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DEPARTMENT OF COMMERCE
BUREAU OF STANDARDS
WASHINGTON

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House Heating with Oil

Numerous inquiries have been received by the Bureau in reference to the substitution of fuel oil for coal for heating. Many of these inquiries request recommendations as to what type or make of burner should be installed, or request the Bureau's opinion on some designated burner. In reply to such inquiries, it may be said that the Bureau has no test data available on which such opinions could be based, and if it had, it would not be in a position to make specific recommendations on competitive products. Such a recommendation, to be fair, would have to be based on a full knowledge of the performance of all burners on the market and of all other factors which should be taken into account, and it is obviously impossible to have such knowledge. The Bureau can, however, properly give out such information as is available, allowing any one to draw the conclusions applicable to his own particular case with the aid of the facts presented.

It is the purpose of the following pages to supply some of the general information which would be useful to anyone interested in oil burning equipment. It is only natural that more emphasis should be given here to the kind of information not ordinarily available to the prospective purchaser, or to matters which are often overlooked, while those points on which the purchaser may be expected to be thoroughly informed by reading of advertising literature, talking with salesmen, etc., will receive much briefer mention.

Oils

Crude oil is the product taken from the oil wells. This oil is rarely used for heating, and is never sold for use in domestic heating plants, for two reasons, first, nearly all crude oils yield products such as gasoline, lubricating oil, etc., which are too valuable to be used in this way, and second, the gasoline content makes the oil highly inflammable so that its use would be unnecessarily hazardous. This explanation is given because the term "crude oil" is erroneously used in many instances, instead of the correct term, "fuel-oil."

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Fuel oil is a part of the crude oil which cannot profitably be converted into the more valuable products such as gasoline, lubricating oil, etc. It is therefore, one of the cheaper products obtained from crude oil, although its selling price is, like that of the other products, dependent upon existing conditions, and subject to variations from time to time.

The various grades of fuel oil on the market are classified and described commercially, by their density, as determined by a hydrometer, an instrument now familiar to large numbers of persons who take an interest in their storage batteries. The hydrometers used in testing oils have a special scale known as the A.P.I. (American Petroleum Institute) scale, a digression from the original Baume scale.

On the A.P.I. scale, the density of water is represented by the number ten, while the density or "gravity" as it is known to the oil trade, of kerosene is between 40 and 48 "degrees A.P.I. The heavier fuel oils, of gravity from 12 to 20 degrees, are rarely seen by the general public. They are used for firing large boilers, but many are so viscous that it is necessary to warm them by means of steam coils in order to permit pumping out of storage tanks, and in order to burn them satisfactorily they must be heated to still higher temperatures when they reach the burners. These heavy fuel oils are the cheapest of all, but needless to say, they are never used for domestic heating. The oils available for domestic heating include kerosene, gravity 40 to 48 degrees, gas oil, gravity 32 to 40 degrees, and the heavier distillates, ranging down to oils having a gravity of 24°, which appears to be about the heaviest oil recommended for use with any type of burner designed for small heating plants. Oils of about 40 degrees gravity are sometimes sold as furnace oil. As a general rule, the lighter the oil, the higher the cost.

Some burners can be made to operate with the used oil drained from automobile crank cases, and the claim is sometimes made that a burner which will handle this oil is for this reason, capable of burning any fuel oil. As a matter of fact, used crank case oil is likely to have a gravity between 24 and 30 degrees, and would not be classed with the very heavy fuel oils.

It may be noted that the properties of an oil are by no means completely determined if its gravity is known, and that it is very easy to find two oils of the same gravity, one of which may be thoroughly satisfactory for a given purpose, while the other may be almost unusable. However, practically

the only description readily obtainable concerning fuel oils is their gravity, and it seems necessary at present, to designate the oils by this admittedly somewhat inadequate method.

Comparison of Oil and Coal

The advantages usually claimed for oil fuel are cleanliness, convenience, better control of the fire, availability of the fuel at times when coal can be obtained with difficulty, if at all, and sometimes lower cost of fuel.

There are also possible disadvantages connected with the use of oil fuel, among which may be mentioned soot, odor, noise, higher cost, due to high first cost of some types of installations, or higher operating cost, and increased fire risk.

The use of oil undoubtedly involves a greater fire risk than the use of coal. The greater hazard, however, usually leads to the adoption of additional precautions, which in many localities are mandatory. The important precautions to be observed are covered by the "Regulations of the National Board of Fire Underwriters for the Construction and Installation of Oil Burning Equipments and for the Storage and Use of Oil Fuels." These regulations are recommended by the National Fire Protection Association, 40 Central Street, Boston, Mass., which can supply copies of the pamphlet containing the Regulations. In many localities these regulations have been incorporated, in whole or in part, into local regulations.

With a suitable installation it is undoubtedly true that oil will be superior on the grounds of cleanliness and convenience, as well as ease of control. It must not be overlooked, however, that occasionally an oil burner fails to function properly, and if allowed to burn with a smoky flame, may do more damage to furnishings and decorations in a few hours than would be done by a coal burner in several years. This does not mean, of course, that every oil burner will at some time cause such damage, but instances have been frequent enough to make it worth while for the prospective purchaser, or the owner, to have the possibility in mind.

The questions of odor and noise are more appropriately considered in connection with burners.

In addition to the questions considered in the above paragraphs there remain those of availability and cost of fuel which are rather intimately related. The yield of the heavier

oils is considerably larger than that of the lighter and the extensive use of oil for domestic heating would probably make it necessary to use the heavier oils extensively.

At the present time the amount of the lighter oils which can be produced is adequate to meet the demand, but the extensive introduction of oil burning appliances for house heating would probably result in a demand for this grade of fuel which would greatly influence the price. In the future, oil-burning installations which can utilize the heavier grades of fuel will undoubtedly have a distinct advantage, not only on account of the lower price, but on account of the greater quantity of such fuels available.

The availability of a particular grade of fuel may depend upon the locality. It is probable that in most of the smaller cities of the country, a barrel of low grade fuel oil, delivered to the customer would at present cost more than a barrel of kerosene, in spite of the fact that the cost of the fuel oil, at a distributing center, might be only one-third that of kerosene. Before installing any type of oil-burning equipment, the purchaser should, of course, assure himself that means are available for supplying the grade of fuel required.

The relative cost of fuel for heating with oil and with coal, including such auxiliary costs as electric power, gas, etc., in any particular installation, could not in general be determined without detailed data, but certain general considerations are of interest. The heat of combustion of one gallon of 40 degree oil is about 140,000 Btu. (A British thermal unit, or Btu. is the amount of heat required to raise the temperature of one pound of water by 1°F.) Heavier oils will have a somewhat higher heat of combustion per gallon, while lighter oils will yield lower values. The heat of combustion of coal ranges from over 14,000 Btu. per pound for the higher grades to below 10,000 Btu. per pound for the lower grades. Thus one gallon of a light fuel oil has the same heat of combustion as 10 to 14 pounds of coal, depending upon the grade of coal. In the comparisons to follow, the average figure, that one gallon of fuel oil has the same heat of combustion as 12 pounds of coal, will be used.

In order to heat a house, a certain number of Btu. must be supplied, and the cost of fuel, other things being equal, will be proportional to the cost per Btu. In the following table, the cost of seven gallons of oil, yielding approximately one million Btu. is compared with the cost of 84 pounds of coal, yielding according to the assumption stated, the same number of Btu.

Cost per million Btu. with oil heating (100% efficiency assumed) and coal heating (100% efficiency assumed).

Cost of Oil per gallon	Cost of 7 gal. (1 million Btu)	Cost of Coal per 2000 lb.	Cost of 84 lb. (1 million Btu)
5 cents	$0.35	$5.00	$0.21
6 "	.42	6.00	.25
8 "	.56	8.00	.34
10 "	.70	10.00	.42
12 "	.84	12.00	.50
15 "	1.05	15.00	.63

From the above table it might be inferred that coal at $12.00 per ton of 2000 pounds was equivalent to oil at about 7 cents per gallon or that heating with oil at 12 cents per gallon would cost twice as much as heating with coal at $10.00 per ton.

Such a comparison would probably be unfair to oil, for a number of reasons. Coal is never burned completely, while the losses due to incomplete combustion of oil are probably very small in a good installation. A suitable type of oil burner will permit a close control of the fire and for this reason oil heating might be much less wasteful than coal heating. This would be particularly true in the spring and fall when heat is only required occasionally.

A fairer comparison may perhaps be made by assuming that of the heat of combustion of coal 50% is usefully applied, and that oil is used 1 1/4 times as efficiently as coal so that 62 1/2 per cent of the heat of combustion of the oil is usefully applied in domestic heating. If this is true, the cost per million Btu actually utilized, would be as shown in the following table:

Cost per million Btu. with oil heating (62 1/2% efficiency) and coal heating (50% efficiency).

Cost of oil per gallon	Cost of heat from oil per million Btu	Cost of Coal per short ton 2000 lb.	Cost of Coal per long ton 2240 lb.	Cost of heat from coal per million Btu
5 cents	$0.56	$5.00	$5.60	$0.42
6 "	.67	6.00	6.70	.50
8 "	.89	8.00	8.95	.68
.10 "	1.12	10.00	11.20	.84
.12 "	1.34	12.00	13.40	1.00
15 "	1.68	15.00	16.80	1.26

In using this table, the assumptions on which it is based should be clearly borne in mind. It is believed that comparisons based on this table will not be far from average results obtained. On the basis used in this table one gallon of oil would replace about 15 pounds of coal. Claims made by manufacturers of oil burners range from 100 gallons of oil replacing a ton of coal, (1 gallon equivalent to 20 to 22.4 pounds) to 160 gallons replacing a ton of coal (1 gallon equivalent to 12.5 to 14 pounds of coal.)

In making the above comparisons, only the fuel cost has been considered. If the burner is operated by an electric motor the power cost will also require consideration. A 1/4 horsepower motor which is the size used in many burners, has a power input of about 300 watts at full load. If the motor were in operation 12 hours each day and the charge for power were 10 cents per kilowat hour, the power cost would be 36 cents per day or about $11.00 per month. On the other hand, if the motor were in operation only six hours per day and the power rate were only 3 cents, the power cost would be only about $1.60 per month. In a large number of cases the power costs will probably be found to lie between these two limits.

Because of lack of authentic data, the calculations have necessarily been based on assumptions. Reliable comparative data, applicable to average installations, could probably be obtained better by taking the results of experience in a large number of installations over a period of years, then by laboratory tests. Such data are not at present available.

Burners

At present, (1924) practically all of the oil burners on the market are designed for use in existing types of coal burning heaters. The first classification which the prospective purchaser will be interested in noting is that some burners require no auxiliary power, such as an electric motor while others depend upon such power for their operation. Burners of the former type are usually of comparatively simple construction and are supplied from an elevated tank from which the oil flows to the burner by gravity. In burners of this type the oil is heated in the burner to a temperature high enough to cause it to burn readily. Such burners are limited to the use of kerosene or gas oil down to 38 or perhaps 36 degree gravity, so that while they have the advantages of simplicity and lower first cost, their operating cost will tend to be high because of higher cost of fuel. Under some conditions they may produce objectionable amounts of smoke and soot, and in general, they require more frequent attention and regulation than the more elaborate types referred to later.

There are numerous forms of these simple burners, but there is one form which is in general unsatisfactory. In this form of burner, the oil is vaporized in a closed pipe or casting, and the vapor issuing from very small holes is ignited and in burning, heats the oil in the closed pipe, thus providing a continuous supply of vapor. Such burners operate well on gasoline, but with heavier oils, have a tendency to clog, and require constant attention. To start such a burner the vaporizer must first be heated, which is sometimes done with wood alcohol or gasoline, sometimes with kerosene, in case the smoke produced is not too objectionable. The regulations of the National Board of Fire Underwriters, which have been adopted, in whole or in part, in many localities provide that "Burners containing - - - oil conveying pipes or parts subject to intense heat or carbonization are prohibited." Such a regulation would prohobit the use of burners of the type described. Special mention of this type of burner seems to be called for, because it can be very easily assembled from a few pieces of pipe and a casting or two, exploited as a wonderful invention, and put on the market by irresponsible persons.

Of the power operated burners, most of which employ electric motors, although water motors are also used, there is a large variety of types and forms. The classification which is perhaps of most interest to the purchaser, concerns the

type of fuel used. Some of the motor operated types are of such design that they can burn only the lighter fuels, while others are capable of handling a much larger variety. As a general rule, a burner which will operate satisfactorily on a heavy oil, say of 24 degree gravity will also operate satisfactorily on the lighter oils. The owner of a burner capable of burning the heavier oil has therefore the advantage of having a wider variety of oils to choose from, as well as the possibility of using a cheaper fuel.

While the differences between burners mentioned above, are of importance, there are many other factors to be considered in making a choice, which in many cases will be determined by considerations other than those mentioned. Other features to be considered include reliability, safety, efficiency, quietness in operation, odor, smoke, and initial and operating costs.

On the matter of reliability and safety, no generalization can be made, except that these depend upon good design and workmanship, and proper installation. Numerous types of burners have been tested and approved by Underwriters Laboratories, Inc., 207 East Ohio Street, Chicago, Illinois, and the purchaser of such an approved type of burner may have considerable assurance that most of the features which, if present, would make a burner a special fire hazard, have been eliminated, and that necessary safeguards have been provided.

In reference to efficiency, it may be noted that in general any successful burner must burn the oil almost completely, as otherwise it would produce so much smoke as to be intolerable. The efficiency of the combination of burner and heating appliance, which determines what proportion of the heat produced by burning the fuel is usefully applied, and determines the fuel requirements, is subject to wide variation, depending upon the type and condition of the heating appliance, the type of burner, the method of installation, the method of operation, etc. A very hot flame does not necessarily mean high efficiency, and such a flame is undesirable because of its destructive effects. If combustion is reasonably complete the amount of heat produced with a burner depends upon the amount of fuel burned and not upon the intensity of the flame. However, if complete combustion is obtained by supplying a large excess of air to the burner, much heat will be wasted up the flue, and the over all efficiency will be low.

Special heaters designed exclusively for oil burning, are just beginning to appear on the market. With such heaters and a suitable burner, higher efficiency should be obtained than from an oil burner installed in a coal-burning appliance.

On the other hand, the possibility of returning to coal burning in case this should later become desirable, may prove to be a valuable feature.

The odor, noise and smoke will depend upon the fuel used and the type of installation and information upon these features should be obtained before making a purchase. The noise may be due either to the roaring of the flame or to a mechanical appliance, such as a motor driven fan. It should be borne in mind that noise due to mechanical appliances tends to increase as the appliance becomes older. A noise that may appear to be unimportant in an installation on exhibition may, to a person of nervous temperament, become intolerable if continued, either continuously or intermittently, for extended periods. In some installations, the noise has proven to be the most objectionable feature.

Oil burners are perhaps less adapted to installation in hot air furnaces than in other types of heating appliances. It is possible that a furnace which has given satisfactory service with coal, will be entirely unsatisfactory with an oil burner, due to leakage of flue gases into the circulating air. This is most likely to occur if the burner is of the type equipped with a blower, as this tends to cause a higher pressure in the fire box than is the case when natural draft only is used. Some manufacturers prefer not to install their burners in hot air furnaces.

When examining oil burners with a view to purchase attention should be given to such features as ease of starting, method of control, adaptability to automatic control, etc. Good workmanship is an important factor, and it is well to be assured that the manufacturer of the burner is reliable and likely to continue in business, and that prompt and reliable service will be available in case repairs or adjustments are necessary. The initial cost will naturally receive consideration.

Several types of oil burners were described in the Heating and Ventilating Magazine, 1123 Broadway, New York City, during 1922 and 1923. These descriptions and some other material have been issued separately under the title "House Heating with Fuel Oil." Other articles on use of oil have been published during 1924.

Oil Storage

In purchasing an oil burner, the desirability of providing storage for an adequate amount of oil is often overlooked. Many burners as sold have only a 50 gallon storage tank which

may be sufficient for only a few days use in cold weather. While the handling and distribution of oil appears to be much more efficiently organized than that of coal, so that regular delivery of oil will probably be obtained with much more certainty than is the case with coal, it is certainly prudent to provide for storage, not only as a means of avoiding shortage, but to make it possible to take advantage of periods of lower prices. Since a tank 4 feet in diameter and 10 feet long holds about a thousand gallons, it will be seen that the purchase and installation of fuel tanks, which should preferably be buried in the ground, represents no inconsiderable part of the cost of an oil burning installation. Detailed specifications for the construction and installation of oil storage tanks are included in the "Regulations of the National Board of Fire Underwriters" already referred to.

The Real Cost of Heating

The items chargeable to cost of heating include fuel cost, cost of electric power, etc., depreciation of equipment, repairs, interest on investment, space occupied, labor costs, and possibly injury to the house by dirt, dust, smoke, soot, etc. While as a business proposition, a correct estimate of the cost of heating can only be made by taking all such items into account, it is true that for house heating many persons will be interested only in one or more of the items, being content to overlook others or to charge them up in other ways. Thus the result of a comparison of the relative cost of oil and coal heating will lead to various results, depending upon whether all the items are included or not.

If the comparison is made on the basis of fuel and power costs only, no very positive advantage appears at present. If future costs are to be taken into consideration, it is to be remembered that the coal market for domestic fuels, is probably much more stable than the oil market, and that the price of oil is likely to vary through a wide range. It should be remembered that a change of one cent a gallon in the price of oil is equivalent in most cases to more than one dollar per ton in the price of coal. Then while the user of coal can rest fairly comfortable in the assurance that at worst the cost of his fuel will increase only a little each year, the user of oil must be prepared for large variations in fuel cost, and to find that ultimately oil may be difficult to obtain.

It is undoubtedly true that in the long run, the cost of heating with the more desirable fuel will be higher. At present the cost of heating with hard coal is recognized as being higher than with soft coal, and the hard coal is enabled to command the higher prices because of certain inherent advantages for domestic use. Similarly, oil being a liquid fuel has certain inherent advan-

tages, and some attendant disadvantages, but on the whole, it will probably come to be considered the superior fuel and as such, is likely to command a higher price. The advantages of oil may be off-set to some extent, by new developments in coal-burning and coal-handling equipment. Such developments stimulated no doubt by the competition due to oil, have already appeared, and are being promoted vigorously.

If a coal burning installation is replaced by an oil-burning one, and fuel costs, power costs, depreciation, repairs, and interest chargeable to the added investment only be considered, it is safe to say that the cost of oil heating will be found greater than that of coal heating.

If, on the other hand, in addition to the costs mentioned in the preceding paragraph, labor costs, including cost of handling and removing ashes (the latter in many cases being paid indirectly in the form of taxes) are taken into consideration, it is probable that the use of oil would show a substantial saving.

In addition to persons interested in comparisons of the kind just given, there will be large numbers of others to whom cost, no matter how calculated, will not be as important unless it be beyond all reason, as other considerations such as convenience, comfort, cleanliness, etc.. Such persons would purchase an oil burning equipment largely because they preferred it.

In such cases, heating with the manufactured gas used for cooking and lighting might also be considered, since in everything but cost, and perhaps availability in very cold weather, gas would be superior to oil. The initial cost of the gas burner itself is comparatively small, but as it would probably be advantageous to put in a heater designed for gas, rather than to use the gas in an existing coal-burning appliance, the initial costs would not differ greatly. Estimates of the relative cost of heating with gas, similar to those made here in comparing coal and oil, can be made by using the data for the heating value, in Btu per cubic foot, which the gas company maintains, and the cost of gas. In reference to availability, consideration should be given to the fact that where gas is used extensively for heating, as it is where natural gas is used, the demand for gas in cold weather has sometimes been larger than could be supplied.

It is in order in this connection to call attention to the subject of insulation of houses. The walls of many houses are not good insulators, and the addition of a half inch of a good insulating material to the walls and roof of such a house, and

good construction of doors and windows to prevent excessive leakage of air, will pay a good return on the investment, not only in lower cost of heating, but in increased comfort.

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