15238
(412) 782-3500
Products: FYRIZER DIGITAL COMBUSTION ANALYZERS
Model 10 and Model 200
2. R. W. Beckett Corporation
P.O. Box 1289
Elyria, OH 44036
(216) 327-1060
Products: COMBUSTION EFFICIENCY ANALYZERS
Model C1100 and Model C1200

3. Energy Efficiency Systems Inc.
1211 Steward Avenue
Bethpage, NY 11714
(516) 938-6680
Products: PORTABLE COMBUSTION EFFICIENCY COMPUTERS
Enerac Models 942, 842, 642, 242, and 50

(These products are also distributed by M-C Products, Division of Material Control, Inc., 7720 E. Redfield Road, Suite 2, Scottsdale, Arizona 85260, (602) 998-9577.)

4. Honeywell Inc.
Flame Safeguard Center
(800) 328-5111
Product: COMBUSTION EFFICIENCY ANALYZER

5. Lynn Product Company
400 Boston Street
Lynn, Massachusetts 01905
(617) 593-2500
Products: Oxygen Combustion Analyzer and Digital Combustion Analyzers.
Models 6000, 6000B, 6000DR, and 6400DCA.

6. Neotronics N.A. Inc.
Box 370
Gainesville, GA 30503
Product: Fuel Efficiency Monitor, F.E.M.

This list above is presented as a source for obtaining further information and does not represent any exhaustive efforts in determining a complete list of equipment manufactures and product lines. The various models and products cover a range of performance, costs, design, and operational characteristics. An analysis would have to be made for each activity (user) as to the appropriateness of first the purchase of an automatic device versus a manually operated Bacharach type test kit, and secondly which particular manufacturer, type, and model to purchase. This would depend on the number of units to be tested, skills of equipment operators, availability of a.c. line voltage at test site locations, etc.

Measurement of Flue Gas Temperature

Flue gas temperature (or often called stack temperature) is normally determined with a bi-metallic dial thermometer with a range of 200 to 1000°F (see Figure B.6). The bi-metallic element is a single helix, low mass coil fitted closely to the inside of a stainless steel stem. The stainless stem is 3/16 inches OD and can be easily inserted into a 1/4 inch hole in a flue pipe. Stem mounting sleeves are also available, which make it possible to hold the thermometer in pipe ducts with the stem inserted at the proper length.

MAKE SURE THE THERMOMETER IS READING CORRECTLY AND RECORD THE TEMPERATURE.

On these types of thermometers, the dial can easily loosen from the stem and rotate so that inaccurate temperature readings are displayed. There have been cases where dial thermometers have been as much as 200°F off from the actual temperature. Frequent calibration of these thermometers against a mercury thermometer by inserting both side by side in a heated flue or duct is recommended.

The net stack temperature is found by determining the room temperature and subtracting this value from the flue gas temperature. Don't forget to do this! Also, it is extremely important that flue gas temperature is measured at steady-state condition. This usually requires about fifteen minutes of burner operation. However, the best way to determine if the system is at steady-state is to insert the thermometer in the flue pipe. When the temperature rises less than 5°F during a one minute period, steady-state conditions exist. Remember, if you don't wait for steady-state you will record a temperature that is lower than actual and this will produce a steady-state efficiency which is higher than actual. By doing this, you may think the unit is operating at a reasonable efficiency level when it really isn't. You may also be denying your activity command the opportunity to recommend the installation of a new, flame-retention oil burner that can aid in achieving high steady-state efficiency and conserve fuel.

There are other devices that can be used to measure the flue gas temperature such as mercury-filled glass thermometers or thermocouples with potentiometers. Don't even consider a glass thermometer for other than calibration use, it's risky! They are fragile and easily broken and furthermore, mercury vapor is hazardous to your health. Thermocouples, however, are a possible alternative to dial thermometers; they are accurate, have a quick response to temperature change, and are easy to use. Although thermocouples are inexpensive, a good potentiometer is somewhat more expensive than a dial thermometer. For this reason it appears that presently the best bet for temperature measurement is your trusty dial thermometer - just make sure it's reading correctly.

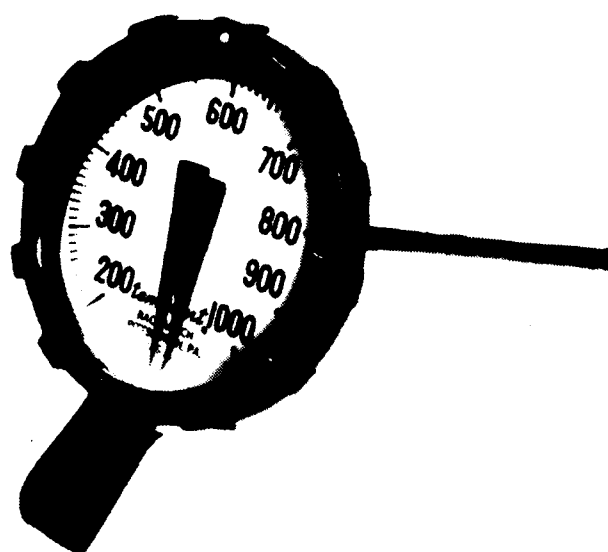


Figure B.6. Flue gas thermometer.

Smoke Measurement

You should realize by now that determining only the steady-state efficiency does not present the whole picture needed to properly adjust an oil burner. High efficiency with a high smoke level will likely become low efficiency or, even worse, require a service call resulting from plugged flue passages. The objective of a smoke test is to measure the smoke content in the flue gases and then, in conjunction with other steady-state test results, adjust the burner to optimum operation.

The American Society for Testing and Materials in 1965 adopted a standard method of test for smoke density in flue gases from distillate fuels (ASTM: D2165-65). This method covers the evaluation of smoke density in the flue gases from burning distillate fuels. It is intended primarily for use with home heating equipment burning kerosene or heating oils. It may be used in the laboratory or in the field to compare fuels for clean burning or to compare heating equipment.

A test smoke spot is obtained by pulling 2250 cubic inches of flue gas through a square inch of standard filter paper (or a proportionally smaller volume of flue gas and proportionally smaller filter area). The color (or shade) of the spot thus produced is visually matched with a standard scale, and the smoke density is expressed as a "smoke spot" number.

The most widely used smoke measuring device is the Bacharach True-Spot Smoke Tester which is based on the principle of filtering soot particles out of a sample of flue gas. The device is quite simple and rugged (see Figure B.7). It consists of a hand held piston in a tube with a clamping device at the inlet to the tube to hold a piece of white filter paper. The inlet tube is connected through flexible rubber hosing to a solid steel probe that can be inserted into a 1/4 inch hole in a flue pipe or duct. At the outlet end of the piston is a handle that is used to stroke the piston within the tube.

The operation of the device is simple and consumes very little time. After the burner has been in operation for at least five minutes, place the filter paper into the clamping device, insert the steel probe into the flue pipe hole, and slowly withdraw the piston fully from the tube. Hold the piston in the fully open position for about 3 seconds and then slowly push the piston completely in. Repeat the stroking procedure ten times. This allows an exact volume of gas to be passed through the filter paper. When the filter paper is removed, the amount of soot which has been filtered onto the paper will leave a circular colored spot. The darkness of the "smoke spot" is then compared against a Bacharach Oil Burner Smoke Scale (a scale from 0 to 9 representing increasing shades of darkness). If there is no soot, the paper will be white colored.

Figure B.8 shows the rating scale used by Bacharach. Actual comparison to determine a number rating is made by holding the filter paper behind the smoke scale so that the spot on the filter paper fills the center hole in the spot on the smoke scale. This allows direct comparison with the various spots on the scale.

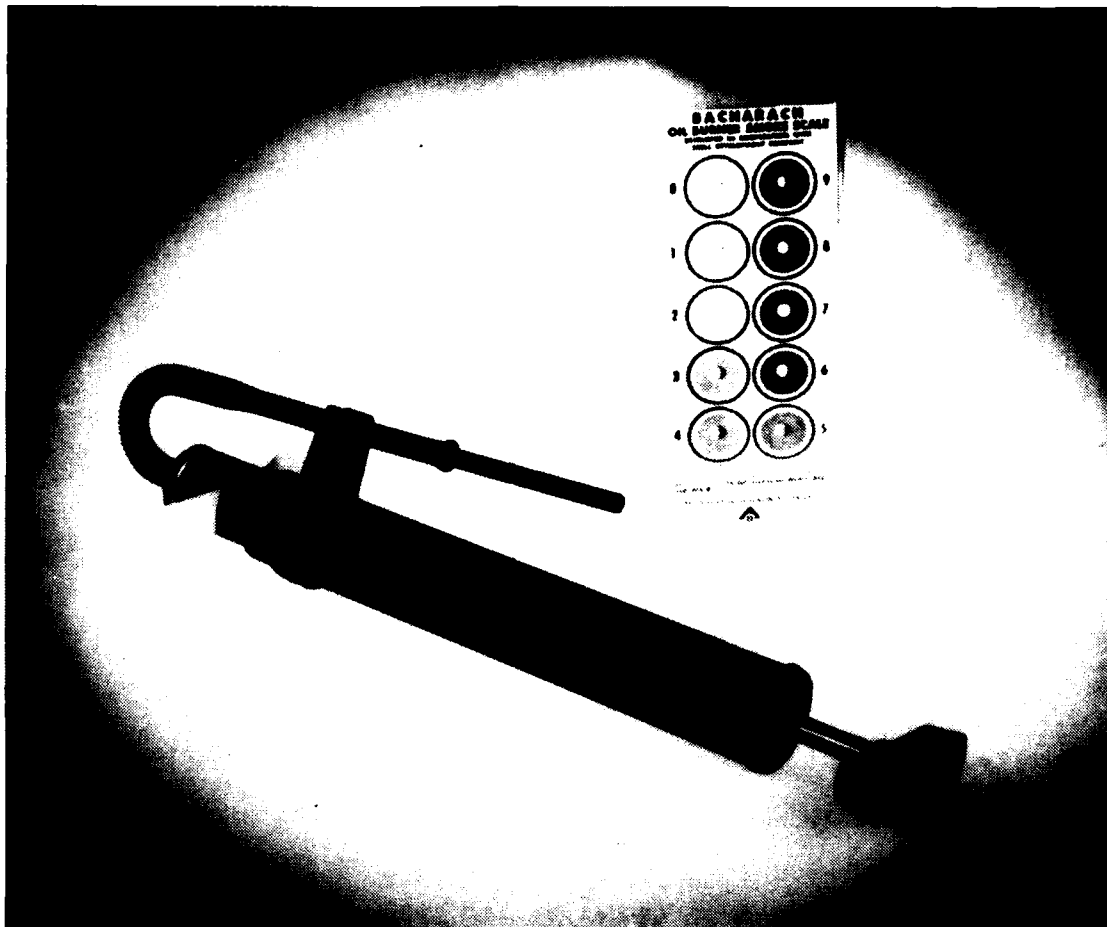


Figure B.7. Bacharach smoke spot tester.

Automatic electronic combustion analyzers also measure smoke by using a pump to draw a measured volume of flue gas (2250 cu.in. per sq.in. of filtering area) through filter paper (identical to the paper used in the Bacharach True-Spot Smoke Tester) that is inserted in the gun assembly. The "smoke spot" is then compared against an oil burner smoke scale.

Draft

Correct draft is essential for efficient burner operation. There are two types of devices that are commonly used to measure draft - a Bacharach Drafrite Pocket Draft Gauge or a Bacharach MZF Draft Gauge. The Drafrite is small and easy to use while the MZF is more sensitive yet also easy to use. The Drafrite is a slim, hand held, rectangular device with a curved draft scale placed behind a free floating pointer. The back of the device has an opening in which short metal tubes screwed in series can be inserted. The end of the metal tubes can be placed in the flue pipe and the pointer will indicate the draft on the numbered scale. These metal tubes may melt if left in the flue for too long. Be Careful!

The MZF Draft Gauge also contains a pointer located over a large scale. Rubber tubing is connected to an opening at the rear of the device and also is fitted, at the other end, onto a metal probe. Upon inserting the probe into a flue or over the fire in a boiler or furnace, the pointer moves in direct proportion to the magnitude of the draft.

Either of these devices are acceptable for use in determining draft, if they are used properly. Both draft measurement devices are shown in Figure B.9

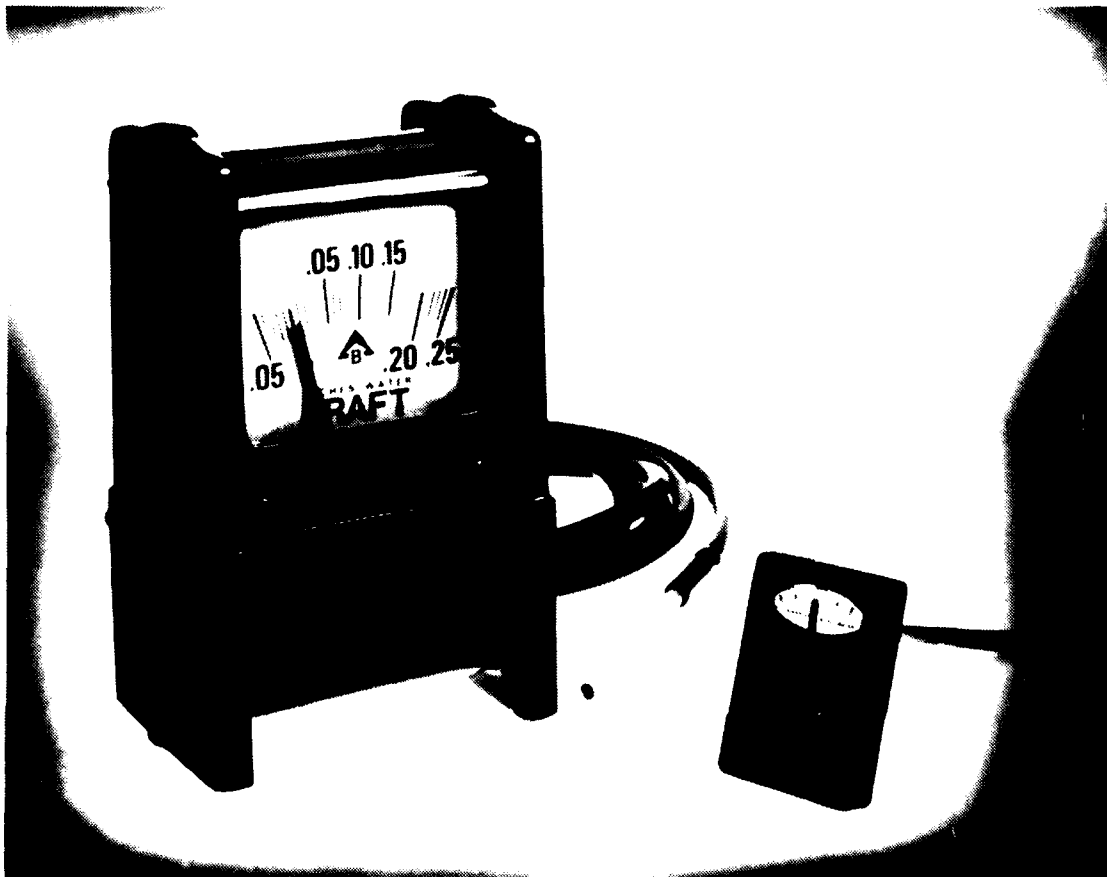


Figure B.9. Draft measurement devices.

APPENDIX C

BURNER INSTALLATION INSTRUCTIONS

This appendix contains copies of six manufacturer's installation manuals for ten different models of retention head oil burner designs sized for small (single or two family) residential applications. The selection of these particular manufacturers and models for inclusion in this guide should not be considered as a recommendation, approval, or endorsement of these products. The purpose of this appendix is for use as an information source for the maintenance and adjustment of retention head burners which may already be in use in Naval residential shore facility housing. The models and types of burners included were selected based on BNL's previous experience (seven years) with the residential oil heating industry during its research programs conducted for the U.S. Department of Energy. The factors considered for selection were quite simply production and market share of the individual models. Those models omitted from this report were deleted based on the lower probability of encountering those equipment types in the field. This was based on a qualitative analysis conducted by the BNL staff. The other factor involved in this choice was the rather large volume of material already contained in this report. In order to keep this report from becoming too large we have agreed to include more details with regard to burner performance, a survey of equipment manufacturers, and selection criteria guidance in future project reports. One report will be a User Data Package. The initial draft of the User Data Package will be delivered to NCEL on or about 30 June 1984. A draft Technical Report on the laboratory test and evaluation of "large" (6-10 GPH) burners will be issued on or about 15 February 1984. A Technical Note on the field test and evaluation of small burners will be issued on or about 30 June 1984.

For any burners that might already be in use at Naval residential shore facility housing sites which have not been included in this appendix we strongly recommend that technicians and/or service contractors obtain installation and adjustment information directly from the manufacturers, use them, and keep them on file for future reference. Any equipment which is purchased in the future should include these manuals and after installation the manuals should again be retained for future reference.

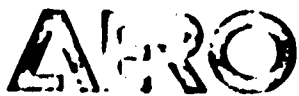
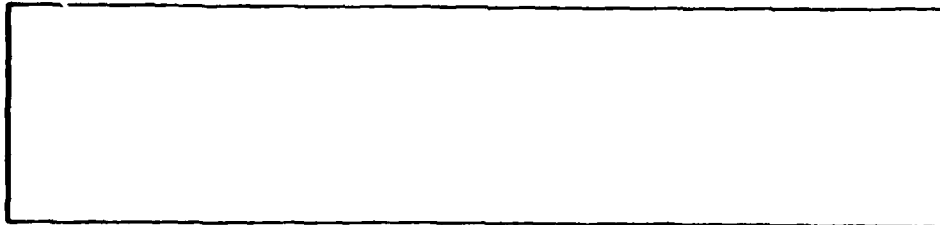
SERVICE AND INSTALLATION MANUAL

For MODEL NUMBERS F-AFC & HF-AFC OIL BURNERS

**These burners are listed by the Canadian Standards Association
Testing Laboratories as approved.**

These burners are approved for use with Group 1 or 2 Controls, for burning fuel oil not heavier than No. 2 (furnace) oil.

The installation of a burner shall be in accordance with the regulations of authorities having jurisdiction. Reference is being made to C.S.A. Standard B139 - 1976, "Installation Code for Oil Burning Equipment".



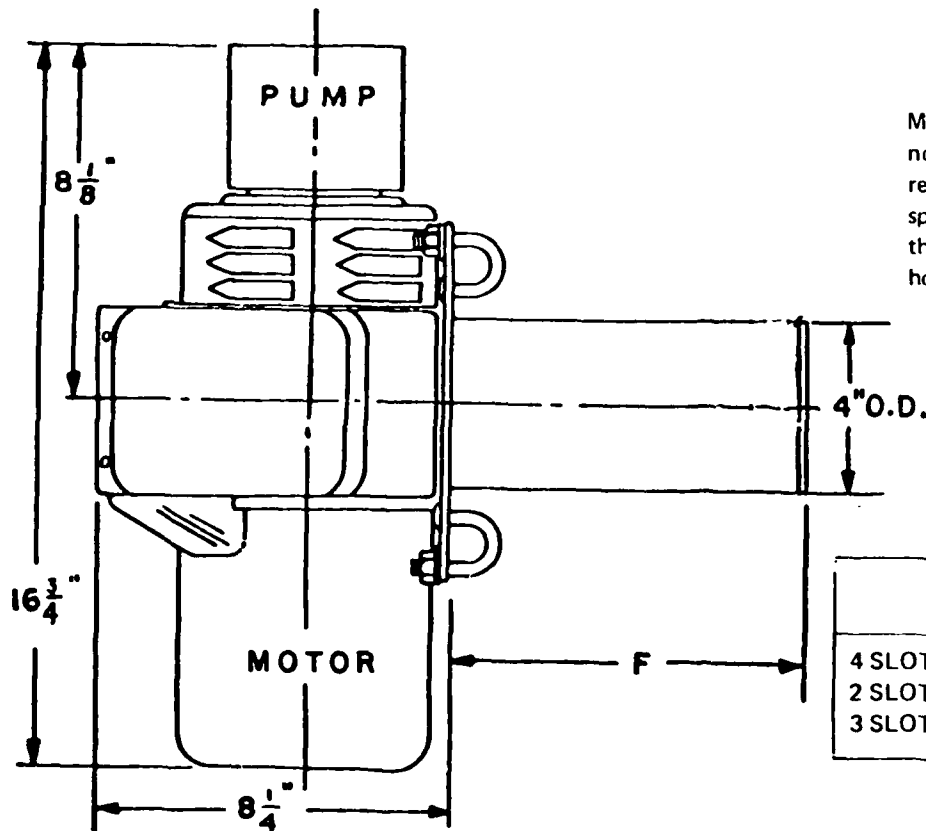
AERO ENVIRONMENTAL LIMITED

37 Hanna Avenue - Toronto, Ontario M6K 1X2

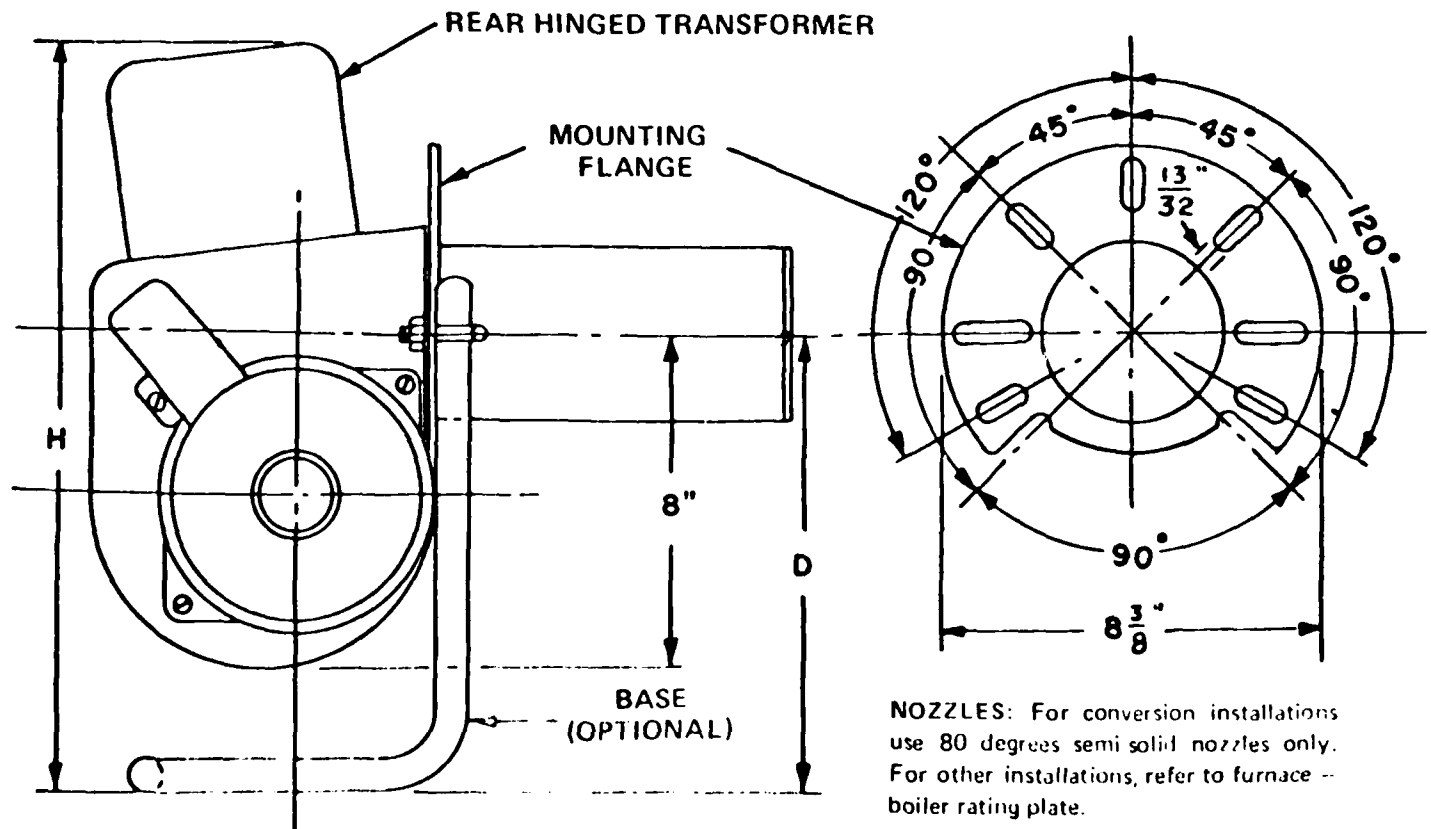
SERIES "F-AFC" & "H-FAFC"

NOTE

Min. free blast tube length, F, is 5" for normal construction as shown. It may be reduced down to 2-1/2" thru use of a spacer between the mounting flange and the housing. This will increase the 8-1/4" housing depth correspondingly.



	BOLT CIRCLE DIA.	
	MIN.	MAX.
4 SLOTS @ 90 degrees	6-7/8"	7-1/2"
2 SLOTS @ 180 degrees	5-3/8"	7-1/2"
3 SLOTS @ 120 degrees	5-7/8"	7-1/2"



NOZZLES: For conversion installations use 80 degrees semi solid nozzles only. For other installations, refer to furnace -- boiler rating plate.

1. LOCATION OF OIL BURNER

These oil burners are normally flange mounted, an adjustable base, as shown, is available.

A rear hinged transformer is standard equipment. By removing one screw on the front side of the housing, the transformer may be swung up and the electrode assembly easily removed through the opening. High tension leads are spring bus bars; no screw connection. The junction box is an integral part of the burner housing. If primary control is mounted on burner a 4' x 4' field junction box is supplied mounted.

II. DESCRIPTION & REMOVAL OF ELECTRODE ASSEMBLY

Remove screw B, Fig. 3, and rotate transformer on its hinge. After opening the tubing connection at the side of the blower housing, remove the clamp nut, E, and disengage the oil line. Remove the firing assembly by rotating it 1/4 turn in a clockwise direction and then pulling it outward and upward. Refer to Fig. II for firing assembly adjustments. To reinstall the firing assembly, insert it with the bend of the tubing in the vertical plane and rotate it 1/4 turn counterclockwise so the bend coincides with the outlet in the housing. Make sure the bus bars are positioned so that they will contact the transformer terminal nuts when the transformer is in its normal position.

DIMENSIONS

F	STANDARD FREE BLAST TUBE LENGTH (Including Endcone)	8", 11" & 16" (other lengths available)
F (Min.)	MINIMUM FREE BLAST TUBE LENGTH	5" (see note page 2)
H*	OVERALL HEIGHT	14-9/16" to 17-9/16"
D*	DISTANCE FROM CENTRE OF NOZZLE TO FLOOR	8" to 11"
W	WEIGHT (PACKED)	50 LBS. (Approx.)

* WHEN BASE MOUNTED

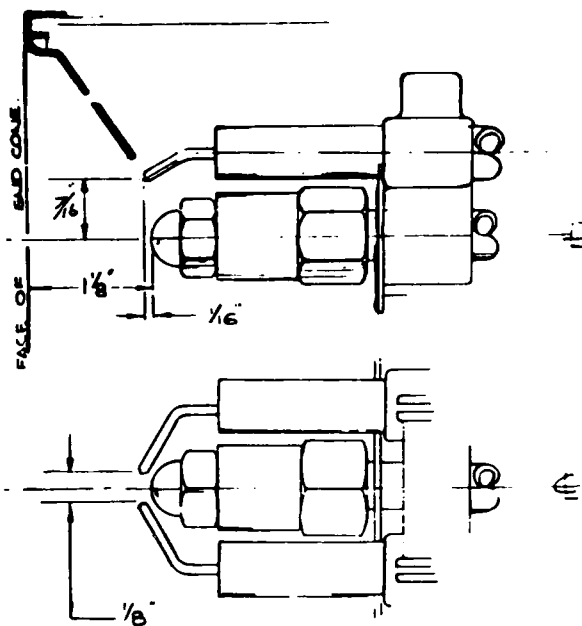
Standard Capacities. (On O.E.M. applications, capacities may vary. See unit nameplate.)

Model	Rating	End Cone	Fan	Nozzle Spray Angle	Nozzle Type	Static Disc
F-AFC-1	.50-.65	AFC-1	524-316	80 degrees	Semi-solid	Turbo, 3"
F-AFC-2	.65-1.25	AFC-2	524-316	80 degrees	Semi-solid	Turbo, 3"
F-AFC-3	1.25-1.75	AFC-3	524-316	80 degrees	Semi-solid	Turbo, 3"
F-AFC-4	1.75-2.25	AFC-4	524-316	80 degrees	Semi-solid	Turbo, 3"
F-AFC-5	2.25-2.75	AFC-5	524-316	80 degrees	Semi-solid	Turbo, 3"
HF-AFC-1	.75-1.25	AFC-1	524-316	80 degrees	Semi-solid	Turbo, 3-3/8"
HF-AFC-2	1.25-2.25	AFC-2	524-316	80 degrees	Semi-solid	Turbo, 3-3/8"
HF-AFC-3	2.25-3.00	AFC-3	524-316	80 degrees	PLP or like	Turbo, 3-3/8"
HF-AFC-4	2.50-3.50	AFC-4	524-316	80 degrees	PLP or like	Turbo, 3-3/8"
HF-AFC-5	3.00-5.00	AFC-5	524-316	80 degrees	PLP or like	Turbo, 3-3/8"

NOTE: On 50 cycle, reduce maximum input by 20%.

MOTOR H.P.:	(F-AFC)	1/8: R.P.M. 60 CY 1725, 50 CY 1500
MOTOR H.P.:	(HF-AFC)	1/4: R.P.M. 60 CY 3450, 50 CY 2800

Fuel pump standard single-stage, optional 2 stage.



**ELECTRODE SETTING
MODELS FAFC AND HFAFC**

Fig. 11

III - PROPER INSTALLATION OF BURNER

1. To facilitate removal of the burner without disturbing the refractory, insulation and ashpit pouch seal, insert into the air tube opening in the refractory a metal sleeve of the same outside diameter as the hole in the refractory. The sleeve should be long enough to extend from the inside of the refractory to the outside edge of the ashpit pouch. Wrap fireproof insulation around the air tube. Insert the burner in the sleeve so that it extends within 1/4" of the inside end of the sleeve. Use a spirit level when adjusting the position of the burner to provide a downward pitch of one or two degrees toward the refractory. Having made these adjustments, securely lag the burner to the floor.

2. Place fireproof insulation between the refractory and the walls of the combustion chamber and in the front of the ashpit pouch. Close the ashpit door opening with a mixture of asbestos and Portland cement. Use a trowel to obtain a smooth surface that is flush with the edge of the ashpit and one that will not permit any air leaks. Fill any space between the burner air tube and the metal sleeve with asbestos.

3. TO INSTALL NOZZLE, see II - Description & Removal of Electrode Assembly. Remove the plastic cover on the nozzle and install the nozzle. If it is necessary to change the nozzle size, simply install a nozzle of the desired size - no adjustments need be made. Check to see that the electrode gap is 1/8" and that the tips of the electrodes are 1/16" in front of the nozzle and 7/16" above the center of the nozzle (see Fig. 11). Reinstall the electrode assembly. Tighten the clamp nut and also the flare nut. Rotate the transformer to its original position and tighten the screw. Note: Use proper nozzle wrench.

4. After referring to the instructions for the oil pump, install the oil pump in the oil line.

5. Install the primary control and thermostat in accordance with instructions supplied.

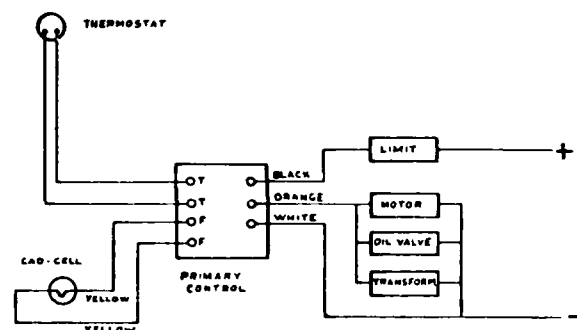
* Look at blast tube from front end and check nozzle for being in centre on end cone opening. If it is not, adjust knurled nut and inside nut on oil pipe.

IV - CONTROLS AND WIRING

For specific control wiring instructions, refer to wiring diagram packed with the controls. All controls should be installed and regulated in accordance with the control manufacturer's instructions, which are attached to and made a part of this Manual.

The wiring of the controls on the burner and the internal wiring in the control panel have been completed and tested at the factory and should not be altered except in accordance with the control manufacturer's instructions for regulating ignition, time and safety lockout.

Wiring at the burner shall be done in approved 3-wire flexible conduit or rigid conduit. All wiring except that specifically indicated for low voltage should be completed in accordance with the Canadian Electrical Code, Part I, and local authorities having jurisdiction.



V - INSTALLATION OF CONTROLS

1. The basic controls to be used with the burner are the thermostat, primary control, limit control and barometric draft control. For special installations having forced hot water, booster pumps, unit heaters, etc., additional controls will be required. For wiring diagram and installation, refer to instructions packed with each control.

2. A brief explanation of the purpose of the various controls may aid in their installation. The thermostat, obviously, controls the operation of the automatic heating plant to keep room temperature at the point desired. New thermostats have a "heat anticipating" feature that artificially supplies heat to the bimetal elements in the thermostat when the burner is operating. This internal heat opens the contacts in the thermostat before the air temperature reaches the indicated point. The amount of internal heat is regulated so that the normal and natural "coasting" of heat built up when the burners stops brings the air temperature to the desired point. Without "heat anticipation," air temperature often exceeded the thermostat setting, and temperature control was far less accurate.

3. The primary control is of the type that controls the burner in accordance with the instructions supplied.

When the thermostat calls for heat, the primary control starts the burner's high voltage ignition and burner motor.

When the ignition system is operating, the control then starts the burner. After a period of several seconds the control virtually "checks," from a temperature standpoint, to see whether the fire is burning.

If there is no fire, the primary control shuts off the burner, and refuses to restart it until the control is re set by means of its re set button. The primary control additionally will stop the burner if, at any time during operation, the fire should go out. This control thus keeps the burner from running and pumping oil into the combustion chamber unless it is being ignited and burned, thereby providing complete protection.

4. The steam, hot water, and warm air limit controls function to keep the temperature or steam pressure from exceeding limits of safety. Should the limit control stop the operation of the burner, it will allow it to resume operation as soon as the temperature or pressure drops to a desirable operating level.

5. The operating controls on boilers and the fan control on furnaces control the operation of the water circulator or circulating fan, allowing them to run only when the water or air in the heating unit is warm enough. These controls are usually combined with the limit controls in a single control unit in each case.

6. The low water cut-off in steam boilers stops the burner if the water level in the boiler should fall below safe limits. No steam boiler should be operated without one.

7. The reverse acting operating control on hot water boilers keeps the water circulator from operating except in the high temperature range of the boiler, so that the boiler can provide heat for domestic hot water without heating the house in summer or on warm days.

8. The barometric draft control automatically keeps the draft in the combustion chamber from exceeding an established level, usually 0.02 inch in the combustion chamber. Drafts greater than that are automatically "short circuited" by the draft control, so that there is no tendency for excessive drafts to "pull the fire up the chimney."

9. All wiring must conform to Canadian Standards Association, local, and Canadian Electrical Codes. Do not, in any case, use less than number 14 A.W.G. wire for line voltage wiring. The burner should be wired with lines directly from the power supply cabinet and not from any lighting circuit. It is to be protected by a 15 ampere fuse.

VI - AIR SUPPLY

The furnace or boiler should be provided with adequate fresh air for combustion. If the furnace or boiler is installed in a utility room or closet, grilles should be placed near the ceiling and the floor to provide ventilation as well as air for combustion. One square inch minimum free area per 1,000 B.T.U. per hour input or 135 square inches for each gallon per hour input are required in each grille. Outdoor connections should be screened and provided with louvers.

VII - DRAFT

1. The burner should be ignited and the draft rate adjusted to that required for the particular installation.

2. Draft shall be adjusted to amount recommended.

3. Combustion air adjustments are to be made to give the highest CO₂. Set air for smoke spot. If the minimum required percentage of CO₂ cannot be obtained in the breeching, it will be permissible to take CO₂ over the fire, which will be acceptable. A considerable difference between the two CO₂ readings indicates a leak of air into the flue passes or fire box of the boiler.

4. Stack temperature shall be recorded after 10 minutes of operation.

VIII - ADJUSTMENT OF BURNER FOR BEST EFFICIENCY

1. Set the room thermostat 10 degrees higher than the temperature on the thermometer. Adjust the limit control to 180 degrees. See that the manual reset button of the integral thermal overload switch on the oil burner motor is pushed in. Open all valves and oil lines. Open the fire door or observation door of the furnace or boiler. To purge the air from the oil line and oil pump loosen the plug in the gauge port of the pump (see oil pump instructions). Close the burner switch and allow the burner to run until there are no air bubbles in the oil issuing from the gauge port of the pump. Then tighten the plug in the pump.

2. To obtain best efficiency and performance, adjust the draft regulator alternately with the burner air band adjustment until a 10 to 12% CO₂ flue gas analysis is obtained with .01-.02" W.C. over-fire draft. To approach this CO₂ reading, close the burner air supply adjustment until a smoky flame is obtained, and then open it only enough so that a clean flame is apparent immediately after the fire-door or observation door is opened. Use instruments for proper adjustment of burner. (Smoke analyser & draft tester).

3. Check the safety controls for proper operation as described in the control manufacturer's instructions.

4. Be sure to leave the installation in a clean and tidy condition.

5. Advise the home owner how to start and stop the oil burner.

6. Return in two or three weeks and recheck burner adjustment and operation. Repeat steps one through six.

IX - CARE OF HEATING SYSTEMS, FLUE AND CHIMNEY

HEATING SYSTEMS: Different heating units present different problems in care and cleaning. Before installation and during free service period heating units should be thoroughly checked for leakage and air seal.

FLUES: The flue passages should be thoroughly cleaned and resealed to prevent heat loss and poor heat absorption. Wire brushes with suitable handles and vacuum cleaners make good cleaning tools.

The flue pipe should have no obstructions caused by hand dampers or foreign matter.

CAUTION: Oil burning equipment shall be connected to flues having sufficient draft at all times to assure safe and proper operation of the burner.

X - INSTRUCTIONS FOR REMOVAL AND REPLACING BURNER PARTS

MOTOR, FAN AND FLEXIBLE COUPLING (Refer to Fig. III)

Loosen set screw F. Remove the two screws A1 and A2. The motor may now be removed from the housing, with the fan and coupling attached to its shaft. To remove the coupling, loosen set screw and pull rubber coupling away from shaft. To remove the fan from the motor shaft, loosen set screw C.

PUMP

Loosen screws D1 and D2. Open pipe and tubing connections loosen set screw and remove pump.

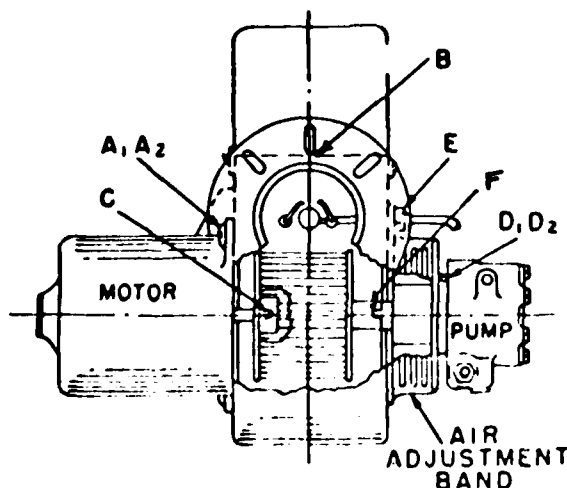


FIG. III

TRANSFORMER

TABLE D1
RECOMMENDED COMBUSTION CHAMBER SIZES FOR
"GUN TYPE" CONVERSION OIL BURNERS

Firing Rate Gallons (U.S.) per hour	Floor Area			Typical Dimensions				
	Square Inches			Rectangular Inches			Round Inches	
	Mini- mum	Recom- mended	Maxi- mum	Width	Length	Height	Dia- meter	Height
0.75	56	71	86	8	9	14	9	14
0.85	64	81	98	8	10	14	10	14
1.00	75	95	115	9 1/2	10	14	11	14
1.25	94	119	144	10	12	14	12	14
1.35	101	128	155	11	12	14	13	14
1.50	113	143	171	11	13	15	13	15
1.65	124	157	188	12	13	15	14	15
1.75	131	166	200	12	14	16	14 1/2	16
2.00	150	188	228	13	15	16	15 1/2	16
2.25	169	212	257	13	16	16	16 1/2	16
2.50	188	235	285	14	17	17	17	17
3.00	222	282	339	15	19	17	19	17
3.50	259	329	396	16	20	18	20 1/2	18
4.00	296	376	452	18	21	18	22	18
4.50	333	423	509	18	23	18	23	18
5.00	370	465	560	19	24	19	24	19

Notes: 1. Table D1 is applicable for either "common" firebrick or "insulating" firebrick. Insulating firebrick is suitable for all sizes of chambers and, when used, should be of the following grades:

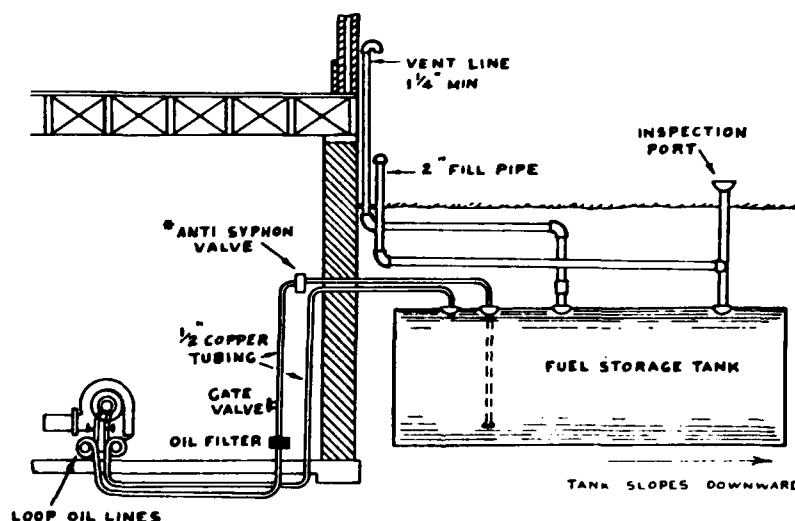
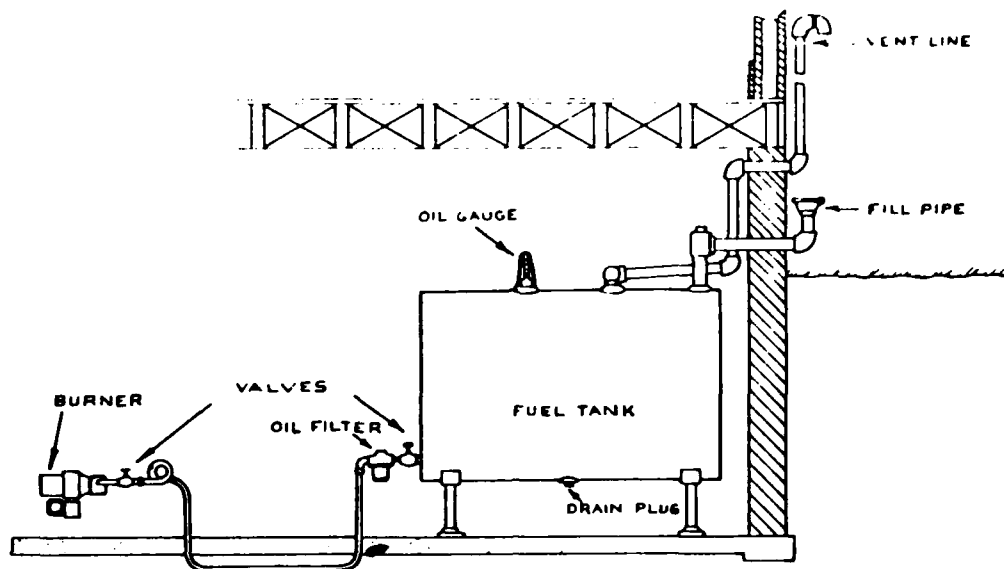
Firing Rate Grade of Insulating Firebrick

Less than 5 gallons (U.S.) per hour 2,300 degrees F brick

5-10 gallons (U.S.) per hour 2,600 degrees F brick

Over 10 gallons (U.S.) per hour 3,000 degrees F brick

2. The "Typical Dimensions" in Table D1 are suitable for nozzles having spray angles of 80 degrees in the lower firing rates (3 gallons per hour or less) and 60 degrees in the higher firing rates (over 3 gallons per hour). When the burner or the installation conditions require the use of a wider (90 degree) or narrower (30-45 degrees) spray angle, the length-to-width relationships for rectangular chambers specified in Table D1 should be adjusted to suit the conditions encountered. The recommended floor area in Table D1 should be maintained when adjusting the relationship of the dimensions to accommodate wide or narrow spray angles and in no case should the floor area be less than the appropriate minimum value specified in Table D1.



- * Anti-Syphon valve on installations with tank above burner level
- * Check valve on installations with tank below burner level

1. The oil tank should be installed in accordance with local regulations and those of the Canadian Standards Association. Galvanized tanks and piping are not recommended.

2. Gravity supply tanks located inside buildings shall not exceed 250 gallons individual capacity, or 500 gallons aggregate capacity (in one building). Inside tanks larger than the above must be installed in an enclosure or casing constructed of reinforced concrete at least 6" thick, or of brick at least 8" thick, bonded to the floor. The space between the enclosure and the tank shall be completely filled with well-tamped earth or sand. Instead of an enclosure, the tank may be encased in reinforced concrete at least 6" thick applied directly to the tank.

3. Underground oil supply tanks should be located so that the top of the tank is below the level of all piping to which the tank is connected, so that oil cannot be discharged through a broken pipe or connection by syphoning. The tank shall be buried so as to be covered by not less than two feet of earth, or one foot of earth on top of which is placed a slab of reinforced concrete not less than 4 inches thick. A well-tamped earth foundation shall be provided beneath the concrete slab, which shall extend at least one foot beyond the tank in all directions. The tank shall be set on a firm foundation and sand shall be packed around it. When necessary, to prevent floating, it shall be securely anchored or weighted.

4. Proper allowance shall be made for expansion, contraction, jarring and vibration. With the exception of fill lines and test wells, pipe lines shall be provided with double swing joints, which will permit the tank to settle without straining the pipe connections. Tanks shall be equipped with an open vent or an approved automatically operated vent, which will permit discharge to the open air. Vent pipe and vent opening shall be large enough to prevent abnormal pressure in the tank during filling, 1-1/4" pipe size being the minimum. The vent and fill pipes should drain to the tank, and the lower end of the vent pipe shall not be cross-connected with the fill pipe. The outer end of vent pipe shall be provided with a weather-proof hood which should be high enough above the ground to prevent its being obstructed with snow or ice. The vent pipe shall not be closer than two feet, either vertically or horizontally, from any window or other building opening.

5. The storage tank shall be filled only through a 2" fill pipe terminating outside of the building, no closer than five feet from any building opening at the same or lower level. A metal cover designed to prevent tampering shall be provided.

6. Complete piping of suction and return lines to and from burner with 3/8" or 1/2" copper service pipe and fittings for same. Lay pipe in 6" wide by 12" deep trench. The suction pipe should not come closer than 3" to 4" from bottom of tank. None of the other pipes should come inside of tank. A special suction line fitting is used to let suction pipe through. Make a hole, large enough to permit entry of both pipes, through wall where pipes are to enter basement, 12" below ground. The copper pipes should be laid in one piece from tank to burner, without traps, being sure to leave a sufficient coil of pipe inside basement to reach to burner installation. (CAUTION: Be sure to fill in around pipes with cement to make basement wall water-tight).

7. All piping shall be approved copper tubing, at least 3/8" O.D. (1/2" O.D. copper tubing is preferred) having a wall thickness not less than 0.049" shall be used in connecting the burner to the tank. The piping shall be protected from possible injury, and shall be rigidly fastened in place in a workmanlike manner. Where practicable, it should be buried underground, or in a concrete floor, or placed in a metal-covered pipe trench. Do not cover the piping until the burner has been installed and operated so that any leaks may be corrected. Pipe joints and connections shall be made tight, and unions and tubing fittings of an approved type only shall be used. Use only pipe thread compound resistant to oil. A filter shall be installed in the oil supply line to the burner.

To determine the proper fuel line size, refer to the fuel unit instructions shipped with the oil burner.

8. CSA Listed Oil Burner shall be installed in the oil supply line from the tank to the tank.

XIII – DRAFT REGULATOR, SETTING

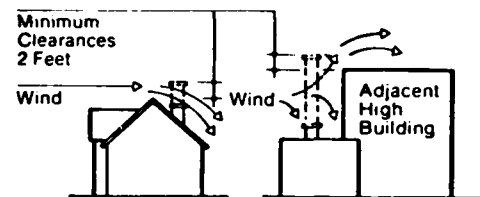
A draft regulator of approved design is recommended, the same nominal size as the flue pipe, and an adjustable type to secure the proper adjustment of flue gas. It should be placed between chimney and stack control (if used) in a position such that the intruding air through the draft regulator will not cool the thermal element of the stack control.

Adjust draft to 0.04–0.05 W.C. at the breech and 0.01–0.02 W.C. over the fire or as indicated on the furnace, boiler rating plate.

XIV – CHIMNEY SIZE AND INSPECTION

1. Starting with minimum gallonage, the minimum size recommended is 7" flue pipe with 8" x 8" inside chimney.

2. A chimney flue shall extend at least 3 feet above the highest point at which the chimney comes in contact with the roof, and not less than 2 feet above the highest roof surface or structure within 10 feet horizontally of the chimney.



NOTE: Incorrect chimney design as shown by solid lines may result in down drafts.

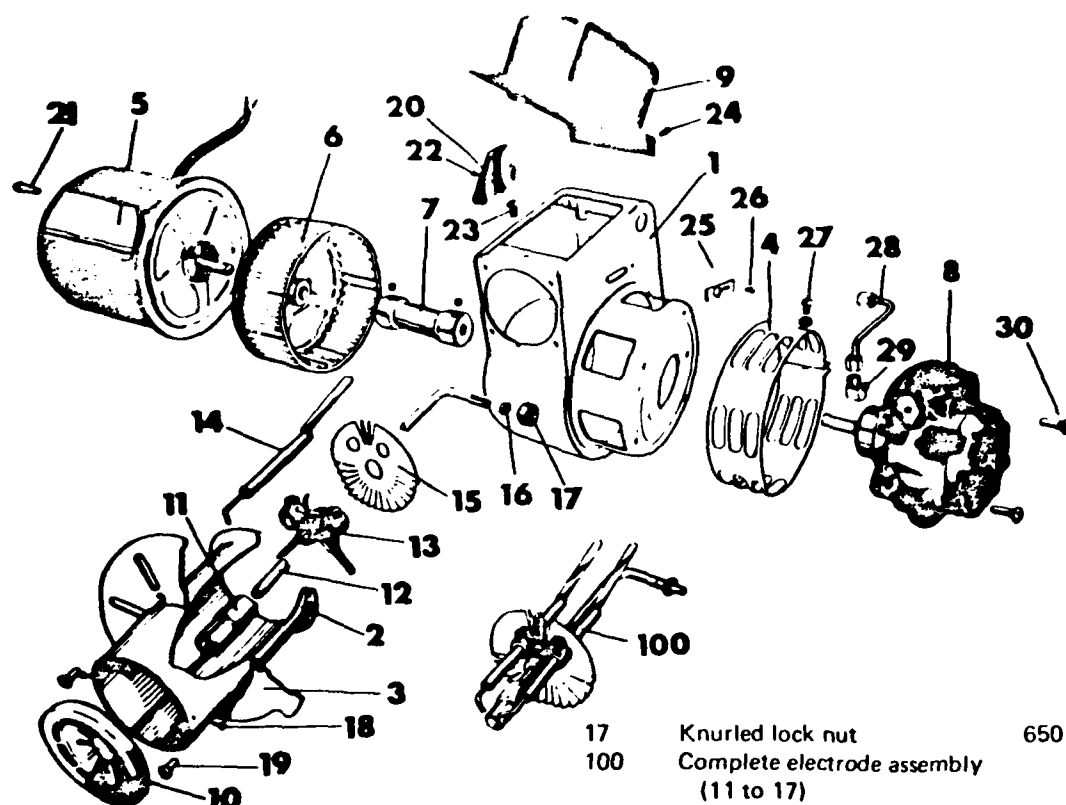
3. Any accumulation of soot or debris in chimney offsets should be removed.

4. Any obstructions such as a protruding joint or a piece of broken tile wedged in the chimney should be removed.

5. No other appliance connection should be made to the same flue pipe.

6. The flue pipe should have an upward pitch toward the chimney of at least 1/4 inch per foot of length. It should fit tightly and should not project into the chimney.

7. Any leakage between tiles, around cleat doors, or around the vent pipe should be sealed.



PARTS LIST Model F-AFC and HF-AFC Oil Burners

Item No.	Part Name and Description	Part No.	Quan. Req.
1	F housing	65000	1
2	Blast tube, available from 5" to 16" (specify blast tube length)		1
3	Mounting flange - Standard	65004	1
4	Air band assembly	65518	1
5	Motor:		1
	F-AFC, 1/8 HP, 1725 RPM	30044	
	HF-AFC, 1/4 HP, 3450 RPM	65052	
6	Fan, 524-316	65046	1
7	Flexible metal-end coupling	B1540	1
8	Fuel pump:		1
	J2-CB-100 single-stage	30055	
	J3-CB-100 single-stage	30056	
	H3-CB-100 two-stage	30057	
9	Transformer, 421-456	30060	1
10	End cone:		1
	AFC-1	65006	
	AFC-2	65007	
	AFC-3	65008	
	AFC-4	65009	
	AFC-5	65010	
11	Nozzle adaptor	30038	1
12	Oil pipe, aluminum (specify blast tube length)		1
13	Electrode holder	65019	1
14	Electrodes (with porcelains)		1 pr.
14A	Bus bars (specify length)		1 pr.
15	Turbo static disc		1
	F-AFC, 3"	65020	
	HF-AFC, 3-3/8"	65064	
16	Jam hex nut	30037	1
	Knurled lock nut	65018	1
	Complete electrode assembly (11 to 17)		1
	AFC end cone screws	30053	2
	Blast tube screw (specify length)		4
	Raceway	65062	1
	Motor screws	30054	2
	Raceway screw	30095	1
	Transformer lock-down screw	30063	1
	Transformer hinge screws	30062	2
	Slide plate	65017	1
	Slide plate pop rivet	65012	1
	Air band locking screw	30054	1
	Air band locking nut	30001	1
	Oil line assembly	65524	1
	Compression elbow, 90 degree	30073	1
	Fuel pump screws	30054	2
	Nozzle (specify gph, angle, pattern)		1
	Spacers, available in 1/4" increments 1/4" to 2-1/2" (specify width)		
	Oil burner mounting gasket, 1/8"	30018	1
	Base assembly (including brackets & nuts)	66004	
	Carton - complete		

If required, a junction box, a primary safety relay and a flame viewing cadmium all can be mounted on burner.

When ordering parts, always give: (1) Model; (2) Part Name; (3) Part Number; (4) Size; (5) Quantity Required.

NOTE: Prices available on request are f.o.b. our factory, 37 Hanna Ave., Toronto, Ontario.

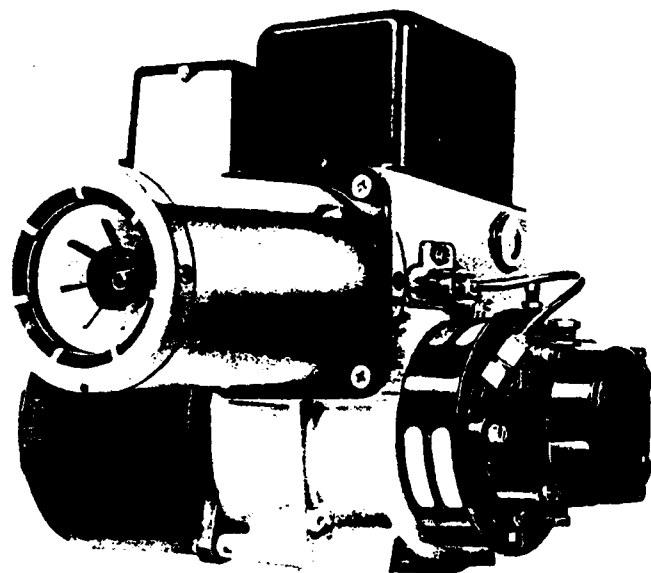
TERMS: 1-1/2% 10 Days; Net 30 Days on approved credit; otherwise C.O.D.

MINIMUM BILLING CHARGE: \$10.00 per order.

RWB

Beckett

INSTRUCTION MANUAL

model AF**OIL BURNER****SPECIFICATIONS****CAPACITIES - MODEL AF**

..... 0.40 to 3.00 gallons per hour
 56,000 to 420,000 BTU/HR Input

FUELS

No. 1 or No. 2 Heating Oil (ASTM D396) Only
 In Canada, No. 1 or No. 2 Furnace Oil

DIMENSIONS (Standard)

Height 11-1/2"
 Width 12-7/8"
 Depth (Chassis Only) 6-9/16"

ELECTRICAL CHARACTERISTICS (See Note)

Power Supply 115 V/60 Hz 1 PH
 Operating Load (Max.) 5.8 Amps
 Motor 1/7 HP, 3450 RPM, N.E.M.A. "M" Flange, manual
 reset overload, protection
 Ignition 10,000 V/23 ma secondary, continuous-
 duty shielded, transformer or solid-state ignition system

FUEL UNIT

..... Sundstrand, or Webster

Dear Homeowner:

Over forty years of engineering and product development have gone into your new oil burner. Its quality and design are unsurpassed. Properly installed and maintained it will provide many years of efficient, trouble-free operation. Please read this Instruction Manual carefully, and give special attention to the following points:

- An oil burner must have a generous supply of combustion air to operate properly. Please refer to the information in this manual for details.
- NEVER attempt to use gasoline in your heating appliance. Gasoline is more combustible than fuel oil and could result in a serious explosion. NEVER burn garbage or refuse in your heating appliance or try to light oil by tossing burning material into the heater.
- **INSTALLATION AND ADJUSTMENT OF THE BURNER REQUIRES TECHNICAL KNOWLEDGE AND THE USE OF COMBUSTION TEST INSTRUMENTS. DO NOT TAMPER WITH THE UNIT OR CONTROLS. CALL YOUR SERVICEMAN.**

Beckett warrants its equipment specifically to those who have purchased it for resale, including your dealer. In the event of any problems with your equipment or its installation, you should contact your dealer for assistance.

TO THE INSTALLER

INSTALLATION OF THE BURNER MUST BE DONE BY A QUALIFIED INSTALLER IN ACCORDANCE WITH REGULATIONS OF THE NATIONAL FIRE PROTECTION STANDARD FOR OIL-BURNING EQUIPMENT, NFPA NO. 31, AND IN COMPLETE ACCORDANCE WITH ALL LOCAL CODES AND AUTHORITIES HAVING JURISDICTION. FOR RECOMMENDED INSTALLATION PRACTICE IN CANADA, REFERENCE SHOULD BE MADE TO CSA STANDARD B139.

A QUALIFIED INSTALLER IS AN INDIVIDUAL OR AGENCY WHO IS RESPONSIBLE FOR THE INSTALLATION AND ADJUSTMENT OF THE EQUIPMENT AND WHO IS PROPERLY LICENSED AND EXPERIENCED TO INSTALL OIL-BURNING EQUIPMENT IN ACCORDANCE WITH ALL CODES AND ORDINANCES.

A properly designed chimney of adequate size and height and adequate combustion air supply are essentials for the best operation of any heating plant.

When installing the heater and/or burner be sure to provide adequate space for easy service and maintenance.

CONCEALED DAMAGE

If any damage to the burner or controls is found during unpacking notify the carrier at once and file the appropriate claim.

Underwriter's Laboratories has certified this burner to comply with the commercial standards CS75, and has listed it for use with #1 or #2 fuel oil as specified in ASTM D396. State and local approvals are shown on burner rating label. The burner is certified in Canada by Canadian Standards Association (CSA). All oil burners should be installed in accordance with regulations of the National Fire Protection Association pamphlet #31 and in complete accordance with all local codes and authorities having jurisdiction. Regulation of these authorities take precedence over the general instructions provided in this installation manual. For recommended installation practice in Canada, reference should be made to CSA Standard B 139.

R.W. BECKETT CORPORATION

38251 Center Ridge Road • P.O. Box 1289 • Elyria, Ohio 44036

GENERAL INFORMATION

FUEL UNITS & TUBING INSTALLATION

Burners are most commonly installed with a single stage fuel unit. This fuel unit, when connected with a supply line only, is satisfactory where the fuel supply is on a level with, or above the burner permitting gravity flow of oil. When it is necessary to lift oil to the burner, a return line should be connected between the fuel unit and tank. This requires insertion of the "by-pass" plug into the fuel unit. If lift exceeds approximately 10 ft., a two-stage pump should be installed with a return line.

When a return line is used, with either single or two-stage pumps, air is automatically returned to the tank making the unit self-purging.

Use of continuous runs of heavy wall copper tubing is recommended. Always use flare fittings. Avoid use of fittings in inaccessible locations. Avoid running tubing against heating unit and across ceiling or floor joists. If possible install under floor.

Specific information on piping, fuel unit connections, lift capabilities, and tank installations is provided in the instructions of the fuel unit manufacturer.

COMBUSTION AIR

Burner must be installed in area with adequate fresh air available to support combustion.

Appliances located in confined spaces: The confined space shall be provided with two permanent openings, one near the top of the enclosure and one near the bottom. Each opening shall have a free area of not less than one square inch per 1,000 Btu per hour of the total input rating of all appliances in the enclosure, freely communicating with interior areas having in turn adequate infiltration from the outside.

WIRING

The wiring must be in accordance with the National Electric Code and local codes and regulations.

Wiring diagrams are included in the heating unit installation instructions.

UPGRADING OR CONVERSION

ATTACHING AIR TUBE COMBINATION (CHASSIS PLAN ONLY)

If the air tube combination and oil burner chassis are packaged separately, the assembly is completed as follows:

1. Attach air tube to burner housing using four sheet metal screws. (If using an adjustable burner mounting flange, first attach flange to air tube.)
2. Insert nozzle line electrode assembly into tube and position nozzle from head, using 'Z' dimension shown elsewhere in these instructions. Check to be certain nozzle and head are concentric.
3. Secure escutcheon plate by tightening screw at side of housing.
4. Secure nozzle line using bulkhead lock nut. When a knurled lock nut is supplied, the recessed side is to face away from burner housing.
5. Attach connector tube (from pump to nozzle line). With long air tube combinations, insertion of the nozzle line electrode assembly into the air tube is facilitated by rotating the assembly 180° from its installed position, inserting it partially into the air tube, and then rotating it back to its proper position.

SETTING THE BURNER

Use a mounting flange or pedestal as required.

The end of the burner air tube should be ¼" back from the inside surface of the front wall of the combustion chamber.

Insulate around air tube to prevent overheating of tube, nozzle and components. Make sure that insulation and cement do not obstruct face of burner head.

IMPORTANT CAUTIONS READ BEFORE STARTING

CAUTION:

STAINLESS STEEL COMBUSTION CHAMBERS

The higher temperature levels produced by high-performance flame retention burners may exceed the temperature ratings of stainless steel combustion chambers and can result in chamber burn-outs.

Where a burner upgrading is being made in a unit with a stainless steel chamber, please observe at least one of these precautions:

1. Line the Chamber with a "wet-pac" ceramic liner.
2. Adjust inlet air to the burner so that the CO₂ level is below 11%.

OIL

Before starting the burner be sure fuel tank is adequately filled with clean No. 1 or No. 2 furnace oil. *Crankcase oil, waste oil or GASOLINE should never be used.* Water, rust, or other contamination in the fuel supply system will cause malfunction and premature failure of the internal parts of the fuel unit.

POWER CIRCUIT

Be sure that burner and controls are wired correctly and that the line switch is properly fused (20 amp). In Canada wiring to be done in accordance with the Canadian Electrical Code, Part I.

NOZZLE

Be sure that specified nozzle is installed and that any covering over nozzle is removed prior to starting the burner.

NOZZLE AND ELECTRODE SETTING

Be sure nozzle and electrodes are positioned as shown elsewhere in these instructions. Improper adjustment can result in oil impingement or ignition difficulties.

AIR TUBE INSERTION

The burner head should be ¼" back from the inside wall of the combustion chamber. Under no circumstances should the burner head extend into the combustion chamber.

FUEL UNIT

Be sure that fuel unit is arranged for the type of oil supply system installed . . . "One Pipe" or "Two Pipe". Be sure that all connections are tight.

Fuel units generally require manual venting of air when initially started. Failure to vent the air from the fuel unit through the vent plug provided may result in an air lock within the pump that will prevent oil from being delivered to the nozzle. See also Fuel Unit Manufacturer's instructions.

LINE OIL FILTER

Use an oil filter of generous capacity for all installations. Install inside the building between the tank shutoff valve and the burner. For ease of servicing, locate the filter and a shut-off valve close to the oil burner.

OIL SHUTOFF VALVE

Install approved high quality shutoff valves in oil supply line in accessible locations, one close to the tank and another close to oil burner, but ahead of the filter. Note that some types of filters are made with a built-in shutoff valve.

STARTING AND ADJUSTMENT PROCEDURE

Caution: Do not attempt to start the burner when excess oil has accumulated, when the furnace or boiler is full of vapour, or when the combustion chamber is very hot.

1. Set thermostat substantially above room temperature.
2. Open shut-off valves in the oil supply line to the burner.

HOMEOWNER INFORMATION

OIL SUPPLY

Do not allow the fuel tank to run out of oil. During the summer be sure that your fuel tank is kept full; this will prevent condensation of moisture on the inside surfaces of the tank.

IF YOUR TANK RUNS DRY, IT MAY BE NECESSARY TO MANUALLY VENT THE AIR FROM THE PUMP AND LINES WHEN RE-STARTING THE BURNER.

COMBUSTION AIR SUPPLY

Your burner requires a generous amount of clean combustion air in order to burn the fuel completely. Lack of adequate combustion air may result in erratic operation of the burner or noisy combustion or fuel odors in the air. Remember your need for outside air will be greatly increased if you have a vented dryer in the basement or other venting fans in the home.

OILING MOTOR

Motor life will be increased by proper oiling. Use a few drops of non-detergent oil at both motor oil holes twice each year.

FILTER

The line filter cartridge should be replaced every year to avoid contamination of the fuel unit and atomizing nozzle.

AREA AROUND HEATING UNIT

Should be kept clean and free of any combustible materials — especially papers and oily rags.

NEVER

Burn garbage or refuse in your heating unit. Never try to ignite oil by tossing burning papers or other material into your heater.

SERVICE INFORMATION

"Preventive maintenance" is the best way to avoid unnecessary expense and inconvenience. Have your heating system and burner inspected at regular intervals by a qualified service man. If difficulty occurs, follow these simple checks before calling the service man.

1. Be sure there is oil in the tank and valve is open.
2. Be sure the thermostat is set above Room Temperature.
3. Be sure main Line Switch is "ON" and fuses are not blown.
4. Reset Safety Switch of Burner Primary Control.
5. Press Thermal Protector Button of Burner Motor.
6. If installation is equipped with Manual Reset Limit Control . . . Press Reset Button.
7. If burner runs but there is no flame, fuel unit may be air-bound. Follow instructions for venting fuel unit.

THE FOLLOWING INFORMATION IS IMPORTANT IN SERVICING THE BURNER

1. Burner Components: If replacement of burner parts is necessary, always use parts recommended by the manufacturer. Specify part number & description when ordering.
2. Nozzles: Use of the correct atomizing nozzle is very important. If replacement is necessary, use the same type supplied by the manufacturer. Nozzle capacity and type are stamped on the hex-portion of the nozzle body. Use extreme care in handling nozzles to avoid scratches or dirt that could cause leaks or affect the oil spray pattern.
3. Electrode Setting is important for reliable ignition of the oil. Check to be sure setting is in accordance with instructions provided elsewhere in this manual.
4. Fan and blower housing should be kept clean of dirt and lint. If heating unit is located near unvented dryer, special care must be taken that lint does not restrict air passages in burner

3. Check initial air adjustment. Normally the bulk air band (3) should be closed and the shutter (2) partially open.
4. Close line switch to start burner. If burner does not start immediately, re-set manual overload switches on motor and control.
5. Vent fuel unit as soon as burner motor starts rotating. To vent, loosen vent plug while holding an empty container under the vent opening to catch oil which will be expelled. Drain at least 1/2 pint of oil from the pump then close the vent plug. The ignition should be instantaneous with closing the vent plug.

If the burner starts and runs but stops again during the venting operation, wait three to five minutes for the safety switch to cool then re-set the manual switch and repeat the procedure until ignition is obtained. Sometimes after venting is accomplished and oil is ignited, the fire will again go out. This probably means that additional venting is necessary. Repeat the above venting procedure.

AIR ADJUSTMENT

Adjust air supply by loosening lock screws and moving air shutter (2) and if necessary the bulk air band (3). Allow just sufficient air to obtain clean combustion determined by visual inspection. Reduce air supply until flame tips appear slightly smoky, then increase air just enough to make the flame tips appear absolutely clean.

DRAFT CONTROL ADJUSTMENT

When the burner air supply and draft are properly adjusted the combustion chamber draft will normally be .01" - .02" WC. Larger installations may require slightly greater draft.

FINAL ADJUSTMENTS

At this point a final adjustment should be made using suitable instruments for smoke spot and CO₂ (or O₂) measurements. Unless otherwise specified in appliance manufacturer's instructions, the unit should be set as follows: After allowing 10 minutes for warm up, air should be set so that the smoke number is zero or a trace; less than no. 1 smoke is highly desirable and should never exceed this limit. (Note: Occasionally a new heating appliance will require longer warm up time in order to burn clean because of the evaporation of oil deposits on the heat exchanger and other surfaces. CO₂ measured in the stack (ahead of the draft control) should be a minimum of 10% for knocked down appliances or retrofit applications and a minimum of 12% for units with burners tested and supplied by manufacturers as a package.

Tighten all locking screws after final adjustments are made.

The unit should be started and stopped several times to make sure there are no significant rumbles or pulsations.

CHECKING THE CONTROLS

Check and adjust all controls in accordance with the Control Manufacturer's instruction sheets. Be sure the primary control safety switch operates properly so that safety shutdown will occur in the event of equipment malfunction.

FINAL CHECKS

Be sure air shutter and draft control are locked . . . that there is an ample supply of fresh air to the room in which the unit is located, and there are no oil leaks.

INSTRUCTING THE HOMEOWNER

The operation and care of the heating system should be explained to the home owner, including how to adjust the thermostat, necessity of air supply to the burner, care of the burner, and the simple checks to make before calling for service if the burner fails to operate automatically.

OIL BURNER CERTIFICATE

AS REQUIRED BY COMMERCIAL STANDARD CS75-56

The Oil Burner Model No., Serial No., installed at
(Make)

..... bears a label evidencing compliance with commercial Standard CS75-56, and
(Address of Installation)
has been installed in accordance with the instructions in the manufacturer's installation manual and in conformity with local regulations, codes, and ordinances.

The boiler, (), furnace (), is a No., and
the heating load consists of: (Make)

1. Btu, or square feet steam (), hot water () radiation; and
2. Btu, or square feet of equivalent steam (), hot water () radiation in domestic hot water load; or
3. Btu, or square inches of cross-sectional area of warm air supply pipes measured at the furnace take off; or
4. Btu, or square feet of equivalent steam (), hot water () radiation in the following special load:

.....
All necessary permits have been secured, and the installation has been tested in accordance with the test procedure of Commercial Standard CS75-56 and the following reading taken:

CO₂ { Over Fire.....
 { At Breeching..... Stack Temperature at Breeching.....°F

Draft { Over Fire.....
 { At Breeching..... } inches H₂O. Firing Rate.....gals./hr.

All controls and limiting devices have been checked for proper operation.....

Fuel used, Grade No..... per ASTM D396 Standard Specification

Field service equipment smoke scale reading

The above test results are certified to be true:

For service call: (Name of Company making installation)

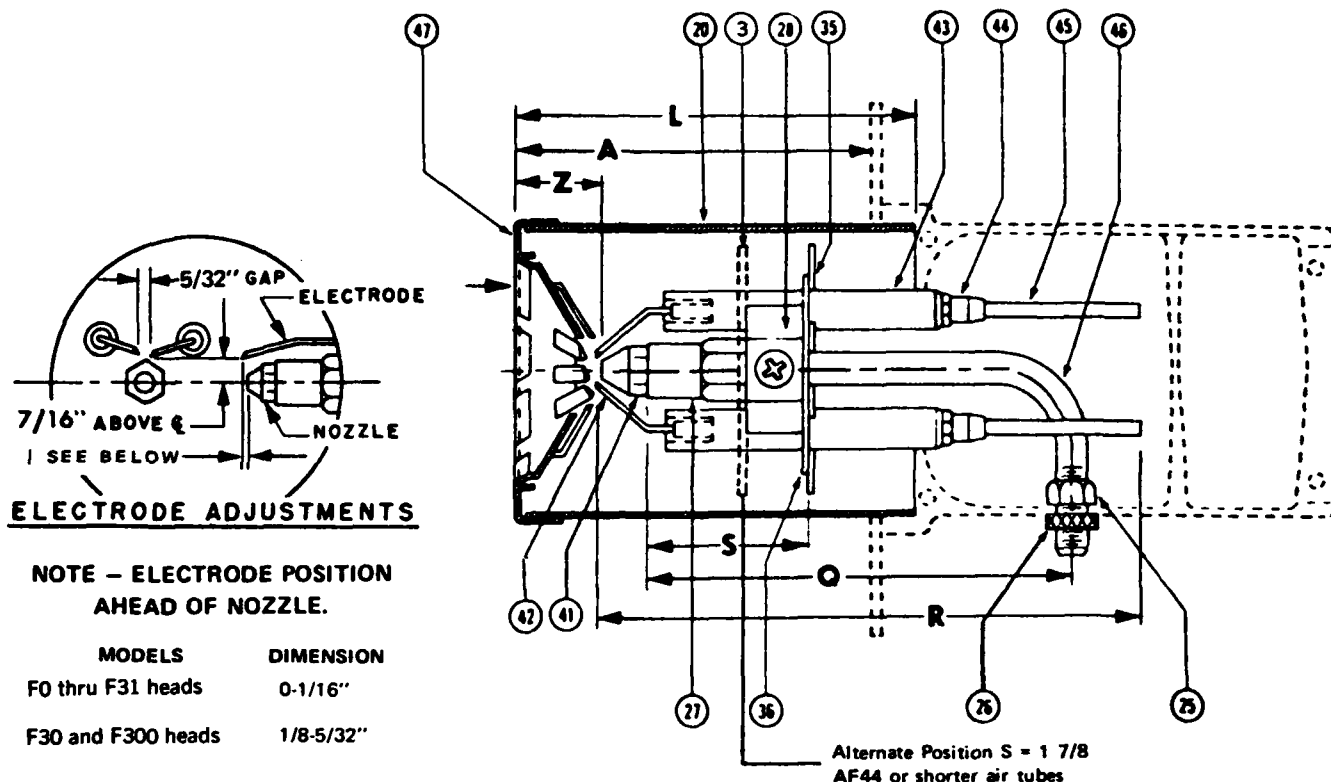
..... (Name) Per (Signature)

..... (Address) (Address)

..... (Telephone) (Telephone)

Date

AIR TUBE COMBINATION DETAILS



AIR TUBE COMBINATION PARTS

REF.	DESCRIPTION	PART NO.
20	Air Tube	Note
47	Burner Head, Specify Type F	
Nozzle Line Electrode Assembly, Consisting Of		
25	Bulkhead Fitting	3-488
26	Locknut Bulkhead Fitting	3-666
27	Nozzle Adapter - Single	2-13
28	Electrode Clamp	1-49
	Static Plate and Nozzle Line Support Assembly	Note
35	Centering Spider	5-503
36	Static Plate (Not Used on "XS" Combs)	Note
	Static Plate Holding Screws	4-218
41	Nozzle	
42	Electrode Rod and Tip	Note
43	Porcelain	Note
44	Electrode Rod Extension Adapter, as Req'd.	Note
45	Electrode Rod Extension, as Req'd.	Note
46	Nozzle Line and Vent Plug	Note

Note Specify Burner model number "AF", part description; air tube combination with useable air tube length (Dimension "A") and firing rate.

NOZZLES

UNIT APPLICATIONS: When burner is supplied as an integral component of a heater the best nozzle choice will have been determined by extensive testing. The heater manufacturers recommendation should be closely followed.

UPGRADING OR CONVERSION - 80° Hollow or Solid Nozzle

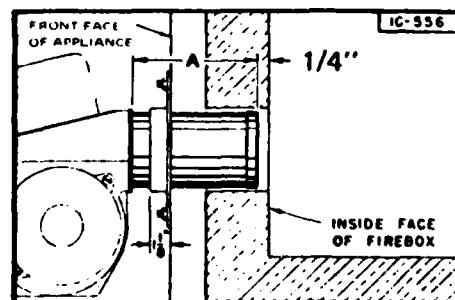
DIMENSIONAL RELATIONSHIPS

"A" = Useable Air Tube Length
 "L" = "A" + 5/8"
 "R" = "A" + 2-3/8" "Z" = 1-1/8"
 "Q" = "A" + 1-1/16" "S" = 2-5/16"

STANDARD AIR TUBE COMBINATIONS

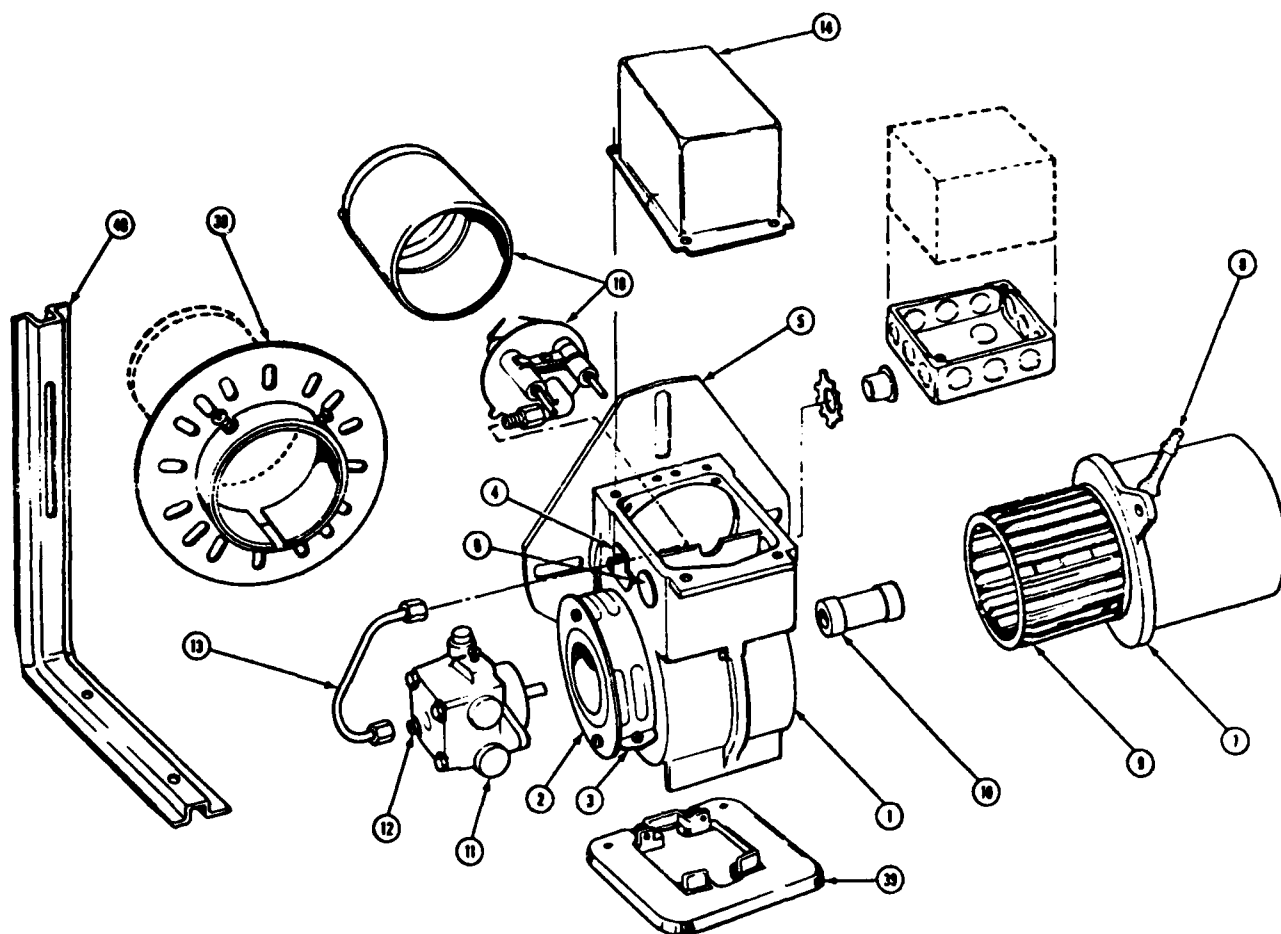
Air Tube Dimen. "A"	Firing Range G. P. H.					
	.50-.75	.75-1.25	.85-1.65	1.10-2.00	1.65-2.50	2.25-3.00
6-5/8"	AF 65XR	AF 65XN	AF 65YB	AF 65XO	AF 65XP	AF 65XS
7-1/4"	AF 72XR	AF 72XN	AF 72YB	AF 72XO	AF 72XP	AF 72XS
9"	AF 90XR	AF 90XN	AF 90YB	AF 90XO	AF 90XP	AF 90XS
10-1/2"	AF104XR	AF104XN	AF104YB	AF104XO	AF104XP	AF104XS
13"	AF130XR	AF130XN	AF130YB	AF130XO	AF130XP	AF130XS
16"	AF160XR	AF160XN	AF160YB	AF160XO	AF160XP	AF160XS
Head	F0	F3	F6	F12	F22	F30

To determine the Air Tube Length:



The Air Tube Length (Dimension A) is the distance from the front of the burner housing to the drain hole in the burner head. (NOTE: Adjustable flange width — 1-1/8")

PARTS



WHEN ORDERING PARTS - STATE BURNER MODEL, PART DESCRIPTION AND PART NUMBER

REF	DESCRIPTION	PART #
1	Burner Housing Assembly	
	Burner Housing with Inlet Bell	5-624
2	End Air Shutter	3-494
3	Bulk Air Band	3-492
4	Nozzle Line Escutcheon Plate	3-493
5	Unit Flange or	3-230
	Square Plate	3-399
	Holding Screws	4-99
6	Hole Plug-Wiring Box	2-139
7	Drive Motor	2-456
	Motor Holding Screws	4-189
8	Wire Guard, Motor Lead	3-345
9	Blower Wheel 3-13/16" OD. x 2-7/8"	2-458
	4-1/4" OD. x 3-7/16"	2-459
10	Flexible Coupling	2-454
11	Fuel Unit Sundstrand	2-460
	Webster	2-463
	Webster (Two Stage)	2-554
	Sundstrand (Two Stage)	2-583
12	Pump Outlet Fitting	2-256
	Pump Holding Screws	4-189
13	Connector tube assembly (Sundstrand)	
	(or Webster)	5-636
14	Ignition Transformer	
	(10,000 V/23 ma.)	2-442
	Hinge Screws	4-217
	Holding Screws	4-198
	Contact Spring Terminals	3-245

REF	DESCRIPTION	PART #
18	Air Tube Combination	*
	Air Tube Gasket	3-416
38	Adjustable Mounting Flange	5-432
39	Pedestal Support	5-685
40	Extended Pedestal Kit	5-606
	*Specify Air Tube Combination (see overleaf)	

SUGGESTED COMBUSTION CHAMBER DIMENSIONS - UPGRADING OR CONVERSION

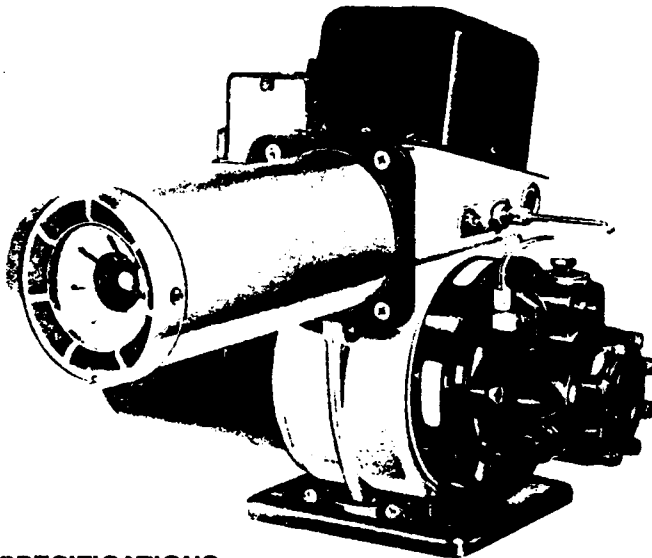
Chamber Dimensions (In Inches)					
Firing Rate (GPH)	Round I.D.	Rectangular W L		Height	Floor To Nozzle
.50	8	7	8	12	5-6
.75	9	8	9	12	5-6
1.00	10	9	10	12-1/2	5-6
1.25	11	10	11	12-1/2	5-6
1.50	12	11	12	13	6-7
2.00	14	12	15	13-1/2	6-7
2.50	16	13	17	14	7-8
3.00	18	14	18	15	7-8



INSTRUCTION MANUAL

model SF

OIL BURNER



SPECIFICATIONS

CAPACITIES MODEL SF

..... 2.50 to 5.50 gallons per hour
..... 350,000 to 770,000 BTU/HR Input

See SPECIAL AIR TUBE COMBINATIONS DETAILS For
Special Firing Rates

FUELS

No. 1 or No. 2 Heating Oil (ASTM D396) Only
In Canada, No. 1 or No. 2 Furnace Oil

DIMENSIONS (Standard)

Height 13-5/8"
Width 15-3/8"
Depth (Chassis Only) 8-1/2"

ELECTRICAL CHARACTERISTICS (See Note)

Power Supply 115 V/60 Hz 1 PH
Operating Load (Max.) 7.1 Amps
Motor 1/4 HP 3450 RPM, N.E.M.A. "N" Flange, manual
reset, overload protected
Ignition 10,000 V/23 ma secondary, continuous
duty, shielded transformer or solid-state ignition system

FUEL UNIT

..... Sundstrand, or Webster

NOTE:

50 Hertz electrical components are available on special order.

Dear Homeowner:

Over forty years of engineering and product development have gone into your new oil burner. Its quality and design are unsurpassed. Properly installed and maintained it will provide many years of efficient, trouble-free operation. Please read this Instruction Manual carefully, and give special attention to the following points:

- An oil burner must have a generous supply of combustion air to operate properly. Please refer to the information in this manual for details.
- NEVER attempt to use gasoline in your heating appliance. Gasoline is more combustible than fuel oil and could result in a serious explosion. NEVER burn garbage or refuse in your heating appliance or try to light oil by tossing burning material into the heater.
- **INSTALLATION AND ADJUSTMENT OF THE BURNER REQUIRES TECHNICAL KNOWLEDGE AND THE USE OF COMBUSTION TEST INSTRUMENTS. DO NOT TAMPER WITH THE UNIT OR CONTROLS. CALL YOUR SERVICEMAN.**

Beckett warrants its equipment specifically to those who have purchased it for resale, including your dealer. In the event of any problems with your equipment or its installation, you should contact your dealer for assistance.

TO THE INSTALLER

INSTALLATION OF THE BURNER MUST BE DONE BY A QUALIFIED INSTALLER IN ACCORDANCE WITH REGULATIONS OF THE NATIONAL FIRE PROTECTION STANDARD FOR OIL-BURNING EQUIPMENT, NFPA NO. 31, AND IN COMPLETE ACCORDANCE WITH ALL LOCAL CODES AND AUTHORITIES HAVING JURISDICTION. FOR RECOMMENDED INSTALLATION PRACTICE IN CANADA, REFERENCE SHOULD BE MADE TO CSA STANDARD B139.

A QUALIFIED INSTALLER IS AN INDIVIDUAL OR AGENCY WHO IS RESPONSIBLE FOR THE INSTALLATION AND ADJUSTMENT OF THE EQUIPMENT AND WHO IS PROPERLY LICENSED AND EXPERIENCED TO INSTALL OIL-BURNING EQUIPMENT IN ACCORDANCE WITH ALL CODES AND ORDINANCES.

A properly designed chimney of adequate size and height and adequate combustion air supply are essentials for the best operation of any heating plant.

When installing the heater and/or burner be sure to provide adequate space for easy service and maintenance.

CONCEALED DAMAGE

If any damage to the burner or controls is found during unpacking notify the carrier at once and file the appropriate claim.

Underwriter's Laboratories has certified this burner to comply with the commercial standards CS75, and has listed it for use with #1 or #2 fuel oil as specified in ASTM D396. State and local approvals are shown on burner rating label. The burner is certified in Canada by Canadian Standards Association (CSA). All oil burners should be installed in accordance with regulations of the National Fire Protection Association pamphlet #31 and in complete accordance with all local codes and authorities having jurisdiction. Regulation of these authorities take precedence over the general instructions provided in this installation manual. For recommended installation practice in Canada, reference should be made to CSA Standard B 139.

R.W. BECKETT CORPORATION

38251 Center Ridge Road • P.O. Box 1289 • Elyria, Ohio 44036

GENERAL INFORMATION

FUEL UNITS & TUBING INSTALLATION

Burners are most commonly installed with a single stage fuel unit. This fuel unit, when connected with a supply line only, is satisfactory where the fuel supply is on a level with, or above the burner permitting gravity flow of oil. When it is necessary to lift oil to the burner, a return line should be connected between the fuel unit and tank. This requires insertion of the "by-pass" plug into the fuel unit. If lift exceeds approximately 10 ft., a two-stage pump should be installed with a return line.

When a return line is used, with either single or two-stage pumps, air is automatically returned to the tank making the unit self-purging.

Use of continuous runs of heavy wall copper tubing is recommended. Always use flare fittings. Avoid use of fittings in inaccessible locations. Avoid running tubing against heating unit and across ceiling or floor joists. If possible install under floor.

Specific information on piping, fuel unit connections, lift capabilities, and tank installations is provided in the instructions of the fuel unit manufacturer.

COMBUSTION AIR

Burner must be installed in area with adequate fresh air available to support combustion.

Appliances located in confined spaces: The confined space shall be provided with two permanent openings, one near the top of the enclosure and one near the bottom. Each opening shall have a free area of not less than one square inch per 1,000 Btu per hour of the total input rating of all appliances in the enclosure, freely communicating with interior areas having in turn adequate infiltration from the outside.

WIRING

The wiring must be in accordance with the National Electric Code and local codes and regulations.

Wiring diagrams are included in the heating unit installation instructions.

UPGRADING OR CONVERSION

ATTACHING AIR TUBE COMBINATION (CHASSIS PLAN ONLY)

If the air tube combination and oil burner chassis are packaged separately, the assembly is completed as follows:

1. Attach air tube to burner housing using four sheet metal screws. (If using an adjustable burner mounting flange, first attach flange to air tube.)
2. Insert nozzle line electrode assembly into tube and position nozzle from head, using 'Z' dimension shown elsewhere in these instructions. Check to be certain nozzle and head are concentric.
3. Secure escutcheon plate by tightening screw at side of housing.
4. Secure nozzle line using bulkhead lock nut. When a knurled lock nut is supplied, the recessed side is to face away from burner housing.
5. Attach connector tube (from pump to nozzle line). With long air tube combinations, insertion of the nozzle line electrode assembly into the air tube is facilitated by rotating the assembly 180° from its installed position, inserting it partially into the air tube, and then rotating it back to its proper position.

SETTING THE BURNER

Use a mounting flange or pedestal as required.

The end of the burner air tube should be ¼" back from the inside surface of the front wall of the combustion chamber.

Insulate around air tube to prevent overheating of tube, nozzle and components. Make sure that insulation and cement do not obstruct face of burner head.

IMPORTANT CAUTIONS READ BEFORE STARTING

CAUTION: STAINLESS STEEL COMBUSTION CHAMBERS

The higher temperature levels produced by high-performance flame retention burners may exceed the temperature ratings of stainless steel combustion chambers and can result in chamber burn-outs.

Where a burner upgrading is being made in a unit with a stainless steel chamber, please observe at least one of these precautions:

1. Line the Chamber with a "wet-pac" ceramic liner.
2. Adjust inlet air to the burner so that the CO₂ level is below 11%.

OIL

Before starting the burner be sure fuel tank is adequately filled with clean No. 1 or No. 2 furnace oil. *Crankcase oil, waste oil or GASOLINE should never be used.* Water, rust, or other contamination in the fuel supply system will cause malfunction and premature failure of the internal parts of the fuel unit.

POWER CIRCUIT

Be sure that burner and controls are wired correctly and that the line switch is properly fused (20 amp). In Canada wiring to be done in accordance with the Canadian Electrical Code, Part I.

NOZZLE

Be sure that specified nozzle is installed and that any covering over nozzle is removed prior to starting the burner.

NOZZLE AND ELECTRODE SETTING

Be sure nozzle and electrodes are positioned as shown elsewhere in these instructions. Improper adjustment can result in oil impingement or ignition difficulties.

AIR TUBE INSERTION

The burner head should be ¼" back from the inside wall of the combustion chamber. Under no circumstances should the burner head extend into the combustion chamber.

FUEL UNIT

Be sure that fuel unit is arranged for the type of oil supply system installed . . . "One Pipe" or "Two Pipe". Be sure that all connections are tight.

Fuel units generally require manual venting of air when initially started. Failure to vent the air from the fuel unit through the vent plug provided may result in an air lock within the pump that will prevent oil from being delivered to the nozzle. See also Fuel Unit Manufacturer's instructions.

LINE OIL FILTER

Use an oil filter of generous capacity for all installations. Install inside the building between the tank shutoff valve and the burner. For ease of servicing, locate the filter and a shut-off valve close to the oil burner.

OIL SHUTOFF VALVE

Install approved high quality shutoff valves in oil supply line in accessible locations, one close to the tank and another close to oil burner, but ahead of the filter. Note that some types of filters are made with a built-in shutoff valve.

STARTING AND ADJUSTMENT PROCEDURE

Caution: Do not attempt to start the burner when excess oil has accumulated, when the furnace or boiler is full of vapour, or when the combustion chamber is very hot.

1. Set thermostat substantially above room temperature.
2. Open shut-off valves in the oil supply line to the burner.

AD-A139 767

INTERIM GUIDANCE FOR OIL HEATING EQUIPMENT SELECTION
FOR NAVAL RESIDENTIAL HOUSING(U) BROOKHAVEN NATIONAL
LAB UPTON NY R F KRAJEWSKI ET AL. JAN 84

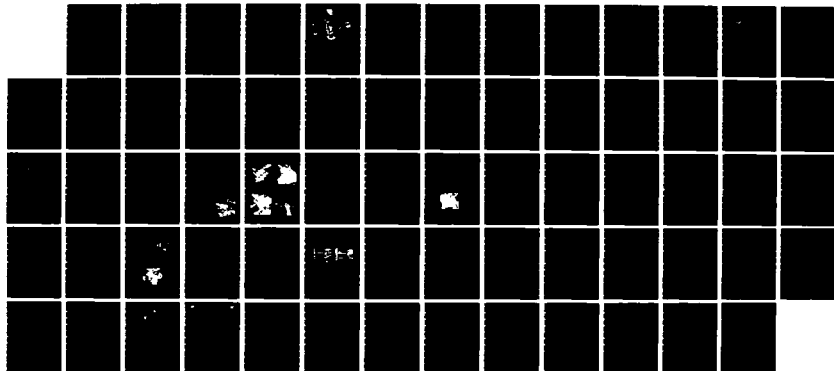
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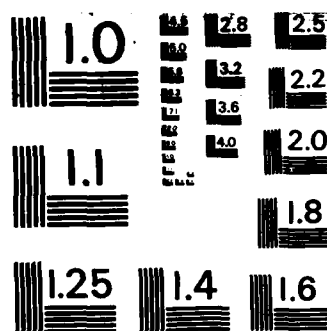
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MICROCOPY RESOLUTION TEST CHART
NATIONAL BUREAU OF STANDARDS - 1963 - A

HOMEOWNER INFORMATION

OIL SUPPLY

Do not allow the fuel tank to run out of oil. During the summer be sure that your fuel tank is kept full; this will prevent condensation of moisture on the inside surfaces of the tank.

IF YOUR TANK RUNS DRY, IT MAY BE NECESSARY TO MANUALLY VENT THE AIR FROM THE PUMP AND LINES WHEN RE-STARTING THE BURNER.

COMBUSTION AIR SUPPLY

Your burner requires a generous amount of clean combustion air in order to burn the fuel completely. Lack of adequate combustion air may result in erratic operation of the burner or noisy combustion or fuel odors in the air. Remember your need for outside air will be greatly increased if you have a vented dryer in the basement or other venting fans in the home.

OILING MOTOR

Motor life will be increased by proper oiling. Use a few drops of non-detergent oil at both motor oil holes twice each year.

FILTER

The line filter cartridge should be replaced every year to avoid contamination of the fuel unit and atomizing nozzle.

AREA AROUND HEATING UNIT

Should be kept clean and free of any combustible materials — especially papers and oily rags.

NEVER

Burn garbage or refuse in your heating unit. Never try to ignite oil by tossing burning papers or other material into your heater.

SERVICE INFORMATION

"Preventive maintenance" is the best way to avoid unnecessary expense and inconvenience. Have your heating system and burner inspected at regular intervals by a qualified service man. If difficulty occurs, follow these simple checks before calling the service man.

1. Be sure there is oil in the tank and valve is open.
2. Be sure the thermostat is set above Room Temperature.
3. Be sure main Line Switch is "ON" and fuses are not blown.
4. Reset Safety Switch of Burner Primary Control.
5. Press Thermal Protector Button of Burner Motor.
6. If installation is equipped with Manual Reset Limit Control . . . Press Reset Button.
7. If burner runs but there is no flame, fuel unit may be air-bound. Follow instructions for venting fuel unit.

THE FOLLOWING INFORMATION IS IMPORTANT IN SERVICING THE BURNER

1. Burner Components: If replacement of burner parts is necessary, always use parts recommended by the manufacturer. Specify part number & description when ordering.
2. Nozzles: Use of the correct atomizing nozzle is very important. If replacement is necessary, use the same type supplied by the manufacturer. Nozzle capacity and type are stamped on the hex-portion of the nozzle body. Use extreme care in handling nozzles to avoid scratches or dirt that could cause leaks or affect the oil spray pattern.
3. Electrode Setting is important for reliable ignition of the oil. Check to be sure setting is in accordance with instructions provided elsewhere in this manual.
4. Fan and blower housing should be kept clean of dirt and lint. If heating unit is located near unvented dryer, special care must be taken that lint does not restrict air passages in burner.

3. Check initial air adjustment. Normally the bulk air band (3) should be closed and the shutter (2) partially open.
4. Close line switch to start burner. If burner does not start immediately, re-set manual overload switches on motor and control.
5. Vent fuel unit as soon as burner motor starts rotating. To vent, loosen vent plug while holding an empty container under the vent opening to catch oil which will be expelled. Drain at least 1/2 pint of oil from the pump then close the vent plug. The ignition should be instantaneous with closing the vent plug.

If the burner starts and runs but stops again during the venting operation, wait three to five minutes for the safety switch to cool then re-set the manual switch and repeat the procedure until ignition is obtained. Sometimes after venting is accomplished and oil is ignited, the fire will again go out. This probably means that additional venting is necessary. Repeat the above venting procedure.

AIR ADJUSTMENT

Adjust air supply by loosening lock screws and moving air shutter (2) and if necessary the bulk air band (3). Allow just sufficient air to obtain clean combustion determined by visual inspection. Reduce air supply until flame tips appear slightly smoky, then increase air just enough to make the flame tips appear absolutely clean.

DRAFT CONTROL ADJUSTMENT

When the burner air supply and draft are properly adjusted the combustion chamber draft will normally be .01" - .02" WC. Larger installations may require slightly greater draft.

FINAL ADJUSTMENTS

At this point a final adjustment should be made using suitable instruments for smoke spot and CO₂ (or O₂) measurements. Unless otherwise specified in appliance manufacturer's instructions, the unit should be set as follows: After allowing 10 minutes for warm up, air should be set so that the smoke number is zero or a trace; less than no. 1 smoke is highly desirable and should never exceed this limit. (Note: Occasionally a new heating appliance will require longer warm up time in order to burn clean because of the evaporation of oil deposits on the heat exchanger and other surfaces. CO₂ measured in the stack (ahead of the draft control) should be a minimum of 10% for knocked down appliances or retrofit applications and a minimum of 12% for units with burners tested and supplied by manufacturers as a package.

Tighten all locking screws after final adjustments are made.

The unit should be started and stopped several times to make sure there are no significant rumbles or pulsations.

CHECKING THE CONTROLS

Check and adjust all controls in accordance with the Control Manufacturer's instruction sheets. Be sure the primary control safety switch operates properly so that safety shutdown will occur in the event of equipment malfunction.

FINAL CHECKS

Be sure air shutter and draft control are locked . . . that there is an ample supply of fresh air to the room in which the unit is located, and there are no oil leaks.

INSTRUCTING THE HOMEOWNER

The operation and care of the heating system should be explained to the home owner, including how to adjust the thermostat, necessity of air supply to the burner, care of the burner, and the simple checks to make before calling for service if the burner fails to operate automatically.

OIL BURNER CERTIFICATE

AS REQUIRED BY COMMERCIAL STANDARD CS75-56

The Oil Burner Model No., Serial No., installed at
(Make)

..... bears a label evidencing compliance with commercial Standard CS75-56, and
(Address of Installation)
has been installed in accordance with the instructions in the manufacturer's installation manual and in conformity with local regulations, codes, and ordinances.

The boiler, (), furnace (), is a No., and
the heating load consists of: (Make)

1. Btu, or square feet steam (), hot water () radiation; and
2. Btu, or square feet of equivalent steam (), hot water () radiation in domestic hot water load; or
3. Btu, or square inches of cross-sectional area of warm air supply pipes measured at the furnace take off; or
4. Btu, or square feet of equivalent steam (), hot water () radiation in the following special load:

.....
All necessary permits have been secured, and the installation has been tested in accordance with the test procedure of Commercial Standard CS75-56 and the following reading taken:

CO₂ { Over Fire
 { At Breeching Stack Temperature at Breeching °F

Draft { Over Fire } inches H₂O. Firing Rate gals./hr.
 { At Breeching }

All controls and limiting devices have been checked for proper operation

Fuel used, Grade No. per ASTM D396 Standard Specification

Field service equipment smoke scale reading

The above test results are certified to be true:

For service call:

.....
(Name of Company making installation)

.....
(Name)

Per
(Signature)

.....
(Address)

.....
(Address)

.....
(Telephone)

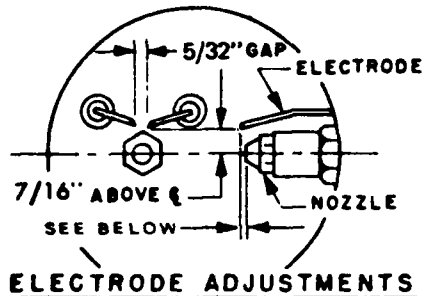
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Date

AIR TUBE COMBINATION DETAILS

DIMENSIONAL RELATIONSHIPS

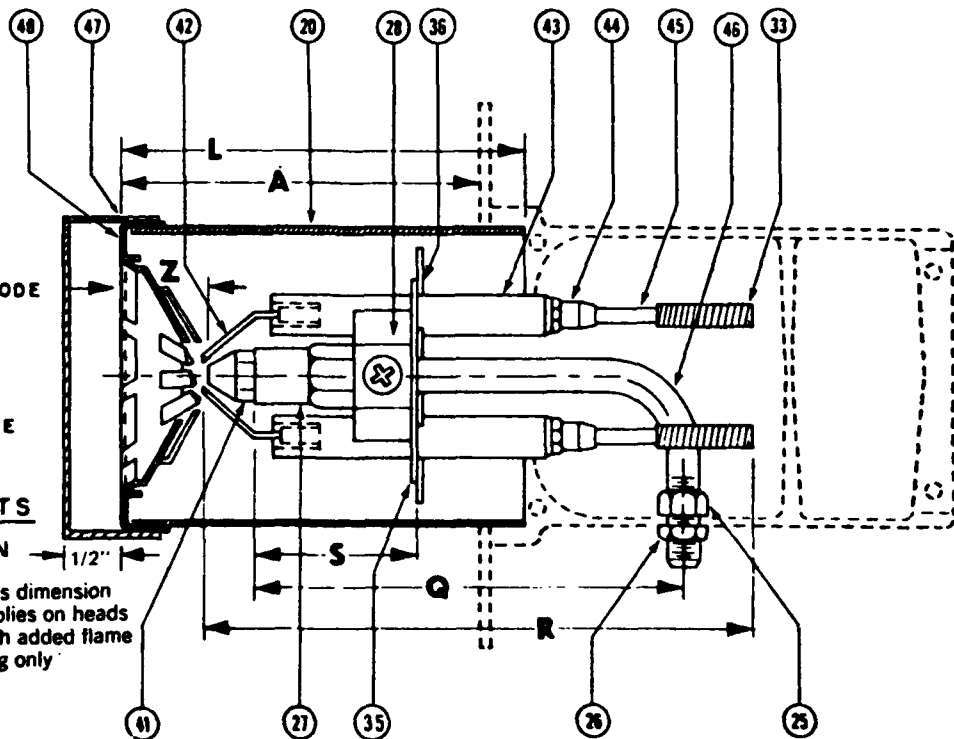
"A" = Useable Air Tube Length
 "L" = "A" + 5/8"
 "R" = "A" + 2-7/8"
 "S" = 2-5/16"
 "Q" = "A" + 3 - 1/4"
 "Z" = 1-1/8"



**NOTE - ELECTRODE POSITION
 AHEAD OF NOZZLE.**

This dimension
 applies on heads
 with added flame
 ring only

MODELS	DIMENSION
F0 thru F31 heads	0-1/16"
F30 and F300 heads	1/8-5/32"



AIR TUBE COMBINATION PARTS

REF.	DESCRIPTION	PART #
20	Air Tube	Note
25	Nozzle Line Fitting (Pump End)	3-421
26	Lock Nut, Nozzle Line Fitting	4-98
27	Nozzle Adapter - Single	2-13
28	Electrode Clamp	1-49S
33	Contact Springs (as reqd.)	3-241
	Static Plate and Nozzle Line Support Assembly	Note
35	Centering Spider	5-503
36	Static Plate (See special A.T. Combs.)	None
	Static Plate Holding Screws	4-218
41	Nozzle	
42	Electrode Rod and Tip	Note
43	Porcelain	Note
44	Electrode Rod Extension Adapter, as reqd.	
45	Electrode Rod Extension, as reqd.	Note
46	Nozzle Line and Vent Plug	Note
47	Burner Head, (one piece head and shield) Type F-300	

Note: Specify Burner model number "SF", part description;
 air tube combination with air tube length (Dimension "A")
 and firing rate.

NOZZLES

UNIT APPLICATIONS: When burner is supplied as an integral
 component of a heater the best nozzle choice will have been
 determined by extensive testing. The heater manufacturers
 recommendation should be closely followed.

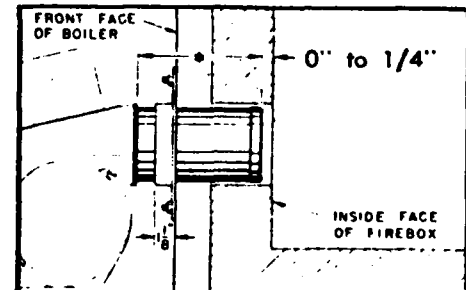
UPGRADING OR CONVERSION: Use 80° Solid Cone
 Nozzle.

STANDARD AIR TUBE COMBINATIONS

Air Tube Length-"A"	6-5/8"	9"	13"	16"
Combination Number	SF65FT	SF90FT	SF130FT	SF160FT

SPECIAL AIR TUBE COMBINATIONS

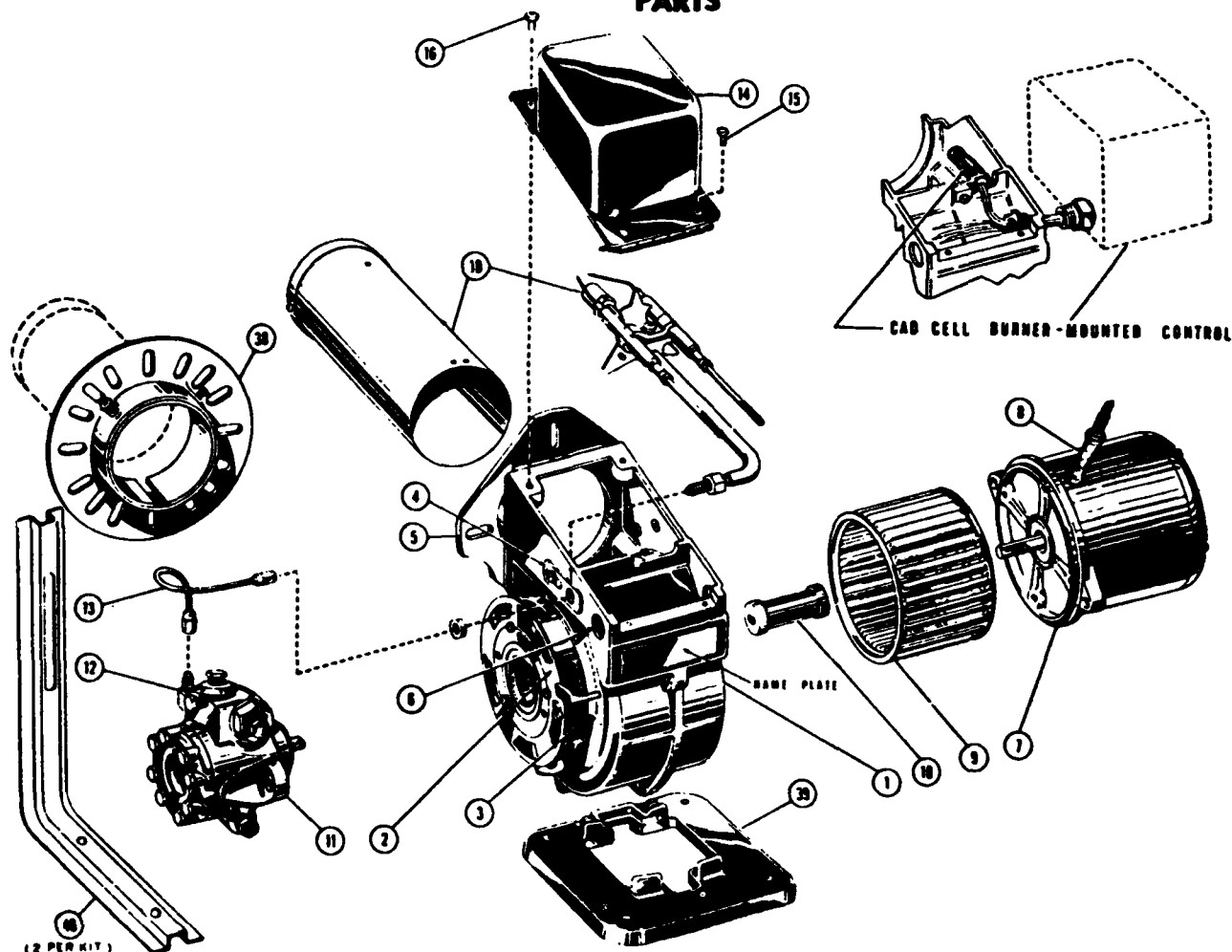
Description	Useable Air Tube Length			
	6-5/8"	9"	13"	16"
Comb. with Type F12 burner head 48 and 2-3/4" static plate 36 Firing Range 1.25 - 2.25	SF65FO	SF90FO	SF130FO	SF160FO
Comb. with Type F-22 burner head 48 and 2-3/4" static plate 36. Firing Range 1.75 - 2.75	SF65FP	SF90FP	SF130FP	SF160FP



To determine

The Air Tube Length (") is the distance from the front of the
 burner housing to the face of the burner head and/or shield.
 (NOTE: Adjustable flange width - 1-1/8").

PARTS



WHEN ORDERING PARTS - STATE BURNER MODEL, PART DESCRIPTION AND PART NUMBER

REF.	DESCRIPTION	PART NO.
1	BURNER HOUSING ASSEMBLY	
	Burner Housing with Inlet Bell	5-348S
2	End Air Shutter	3-215
3	Bulk Air Band	3-217
4	Nozzle Line Escutcheon Plate	3-218
5	Unit Flange or	3-230
	Square Plate	3-399
	Holding Screws (not shown)	
6	Hole Plug-Wiring Box (not shown)	2-139
7	DRIVE MOTOR	2-364
	Motor Holding Screws	4-82
8	Wire Guard, Motor Lead	3-345
9	BLOWER WHEEL Regular	2-288
	Large (See Special Note)	2-383
10	FLEXIBLE COUPLING	12-290
11	FUEL UNIT	
	Single-Stage Sundstrand "J"	2-396
	Two-Stage Sundstrand "H"	2-393
	Single-Stage Sundstrand "A"	2-591
12	Pump Outlet Fitting	2-256
	Pump Holding Screws (not shown)	4-82
13	Connector tube assembly pump to	
	nozzle line	5-394
14	Ignition Transformer (10,000V/23 ma.) . .	2-289
15	Hinge Screws	4-217
16	Holding Screws	4-220
17	Contact Spring Terminals(not shown) . .	3-245

REF	DESCRIPTION	PART #
18	Air Tube Combination	*
	Air Tube Gasket (not shown).	3-416
38	Adjustable Mounting Flange	5-432
39	Pedestal Support	5-685
40	Extended Pedestal Kit	5-606
	*Specify Air Tube Combination (see overleaf)	

SPECIAL NOTE: When positive firebox pressure exists, large burner fan may be required. (See parts list)

SUGGESTED COMBUSTION CHAMBER DIMENSIONS - UPGRADING OR CONVERSION

Firing Rate (GPH)	Chamber Dimensions (in inches)				
	Round I.D.	Rectangular		Height	Floor To Nozzle
		W	L		
1.25	11	10	11	12	5-6
1.50	12	11	12	13	6-7
2.00	14	12	15	13	6-7
2.50	16	13	17	14	7-8
3.00	18	14	18	15	7-8
3.50	19	15	19	15	7-8
4.00	20	16	21	16	8-9
5.00	23	18	23	18	9-10
5.50	24	19	24	19	10-11

†Use Coupling No. 2-433 With Model A Fuel Units

INSTALLATION AND OPERATING INSTRUCTIONS

For Use By Qualified Service Technicians Only

CARLIN OIL BURNERS Models 100CRD and 101CRD (60-Hz)

DESCRIPTION

"CRD" burners feature a combustion head incorporating a new design concept which provides a means to control the air pattern to match the nozzle requirements. The aerodynamics for optimum combustion are easily adjusted for any nozzle size without changing the air-handling hardware.

The letters "CRD" stand for "Controlled Retention — Double Speed."

Use of a small, narrow blower wheel (fan) operating at 3450 rpm provides a more positive, yet quiet, air flow which does not yield to normal draft variations and therefore assures a more constant air-fuel ratio for dependably clean combustion day after day.

Models 100CRD and 101CRD are identical in design except that the 101CRD has a larger diameter blower wheel and a higher firing range.

Model No.	Fan Size	Firing Range
100CRD	4 $\frac{1}{4}$ " dia. x 2 $\frac{1}{8}$ " wide	0.50 - 2.25 GPH
101CRD	4 $\frac{1}{4}$ " dia. x 2 $\frac{1}{8}$ " wide	1.75 - 2.75 GPH

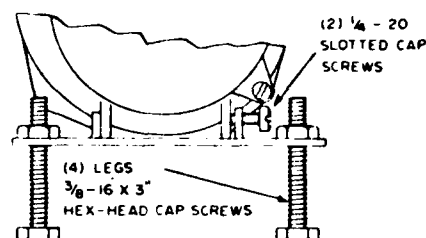
Model 100CRD is available with an optional 'A' style air tube introduced in October '79. The optional 'A' style air tube assembly was developed for improved performance in short, square or round refractory lined chambers.

The firing range of the 100CRD when using the 'A' style air tube assembly remains at 0.50-2.25 gph. The 'A' style air tube assembly (Part No. 1051A) is interchangeable with the standard air tube assembly (Part No. 1051) and uses the standard electrode and combustion head assembly (Part No. 1052).

ASSEMBLING THE BURNER (TWO-PAK)

1. Remove the air tube and nozzle line assembly from the smaller carton. If nozzle is not installed, see instructions under (6), page 2.
2. Remove the main housing assembly from the larger carton.
3. Slide the flange and gasket onto the air tube before installing the air tube in the housing. The flange can be assembled with the hub facing either way so that an additional inch of usable air tube is available when the hub faces the end of the air tube.
4. If the pedestal is included, assemble it to the bottom of the burner by tightening the two 1/4-20 slotted cap screws against the front feet of the housing. See Figure 1. Install the four legs (3/8-16 x 3" hex-head cap screws)

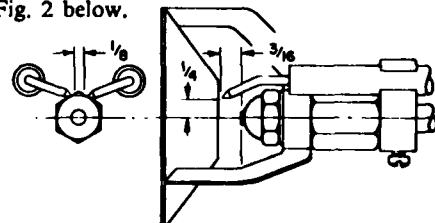
Fig. 1



and adjust to the proper height. Lock in place after final adjustment using jam nuts provided.

5. Loosen the air tube holding clamp. Open transformer. Spread housing using a screwdriver or the like inserted between the two halves of the housing on top, just behind the holding clamp. Insert the air tube into the housing tapping in with a block of wood if necessary to be sure the tube is bottomed in the bored opening. Tighten the air tube holding clamp.
6. Install the nozzle.
 - a. Loosen the clamping screw on the retention ring assembly and slide the retention ring off the adapter.
 - b. Install and tighten the proper nozzle (see Tables 7 & 8) in the adapter. Be careful not to damage the electrode insulators or to bend the wires.
 - c. Replace the retention ring assembly, slipping one of the riveted arms through the 1/8" gap between the electrode ends. This top arm should be straight up. Also be sure that the retention ring clamp is tight against the shoulder on the adapter. Then tighten the clamping screw.
 - d. Check the electrode settings specified as follows: 1/8-inch gap, 1/4-inch above the nozzle centerline, and 3/16-inch ahead of the nozzle tip. See Fig. 2 below.

Fig. 2



7. Swing open the transformer, and slide the nozzle line assembly into the air tube. *Do not force it.* The flame retention ring must be lifted and guided through the throttle ring (a reduced diameter) in the end of the air tube. Then the threaded adapter on the end of the nozzle line is passed through the opening in the left side of the housing.

It is important that the installation of the oil burner, piping and fittings, safety devices, controls, electrical wiring and equipment be done in accordance with national and/or local regulations of the authorities having jurisdiction over such installation.

Table 1. RECOMMENDED MINIMUM INSIDE DIMENSIONS OF REFRACTORY-TYPE COMBUSTION CHAMBERS FOR STANDARD AIR TUBE DESIGN

1 Firing Rate (GPH)	2 Length (L)	3 Width (W)	4 Dimension (C)	5 Suggested Height (H)	6 Minimum Dia. Vertical Cyl.
0.50	7	6	3	8	7
0.65	7.5	7	3.5	9	7.5
0.75	8	7	3.5	9	8
0.85	9	7	3.5	9	8.5
1.00	10	8	4	10	9
1.10	11	8	4	10	9.5
1.25	12	8	4	10	10
1.35	13	8	4	10	11
1.50	14	9	4.5	11	12
1.65	15	9	4.5	11	13
1.75	16	9	4.5	11	14
2.00	17	9	4.5	11	15
2.25	18	10	5	12	16
2.50	19	10	5	12	17
2.75	20	10	5	12	18

NOTES:

1. Flame lengths are approximately as shown in column (2). Some tested boilers or furnaces may operate well with chambers shorter than the lengths shown in column (2).
2. As a general practice any of these dimensions can be exceeded without much effect on combustion.
3. Chambers in the form of horizontal cylinders should be at least as large in diameter as the dimension in column (3). Horizontal stainless steel cylindrical chambers should be 1 to 4 inches larger in diameter than the figures in column (3).
4. Wing walls are not recommended. Corbels are not necessary although they might be of benefit to good heat distribution in certain boiler or furnace designs.

Table 2. RECOMMENDED MINIMUM INSIDE DIMENSIONS OF REFRACTORY-TYPE COMBUSTION CHAMBERS FOR 'A' STYLE AIR TUBE DESIGN

1 Firing Rate (GPH)	2 Length (L)	3 Width (W)	4 Dimension (C)	5 Suggested Height (H)	6 Minimum D.A. Vertical Cyl.
0.50	7	7	3.5	10	7
0.65	8	8	4	10.5	8
0.75	8.5	8.5	4.5	11	8.5
0.85	9	9	4.5	11.5	9
1.00	9.5	9.5	5	12	9.5
1.10	10	10	5	12	10
1.25	10.5	10.5	5.5	12.5	10.5
1.35	11	11	5.5	13	11
1.50	11.5	11.5	6	13.5	11.5
1.65	12	12	6	14	12
1.75	12.5	12.5	6.5	14.5	12.5
2.00	13	13	6.5	15	13
2.25	13.5	13.5	7	15.5	13.5

NOTES:

1. Flame lengths are approximately as shown in column (2). Some tested boilers or furnaces may operate well with chambers shorter than the lengths shown in column (2).
2. At 0.50-0.75 GPH it is recommended that the chamber sizes shown be followed closely for optimum performance. At 0.85-2.25 GPH the dimensions shown may be increased by 10 to 20% with very little effect.
3. Wing walls are not recommended. Corbels are not necessary although they might be of benefit to good heat distribution in certain boiler or furnace designs.

Table 3. RECOMMENDED MINIMUM INSIDE DIMENSIONS OF REFRACTORY-TYPE COMBUSTION CHAMBERS FOR STANDARD AIR TUBE DESIGN

1 Firing Rate (GPH)	2 Length (L) With Target	3 Length (L) Without Target	4 Width (W)	5 Dimension (C)	6 Dimension (D)
0.50	Use a combustion chamber		See Table 2, above		
0.65	Use a combustion chamber		See Table 2, above		
0.75	Use a combustion chamber		See Table 2, above		
0.85	10-11	12	8	4	5
1.00	11-12	13	9	4.5	6
1.10	12-13	14	9	4.5	6
1.25	13-14	15	9	4.5	6
1.35	14-15	16	9	4.5	6
1.50	15-17	18	10	5	7
1.65	16-18	19	10	5	7
1.75	17-19	20	11	5	7
2.00	18-21	22	11	5	7
2.25	19-22	23	12	5.5	7.5
2.50	20-23	24	12	5.5	7.5
2.75	21-24	25	12	5.5	7.5

NOTES:

1. As a general practice any of these dimensions can be exceeded without much effect on combustion.
2. A fiber-type refractory "rug" or fill material to cover the floor area of the combustion space is recommended for cleaner combustion and to protect the base.
3. When a refractory or refractory fiber target is used, the lengths in column (2) apply. If the lengths are equal to or longer than in column (3) no target material is needed unless recommended by the boiler manufacturer.

HOW TO ADJUST THE AIR SHUTTER AND AIR BAND

For more precise regulation of air, these models have an air shutter for fine control plus an air band for coarse control.

The air shutter has a pointer which indicates the percent of opening against a calibrated scale (9 = 90%, fully open = 100%). Lock in place by a screw just above the ear on the fuel unit after final adjustment.

The air band is adjusted by loosening the 1/4-20 screw and nut. Lock in place after final adjustment. See Tables 4, 5, and 6 for approximate settings.

HOW TO ADJUST THE COMBUSTION HEAD

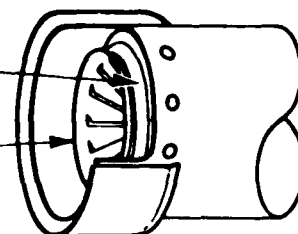
By moving the electrode and combustion head assembly forward or backward, the location of the flame retention ring relative to the throttle ring can be controlled. See Figure 8 (standard design) and Figure 9 ('A' style design). On Model 100CRD with the 'A' style air tube assembly the 'throttle ring' is incorporated into the air cone. See Figure 9. By reading the scale on the nozzle line slide plate, which is calibrated in 1/16-inch divisions (see dimension "A," Figure 10), the position of the flame retention ring in relation to the throttle ring can be determined at a glance. By loosening the locking screw and the thumb-nut and pushing on the thumb-nut, the assembly can be moved to the required position. To lock in place, first tighten the thumb-nut and then the locking screw. For the lower inputs, the position should be close to zero. Tables 4, 5, and 6 give approximate settings for each firing rate.

Fig. 8

STANDARD
AIR TUBE
DESIGN

THROTTLE
RING

FLAME
RETENTION
RING



A STYLE
AIR TUBE
DESIGN

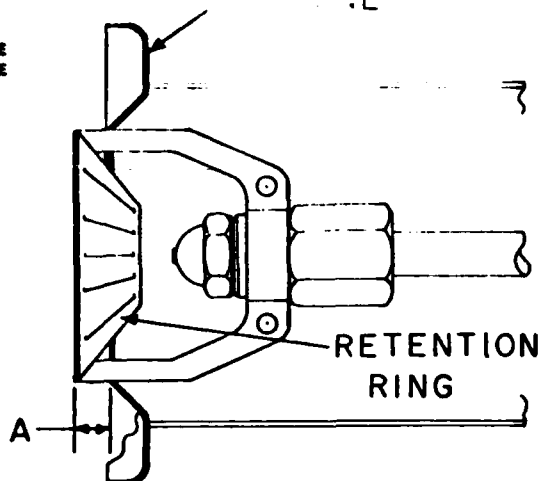
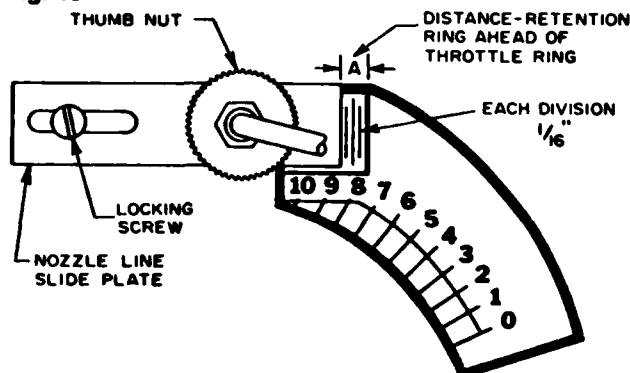


Fig. 10



RETENTION RING AND AIR SHUTTER ADJUSTMENTS

Tables 4, 5, and 6 show for each firing rate the recommended positions of the flame retention ring with the corresponding amounts of air shutter opening. These tables are provided only as a guide. Refer to Figures 8, 9, and 10 for retention ring 'A' dimensions.

Table 4.
RECOMMENDED SETTINGS FOR MODEL 100CRD

Firing Rate (GPH) @ 100 PSI	Retention Ring Setting, Inches on Scale (Dimension "A," Figure 11A)	Air Control Settings	
		Percent Opening Air Shutter	Percent Opening Air Band
0.50	0	0	0
0.65	0	50	0
0.75	Min. 0 Max. 1/8	90 80	0 0
0.85	Min. 0 Max. 1/8	100 85	0 0
1.00	Min. 1/8 Max. 3/8	100 90	25 0
1.10	Min. 1/8 Max. 3/8	100 100	100 15
1.25	Min. 1/8 Max. 1/4	100 100	100 20
1.35	Min. 1/8 Max. 3/8	100 100	100 20
1.50	Min. 3/8 Max. 1/2	100 100	100 25
1.65	Min. 3/8 Max. 1/2	100 100	100 30
1.75	Min. 3/8 Max. 1/2	100 100	100 50
2.00	Min. 1/2 Max. 3/4	100 100	100 50
2.25	Min. 3/4 Max. 1	100 100	100 100

Table 5. APPROXIMATE SETTINGS FOR MODEL 101CRD WITH 'A' STYLE AIR TUBE DESIGN

Firing Rate (GPH) @ 100 PSI	Retention Ring Setting, Inches on Scale (Dimension "A," Figure 10)	Air Control Settings	
		Percent Opening Air Shutter	Percent Opening Air Band
0.50	0	0	0
0.65	0	70	0
0.75	1/8	100	0
0.85	1/8	100	100
1.00	1/8-1/4	100	100
1.10	1/8-1/4	100	100
1.25	1/8	100	100
1.35	1/8-1/4	100	100
1.50	1/8-1/4	100	100
1.65	1/8-1/4	100	100
1.75	1/8-1/4	100	100
2.00	1/2-3/4	100	100
2.25	3/8-1/2	100	100

Table 6. APPROXIMATE SETTINGS FOR MODEL 101CRD WITH STANDARD AIR TUBE DESIGN

Firing Rate (GPH) @ 100 PSI	Retention Ring Setting, Inches on Scale (Dimension "A," Figure 10)	Air Control Settings	
		Percent Opening Air Shutter	Percent Opening Air Band
1.75	3/8	100	50
2.00	1/2	100	100
2.25	1/2	100	100
2.50	3/4	100	100
2.75	3/4	100	100

Table 7. NOZZLE SPECIFICATIONS FOR MODELS 100CRD AND 101CRD WITH STANDARD AIR TUBE DESIGN

Firing Rates (GPH)	Spray Type*	Make
0.65, 0.75	60° AR	Monarch
0.50, 0.60, 0.65, 0.75	60° H or 70° H 70° A	Hago Delavan
0.85 - 2.75	70° S, 60° S	Steinen
0.85 - 2.75	60° SS, 45° SS, 45° H	Hago
0.85 - 2.75	70° B, 60° B	Delavan
0.85 - 2.75	70° R, 60° R	Monarch

*H = Hollow SS = Semi-Solid Hago S = Solid Steinen
A = Hollow B = Solid Delavan R = Solid Monarch
AR = Semi-Solid Monarch

Table 8. NOZZLE SPECIFICATIONS FOR MODEL 100CRD WITH 'A' STYLE AIR TUBE DESIGN

Firing Rate (GPH)	Spray Type*	Make
0.50-0.75	60°, 70°, 80° H 80° A	Hago Delavan Steinen
0.85-2.25	60°, 70°, 80° H 60°, 70°, 80° A 60°, 70°, 80° H or Q	Hago Delavan Steinen

*H = Hollow SS = Semi-Solid Hago
A = Hollow B = Solid Delavan

The above specifications are based upon exhaustive tests and offer the best choice for most conditions. For special applications, other nozzle specifications might provide a more desirable pattern.

Other makes of nozzles may or may not prove satisfactory. Sufficient test data is not available to make other recommendations. The correlation of nozzle sprays between different manufacturers is not consistent.

When the burner is factory wired, the primary control, field connections are made in the 4" x 4" junction box under the control. CSA labeled burners are supplied with a primary control as certified by CSA. The motor, transformer, oil valve and flame detector are pre-wired. High limit, low water cut-off, fire-matic switch, emergency and service switches are wired

Fig. 11

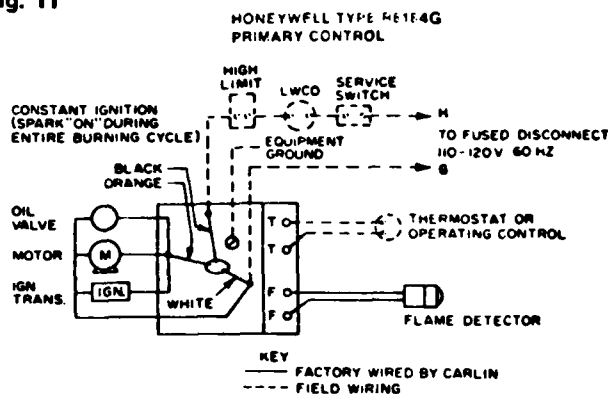
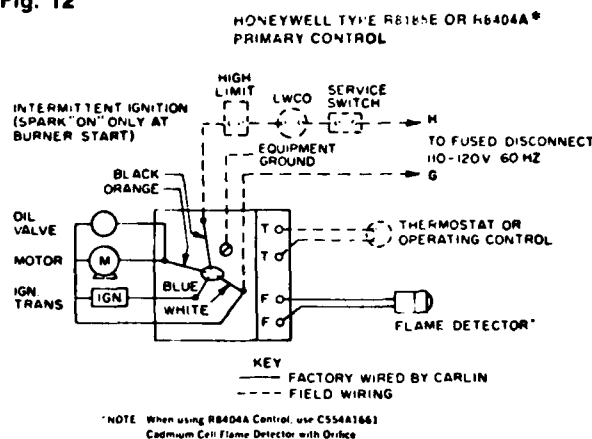


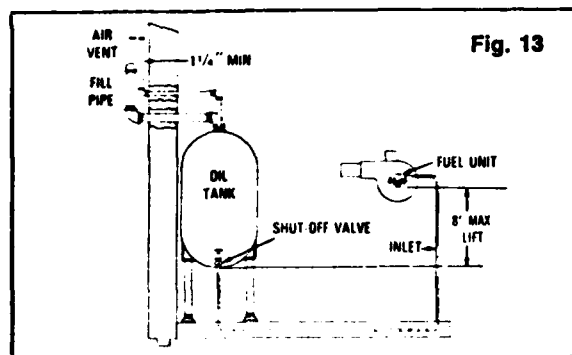
Fig. 12



FUEL UNITS AND OIL LINES

Single-Pipe Oil Lines — Standard burners are provided with single-stage 3450 rpm fuel units with the by-pass plug removed for single-pipe installations.

The single-stage fuel unit may be installed single-pipe with gravity feed or lift. Maximum allowable lift is 8 feet. See Fig. 13.



IMPORTANT: Single-pipe installations must be absolutely airtight or leaks or loss of prime may result. Bleed line and fuel unit completely.

Two-Pipe Oil Lines — For two-pipe systems where more lift is required, the two-stage fuel unit is recommended. Tables 9 (single-stage) and 10 (two-stage) show allowable lift and lengths of 3/8-inch and 1/2-inch OD tubing for both suction and return lines. Refer to Fig. 14.

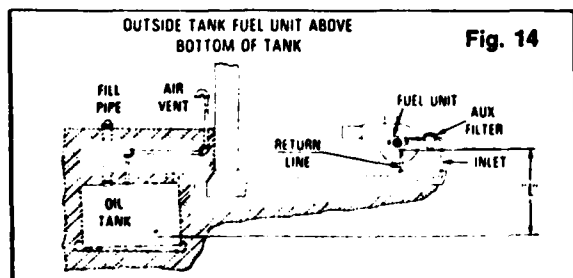


Table 9. SINGLE-STAGE UNITS (3450 RPM) — TWO-PIPE SYSTEMS

Lift "L" (feet) See Fig. 13	Length of Tubing *(feet)	
	3/8" OD	1/2" OD
0	53	100
1	49	100
2	45	100
3	41	100
4	37	100
5	33	100
6	29	100
7	25	99
8	21	83
9	17	68
10	13	52

* Line lengths include both vertical and horizontal lengths.

Be sure that all oil line connections are absolutely airtight. Check all connections and joints. Flared fittings are recommended. Do not use compression fittings.

Open the air-bleed valve and start the burner. For clean bleed, slip a 3/16" ID hose over the end of the bleed valve and bleed into a container. Continue to bleed for 15 seconds after oil is free of air bubbles. Stop burner and close valve.

Table 10. TWO-STAGE UNITS (3450 RPM) — TWO-PIPE SYSTEMS

Lift "L" (feet) See Fig. 13	Length of Tubing *(feet)	
	3/8" OD	1/2" OD
0	68	100
2	63	100
4	58	100
6	53	100
8	48	100
10	42	100
12	37	100
14	32	100
16	27	100
18	22	88

* Line lengths include both vertical and horizontal lengths.

Before starting the burner, open the air shutter, the air hand, and the retention ring. Then for your particular firing rate according to Tables 4 & 5, page 4 for 100CRD or Table 6, page 4, for 101CRD.

If the fire is a little too rich, move the combustion head forward by increasing dimension "A," Figure 10, page 4. At the lower inputs, a very slight change is usually enough.

Adjust draft to 0.01 to 0.03 inches W.C. over the fire for natural draft units.

Run a smoke test. Strive for zero or a trace. Each time further adjustment of air or retention ring is made, reset the draft to 0.01 to 0.03 inches W.C. over the fire.

Check CO_2 . This should be over 10 percent, and will often be over 12 percent, in a well-sealed unit at inputs of 1.00 gph and higher.

Check for good ignition and clean cut-off. If cut-off continues to be poor, look for air leaks in the suction line and correct them.

EFFECT OF BACK PRESSURE ON MAXIMUM FIRING RATES

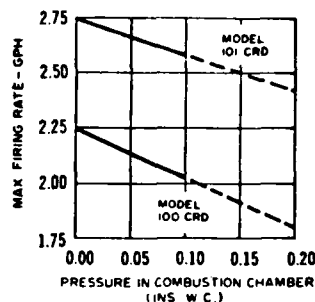
The maximum firing range for 100CRD is 1.75 to 2.75 gph for Model 100CRD and 2.75 gph for Model 101CRD is based on operation with zero to slightly negative pressure such as 0.01 inches to 0.03 inches W.C. draft over the fire as normally encountered in a natural draft unit.

When a unit is designed for forced draft operation with a positive pressure (back pressure) over the fire, the maximum air capacity of the burner is reduced in proportion to the amount of pressure. As a result, the maximum firing rate is also reduced. Figure 15 shows the maximum firing rate in gph of each model with various amounts of pressure in the combustion chamber.

As an example, the Model 100CRD has a maximum firing rate of just over 2.00 gph when fired against a back pressure of 0.10 inches W.C.

Fig. 15

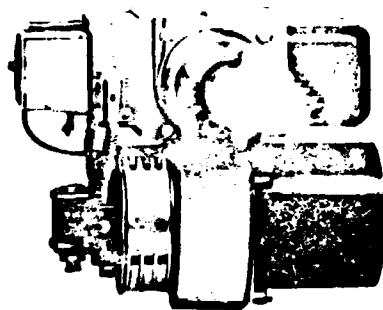
NOTE: Firing the 100CRD and 101CRD at over-fire pressures exceeding 0.10" W.C. is not recommended without pretests.



THE CARLIN COMPANY

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601 MARSHALL PHELPS ROAD
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INSTRUCTION MANUAL

Rev. 6-22-81

SLOAN VALVE COMPANY
10500 SEYMOUR • FRANKLIN PARK, ILL. 60131

INTERburner MARK 1 HIGH EFFICIENCY COMBUSTION EQUIPMENT

SPECIFICATIONS

CAPACITIES

0.40 to 2.00 G/P/H, 56,000 to 280,000 BTU/HR Input.
(G/P/H—based on sea level to 2,000 ft. elevation. For every 1,000 ft. increase, reduce maximum G/P/H 4%)

FUEL

No. 2 Heating Oil

POWER REQUIREMENTS

115 volts, 60 Hz, Single Phase

MOTOR

1/7 H.P., 3,450 R.P.M., N.E.M.A. "M" Flange, Manual Reset Overload Protection.

IGNITION TRANSFORMER

120/10,000 volts, 23 milliamperes, 60 Hz Interrupted Ignition Duty.

FUEL UNIT

3,450 R.P.M., 100 P.S.I., 5/16" Shaft Diameter. Standard with Integral Solenoid Cutoff valve for Clean Starts and Sharp Cutoff.

CONTROLS

24 volt Interrupted Ignition Control Relay with Cad Cell. Insures Long Electrode Life and Low Power Consumption.

HOUSING

A Precision Die Cast Aluminum Housing Machined for Accurate Motor and Pump Shaft Alignment.

BLOWER WHEEL

Balanced One-Piece Blade Strip for Quiet Air Movement. Dimensions 4-3/4 O.D. x 2-1/16" Wide.

MOUNTING

Standard Universal Mounting Flange and Gasket. Burner Stand Kit also available.

GUIDE FOR PROPER INSTALLATION

COMBUSTION AIR

INTERburner must be installed in an area with adequate fresh air to support combustion.

WIRING

The Wiring must be in accordance with the National Electric Code and Local Codes and Regulations.

OIL

Before starting INTERburner make sure that fuel tank is

adequately filled with clean No. 2 Oil—NEVER use crankcase oil or gasoline.

POWER CIRCUIT

Be sure that INTERburner and controls are wired correctly and that line switch is properly fused.

NOZZLE

Be sure that specified Nozzle is installed prior to starting INTERburner.

CONCEALED DAMAGE

INTERburner Mark I packaging has been quality engineered to protect against potential shipping damage. However, if any damage to INTERburner or to its controls is found during unpacking notify the carrier at once and file the appropriate claim.

STARTING AND ADJUSTMENT PROCEDURE

POSITIONING OF COMBUSTION HEAD

Each INTERburner unit has been test fired and the combustion head assembly factory set for firing at the No. 1 position (see Fig. 1). This is the correct setting to fire from .40 to 65 G/P/H. When other nozzle capacities are fired refer to the Nozzle Specification Chart below.

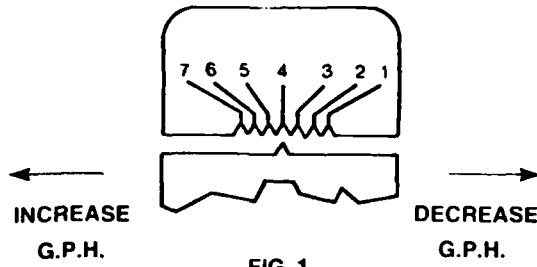


FIG. 1

BURNER SETTING & NOZZLE CHART

* NOZZLE SPECIFICATION	ADJUSTING BLOCK POSITION				
	1	2	3	4	7
70°-80°	40-65	-	-	-	-
60°	-	.75-90	1.0-1.25	-	-
45°	-	-	-	1.35-1.50	1.65-2.0

* NOTE: Final selection of nozzle type and spray angle must be made during installation to conform to size and shape of chamber.

CAUTION:

DO NOT attempt to start INTERburner when excess oil has accumulated, when the furnace or boiler is full of vapor, or when the combustion chamber is very hot.

1. Set the thermostat substantially above room temperature.
2. Open Shutoff Valves in the oil supply line of INTERburner.
3. Check initial air adjustment.
4. Close line switch to start INTERburner. If unit does not start immediately, reset manual overload switches on motor and control.
5. Make certain that fuel pump is piped for the type of oil supply system installed (1 pipe or 2 pipe). Make certain that all connections are tight.
6. Bleeding of the fuel pump is generally required on initial start up. Failure to bleed the air from the fuel pump through the bleeder valve provided may result in an air lock within the pump that will prevent oil from being delivered to the nozzle.
Bleed fuel pump as soon as INTERburner motor starts rotating. To bleed loosen bleeder valve. Drain at least 1/2 pint of clear air free oil from the pump then close bleeder valve. The ignition should be instantaneous with closing the bleeder valve. If INTERburner starts but stops again during venting operations, wait 3 min. for the safety switch to cool then reset manual switch and repeat the procedure until ignition is obtained. Sometimes after bleeding is ac-

complished and the oil is ignited, the fire will go out. This probably means that additional bleeding is necessary. Repeat the above bleeding procedure. See also enclosed fuel pump manufacturer's Instructions.

LINE OIL FILTER

Use an oil filter of proper capacity for all installations. Install inside the building between shutoff valve and INTERburner. For ease of servicing, locate the filter and a shutoff valve close to INTI Rburner.

OIL SHUTOFF VALVE

Install approved shutoff valves in oil supply line in accessible locations, one close to the tank and the other close to INTERburner, but ahead of the oil filter.

DRAFT CONTROL ADJUSTMENT

When INTERburner air supply and draft are properly adjusted the combustion chamber draft will normally be 0 to .01" WC.

AIR ADJUSTMENT

At this point a final adjustment should be made using proper test instruments. The unit should set as follows: After allowing 10 minutes for warm-up, air should be set so the smoke number is "0" to a trace; less than No. 1 smoke is desired. NOTE: Occasionally a new heating unit requires more than this to burn cleanly due to the oil film on the heat exchanger surface. CO₂ measured in the stack (ahead of draft control) should be at least 10%. Unit should be started and stopped several times to assure good operation.

CHECKING CONTROLS

Make certain that the primary control safety switch operates properly so that safety shutdown will occur in the event of equipment malfunction.

FINAL CHECKS

Make certain that the air shutter and draft control are locked, that there is an ample supply of fresh air to the room in which INTERburner unit is located, and there are no oil leaks

ELECTRODE SETTING

Be sure that Electrodes are positioned as shown in these instructions (see page 3 Fig 2) Improper adjustment can result in oil impingement or ignition difficulties.

ELECTRODE SETTING

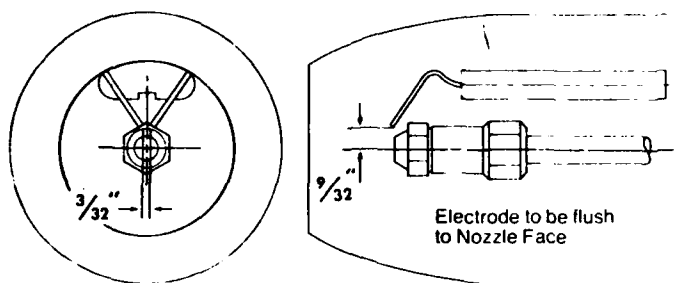
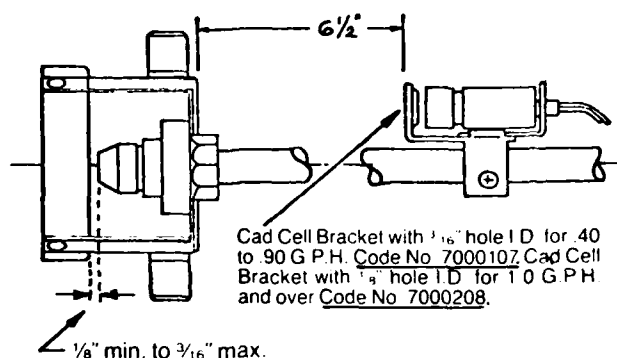


FIG. 2

CAD CELL BRACKET POSITION AND SELECTION



PRACTICES TO BE OBSERVED IN THE INSTALLATION OF THE HIGH COMBUSTION EFFICIENCY INTERburner

The installation of a high combustion efficiency INTERburner as a replacement for less efficient equipment will result in increased flame temperatures. An increase of from 450°F. to as much as 1000°F. may be reflected. Thus care should be taken in the following areas:

1. As the use of the high efficiency INTERburner results in an increased heat release per gallon of fuel oil, the firing rate should be reduced to take full advantage of the increased fuel savings and to prevent overheating.
2. Seal any gaps between the combustion area and the air tube to prevent any potential leakage of hot combustion gases. This is very important at the combustion head. The recirculation of hot combustion gases may cause damage to both INTERburner head and the furnace in a relatively short time if full consideration is not given to the above precautions.
3. A high temperature heat shield, INTERburner "Cool-Head", Kit No. 26991 should be installed where high combustion temperatures are recognized.

INSTRUCTING THE HOMEOWNER

A Qualified INTERburner Installer should instruct the homeowner in the operation and care of the heating system, including how to adjust the thermostat, necessity of air supply to INTERburner, and the simple checks to make before calling for service if the unit fails to operate automatically.

PREVENTATIVE MAINTENANCE

"Preventative Maintenance" is the best way to avoid unnecessary expense and inconvenience. Have your heating system and INTERburner inspected at regular intervals by a qualified INTERburner Installer. If difficulty occurs, follow these simple checks before calling for service.

1. Make certain there is oil in the tank and valve is open.
2. Make certain the thermostat is set above room temperature.
3. Make certain main line switch is "ON" and fuses are not blown.

OIL SUPPLY

Do not allow the fuel tank to run out of oil. During the Summer make certain that your fuel tank is kept full. This will prevent condensation of moisture on the inside surfaces of the tank.

COMBUSTION AIR SUPPLY

Your INTERburner requires a certain amount of combustion air. If the air supply is restricted, the burner will not operate properly and the unit will not be able to maintain the desired temperature.

unit or noisy combustion or fuel odors in the air. Remember, your need for outside air will greatly increase if you have a vented dryer in the basement or other venting fans in the home.

OILING MOTOR

Motor life will be increased by proper oiling. Use a few drops of non-detergent oil at both motor holes twice each year. DO NOT OVER OIL.

OIL FILTER

The line oil filter can ridge should be replaced every year to avoid contamination of the fuel unit and atomizing nozzle.

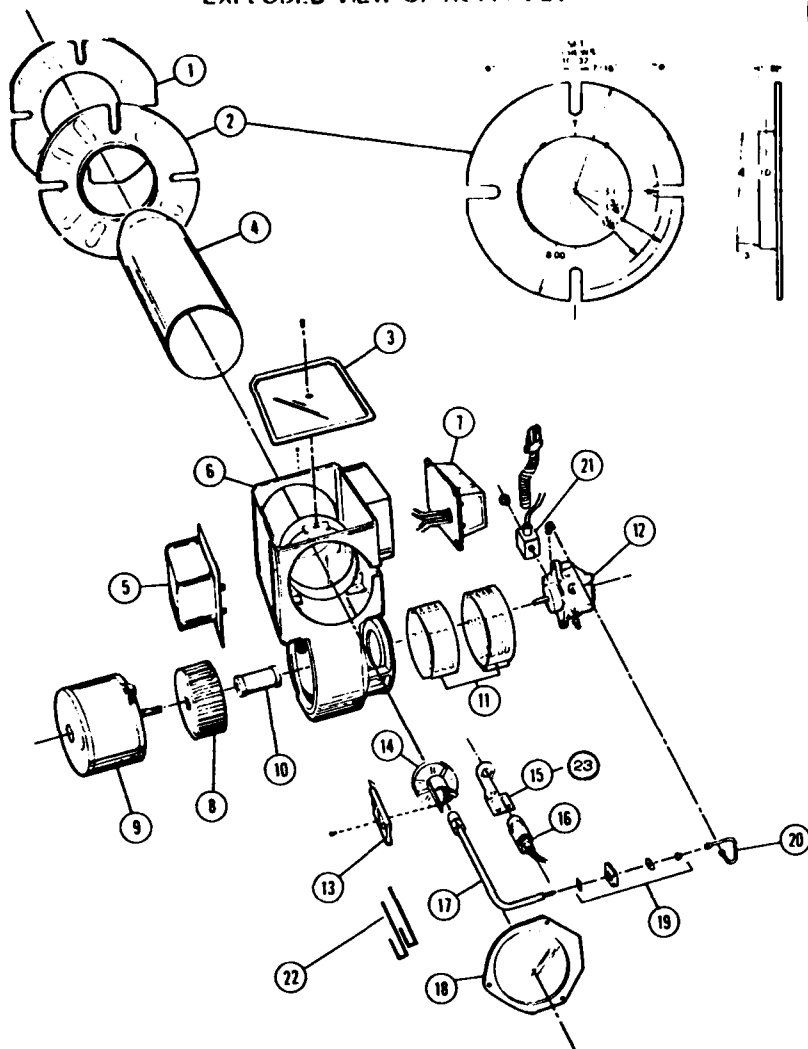
AREA AROUND HEATING UNIT

This area should be kept clean and free of any combustible materials, especially papers and dry rags.

NEVER

Never use the INTERburner for anything other than its intended purpose. The unit is designed for use as a space heater only.

EXPLODED VIEW OF ASSEMBLY



INTERBURNER
MARK I

HIGH EFFICIENCY COMBUSTION EQUIPMENT

PARTS LIST

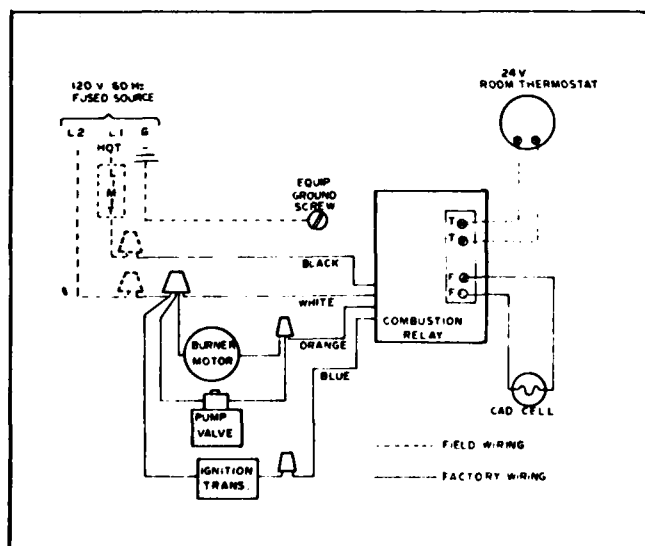
MAJOR COMPONENTS

NO	CODE NO.	DESCRIPTION
5	7000150	Ignition Transformer
7	7000132	Combustion Control Relay
9	7000148	Motor
12	7000123	Single Stage Pump
	7000167	Two Stage Pump
16	7040001	Cad Cell and Holder w/24" Lead

PARTS

1	7000151	Mounting Gasket
2	7000159	Mounting Flange Assembly
3	7000134	Top Cover Plate
4		See Back Page for Draft Tube Kits
6	7000137	Burner Housing
8	7000149	Blower Wheel
10	7000114	Flexible Coupling
11	7000166	Air Band Assembly Kit
13	7000104	Electrode
14	7000001	Combustion Head Assembly
15	7000107	Cad Cell Bracket
	7020003	6" Oil Pipe Assembly
17	7030003	9" Oil Pipe Assembly
	7040003	13" Oil Pipe Assembly
	7050003	16" Oil Pipe Assembly
18	7000135	Back Cover Plate
19	7000165	Adjustment Block Assembly
20	7000131	Oil Line
21	7000168	Solenoid Coil
	7020005	6" Buss Bar
22	7030005	9" Buss Bar
	7040005	13" Buss Bar
	7050005	16" Buss Bar
23	70000208	Cad Cell Bracket 1/8" I.D.

WIRING DIAGRAM INTERburner MARK I



SUGGESTED COMBUSTION CHAMBER DIMENSIONS—UPGRADING OR CONVERSION

Firing Rate (GPH)	Chamber Dimensions (In Inches)			
	Round I.D.	Rectangular W L	Height	Floor To Nozzle C/L
.40 to .65	9	8 x 10	12	5-6
.75 to 1.50	11	10 x 11	13	5-6
1.65 to 2.00	14	12 x 15	14	6-7

SLOAN VALVE COMPANY 10500 SEYMOUR AVE. FRANKLIN PARK, ILL. 60131



ADJUSTABLE UNIVERSAL FLANGE INSTALLATION INSTRUCTIONS

KIT CONTENTS:

- (1) Adjustable Mounting Flange
- (1) Flange Gasket
- (2) 10x32 Screws (installed)
- (1) Installation Instructions

1. Determine the insertion length of Burner Air Tube as follows: Measure the distance from boiler or furnace front plate to the inside edge of the combustion chamber. On cylindrical combustion chambers measure the insertion length on the vertical center-line of the combustion chamber opening.

NOTE: the actual insertion length of the Air Tube must be $\frac{1}{8}$ " to $\frac{1}{4}$ " less than the length as measured. (see fig. 1).

2. Mark the actual insertion length on both sides of the Air Tube, measuring from the end of the Burner Tube. (see fig. 2).

3. **NOTE:** Flange Gasket and Universal Flange must be installed with "TOP" marking at the top side of the Air Tube. This provides a 2° to 4° downward pitch to the Air Tube. (see fig. 3). Slide Universal Flange onto Air Tube, tighten in place. Next, slide Flange Gasket onto Air Tube. Screws should be snug. **DO NOT OVER TIGHTEN.**

4. Verify the actual insertion length of the Air Tube (face of Flange Gasket to end of Burner Head). Mount Burner to appliance. (see fig. 1).

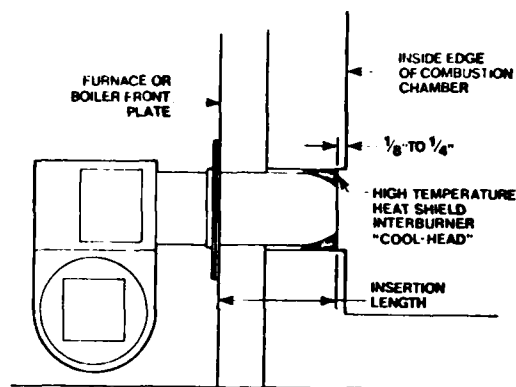


FIG. 1

NOTE: To prevent Burnout of the Air Tube or Burner Head install **INTERburner** "COOL-HEAD" Heat Shield KIT NO. 26991

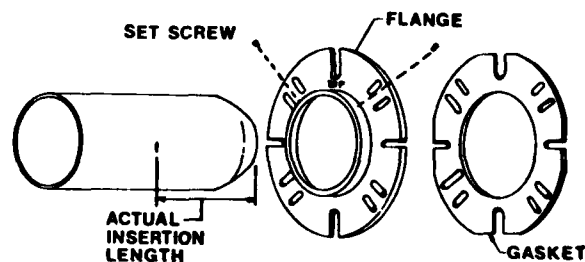


FIG. 2

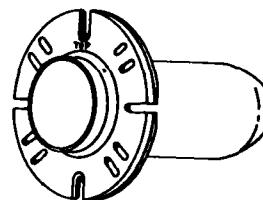


FIG. 3

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INTERburner COOL-HEAD Heat Shield INSTALLATION INSTRUCTIONS

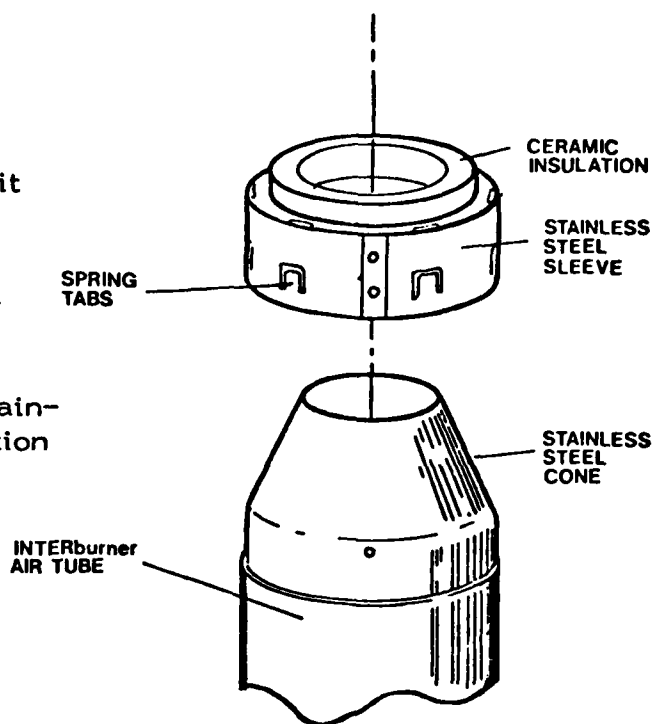
CODE NO. 7000154

INSTALLATION:

Position INTERburner Oil Burner unit with Air Tube UP.

Slip COOL-HEAD Sleeve over Air Cone and press into place. (see diagram)

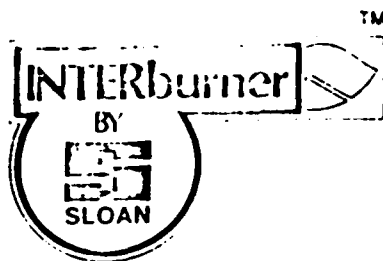
NOTE: Seal any air gaps between stainless steel sleeve and ceramic insulation with high-temp. caulk.



The INTERburner COOL-HEAD Heat Shield comes to you complete-ready to install and is ideal for installations where high combustion temperatures occur after replacement of less efficient heating equipment.

An increase of from 450°F. to as much as 1000°F. may result with the installation of an INTERburner High Efficiency Oil Burner. The COOL-HEAD Heat Shield, when properly installed, prevents Air-Tube burn-out by providing the added insulation protection required for such conditions.

SLOAN VALVE COMPANY 10500 SEYMOUR AVE. FRANKLIN PARK, ILL. 60131



Service Bulletin

DATE: August 14, 1979

BULLETIN NO. 5

SUBJECT: AIR TUBE ALIGNMENT PROCEDURE

INTERburner has been engineered to eliminate critical tolerances normally associated with drawer assembly dimensions. As it is impossible to accurately control the length of any drawer assembly in production the following method of alignment will assure proper settings of the combustion head and combustion cone. Every INTERburner has been designed and tested in order to achieve the ultimate in combustion efficiency. Therefore, it is mandatory that field adjustments be made with utmost care in order to preserve the high quality of the equipment as it is produced. Each INTERburner is pre-set at the factory to the number one setting and must be repositioned to this original setting whenever any of the following four components are changed:

1. Oil Pipe
2. Nozzle Adaptor
3. Combustion Head Assembly
4. Air Tube

PARTS REMOVAL PROCEDURE

1. Remove top cover.
2. Loosen air tube set screw.
3. Extend or remove air tube from housing.
4. Disconnect oil line.
5. Remove rear cover.
6. Disconnect buss bars.
7. Loosen Knurled nut.
8. Withdraw drawer assembly partially.
9. Disconnect cad-cell.
10. Withdraw drawer assembly completely.
11. Check head assembly.

PARTS ASSEMBLY PROCEDURE

1. Insert drawer assembly partially.
2. Connect cad-cell.
3. Insert drawer assembly to full position.
4. Set adjusting block to #1 setting.
5. Tighten Knurled nut.
6. Connect buss bars.
7. Install rear cover.
8. Carefully re-insert air tube until contact is made with three (3) tabs on combustion head spinner.
9. Tighten air tube set screw.
10. Set adjustment block position as required for nozzle size. See instructions on top cover.

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Service Bulletin

DATE: August 14, 1979

BULLETIN NO. 5

SUBJECT: AIR TUBE ALIGNMENT PROCEDURE
PAGE TWO

11. Connect and tighten oil line.
12. Replace top cover.



Service Bulletin

DATE: November 28, 1979

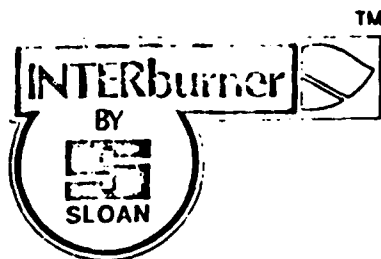
BULLETIN NO. 6

SUBJECT: BURNER STARTS, THEN LOCKS OUT ON SAFETY

PROCEDURE FOR USE OF OHMMETER

Take ohmmeter reading with burner running and locate reading in table below. Read across to determine cause and corrective action.		
--	--	--

OHMMETER READING	CAUSE	ACTION
0 ohms.	Short circuit.	Check for pinched cad cell leadwires.
Less than 1600 ohms but not 0.	Cad cell and application are operating correctly.	None.
Over 1600 ohms but not infinite.	Dirty or defective cell, improper sighting or improper air adjustment.	1. Clean cell face and recheck. 2. Check flame sighting. 3. Replace cell and recheck. 4. Adjust air band to get good reading.
Infinite resistance.	Open circuit.	Check for improper wiring loose cell in holder or defective cell.



Service Bulletin

DATE: December 6, 1979

BULLETIN NO. 7

EFFECTS OF PRESSURE ON NOZZLE FLOW RATE

NOZZLE RATING AT 100 PSI	NOZZLE FLOW RATES IN GALLONS PER HOUR Approx.			
	80 PSI	120 PSI	140 PSI	160 PSI
.50	0.45	0.55	0.59	0.63
.65	0.58	0.71	0.77	0.82
.75	0.67	0.82	0.89	0.95
.85	0.76	0.93	1.00	1.08
.90	0.81	0.99	1.07	1.14
1.00	0.89	1.10	1.18	1.27
1.10	0.99	1.21	1.30	1.39
1.20	1.07	1.31	1.41	1.51
1.25	1.12	1.37	1.48	1.58
1.35	1.21	1.48	1.60	1.71
1.50	1.34	1.64	1.78	1.90
1.65	1.48	1.81	1.95	2.09
1.75	1.57	1.92	2.07	2.22
2.00	1.79	2.19	2.37	2.53

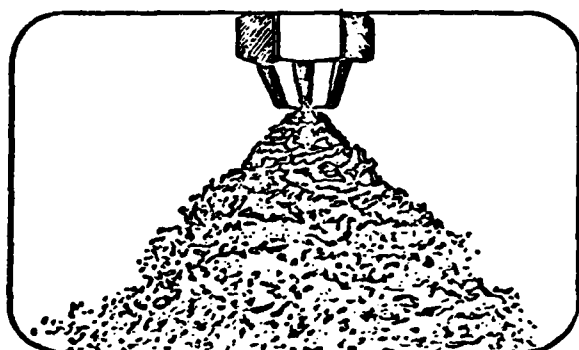


FIG. 1 Spray at 100psi pressure.

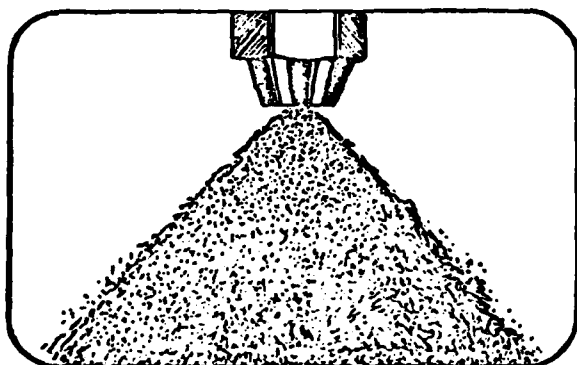
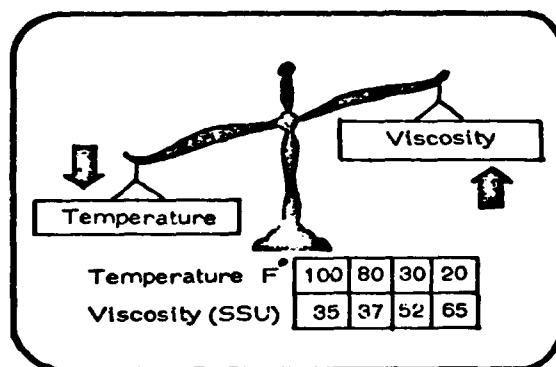


FIG. 2 Spray at 160psi pressure.





Service Bulletin

DATE: December 6, 1979

BULLETIN NO. 7

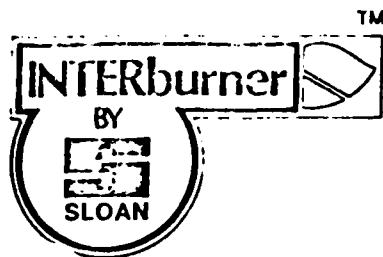
SUBJECT: GUIDELINES FOR INCREASED OIL PRESSURE

For many years it has been a recognized fact that increasing the pump pressure will result in improved atomization, decrease droplet size, a better fuel air mixture and thus a higher degree of burner performance and efficiency. (See figures #1 and #2.)

All standard nozzle GPH flow rates are based on 100 P.S.I. therefore, you must:

- A) Use a pressure gauge to determine the exact discharge pressure to the nozzle.
- B) Use the flow chart to recalculate the new nozzle capacity in GPH.
- C) Readjust the air settings on the burner to coincide with the increased gallon per hour flow rate.
- D) Use your combustion instruments and record the new readings on smoke, CO₂ and draft. In this respect, it is important that you consider this a new installation and take time to adjust the burner to achieve the ultimate in high efficiency and clean firing.

The Mark I INTERburner has a minimum firing rate of .4 GPH, this minimum can only be achieved by operating at 100 P.S.I. Never attempt to achieve lower firing rates by adjusting the pump discharge pressure below 100 P.S.I.



Service Bulletin

DATE: April 23, 1980

BULLETIN NO. 8

SUBJECT: BOILER CONTROLS

The attached wiring diagram indicates the procedure for proper use of the interrupted ignition primary control, as supplied with each INTERburner Mark I, where an existing combination control.

IMPORTANT - NOTE

Make certain to check the High Limit circuit. Manual operation of the High Limit must shut down the burner when wiring change has been completed.

Enclosure

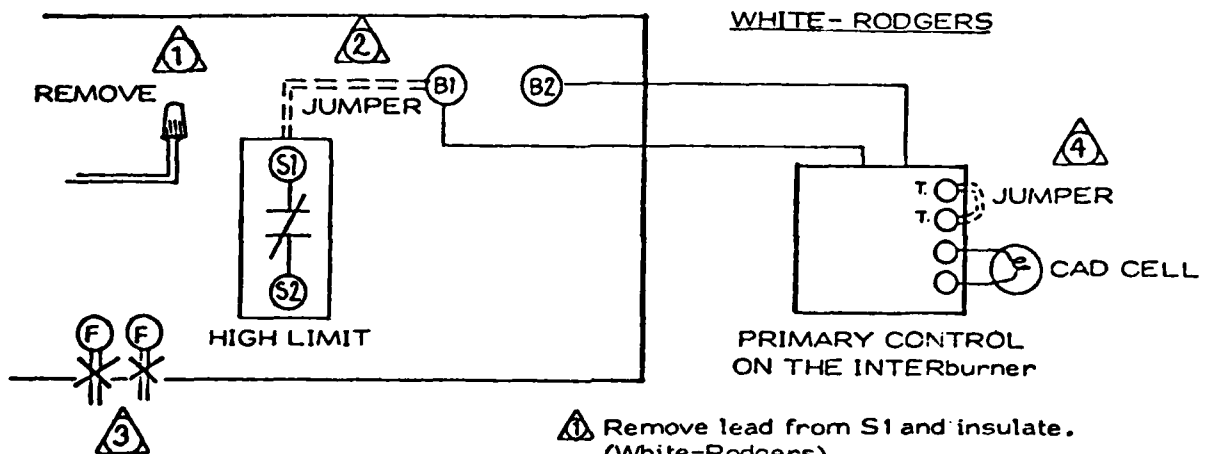


Service Bulletin

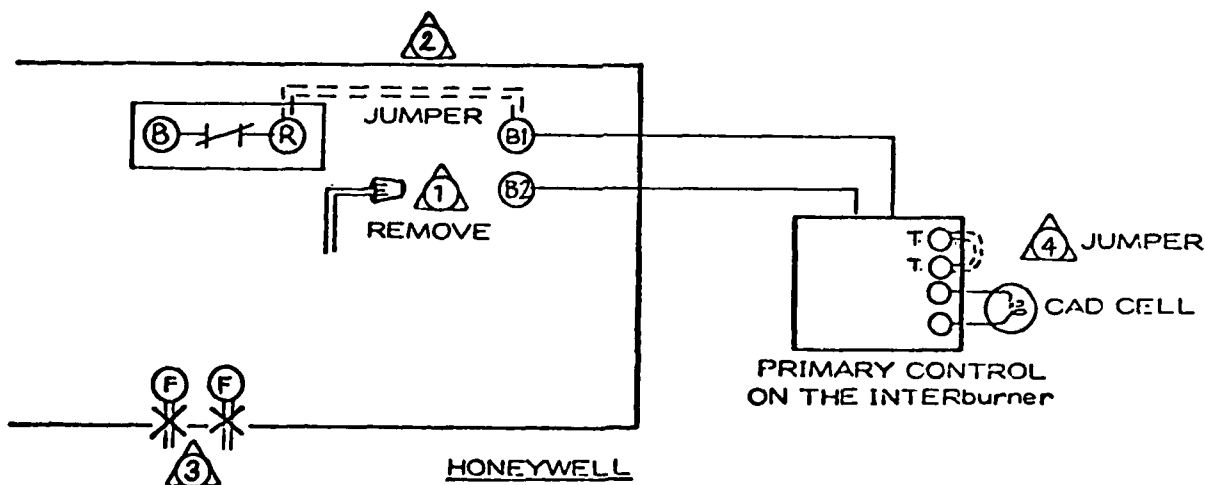
DATE: April 23, 1980

BULLETIN NO. 8 (Enclosure)

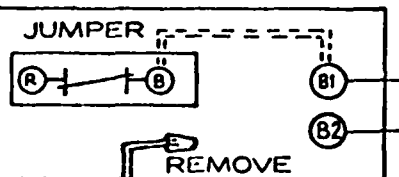
TO CONVERT WHITE-RODGERS OR HONEYWELL COMBINATION BOILER CONTROLS WHERE THE PRIMARY CONTROL IS INCORPORATED IN THE BOILER CONTROL.



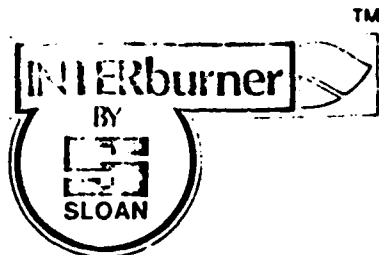
- ① Remove lead from S1 and insulate. (White-Rodgers)
- ② Place jumper in White-Rodgers circuit from S1 to B1. In Honeywell circuit, jumper R to B1.*
- ③ Remove cad cell leads from existing control.
- ④ Jumper 24V thermostat (T.T.) terminals on burner mounted control.



*NOTE: On older Honeywell models, where the sensitive relay was used, R and B terminal designation is reversed. The lead should be removed from the terminal B and a jumper should be placed from B to B1.



SLOAN VALVE COMPANY • 10500 SEYMOUR AVENUE • FRANKLIN PARK, ILLINOIS 60131



Service Bulletin

DATE: March 1, 1982

BULLETIN NO. 9 A

NOTICE: THIS BULLETIN REPLACES SERVICE BULLETIN #9 DATED 5/5/80

SUBJECT: COMBUSTION HEAD ASSEMBLY DIMENSIONS - REVISED

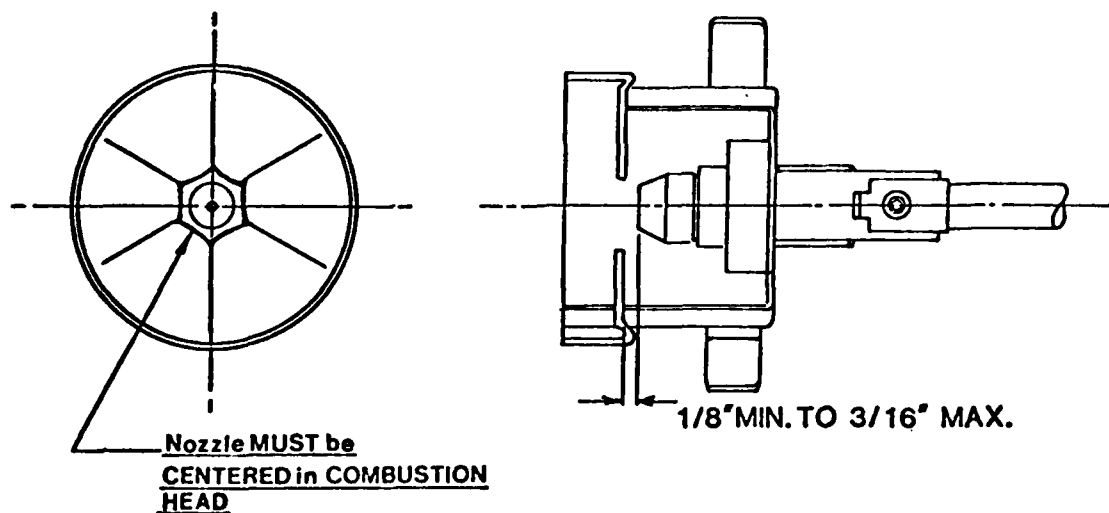
The primary design feature resulting in the extreme high efficiency achieved by INTERburner is found in the combustion head assembly. The dimensions associated with this design are therefore, critical and must be accurately maintained. When ever the combustion head is removed from the nozzle adapter, make certain that it is properly re-positioned in accordance with the dimensions indicated on the drawing below.

The dimension from the face of the nozzle adapter to the face of the nozzle itself will vary slightly from one nozzle manufacturer to another and must be compensated for by positioning the combustion head in relationship with the nozzle.

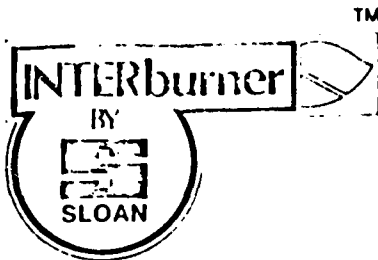
Note: When replacing the combustion head assembly, position the round collar against the hex shoulder of the nozzle adapter and tighten the set screw. If the dimension from the nozzle face of the spinner is not within 1/8" to 3/16", it should be adjusted to the correct dimension.

ALWAYS CHECK THE DIMENSION FROM THE NOZZLE FACE TO THE BACK FACE OF THE SPINNER AND MAINTAIN 1/8" MINIMUM TO 3/16" MAXIMUM CLEARANCE.

ALWAYS CHECK THE CENTERING OF THE NOZZLE IN THE COMBUSTION SPINNER. FAILURE TO DO THIS MAY RESULT IN IMPINGEMENT OF OIL SPRAY, COKING OF SPINNER OR LOPSIDED FIRE.



SLOAN VALVE COMPANY • 10500 SEYMOUR AVENUE • FRANKLIN PARK, ILLINOIS 60131



Service Bulletin

DATE: March 1, 1982

BULLETIN NO. 10 A

NOTICE: THIS BULLETIN REPLACES SERVICE BULLETIN #10 DATED 9/28/81

SUBJECT: PROPER NOZZLE SELECTION - REVISED

This nozzle selection chart has been revised as shown below:

BURNER SETTING & NOZZLE CHART

NOZZLE SPECIFICATION	ADJUSTING BLOCK POSITION				
	1	2	3	4	7
70° -80°	.40-.60	—	—	—	—
60°	.65	.75-.90	1.0-1.25	—	—
45°	—	—	—	1.35-1.50	1.65-2.0

(NOTE: CHART RECOMMENDATIONS BASED ON PUMP PRESSURE OF 100 PSI)

These recommendations are general and apply to the usual or average conditions that occur in the typical retro fit installation. We further amend these recommendations to the effect that, in low firing rate installations of .75 GPH or less, the hollow nozzle is preferable. Similarly, we recommend the solid nozzle for installations over .75 GPH. However, the Installer must recognize his responsibility to evaluate flame pattern as affected by variations in chamber size and shape for optimum nozzle selection in each installation.

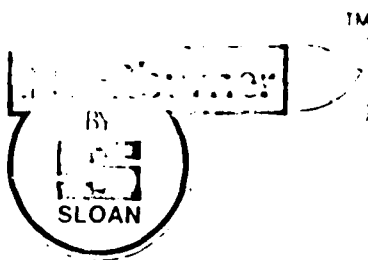
The most detailed reference guides for proper nozzle selection in various firing conditions are available from the nozzle manufacturer. The Installer should always carry one with him as an aid to achieving the correct flame patterning for a specific installation. Historically, we know that 80% of service problems relate back to incorrect nozzle selection. Therefore, your extra caution in this regard is paid back to you in the elimination of future trouble calls.

At times it may be necessary to increase the pump pressure to obtain a more desirable flame pattern. When increasing pump pressure, it is mandatory to refer to the nozzle manufacturers flow rate and pressure chart (or Bulletin No. 7) to determine the new nozzle flow rate.

After the new flow rate has been determined, refer to the INTERburner burner setting and nozzle selection chart for recommended spray angle and adjusting block position.

REFER TO BULLETIN NO. 9A FOR PROPER COMBUSTION HEAD SETTING.

SLOAN VALVE COMPANY • 10500 SEYMOUR AVENUE • FRANKLIN PARK, ILLINOIS 60131



Service Bulletin

DATE: February 16, 1983

BULLETIN NO. 11

NOZZLE BULLETIN

EFFECTIVE WITH DEPLETION OF CURRENT INVENTORY THE MARK I INTERburner WILL BE SHIPPED LESS NOZZLE.

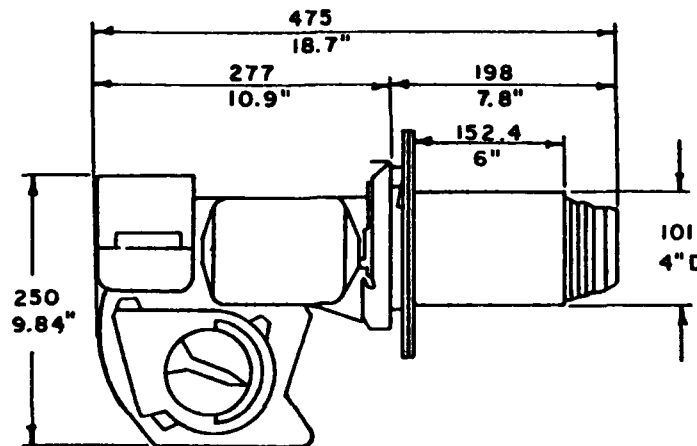
THIS CHANGE IS BEING MADE TO AVOID THE POSSIBILITY OF CONTAMINATION OF THE INSTALLED NOZZLE DUE TO POSSIBLE EXCESSIVE STORAGE TIME, AND TO ASSURE THAT A CORRECT NOZZLE SELECTION IS MADE.

A FRESH NOZZLE IS ALWAYS RECOMMENDED FOR A NEW BURNER INSTALLATION. MANY TIMES THE INSTALLATION HAS BEEN MADE USING THE NOZZLE SHIPPED WITH THE BURNER. THIS NOZZLE CAN BECOME PARTIALLY CLOGGED DUE TO THE BREAKDOWN OF THE OIL DURING STORAGE. THE RESULT CAN BE UNSATISFACTORY BURNER OPERATION.

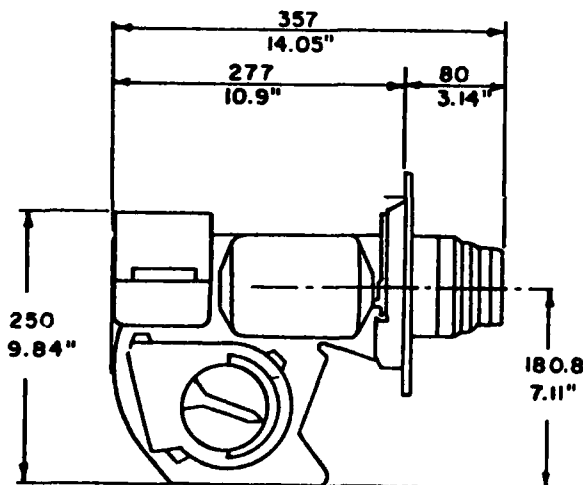
WE WOULD REPEAT OUR STANDARD QII INSTRUCTION THAT THE NOZZLE SELECTION IS DICTATED BY THE REQUIREMENTS OF THE INDIVIDUAL INSTALLATION. THERE IS NO UNIVERSAL NOZZLE SIZE, SPRAY, OR POINT TYPE. THIS DETERMINATION MUST BE MADE ON THE JOB AT THE TIME OF INSTALLATION.

INSTALLATION SERVICE AND OPERATING MANUAL

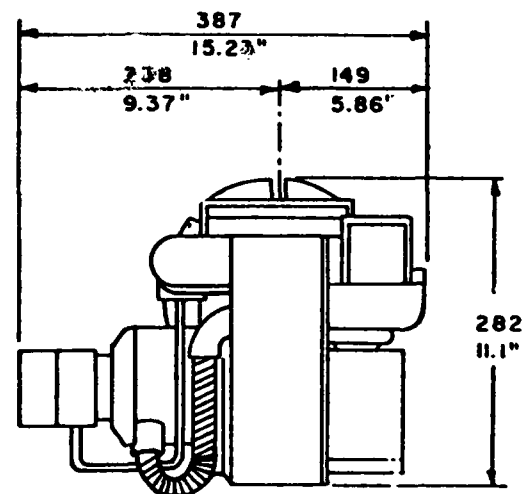
ERTLI AMERICAN OIL BURNER MODEL-OE-1



STANDARD



SHORT



ERTLIAMERICAN

PHONE: N. Y. C. (212) 895-2196; (516) 543-4600. Outside N. Y. State Toll Free (800) 645-4504

ABC SUNRAY CORP., 85 AUSTIN BLVD., COMMACK, N.Y. 11725

INSTALLATION, SERVICE AND OPERATING MANUAL

MODEL OE-1 OIL BURNER

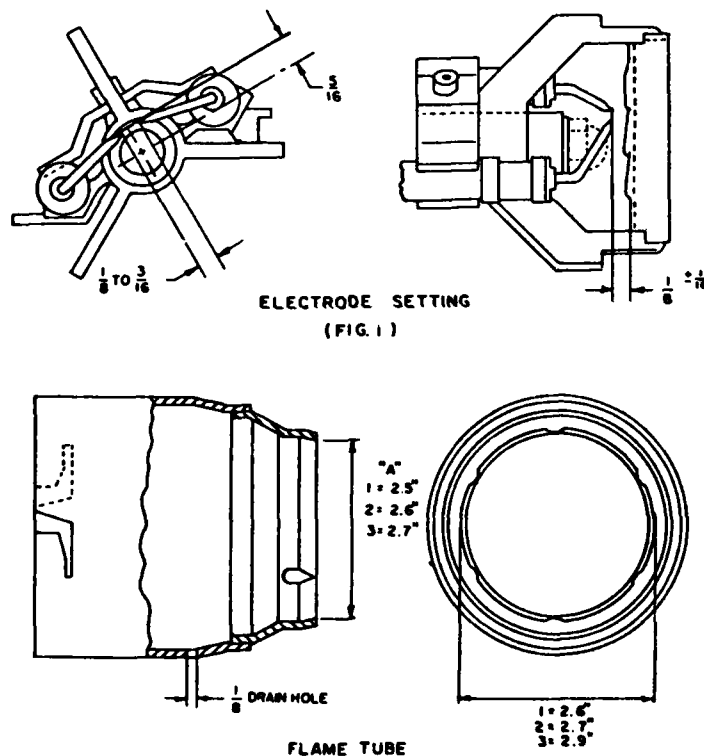
TECHNICAL DESCRIPTION

Burner Data

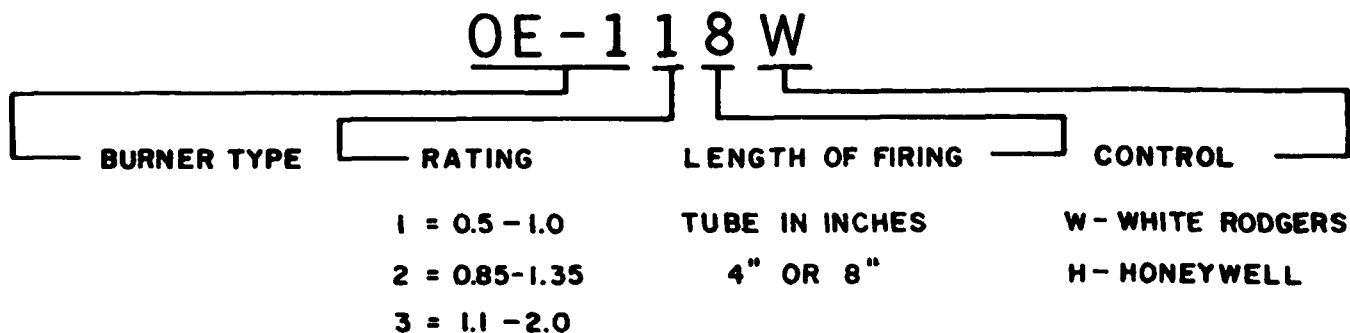
TYPE	COMBUSTION		RATING GPH	PRIMARY CONTROL	MOTOR	IGNITION TRANSFORMER	FUEL UNIT	WEIGHT
	HEAD	OPENING "A"						
OE-1-1	1	2.5"	0.5 - 1.0	Cad Cell Control With Interrupted Ignition	110V 60 CY 1 PH 110W Capacitor Start	Primary 110V Secondary 10,000V	Sundstrand Webster Danfoss	14 Lb.
OE-1-2	2	2.6"	0.85 - 1.35					
OE-1-3	3	2.7"	1.1 - 2.00					

The burner must be matched to the precise boiler back pressure.
Nozzles 45° solids are recommended. 60° solids may also be used.

Dimensions



IDENTIFICATION:



INSTALLATION INSTRUCTIONS #2 FUEL OIL BURNERS

1. UNPACKING

- 1.1 When unpacking the burner, be sure all loose packages are inspected for contents. Check the packing list, electrical rating (voltage, hertz) and for concealed damage.

2. FUEL TANK

- 2.1 All oil storage tanks must be U.L. listed and installed according to the National Board of Fire Underwriters or local ordinances whichever has precedence.
- 2.2 All pipe connections on underground buried tanks must have swing joints except the sounding well (stick well).
- 2.3 The fill line must pitch toward tank $\frac{1}{4}$ " per ft.
- 2.4 The vent pipe should not be less than $1\frac{1}{4}$ " I.P.S. and equipped with an approved vent cap. Pitch the vent pipe toward tank $\frac{1}{4}$ " per ft.
- 2.5 The tank gauge should be installed so that the float will not be under the fill line. On underground tanks, protect the bulb and gauge line inside the tank with rigid iron pipe.

3. OIL PIPING

3.A 275-Gal. Basement Tanks — Gravity Feed.

- 3.1 Use $\frac{1}{2}$ " O.D. copper tubing with flared fittings. Consult the pump manufacturer's specifications for other sizes and iron pipe substitution.
- 3.2 Install an approved hand valve in the tank outlet and close to burner fuel pump ahead of the filter. Connect the filter to the pump with a copper tube pigtail. Do not connect rigid pipe directly to the pump.
 - A return line is not required for this type installation.
- 3.4 If more than one burner is connected to suction line, the tank bottom must be above both burner pumps and the size of line and filter must be increased.

3.B Underground or Vaulted Tanks.

- 3.5 Use $\frac{1}{2}$ " O.D. copper tubing with flared fittings for suction and return lines to avoid underground connections. If the local regulations require rigid pipe, use black wrought iron and malleable fittings with double swing joints to prevent breakage in case the tank settles. (Consult the pump manufacturer's specifications for other sizes and iron pipe substitutions.)
- 3.6 Both suction and return lines should extend to within 4" of the tank bottom.
- 3.7 Slip fittings should be used on the tank for copper suction and return lines. Double-tapped bushings can be used with wrought-iron pipe; however, a bushing welded to the dip tube is preferred.
- 3.8 Install, in the suction line at an outside wall, an approved hand valve and spring loaded ball check. When the tank is vaulted and the bottom of the tank is on the same level as the burner, install a vertical check valve as close to the top of the tank as practical.
- 3.9 If the bottom of the tank is above the level of the burner, an anti-siphon valve is usually required at the highest point.
- 3.10 Install an approved hand valve close to the burner pump, ahead of the filter, and connect the filter to the pump with a copper tube pigtail.
- 3.11 Install a copper tube pigtail between the pump and spring-loaded ball check in the return line.
- 3.12 Avoid fastening suction and return lines to floor beams. If necessary to do so, use loose fitting hangers with soft rubber lining to prevent noise transmission.
- 3.13 A separate suction line should be used for each burner. A common return line may be used, provided a spring-loaded ball check is installed in the return pipe from each fuel unit.

4.

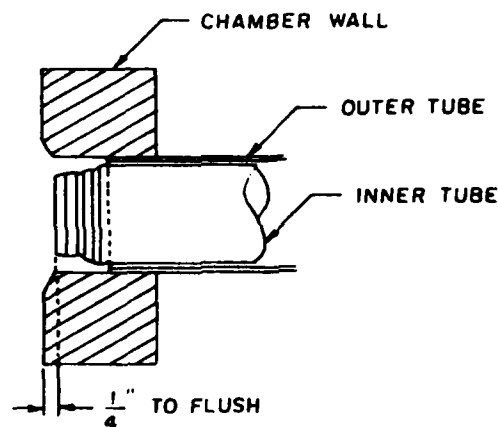
FUEL OIL FILTER

- 4.1 A filter is recommended in the suction line.
- 4.2 Size the filter according to g.p.h. of the nozzle on single pipe installations.
- 4.3 Use larger filters on 2-pipe systems (20 to 30 g.p.h. filter rating).

5.

INSTALLATION

- 5.1 Use a base or flange mounting, whichever is the most practical for the installation. Follow the heating appliance manufacturer's recommendations where applicable.
 - 5.2 Make sure the burner is level.
 - 5.3 Pitch the air tube down approximately 2° toward the nozzle end.
 - 5.4 The end of the inner air tube should be $\frac{1}{4}$ " back to flush with inside of the chamber wall. Improper insertion will distort the fire for the standard 8" tube length. The short tube (3.3" long) can be inserted inside the firing zone in wet base boilers, provided there is no flame impingement and the tube side is completely sealed.
- Note: It is easier to install the outer tube with a universal flange application first. Seal the outer tube with an appropriate material and then cradle in with the gasket in between the burner and the tube. Hence, securing the outer flange and the tube first and then cradling in the burner becomes the easier installation. See Fig. 2.



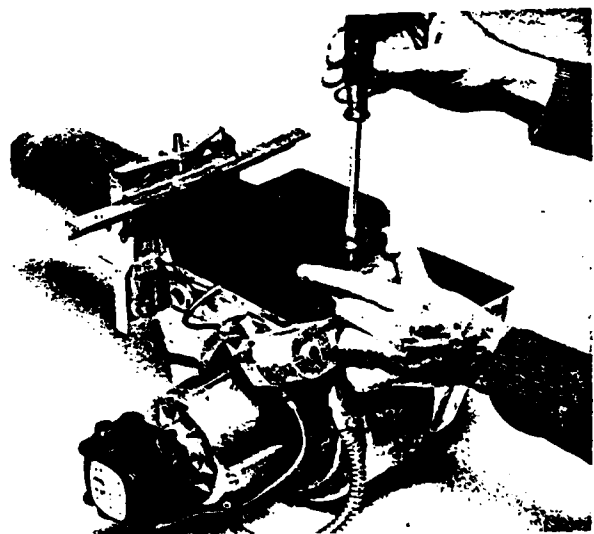
(FIG. 2)

6.

NOZZLES

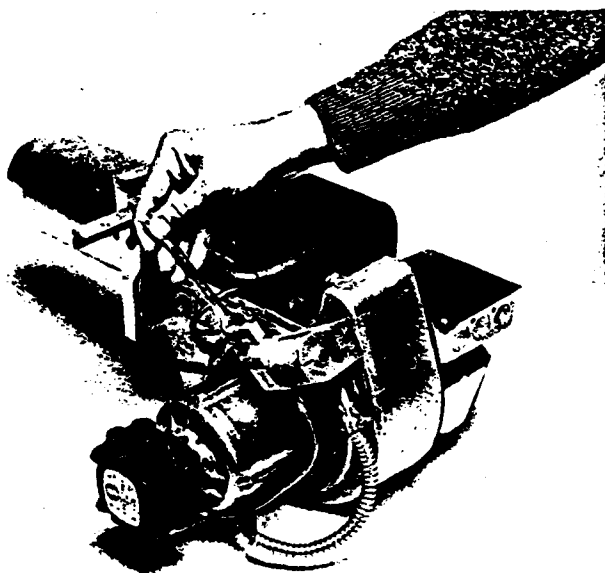
- 6.1 Use a nozzle of the proper size, type and spray pattern as indicated for the burner model. 45° solids are recommended; 60° solids may also be used.
- 6.2 Always remove the nozzle assembly to install or replace the nozzle.
- 6.3 The nozzle assembly can be removed step by step as follows:
 - a) Open up the cover by removing the cover screw.

See Fig. 3.



(FIG. 3)

- b) Disconnect the oil line to the nozzle assembly.
See Fig. 4.



(FIG. 4)

- c) Remove the side screw holding the nozzle assembly. See Fig. 5.



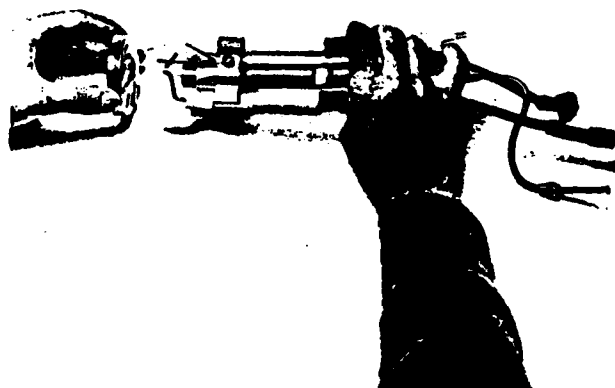
(FIG. 5)

- d) Disconnect the ignition cables at transformer.
e) Use a screwdriver to loosen the assembly bracket.
Then remove entire assembly by pulling backward.
See Fig. 6.



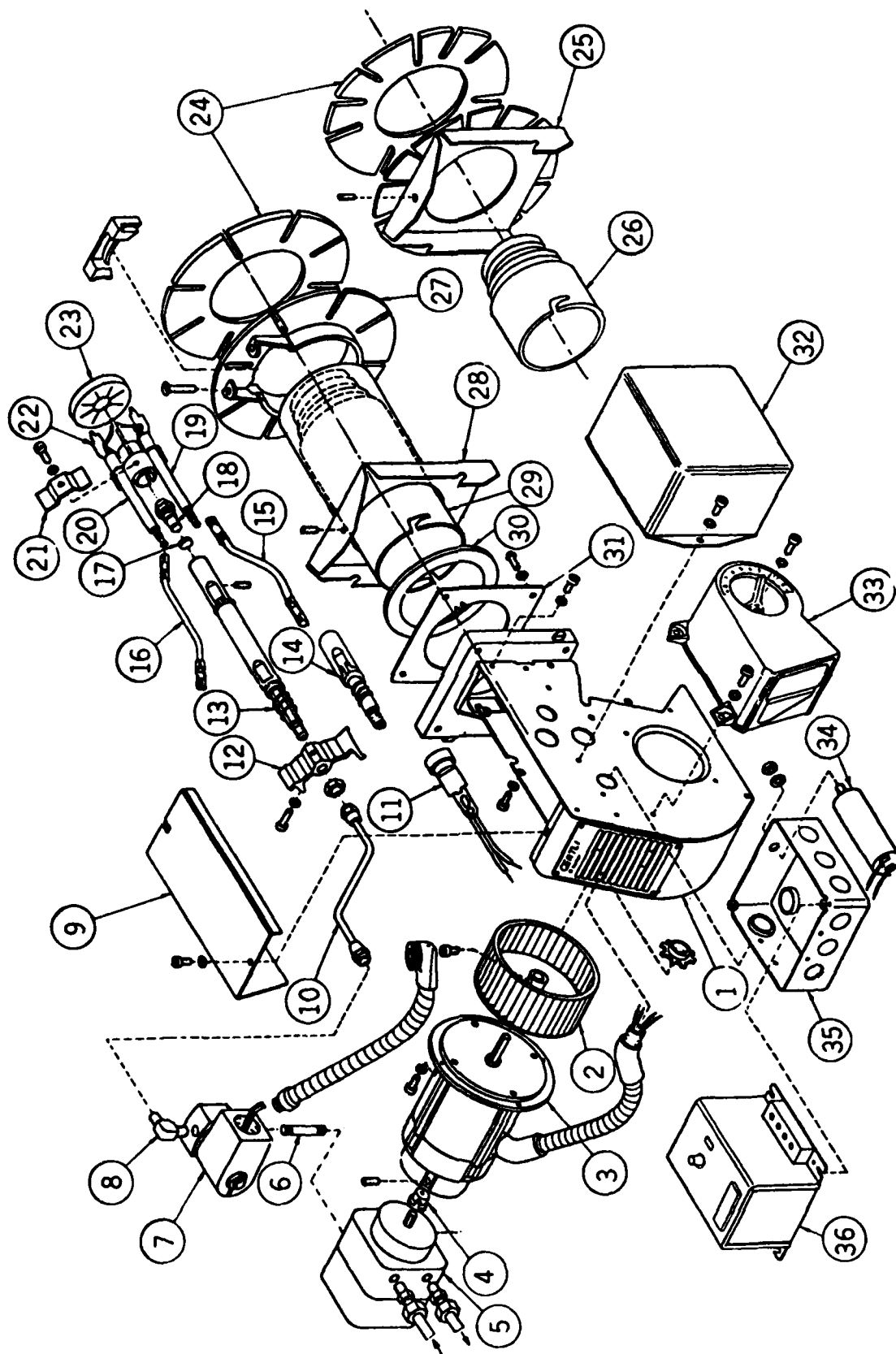
(FIG. 6)

- f) The flame retention cup can now be removed since it is only pressure fitted. The electrode holder can then be pulled off the nozzle adaptor easily. See Fig. 7.



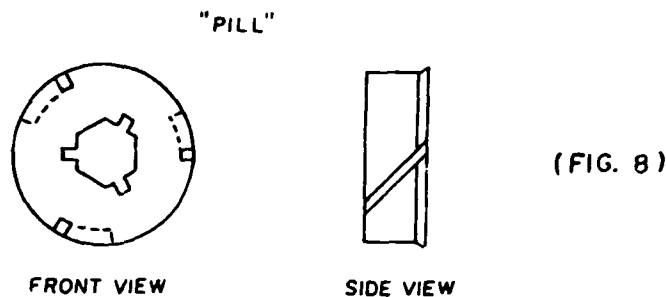
(FIG. 7)

PARTS AND ASSEMBLY



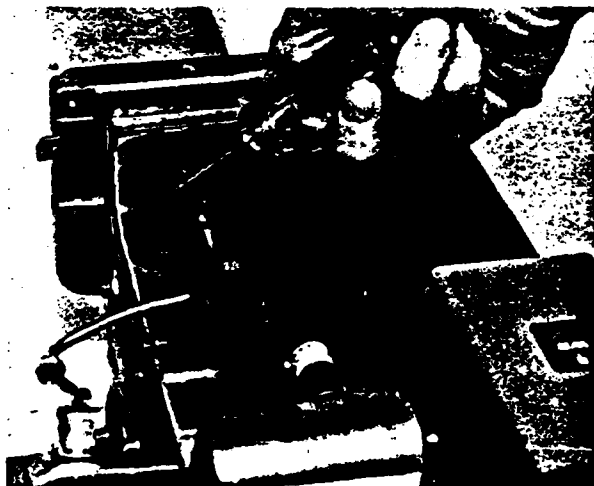
ITEM NO.	PART NUMBER	DESCRIPTION	QUANTITY	ITEM NO.	PART NUMBER	DESCRIPTION	QUANTITY
1	11178582/2	Burner Housing Assembly	1	19	EA46142/3	Ignition Electrode Right Assembly	1
2	12468071	Blower Wheel	1	20	EA46142/2	Ignition Electrode Left Assy.	1
3	12178583/2	Motor, 115V, 60 Hz, 1 Ph, 110W	1	21	14268225/4a	Pipe Clip	1
4	12378572/4	Coupling	1	22	16778565/4	Centering Plate	1
5	PA46759 PA46760 PA40381-W	Sundstrand Oil Pump Danfoss Oil Pump Webster Oil Pump	Select One	23	16178567/4	Flame Retention Disc	1
6	TA46007	1/8" N.P.T. x 1 1/2" Lg. Blk. Iron Pipe	1	24	LA46759	Round Insulated Gasket	1
7	EA41225	Solenoid Valve V4046A1009 or Equiv.	1	25	AB46057	Boiler Mounting Flange Assembly	1
8	TA46001	90° El Brass 1/8" N.P.T. x 3/16" Flare	1	26	16378502/3 16378503/3 16378504/4	Flame Tube #1 4" Long Flame Tube #2 4" Long Flame Tube #4" Long	Select One
9	11378596-3	Cover to Be Used Without Shroud Cover to Be Used With Shroud	Select One	27	AA42811	Universal Flange Assembly (Optional Used with 8" Tube)	1
10	TA46263	Oil Line from Valve to Firing Assy.	1	28	19578560/4	Outer Tube for 8" Tube Only	1
11	EA41253 EA41254	Cad Cell — White Rodgers Cad Cell — Honeywell	Select One	29	16378505/3 16378506/3 16378507/3	Flame Tube #1 Approx. 8" Long Flame Tube #2 Approx. 8" Long Flame Tube # Approx. 8" Long	Select One
12	14278574/3	Nozzle Rod Holder	1	30	19668247/4	Asbestos Gasket	1
13	14278578/3	Nozzle Rod for 8" Tube Only	1	31	11168192/4	Flame Tube Fixing Flange	1
14	14278568/4	Nozzle Rod for 4" Tube Only	1	32	MA10052	10,000V Allanson Transformer or Equiv.	1
15	AA46107 EA46415	Right Ignition Cable for Short Tube Right Ignition Cable for Long Tube	Select One	33	11278584/3	Air Box Assembly (Steel)	1
16	AA46108 EA46144	Left Ignition Cable for Short Tube Left Ignition Cable for Long Tube	Select One	34	17378373/4	Capacitor Assembly	1
17	14277679/4	Pill (Optional)	1	35	SA1553	J Box 4x4x2-1/8" (U.L. Listed)	1
18		Nozzle (To Be Specified by Customer)	1	36	EA1291-1 EA41281-1 SA46074	White Rodgers 669 Cad Cell Control Honeywell R8404 Cad Cell Control Pedestal Legs for OE-1 (Optional)	Select One 2

- 6.4 Use two wrenches to tighten the nozzle.
- 6.5 The nozzle must be tight to prevent an oil leak and burning after the burner has shut off.
- 6.6 A device which shall be referred to as a "pill" may be used to eliminate air trapped between the nozzle and the nozzle adaptor. This triple holed device may be inserted or removed easily with an allen key. See Fig. 8.



Note: This device speeds up removal of air trapped inside the nozzle adaptor; air in the adaptor is the main cause of after drip.

- 6.7 Reinstall nozzle assembly.
- 6.8 Insert nozzle assembly into air tube.
- 6.9 Push forward to seat nozzle assembly bracket into slot at the right side of the burner housing.
- 6.10 Apply a forward pressure with a screwdriver at the left side of the nozzle assembly bracket to align the hole in the bracket with the hole in the housing. See Fig. 9.
- 6.11 Secure nozzle assembly bracket with the slotted hex head screw.
- 6.12 Reconnect the ignition cables.
- 6.13 Reconnect the nozzle oil line.



(FIG. 9)

7. THE ELECTRODE ASSEMBLY

- 7.1 The nozzle and electrode positions are shown in Fig. 1 (Refer to page 2) The electrodes and nozzle adaptor will position themselves to Fig. 1 specs by means of flat surfaces and stops on the electrode porcelains and nozzle adaptor.

8.**CHIMNEY**

- 8.1 Follow the recommendations of the heating appliance manufacturer.
- 8.2 The chimney should extend above the roof line and above or away from surrounding objects. It should be tile-lined, with no obstructions and be in a good state of repair, with no leaks.
- 8.3 The smoke pipe should be inserted flush with the inside of the chimney tile, and sealed in place.
- 8.4 All cleanout doors should be sealed.

9.**DRAFT REGULATORS**

- 9.1 The use of a draft regulator is recommended and should preferably be mounted in the smoke pipe.
- 9.2 Use a draft gauge to adjust to the proper opening. See "draft" 14.1.
- 9.3 The above may not apply to pressurized fire box boilers: Follow instructions furnished with boilers.

10.**AIR FOR COMBUSTION**

- 10.1 A separate fresh air inlet to the boiler room is required for proper combustion.
- 10.2 An opening of one square inch per 1,000 BTUH input is recommended.
- 10.3 If the opening is screened, the area should be increased by as much as 50%.
- 10.4 The boiler room must be closed off from any area where supply or exhaust fans are installed.

11.**COMBUSTION CHAMBERS**

THIS DOES NOT APPLY TO PACKAGED UNITS WHERE THE CHAMBER IS SUPPLIED

- 11.1 Refer to the chart for the correct chamber dimensions. Chambers may vary slightly but should maintain the floor area shown in Table 1.

TABLE 1**MINIMUM COMBUSTION AREA FOR CONVERSION**

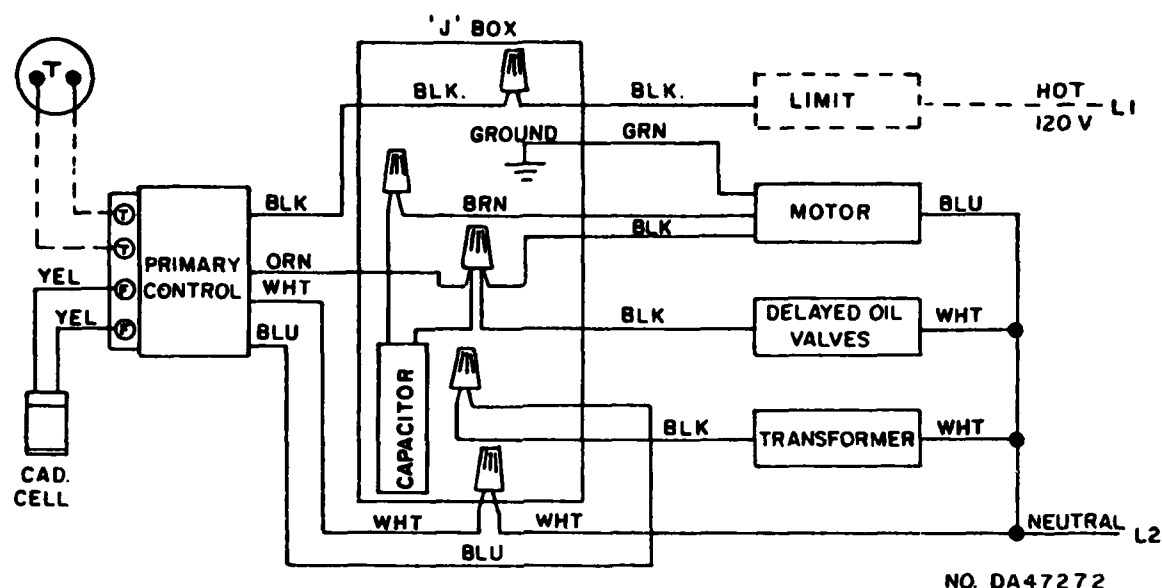
FIRING RATE		NOT APPLICABLE FOR I/B/R OR S/B/I RATED BOILER/BURNER UNITS				RADIATION		
G.P.H.	Length (In.)	Width (In.)	Height (In.)	Boiler Crown Sheet to Center of Nozzle & Floor to Center of Nozzle (In.)	Floor Area (Sq. In.)	Steam (Sq. Ft.)	Water (Sq. Ft.)	Air BTU X 1000
0.50	9	7	8	6	63	200	240	55
0.75	9	8	9	6	72	300	480	84
1.00	10	8	9	7	80	400	640	112
1.25	11	9	10	7	99	500	800	140
1.35	11	10	11	7	110	540	864	151
1.50	12	10	11	7	120	600	960	168
1.65	13	11	12	7	143	660	1056	185
1.75	13	12	13	7	156	700	1120	196
2.00	15	12	13	7	180	800	1280	224

12.

WIRING

12.1 All wiring must comply with the National Electric Code and local ordinances.

12.2 Refer to the diagram supplied with the burner or controls. A typical wiring schematic is enclosed for Intermittent Ignition. See Fig. 10.



NOTE:

1. SET ROOM THERMOSTAT FOR 0.38 AMP (24 VOLTS)
2. PLACE JUMPER ON T-T TERMINALS IF ROOM THERMOSTAT IS NOT USED.
3. FACTORY WIRING ——— FIELD WIRING - - - - -

(FIG. 10)

12.3 Use a 105° C thermoplastic wire — Do not use less than #14 AWG wire.

12.4 Do not fasten conduit or BX cable to hot surfaces.

13.

STARTING THE BURNER

- 13.1 Be sure the boiler, if used, is filled with water. Be sure the oil tank is filled, all valves open and controls set to allow burner operation.
- 13.2 Open the burner air adjustment partially, open the fire or inspection door and turn on the service switch. Adjust draft regulator for maximum chimney draft.
- 13.3 Prime the fuel pump according to the manufacturer's recommendations and check the pump pressure. Pump pressure at 125 psi. See Table 2.
- 13.4 If a safety lockout occurs, reset after 1 to 2 minutes.
- 13.5 Do not run the fuel unit dry for more than 5 minutes.

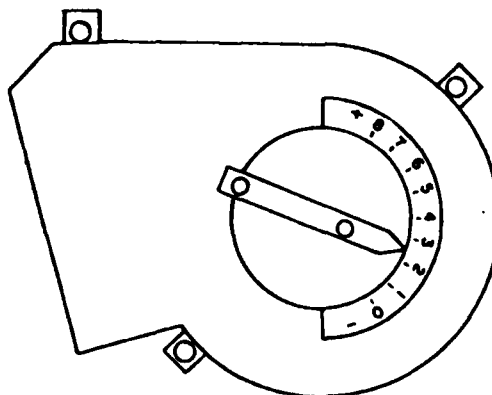
TABLE NO. 2
CALCULATED DELIVERY RATES OF NOZZLES AT VARIOUS PRESSURES
PUMP PRESSURE IN PSIG

100	105	110	115	120	125	130	135	140	145	150
0.5	.51	.52	.54	.55	.56	.57	.58	.59	.6	.61
0.65	.67	.68	.7	.71	.73	.74	.76	.77	.78	.8
0.75	.77	.79	.8	.82	.84	.86	.87	.88	.9	.92
0.85	.87	.89	.91	.93	.95	.97	.99	1.01	1.02	1.04
1.0	1.03	1.05	1.07	1.09	1.12	1.14	1.16	1.18	1.20	1.23
1.1	1.13	1.15	1.18	1.20	1.23	1.25	1.28	1.30	1.32	1.35
1.2	1.23	1.26	1.29	1.31	1.34	1.37	1.39	1.42	1.44	1.47
1.25	1.28	1.31	1.34	1.37	1.39	1.42	1.45	1.48	1.50	1.53
1.35	1.38	1.42	1.45	1.48	1.51	1.54	1.57	1.59	1.62	1.65
1.50	1.54	1.57	1.61	1.64	1.67	1.71	1.74	1.77	1.80	1.84
1.65	1.69	1.73	1.77	1.81	1.84	1.88	1.92	1.95	1.99	2.02
1.75	1.79	1.83	1.88	1.92	1.95	1.99	2.03	2.07	2.11	2.14
2.00	2.05	2.09	2.14	2.19	2.23	2.28	2.32	2.36	2.41	2.45

BURNER CAN BE FIRED AT HIGHER PRESSURES OF 125 TO 130 PSI WHERE BETTER PERFORMANCES ARE OBTAINED. THEREFORE, PUMPS ON THESE BURNERS ARE ADJUSTED FOR 130 PSI WHEREBY YOUR DELIVERY RATES WOULD BE HIGHER AS INDICATED IN ABOVE TABLE. THEREFORE, PLEASE SELECT YOUR NOZZLES AS PER TABLE DELIVERY AT 125 OR 130 PSIG.

13.6 Prime the pump with oil on long suction lines.

13.7 When the fire is established, make a temporary air adjustment to clear any smoke. Leave the fire door open until the combustion chamber is dry. Modern chambers contain organic binder which must be baked out before final burner adjustments can be made. Allow at least 15 minutes firing to "dry" the chamber. When normal temperatures are reached, close the inspection (fire) door, adjust the draft and the air shutter for a clean fire. See Fig. 11.



(FIG. 11)

14.

DRAFT

- 14.1 After the appliance and chamber are up to normal operating temperature, set the draft regulator to get -.02" W.C. over the fire. Use a draft guage.

15.

FINAL CHECKOUT

- 15.1 Use a smoke tester and set the burner air adjustment for not more than a #1 smoke (Shell Bacharach scale).
- 15.2 Recheck the draft and take a CO₂ reading over the fire and in the breeching. The CO₂ reading should be between 11% and 13%.
- 15.3 If #1 smoke is measured, and CO₂ is less than 11%, while firing into a suitable firebox, check for air leaks into the firebox and flues. Seal all leaks found, using non-asbestos furnace cement, and recheck CO₂.
- 15.4 Open the fire door, turn off the oil valve and check out the safety timing of the combustion control.
- 15.5 Check the operation of the limit controls and the thermostat.
- 15.6 Check for oil leaks.
- All installations should be reinspected after 1 to 2 weeks of normal operation.

OIL BURNER OPERATING INSTRUCTIONS

This Burner is listed by UNDERWRITERS' LABORATORIES, INC., and other agencies for fuel oil not heavier than No. 2 commercial standard CS-12-48

Date _____

DATA

Stack CO ₂ % _____	Over fire CO ₂ % _____
Air Shutter Setting _____	Smoke Spot No. _____
Stack Temp. F. ° _____	Room Temp. F. ° _____
Net Stack Temp. F. ° _____	Stack Draft In. W.C. _____
Overfire Draft In. W.C. _____	Nozzle Installed gal./hr. _____
Spray Angle ° _____	Boiler Mfg. _____
Chamber Size _____	Combustion Efficiency _____

WHEN SERVICE OR REPAIRS ARE REQUIRED

Call _____

Day telephone _____ Night telephone _____

Always give the following information:

Burner Model _____ Serial No. _____

Date installed _____

CAUTION

DO NOT use gasoline, crankcase oil or any oil containing gasoline.

DO NOT incinerate garbage or refuse in this unit.

DO NOT tamper with burner or controls —
CALL YOUR SERVICEMAN.

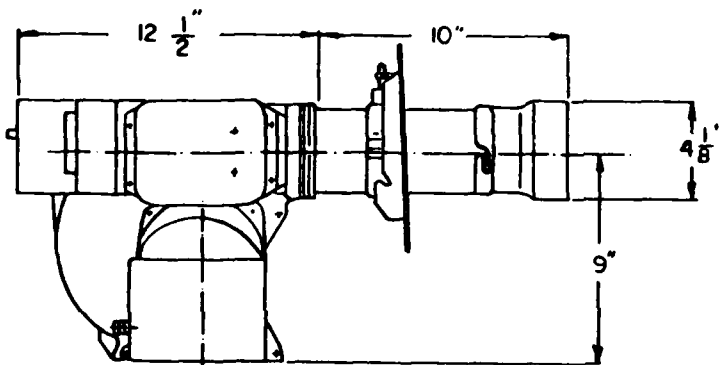
HANG NEAR BURNER

INSTALLATION SERVICE AND OPERATING MANUAL

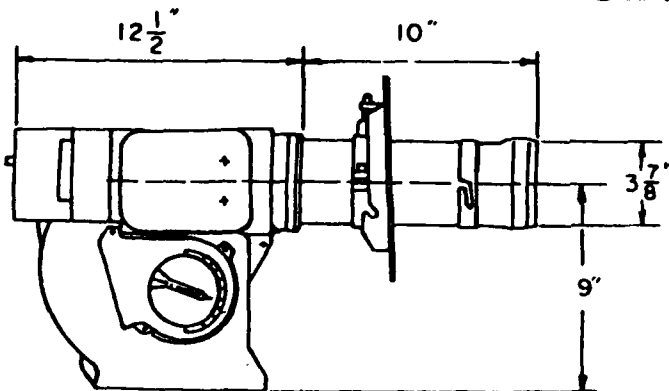
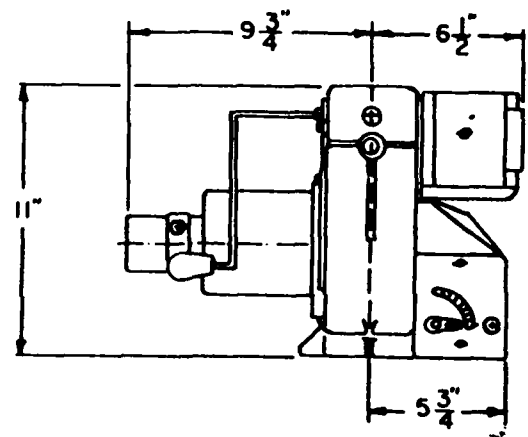
OERTLI AMERICAN

OIL BURNER

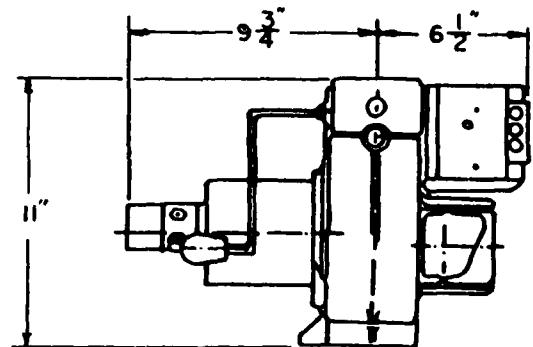
MODEL OE-2



OE-22



OE-21



OERTLI AMERICAN

PHONE: N. Y. C. (212) 895-2196; (516) 543-4600. Outside N. Y. State Toll Free (800) 645-4504

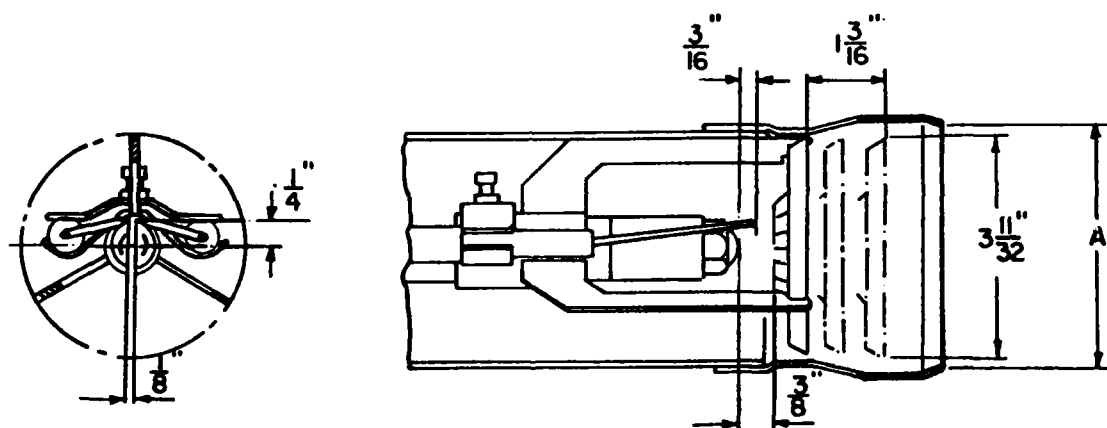
ABC SUNRAY CORP., 85 AUSTIN BLVD., COMMACK, N.Y. 11725

INSTALLATION, SERVICE AND OPERATING MANUAL **MODEL OE-2 OIL BURNER**

TECHNICAL DESCRIPTION **BURNER DATA**

TYPE	COMBUSTION		RATING GPH.	PRIMARY CONTROL	MOTOR	AIR BOX	IGNITION TRANSFORMER	FUEL UNIT	WEIGHT
	HEAD	OPENING "A"							
OE-2	1	3.7 ⁷ / ₈ "	1.65 - 3.5	CAD CELL CONTROL WITH INTERRUPTED IGNITION	110 V 60 HZ 1 PH 240 W CAPACITOR START	SIDE AIR DAMPER	PRIMARY 110 V SECONDARY 12,000 V	U.L. LISTED CAPABLE OF 200 P.S.I.	43 LB
OE-2	2	4.1 ¹ / ₈ "	3.25 - 6.0			BOTTOM AIR SHUTTERS			45 LB

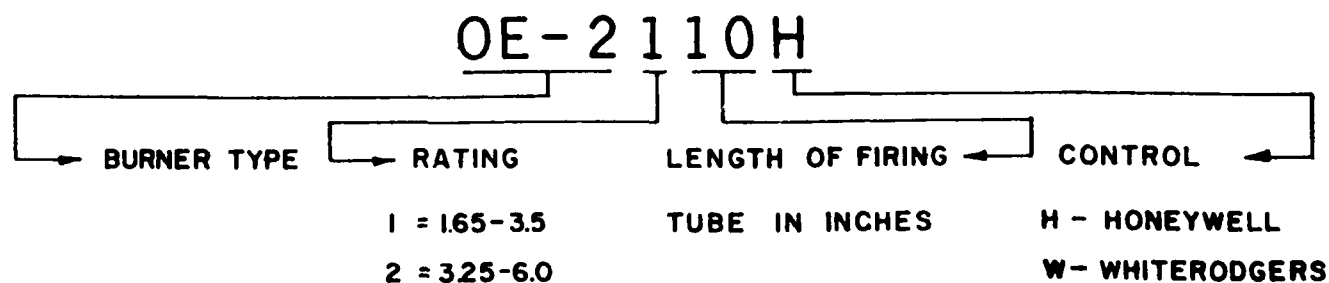
THE BURNER MUST BE MATCHED TO THE PRECISE BOILER BACK PRESSURE.
 NOZZLES 45° SOLIDS ARE RECOMMENDED. 30°, 60°, AND 80° SOLIDS MAY ALSO BE USED.



ELECTRODE SETTING

Fig. 1

IDENTIFICATION:



INSTALLATION INSTRUCTIONS # 2 FUEL OIL BURNERS

1. UNPACKING

- 1.1 When unpacking the burner, be sure all loose packages are inspected for contents. Check the packing list, electrical rating (voltage, hertz) and for concealed damage.

2. FUEL TANK

- 2.1 All oil storage tanks must be U. L. listed and installed according to the National Board of Fire Underwriters or local ordinances, whichever has precedence.
- 2.2 All pipe connections on underground buried tanks must have swing joints except the sounding well (stick well).
- 2.3 The fill line must pitch toward $\frac{1}{4}$ " per ft.
- 2.4 The vent pipe should not be less than $1\frac{1}{4}$ " I. P. S. and equipped with an approved vent cap. Pitch the vent pipe toward tank $\frac{1}{4}$ " per ft.
- 2.5 The tank gauge should be installed so that the float will not be under the fill line. On underground tanks, protect the bulb and gauge line inside the tank with rigid iron pipe.

3. OIL PIPING

3.A 275-Gal. Basement Tanks—Gravity Feed.

- 3.1 Use $\frac{1}{2}$ " O. D. copper tubing with flared fittings. Consult the pump manufacturer's specifications for other sizes and iron pipe substitution.
- 3.2 Install an approved hand valve in the tank outlet and close to burner fuel pump ahead of the filter. Connect the filter to the pump with a copper tube pigtail. Do not connect rigid pipe directly to the pump.
- 3.3 A return line is not required for this type installation.
- 3.4 If more than one burner is connected to suction line, the tank bottom must be above both burner pumps and the size of line and filter must be increased.

3.B Underground or Vaulted Tanks.

- 3.5 Use $\frac{1}{2}$ " O. D. copper tubing with flared fittings for suction and return lines to avoid underground connections. If the local regulations require rigid pipe, use black wrought iron and malleable fittings with double swing joints to prevent breakage in case the tank settles. (Consult the pump manufacturer's specifications for other sizes and iron pipe substitutions.)
- 3.6 Both suction and return lines should extend to within 4" of the tank bottom.
- 3.7 Slip fittings should be used on the tank for copper suction and return lines. Double-tapped bushings can be used with wrought-iron pipe; however, a bushing welded to the dip tube is preferred.
- 3.8 Install, in the suction line at an outside wall, an approved hand valve and spring loaded ball check. When the tank is vaulted and the bottom of the tank is on the same level as the burner, install a vertical check valve as close to the top of the tank as practical.

- 3.9 If the bottom of the tank is above the level of the burner, an anti-siphon valve is usually required at the highest point.
- 3.10 Install an approved hand valve close to the burner pump, ahead of the filter, and connect the filter to the pump with a copper tube pigtail.
- 3.11 Install a copper tube pigtail between the pump and spring-loaded ball check in the return line.
- 3.12 Avoid fastening suction and return lines to floor beams. If necessary to do so, use loose fitting hangers with soft rubber lining to prevent noise transmission.
- 3.13 A separate suction line should be used for each burner. A common return line may be used, provided a spring-loaded ball check is installed in the return pipe from each fuel unit.

4. FUEL OIL FILTER

- 4.1 A filter is recommended in the suction line.
- 4.2 Size the filter according to GPH of the nozzle on single pipe installations.
- 4.3 Use larger filters on 2-pipe systems (20 to 30 GPH filter rating).

5. INSTALLATION

- 5.1 Use a base or flange mounting, whichever is the most practical for the installation. Follow the heating appliance manufacturer's recommendations where applicable.
- 5.2 Make sure the burner is level side to side.
- 5.3 Pitch the air tube down approximately 2° toward the nozzle end.
- 5.4 The end of the air tube should be $\frac{1}{4}$ " back to flush with inside of the chamber wall. Improper insertion will distort the fire. See Fig. 2.

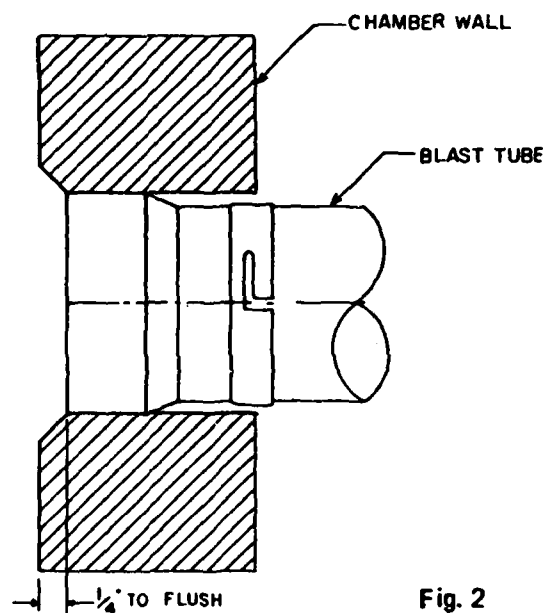


Fig. 2

6.

NOZZLES

- 6.1 Use a nozzle of the proper size, type and spray pattern as indicated for the burner model. 45° solids are recommended; 60° solids may also be used (Ref. Page 2).
- 6.2 Always remove the nozzle assembly to install or replace the nozzle.
- 6.3 The nozzle assembly can be removed step by step as follows:



Fig. 3

- a) Open up the cover by removing the cover screws. See Fig. 3.
- b) Disconnect the oil line to the nozzle assembly. See Fig. 4.
- c) Disconnect the ignition cables at transformer.
- d) Turn assembly to 90° clockwise.
- e) Then pull assembly straight backwards slowly.

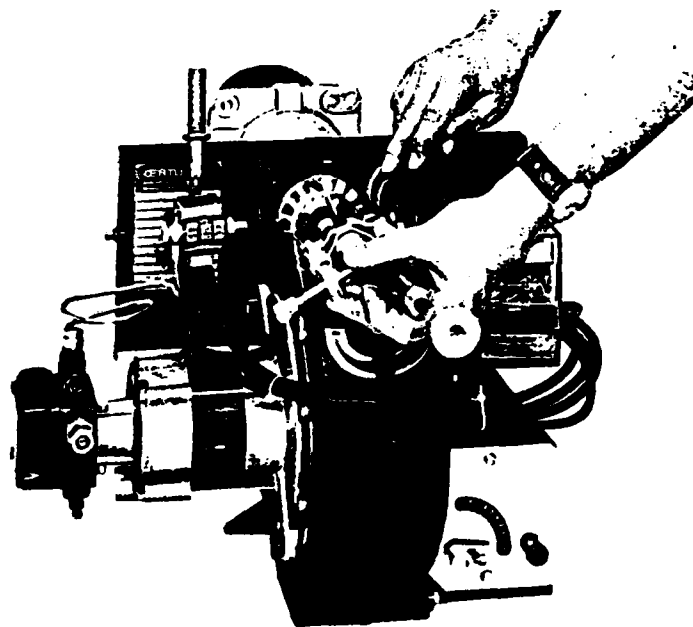
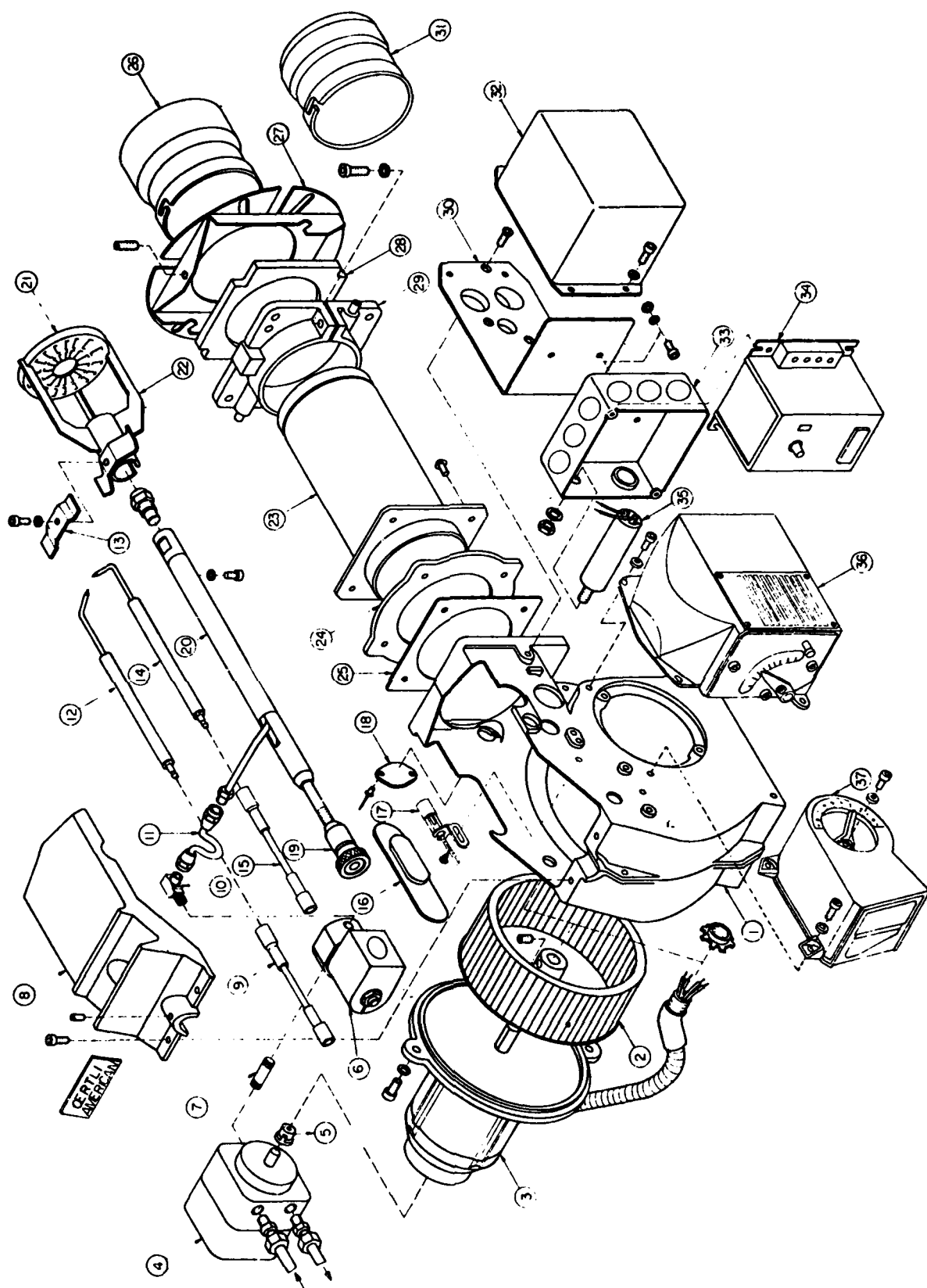


Fig. 4

OE-2
PARTS & ASSEMBLY



MODEL OE-2

ITEM	PART NO.	DESCRIPTION	QUANTITY	ITEM	PART NO.	DESCRIPTION	QUANTITY
1	11179037/3	Housing Assy.	1	20	14279043/4	Nozzle Rod	1
2	12479032/3	Fan Wheel	1	21	16171889/3	Flame Retention Disc	1
3	12179072/2	OE-2 Motor	1	22	16179033/3	Flame Retention Holder Assy.	1
4	PA46761	Oil Pump 200 PSI	1	23	16371897/3A	Air Tube	1
5	12378572/4	Coupling (Oil Pump to Motor)	1	24	19679065/4	Asbestos Flange (Housing To Tube)	1
6	EA41221	Solenoid Valve 300 PSI Honeywell or Equiv.	1	25		And Front Plate Flange Assy.	1
7	TA46007	1/8" x 1 1/2 Black Nipple	1	26	16271870/4	Flame Tube OE-2-2	Choose One
8	11379036/2	Housing Plate	1				Item 26 or 31
9	EA46153	Left Ignition Cable Assy.	1	27	AB46057	Boiler Mounting Flange Assy.	1
10	TA46001	90° Elbows 1/8-27 N.P.T. x 3/16 Flare	1	28	71915/4B	Asbestos Gasket For Mounting	1
11	AA46109	Oil Line From Valve To Nozzle Rod Assy.	1	29	79060	Sliding Flange	1
12	EA46146-1	Electrode Left	1	30	78707/2	Transformer Bracket	1
13	14268225/4	Top Bracket	1	31	16379649/3	Flame Tube OE-2-1	Choose One
14	EA46146-1	Electrode Right	1				Item 26 or 31
15	EA46152	Right Ignition Cable Assy.	1	32	MA46201	Allianson 12,000 Volt Transformer	1
16	14279040/4	Slide Assy.	1	33	SA41553	J Box 4" x 4" x 2"	1
17	EA41253	Cad Cell—White Rodgers	1	34	EA41291-1	Control—White Rodgers 669	1
18	17528638/4A	Cover Plate	1	35	17378573/4	Capacitor Assy.	1
19	16271894/4	Regulating Sleeve (Dial A Flame)	1	36	11278754/2	Air Inlet Housing OE-2-2	Choose One
				37	11278584/3	Air Inlet Box Assy. OE-2-1	Item 36 or 37
				38	16271870/4	Air Inlet Diaphragm	Choose One
							Item 36 or 37
							1

IN ALL COMMUNICATIONS STATE BURNER MODEL AND SERIAL NUMBERS

- 6.4 Flame retention cup can be removed from the bracket using a screwdriver as shown in the Fig. 4A.
- 6.5 Similarly, flame retention cup can be installed by forcing it as shown in the Fig. 4B, first by matching two notches, and then by forcing for the third notch.

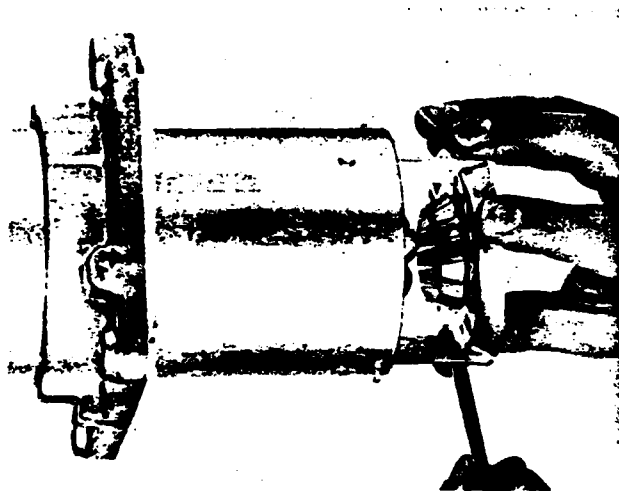


Fig. 4A

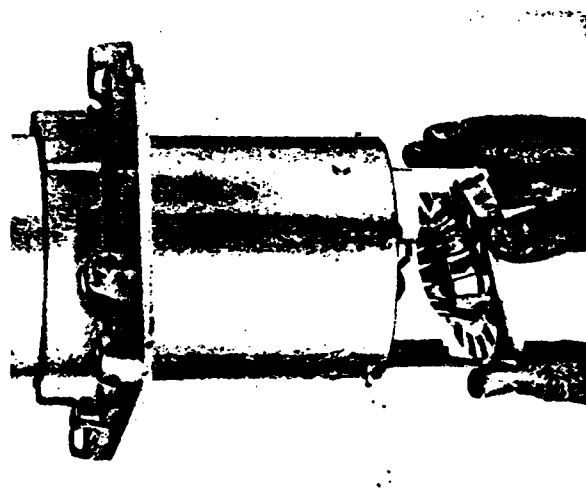


Fig. 4B

7. CHIMNEY

- 7.1 Follow the recommendations of the heating appliance manufacturer.
- 7.2 The chimney should extend above the roof line and above or away from surrounding objects. It should be tile-lined, with no obstructions and be in a good state of repair, with no leaks.
- 7.3 The smoke pipe should be inserted flush with the inside of the chimney tile, and sealed in place.
- 7.4 All cleanout doors should be sealed.

8. DRAFT REGULATORS

- 8.1 The use of a draft regulator is recommended and should preferably be mounted in the smoke pipe.
- 8.2 Use a draft gauge to adjust to the proper opening. See "draft" 13.1.
- 8.3 The above may not apply to pressurized fire box boilers: Follow instructions furnished with boilers.

9.

AIR FOR COMBUSTION

9.1 A separate fresh air inlet to the boiler room is required for proper combustion.

9.2 An opening of one square inch per 1,000 BTUH input is recommended.

9.3 If the opening is screened, the area should be increased by as much as 50%.

9.4 The boiler room must be closed off from any area where supply or exhaust fans are installed.

10.

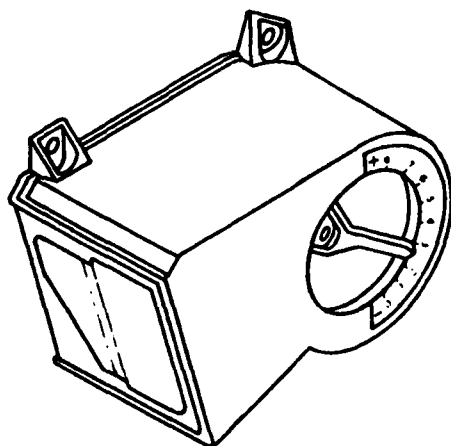
COMBUSTION CHAMBERS

THIS DOES NOT APPLY TO PACKAGED UNITS WHERE THE CHAMBER IS SUPPLIED

10.1 Refer to the chart for the correct chamber dimensions. Chambers may vary slightly but should maintain the floor area shown in Table 1.

TABLE I
MINIMUM COMBUSTION AREA

FIRING RATE		MINIMUM COMBUSTION AREA				RADIATION		
G.P.H.	Length	Width	Height	Boiler Crown Sheet To Center Of Nozzle	Floor To Center Of Nozzle	Steam Sq. Ft.	Water Sq. Ft.	Air BTU X 1000
1.65	13	12	12	7	7	660	1056	185
1.75	13	13	13	7	7	700	1120	196
2.00	15	13	13	7	7	800	1280	224
2.50	16	14	14	7	7	1000	1600	280
3.00	17	15	15	7½	7½	1200	1920	336
3.50	20	15	15	7½	7½	1400	2240	392
4.00	21	16	16	8	8	1600	2560	448
4.50	24	16	16	8	8	1800	2880	504
5.00	25	17	17	8½	8½	2000	3200	560
5.50	27	17	17	8½	8½	2200	3520	616
6.00	27	18	18	9	9	2400	3840	672
6.50	27	19	19	9½	9½	2600	4160	728
7.00	29	19	19	9½	9½	2800	4480	784



OE - 21

Fig. 5

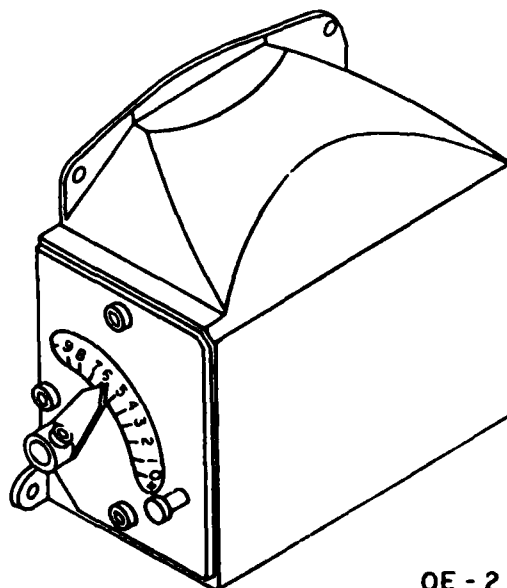


Fig. 6

WIRING

-

NO. DA47272

NOTE:

1. Set room thermostat for 0.38 AMP. (24 volts)
2. Place jumper on T-T terminals if room thermostat is not used.
3. Factory wiring _____ Field wiring - - - - -

Fig. 7

- 11.3 Use a 105°C thermoplastic wire—Do not use less than #14 AWG wire.**
- 11.4 Do not fasten conduit or BX cable to hot surfaces.**

STARTING THE BURNER

- 12.1 Be sure the boiler, if used, is filled with water. Be sure the oil tank is filled, all valves open and controls set to allow burner operation. Be sure the nozzle assembly is correctly positioned for the input (nozzle size) used (Ref. Table 2).
- 12.2 Open the burner air adjustment partially, (Ref. Fig. 5 and 6) open the fire or inspection door and turn on the service switch. Adjust draft regulator for maximum chimney draft.
- 12.3 Prime the fuel pump according to the manufacturer's recommendations and check the pump pressure. Pump pressure at 180 psi. (Recommended pressures are 160 through 180 psi.) See Table 2.

- 12.4 If a safety lockout occurs, reset after 1 to 2 minutes.
- 12.5 Do not run the fuel unit dry for more than 5 minutes.

TABLE NO. 2
CALCULATED DELIVERY RATES OF NOZZLES AT VARIOUS PRESSURES
(Pump Pressure In PSIG)

	100	150	155	160	165	170	175	180	185	190	195	200
NOMINAL NOZZLE SIZE	1.35	1.65	1.18	1.71	1.73	1.76	1.78	1.81	1.84	1.86	1.89	1.91
	1.5	1.84	1.87	1.90	1.93	1.95	1.98	2.01	2.04	2.07	2.09	2.12
	1.65	2.02	2.05	2.09	2.12	2.15	2.18	2.21	2.24	2.27	2.30	2.33
	1.75	2.14	2.18	2.21	2.25	2.28	2.31	2.35	2.38	2.41	2.44	2.47
	1.85	2.26	2.30	2.34	2.38	2.41	2.45	2.48	2.52	2.55	2.58	2.62
	2.0	2.45	2.49	2.53	2.57	2.61	2.64	2.68	2.72	2.76	2.79	2.83
	2.25	2.75	2.80	2.85	2.89	2.93	2.98	3.02	3.06	3.10	3.14	3.18
	2.5	3.06	3.11	3.16	3.21	3.26	3.31	3.35	3.40	3.45	3.49	3.53
	2.75	3.37	3.42	3.48	3.53	3.59	3.64	3.69	3.74	3.79	3.84	3.89
	3.00	3.67	3.73	3.79	3.85	3.91	3.97	4.02	4.08	4.13	4.19	4.24
	3.50	4.29	4.36	4.43	4.49	4.56	4.63	4.69	4.76	4.82	4.89	4.95
	4.00	4.90	4.98	5.06	5.14	5.21	5.29	5.37	5.44	5.51	5.58	5.66
	4.5	5.51	5.60	5.69	5.78	5.87	5.95	6.04	6.12	6.20	6.28	6.36

- 12.6 Prime the pump with oil on long suction lines.
- 12.7 When the fire is established, make a temporary air adjustment to clear any smoke. Leave the fire door open until the combustion chamber is dry. Modern chambers contain organic binder which must be baked out before final burner adjustments can be made. Allow at least 15 minutes firing to "dry" the chamber. When normal temperatures are reached, close the inspection (fire) door, adjust the draft and the air shutter for a clean fire. See Fig. 5 for OE-21 series. For OE-22 series, see Fig. 6 to adjust the air and lock it with side nut. Extra fine tuning can be achieved by dialing the knob (See Fig. 8).

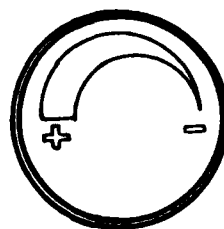


Fig. 8

13.

DRAFT

- 13.1 After the appliance and chamber are up to normal operating temperature, set the draft regulator to get $-.02''$ W. C. over the fire. Use a draft gauge.

14.

FINAL CHECKOUT

- 14.1 Use a smoke tester and set the burner air adjustment for not more than a #1 smoke (Bacharach scale).
- 14.2 Recheck the draft and take a CO_2 reading over the fire and in the breeching. The CO_2 reading should be between 11% and 13%.
- 14.3 If #1 smoke is measured, and CO_2 is less than 11%, while firing into a suitable firebox, check for air leaks into the firebox and flues. Seal all leaks found, using non-asbestos furnace cement, and recheck CO_2 .
- 14.4 Open the fire door, turn off the oil valve and check out the safety timing of the combustion control.
- 14.5 Check the operation of the limit controls and the thermostat.
- 14.6 Check for oil leaks.
All installations should be reinspected after 1 to 2 weeks of normal operation.

OIL BURNER OPERATING INSTRUCTIONS

This Burner is listed by UNDERWRITERS' LABORATORIES, INC., and other agencies for fuel oil not heavier than No. 2 commercial standard CS-12-48.

Date _____

DATA

Stack $CO_2\%$ _____	Over fire $CO_2\%$ _____
Air Shutter Setting _____	Smoke Spot No. _____
Stack Temp. F° _____	Room Temp F° _____
Net Stack Temp. F° _____	Stack Draft In. W. C. _____
Overfire Draft In. W. C. _____	Nozzle Installed gal./hr. _____
Spray Angle $^\circ$ _____	Boiler Mfg. _____
Chamber Size _____	Combustion Efficiency _____

WHEN SERVICE OR REPAIRS ARE REQUIRED

Call _____

Day telephone _____ Night telephone _____

Always give the following information:

Burner Model _____ Serial No. _____

Date installed _____

CAUTION

DO NOT use gasoline, crankcase oil or any oil containing gasoline.

DO NOT incinerate garbage or refuse in this unit.

DO NOT tamper with burner or controls—
CALL YOUR SERVICEMAN.

HANG NEAR BURNER

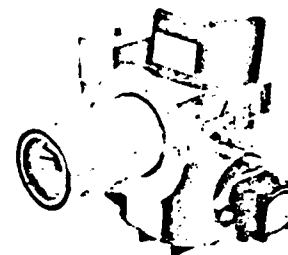


WAYNE HOME EQUIPMENT DIVISION
THE SCOTT & FETZER COMPANY

801 Glasgow Avenue
Fort Wayne, Indiana 46803
Patent Pending

MODEL HS OIL BURNER

Manual 21663



FOR YOUR SAFETY

DO NOT STORE OR USE GASOLINE OR OTHER
FLAMMABLE VAPORS AND LIQUIDS IN THE
VICINITY OF THIS OR ANY OTHER APPLIANCE.

SPECIFICATIONS

FIRING CAPACITIES — Model HS

0.50 to 3.00 GALLONS PER HOUR

70,000 to 420,000 BTU/HR INPUT

FUELS

Use No. 1 or No. 2 heating oil (ASTM D-396) only

WARNING: NEVER ATTEMPT TO USE GASOLINE AS A FUEL FOR THIS
BURNER, AS IT IS MORE COMBUSTIBLE AND COULD RESULT
IN A SERIOUS EXPLOSION.

ELECTRICAL

Power Supply 115V/60HZ/1PH

Motor 3450RPM N.E.M.A. Flange, Manual Reset Overload Protection

Ignition 10,000V/23MA Secondary, Continuous Duty-Shielded Interrupted

50 HERTZ BURNERS AVAILABLE ON SPECIAL ORDER

FUEL UNIT

Sundstrand or Webster

DIMENSIONS (Standard)

Height 12 1/2"

Width 12 7/8"

Depth 7 3/4"

Center Line of Tube to Floor 7"

MOUNTING

Rigid Flange, Adjustable Flange, or Base Mount

BURNER

Since 1928, Wayne has supplied the Homeowner with the best oil burners. You are getting a quality burner, backed by engineering design and product development. It will give you many years of efficient, trouble-free operation. Properly installed and serviced. Please read this manual carefully.

Wayne warrants its burners specifically to those who have purchased it for resale, including your dealer. If, in any case, you have a problem with your burner, or its installation, you should contact your dealer for assistance.

APPROVALS

The burner is U/L listed for use with Group I or Group II primary safety controls. State and local approvals are shown on burner rating label. All burners should be installed in accordance with the National Fire Protection Association, and in complete accordance with all local codes and authorities having jurisdiction. Regulations of these authorities take precedent over the general instructions provided in this manual.

GENERAL INFORMATION

HEATING PLANT — Before placing this burner in a conversion installation, try to provide adequate space to service the burner properly when installing for easy maintenance. The heating system should be carefully inspected for defects and cleanliness, if proper performance is to be obtained. An oil burner is only a means of supplying heat for the firebox and from there the heating system must absorb and circulate the heat. The flue passages and heat absorbing surfaces must be clean to assure maximum heat transfer to the furnace or boiler. Soot and fly ash act as insulators, retarding the transfer of heat. All doors, openings, and cracks should be cemented air-tight to eliminate air infiltration into the heating plant, causing heat loss. Inspect smoke pipe and chimney for elimination of leaks, and obstructions. Be sure of adequate chimney size and height. Install a mechanical draft adjuster, if need be, same size as smoke pipe (see column under "Draft Regulators").

COMBUSTION CHAMBER

The purpose of a combustion chamber is to maintain a high flame temperature, by reflecting the heat back into the flame. A high temperature assures greater combustion efficiency and lower stack losses. An insulating refractory or a Fiber Fax type chamber can be used with this burner. It is important to select and install, if necessary, the correct size chamber on a conversion job (see chart, page 4). On the flamelock conversion burners the atomized oil burns just off the flamelock. On all oil burners the atomized oil must not touch the sides or bottom of chamber, or smoke will result. To eliminate the smoke, excess air will be required, resulting in high stack temperature and lower combustion efficiency. Install burner so the face of air cone of burner is set $\frac{1}{4}$ " behind the inside front wall of the chamber (see Figure 5, page 5). Caution on installing Flamelock burners in stainless steel chambers should be taken, because of the higher temperature levels produced by high performance flame retention burners. The temperature may exceed the temperature ratings of the stainless steel chamber, and can result in chamber burn outs. When you are replacing a standard burner with a flame retention burner, take the following precautions: (1) use "Wet Pac" Ceramic Liner to line the inside of chamber, (2) adjust burner (See column under "Final Adjustments").

FUEL UNITS AND OIL LINES

The model HS oil burner is provided with a single stage 3450RPM fuel unit with the by-pass plug removed for a single pipe installation; this is satisfactory where the fuel supply is on the same level, or above burner, permitting gravity flow of oil. Never exceed 3PSI pressure to the suction side of fuel unit, a pressure over 3PSI may cause damage to the shaft seal and allow it to leak oil. When it is necessary to lift the oil to the burner, a return line should be run between fuel unit and oil supply. (If lift exceeds 10 feet, a two stage fuel unit must be used with a return line.) When a two line installation is made, the by-pass plug must be installed. This is supplied with the burner attached to fuel unit, along with an information pump data sheet in a plastic bag. When oil lines are installed continuous runs of heavy wall copper tubing is recommended. Be sure that all connections are absolutely air-tight. Check all connections and joints. Flared fittings are recommended. Do not use compression fittings. See pump data sheet for sizing, lift and length for tubing recommendations. Use an oil filter of adequate size for all installations, install inside the building between the tank shutoff valve and the burner. For ease of servicing, locate the shutoff valve and filter near the burner.

TANKS AND PIPING

Local codes and regulations must be followed regarding tank and burner installation.

WIRING

All wiring must comply with the National Electric Code and local ordinances. Refer to diagram supplied with burner or controls, making sure the burner and controls are wired correctly and that the line switch is properly fused to burner.

AIR SUPPLY FOR COMBUSTION

Do not install in rooms with insufficient air to supply combustion. Occasionally, it is necessary to install windows or cut holes in a door to these rooms, to obtain sufficient air and to prevent less than atmospheric air pressure in the room. If there is a lack of combustion air, the burner flame will be yellow and formation of soot will occur in the heating unit. In buildings of conventional frame, brick, or stone construction without utility rooms, basement windows, or stair doors, infiltration is normally adequate to provide air for combustion and for operation of the barometric draft control. For installation in an enclosed utility room with an outside wall, a fresh air opening to the outside should be made with a free cross sectional area of twice the area of the flue outlet or 100 square inches for each gallon nozzle size (Example: 10 x 10 for 1.00 GPH). For each 1,000 feet above sea level, increase the fresh air opening by at least four percent. The room should be isolated from any area served by exhaust fans. Do not install an exhaust fan in this room.

CHIMNEY

Follow the recommendations of the heating unit manufacturer. It must be properly designed, of adequate size, and should be above the surrounding objects, tile-lined, with no obstructions, and be in good state of repair. The smoke pipe should set flush with the inside of tile and be cemented in place. All cleanout doors should be sealed.

DRAFT REGULATORS

If a draft regulator is required, it should preferably be mounted in the smoke pipe. Use a draft gauge to adjust to proper opening. When the burner air supply and draft is properly adjusted, the combustion chamber draft will be approximately 0.01" to 0.02" WC and the stack draft will be 0.02" to 0.04" WC. The larger the installation, the greater the draft will be required at the stack to obtain the 0.01" to 0.02" WC at the combustion chamber.

REMOVING DRAFT REGULATORS (where local codes permit)

If the chimney is under 27 feet high the draft regulator can be removed or sealed shut. (A) All doors, openings, and cracks in the heating plant must be sealed or cemented air-tight to eliminate air infiltration. (B) Set combustion to highest CO₂ with not more than a #1 smoke, with a cold chimney, or with the draft regulator wide open. (C) Recheck smoke and CO₂ when unit is cold. Smoke must not exceed a #1. (Remove or seal draft regulator). (D) Check CO₂, smoke, and stack temperature with a hot chimney. The CO₂ should not drop more than 1.5% from a cold chimney condition to a hot chimney condition, and the overfire draft not to exceed .10 in water column.

NOZZLES

Use the proper size, type, and spray pattern nozzle that heater manufacturer recommends. In some cases of upgrading or conversion installations, the use of 80° Hollow or Solid nozzle is the best to start with. To install nozzle, loosen clamping screw on the retention ring assembly and slide the assembly off the adapter. Install and tighten the nozzle in the adapter. Be careful not to damage the electrode insulators, or bend the electrodes. Replace the retention ring assembly on the adapter, make sure the clamp is tight against the shoulder on the adapter, tighten the clamping screw. Check electrode setting. (See Figure 3, page 5)

To remove gun assembly (see Figure 6, page 5), remove two screws (A) holding burner cover in place, swing open transformer. Loosen, but do not remove screw (B) securing side plate clamp. Remove screw (C) securing gun assembly to burner. Do not loosen or remove the screw (D) securing the gun assembly stop plate in position. Remove side plate, disconnect oil line from gun assembly. Lift gun assembly upward while pulling back, do not force it. It may be necessary to rotate the gun assembly 90° to facilitate removal.

To install gun assembly, slide gun assembly into air tube, do not force it. The gun assembly has to be lifted and guided through the air cone in the end of the air tube (E). Start with end of oil pipe at 12 o'clock position, slide gun assembly forward until retention head is located in air cone, then rotate gun assembly 90° counter clockwise.

STARTING PROCEDURE

STARTING BURNER

Be sure main switch is in "OFF" position, thermostat is substantially above room temperature, the oil tank is filled, all valves are open, and controls set for operation. Adjust air supply on burner by loosening screw on indicator, and open partially (See Figure 6, page 5 for inputs and damper adjustments). Open the inspection door and turn on switch. Prime pump according to the pump manufacturer's recommendations and check pressure. If safety lockout occurs, reset after one or two minutes. Do not run fuel unit dry for more than five minutes. When fire is established make a temporary air adjustment for a clean combustion flame, reduce air supply until flame tips appear slightly smoky, then readjust so flame tips are clean looking. Leave inspection door open until chamber is dry. When normal temperatures are reached, close inspection door. (See column under "Draft Regulators").

FINAL CHECKS

At this point a final adjustment should be made by the use of the ADJUSTMENT KIT. After operating ten minutes to warm up unit, a smoke tester should be used to take a smoke reading. Smoke should not be greater than #1 (Shell Barograph scale), and less than #1 smoke is desired. At times, a new heating unit requires more than this to burn clean due to the oil film on the new heater unit surfaces. Recheck draft and take a CO₂ reading over the fire and in the stack. If a large differential between CO₂ readings is noted, air leakage is the most common cause (see column under "Heating Plant"). CO₂ readings must all be taken ahead of draft control, if used. The CO₂ measured in the stack should be at least 9% for oil rates 1.00GPH or below, and be at least 10% for oil rates over 1.00GPH. Units should be started and stopped several times to assure good operation. Open inspection door, turn off oil valve, and check out safety timing of combustion control. Check operation of limit controls and thermostat. Check for oil leaks. NOTE: ALL INSPECTIONS SHOULD BE REINSPECTED AFTER ONE OR TWO WEEKS OF NORMAL OPERATION.

SETTING COMBUSTION EFFICIENCY

(A) Select firing rate desired. (B) Install proper nozzle for appliance (see Figure 2, page 6 for removing gun assembly). (C) Set off-cycle damper and gun adjustments per firing rate (see Figure 7, page 5). (D) Fire burner, adjust combustion damper for yellow tips above combustion chamber. (E) Record CO₂ and smoke. If CO₂ is low, adjust gun setting back 1/32" and repeat CO₂ and smoke test. Continue this adjustment until desired CO₂ and smoke is obtained. Record stack temperature. (F) Check lighting with cold and hot chamber. (G) Check off-cycle damper for any interference, correct if necessary. (H) Lock all adjustment screws, off-cycle damper indicator, combustion damper indicator, and gun setting stop and adjusting plate.

EFFICIENCY CHART FOR NO. 2 FUEL OIL
NET STACK TEMP. (degrees F°)

NET STACK TEMP. (15.5-55.5 °C)														
		300°	350°	400°	450°	500°	550°	600°	650°	700°	750°	800°	850°	900°
CO ₂	15	87½	86½	85¼	84¼	83¼	82	81	79¾	78¾	77½	76½	75½	74¼
		87½	86¼	85	84	83	81¾	80¾	79¼	78½	77¼	76	75	73¾
	14	87¼	86	84¾	83¾	82¾	81½	80¼	79	78	76¾	75½	74½	73
		87	85¾	84½	83½	82½	81¼	80	78¾	77½	76¼	75¼	74	72¼
	13	86¾	85½	84¼	83¼	82	80¾	79½	78¼	77	75¾	74½	73½	71¾
		86½	85¼	84	83	81½	80¾	79	77¾	76½	75¼	73¾	72¾	71
	12	86¼	85	83¾	82½	81¼	79¾	78½	77¼	75¾	74½	73	71½	70¼
		86	84¾	83½	82	80¾	79¼	78	76½	75¼	73¾	72¼	70¾	69½
	11	85¾	84½	83	81½	80¼	78¾	77¼	75¾	74½	73	71½	70	68½
		85½	84	82½	81	79½	78	76½	75	73¾	72	70½	69	67½
	10	85	83½	82	80½	78¾	77¼	75¾	74¼	72¾	71	69½	68	66¼
		84½	83	81½	79¾	78	76½	75	73¾	71¾	70	68¼	66¾	65
	9	84	82¼	80¾	79	77¼	75¾	74	72¾	70¾	68¾	67	65¼	63½
		83½	81¾	80	78¾	76½	74¾	73	71¼	69½	67½	65½	63¾	62
	8	83	81	79¼	77½	75½	73¾	72	70	68	66	64	62	60
		82¼	80¼	78½	76½	74½	72½	70½	68½	66½	64¼	62¼	60	58
	7	81½	79½	77¼	75¼	73¼	71	69	67	64¾	62½	60¼	57¾	55½
		80¾	78½	76¼	74	71¾	69½	67¼	65	62¾	60¼	57¾	55½	53
	6	79¾	77¼	75	72½	70	67¾	65¾	62¾	60¼	57½	55	52½	50
		78½	76	73½	71	68	65½	63	60¼	57½	54½	51¾	49	46½
	5	77¼	74½	71¾	69	65¾	63	60	57	54	51	48	45½	42¼
		75½	72½	69	66¼	63	60	56¾	53½	50¼	47	43½	40¼	36¾
	4	73¼	69¾	66¼	62¾	59¾	55¾	52	48½	45	41¼	37½	33¼	30

FINAL CHECKS

Be sure air shutter adjustments are locked, and the controls on heating unit are adjusted in accordance with the heater and control manufacturer's instruction sheets.

MAINTENANCE

Oiling Motor — By proper oiling twice a year, the motor life will be increased; only a few drops of non-detergent type oil at both motor holes are needed.

Filter — The oil filter cartridge should be replaced once each year so the fuel oil will not become contaminated and plug up fuel pump and nozzle of oil burner.

Nozzle — The nozzle should be changed at least once each year before the start-up of the heating season. Replace with proper nozzle.

Components — If for any reason any of the burner parts have to be replaced, always use parts recommended by the manufacturer. Specify part numbers and description when ordering. (IN ALL COMMUNICATIONS STATE BURNER MODEL AND SERIAL NUMBERS).

Electrode Settings — This is very important for reliable ignition of the oil; check these once a year in accordance with the instructions provided in this manual.

Fan & Blower Housing — This must be kept clean, free of dirt and lint; open transformer to check fan blades for above, be sure the electric power is off on burner when the transformer is opened up for this inspection.

SEASONAL EFFICIENCY

Extremely high efficiencies can be obtained with the model HS oil burner while running and when the burner is in the "OFF" position.

The unique off-cycle damper (Figure 4, page 5) in the burner shuts off the air when the burner is not running. With the draft regulator removed or sealed, seasonal efficiencies can be improved even more.

Suggested Combustion Chamber Dimensions Conversion or Upgrading Chamber Dimension (In Inches)

Firing Rate (GPH)	Square Chamber	Diameter Round Chamber	Height	Floor To Nozzle
0.50	7 x 7	8	11	5 - 6
0.75	8 x 8	9	12	5 - 6
0.85	8½ x 8½	9	12	5 - 6
1.00	9 x 9	10⅞	12½	5 - 6
1.25	10 x 10	11⅞	12½	5 - 6
1.35	10½ x 10½	11¾	12¾	5 - 6
1.50	11 x 11	12⅞	13	5 - 6
1.65	11½ x 11½	13	13¼	5 - 6
2.00	12⅞ x 12⅞	14¼	13½	6 - 7
2.50	14¼ x 14¼	16	14	7 - 8
3.00	15½ x 15½	17½	15	7 - 8

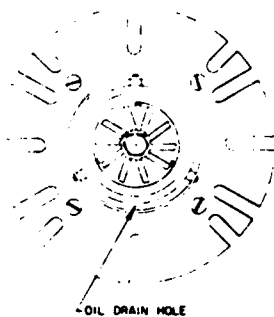


Figure 1

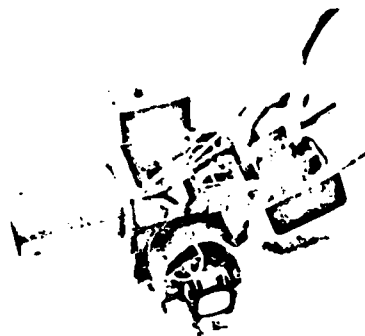


Figure 2

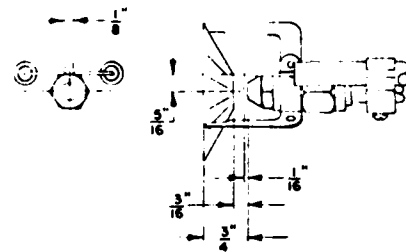


Figure 3

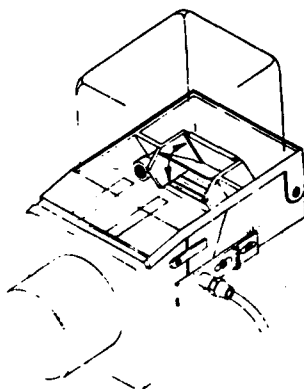
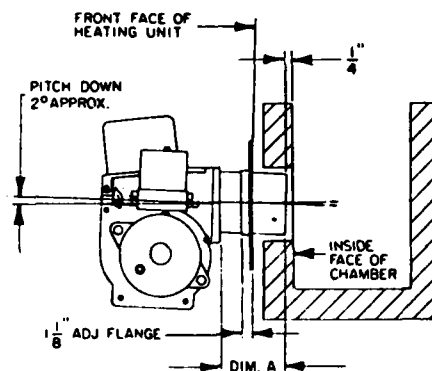


Figure 4

TO DETERMINE THE AIR TUBE LENGTH



The Air Tube Length (Dim. A) is the distance from the front of Air Tube Retainer Flange to the face of Air Cone. Note adjustable flange width.

Figure 5

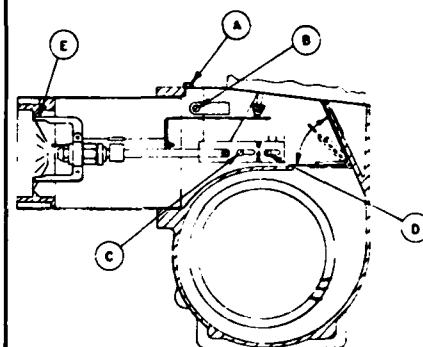
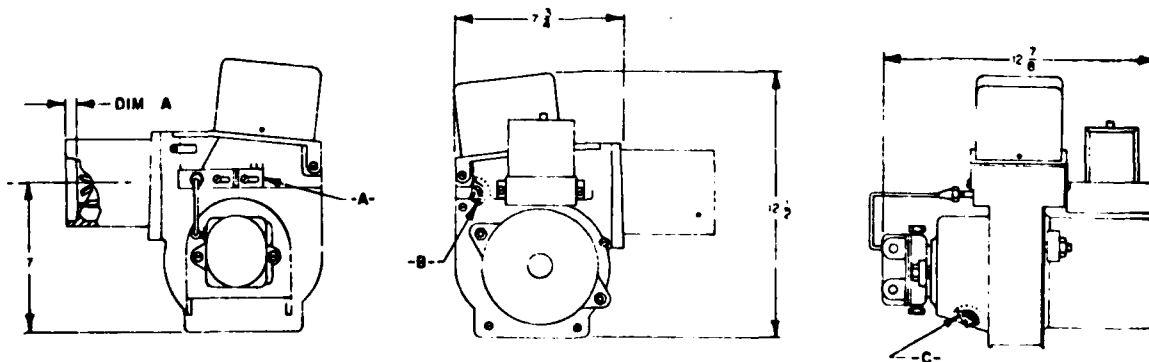


Figure 6

MODEL "HS" OIL BURNER

60° to 80° Solid Cone Nozzles — Long Flame
60° to 80° Hollow Cone Nozzles — Short Flame

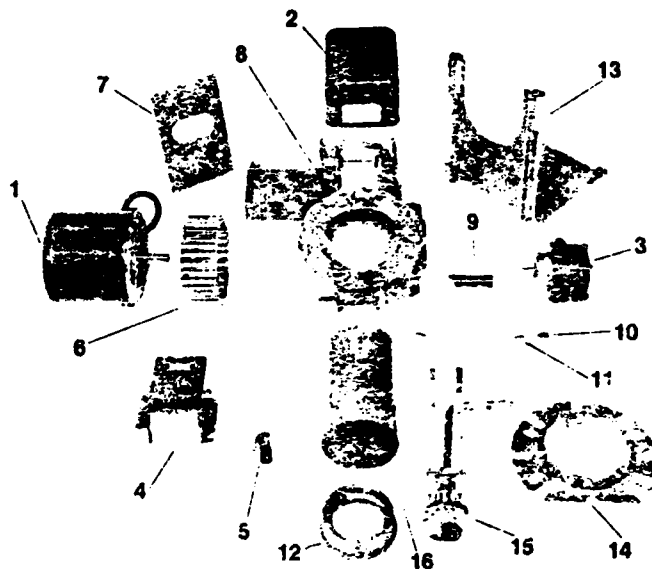
Figure 7



NOTE: START BURNER WITH LISTED SETTINGS, ADJUST "A" TO CHANGE FLAME SHAPE AND IMPROVE CO₂

GPH INPUT	—A— FLAMELOCK SETTING	—B— OFF CYCLE DAMPER SETTING*	—C— COMBUSTION EFFICIENCY DAMPER
0.50 to 0.75	9/16" - No. 1	No. 1	Set to Desired CO ₂ and Smoke
0.85 to 1.75	7/16" - No. 2	No. 2	Set to Desired CO ₂ and Smoke
2.00 to 3.00	1/16" - No. 3	No. 2	Set to Desired CO ₂ and Smoke

BURNER COMPONENTS MODEL HS

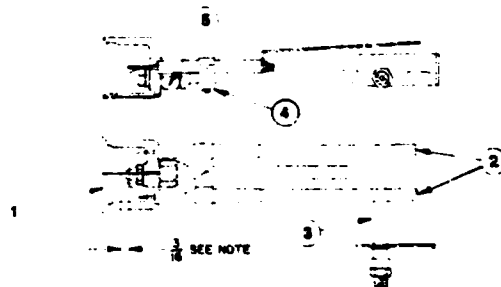


STATE BURNER MODEL, PART DESCRIPTION, AND PART NUMBER WHEN ORDERING PARTS

NO.	DESCRIPTION	PART NO.	NO.	DESCRIPTION	PART NO.
1	Motor — 1/8 HP	20627	13	Pedestal	2794
2	Transformer	21659	14	Adjustable Flange w/Gasket	62259
3	Fuel Unit — Type A	13495	15	Gun Assembly 6"	30879-013
	Fuel Unit — Type B	13634		Gun Assembly 9"	30879-025
4	Relay	13084		Gun Assembly 12"	30879-037
5	Cad Cell	13666		Gun Assembly 15"	30879-049
6	Blower Wheel	21642		Gun Assembly 18"	30879-061
7	Housing Cover Assembly	21680	16	Air Tube 6"	21682-013
8	Housing Assembly	30885		Air Tube 9"	21682-025
9	Coupling	100386		Air Tube 12"	21682-037
10	Elbow	13494		Air Tube 15"	21682-049
11	Oil Line Assembly	14451		Air Tube 18"	21682-061
12	Air Cone	100389			

GUN ASSEMBLY DETAILS MODEL HS

NO.	DESCRIPTION	PART NO.
1	Flamelock Assembly	100393
2	Electrode Assembly (Pair)	21684
3	Oil Pipe Assembly 6"	21670-013
	Oil Pipe Assembly 9"	21670-025
	Oil Pipe Assembly 12"	21670-037
	Oil Pipe Assembly 15"	21670-049
	Oil Pipe Assembly 18"	21670-061
4	Electrode Holder Assembly	21679
5	Nozzle Adapter	12362



NOTE: BACKSIDE OF FLAMELOCK TO NOZZLE FACE.

BLUE ANGEL™ REPLACEMENT AIR TUBE COMBINATIONS

Includes Air Tube, Air Cone and Gun Assembly

Air Tube Combination — 6"	03884-013	Air Tube Combination — 15"	03884-049
Air Tube Combination — 9"	03884-025	Air Tube Combination — 18"	03884-061
Air Tube Combination — 12"	03884-037		



OIL BURNER CERTIFICATE



The _____ Oil Burner Model No. _____ Serial No. _____
(MAKE)
installed at _____, bear a label evidencing compliance with commercial Standard CS75-76,
(ADDRESS OF INSTALLATION)
and has been installed in accordance with the instructions in the manufacturer's installation manual and in conformity with local regulations, codes, and ordinances.

The Boiler _____ Furnace _____ No. _____, and the
(MAKE)
Input of unit consists of _____ G.P.H., or _____ BTUH
CO₂ Over Fire _____ Flue Gas Temperature at Breeching _____ °F
CO₂ At Breeching _____ Ambient Temperature _____ °F
Draft Over Fire _____ Net Flue Gas Temperature _____ °F
Draft At Breeching _____ Firing Rate _____ gals./hrs.
(inches H₂O) Oil Pressure _____ PSIG

All controls and limiting devices have been checked for proper operation _____

Fuel used, Grade No. _____ of Commercial Standard CS12-48. Field services equipment smoke scale reading _____

The above test results are certified to be true: _____

(NAME OF COMPANY MAKING INSTALLATION)

Per _____ Address: _____ Phone: _____
(SIGNATURE)

FOR SERVICE CALL:

Name _____ Phone: _____

Address: _____ Date: _____

LIMITED WARRANTY

Wayne Home Equipment (Wayne) warrants its products and components to be free from defects due to faulty workmanship or defective materials at time of shipment and under normal use and service for twenty-four (24) months from the date of installation by a qualified installer. This LIMITED WARRANTY does not extend or apply to Wayne's products, or any component thereof, which have been misused, neglected, improperly installed or otherwise abused. Equipment which is defective in material or workmanship and which is removed within the specified time period will be repaired or replaced as follows:

- (1) Fuel units, controls, motors and transformers should be returned to an authorized service point or distributor of Wayne for determination of applicability of this LIMITED WARRANTY as to repair or replacement where said service point or distributor is reasonably available in customer's locality.
- (2) Where such local service is not available for components involving said fuel units, controls, motors, and transformers, or where other components are involved, such products should be returned, freight prepaid, to Wayne's home office.
- (3) Products determined to be covered under this LIMITED WARRANTY by Wayne shall be either repaired or replaced at Wayne's sole option.
- (4) Wayne is not responsible for any labor cost for removal and replacement of said products and equipment associated therewith.
- (5) Fuel units, controls, motors and transformers, or other components which are so repaired or replaced will carry this LIMITED WARRANTY equal to the unexpired portion of the original product LIMITED WARRANTY.
- (6) If inspection by Wayne does not disclose any defect covered by this LIMITED WARRANTY, the product will be repaired or replaced at the expense of the customer and Wayne's regular charges will apply.

THE FOREGOING STATES THE SOLE AND EXCLUSIVE REMEDY FOR ANY BREACH OF WARRANTY OR FOR ANY OTHER CLAIM BASED ON ANY DEFECT IN, OR NON-PERFORMANCE OF, THE PRODUCTS, WHETHER SOUNDING IN CONTRACT, WARRANTY, OR NEGLIGENCE. NO OTHER WARRANTY, WHETHER EXPRESSED OR IMPLIED, INCLUDING ANY WARRANTY OF MERCHANTABILITY OR FITNESS FOR A PARTICULAR PURPOSE, SHALL EXIST IN CONNECTION WITH THE SALE OR USE OF SUCH PRODUCTS, AND IN NO EVENT WILL WAYNE BE LIABLE FOR ANY INCIDENTAL OR CONSEQUENTIAL DAMAGES OF ANY NATURE. Wayne neither assumes nor authorizes any person to assume for Wayne any other liability or obligation in connection with the sale of these products.

15% FEDERAL INCOME TAX CREDIT WITH BLUE ANGEL

The HS Burner is a furnace/boiler type replacement burner which reduces the amount of fuel used.

You are eligible to deduct 15% of the HS Burner installation cost from your Federal Income Tax subject to IRS limitations. Use IRS Form 5695, available from your Regional IRS office, or write: IRS, Washington, D.C. 20224.

HS Burner Installation Date _____

INSTALLATION LOCATION

INSTALLING CONTRACTOR

Name: _____ Name: _____

Address: _____ Address: _____

Total cost of installation including material and labor _____

The invoice for the total installation cost should be avail:

APPENDIX D

CAUTIONARY COMMENTS REGARDING SOME ENERGY CONSERVATION MEASURES

Some energy conservation measures have not been subjected to unbiased evaluation and are therefore to be judged with caution even though their principles appear to be soundly based. Other measures have neither a solid foundation in theory nor have withstood evaluation in the laboratory and these must be avoided without reservation.

In the first category the following energy conservation measures are:

1. Devices for fuel oil preheating.
2. Devices for shutting the burner combustion air inlet when the burner is off; inlet air damper.

Fuel Oil Preheating

Fuel oil preheating devices have entered the market for the purpose of improving the atomization of #2 fuel oil under conditions where the oil is cold due to exposure to ambient conditions. Under cold conditions the increase in viscosity of #2 fuel oil may have an adverse effect on atomization. In addition the density of the fuel oil is greater under cold conditions which could cause fuel rich (soot forming) operation of a burner which had been adjusted during warmer conditions. In each of these situations fuel preheating would appear to be an answer from a theoretical point of view, but these issues have not been evaluated in controlled tests.

Any claims for these kind of devices as having significant impact for energy conservation beyond promoting proper operation of burners under cold weather conditions should be viewed as unvalidated.

Inlet Air Dampers

Some burner manufacturers have included mechanisms for shutting the combustion air openings in the blower inlet during burner off periods. In principle this should have similar effects as vent dampers which were discussed earlier in this report. These effects showed that the suppression of off period air flow through the boiler heat exchanger would reduce off-cycle losses. Since the location of the shut-off device in the burner is upstream of the heat exchanger as opposed to the vent damper which is located downstream of the heat exchanger it is not clear if the resulting savings would be the same as with the vent damper. The precise savings have yet to be quantified through comparative controlled tests.

In the second category, the measures are not effective in principle or when subjected to controlled testing. The measures included here are:

1. Fuel Oil Emulsions
2. Combustion Air Humidification
3. Blower Air Turbulence

Fuel Oil Emulsions

The emulsions are formed by blending #2 fuel oil with quantities of water. The sought after performance change was improved atomization effects provided by the rapid conversion of entrained water to steam. It was thought that the improvement in fuel atomization would improve combustion through a reduction of excess air requirements and that the resulting efficiency improvement would more than offset the increase stack gas heat loss due to steam formation.

The principles embodied in this system may have some applicability to heavy oil where fine atomization of the fuel is difficult. This application was not tested at BNL. For #2 fuel oil, however, fine atomization is not a problem and is accomplished successfully using high pressure atomizing nozzles as long as the fuel temperature is at indoor ambient conditions.

The system principles were put to test in the laboratory using prototype equipment provided by an inventor. The results indicated that no improvement could be observed and in fact efficiency performance was degraded as a function of the percentage of water entrained in the #2 fuel oil.

The results of these tests are contained in BNL findings report #77-9-H1 addressed to Camin Industries, October 1977.

Combustion Air Humidification

The basic operation used in these devices provided for part of the induced combustion air to be bubbled through water and then reintroduced into the combustion air stream within the burner blower housing. In all cases an additive was used in the water and was purported to have catalytic properties which were transferred to the combustion air through the bubbling action.

In tests conducted at BNL these systems were found to produce negligible improvement (well within experimental error) in the efficiency of residential heating equipment. The results of these tests are contained in the following BNL finding reports:

<u>Report No.</u>	<u>System Manufacturer</u>	<u>Date</u>
77-5-H1	AFTCO Systems	June 1977
78-23-H2	Energy Conservation Laboratories, Inc.	November 1978
78-24-H2	Vapor Pak Inc.	November 1978
78-27-H2	Dynamic Energy Resources, Inc.	January 1979
78-29-H2	Save Fuel Inc.	January 1979

Blower Air Turbulence

This device was designed to be installed within the burner blower housing, downstream of the blower wheel and upstream of the blast tube. The device was purported to increase air turbulence within the blast tube and consequently improve air fuel mixing and combustion.

Tests of the device at BNL showed negligible improvement in efficiency (well within experimental error) using the device. The results of these tests are contained in BNL Findings Report 78-30-H2 for Turbo-Miser, January 1979.

Fuel Oil Additives

The use of fuel oil additives are frequently offered as a means of reducing sludge contaminant in storage tanks. Some manufacturers extend their claims to combustion and efficiency improvements. These claims included soot reduction, soot removal, improved combustion, and increased efficiency. While there may be some benefits regarding the reduction of sludge formation it is difficult to theoretically support any improvement in a well adjusted residential heating system using #2 fuel oil.

Tests were conducted at BNL of four proprietary fuel oil additives. These tests were conducted on a well adjusted system as well as conditions which were deliberately set off design. Measurements and evaluations of smoke versus carbon dioxide (CO₂) formation, soot removal and steady state stack loss efficiency were conducted. No substantiation of the manufacturers claims regarding performance improvement was accomplished in these tests.

In the light of these tests and an understanding of the principles involved with #2 fuel oil combustion, heat transfer and existing residential heating equipment offered in this interim guide the only reasonable judgement that can be made regarding energy conservation measures is:

"If the claims offered for an energy conservation measure sound too good to be true then they probably are."

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 Operations Div, Cherry Point; PWD - Utilities Div, Iwakuni, Japan; PWO, Iwakuni, Japan; PWO, Yuma
 AZ
 MCDEC NSAP REP, Quantico VA
 MCLB B520, Barstow CA; Maintenance Officer, Barstow, CA; PWO, Barstow CA
 MCRD SCE, San Diego CA
 NAF PWD - Engr Div, Atsugi, Japan; PWO, Atsugi Japan
 NALF OINC, San Diego, CA

NARF Code 100, Cherry Point, NC; Code 612, Jax, FL; Code 640, Pensacola FL; SCE Norfolk, VA
 NAS CO, Guantanamo Bay Cuba; Chief of Police, Kingsville TX; Code 114, Alameda CA; Code 183 (Fac. Plan
 BR MGR); Code 183, Jacksonville FL; Code 18700, Brunswick ME; Code 18U (ENS P.J. Hickey), Corpus
 Christi TX; Code 8E, Patuxent Riv., MD; Dir of Engrng, PWD, Corpus Christi, TX; Grover, PWD,
 Patuxent River, MD; Lakehurst, NJ; Lead. Chief. Petty Offr. PW/Self Help Div, Beeville TX; PW (J.
 Maguire), Corpus Christi TX; PWD - Engr Div Dir, Millington, TN; PWD - Engr Div, Gtmo, Cuba; PWD -
 Engr Div, Oak Harbor, WA; PWD Maint. Cont. Dir., Fallon NV; PWD Maint. Div., New Orleans, Belle
 Chasse LA; PWD, Code 1821H (Pfankuch) Miramar, SD CA; PWD, Maintenance Control Dir., Bermuda;
 PWO (Code 18.2), Bermuda; PWO Belle Chasse, LA; PWO Chase Field Beeville, TX; PWO Key West FL;
 PWO Lakehurst, NJ; PWO Patuxent River MD; PWO Sigonella Sicily; PWO Whiting Fld, Milton FL; PWO,
 Cecil Field FL; PWO, Dallas TX; PWO, Glenview IL; PWO, Millington TN; PWO, Miramar, San Diego CA;
 PWO, Oceana, Virginia Bch VA; PWO, So. Weymouth MA; SCE Norfolk, VA; SCE, Barbers Point HI;
 SCE, Cubi Point, R.P.; Security Offr, Patuxent Riv. MD
 NATL RESEARCH COUNCIL Naval Studies Board, Washington DC
 NAVACT PWO, London UK
 NAVAEROSPREGMEDCEN SCE, Pensacola FL
 NAVAIRDEVCCEN Chmielewski, Warminster, PA; PWD, Engr Div Mgr, Warminster, PA
 NAVAIRPROPTSTCEN CO, Trenton, NJ
 NAVAUDSVCHQ Director, Falls Church VA
 NAVCOASTSYSCEN CO, Panama City FL; Code 715 (J Quirk) Panama City, FL; Library Panama City, FL;
 PWO Panama City, FL
 NAVCOMMAREAMSTRSTA PWO, Norfolk VA; SCE Unit 1 Naples Italy; SCE, Guam; SCE, Wahiawa HI;
 Sec Offr, Wahiawa, HI
 NAVCOMMSTA Code 401 Nea Makri, Greece; PWD - Maint Control Div, Diego Garcia Is.; PWO, Exmouth,
 Australia; SCE, Balboa, CZ
 NAVCONSTRACEN Curriculum/Instr. Stds Offr, Gulfport MS
 NAVEDTRAPRODEVCCEN Technical Library, Pensacola, FL
 NAVEDUTRACEN Engr Dept (Code 42) Newport, RI
 NAVEODTECHCEN Code 605, Indian Head MD
 NAVFAC M & O Officer Bermuda; PWO, Brawdy Wales UK; PWO, Centerville Bch, Ferndale CA; PWO,
 Point Sur, Big Sur CA
 NAVFACENGCOM Alexandria, VA; Code 03 Alexandria, VA; Code 03T (Essoglou) Alexandria, VA; Code
 04B3 Alexandria, VA; Code 051A Alexandria, VA; Code 09M54, Tech Lib, Alexandria, VA; Code 100
 Alexandria, VA; Code 1113, Alexandria, VA; Code 111B Alexandria, VA; code 08T Alexandria, VA
 NAVFACENGCOM - CHES DIV. Code 403 Washington DC; Code 406 Washington DC; FPO-1 Washington,
 DC; Library, Washington, D.C.
 NAVFACENGCOM - LANT DIV. Code 111, Norfolk, VA; Code 403, Norfolk, VA; Eur. BR Deputy Dir,
 Naples Italy; Library, Norfolk, VA; RDT&ELO 102A, Norfolk, VA
 NAVFACENGCOM - NORTH DIV. Code 04 Philadelphia, PA; Code 04AL, Philadelphia PA; Code 09P
 Philadelphia PA; Code 11, Phila PA; Code 111 Philadelphia, PA; ROICC, Contracts, Crane IN
 NAVFACENGCOM - PAC DIV. (Kyi) Code 101, Pearl Harbor, HI; CODE 09P PEARL HARBOR HI; Code
 402, RDT&E, Pearl Harbor HI; Library, Pearl Harbor, HI
 NAVFACENGCOM - SOUTH DIV. Code 403, Gaddy, Charleston, SC; Code 406 Charleston, SC; Code 90,
 RDT&ELO, Charleston SC; Library, Charleston, SC
 NAVFACENGCOM - WEST DIV. AROICC, Contracts, Twentynine Palms CA; Code 04B San Bruno, CA;
 Library, San Bruno, CA; 09P/20 San Bruno, CA; RDT&ELO San Bruno, CA
 NAVFACENGCOM CONTRACTS AROICC, NAVSTA Brooklyn, NY; AROICC, Quantico, VA; Contracts,
 AROICC, Lemoore CA; Dir, Eng. Div., Exmouth, Australia; Dir. of Constr, Tupman, CA; Eng Div dir,
 Southwest Pac, Manila, PI; OICC, Southwest Pac, Manila, PI; OICC-ROICC, NAS Oceana, Virginia
 Beach, VA; OICC/ROICC, Balboa Panama Canal; OICC/ROICC, Norfolk, VA; ROICC AF Guam; ROICC
 Code 495 Portsmouth VA; ROICC Key West FL; ROICC MCAS El Toro; ROICC, Keflavik, Iceland;
 ROICC, NAS, Corpus Christi, TX; ROICC, Pacific, San Bruno CA; ROICC, Yap; ROICC-OICC-SPA,
 Norfolk, VA
 NAVHOSP PWD - Engr Div, Beaufort, SC
 NAVMAG PWD - Engr Div, Guam; SCE, Subic Bay, R.P.
 NAVOCEANSYSCEN Code 4473B (Tech Lib) San Diego, CA; Code 523 (Hurley), San Diego, CA; Code 6700,
 San Diego, CA; Code 811 San Diego, CA
 NAVORDMISTESTFAC PWD - Engr Dir, White Sands, NM
 NAVORDSTA PWD - Dir, Engr Div, Indian Head, MD; PWO, Louisville KY
 NAVPETOFF Code 30, Alexandria VA
 NAVPETRES Director, Washington DC
 NAVPGSCOL PWO Monterey CA
 NAVPHIBASE CO, ACB 2 Norfolk, VA; PWO Norfolk, VA; SCE Coronado, SD,CA
 NAVREGMEDCEN PWD - Engr Div, Camp Lejeune, NC; PWO, Camp Lejeune, NC
 NAVREGMEDCEN PWO, Okinawa, Japan

NAVREGMEDCEN SCE; SCE San Diego, CA; SCE, Camp Pendleton CA; SCE, Guam; SCE, Newport, RI;
 SCE, Oakland CA
 NAVREGMEDCEN SCE, Yokosuka, Japan
 NAVSCOLCECOFF C35 Port Hueneme, CA
 NAVSCSOL PWO, Athens GA
 NAVSEASYSCOM Code 0325, Program Mgr, Washington, DC; Code PMS 395 A 3, Washington, DC; SEA
 04E (L Kess) Washington, DC
 NAVSECGRUACT PWO Winter Harbor ME; PWO, Adak AK; PWO, Edzell Scotland; PWO, Puerto Rico;
 PWO, Torri Sta, Okinawa
 NAVSECSTA PWD - Engr Div, Wash., DC
 NAVSHIPYD Code 202.4, Long Beach CA; Code 202.5 (Library) Puget Sound, Bremerton WA; Code 380,
 Portsmouth, VA; Code 382.3, Pearl Harbor, HI; Code 400, Puget Sound; Code 440 Portsmouth NH; Code
 440, Norfolk; Code 440, Puget Sound, Bremerton WA; Code 453 (Util. Supr), Vallejo CA; Code 457
 (Maint. Supr.) Mare Island, Vallejo CA; Library, Portsmouth NH; PW Dept, Long Beach, CA; PWD (Code
 420) Dir Portsmouth, VA; PWD (Code 450-HD) Portsmouth, VA; PWD (Code 453-HD) SHPO 03,
 Portsmouth, VA; PWO, Bremerton, WA; PWO, Mare Is.; PWO, Puget Sound; SCE, Pearl Harbor HI
 NAVSTA Adak, AK; CO, Brooklyn NY; Code 16P, Keflavik, Iceland; Code 4, 12 Marine Corps Dist, Treasure
 Is., San Francisco CA; Dir Engr Div, PWD, Mayport FL; Dir Mech Engr 37WC93 Norfolk, VA; Engr. Dir.,
 Rota Spain; Long Beach, CA; Maint. Cont. Div., Guantanamo Bay Cuba; PWD - Engr Dept, Adak, AK;
 PWD - Engr Div, Midway Is.; PWO, Keflavik Iceland; PWO, Mayport FL; SCE, Guam; SCE, Pearl Harbor
 HI; SCE, San Diego CA; SCE, Subic Bay, R.P.; Utilities Engr Off. Rota Spain
 NAVSUPPACT CO, Naples, Italy; PWO Naples Italy
 NAVSUPPFAC PWD - Maint. Control Div, Thurmont, MD
 NAVSURFWPNCEN PWO, White Oak, Silver Spring, MD
 NAVTECHTRACEN SCE, Pensacola FL
 NAVTELCOMMCOM Code 53, Washington, DC
 NAVWARCOL Dir. of Facil., Newport RI
 NAVWPNCEN Code 2636 China Lake; PWO (Code 266) China Lake, CA; ROICC (Code 702), China Lake CA
 NAVWPNSTA (Clebak) Colts Neck, NJ; Code 092, Concord CA; Code 092A, Seal Beach, CA
 NAVWPNSTA PW Office Yorktown, VA
 NAVWPNSTA PWD - Maint. Control Div., Concord, CA; PWD - Supr Gen Engr, Seal Beach, CA; PWO Colts
 Neck, NJ; PWO, Charleston, SC; PWO, Seal Beach CA
 NAVWPNSUPPCEN Code 09 Crane IN
 NCTC Const. Elec. School, Port Hueneme, CA
 NCBC Code 10 Davisville, RI; Code 15, Port Hueneme CA; Code 155, Port Hueneme CA; Code 156, Port
 Hueneme, CA; Code 25111 Port Hueneme, CA; Code 430 (PW Engrng) Gulfport, MS; Code 470.2,
 Gulfport, MS; Library, Davisville, RI; NEESA Code 252 (P Winters) Port Hueneme, CA; PWO (Code 80)
 Port Hueneme, CA; PWO, Davisville RI; PWO, Gulfport, MS; Technical Library, Gulfport, MS
 NMCB FIVE, Operations Dept; THREE, Operations Off.
 NOAA (Mr. Joseph Vadas) Rockville, MD; Library Rockville, MD
 NRL Code 5800 Washington, DC
 NROTC J.W. Stephenson, UC, Berkeley, CA
 NSC Code 09A Security Offr, Norfolk, VA; Code 54.1 Norfolk, VA; SCE Norfolk, VA; SCE, Charleston, SC
 NSD SCE, Subic Bay, R.P.
 NSWSES Code 0150 Port Hueneme, CA
 NTC SCE, San Diego CA
 NUSC DET Code 131 New London, CT; Code 5202 (S. Schady) New London, CT; Code EA123 (R.S. Munn),
 New London CT; Code SB 331 (Brown), Newport RI
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 ONR Code 221, Arlington VA; Code 700F Arlington VA
 PACMISRANFAC HI Area Bkg Sands, PWO Kekaha, Kauai, HI
 PHIBCB 1 P&E, San Diego, CA
 PWC ACE Office Norfolk, VA; CO, (Code 10), Oakland, CA; Code 10, Great Lakes, IL; Code 105 Oakland,
 CA; Code 105, Oakland, CA; Code 110, Great Lakes, IL; Code 110, Oakland, CA; Code 120, Oakland CA;
 Code 154 (Library), Great Lakes, IL; Code 200, Great Lakes IL; Code 400, Great Lakes, IL; Code 400,
 Pearl Harbor, HI; Code 400, San Diego, CA; Code 420, Great Lakes, IL; Code 420, Oakland, CA; Code
 424, Norfolk, VA; Code 500 Norfolk, VA; Code 500, Great Lakes, IL; Code 500, Oakland, CA; Code 505A
 Oakland, CA; Code 600, Great Lakes, IL; Code 610, San Diego Ca; Code 700, Great Lakes, IL; Library,
 Code 120C, San Diego, CA; Library, Guam; Library, Norfolk, VA; Library, Pearl Harbor, HI; Library,
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 Dept (R Pascua) Pearl Harbor, HI; Utilities Officer, Guam
 SPCC PWO (Code 120) Mechanicsburg PA
 TVA Smelser, Knoxville, Tenn.; Solar Group, Arnold, Knoxville, TN
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 US GEOLOGICAL SURVEY (Chas E. Smith) Minerals Mgmt Serv, Reston, VA
 USAF REGIONAL HOSPITAL Fairchild AFB, WA

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 USCG R&D CENTER Library New London, CT
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 LIVERMORE LAB, TOKARZ); UCSF, Physical Plant, San Francisco, CA
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