COMBUSTION OF NUMBER 2 FUEL OIL, DOMESTIC PRESSURE ATOMIZING OIL BURNERS, PUMPS & PIPING, CONTROLS

NORTH CAROLINA PETROLEUM & CONVENIENCE MARKETERS
7300 Glenwood Avenue
Raleigh, North Carolina 27612
Phone (919) 782-4411
www.ncpcm.org
www.ncoilheat.org

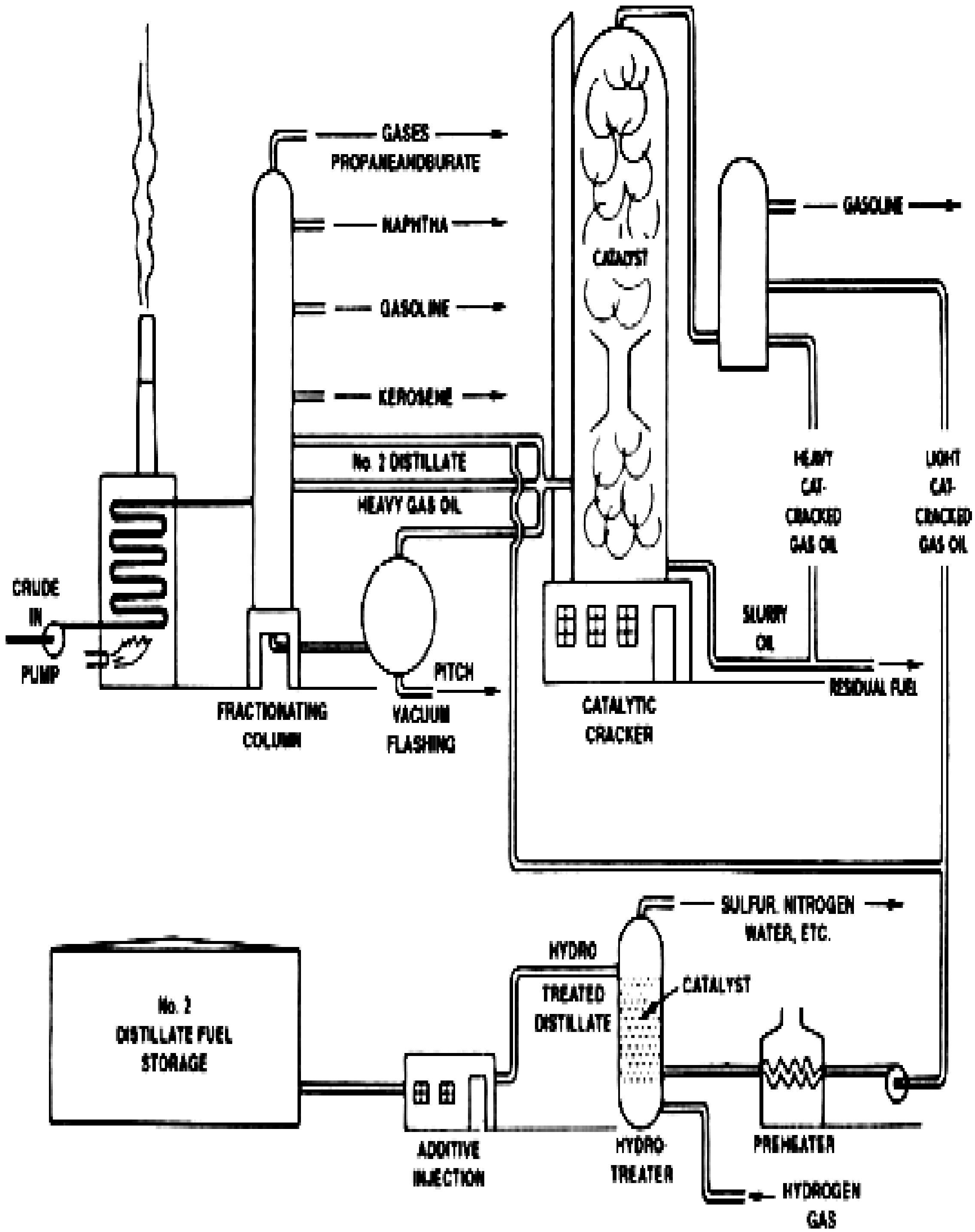
Tim Laughlin, P.E.
Technical Director

April 2013

www.nora-oilheat.org
Phone: (703) 340-1660
600 Cameron Street, Suite 206
Alexandria, VA 22314

TABLE OF CONTENTS

TYPICAL PETROLEUM REFINERY



FUEL OIL DESCRIPTIONS & SPECIFICATIONS

Crude is separated into the various heating fuels at the refineries. The lighter liquid heating fuels, called distillates, are products of the distillation process, and are practically sediment-free. They are further engineered chemically for optimum performance by the addition of various components called “additives” to inhibit rust formation, water absorption, and gum formation. Distillates are classified as follows:

Kerosene (K-1): A low sulfur content product with a distillation range of about 325° to 550°F., uses include suitability for lighting and cooking employing simple burners (wick). Industries, particularly ceramic, use kerosene where critically clean firings are required. Occasionally, kerosene (K-1 or the higher sulfur K-2) is used for diesel fuel where minimum exhaust odor and smoke are desired. As of July 1, 1998, this product may be dyed. Ultra Low-sulfur grade available. Average of 134,000 BTUs per gallon

Fuel Oil No.-1: A light liquid distillate with distillation range of about 325 to 570 °F. Use is generally in vaporizing “pot-type” burners for space heaters, but is not recommended for wick burners. As of Oct. 1, 1993, this product may be dyed. Ultra Low-sulfur grade available. Average of 135,000 BTUs per gallon.

Fuel Oil No.-2: A slightly heavier distillate with a maximum distillation temperature of 675 °F. Use is for mechanically atomizing type burners and where sediment in fuel and preheating are prohibited or limited. This is the general fuel for automatic oil-fired heating equipment. It is also used by utilities for gas enrichment purposes and by industry for many purposes such as baking, evaporating, annealing, and drying, etc. As of Oct. 1, 1993, this product may be dyed. Ultra Low-sulfur grade available. Average of 140,000 BTUs per gallon.

The remaining oil fuels are termed “residual” because they are residues remaining in the distillation equipment after other lighter fuels have been boiled off. Residuals are classified as:

Fuel Oil No.-4: Sometimes consists entirely of heavy distillates, but generally is a mixture, a distillate and a residual stock. Use is for installations where preheating is not required. Average of 145,000 BTUs per gallon.

Fuel Oil No.-5: A residual oil with some distillate content, but requiring pre-heating. Use is in commercial and industrial oil burners. Sale is by the gallon, tanker or truckload minimum. Average of 150,000 BTUs per gallon

Fuel Oil No.-6: Often called “Bunker C,” this is the heaviest residual fuel, and preheating is required to increase fluidity for handling and to permit atomization for burning. Use is generally in ships and industry for steam generation and process operations. Sale is by the gallon, tanker or truckload minimum. Average of 155,500 BTUs per gallon.

Table 1- Approximate Gravity and Calorific Value of Standard Grades of Fuel Oil

Commercial Standard No.	Approximate Gravity (API)	Weight Pounds per Gallon	Heating Value Range BTU per Gallon
Kerosene	50-42	6.00-6.49	135,550-131,100
1	30-45	6.95-6.67	137,000-132,900
2	30-45	7.21-6.87	141,000-135,800
4	12-32	8.22-7.21	153,300-140,600
5	8-20	8.45-7.78	155,900-148,100
6	6-18	8.57-7.88	157,300-149,400

Standard Specification for Fuel Oils/Diesel Fuels
SEE: ASTM D396, D3699 & D975
TYPICAL SPECIFICATIONS

	Kerosene #1	No. 2 Fuel Oil	No. 2 HYW. Diesel Fuel	No. 6 Fuel Oil
Gravity-API	42.8	33.5	35.3	8.4
Flash Point °F (min.)	100°	100°	125°	140°
Viscosity-CS @ 104 °F (min.)	1.0	1.9	1.9	
Pour Point °F (max)	-15°	21°	0°	60°
Viscosity-CS @ 212 °F				15
Sediment & Water, Vol. %	0.001	0.05	0.05	2.00
Ash, wt.% (max)			.01	0.053
Sulfur, vol% Ultra Low Sulfur Grades	400 ppm 15 ppm	5000 ppm 15 ppm	15 ppm	2.00
Heat of Combustion, BTU/Gallon	134,200	139,500	138,400	155,500

No. 2 Fuel Oil begins to form wax crystals upon a 24 hour exposure to a temperature of 15ºF.

HEATING VALUES-BTU CONTENTS of VARIOUS FUELS. The chart below compares the various forms of heating fuels in terms of British Thermal Units (BTU). Each fuel type is compared to the other fuel types in two ways. How many of the fuels measured units does it take to make 1 million BTUs, and how each fuel units does it take to make another fuel type. For example, consider # 2 fuel oil; 1 gallon of #2 fuel oil holds as many BTUs as approximately 1.167 gals of gasoline, 1.04 gallons of # 1 kerosene, 0.900 gals. of # 6 fuel oil, 1.53 gallons of propane, 1.4 therms of natural gas, 41.02 Kilowatts of electricity, and 0.0043 cords of dry oak wood (approximately 1/2 stick of 6 inch dia. 4.0 ft. long fire wood). It would also take 7.14 gallons of # 2 fuel oil to equal 1 million BTUs.

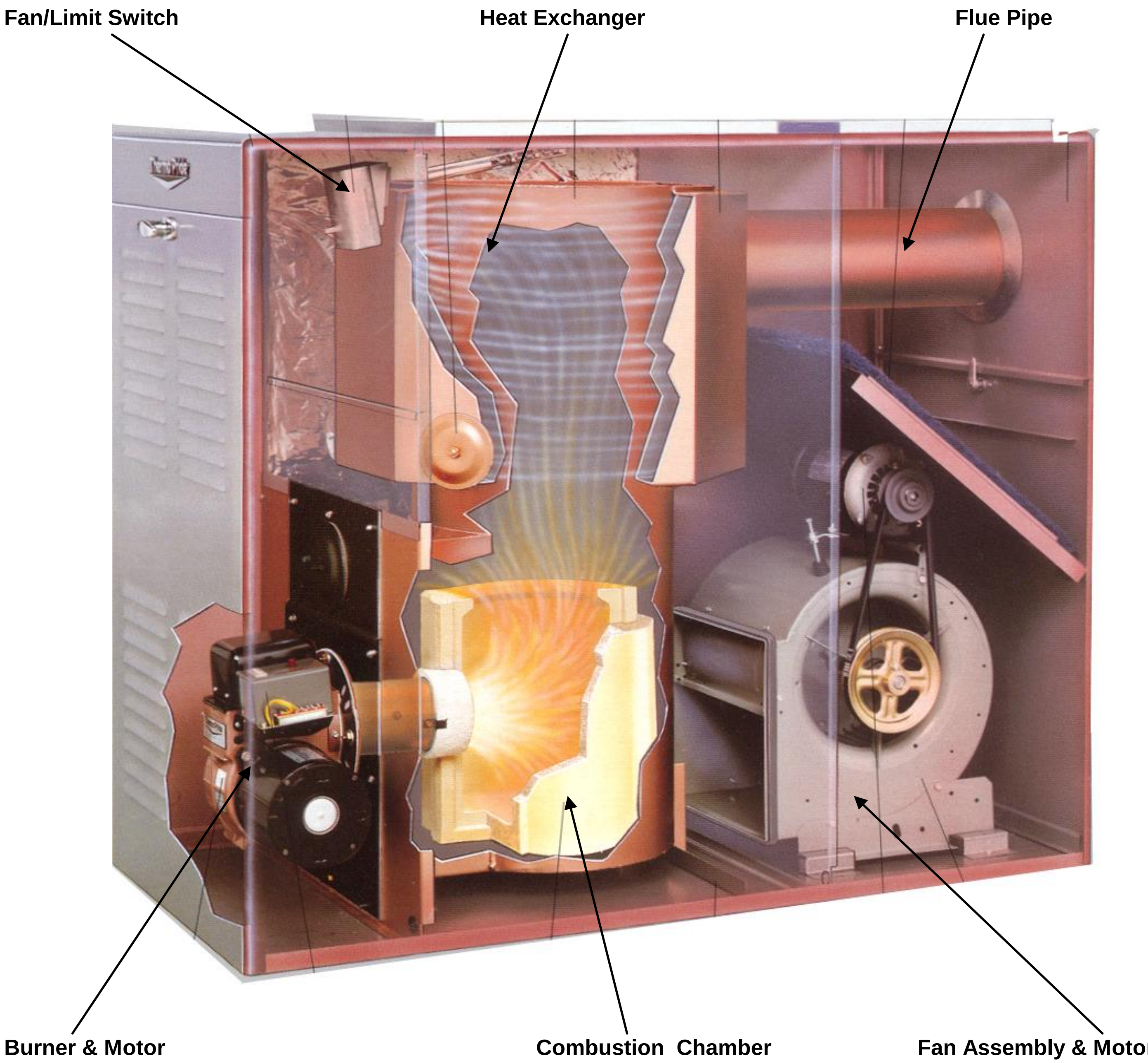
The chart does not take into consideration how efficient the fuel would be burned or how much heat would be transferred to the area to be heated. For consideration purposes, most fossil fuel furnaces would have an 80% efficiency, electric strip elements at 100%, fireplaces at 0 to 10% efficiency, and heat pumps at the theoretical 200% range.

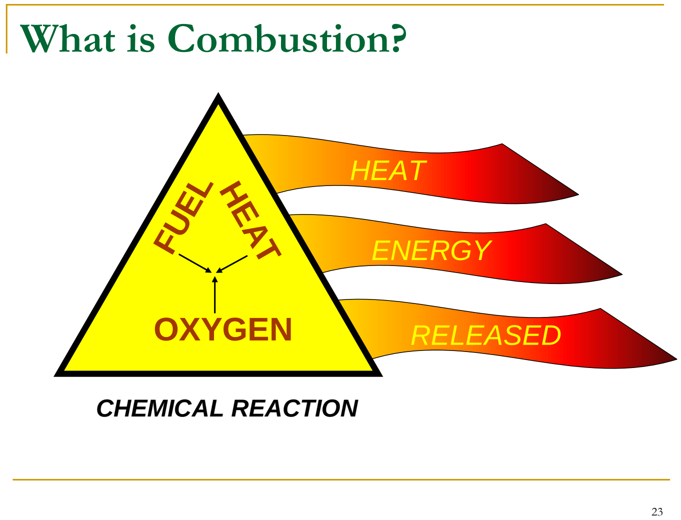
FUEL TYPE	1.00 million BTUs	Gasoline gal.	#2 Fuel Oil/gal.	#1 Kero gal.	#6 Fuel Oil/gal.	Propane gal.	Natural Gas Therm	Electric KWH	Wood (Oak) cord
1gal. Gasoline @ 120,000 BTUs (summertime)	8.33	1.00	.8571	.8889	.7717	1.31	1.20	35.16	.0037
1 gal. #2 Fuel Oil @ 140,000 BTUs	7.14	1.167	1.00	1.04	.9000	1.53	1.40	41.02	.0043
1 gal Kerosene @ 135,000 BTUs	7.41	1.125	.964	1.00	.868	1.475	1.35	39.55	.0042
1 gal. #6 Fuel Oil @ 155,500 BTUs	6.43	1.296	1.111	1.152	1.00	1.70	1.55	45.56	.0048
1 gal. Propane @ 91,500 BTUs	10.93	.763	.654	.678	.588	1.00	.915	26.81	.0028
1 Therm of Natural Gas @ 100,000 BTUs	10.00	.833	.714	.741	.643	1.09	1.00	29.30	.0031
1 Kilo Watt Hour Ele. @ 3,413 BTUs	293.0	.0284	.0244	.0253	.0220	.0373	.0341	1.00	.00011
1 Cord dry Oak Wood @ 32,500,000 BTUs	.0308	270.8	232.1	240.7	209.0	355.2	325.0	9,522	1.00

GRAVITIES, DENSITIES AND HEATS OF COMBUSTION OF FUEL OILS
VALVES FOR 10 TO 49 DEG. API, INCLUSIVE, REPRINTED FROM BUREAU OF STANDARDS MISCELLANEOUS PUB. NO. 97 "THERMAL PROPERTIES OF PETROLEUM PRODUCTS"
(FIGURE-2)

Gravity at 60/60 °F	Density at 60 °F	Total Heat of Combustion (At Constant Volume)			
DEG. API	Specific Gravity	LB per Gallon	BTU per Pound	BTU per Gallon	CAL. per Gram
5	1.0366	8.643	18,250	157,700	10,140
6	1.0291	8.580	18,330	157,300	10,180
7	1.0217	8.518	18,390	156,600	10,210
8	1.0143	8.457	18,440	155,900	10,240
9	1.007	8.397	18,490	155,300	10,270
10	1.000	8.337	18,540	154,600	10,300
11	0.9930	8.279	18,590	153,900	10,330
12	0.9861	8.221	18,640	153,300	10,360
13	0.9792	8.164	18,690	152,600	10,390
14	0.9725	8.106	18,740	152,000	10,410
15	0.9659	8.058	18,790	151,300	10,440
16	0.9593	7.998	18,840	150,700	10,470
17	0.9529	7.944	18,890	150,000	10,490
18	0.9465	7.891	18,930	149,400	10,520
19	0.9402	7.839	18,980	148,800	10,540
20	0.9340	7.787	19,020	148,100	10,570
21	0.9279	7.736	19,060	147,500	10,590
22	0.9218	7.686	19,110	146,800	10,620
23	0.9159	7.636	19,150	146,200	10,640
24	0.9100	7.587	19,190	145,600	10,680
25	0.9042	7.538	19,230	145,000	10,680
26	0.8984	7.490	19,270	144,300	10,710
27	0.8927	7.443	19,310	143,700	10,730
28	0.8871	7.396	19,350	143,100	10,750
29	0.8816	7.350	19,380	142,500	10,770
30	0.8762	7.305	19,420	141,800	10,790
31	0.8708	7.260	19,450	141,200	10,810
32	0.8654	7.215	19,490	140,600	10,830
33	0.8602	7.171	19,520	140,000	10,850
34	0.8550	7.128	19,560	139,400	10,860
35	0.8498	7.085	19,590	138,800	10,880
36	0.8448	7.043	19,620	138,200	10,900
37	0.8398	7.001	19,650	137,600	10,920
38	0.8348	6.960	19,680	137,000	10,940
39	0.8299	6.920	19,720	136,400	10,950
40	0.8251	6.879	19,750	135,800	10,970
41	0.8203	6.839	19,780	135,200	10,990
42	0.8155	6.799	19,810	134,700	11,000
43	0.8109	6.760	19,830	134,100	11,020
44	0.8063	6.722	19,860	133,500	11,030
45	0.8017	6.684	19,890	132,900	11,050
46	0.7972	6.646	19,920	132,400	11,070
47	0.7927	6.609	19,940	131,900	11,080
48	0.7883	6.572	19,970	131,200	11,100
49	0.7839	6.536	20,000	130,700	11,110

Heating Plant Nomenclature





Oil is a complex mixture of compounds containing carbon (C) and hydrogen (H). These two elements must combine with oxygen (0) to burn. A certain theoretical amount of oxygen must be supplied to combine with (burn) all the carbon and hydrogen. For ordinary equipment, oxygen is supplied mixed with nitrogen (ordinary air). Number 2 fuel oil is comprised mainly of 84% carbon and 15% hydrogen along with various other chemicals in small amounts. Air is roughly comprised of 20.9% Oxygen and 79% inert Nitrogen.

<u>For ideal or perfect operation</u>:
Fuel Oil----+-----Air------------burns (equals)------Carbon Dioxide----+-----Water--------+----------Nitrogen
C+H--------+ ---O_2/N_2---------burns (equals)-----------CO_2-------------+-------H_2O---------+--------------N

<u>Actual operation</u>:
Fuel Oil--+--Air (EXCESS)---burns (equals)---Carbon Dioxide--+--Water--+---Nitrogen---+--Unused O_2
C+H--------+-------O_2/N_2---------burns (equals)----------CO_2------------+-----H_2O---+------N---------+------O_2

Since practical equipment is not perfect, it cannot match every atom of oxygen with corresponding carbon and hydrogen atoms. To insure that all carbon and hydrogen atoms find available oxygen atoms, excess air must be fed so that some oxygen will go through combustion process unused and appear in the products of combustion. See above.

Since all fuels burn as a vapor, it is important to either convert the liquid fuel to a gas in the burner or else divide it into such small particles or droplets that heat within the combustion zone of the boiler or furnace will vaporize the fuel during its residence time in the flame zone.

While gasification of the fuel is important, it is equally important to create enough turbulence between the incoming air and fuel to assure complete mixing and therefore, complete, smoke-free combustion.

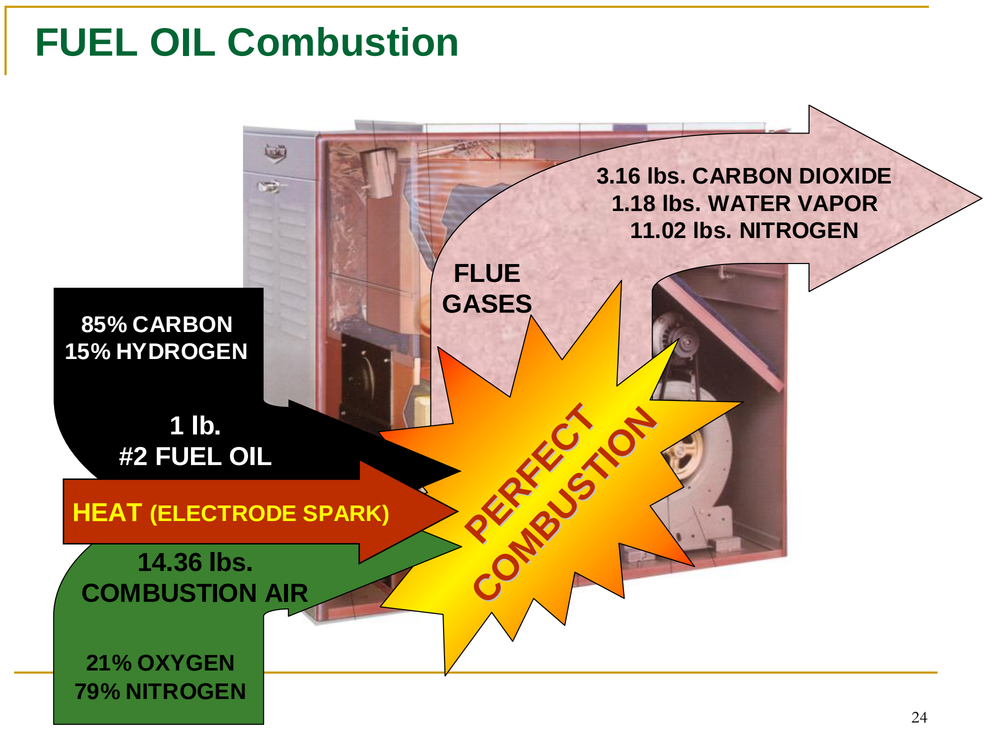
To have combustion, three factors must be present; <u>fuel, air, and heat</u>. During the ignition period, heat is provided by the ignition system. On the lighter grades of oil, direct electrical spark is used. A step up transformer with a 10,000 volt secondary is used to provide sufficient voltage for ignition of the flame. Igniters are now coming online to produce voltages in the neighborhood of 14,000 volts. If the flame is too cool, incomplete combustion will result. This cooling of the flame can occur when the relationship between the combustion chamber and the flame is incorrect. Chambers that are too small or too large can produce this condition. This incomplete combustion will result in smoke emission and wasted fuel. Oil burns like an onion peels so that it is necessary to have sufficient air present to complete the combustion of each successive layer as it forms. Consequently, mixing of the air and oil is as important as having a sufficient quantity of oil and air present.

Figure 4 on page 7 can be broken down in the following manner for TYPICAL ACTUAL combustion conditions. To burn 1 gallon of oil that weights 7.17 pounds, it would take 154.44 pounds of air or 2,059.22 cubic feet. The combustion process would produce about 8.64 pounds of water which is little over a gallon. It would produce approximately 22.66 pounds of Carbon Dioxide. Approximately 130.42 pounds of Air would go through the process essentially unaffected chemically. It would also produce small amounts of trace gases such as Carbon Monoxide, Nitrogen Oxides and Sulfur Oxides. The combustion process with one gallon of fuel oil would produce approximately 140,000 BTUs of heat energy.

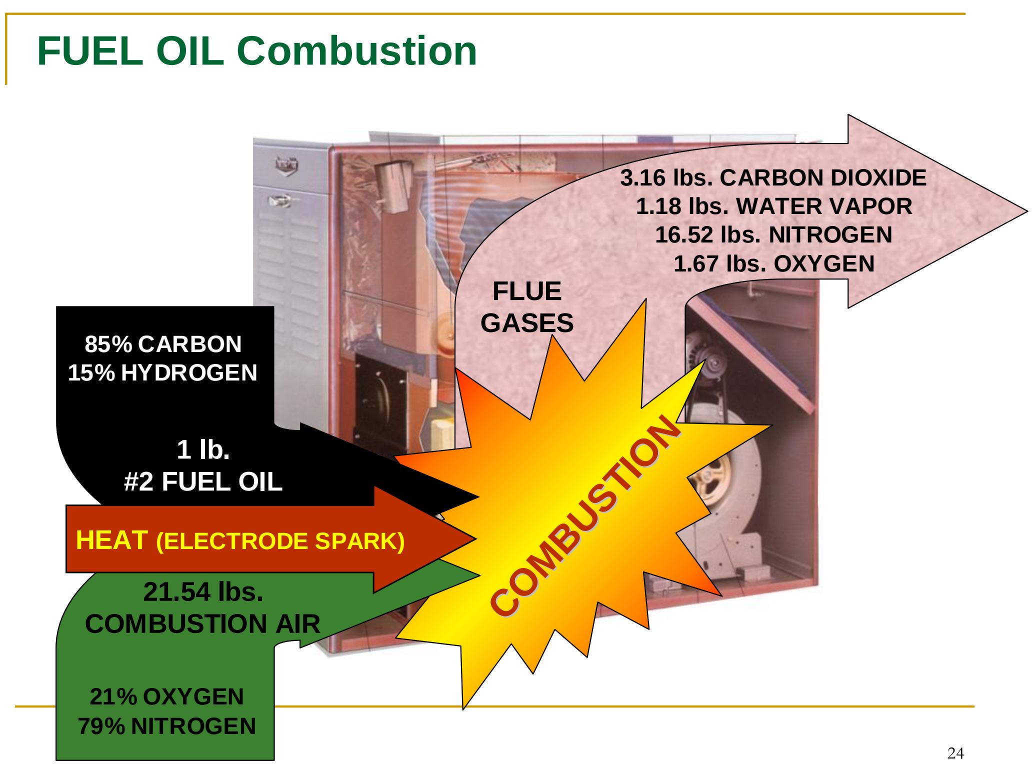
PRODUCTS OF COMBUSTION OF FUEL OIL AND AIR

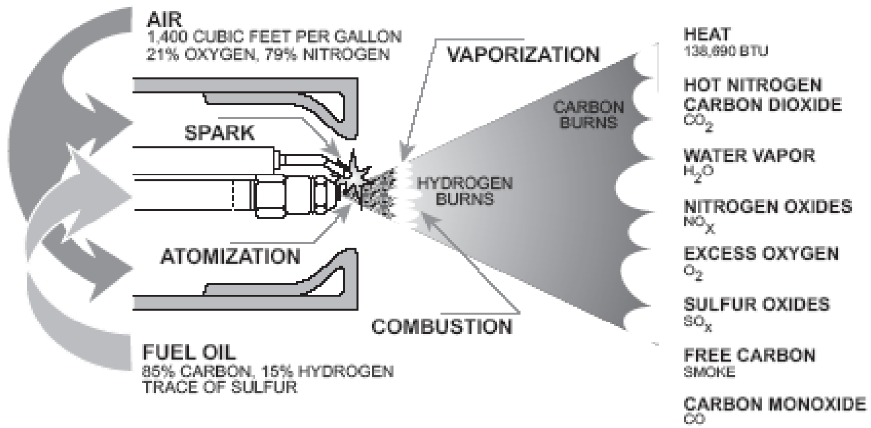
Figure 4

I) THEORETICAL-IDEAL



II) TYPICAL ACTUAL



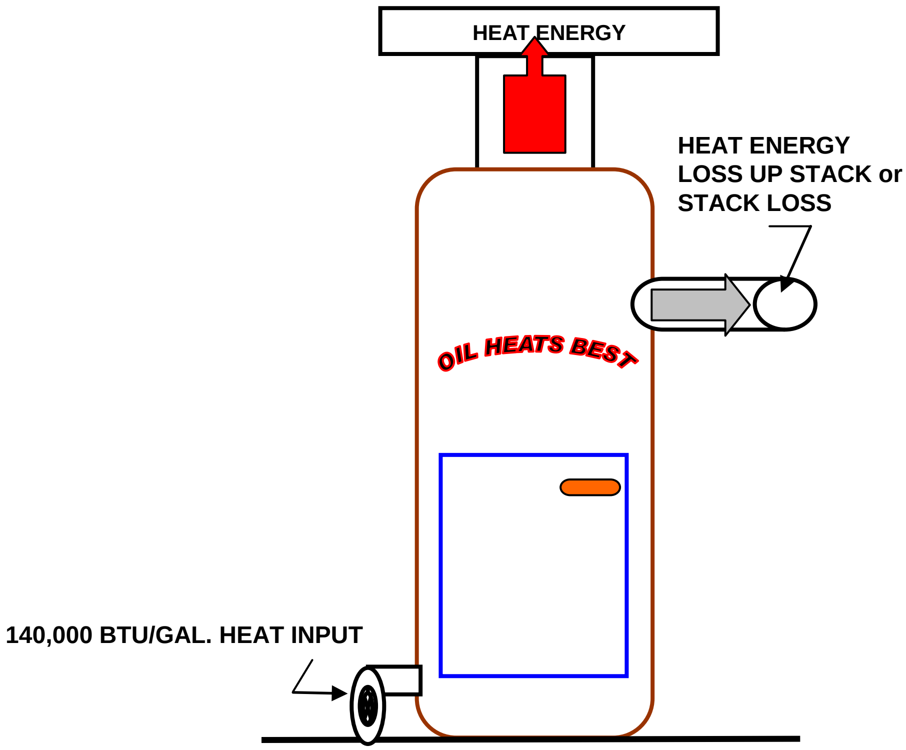


CARBON DIOXIDE & OXYGEN PERCENTAGES IN FLUE GAS VS. EXCESS AIR LEVEL PERCENTAGES

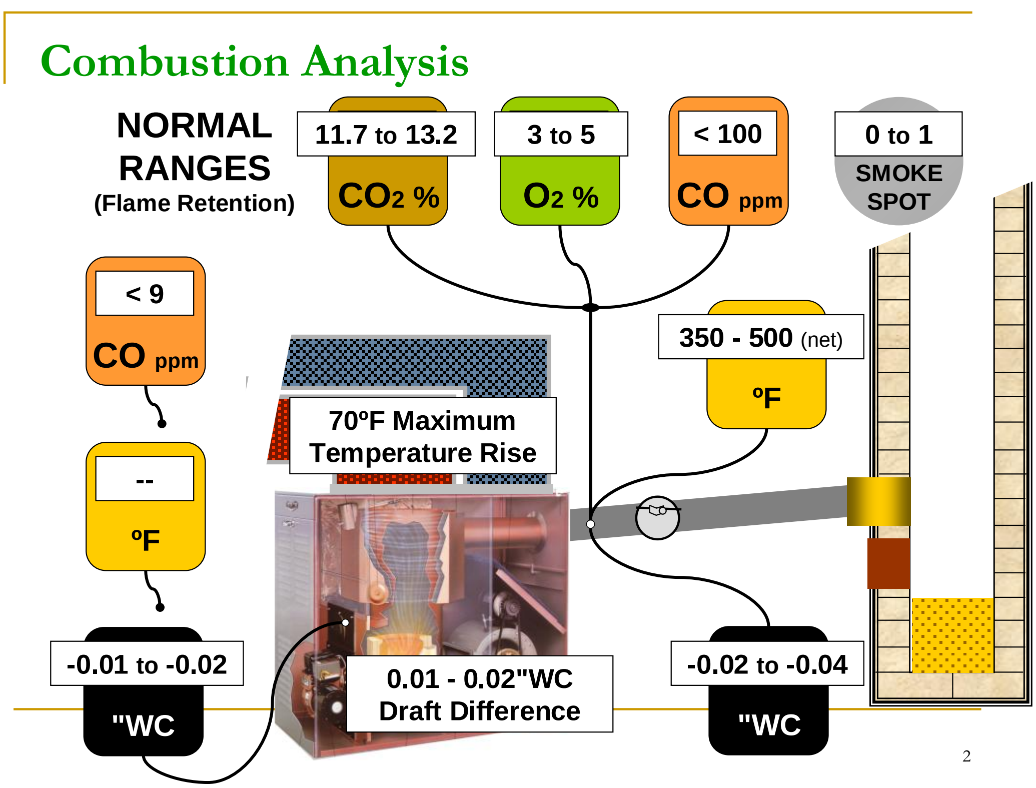
NUMBER 2 OIL			
CO_2 %	O_2 %	EXCESS AIR %	FLAME TEMP. ºF.
5	14	210	1900
5.5	13.4	182	
6	12.8	155	2020
6.5	12.4	137	
7	11.4	120	2180
7.5	10.8	105	
8	10.0	91	2300
8.5	9.5	80	
9	8.7	70	2420
9.5	8.0	61	
10.0	7.4	53	2560
10.5	6.7	46	
11.0	6.0	40	2700
11.5	5.4	33	
12.0	4.8	27	2820
12.5	4.0	20	
13.0	3.4	16	2960
13.5	2.7	13	
14.0	2.0	9	3036
14.5	1.3	5	
15.0	.6	2	3200

DISTRIBUTION OF HEAT AS DETERMINED BY THE STACK LOSS METHOD

(Figure 5)



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



TESTING & ADJUSTING OIL BURNING OPERATIONS

The correct observation and diagnosis of oil burner combustion quality is not possible without proper equipment, and the need for such equipment and skill is a major significance in present day oil heat promotion. The Combustion Test Kits now come in the old manual style or the newer electronic versions. The electronic version can do carbon monoxide reading as well as instantaneous combustion reading. The electronic test analyzers only require the push of a button. Correct use of manual/electronic combustion analyzing instruments is mandatory and will conform to the following procedure:

a. **Set primary air shutter for the best appearing yellow flame without odor or smoky tips. In equipment you cannot see the Flame you should observe the flue pipe exhaust. Operate combustion until steady-state conditions of draft and flue gas temperature have been reached. Usually in five minutes; flue gas temperature should rise 100 degrees per minute and level off around 500 -550 degrees.**

b. **Using a good draft gauge, adjust draft regulator for the desired, stable reading as prescribed by the manufacturer. Until this requirement is performed, no further testing and adjustment is valid. Normally a minimum over-fire draft is -0.0l" to -0.02" water column.**

c. **Using a smoke-tester, make several tests with alternating primary air adjustments until smoke readings (Bacharach-Shell Scale) gradually diminish and barely reach Number 0 without additional excess air.**

d. **Make a test of the carbon dioxide (C02) or oxygen (02) percentage in the flue gas. The desired C02 reading is 10 percent, minimum (with no smoke). Low C02 or high 02 percentages mean lower efficiency, indicating excessive air being fed to the fire-box or secondary flue passages. Causes of excessive air dilution of flue gases could be;**

    -Excessive primary air
    -Poor atomization (requiring excessive primary air).
    -Poor match of nozzle and burner air-spray patterns, usually the wrong nozzle.
    -Poor combustion chamber design or condition, inadequate height.
    -Excessive leaks around burner tube, inspection door.

e. **After the lowest possible percentage 02 (or highest percentage C02) (with no smoke) has been obtained, a final reading of flue gas temperatures at the furnace/boiler flue outlet is necessary to complete the thermal combustion efficiency test. If draft adjustment is correct and firing rate is correct, excessive flue gas temperature indicates too much primary air or the presence of insulating deposits (soot and scale) on the heat exchanger surfaces. Very low stack temperatures could indicate excessive under firing, and flue condensation could result (acid). The following tables (page 12) of combustion efficiency percentages are functions of C02 or 02 percentage and flue gas temperatures.**

COMBUSTION TESTS
(CONFIDENTIAL INFORMATION)

Name:____

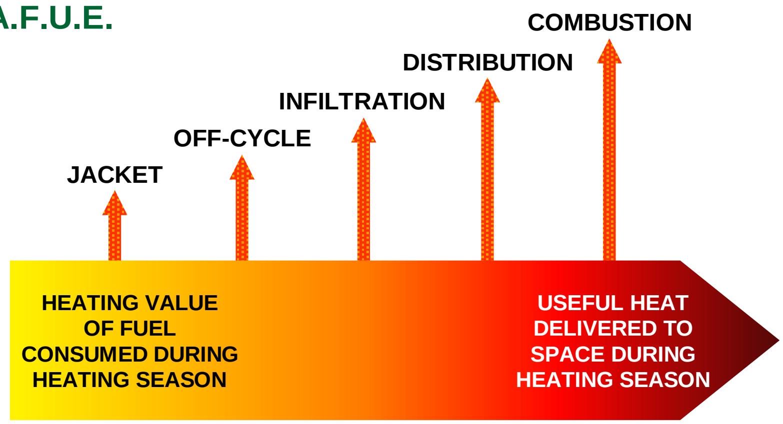
Address:____

PHONE: ____

	Before	Improved
Date		
Nozzle		
Draft, Over-fire		
Smoke Number		
C02 Percent (or 02)		
Net Stack Temperature		
EFFICIENCY	%	%

Recommended Improvements and Retrofits:

FUEL OIL Combustion Manual
A.F.U.E.



ANNUAL FUEL UTILIZATION EFFICIENCY
(Includes All Heat Losses Associated With Equipment Operation)

4

Improvement Cost	**Annual Fuel Saving**	**Pay-Back Time**
$_________approx.	**$__________approx.**	**$__________approx.**

Company:____

Address:____

Telephone:____

Technician:____

NO. 2 FUEL OIL EFFICIENCY TABLES

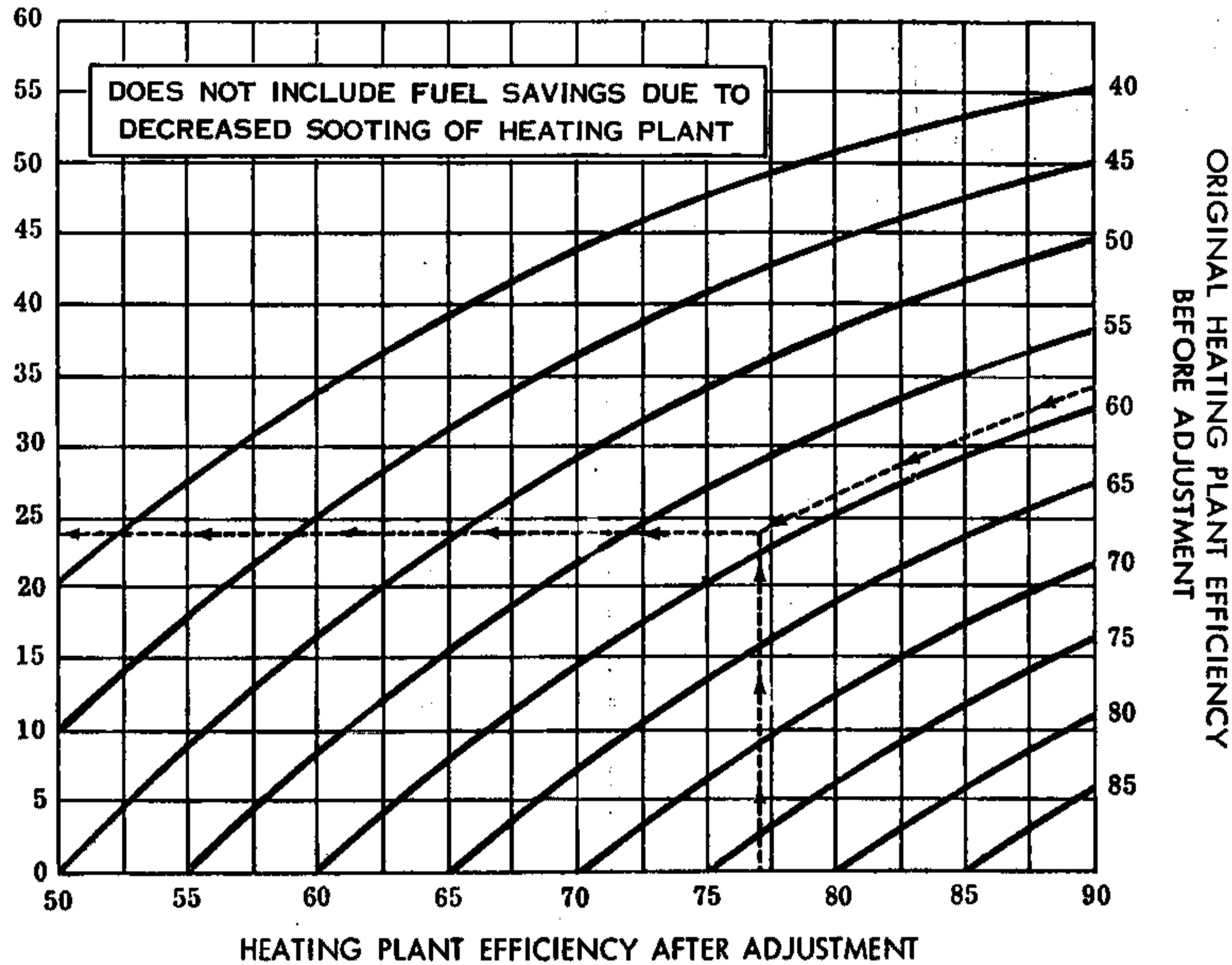
NET STACK TEMPERATURE ºF

%02	200	250	300	350	400	450	500	550	600	650	700	750	800	%CO2
1	89.6	88.4	87.3	86.2	85.1	84.0	82.9	81.7	80.6	79.5	78.4	77.3	76.2	14.7
2	89.4	88.2	87.0	85.9	84.7	83.6	82.4	81.2	80.1	78.9	77.7	76.6	75.4	14.0
3	89.2	87.9	86.7	85.5	84.3	83.1	81.9	80.7	79.4	78.2	77.0	75.8	74.6	13.2
4	88.9	87.7	86.4	85.1	83.8	82.6	81.3	80.0	78.7	77.5	76.2	74.9	73.6	12.5
5	88.7	87.3	86.0	84.6	83.3	82.0	80.6	79.3	77.9	76.6	75.3	73.9	72.6	11.7
6	88.4	87.0	85.5	84.1	82.7	81.3	79.9	78.5	77.0	75.6	74.2	72.8	71.4	11.0
7	88.0	86.5	85.0	83.5	82.0	80.5	79.0	77.5	76.0	74.5	73.0	71.5	70.0	10.3

NET STACK TEMPERATURE ºF

%CO2	300	350	400	450	500	550	600	650	700	750	800	850	900
15.0	87.5	86.5	85.25	84.25	84.25	82.0	81.0	79.75	78.75	77.5	76.5	75.5	74.25
14.5	87.5	86.25	85.0	84.0	83.0	81.75	80.75	79.25	78.5	77.25	76.0	75.0	73.75
14.0	87.25	86.0	84.75	83.75	82.75	81.5	80.25	79.0	78.0	76.75	75.5	74.5	73.0
13.5	87.0	85.75	84.5	83.5	82.5	81.25	80.0	78.75	77.5	76.25	75.25	74.0	72.25
13.0	86.75	85.5	84.25	83.25	82.0	80.75	79.5	78.25	77.0	75.75	74.5	73.5	71.75
12.5	86.5	85.25	84.0	83.0	81.5	80.25	79.0	77.75	76.5	75.25	73.75	72.75	71.0
12.0	86.25	85.0	83.75	82.5	81.25	79.75	78.5	77.25	75.75	74.5	73.0	71.5	70.25
11.5	86.0	84.75	83.5	82.0	80.75	79.25	78.0	76.5	75.25	73.75	72.25	70.75	69.5
11.0	85.75	84.5	83.0	81.5	80.25	78.75	77.25	75.75	74.5	73.0	71.5	70.0	68.5
10.5	85.5	84.0	82.5	81.0	79.5	78.0	76.5	75.0	73.75	72.0	70.5	69.0	67.5
10.0	85.0	83.5	82.0	80.5	78.75	77.25	75.75	74.25	72.75	71.0	69.5	68.0	66.25
9.5	84.5	83.0	81.5	79.75	78.0	76.5	75.0	73.25	71.75	70.0	68.25	66.75	65.0
9.0	84.0	82.25	80.75	79.0	77.25	75.75	74.0	72.25	70.75	68.75	67.0	65.25	63.5
8.5	83.5	81.75	80.0	78.25	76.5	74.75	73.0	71.25	69.5	67.5	65.5	63.75	62.0
8.0	83.0	81.0	79.25	77.5	75.5	73.75	71.75	70.0	68.0	66.0	64.0	62.0	60.0
7.5	82.25	80.25	78.5	76.5	74.5	72.5	70.5	68.5	66.5	64.25	62.25	60.0	58.0
7.0	81.5	79.5	77.25	75.25	73.25	71.0	69.0	67.0	64.75	62.5	60.25	57.75	55.5
6.5	80.75	78.5	76.25	74.0	71.75	69.5	67.25	65	62.75	60.25	57.75	55.5	53.0
6.0	79.75	77.25	75.0	72.5	70.0	67.75	65.25	62.75	60.25	57.5	55.0	52.5	50.0
5.5	78.5	76.0	73.5	71.0	68.0	65.5	63.0	60.25	57.5	54.5	51.75	49.0	46.5
5.0	77.25	74.5	71.75	69.0	65.75	63.0	60.0	57.0	54.0	51.0	48.0	45.5	42.75
4.5	75.5	72.5	69.5	66.25	63.0	60.0	56.75	53.5	50.25	47.0	43.5	40.25	36.75
4.0	73.25	69.25	66.25	62.75	59.25	55.75	52.0	48.5	45.0	41.75	37.5	33.75	30.0

TO DETERMINE PERCENT OF FUEL SAVINGS



HEAT EXCHANGERS

The purpose of the heat exchanges is to transfer *heat* (energy) from the combustion gases to the medium to be heated: air in furnaces or water in boilers. The area of heat transfer surfaces has been determined by the manufacturer so that continuous firing at the input rate designated on the nameplate will not cause a further temperature rise beyond some maximum point. Such a point will depend upon the incoming temperature and flow rate of the heated medium. Heat transfer occurs in two ways with an oil-fired operation:

Radiation from the luminous flame directly to "primary" heating surfaces within sight of the flame.

Convection by hot combustion gases coming in contact with "secondary" heat transfer surfaces, mostly out-of-sight from the flame.

A perfect heat exchanger would transfer all heat generated by combustion to the customer except that required to raise combustion air to indoor temperature from outdoor temperature. However, practicality and economics in heat exchanger design limit heat absorption capability in two ways:

1) **Temperature Difference: The greater the temperature difference between flue gases and heated medium, the more heat transferred. Air or water returning to the fired unit at room temperature must be raised above room temperature to transfer any heat, thus the possible difference begins to narrow. Boilers may have minimum temperatures of 150 degrees or more. A hotter flame, such as with a flame-retention oil burner, increases the temperature difference, the heat transfer rate, and results in lowered exit flue gas temperature.**

2) **Contact Time: 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 12 indicates the relationship between excess air and the flame temperature and volume of combustion gases.**

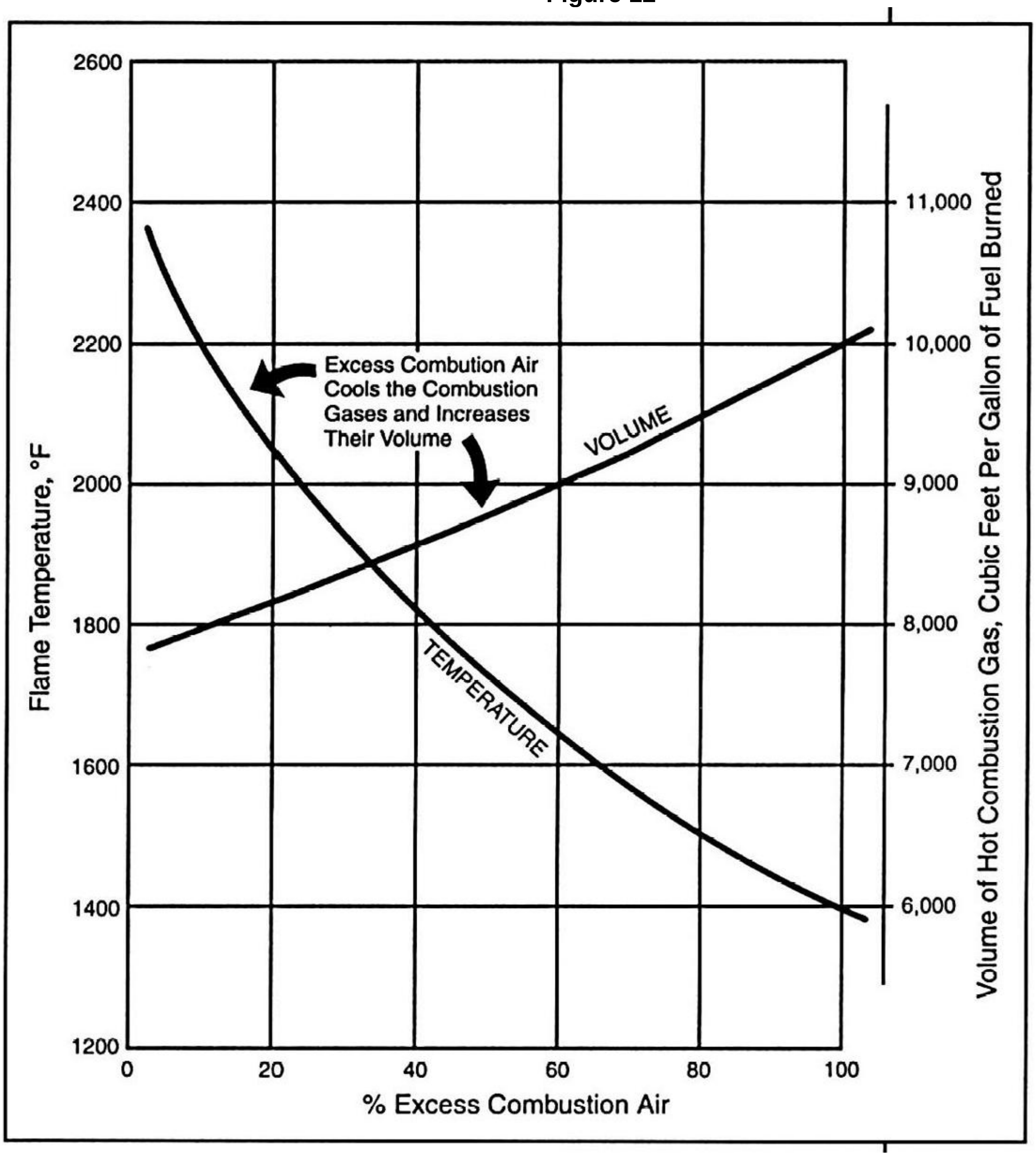
Contamination of the heat exchanger can also limit its transfer capability. Smoke (often called soot) acts as an insulator! Smoke deposits from smoky combustion can collect on the heat exchanger surfaces and reduce the effectiveness of the heat transfer process. Estimates have been made indicating that a 1/8 inch thick coating of soot on heat exchanger walls has the same insulating ability as a 1-inch thick fiberglass sheet.

EXCESS AIR EFFECTS ON HEAT TRANSFER

In the preceding pages, it was emphasized that some excess combustion air above theoretical requirement must be supplied to achieve complete combustion to CO_2 and H2O from oil and air with no unburned oil remaining. The increasing of excess air, however, lowers heat transfer efficiency by:

- **-Absorption of additional heat into the inert nitrogen and unused oxygen which passes to outdoors.**
- **-Dilutes combustion gases, dropping their temperature and thereby decreasing their rate of heat transfer.**
- **-Increases the volume of flue gas which causes a faster travel over the heat transfer surfaces. Thus less heat is transferred and exit flue gas temperature increases.**

Figure 12



DOMESTIC & SMALL COMMERCIAL OIL BURNERS

High pressure, atomizing oil burners are applicable for residential and commercial automatically fired furnaces and boilers designed for oil and include firing capacities up to about 40 g.p.h. Fuel handling components are designed and calibrated for Number 2 Fuel Oil at standard conditions (100°F., viscosity 35ssu or 2.7 cs). The basic functions of an oil burner are:

- **Transport oil from remote storage as required**
- **Supply the correct oil feed rate**
- **Supply the correct air feed rate**
- **Prepare oil and air for combustion by initiating mixing process**
- **Provide ignition of the oil on initial start-up**

The oil burner can be described as having four systems:

1. **Power System: Fractional H.P. Motor, Flexible Coupling.**
2. **Fuel Handling System: Fuel pump, oil tubing, nozzle & adapter.**
3. **Air Handling System: Centrifugal blower & inlet adjustments, electrode support, end cone assembly.**
4. **Ignition System: Ignition transformer, hi-voltage leads, insulators, and ARC-tips.**

Page 17 describes cutaway view and main parts of a typical oil burner.

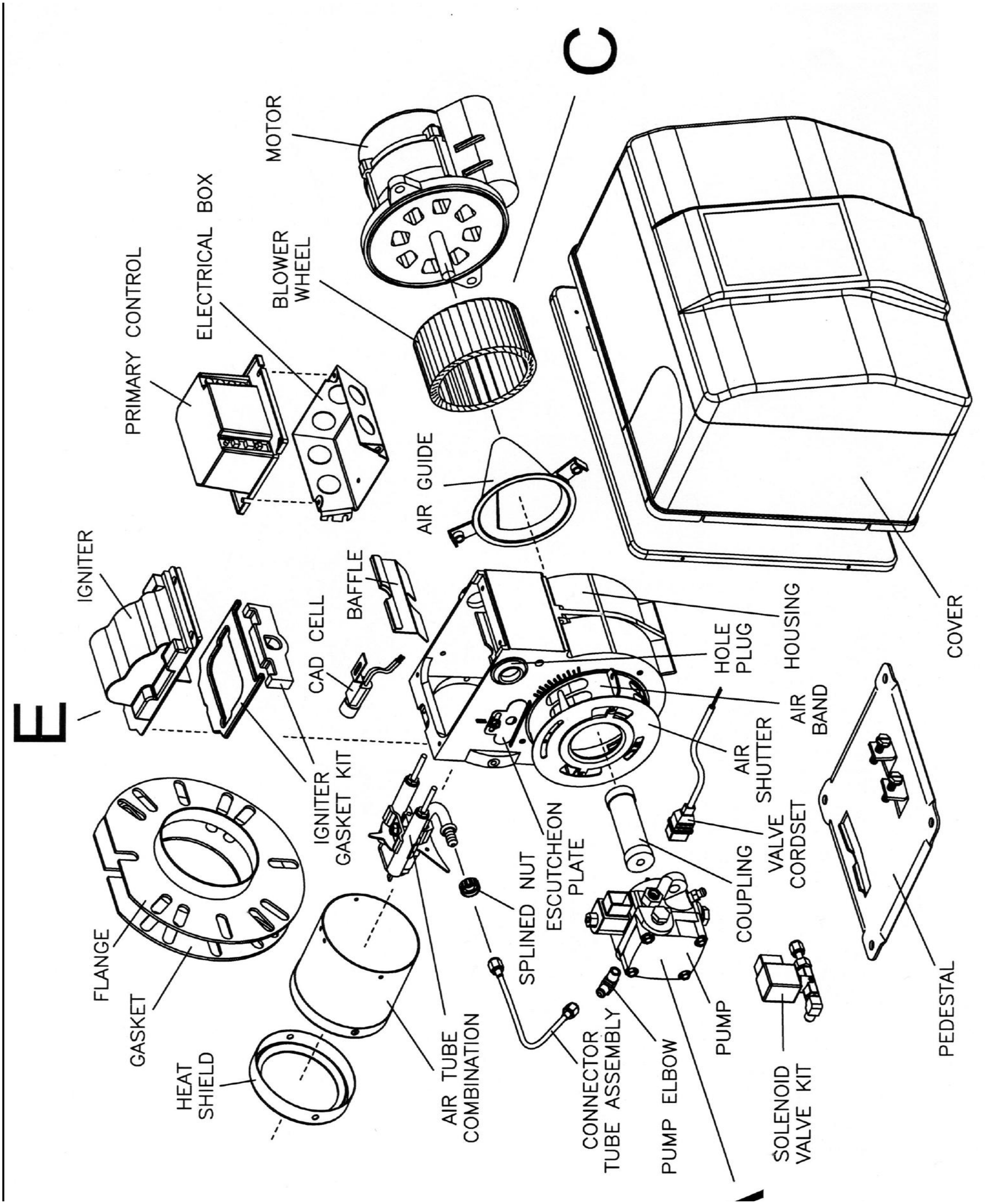
<u>Cold oil and cold combustion air together can sometimes cause problems</u>. The heavy, cold oil droplets are carried away from the burner head by cold excess oxygen. The increase in oxygen can be offset by the increase in flow rate of cold oil, but cold oil is usually the predominant factor. The combination of cold air and cold oil can lead to delayed ignition, impaired flame retention, or a smoky fire due to larger oil droplets and flame envelopes.

To eliminate or minimize the impact of cold oil on burner performance, consider the following steps:

1. **Move aboveground tanks inside, or bury tanks below the ground frost line, insulate supply lines.**
2. **Apply heat tape to supply lines, but only if suited to the application and local building and electrical codes allow.**
3. **Add fuel oil treatment to the fuel supply in order to lower the cloud and pour points. Consult your oil heating distributor for local recommendations.**
4. **Use a one-pipe supply line if possible (oil is warmed in the fuel pump due to internal re-circulation).**
5. **Raise pump pressure from 100 psi to 140 psi. In most cases, this will provide better atomization, but will also raise the firing rate so the next smaller nozzle size should be used. If this is done, attach a tag to the pump showing the new pressure setting so the next serviceman will be advised.**
6. **Nozzle line heaters can be used to improve performance by ensuring a start with warmed oil.**

The impact of cold air on burner performance is not as great as that of cold oil, but the following should be kept in mind:

1. **Chimney draft will be greater in cold winter weather than in mild weather when many systems are given pre-season check-ups.**
2. **If suitable for the application, consider a concentric-flue arrangement (such as used in mobile homes) to pre-warm the outside combustion air.**
3. **Obtain a trace of smoke at steady state operation; then measure CO2 or O2 and increase the burner air setting in order to lower the CO2 by approximately 2 percentage points or raise the Oxygen by approximately 3 percentage points at a zero smoke level. Remember, with direct outside combustion air intake, excessive combustion air at the time of burner set-up may lead to ignition or retention problems in cold weather. Finally, always use combustion test instruments to make adjustments when you install or service a burner.**



E
C
MOTOR
ELECTRICAL BOX
PRIMARY CONTROL
BLOWER WHEEL
AIR GUIDE
IGNITER
BAFFLE
CAD CELL
IGNITER GASKET KIT
HOUSING
HOLE PLUG
AIR BAND
AIR SHUTTER
ESCUTCHEON PLATE
SPLINED NUT
VALVE CORDSET
COUPLING
COVER
FLANGE
GASKET
HEAT SHIELD
AIR TUBE COMBINATION
CONNECTOR TUBE ASSEMBLY
PUMP ELBOW
PUMP
SOLENOID VALVE KIT
PEDESTAL

ELECTRONIC IGNITORS & TRANSFORMERS

IGNITORS:

During the last decade, you may have noticed an increase in the number of applications that use electronic or “solid state” ignitors. Electronic ignitors have proven to be durable, effective ignition components. Electronic ignitors are mounted on a burner housing base plate similar to that of a transformer.

They are smaller (1/4 to 1/2 the size) and weigh less than a transformer (1 lb. compared to 8 lb.) and have oil ignition characteristics similar to that of a transformer. Industry contends that electronic ignitors offer improved performance with cold oil or delayed spark conditions and consume 75 percent less power than transformers.

Other characteristics of electronic ignitors include:

- **Have output currents and peak voltages that can be up to double that of iron core transformers;**
- **Produce a spark intensity that can be less sensitive to line voltage fluctuations; and**
- **Are epoxy sealed for moisture resistance and non-rusting plastic enclosures.**

Electronic ignitors receive 120 VAC and change it to DC (Direct Current) voltage inside. The DC voltage turns power transistors on and off very quickly, conducting current through the primary coil of its small internal transformer at a frequency of 15,000 to 30,000 Hz. The secondary coil of this special high frequency transformer produces a high voltage ignitor output that has a frequency of 15,000 to 30,000 Hz. Remember: the ability of an ignitor depends on more than just high voltage - it depends on arc out-put current as well! Spark heat energy = voltage x current.

The electronic ignitor does not require extensive maintenance. However, there are areas to consider:

1. **Similar to the iron core transformer, the electronic ignitor must be kept clean and dry. Prolonged exposure to moisture can cause arc tracking and potential failure. Wipe dirt and oil from all surfaces.**
2. **Check insulator bushings and make sure they are clean and free from any crazing or cracks. Replace units that show evidence of damage.**
3. **Examine the ignitor input leads for cuts or tears in the insulation. Route the leads securely so that they are not pinched when the ignitor is closed. Make sure the wire nuts are tight and no bare wires are exposed.**
4. **If the ignitor has gasketing, check the sealing surfaces and replace any suspect gaskets.**
5. **The secondary electrode springs should be clean, should be aligned perpendicular to the ignitor base, and should make solid contact with burner electrode rods when the ignitor is in the closed position. If the springs makes poor contact, the ignition performance could be impaired.**
6. **Perform the following test to check that the ignitor is grounded to the burner. First, turn off the power to the burner.**

The <u>Ohmmeter</u> resistance between an electrode spring and the exposed metal of the burner (for instance, the copper line or a housing bolt) should be less than 2000 Ohms. If this resistance is infinite, the ignitor is not grounded to the burner. This resistance should be the same as the other spring-to-burner resistance, and it should be 1/2 of the spring-to-spring resistance. If the two spring-to-burner resistances differ by more than 20 percent, the ignitor should be replaced.

TRANSFORMERS:

The ignition transformer takes 120 volts AC and transforms it into 10,000 volts AC to ignite the oil droplets. There are a number of ways to test the output voltage of the transformer. The most accurate is to use a voltmeter capable of measuring 10,000 volts. With 120 volts input to the transformer, the output should be approximately 10,000 volts. If below 9,000 volts, the transformer is weak and should be replaced. There are other types of testers that have a scale that indicates whether the transformer is “good” or “bad.” Some use a screwdriver to draw an arc to test the transformer. This is not recommended due to risk of electrical shock. However, if not prolonged, this method should not cause damage.

A wide electrode gap beyond the 1/8” – 5/32” could be a problem. Any gap beyond the specified dimension is not recommended for two reasons. First, exceeding any specification for setup could cause improper operation of the oil burner. Second, as the gap is widened, the high voltage stress on the secondary coil increases and could shorten the life of the transformer.

Excessive moisture can cause problems. Surface moisture on ceramic insulators can cause arcing between terminals or to ground, eventually damaging the transformer. Moisture can also get inside the transformer. This moisture causes internal arcing inside the transformer resulting in damage or early failure. An occasional problem is tar leakage caused by excessive radiant heat from combustion and long-running cycles in high ambient temperatures. With some internal failures, the transformer can also overheat and cause the tar to melt. Transformers will not cause radio and TV interference if properly set up. They are designed with internal shielding to prevent this. But if improperly set up, premature arcing in the ignition system can cause TV interference or decrease the energy needed to ignite the oil. Discoloration of the secondary output terminals indicates a bad connection.

THE EFFECTS OF PRE-PURGE AND POST-PURGE ON OILHEAT BURNERS

Without purge capabilities, burner blowers are turned on at the time the flame is ignited, and turned off when the flame is extinguished. This works well in most cases, but some applications present problems. When a heating system thermostat signals the need for heat, it is desirable to supply it promptly. Any delay in providing heat can cause discomfort for home or building occupants, precipitate nuisance service calls, and have a negative effect on fuel efficiency. To supply heat quickly, the burner flame must ignite instantly and smoothly. It requires adequate airflow (draft) to accomplish this. Typically, when an oil burner has been off for a while, natural draft in the chimney can become neutral. Cold chimneys contain heavy air that must become heated and start to flow upward before draft can occur. There could even be a down draft due to wind gusts. In chimneyless, direct vented systems there may be no draft at all at start up. With power vented systems, draft levels may fluctuate widely. That's where pre-purge is used.

PRE-PURGE

The pre-purge controls currently offered by Burner Manufactures and others as a factory-installed option on most of its models. These burners turn the blower on several seconds before the flame is ignited. This establishes the level of airflow required for fast, smooth ignition. This airflow is already fully established when ignition occurs. The burner doesn't have to "struggle" to achieve ignition under inadequate draft conditions. Another significant factor is the stability and capacity of the ignition arc. The arc should be at full strength and well established when the oil is delivered from the nozzle—otherwise, delayed ignition, noisy pulsation, and smoking can occur under certain adverse conditions. With pre-purge, the arc is allowed to reach its maximum potential, contributing to easier ignition of the oil droplets and producing a cleaner burning flame from the moment of ignition. In addition, the oil pressure level in the pump is stabilized well before the oil solenoid valve opens. Oil is delivered to the nozzle at a steady pressure, for optimum atomization of the fuel.

POST-PURGE

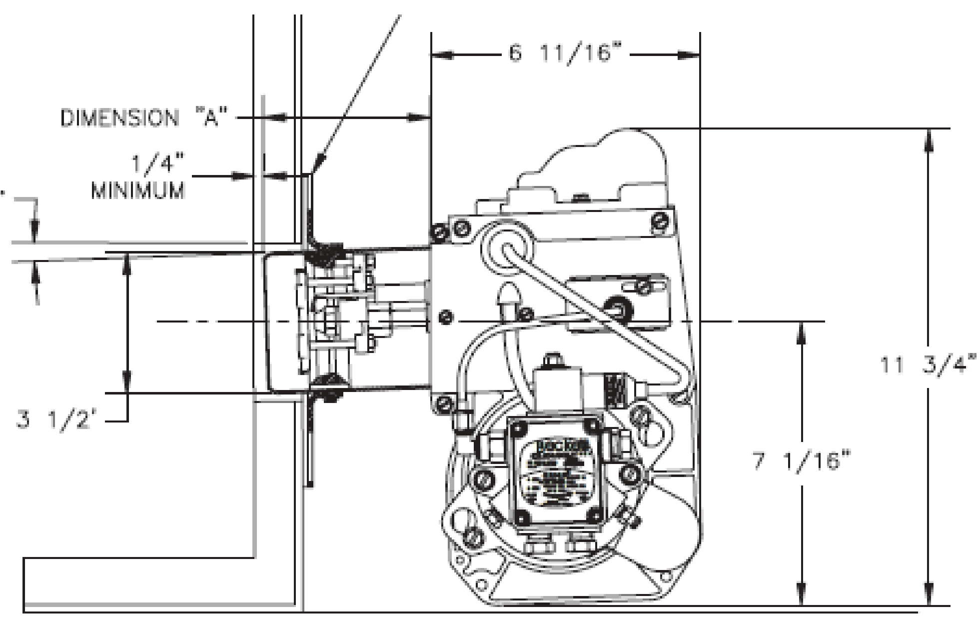
Post-purge is involved with the other end of the burner Cycle. When the desired heat level in the home or building has been achieved, the thermostat calls for burner shut-off, which occurs immediately without post-purge. As a result, combustion gases may still be present in the flue without sufficient airflow to evacuate them. Draft reversals may also occur, forcing flue gases back into the flue pipe and the combustion chamber. This can cause odor problems and/or leaking combustion gases into the home. The heat from the gases can also affect nozzles and other system components. Post-purge keeps the blower operating for a selected period after burner shut-off. Flue gases are evacuated, draft-reversal is eliminated, and nozzles are protected from overheating. Most controls used by Beckett are adjustable to the specific requirements of the heating system. Direct vent systems have created a special application for post-purge capability. With direct venting, the positive air pressure created by the burner blower, is relied on to move combustion gases through the flue and evacuates them from the system. It is vital, therefore, the blower continue to operate for a period of time at the end of each burner cycle. In the past, pre-purge and post-purge capability was obtained for the most part through retrofit installation of optional kits. Now, factory-installed controls provide greater convenience for oilheat service technicians and reduced costs for homeowners.

FLAME RETENTION OIL BURNERS

Beginning about 1952 in commercial burners, and introduced in the late 1960's for residential burners, the Flame Retention concept has proven to be a historic advance in oil burning technology. The Flame Retention Burner is almost universally characterizes the "standard" burner. The FR Burner can produce significant improvements in overall oilheat equipment efficiency while simultaneously reducing the number of burner-related service calls. The combustion head of the FR Burner has a series of radial, and sometimes circular, slots that establish a rotation to the air discharge pattern by their tangential discharge design. High velocity air is forced into the oil spray immediately as it leaves the nozzle, and the resulting quickly formed mixture burns sooner and quicker than the older type of burners. The flame front begins a fraction of an inch from the discharge slots. The resulting flame is smaller, therefore hotter, than a flame from the older burner. The flame sustains its own gasification, mixing, and combustion processes and is not critically dependent on an insulative combustion chamber. The pressure drop is high through the restrictive head and pulsation, including the initial ignition pulse, cannot push into the burner head. Because of simplified combustion chamber design and restricted burner head exposure, nozzle heat damage is diminished. If the burner operates toward the low end of its capacity range, the burner can supply draft requirements also and it becomes a forced-draft burner.

To attain the high air pressure required, the burner motor speed is usually 3450 RPM. The effect of this air handling design is to create better air-oil mixing and contain the flame within the air pattern. This produces a higher flame temperature with less excess air.

Flame retention burners typically operate with higher steady-state efficiencies partly attributable to better oil-air mixing, therefore producing higher CO_2 and requiring less excess air. Also the higher flame temperature improves heat transfer to the heat exchanger thereby lowering flue gas exit temperature.



Flame Retention Burner Combustion and Its Advantages

The Flame Retention Burner mixes atomized oil with air in a manner which produces maximum fuel efficiency and stability. Key to proper mixing is a precision designed one-piece, stainless steel burner head. The head rotates combustion air at velocity directly in front of the burner head in a small concentrated zone. Here the atomized oil is introduced from the nozzle and a controlled, very stable flame front is established. The air-to-fuel ratio is precisely maintained with this approach, resulting in maximum fuel efficiency and minimum waste in the form of pollutants.

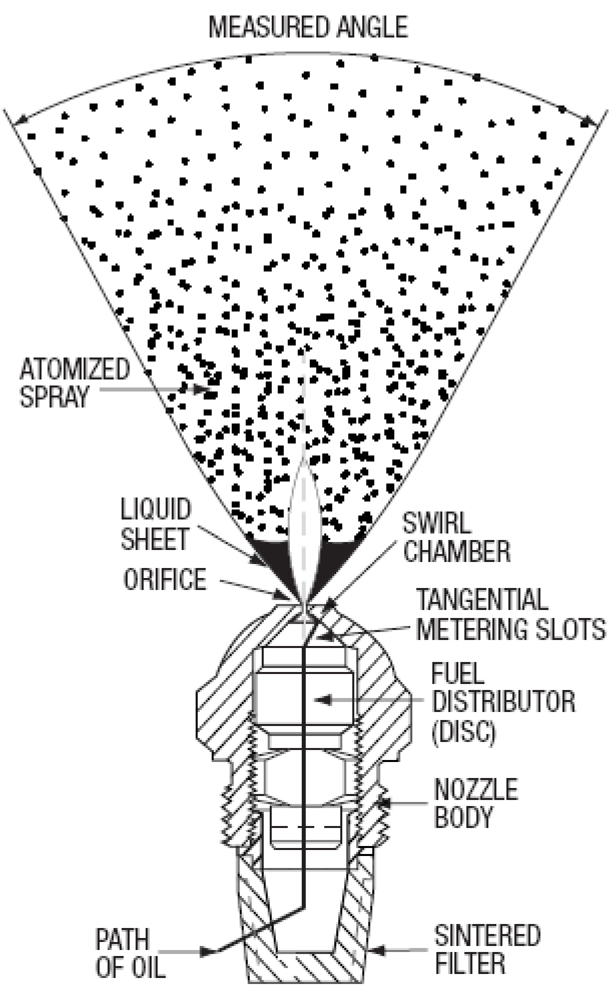
The flame base is ‘locked’ in place approximately 1/8 to 1/4 of an inch beyond the burner head. No target wall or combustion chamber is needed for flame stabilization.

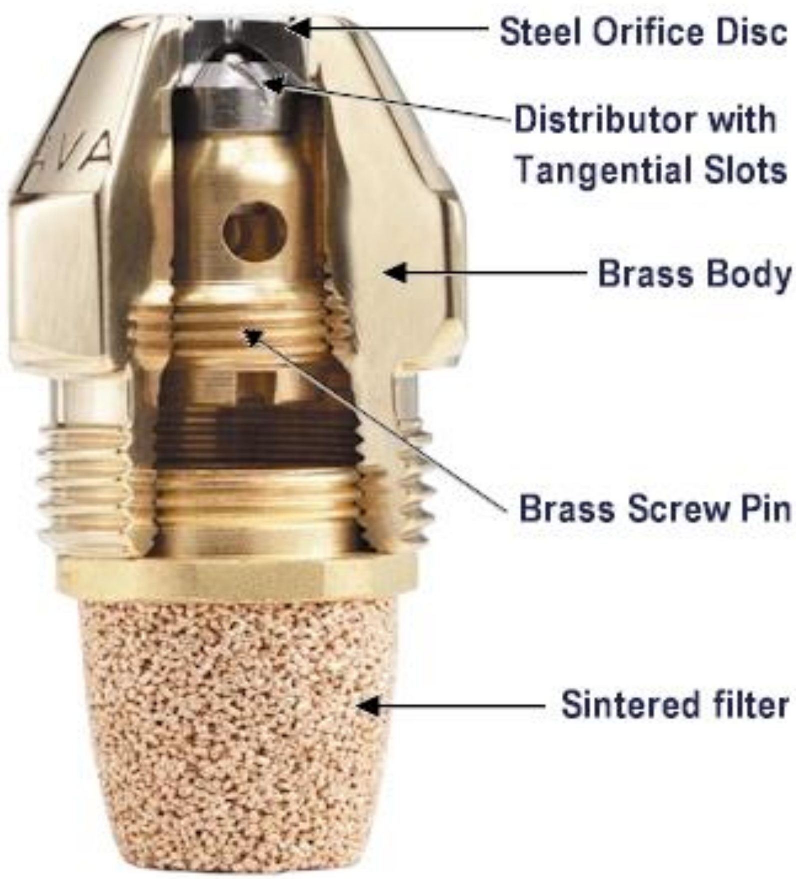
When looking at the manufacturing of an oil burning device, the Flame Retention Burner is a significant improvement over conventional designs:

1. **More energy is produced from the same amount of oil consumed.**
2. **The flame is smaller and more stable than that of an equivalent burner with a conventional head. Pulsation is almost never a problem.**
3. **There is less probability of pulsation or stack draft interference.**
4. **The higher temperature permits a smaller physical unit with no less heat exchange capacity.**
5. **More efficient combustion is obtained with less fuel and no smoke.**
6. **There are fewer products of incomplete combustion to reduce burner efficiency and lead to maintenance.**

NOZZLES

- The nozzle atomizes the oil, provides a pattern of oil spray, and delivers a fixed amount of oil. The flow rate stamped on the nozzle is at 100 psi. Increasing pump pressure will increase the flow rate. Pressure determines droplet size.
- The nozzle creates the flow rate, spray angle, & pattern with the tangential slots, swirl chamber, & orifice.
- Cold oil & other high viscosity problems can be eliminated by: increasing pump pressure & decreasing nozzle size, installing a nozzle line heater, or treating the oil.
- When installing a nozzle you should: work clean, and flush out the nozzle line & adapter.
- Pick a nozzle spray pattern that matches the air-oil mixing design of the burner, and the shape of the chamber. The air-oil mix is the most important efficiency factor.
- Nozzle overheating may be caused by: low draft, air tube sticking too far into the chamber, & a hard brick chamber.
- Increasing the pump pressure will increase the flow rate.
- A poor mix of air and oil is the single biggest cause of low efficiency
- Nozzle overheating causes coking
- Nozzle after drip is caused by defective shut-off valve, air in the line, oil expansion caused by reflected heat





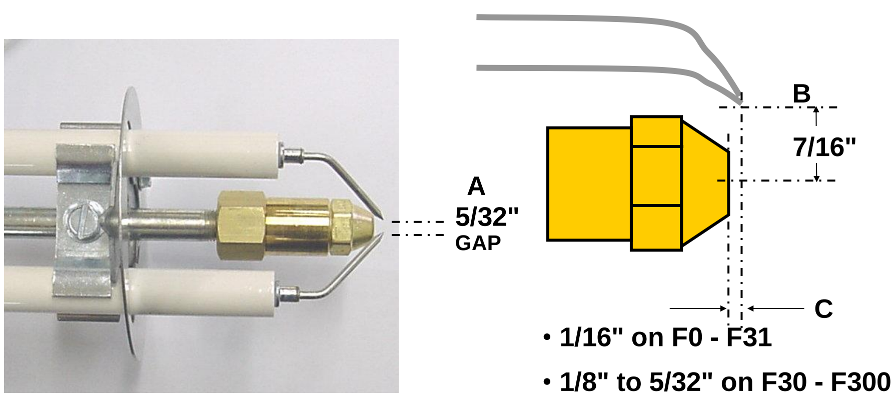
NOZZLE CAPACITIES
U.S. Gallons Per Hour No. 2 Fuel Oil

Rated GPH @ 100 PSI	Operating Pressure: pounds per square inch							
	125	140	150	175	200	250	275	300
.40	.45	.47	.49	.53	.56	.63	.66	.69
.50	.56	.59	.61	.66	.71	.79	.83	.87
.60	.67	.71	.74	.79	.85	.95	1.00	1.04
.65	.73	.77	.80	.86	.92	1.03	1.08	1.13
.75	.84	.89	.92	.99	1.06	1.19	1.24	1.30
.85	.95	1.01	1.04	1.13	1.20	1.34	1.41	1.47
.90	1.01	1.10	1.10	1.19	1.27	1.42	1.49	1.56
1.00	1.12	1.18	1.23	1.32	1.41	1.58	1.56	1,13
1.10	1.23	1.30	1.35	1.46	1.56	1.74	1.82	1.91
1.20	1.34	1.42	1.47	1.59	1.10	1.90	1.99	2.08
1.25	1.39	1.48	1.53	1.65	1.77	1.98	2.07	2.17
1.35	1.51	1.60	1.65	1.79	1.91	2.14	2.24	2.34
1.50	1.88	1.17	1.84	1.98	2.12	2.37	2.49	2.60
1.65	1.84	1.95	2.02	2.18	2.33	2.61	2.73	2.86
1.75	1.96	2.07	2.14	2.32	2.48	2.77	2.90	3.03
2.00	2.24	2.37	2.45	2.65	2.83	3.16	3.32	3.46

RECOMMENDED ELECTRODE SETTING

FUEL OIL Combustion Manual

Electrode Settings BECKETT (F-HEADS)



Nozzle	GPH	A	B	C
45°	(.75 to 4.00)	5/32" to 3/16"	5/16" to 7/16"	1/4" to 5/32"
60°	(.75 to 4.00)	5/32" to 3/16"	7/16"to 5/8"	1/4" to 5/32"
70°	(.75 to 4.00)	5/32" to 3/16"	7/16"to 5/8"	1/8"
80°	(.75 to 4.00)	5/32" to 3/16"	7/16"to 5/8"	1/8"
90°	(.75 to 4.00)	5/32" to 3/16"	7/16"to 5/8"	1/32"

Above 4.00 GPH consult manufactures guide for dimensions. Electrode setting gauges are supplied by oil burner manufactures for easy setting of dimensions. For cold oil and cold air, the smallest setting will work best for smooth ignition.

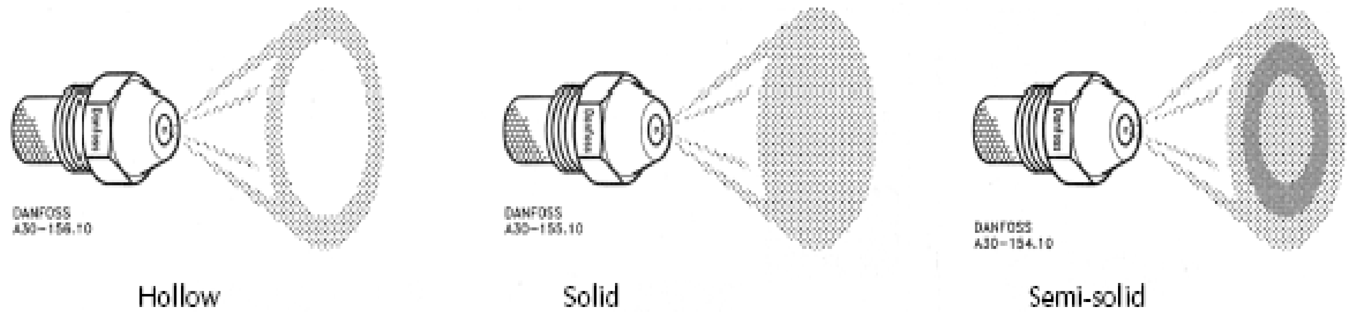


Figure 4-15 Nozzle Spray Patterns

Figure 4-17 Spray Angles

COLDER OIL CAUSES MORE OIL TO FLOW FROM THE TIP OF THE NOZZLE

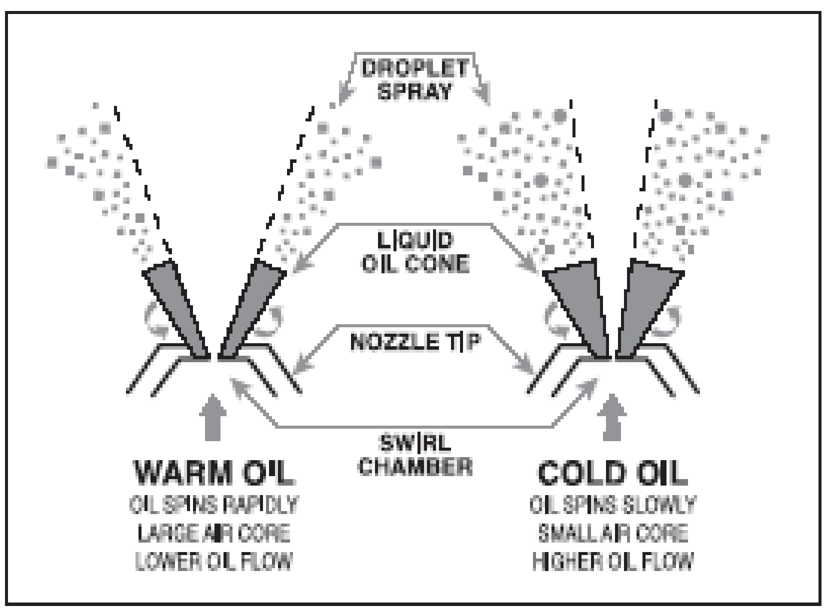


Figure 4-10 Comparison of Warm vs. Cold Oil On Nozzle Flow Rates

HIGHER FLOW RATES WITH COLD OIL

OIL INPUT FIRING RATE

Maximum firing rate depends upon available heat transfer surface and combustion volume to produce a certain design heat output capacity at an optimum thermal efficiency. Under-firing can cause objectionable flue condensation from too low flue gas temperatures. Over-firing shortens equipment life, induces combustion problems, and rapidly reduced operating economy through curtailed thermal efficiency.

Equipment Oil Input Rate = <u>Gross Output BTU/Hour</u>

Oil Heat Content X Steady-State Efficiency = Net Output BTU/Hour

(#2 oil: 140,000 BTUs/gal.; typical AFUE efficiency: 82%)

Page 26, "Standard Oil Nozzles and Gross Output" gives GPH oil rates for various outputs for several combustion efficiencies of No. 2 oil.

Firing Rate Determination & Optimization for Actual Load Requirements

By lengthening burner "on periods," the average steady-state efficiency is increased. Recent DOE test procedures have proven that stand-by losses during burner "off" times are substantial with the older type burner and that reducing the nozzle size substantially increases savings. Most homes in recent years have added insulation thereby certainly reducing the needed furnace capacity and nozzle size.

A procedure has been developed that determines the optimum nozzle size based on the amount of oil consumed and the Degree Days occurring concurrently with the oil consumption. This method relates theoretically to the capacity need of the house, and the burner would operate almost continuously on the coldest days of the year. See page 27 for chart application.

1. **Obtain the Average Winter K-Factor (Degree Days per gallon). Use the average K-Factor, if available, of December, January, and February. Gallonage statistics should be excerpted from the customer's delivery records. The degree-days may be learned from an oil dealer with a degree-day recorder or from the U.S. Weather Bureau. Divide degree days by gallons of No. 2 use in a winter to obtain K-Factor.**
2. **Obtain Outdoor Design Temperature. Typically, Wilmington is 26 degrees, Raleigh is 20 degrees, and Asheville is 14 degrees.**
3. **Calculate "Design Nozzle Size" as follows (also see Page 27):**

   Design Nozzle Size = 1.15 x (70 degrees - DT) / K-factor x 24.

   1.15-Allowance for morning temperature recovery following night set-back.

   70 degrees - assumed average indoor house temperature.

   DT - outdoor winter design temperature, ºF.

   K-Factor = Degree Days per Gallon
   24 = 24 hours per day

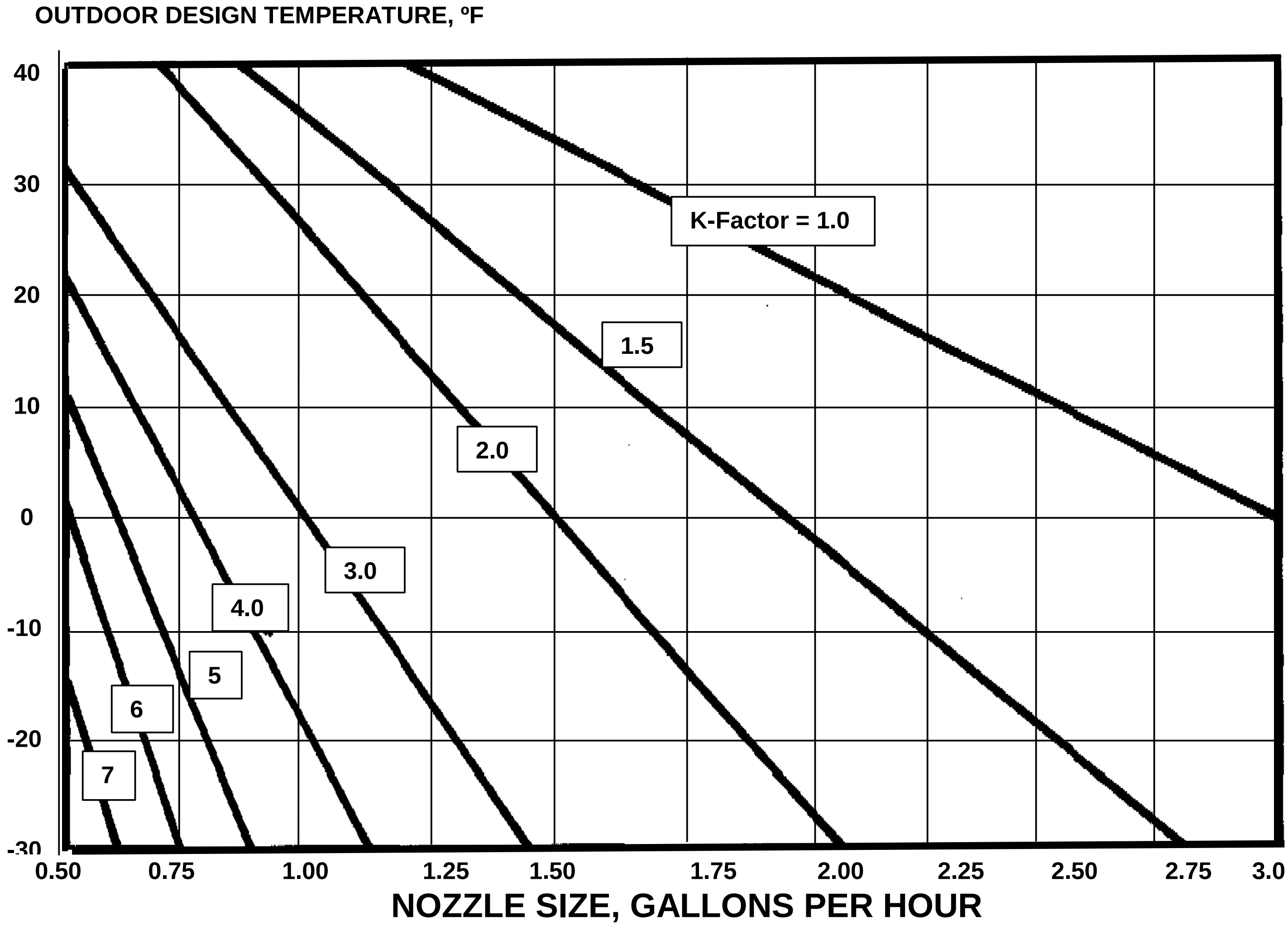
STANDARD OIL NOZZLES AND GROSS OUTPUTS
(Various Combustion Efficiencies)
No. 2 Fuel Oil at 140,000 BTUs/Gallon

NOZZLE SIZE GPH @ 100 PSI	GROSS OUTPUT, BTU/HOUR				
	Combustion Efficiencies in Percent				
	75%	80%	82.5%	85%	87%
.30	31,500	33,600	34,650	35,700	36,540
.40	42,000	44,800	46,200	47,600	48,720
.50	52,500	60,000	61,875	63,750	65,250
.55	57,750	61,600	63,525	65,450	67,000
.60	63,000	67,200	69,300	71,400	73,080
.65	68,250	72,800	75,100	77,350	79,200
.70	73,500	78,400	80,850	83,300	85,250
.75	78,750	84,000	86,600	89,250	91,350
.80	84,000	89,600	92,400	95,200	97,450
.85	89,250	95,200	98,200	101,150	103,530
.90	94,500	100,800	103,950	107,100	109,600
1.00	105,000	112,000	115,500	119,000	121,800
1.10	115,500	123,200	127,050	130,900	134,000
1.25	131,250	140,000	144,400	148,750	152,250
1.30	136,500	145,600	150,150	154,700	158,340
1.35	141,750	151,200	155,900	160,650	164,450
1.40	147,000	156,800	161,700	166,600	170,500
1.50	157,500	168,000	173,250	178,500	182,700
1.65	173,250	184,800	190,600	196,350	201,000
1.75	183,750	196,000	202,100	208,250	213,150
2.00	210,000	224,000	231,000	238,000	243,600

DETERMINATION OF DESIGN NOZZLE SIZE

DESIGN NOZZLE SIZE = 1.15 X (70 - DT° outdoor design) ÷ (K-FACTOR X 24)

This graph may be use instead of the formula to determine optimum nozzle size. Optimum nozzle size would be for a furnace to be on nearly 100% of the time during the coldest day of the year. Nozzles too big for the heating load cause overall system efficiency to suffer. When using the below graph for K-Factors greater than 7, the design nozzle size should be 0.50 gallons per hour. Presently, 0.50 GPH nozzle size is the smallest nozzle size recommend for residential application.



North Carolina-Selected Cities

Heating Degree Day Normal's (Base 65ºF)

Station	JUL	AUG	SEP	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	ANN
Albermarle			6	179	391	667	769	594	402	166	46		3220
Asheboro			11	180	387	676	787	622	417	166	43		3289
Asheville	5	5	64	295	525	791	908	736	546	284	117	18	4308
Banner Elk	38	37	156	437	675	942	1063	899	735	483	268	94	5827
Belhaven				154	340	623	735	596	416	157	19		3040
Black Mt.			63	277	510	763	874	708	530	284	116	15	4140
Blowing Rock	32	41	156	450	681	980	1104	932	775	495	265	92	6003
Brevard			42	274	507	763	859	689	524	285	107	9	4059
Burlington			17	208	438	735	853	683	481	208	57		3680
Canton			79	337	576	822	930	759	583	330	150	21	4587
Cape Hatteras				90	265	503	639	546	421	196	38		2698
Chapel Hill			25	238	450	744	862	694	496	224	69		3802
Charlotte			6	161	391	694	797	630	437	183	42		3341
Concord			12	197	414	710	822	652	453	186	51		3497
Cullowhee			39	273	519	778	874	700	524	285	111	9	4112
Dunn			11	200	435	710	818	658	443	190	37		3502
Durham			27	228	462	753	865	717	518	235	62		3867
Edenton			6	139	320	592	713	577	399	153	19		2918
Elizabeth City			6	143	350	623	741	608	443	192	33		3139
Elizabethtown			6	147	346	601	707	566	360	142	14		2889
Fayetteville			8	166	374	654	766	608	412	154	27		3169
Fletcher			70	343	576	859	967	784	614	348	139	13	4713
Franklin			36	270	519	775	874	703	530	292	112	8	4119
Gastonia			11	179	414	685	781	616	425	176	51		3338
Goldsboro			7	158	353	632	744	585	398	142	21		3040
Greensboro			16	226	465	760	877	700	502	235	78	6	3865
Greenville				172	369	642	756	596	406	156	32		3129
Hamlet			8	180	396	673	778	602	405	147	26		3215
Henderson			19	260	486	781	902	731	530	250	79		4038
Hendersonville		6	50	299	528	784	884	714	530	286	108	14	4203
Hickory			16	218	456	741	846	678	481	218	68	6	3728
High Point			12	185	411	701	809	641	437	178	46		3420
Jackson			13	198	426	716	846	686	481	227	47		3640
Kinston			9	174	370	651	756	610	419	171	36		3196
Laurinburg				139	365	362	732	582	376	140	18		2984
Lenoir			19	209	453	732	831	661	462	209	68	6	3650
Lexington			14	197	420	707	809	636	430	182	52		3447
Lumberton			10	190	386	657	760	602	414	164	29		3212
Marion			21	210	453	729	828	658	453	203	56		3611
Morehead City				82	263	506	623	515	366	138	13		2506
Morganton			28	215	462	732	825	652	459	209	59		3641
Mount Airy			23	249	498	794	896	720	515	252	76		4023
N. Wilksboro			40	303	540	840	949	770	574	290	108	8	4422
Raleigh			8	181	386	691	812	650	446	178	45		3397
Reidsville			23	252	474	781	905	734	530	249	78	5	4031
Rocky Mt.			12	172	392	667	778	630	440	185	40	5	3321
Salisbury			21	234	489	772	890	711	515	241	65		3938
Shelby			15	207	429	707	794	624	422	190	49		3437
Statesville			24	242	486	772	865	689	493	230	63	6	3870
Tryon			9	175	390	660	750	588	395	167	47		3181
Williamston			7	162	377	645	760	627	426	182	28		3214
Wilmington				102	259	519	631	496	338	115	10		2470
Wilson			14	196	402	676	794	636	440	179	34		3371

HEATING DEGREE DAYS

<u>Degree Days</u> for a 24-hour time period is the difference between 65°F and the average 24-hour temperature.

$$\text{Formula: } DD = 65 - \frac{(TH + TL)}{2}$$

Example: High reading 50°F, Low reading 20°F

$$\text{Degree days} = 65 - \frac{(50 + 20)}{2} = 65 - 35$$

Degree days equal 30

<u>Typical Problem:</u>

January, 1999, was reported to have 828 degree days at the Raleigh-Durham Airport. The average daily minimum temperature was 29. 40°F. What was the average maximum daily temperature?

Solution: 828 Degree Days divided by 31 equals 26.71DD/Day average

$$26.71 \text{ DD/Day equals } 65 - \frac{(\text{Avg. High Temp.} + 29.4°F)}{2}$$

Avg. High Temp = (2 x 38.29) - 29.4°F

Avg. High Temp. equals 47.18°F

COMBUSTION CHAMBERS

The purposes of a combustion chamber are to:

- **(a) "Insulate" the fire, thereby reducing its radiation losses and keeping its temperature high.**
- **(b) Contain the flame, produce recirculation, and assist in the air-oil mixing process.**
- **(c) Protect certain surfaces that do not transfer heat from heat damage.**

MATERIAL

Since the Chamber is to insulate the flame, it should be composed of insulating, high temperature refractory material which reaches incandescence in the quickest possible time.

SHAPE

The combustion chamber should be shaped to provide the closest approach to all parts of the flame, theoretically, without impingement of unvaporized-unburned oil droplets on its surface. The flame shape is mostly determined by the burner manufacturer in the air discharge pattern from the burner nose cone. Some chambers, for wide flame angles, will be round or square. Other chambers may be elongated rectangles for narrow flame patterns. Chambers should be constructed with corners covered or mitered with 45-degree inserts to attain streamline, flame-flow patterns. Corbelling may be required at the rear of larger chambers.

SIZE

Correct combustion will approximately follow these specifications:

Inside Floor Area	**80 Square Inches per GPH (up to 3.00 GPH)**
	90 Square Inches per GPH (3.00 to 5.00 GPH)
	100 square Inches per GPH (all over 5.00 GPH)

Too small a chamber may result in flame impingement on its surfaces causing smoke generation and chamber damage. Too large a chamber may cause cooling of the flame to the point where flame stability is difficult and smoke occurs.

COMBUSTION THEORY & OIL BURNING

	Oil Use GPH	Sq. Inch Area Combustion Chamber	Square Combustion Chamber Inches	Dia. Round Combustion Chamber Inches	Rectangular Combustion Chamber Inches x Inches	Height from Nozzle to Floor Inches			
						Typical Burner	Typical Burner 1-Nozzle	Sunflower Burner 1-Nozzle	Sunflower Burner 2-Nozzle
	.75	60	8 x 8	9		5	X	5	X
	.85	68	8.5 x 8.5	9		5	X	5	X
	1.00	80	9 x 9	10-1/8		5	X	5	X
80 Sq.	1.25	100	10 x 10	11¼		5	X	5	X
In.	1.35	108	10.5 x 10.5	11¾		5	X	5	X
per Gal.	1.50	120	11 x 11	12-3/8	10 x 12	5	X	6	X
	1.65	132	11.5 x 11.5	13	10 x 13	5	X	6	X
	2.00	150	12½ x 12½	14¼	6	x	7	X	
	2.50	200	14¼ x 14¼	16	12 x 16½	6.5	X	7.5	X
	3.00	240	15½ x 15½	17.5	13 x 18½	7	5	8	6.5
90 Sq.	3.50	315	17¾ x 17¾	20	15 x 21	7.5	6	8.5	7
In.	4.00	360	19 x19	21½	16 x 22.5	8	6	9	7
per Gal.	4.50	405	20 x 20		17 x 23.5	8.5	6.5	9.5	7.5
	5.00	450	21¼ x 21¼		18 x 25	9	6.5	10	8
	5.50	550	23.5 x 23.5		20 x 27½	9.5	7	10.5	8
	6.0	600	24.5 x 24.5		21 x 28½	10	7	11	8.5
100 Sq.	6.50	650	25.5 x 25.5		22 x 29½	10.5	7.5	11.5	9
In.	7.00	700	26.5 x 26.5		23 x 30½	11	7.5	12	9.5
Per Gal.	7.50	750	27¼ x 27¼		24 x 31	11.5	7.5	12.5	10
	8.00	800	28¼ x 28¼		25 x 32	12	8	13	10
	8.50	850	29¼ x 29¼		25 x 34	12.5	8.5	13.5	10.5
	9.00	900	30 x 30		25 x 36	13	8.5	14	11
	9.50	950	31 x 31		26 x 36½	13.5	9	14.5	11.5
	10.00	1000	31¾ x 31¾		26 x 38½	14	9	15	12

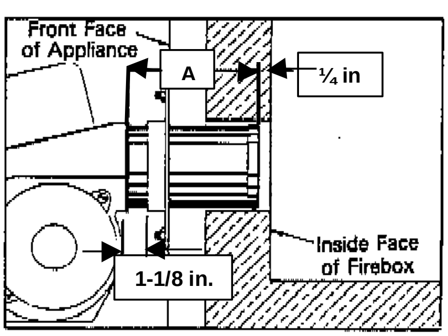
RECOMMENDED COMBUSTION CHAMBER DIMENSIONS

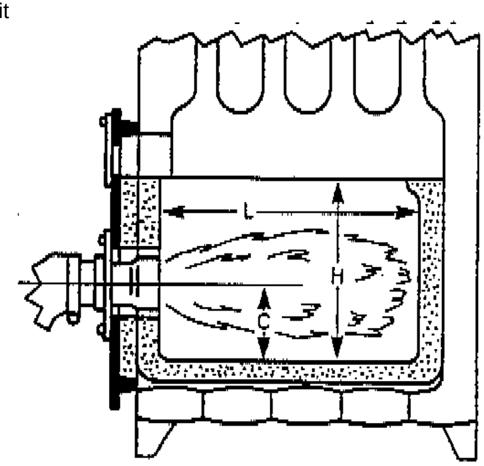
1 Firing Rate	2-Length (L)	3-Width (W)	4-Dimension (C)	5-Height (H)	6-Min. Dia. Vertical Cyl.
.50	8	7	4	8	8
.65	8	7	4.5	9	8
.75	9	8	4.5	9	9
.85	9	8	4.5	9	9
1.00	10	9	5	10	10
1.10	10	9	5	10	10
1.25	11	10	5	10	11
1.35	12	10	5	10	11
1.50	12	11	5.5	11	12
1.65	12	11	5.5	11	13
1.75	14	11	5.5	11	13
2.00	15	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). As a general practice, any of these dimensions can be exceeded without much effect on combustion.
2. 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.
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, especially with non-retention burners.

"A" = Usable air tube length **Slope Burner to Chamber 2º**





DRAFTS, FLUES, & COMBUSTION AIR

Draft Requirements for Ordinary "Natural Draft" Burner Installations"

The heat containing products of combustion must flow from the combustion zone and pass heat absorbing surfaces at an ideal velocity. To overcome the friction pressure loss offered by flue passages and venting systems, sufficient pressure difference, commonly called "draft," must exist. The right draft for boiler or furnace will be determined and prescribed by the equipment manufacturer and measured in terms of fractions of inches, water column (w.c.) pressure at the flue outlet of the unit and over-fire. Draft should be as constant as possible and natural drafts available from chimneys may be regulated for constancy by draft regulators.

STANDARD OVERFIRE DRAFT = (NEGATIVE) -.01" to - .02" WATER COLUMN.

(Where operation is not forced draft.)

Uncontrolled and unregulated draft may produce problems as follows:

a. **Excessive over-fire draft causing too rapid removal of flue gases; high stack temperature, and, flue waste.**
b. **Insufficient overfire draft-causing combustion troubles—mostly pulsation and smoke generation.**
c. **Variation in draft from cold start to hot operating conditions. The input of primary air from the oil burner blower varies somewhat with the pressure in the firebox. Lower pressure (greater draft) permits more primary air feed by the oil burner blower.**
d. **Normal draft for #2 oil units will vary from negative -.03" w.c. to -.06" w.c. in the flue outlet, dependent upon the manufacturers' recommendations; this draft is to produce over-fire draft (-.0l" w.c. to -.02" w.c.).**

The available natural draft will vary greatly depending upon:

-temperature of gases and flue components.
-temperature of outdoor air, (the colder the air, the greater the available draft).

The required draft at the gas exit of the equipment (and overfire) is constant. Therefore, as the available draft increases, a DRAFT REGULATOR by-pass will begin to open when the draft exceeds its adjusted setting, which is the draft required at the exit. When air enters the regulator and mixes with the hot flue gases, they are cooled and less draft will be produced. Failure to curtail the rising available draft will result in faster moving flue gases, higher exit temperatures, and waste.

Example of draft changes in a chimney

Condition	Outside Temperature, °F	Chimney Temperature, °F	Draft inches water column
Winter Start Up	20	110	.050
Winter Operation	20	400	.136
Fall Start Up	60	80	.011
Fall Operation	60	400	.112

Draft regulators must be adjusted for the equipment over-fire and flue outlet draft requirements, and regulators must be inspected periodically for workability.

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 over-fire 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 operating conditions. Normally an over-fire draft of negative -.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 over-fire draft is higher than -.02 inch, 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 overfire draft drops, the burner air delivery is reduced and the flame becomes even smokier. It is a vicious cycle, which gets increasingly worse.

2. Draft at the Breech (Vent Pipe) Connection

After the over-fire 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" when the overfire draft is -.01" to -.02".

Chimneys: Sizing (See Page 35)

Chimneys should extend 3 feet above the highest point of the roof or otherwise capped for protection against down-drafts. Chimneys should always have a tiled vitrified or stainless steel liner. The State Building Code is specific for these requirements.

Any resistance within the chimney should always be corrected. Soot should be removed, leaky or otherwise defective chimneys should be corrected, hollow space (usually referred to as clean-outs) below smoke pipe should be filled in. Make sure that no other heating appliances (particularly gas burning fireplaces) are connected to the same chimney.

The connection between boiler and chimney opening should be as straight as possible (don't use 90° elbows if possible - 45° LR cause much less resistance) to avoid any unnecessary resistance. If old smoke pipes on existing jobs have to be reused, clean thoroughly. Flue pipes should never grade downwardly.

Mechanical Draft

Mechanically controlled draft consists of two types, induced and forced.

Forced draft for small equipment usually is a function of the oil burner's primary air combustion air blower which is sized and powered to feed air into the combustion zone with sufficient pressure to overcome all draft friction losses in the flue system. Typically, blower motor speeds are 3450 RPM, and a delayed-opening oil valve permits stabilization of air flow and oil pressure before ignition to prevent smoke starts. Pre and Post purge controls are now on the market to further reduce noisy starts and smoke.

Induced draft requires the installation of a centrifugal blower at the chimney connection. To establish the correct draft at the flue outlet, a draft regulator or air orifice must be used. Because normal flue gas travel cannot occur through the flue pipe without induced draft fan operation, some safety devices to <u>prove</u> blower operation is required, such as a motor centrifugal switch, air sail switch, or air pressure sensitive control.

Chimneys for mechanical draft installations may consist of simple vent outlets or smaller Type "L" for oil, or type "B" for gas, vent-pipe systems.

Air Supply To Boiler Rooms

Outside air must be admitted to the space where the burner is located for three possible reasons. In every installation, air must be supplied for combustion. In some cases, additional air must be admitted for ventilation. In flue arrangements with barometric draft regulators or gas diverters, air must also be provided to replace that drawn up the flue through these devices.

Combustion Air For General Residential Installations

Adequate combustion air must be provided in the location in which the burner is installed. The area of the air inlet should be at least equivalent to the area of the smoke pipe at the point where it enters the flue. However, local building codes will be very specific on air access requirements. Negative building pressures caused by exhaust fans should be avoided and corrected as these may cause downdrafts and other venting problems.

CHIMNEY & FLUE SIZING

Flue and Chimney Exhaust

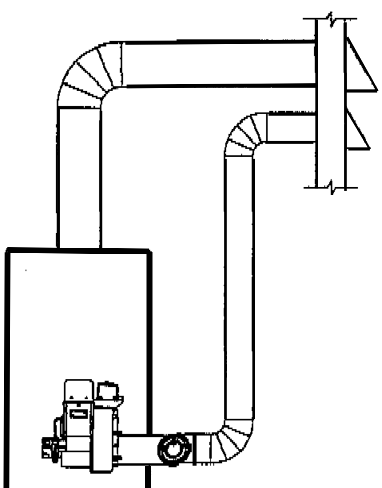
1. **Flue Pipe:** The flue pipe should be the same size as the breech connection on the heating plant. For modern designed oil heating plants, this should cause no problem in sizing the flue pipe. The sizes generally are 6" under 1 GPH, 7" to 1.50 GPH and 8" for 1.50 to 2.00 GPH. The flue pipe should be as short as possible and installed so that it has a continuous rise from the hearing 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 pipe before it contacts the chimney and after the stack primary control, if one is used. Make sure the draft regulator diameter 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. The inside cross-sectional area of the chimney should be one square inch for each 6500 BTU input, but never less than 8 inches in diameter. Please consult manufactures specs and building code for new installations.

Gross BTU Input	Rectangular Tile	Round Tile	Minimum Height
144,000	8.5" x 8.5"	8"	20 feet
235,000	8.5" 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

SIDE WALL VENTING WITH NO CHIMNEY

The first benefit of a side-wall venting system is that it eliminates the need for a chimney. This can result in potential savings in new home construction. There is also the opportunity to retrofit chimneyless (i.e., electrically heated) homes. The second benefit is the potential for increased efficiency. Condensation of acids in the flue gases occurs when the flue gas temperature drops to about 200ºF. The minimum recommended gross stack temperature at the breeching is usually 500ºF to 550ºF with conventional appliances. In the side-wall vented system, flue gases are not cooled in a chimney. Heat that is typically lost in the chimney can be extracted in the heating appliance, dropping the gross stack temperature to 300ºF to 350ºF. This raises the steady state efficiency.

Acid will not condense in the short side-wall duct; water vapor won't either. Keep in mind that water vapor in the flue gas will condense if flue gas temperatures drop below about 120ºF. Make sure, however, that you are operating at the 300ºF to 350ºF gross stack temperature with power side-wall venting only when the manufacturer has designed or approved his furnace or boiler for this arrangement. However, the advantage of chimneyless construction and the reduction of exhaust gases to a safe 200 to 300ºF range without a special high efficiency appliance can often be accomplished by dilution of the flue gases via a barometric damper upstream of the induced draft fan.



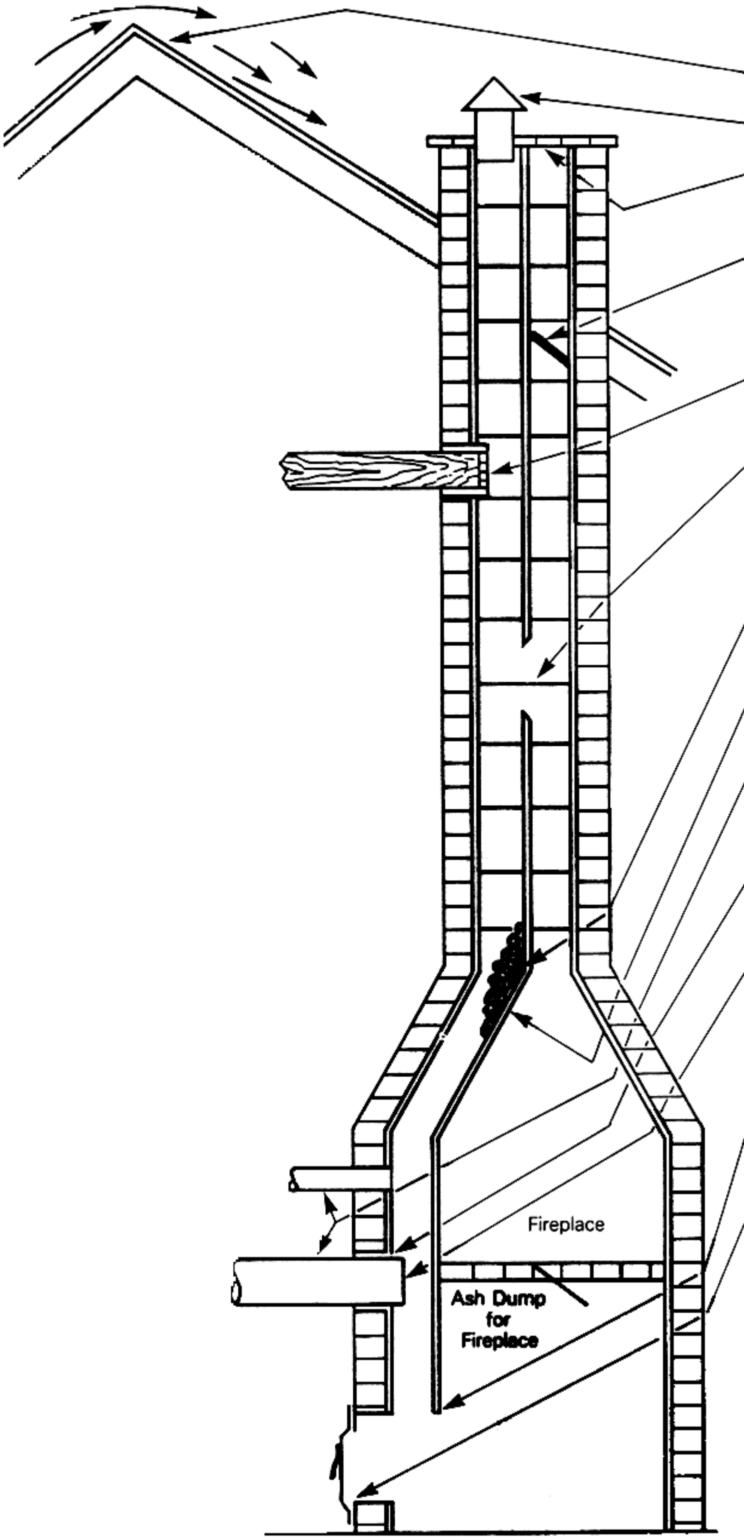
SEALED COMBUSTION & SIDE-WALL VENTING

CONCERNS

Safety concerns are of primary importance with any heating system and should be with side-wall vented applications. As previously stated, air flow proving switches are typically used to ensure proper draft from the induced draft fan. Temperature sensing switches can be utilized as backup protection for a blocked vent condition. Side-wall fittings must be designed for walls constructed of combustible materials. The side-wall presence of flue products at 200°F to 300ºF must be considered.

Reliable Operation is a second concern. Wind direction and velocity can have a great impact on a side-wall exhaust vent and must be considered both in system design and in installation. A closed air system with outside intake on the same wall as the exhaust vent will tend to reduce this problem. Clean burner operation is critical to avoid fume and staining problems. Corrosion due to stack temperatures being too low (and resultant condensing) must be prevented.

There are also local building code requirements that restrict the installation of side-wall vent systems. Industry progress is being made in this area, but check local/state building code requirements before planning a side-wall vented installation.



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

OIL PUMPS & PIPING

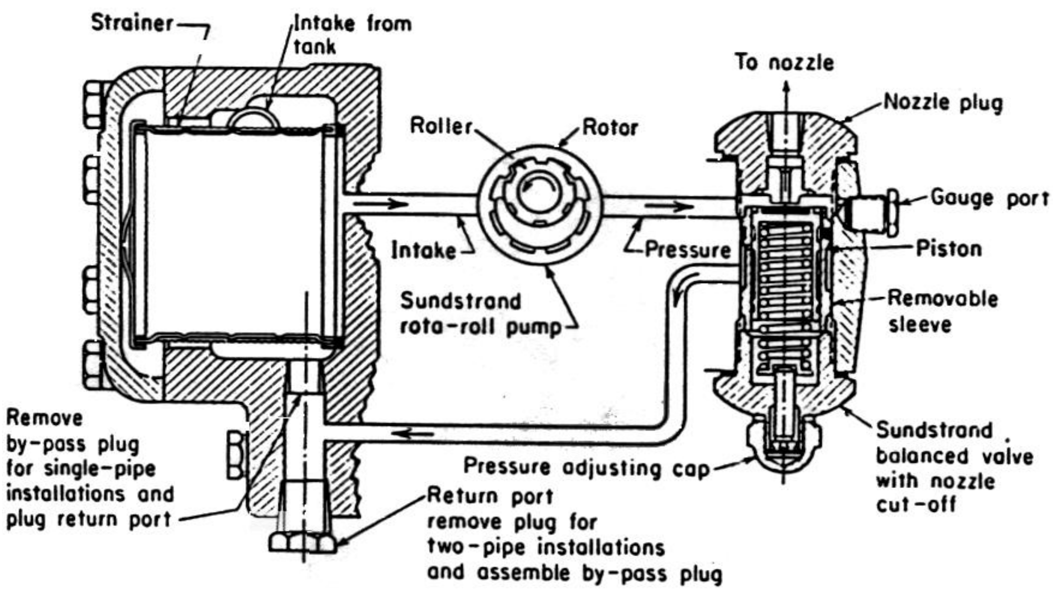
The function of the fuel oil pump on high pressure gun-type burners is to pick up the oil and deliver it to the nozzle at a constant pressure. The pump provides the energy to atomize the oil through the nozzle. These gear-type pumps also provide a filtration strainer chamber and the pump's gear teeth can crush small bits of debris to allow the grit to go through the nozzle. These highly machined gears provide both pressure and vacuum. The two main types are the single-stage and two-stage fuel units. The difference is that the two-stage fuel unit has two sets of pump gears. The first stage is used to purge the pump of air and supply an uninterrupted flow of oil to the second stage, provide the vacuum to fill the strainer chamber and shaft seal chamber to the low pressure side of the pressure regulating valve, then back to the tank. The second stage of gears provides the pressure for the oil taken from the strainer chamber, with the surplus oil being bypassed back to the strainer chamber.

<u>Two-stage fuel units have two primary advantages;</u>

1) Higher intake vacuums are permissible with this unit. (Longer Pipe Runs)

2) Permits any air (leaks) to be delivered back to the tank without effecting pump operation. Pump will not have to be bled during start-up (two pipe only).

Although some technicians will not use two-pipe systems with aboveground tanks because of the input of cold oil, single-stage one pipe fuel units pump five to ten times the oil needed by the nozzle and bypass this excess oil back to the strainer chamber, thus warmer fuel oil. It is important to remember that both types of pumps might be found in a one pipe or two-pipe system.



Oil-flow diagram for Sundstrand single-stage pump.

Piping from the tank to the fuel unit must be installed in accordance with local building codes and or the National Fire Protection Association (NFPA) code 31. Tight and leak proof connections are a must especially for single pipe installations. On the tank itself, liquid level indicators, overflow devices, and venting with emergency venting should be installed if required by code. Piping must have a shut off valve near the tank, a globe valve before the filter, and anti-siphon valves if it is gravity feed system. It must have an oil safety valve, which reduces the pressure at the pump to the code requirement of 3 psi. Piping must not be smaller the 3/8 inch I.D. steel, or 3/8 inch O.D. copper; in most cases 1/2 inch soft copper should be used. All piping should be protected against sharp kinks and crushing.

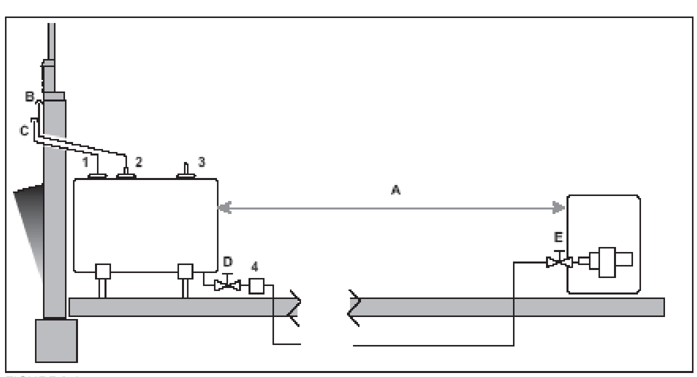


TABLE OF RESISTANCE IN TUBING

Inches of Vacuum Required to Lift Oil for Combined Horizontal Run & Vertical Lift
Based on Suntec Single Stage Pump

LIFT, Height ft.	Diameter of Tubing, inch													
	3/8	1/2	3/8	1/2	3/8	1/2	3/8	1/2	3/8	1/2	3/8	1/2	3/8	1/2
	Vacuum, inch Hg													
10	9	8	9.5	8.5	10	9	10.5	9.5	11	10	12.5	11.5	14	13
9	8	7	8.5	7.5	9	8	9.5	8.5	10	9	11.5	10.5	13	12
8	7	6	7.5	6.5	8	7	8.5	7.5	9	8	10.5	9.75	12	11
7	6.5	5.5	6.75	5.75	7.25	6.25	7.75	6.75	8.25	7.25	9.75	8.75	11.2	10.2
6	5.5	4.5	6	5	6.5	5.5	7	6	7.5	6.5	9	8	10.5	9.5
5	5	4	5.5	4.5	6	5	6.5	5.5	7	6	8.5	7.5	10	9
4	4.5	3.5	5	4	5.5	4.5	6	5	6.5	5.5	8	7	9.5	8.5
3	4	3	4.5	3.5	5	5	5.5	4.5	6	5	7.5	6.5	9	8
2	3.5	2.5	4	3	4.5	3.5	5	4	5	4.5	7	6	8.5	7.5
1	3	2	3.5	2.5	4	3	4.5	3.5	5.5	4	6.5	5.5	8	7
Length of run, ft.	10		20		30		40		50		75		100	

Vacuum for pump Model A system should not exceed 6 in. for single pipe and 12 in. for two-pipe.

HEATING OIL FUEL TREATMENT:

Adding to the complex variables that a heating oil businessman must master is a relatively new challenge. The fuel oil that is being sold today is significantly different than that of just a few years ago. Heating fuels are now dyed red for EPA & IRS reasons. Lower sulfur fuels are out on the market along with poor grades of heating fuels. Sulfur is believed to prevent the growth of some bacteria and fungus at the water-oil boundary in the tank. Fuel quality must be as stable and constant as possible. Contaminated or poor quality fuel produces particulates and sludge that a fuel oil technician sees when he changes filters and nozzles. These solids seem to appear out of nowhere when they are actually produced by the fuel itself.

The specifications and the tests used to measure the specifications of your fuel oils have not kept up with the changes in the production of your fuel. That is why what appears to be perfectly good fuel can change while you are buying and selling it into a problem fuel. This is a concern of all producers of fuel oil.

Repolymerization, oxidation, and fuel contaminated with microbes would happen to #2 fuels regardless on how it was refined. The cracking process simply accelerates the time frame that particulate and gums will form. The impact on heating oil dealers is an increase in service calls as these solids impact the storage and fuel metering systems of your customers.

Most of us are familiar with other variables that impact fuel quality such as bacteria and fungus, water, cold flow concerns such as waxing and gelling, rust from storage tanks, and the natural oxidation of the fuel. All of these things contribute to the degradation of fuel quality. Repolymerization, once considered to be a concern only for long term fuel storage such as for emergency power, is emerging as the most significant threat to fuel reliability today.

The good news is that there are solutions to these problems. There is a family of chemicals that when added to fuel in small doses will act like clot busters in the arteries of a heart patient to breakup the gums and particulate to microscopic size so that fuel will pump and burn efficiently. These materials can be added to fuel to prevent the formation of these clots as well as return repolymerized fuel to a usable condition. Therefore, you will want to include an additive that is effective against repolymerization as well as bacteria, fungus, oxidation, and rust along with cold flow materials as is appropriate.

The solutions to fuel reliability are a combination of good storage tank maintenance procedures such as draining and cleaning bulk storage tanks annually, and the use of the right additives designed to meet the needs of today's heating oil. Bacteria, microbes, and fungus cannot grow without water in the tank.

For additional information, please call these chemical firms: 800-237-4532, Fuel Right 800-642-1910; Angus Chemical 800-362-2580; Index Chemical 800-654-4108; Park Hill Chemical 800-678-7275; Nutmeg Chemical 203-777-7691. Remember—too much additive or mixing of certain additives can also cause problems.

FINDING OIL SUPPLY LINE LEAKS

Many air leaks in the oil supply line are caused by the use of compression fittings. But there are also other causes of leaks.

The following symptoms may indicate air leaks:

1. Loss of flame retention, (flame pulsates on the end cone).
2. Loss or oil prime causing lockout on safety.
3. Rough or noisy starts and stops.
4. Pump whine and pressure fluctuation.
5. Nozzle after-drip. (If this causes after-burn in the combustion chamber, smoke may occur. Oil may also accumulate in the air tube.)

Several methods can be used to locate suction line leaks. The most common are:

1. Pressure testing
2. Vacuum testing
3. Visual testing
3. Electronic detection

PRESSURE TESTING

1. Disconnect the oil supply line as close to the tank as possible.
2. (Two-pipe system) Disconnect the return line and plug the return port at the fuel unit. (Single-pipe system) Begin with the next step.
3. Install a pressure gauge in the gauge port of the fuel unit.
4. Pressurize the line to 8 to 10 psi. with a hand pump. Do not exceed 10 psi or you may cause seal separation from the pump shaft, damaging the fuel unit.
5. Monitor the pressure reading. It should hold on the pressure gauge for 10 to 15 minutes. A sudden or gradual drop in this reading indicates a leak.
6. Apply a leak detector fluid or solution on the fittings and connections to visually locate the leak.

VACUUM TESTING (FUEL UNIT TEST)

1. Disconnect the supply line at the fuel unit.
2. (Two-pipe system) Disconnect the return line and place an open container below the return port of the fuel line. (Single-pipe System) Connect a bleed hose to the bleeder port. Place the other end of the hose into an open container.
3. Fill the fuel pump of either system with oil. Install a vacuum gauge into the inlet port.
4. Start and run the burner until a vacuum or 10-15 in. Hg is reached. On a single pipe system, open the bleed port while the burner is running to raise the vacuum. Once the vacuum is reached, close the bleed port.
   Note: On both systems, jumper the F-F terminals after burner start-up to allow sufficient time to reach the vacuum reading.
5. With the burner running at the required vacuum:
   (Two-pipe) Plug the return. Turn the power to the burner OFF. (Single-pipe) Close the bleed port. Turn the power to the burner OFF.
6. On either system, check the vacuum reading after shutdown. If it does not hold for 5 minutes, recheck all connections to assure they are tight. Rerun the test.
7. If the vacuum reading continues to go down, replace or repair the fuel unit. Once the fuel unit is airtight, check the supply lines for air teaks.

(SUCTION LINE TEST)

A shutoff valve near the oil tank makes this test most effective.

1. On either a single- or two-pipe system, install a vacuum gauge in the optional inlet port of the pump. Do not disconnect the suction line.
2. Close the shutoff valve nearest the oil tank.
3. Start the burner and allow the vacuum to stabilize.
   Note: On both systems, you may need to Jumper the F-F terminals after burner start-up to allow sufficient time to stabilize the vacuum reading.
4. When the vacuum reading has stabilized, turn off the power to the burner.
5. If the vacuum does not hold steady for *5* minutes and the fuel unit has been tested and found leak tight, the leak is probably between the fuel unit and the shutoff valve.
6. Proceed with a leak detection method of your choice to locate the leaking fitting or connection point.

If the system does not have a shutoff valve near the tank, test with all alternate method, such as Pressure, Visual, Sight Glass or Electronic testing.

VISUAL TESTING

Visual testing is one of the simplest methods for locating oil supply line air leaks using either flared in-line tubing or an in-line sight glass. The flared tubing is an 8 to 10 in. piece of clear plastic tubing, 3/8" or 1/2", depending on the line size. A male flared fitting is on one end; a female flared fitting is on the other. The sight glass is used in the air conditioning and refrigeration industry. It consists of a Pyrex™ viewing window mounted in a brass body. Sight glasses are made with either 3/8" or 1/2" flared connections.

Using either the flared tubing or a sight glass:

1. Install the tester into the supply line at the fuel unit inlet, making sure all connections are tight.
2. Start the burner and watch the oil flow through the tester. (Two-pipe) Allow the oil to flow for approximately 3 minutes to purge air that entered the system when the tester was installed. (Single-pipe) Purge any air through the bleed port for 3 minutes.
3. Watch the oil flow at the tester. Any bubbles, no matter how small, indicate either an air leak or gasification due to restriction.
4. Install the tester at all connections, working toward the tank. If the bubbles disappear at any connection, the problem should be between there and the previous connection.

If the system includes an underground tank and you see bubbles in the line at the last accessible connection, the problem may be in either the inside or outside section of the buried line. The line may have to be exposed in order to test the connections and tubing. Once the source of trouble has been found, repair and retest to verify the system is free of bubbles.

ELECTRONIC DETECTION

The electronic sight glass is excellent for locating leaks. It resembles a hand-held meter and mounts anywhere in the oil supply line. Two transducers are spaced a short distance from each other. When operating, one transducer transmits and the other receives ultrasonic signals. The varying rate of signal pulse indicates the location and quantity of bubbles flowing through the system. This unit is very effective and greatly simplifies troubleshooting.

CONCLUSION

Suction line leaks do not always cause oil to drip from a fitting, but a number of techniques can be used to locate the leak(s). Choosing and using one of the methods described is well worth the time and effort required.

USEFUL FORMULAS

BTU = Amount of heat to raise 1 pound of water 1 degree F.
SPECIFIC HEAT = Amount of BTUs to raise 1 pound of a substance 1 degree F.

HEATING PURE WATER IN BTUs per HOUR

Q = Gallons x 8.334 Lbs./gal. x Degrees raised in temp. x 1 BTU/Lb.-F

$$\text{Gallons Per Minute (GPM)} = \frac{\text{Q BTUs/Hour}}{\text{500 x Degrees Change}}$$

1 GPM, 10 DEGREES CHANGE, YIELDS 5000 BTUs/HOUR
1 GPM, 20 DEGREES CHANGE, YIELDS 10,000 BTUs/HOUR

BLENDING WATER

$V1 \times T1 + V2 \times T2 = V3 \times T3$
$V1 + V2 = V3$
$T3 = (V1 \times T1) + (V2 \times T2) \div V3$

AIR HEATING (Sensible)

Q BTUs/Hour = CFM x 1.08 x Temp Diff.
(1.08 BTU-Min./F.-Cu.Ft.-Hr. = .24 BTU/Lb.-F. x .075 Lb./Cu.Ft. x 60 min/hr.)

AIR BLENDING

$W1 \times T1 + W2 \times T2 = W3 \times T3$
W = CFM ÷ Cu. Ft. / Lb.
Cubic Foot per pound depends upon its temperature (see psychometric chart).

ENERGY TO HEAT WATER

$$\text{Oil Gallons} = \frac{\text{Gals. Water x 8.334 Lbs./gal. x Degree Rise x 1 BTU/ Lb.-F.}}{\text{140,000 BTUs/ Gal.-Oil x Efficiency}}$$

$$\text{GPH Water Heated} = \frac{\text{GPH Oil Input x 140,000 BTUs/Gal. x Efficiency}}{\text{8.33 LB/gal. x Degrees Rise x 1 BTU/Lb.-F}}$$

ESTIMATE HEATING ENERGY CONSUMPTION

Degree Day Method-Annual

$$F = \frac{HL \times 24 \times DD}{E \times P \times T.D.}$$ **(Not to be used for Heat Pumps)**

HL is the design heating load (BTU/Hour).
DD is the degree days for the location.
E is the seasonal efficiency.
P is the heating value of the fuel (BTUs).
T.D. is the design temperature difference (F).
F is the annual fuel consumption.

$$\textbf{Heat Pumps KWH/YR.} = \frac{\textbf{0.77 x HLH x HL}}{\textbf{1,000 x HSPF}}$$ **(Heating Season Performance Factor)**

$$\text{HLH} = \frac{\text{Heating Degree Days x 24}}{\text{65 - Winter Design Temp.}}$$

OIL FIRED WATER HEATERS/BOILERS

- **Oil fired water heaters are 2 & 1/2 times more efficient than gas fired water heaters, and 5 times more efficient than electric water heaters.**
- **A 30 gallon electric water heater takes 1 hour to recover its contents. A highly efficient oil fired water heater takes 17 to 20 minutes. In comparison, a gas water heater takes an average of 40 to 45 minutes.**
- **Replacing an electric water heater with an oil fired water heater can lower water heating costs by an average of $485 a year, lower greenhouse gas emissions, and will produce a 50 to 100% return on consumer investment. Replacing a gas water heater can lower costs by an average of $225 to $275 a year.**
- **Oil fired water heaters are no longer thought of as "just for heating domestic water." They are, and have been, a valuable and reliable heat source for combined appliance application such as hydro-air systems and radiant floor heating. Oil fired water heaters have higher BTU inputs, higher efficiencies, and faster recovery.**
- **Don't have a chimney, no problem. Bock Company offers a Balanced Flue Combustion (BCS) System which includes a specially designed water heater, burner, and side wall flue system that can be installed almost anywhere.**

THE HEAT PUMP HELPER

The "Heat Pump Helper" is design with an oil fired domestic water heater/boiler and hot water coil. The oil fired water heater provides domestic hot water all year. There is a hot water coil installed in the air handler or the duct work of the home. The coil is piped to the water heater and a circulator pump. In the wintertime, the pump is controlled by an aqua-stat designed to turn the pump on at a preset temperature.

When your heat pump needs economical back-up heat, say at a preset ambient temperature of 35ºF, the aqua-stat signals the pump to operate, sending 160º water to the properly sized coil at the air handler. The return water to the water heater will be about 140º.

NORTH CAROLINA COST OF OPERATION

The formula for determining yearly cost of operation for fossil fuel water heaters is:

$$\left(\frac{47743\text{ BTUs}}{\text{EF}}\right) \times \left(\frac{\text{Unit Fuel Costs}}{\text{Fuel BTUs}}\right) \times 365 + (\text{monthly service charge})$$

47743 BTUs is the amount of energy needed to heat 64.3 gallons of water at a 90º rise
(64.3 gallons is the US Dept of Energy daily average usage of hot water for the home.)
EF is the DOE energy factor of the equipment: EF oil = .68; EF gas = .53; EF electric = .79

The formula for determining yearly cost of operation for electric water heaters is:

$$(13.99 \div \text{EF}) \times \text{Unit Fuel Costs} \times 365$$

Cost to heat water for one year for oil at $X per gallon.
Cost to heat water for one year for gas at $X per therm.
Cost to heat water for one year for propane at $X per gallon.
Cost to heat water for one year for electricity at $X per KW.

Equipment pay back from gas/propane is about X years.
Equipment pay back from electric is about X years.

THERMOSTATS

Most warm air t-stats operate by sensing temperature changes in the home. The <u>bimetallic element</u> comprises two dissimilar metal strips, bonded together, which expand or contract with a change in temperature at different rates of speed. This difference in expansion rate will cause the bonded bimetallic element to bend or warp with temperature changes. By bending or moving when heat is applied to it or taken away from it, it creates a force that is utilized to "make" or "break" an electric contact. "Making" or "breaking" a contact means closing or opening a circuit respectively.

It will also be found that, in some designs, a bellows filled with a highly volatile liquid is used for closing and opening contacts. The volatile liquid vaporizes at low temperatures creating a pressure that makes the bellows expand to open, or contract to close a circuit. In some t-stats, mercury switches are used instead of open blade-type switches. These sealed mercury switches are by far the most trouble free.

With open blade type, metal to metal contacts as room temperature is dropping. As the moveable contacts approach the fixed contacts, a permanent magnet located near the fixed contact acts quickly when the contacts are close together causing the contacts to snap in. This works the same way upon rising room temperature. The moveable contact will "snap" away from the fixed contact, opening the circuit, stopping the burner. This <u>"snap acting t-stat"</u> eliminates arcing and pitting of the contacts and possible "chattering" noise.

When a <u>mercury-tube switch</u> is employed, on a drop in room temperature the bimetal causes the mercury tube to tilt from the "off" position to the "on" position. When this occurs, the liquid mercury flows from one end of the tube to the other; the weight of the mercury causes the delicately balanced mercury tube to tilt to the "on" position and the pool of mercury makes a positive contact between the two electrodes in the tube, with no possibility of chattering. Then, on a rise in room temperature, the reverse flow of the mercury to the other end of the mercury tube opens the circuit turning the burner off.

Today's programmable automatic thermostats operate with a differential of +- 1º F., max. 2º F differential. Most people can sense a temperature change around 1.8°

HEAT ANTICIPATING PRINCIPLE

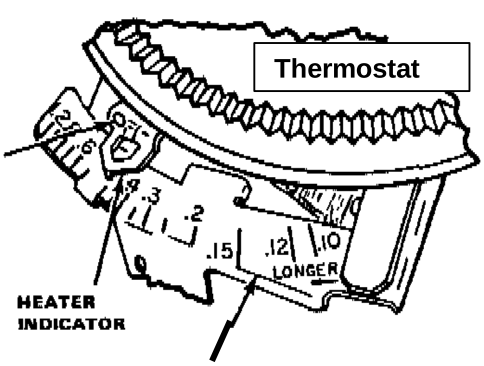
The <u>differential</u> of a t-stat is the number of degrees of temperature change that is required to cause its bimetal or bellows to move the required distance to close or open its electrical contacts. If we were to slowly turn the dial of a t-stat back and forth, opening and closing its electrical contacts and noting the number of degrees difference between the opening and closing, this would be called the <u>"mechanical differential"</u> of that particular thermostat. For example, if a thermostat opened at 70º and its contacts closed at 68º, its mechanical differential would be 2º. Obviously, we would have heat override problems if we were to depend entirely upon the mechanical differential of a thermostat to turn the burner on and off.

Manufacturers have incorporated in their thermostats a <u>heat anticipating</u> heater which greatly increases the sensitivity of the thermostat. It reduces the mechanical differential. The heater is wired so that electric current flows through it when the thermostat calls for heat. The anticipating heater actually creates heat near the bimetallic element. This causes the thermostat to break its contacts prior to the room air reaching the temperature of the dial setting, and the burner is turned off slightly ahead of the time that the room air temperature increases to the dial setting of the thermostat. The fan, in a warm-air system, continues to operate bringing the room air temperature up to the dial setting but not beyond that point to the extent that there would be an uncomfortable overriding by the heating system.

The t-stat heat anticipating heater must be adjusted to match the current that is supplied to the thermostat circuit by the model of the <u>primary control</u> that is in use. Current flow in this 24 volt circuit generally varies from 0.2 amperes to 0.6 amperes depending on the make and model of primary control that is in the control system. This current setting will usually be found inside the cover of the primary control.

***The figure shows the heater indicator and the scale in a thermostat*. If it appears that the "on" cycles are too short or too long, check the heater adjustment against the current requirement of the primary control used.**

To lengthen operations, move the heater indicator preferably not more than half a division in the direction of the scale arrow. To shorten operations move the indicator in the opposite direction. If the heat anticipator of the t-stat is set at .2 amps while the primary control is supplying .4 amps, the burner cycle will be short. In this case, the burner will operate "on" and "off" for short periods of time, which is commonly known as "short cycling." *Always* follow the manufacturer's recommendations for heat anticipator setting.



SCALE

LIMIT CONTROLS

A limit control is usually a line voltage temperature or pressure actuated switch used as a safety device. Limit controls are of either the direct acting, or reverse acting type. Direct acting controls break (open) their contact on temperature rise while the reverse acting controls make (close) contact on temperature rise. The "high limit" is a safety device to turn off the burner should temperatures be too high within the furnace or boiler, or excessive steam pressure in a steam boiler. This control should be wired so that it can turn off the oil burner only-never the circulator or fan.

A "low limit or operating control" is a limit which is used to control the operation of something. One type of operating limit control is used to start and stop the burner to maintain boiler-water temperature. Because it is set at a lower temperature than the high limit, it is referred to as a "low limit."

The most common reference to this control is with a forced hydronic, hot water, system. When domestic hot water is required of the boiler, a reverse acting limit control is used to turn the circulator off should boiler-water temperature become too low. The full output of the burner can then be used to maintain domestic hot water. During this period, delivery of heat to the rooms is interrupted, and the house may cool off a bit. This is not as objectionable, however, as insufficient hot water for baths or laundry.

Warm air limit controls are the safety devices to prevent both the furnace and the duct work from excessively high temperatures. On forced warm-air systems a fan control is used to independently operate the blower. After the burner has been on for a short period, the element of the fan control will sense the desired amount of heat in the plenum or bonnet of the furnace and start the blower. The blower will then run as long as there is heat which can be for some time after the burner has stopped.

Both the high limit control and the fan control may be operated by a bimetallic element, a liquid expanding or contracting and moving a diaphragm, or an expanding and contracting quartz rod as heat sensing elements.

The high limit line voltage safety control is used to prevent the heated air in the bonnet of the furnace from increasing in temperature above the setting of the high limit dial. The high limit control may employ either metal-to-metal contacts or a mercury switch to "make" and/or "break" its circuit.

The function of the fan control is to operate the blower fan when the bonnet air temperature is within the fan control dial settings. The fan control will permit the fan to operate when the air temperature in the bonnet rises above the "fan on" setting as prescribed for the specific system. The fan control will prevent blower operation in the event the bonnet air temperature is below the "fan off" setting of the fan control dial. This prevents cool air from being forced into the living area during cold weather. Most fan controls provide for manual operation to provide summer air circulation.

Fan and limit controls may also be combined into one housing where the helix-type bimetallic element operates both the fan control switch and the high limit control switch. The single dial as shown has indicators for the "fan on" position and the "fan off" position as well as an indicator for the high limit setting.

The heat sensing element, or bimetallic element, expands and contracts with a change in furnace bonnet or plenum temperature. Since the element is helical in shape, it tends to turn with a circular motion clockwise or counterclockwise, depending upon whether the furnace bonnet air is being heated or cooled.

Type of System	Fan & Limit Control Settings In Fahrenheit		
	“Limit Set Point”	“Fan-Off”	“Fan-On”
Average Furnace & System	200	120	100
Oversized Furnace and/or System	170	130	90
Undersized Furnace and/or System	230	160	130

In the event the fan failed to operate, or the air filters are clogged, the temperature in the furnace bonnet would continue to rise going beyond the "fan on" position and ultimately reaching the high limit indicator setting of 200° as shown in the above table. Upon reaching this point, the limit control would "open" its electrical contacts in its switch thus preventing line voltage from reaching the No. 1 terminal of the primary control. This would prevent line voltage from reaching the oil burner motor and ignition transformer thus causing the oil burner to go "off." The high limit control would continue to hold its electrical switch contacts "open" until the air temperature in the bonnet had dropped below the 200ºF mark and differential of the switch. The helical element would at the same time cool, rotating in a counterclockwise direction, causing the limit indicator to also rotate in a counterclockwise direction until the scale plate had traveled below the 200ºF setting. Once this point has been reached, line voltage power would once again be restored to the No. 1 terminal of the primary control. If the room thermostat is still calling for heat, the burner would once again operate.

PRIMARY CONTROLS

The primary control must: 1. Control the ignition transformer and, in turn, the burner motor. 2. Prove the presence or absence of flame. 3. Shut down the system on malfunction such as failure to establish flame on start, flame failure during run, and power failure.

For automatic operation, three basic controls must be incorporated in each system: 1. The thermostat or controller. 2. The limit control. 3. The primary control (with flame detection). The key to the primary control's supervision of the burner is its ability to prove the presence or absence of flame on the start and during the run. The primary must allow the burner to run only when flame is present and must shut it down if flame cannot be proved.

The thermostat transmits the need for heat to the primary control and also signals when the need for heat has been satisfied. The limit control protects the system from overheating. Whether the limit is a warm air, water temperature, or pressure control, the function and operation are basically the same. The limit action is to break the power supply to the primary control, causing a complete shutdown. The third standard control is the primary which operates under control of the thermostat and subordinate to the limit controls to supervise burner operation. Each of these controls act on a yes (okay to run) or no (stop everything) basis, but together in a properly designed and installed system. They provide safe burner operation to satisfy a need, or they shut down the burner when the need is satisfied or when an unsafe condition exists.

The primary control is the heart of the oil burner control system and has 3 basic control functions. *First,* it must respond to the heating requirements indicated by the thermostat. This includes responding to the need for heat and to the satisfaction of the heating requirement. *Second*, it must shut down the system on limit action. This is accomplished by putting the limit in the power supply line to the primary control so that limit action immediately stops the burner. *Third,* it must supervise the starting, stopping, and running of the burner. This means that the primary control must be capable of controlling the ignition transformer and burner motor, proving the presence or absence of the flame, and shutting down the system on malfunction or flame failure.

The primary control uses the information transmitted to it from the detector to shut down the burner (or allow it to operate) through the use of a safety switch. The safety switch consists of a small bimetal element and a separate safety switch heater. When current is allowed to pass through the safety switch heater, the bimetal heats and starts to warp. When it warps sufficiently, the safety switch breaks and the system shuts down. The safety switch must be manually reset any time it opens. The bimetal is calibrated so that it warps open in a specified amount of time which is the safety switch timing for the control. To prevent the control from locking out on safety, this switch must be bypassed so the bimetal does not heat. This is done by the flame detector, if it proves the presence of flame.

There are two methods of detecting the flame. Thermal detectors respond to an increase or decrease in stack temperatures through a bimetal element inserted into the stack or the old type stack mounted primary controls. Visual detectors respond to the light emitted by the oil flame (cad cells). Cad cells respond by letting electricity pass through them upon the presence of a flame (light) after a few seconds.

Both visual and thermal detector primaries are available with either intermittent, or interrupted ignition. In intermittent ignition systems, ignition comes on when the burner motor is energized and stays on as long as the burner is firing. In interrupted ignition systems, ignition comes on when the burner motor is energized and goes off either when the burner flame is established or after a preset ignition timing period.

Whether the primary control is of the thermal or visual detector type, it MUST be capable of performing the three basic functions as mentioned, because the end results must be the same. Also, primary controls may be either stack-mounted or burner-mounted (cad cells). However mounted, they *all must have in their circuit a device for detecting the presence of, or the absence of, a flame. This feature represents the most important function of any primary control.*

***Stack mounted* primaries are manufactured with the flame detecting device built in. *Burner mounted* primaries require a separate flame detecting device.**

WIRING COLOR CODE FOR INDUSTRY STANDARD
OIL PRIMARY CONTROLS

CARLIN Model No. 60200-02
HONEYWELL Model No. 7184

1)	**Cad Cell**	**Yellow**
2)	**Power Wiring L1**	**Black**
3)	**Carlin Power Wiring L1**	**Red w/ White Stripe**
4)	**Ground L2**	**White**
5)	**Limit**	**Red or Red w/ White Stripe**
6)	**Carlin Limit**	**Black**
7)	**Ignitor**	**Blue**
8)	**Valve Delay Off/On**	**Violet**
9)	**Burner Motor**	**Orange**
10)	**Thermostat (24 volt W)**	**White**
11)	**Thermostat (24 volt R)**	**Red**

CARLIN Model No. 60200-02 & HONEYWELL Model No. 7184 can check for proper cad cell operation by observing LED flashes. If these controls lock out 3 times in a row without a complete heat cycle between attempts, the lockout becomes restricted in order to prevent repetitious resetting by the homeowner. To reset, hold down the reset button for 30 seconds (until the LED flashes twice.

For Honeywell 8184 or Carlin 50200-02, Others:

Orange wire from primary control ties into the Burner, Ignition and Optional Oil Valve. Some models can independently control Ignition (interrupted) and Oil Valve along with pre and post purge options.