FUEL OIL IN INDUSTRY

By

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PRINCIPLES OF FUEL OIL COMBUSTION

Combustion is nothing more nor less than a chemical union of oxygen with some combustible material such as carbon. The decaying autumn leaf is an example of combustion. In this case the organic matter of the leaf forms a slow chemical union with the oxygen of the air. Heat accelerates all chemical unions and the greater the intensity of the heat applied, the more rapidly the elements unite. The process of the combustion of the autumn leaf is slow because insufficient heat is developed to induce rapid combustion.

The explosion of black powder, dynamite or any other of the high explosives, is another example of combustion. Black powder is a mechanical mixture of sulphur, charcoal and potassium nitrate. In this mixture theoretically each particle of sulphur has beside it one particle of charcoal and one particle of potassium nitrate. Sulphur, which burns easily, is put in the mixture to generate sufficient heat for the liberation of the oxygen which is contained in the potassium nitrate. Inasmuch as all of the elements necessary for combustion, that is, heat-giving substance, combustible material, and oxygen are combined in black powder. the rate of burning is thousands of times greater than is that of the decaying automn leaf. Since sulphur, charcoal, and potassium nitrate are only mechanically mixed, it follows that in practice every particle of sulphur does not have adjacent to it a particle of charcoal and a particle of potassium nitrate. Accordingly the speed of combustion of black powder is relatively slow as compared with that of the high explosives in which the oxygen-carrying material and the combustible are chemically united so that no matter how finely the explosive may be divided, each atom is composed of the combustible and of the oxygen-giving material. The heat necessary for the union of combustible and oxygen in the high explosives is generated by an easily explosible detonator. The intense rapidity of combustion in high explosives is shown by the fact that if a pipe five miles long were filled with nitroglycerine and a blasting cap detonated at one end, the entire column would be converted into gas in about one second.

From these examples it will be seen that the speed and efficiency of combustion depend upon the intimacy of the mixture of combustible material with oxygen, and that combustion may extend over a long period of time or may be instantaneous. To the engineer, combustion means the chemical union of the combustible of a fuel and the oxygen of the air at such a rate as to cause rapid increase in temperature.

Fuel oil consists principally of various combinations of hydrogen whose chemical symbol is H, and carbon (C), together with small amounts of nitrogen (N), oxygen (O), sulphur (S), and water (H_2O). The moisture in oil fuel should not exceed two percent because it not only acts as an inert impurity, but must be converted into steam in the furnace, which still further reduces the heat value of the fuel per pound. In the ordinary furnace all the oxygen for the combustion of fuel oil is obtained from the air which is a mechanical mixture of 79.3 parts of nitrogen by volume and 20.7 parts of oxygen.

When the combustible elements of fuel oil unite with oxygen they do so in definite proportions which are always the same Carbon, hydrogen and sulphur require theoretically a certain fixed amount of air for complete burning. The formula for the complete combustion of carbon is $C + O_2 = CO_2$. One pound of carbon requires for complete combustion 2.66 pounds of oxygen. The dry air requirements for the combustion of one pound of carbon are 11.58 pounds. The formula for the combustion of hydrogen is $2H_2 + O_2 = 2(H_2O)$ (water). One pound of hydrogen requires for complete combustion 8.00 pounds of oxygen. For the combustion of one pound of hydrogen, 34.8 pounds of dry air are required. The formula for the complete combustion of sulphur is $S + O_2 = SO_2$. One pound of sulphur requires for its complete combustion 1.00 pound of oxygen. For the combustion of one pound of sulphur, 4.35 pounds of dry air are necessary.

The theoretical air requirements for different densities of fuel oil have been compiled by C. R. Weymouth (Trans., A. S. M. E., Vol. 30, p. 803), and are given in Table 1.

It is not possible to burn oil practically with the theoretical air requirements, and sometimes in furnaces of poor design 100 to 200 percent of excess air is used with a resulting great loss of heat. The maximum excess air required should be 25 percent. Insufficient air gives incomplete combustion with a consequent loss in unburned heat units and an excess of air cools the flame and carries away large quantities of heat in the flue gases. The air excesses for various boiler efficiencies are given in Table 2.

Table 1.—POUNDS OF AIR PER POUND OF OIL AND RATIO OF AIR SUPPLIED TO THAT CHEMICALLY REQUIRED.

Percent CO_2 by Volume as Shown by Analysis of Dry Chimney Gases.	Light Oil. C, 84%; H, 13%; S, 0.8%; N, 0.2%; O, 1%; H^2O, 1%.		Medium Oil. C, 85%; H, 12%; S, 0.8%; N, 0.2%; O, 1%; H^2O, 1%.		Heavy Oil. C, 86%; H, 11%; S, 0.8%; N, 0.2%; O, 1% H^2O, 1%.	
	Lb. of Air per Lb. of Oil.	Ratio of Air Supply to Chemical Requirements.	Lb. of Air per Lb. of Oil.	Ratio of Air Supply to Chemical Requirements.	Lb. of Air per Lb. of Oil.	Ratio of Air Supply to Chemical Requirements.
4	51.40	3.607	51.93	3.704	52.45	3.803
5	41.31	2.899	41.71	2.975	42.12	3.054
6	34.58	2.427	34.90	2.490	35.23	2.554
7	29.77	2.089	30.04	2.143	30.31	2.198
8	26.17	1.836	26.39	1.883	26.62	1.930
9	23.37	1.640	23.56	1.680	23.75	1.722
10	21.12	1.482	21.29	1.518	21.45	1.555
11	19.83	1.391	19.43	1.386	19.58	1.419
12	17.76	1.246	17.88	1.276	18.01	1.306
13	16.46	1.155	16.57	1.182	16.69	1.210
14	15.36	1.078	15.45	1.102	15.55	1.127
15	14.39	1.010	14.48	1.033	14.57	1.056

Figure 1 shows the heat losses due to excess air in burning fuel.

It is well known that with charcoal or coke a very intense combustion can be maintained with very little smoke and within a comparatively small space. The reason for this is that even at the highest temperature the fuel is solid. Therefore, no carbon can leave the fuel bed except as a constituent of CO or CO_2. When carbon is not supplied with sufficient air for complete combustion it burns to CO instead of to CO_2. When carbon is burned only to CO it provides only two-thirds of the heat which it is capable of yielding up when burned to CO_2. When completely burned, fuel which consists of 100 per cent carbon will show a percentage by volume of 20.7 CO_2 in the flue gases. Under good furnace conditions, when burning fuel oil which contains a high percentage of carbon the average theoretical CO_2 percentage of flue gases is from 13 to 14 per cent. Table 3 shows the corresponding losses that occur when various percentages of CO_2 are indicated in the flue gases.

In order to determine whether the fuel oil is obtaining the correct amount of air, it is necessary to analyze the flue gases. A flue gas analysis gives the proportion by volume of the principal constituent gases produced by the combustion of any fuel. The gases usually determined in such an analysis are CO_2, O, and CO. The volume remaining after these gases are removed is considered to be nitrogen (N).

The apparatus most commonly used for flue gas analysis is known as the Orsat. The Orsat apparatus (See fig. 2) is de-

Table 2.—BOILER EFFICIENCY FOR EXCESS AIR SUPPLY (OIL FUEL)

Excess Air Supply, Percent.....	10	50	75	100	150	200
Assumed temperature of escaping gases, deg. Fahr........	400	450	475	490	Over 500	Over 500
Corresponding ideal efficiency of boiler, percent.............	84.2	80.27	77.66	75.22	Under 70.94	Under 67.09
Possible saving in fuel due to reduction of ail supply to 10 per cent excess, expressed as percent of oil actually burned under assumed conditions......	0	4.67	7.78	10.68	Over 15.76	Over 20.32

scribed as follows: "The burette "a" is graduated in cubic centimeters up to 100, and is surrounded by a water jacket to prevent any change in temperature from affecting the density of the gas being analyzed. For accurate work it is advisable to use four pipettes, "b," "c," "d," "e," the first containing a solution of caustic potash for the absorption of carbon dioxide, the second an alkaline solution of pyrogallol for the absorption of oxygen, and the remaining two an acid solution of cuprous chloride for absorbing the carbon monoxide. Each pipette contains a number of glass tubes, to which some of the solution clings, thus facilitating the absorption of the gas. In the pipettes "d" and "e," copper wire is placed in these tubes to re-energize the solution as it becomes weakened. The rear half of each pipette is fitted with a rubber bag, one of which is shown at "k," to protect the solution from the action of the air. The solution in each pipette should be drawn up to the mark on the capillary tube. The gas is drawn into the burette through the U-tube "h," which is filled with spun glass, or similar material, to clean the gas. To discharge any air or gas in the apparatus, the cock "g" is opened to the air and the bottle "f" is raised until the water in the burette reaches the 100 cubic-centimeter mark. The cock "g" is then turned so as to close the air opening and allow gas to be drawn through "h," the bottle "f" being lowered for this purpose. The gas is drawn into the burette to a point below the zero mark, the cock "g" then being opened to the air and the excess gas expelled until the level of the water in "f" and in "a" is at the zero mark. This operation is necessary in order to obtain the zero reading at atmospheric

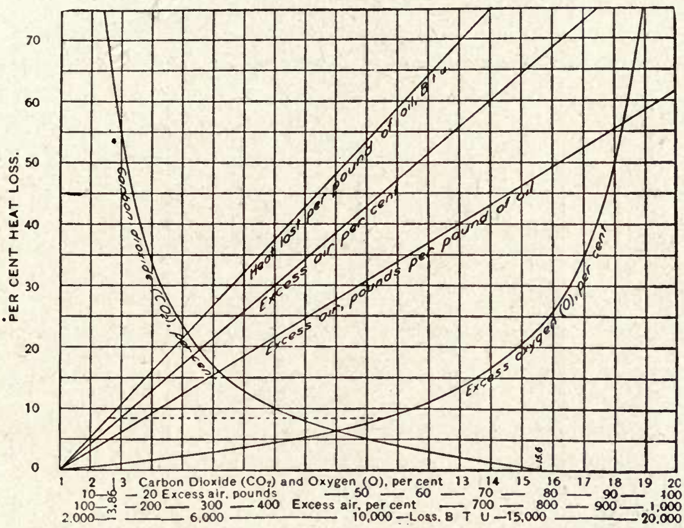

FIG. 1.—Curves showing heat losses due to excess air. Calculated on following conditions: Oil as fired—18 633 B. t. u., 84.73 per cent carbon. 11.74 per cent hydrogen, 1.06 per cent sulphur, 5 per cent nitrogen, 0.87 per cent oxygen, 0.7 per cent moisture, and 0.4 per cent sediment; atmospheric temperature, 55° F.; humidity, 88; stack temperature, 500° F.; Kern oil, 15° B.

pressure. The apparatus should be carefully tested for leakage, as well as all connections leading thereto. Simple tests can be made as, for example: If after the cock "g" is closed, the bottle "f" is placed on top of the frame for a short time and again brought to the zero mark,, and the level of the water in "a" is above the zero mark, a leak is indicated. Before taking a final sample for analysis, the burette "a" should be filled with gas and emptied once or twice, to make sure that all the apparatus is filled with the new gas. The cock "g" is then closed and the cock "i" is opened and the gas driven over into "b" by raising the bottle "f." The gas is drawn back into "a" by lowering "f" and when the solution in "b" has reached the mark in the capillary tube, the cock "i" is closed and a reading is taken on the burette, the level of the water in the bottle "f" being brought to the same level as the water in "a." The operation is repeated until a constant reading is obtained, the number of cubic centimeters, absorbed as shown by the reading, being the percentage of CO_2 in the flue gases. The gas is then driven over into the pipette "c" and a similar operation is carried out. The difference between the resulting

Table 3.—CO_2 AND FUEL LOSSES.[a]

Percent CO_2.	Percent Excess Air	B. t. u. Loss.	Percent Fuel Loss.
15.6	0	0	.0
16	5	75	.4
14	10	186	1.
13	18	317	1.7
12	28	447	2.4
11	40	633	3.4
10	54	856	4.6
9	70	1118	6.
8	93	1435	7.8
7	120	1900	10.2
6	152	2460	13.2
5	198	3205	17.2
4	273	4380	23.5
3	396	6340	34.
2	635	10150	54.5
1			

reading and the first reading gives the percentage of oxygen in the flue gases. The next operation is to drive the gas into the pipette "d," the gas being given a final wash in "e," and then passed into the pipette "c" to neutralize any hydrochloric acid fumes which may have been given off by the cuprous chloride solution, which, especially if it be old, may give off such fumes, thus increasing the volume of the gases and making the reading on the burette less than the true amount. The process must be carried out in the order named, as the pyrogallol solution will also absorb carbon dioxide, while the cuprous chloride solution will also absorb oxygen. As the pressure of the gases in the flue is less than the atmospheric pressure, they will not of themselves flow through

a. Weymouth, Trans. A. S. M. E., Vol. 30, p. 803.

the pipe connecting the flue to the apparatus. The gas may be drawn into the pipe in the way already described for filling the apparatus, but this is a tedious method. For rapid work a rubber bulb aspirator connected to the air outlet of the cock "g" will enable a new supply of gas to be drawn into the pipe, the apparatus

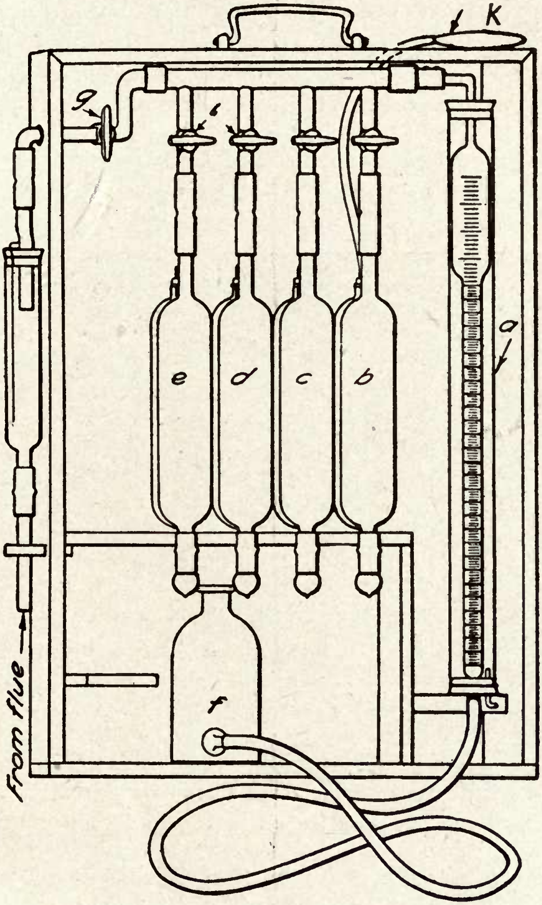

FIG. 2.—Orsat apparatus for testing flue gases

then being filled as already described. Another form of aspirator draws the gas from the flue in a constant stream, thus insuring a fresh supply for each sample. The analysis made by the Orsat apparatus is volumetric. If the analysis by weight is required it can be found from the volumetric analysis as follows: Multiply the percentages by volume by either the densities or the molecular weight of each gas, and divide the products by the sum of all the products; the quotients will be the percentages by weight. For most work sufficient accuracy is secured by using the even values of the molecular weights. The even values of the molecular weights are:

Carbon Dioxide (CO_2)	44
Carbon Monoxide (CO)	28
Oxygen (O)	32
Nitrogen (N)	28

A typical flue gas analysis is as follows: Carbon dioxide, 12.2; carbon monoxide, 0.4; oxygen, 6.9; nitrogen, 80.5; total, 100.0.

FIG. 3.—Dense smoke from burning oil tanks

Inasmuch as perfect combustion of coal will give a higher CO_2 reading than perfect combustion of oil, a possible error may arise among engineers who have been familiar with coal burning in interpreting the CO_2 content in flue gas when burning fuel oil. The possibility of this error may be demonstrated by the following example: Assume a sample of coal having the following ultimate analysis: Carbon, 73 percent; hydrogen, 4 percent; oxygen, 8 percent, and the residue ash. In each pound of coal it will be necessary to supply for complete combustion of the carbon

$0.73 \times 2\frac{2}{3} = 1.95$ pounds of oxygen. The oxygen required for the complete combustion of the hydrogen will be $0.04 \times 8 = 0.32$ pounds. The total oxygen required, therefore, will be $1.95 + 0.32 = 2.27$ pounds. The coal itself, however, contains 0.08 pounds of occluded oxygen. Subtracting this amount from the total oxygen required leaves 2.19 pounds of oxygen, which must be furnished by the air. The amount of air necessary to supply the required oxygen is $\frac{2.19}{0.23} = 9.53$ pounds and this amount of air will contain 7.34 pounds of nitrogen. The amount of CO_2 in the flue gas which will be produced by the 0.73 pounds of carbon in one pound of coal is $0.73 \times 3\frac{2}{3} = 2.68$ pounds. Water vapor to the amount of 0.36 pounds will be formed by the combustion of the hydrogen, but the water vapor before reaching the Orsat apparatus will condense, and, therefore, will not appear in the analysis. Hence, flue gas will contain 2.68 pounds of CO_2 and 7.34 pounds of nitrogen, totalling 10.02 pounds of gas for each pound of coal. This will give by weight $\frac{2.68}{10.02} \times 100 = 26.7$ per cent CO_2 and $\frac{7.34}{10.02} \times 100 = 73.3$ per cent of nitrogen. The relative volumes of CO_2 and nitrogen will be $\frac{26.7}{22} = 1.21$ for CO_2 and $\frac{73.3}{14} = 5.24$ for N, since the ratio of the weights of N to CO_2 is 14 to 22. By volume the percentages will be $\frac{1.21}{6.45} = 18.8$ per cent CO_2 and $\frac{5.24}{6.45} = 81.2$ per cent N. Follow the same calculation through with an average sample of fuel oil. This may be assumed to contain 85 per cent carbon, 12 per cent hydrogen and 3 per cent oxygen. The oxygen required by the carbon of the fuel oil will be 2.27 pounds and combustion will produce 3.12 pounds of CO_2. The oxygen required for the combustion of the hydrogen will be 0.96 pounds of oxygen per pound of oil burned and water vapor will be produced to the amount of 1.08 pounds. The net oxygen requirements will, therefore, be $2.27 + 0.96 - 0.03 = 3.20$ lbs. To provide this amount of oxygen 13.91 pounds of air must be introduced and this amount of air carries with it 10.71 pounds of nitrogen. As in the combustion of coal the water vapor will be condensed and the flue gas per pound of oil will be 3.12 + 10.71 = 13.83 pounds, which by weight will have a composition of 22.5 per cent CO_2 and 77.5 per cent nitrogen. The percentage of CO_2 by volume will be 15.6 and the percentage of N will be 84.4.

It is, of course, understood that these calculations are based on ideal theoretical conditions where there is complete combustion without excess air. In the samples of coal and oil under discussion, the coal might theoretically give an 18.8 per cent CO_2 reading whereas the oil could not possibly show a higher percentage than 15.6 because the oil has a greater amount of hydrogen than has the coal and hydrogen requires oxygen for its combustion and the air supplying the oxygen brings with it nitrogen which appears in the flue gas. The water vapor that the hydrogen produces does not appear in the flue gas analysis and the hydrogen, of course, does not produce CO_2. It is easily seen that the higher the hydrogen content of the fuel, the lower will be the theoretical CO_2 percentage in the flue gas.

A factor which is rarely considered in efficiency tests of fuel oil is the humidity of the atmosphere at the time of the test. With a high humidity of the atmosphere some of the oxygen in a given space is displaced by water vapor, and, therefore, for complete combustion of the fuel oil an excess in the volume of air will be required with a consequent loss of heat in the stack. In tests conducted by the U. S. Naval Liquid Fuel Board, the decision was arrived at that when operating a boiler at a given capacity the efficiency varies inversely with the humidity.

Table 4 gives the physical changes in air brought about by changes in temperature. Relative humidity is expressed as a percentage and is the ratio of the quantity of water vapor which is present in the air at any given temperature and pressure to the quantity of vapor necessary to saturate completely the space occupied by the air.

Since in the charcoal fire at the temperature of the union of the carbon with oxygen the fuel is solid, it can present a large surface upon which the oxygen can act, and an atom of carbon cannot break away from the fuel bed without being first united with at least one atom of oxygen and forming CO. In burning fuel oil the fuel is already on the way to the chimney before it is even partially burned and is carried along by the current of gases. Therefore, before being cooled, plenty of time must elapse or otherwise it will form soot. If the oil is not properly atomized at the burner the separate oil particles are too large and at the same time are not surrounded with a sufficient number of particles of air to insure their complete combustion. The heavier drops of oil progressively distill and particles of free carbon or soot are deposited. The lighter oils and gases resulting from this distillation consist, like the gases from coal, principally of carbon and hydrogen. In an atmosphere deficient in oxygen the hydro-

Table 4.—PHYSICAL CHANGES IN AIR DUE TO TEMPERATURE

Temperature of the Air.	Weight of 100,000 Cubic Feet of Pure Air.	Weight of Water in 100,000 Cubic Feet of Saturated Aqueous Vapor.	Quantity of Water per 100,000 Cubic Feet of Air.
Deg. F.	Pounds.	Pounds.	Gallons.
0	8,635.4	6.9	0.823
10	8,459.4	11.1	1.329
20	8,275.5	17.6	2.114
30	8,106.3	27.6	3.312
40	7,943.9	40.7	4.878
50	7,787.9	58.2	6.979
60	7,637.9	82.1	9.843
70	7,493.5	114.0	13.686
80	7,354.6	156.2	18.776
90	7,220.6	211.3	25.439
100	7,091.4	282.4	34.058

gen burns first and the carbon is deposited. Naturally when we consider that oil is a liquid originally and not a dense substance like coal, and particularly that it is blown into the furnace by compressed air or steam, the likelihood of its incomplete combustion with consequent deposition of soot is much less than is the case with coal.

An essential for the successful burning of fuel oil is the exposure of the largest possible surface to the action of the oxygen of the air. Bulk oil presents comparatively a small surface. If a tank of fuel oil is ignited, the air is able to reach only the uppermost surface of the liquid and combustion is relatively slow and incomplete, being accompanied by dense clouds of black smoke consisting of unburned carbon. (See fig. 3.) When fuel oil is broken up into fine drops the surface exposed is the sum of the surface of all the drops. The smaller the drops the more nearly spherical they are. Drops of oil one one-thousandth of an inch in diameter are known to assume the spherical form with a rigidity comparable to that of a steel ball one inch in diameter. The drop of oil assumes this spherical form through "surface tension," which is a very peculiar property belonging to both solids and liquids. Cohesion of the molecules appears to be greater at the surface than within the body of the globule. Cohesion may be explained as an attractive force between particles of the same material. It appears as though a thin envelope surrounds and holds together the particles composing the drop of oil.

The work necessarily performed by the atomizing agent is simply the work of stretching the surface of the drops. It will easily be seen, therefore, that to properly atomize fuel oil to such a form that it can be burned efficiently under boilers is purely mechanical rather than a chemical problem.

CHAPTER II

PHYSICAL AND CHEMICAL PROPERTIES OF FUEL OIL

Crude petroleum in its raw or unrefined state varies considerably in character and appearance, according to the locality from which it is obtained. Petroleum is a very complex mixture of organic compounds which are chiefly hydrocarbons, that is, compounds composed of hydrogen and carbon. Although the hydrocarbons are the chief constituents of petroleum it also contains in small amounts, sulphur, oxygen, and nitrogen. While petroleums from various sections of the country differ considerably in character, they may, however, be divided into three main classes:

1. Those in which the residue is predominantly paraffin wax.
2. Those in which the residue is predominantly asphalt.
3. Those in which the residue is a compound of paraffin wax and asphalt.

The paraffin petroleums of the United States occur chiefly in the eastern part of the country. The asphaltic petroleums are found in California and in the Gulf region and the compound paraffin-asphalt base petroleum is found generally in the mid-continent field.

It is possible to burn crude petroleum itself as a fuel and nearly one-fifth of the domestic consumption is thus utilized, but while the evaporative efficiency of crude and refined oil is practically the same no matter from what locality the oil may come, the danger of using crude oil is much greater than that of using fuel oil. The most of the petroleum produced in the United States is refined into a series of products. The four main products obtained through the distillation of petroleum in refineries are gasoline, kerosene, fuel oil, and lubricating oil. There are, of course, a large number of by-products obtained in the process of refining of which benzine, vaseline, paraffin, road oil, asphalt and petroleum coke are well-known examples. Table 5 gives analyses of typical American oils used as fuels.

TABLE 5.—ANALYSES OF TYPICAL AMERICAN OILS USED AS FUEL

Location.	Authority.	Physical Properties.					Chemical Properties.				
		Gravity.		Flash Point, Deg. Fahr.	Burning Points Deg. Fahr.	Viscosity at 68 Deg. Fahr. Engler Scale.	C Carbon.	H Hydrogen	O Oxygen.	S Sulphur.	B. t. u. per Lb.
		Baume at 60 Deg. Fahr.	Specific at 60 Deg. Fahr.								
California Crude:											
Coalinga	Bulletin No. 19	17.52	0.9498	192	230	341.5	86.37	11.30	1.14	0.60	18,727
Kern River		15.16	0.9645	226	266	915.6	86.36	11.27	0.74	0.89	18,553
McKitterick	U. S. Bureau of	16.37	0.9566	188	207	200.0	86.51	11.41	0.58	0.74	18,508
Midway	Mines (1912)	16.34	0.9570	172	210	518.0	86.58	11.61	0.74	0.82	18,613
Sunset		14.37	0.9701	192	235	527.0	85.64	11.37	0.84	1.06	18,478
Kansas Crude	B. F. McFarland	31.66	0.866	52	77	....	85.40	13.07	....	....	....
Louisiana crude	C. E. Coates	....	....	....	....	....	....	....	....	0.34	19,814
Ohio distillate	Deville	27.83	0.887	....	....	....	84.20	13.10	2.70[b]	....	18,718
Ohio distillate	N. W. Lord	38.25	0.838	177	212	....	....	....	....	....	....
Penna. crude	Deville	39.50	0.826	....	....	....	82.00	14.80	3.20[b]	....	17,930
Penna. distillate	Deville	27.80	0.886	....	....	....	84.90	13.70	1.40[b]	....	19,210
West Va. crude	Deville	36.46	0.841	....	....	....	84.36	14.10	1.60[b]	....	18,400
Wyoming crude	E. E. Slosson	20.00	0.933	273	343	....	....	....	....	0.67	19,440
Texas crude	Denton	22.17	0.920	142	181	....	84.60	10.90	2.87[b]	1.63	19,060
Texas distillate	U.S.Naval Report	21.18	0.926	216	240	....	83.26	12.41	3.83	0.50	19,481
Oklahoma crude	Armour & Co.	25.00	0.903	264	286	92.0[a]	87.93	11.37	0.19	0.41	19,650

a. Relative viscosity, Saybolt scale. b. O.+N.

When crude petroleum is distilled, the most volatile products are given off first. Gasoline, as the term is commercially used, covers those products which are more volatile than kerosene and includes, therefore, some benzine and naphtha. The next most volatile constituent of crude petroleum is kerosene, which is the common type of illuminating oil and is heavier than gasoline, but lighter than distillate which is taken out immediately after kerosene and can be considered a high grade special fuel oil. Under the heading fuel oil are included all of those distillates which are heavier than illuminating oils and lighter than lubricating oils. Fuel oil, therefore, includes gas oil. Gas oil is nothing more than a high-grade fuel oil which is used in the manufacture of gas. The term fuel oil also includes the residuum left after gasoline and kerosene only have been extracted from petroleum.

Inasmuch as the crude oils from different sections of the country vary widely in chemical composition, it is only natural to expect that the fuel oils obtained as a result of the distillation of these crude petroleums will also vary widely in ultimate analyses.

In purchasing fuel oil it is sufficient to specify the desired viscosity, specific gravity, flash point, calorific value, water content, and sulphur content. The specifications of the U. S. Navy for fuel oil at Atlantic and Gulf ports are:

Specifications

"(a) Fuel oil shall be a hydrocarbon oil free from grit, acid and fibrous or other foreign matter likely to clog or injure the burners or valves. If required by the Navy Department it shall be strained by being drawn through filters of wire gauge having 16 meshes to the inch. The clearance through the strainer shall be at least twice the area of the suction pipe and strainers shall be in duplicate.

(b) The unit of quantity to be the barrel of 42 gallons of 231 cu. in. at a standard temperature of 60° F. For every decrease or increase of temperature of 10° F. (or proportion thereof) from the standard, 0.4 of 1 per cent (or prorated percentage) shall be added or deducted from the measured or gauged quantity for correction.

(c) The flash point shall not be lower than 150° F. as a minimum (Abel or Pennsky-Marten's closed cup) or 175° F. Tagliabue open cup. In case of oils having a viscosity greater than 8 Engler at 150° F. the flash point (closed cup) shall not be below the temperature at which the oil has a viscosity of 8 Engler.

(d) Viscosity shall not be greater than 40 Engler at 70° F.

(e) Water and sediment not over 1 per cent. If in excess of 1 per cent the excess to be subtracted from the volume or the oil may be rejected.

(f) Sulphur not over 1.5 per cent.

NOTE:—If the Engler viscometer is not available, the Saybolt standard universal viscosimeter may be used. Equivalent viscosities:

88 Engler............	300 seconds Saybolt
40 Engler............	1,500 seconds Saybolt"

VISCOSITY OF FUEL OIL

The viscosity of an oil is inversely proportional to its fluidity, and is a measure of the internal friction in the oil itself, that is, of its resistance to free flowing. Inasmuch as there are a number of different instruments for the purpose of measuring viscosity, and since there is no recognized standard instrument or method of measuring it, the term "viscosity" means nothing unless there are also stated the name of the instrument used, the temperature at which the viscosity was determined, and the amount of oil tested. The viscosity of an oil is generally stated as the time in seconds required for a given quantity of the oil in question to flow through a small orifice at the stated temperature. It can be stated as the ratio of the time of flow of the oil being tested to the time of flow of water or some oil chosen as a standard at a stated temperature. Common types of viscosimeters or instruments for measuring the viscosity of oil are the Engler, Saybolt and Tagliabue. In stating viscosity the name of the instrument used should always be given. Figure 4 shows a Saybolt viscosimeter. The tentative test for the viscosity of lubricants adopted by the American Society for Testing Materials[a] is as follows:

1. Viscosity shall be determined by means of the Saybolt Standard Universal Viscosimeter.

2. (a) The Saybolt Standard Universal Viscosimeter is made entirely of metal. The standard oil tube J is fitted at the top with an overflow cup E and the tube is surrounded by a bath L. At the bottom of the standard oil tube is a small outlet tube through which the oil to be tested flows into a receiving flask R,

a. Reprinted by permission.

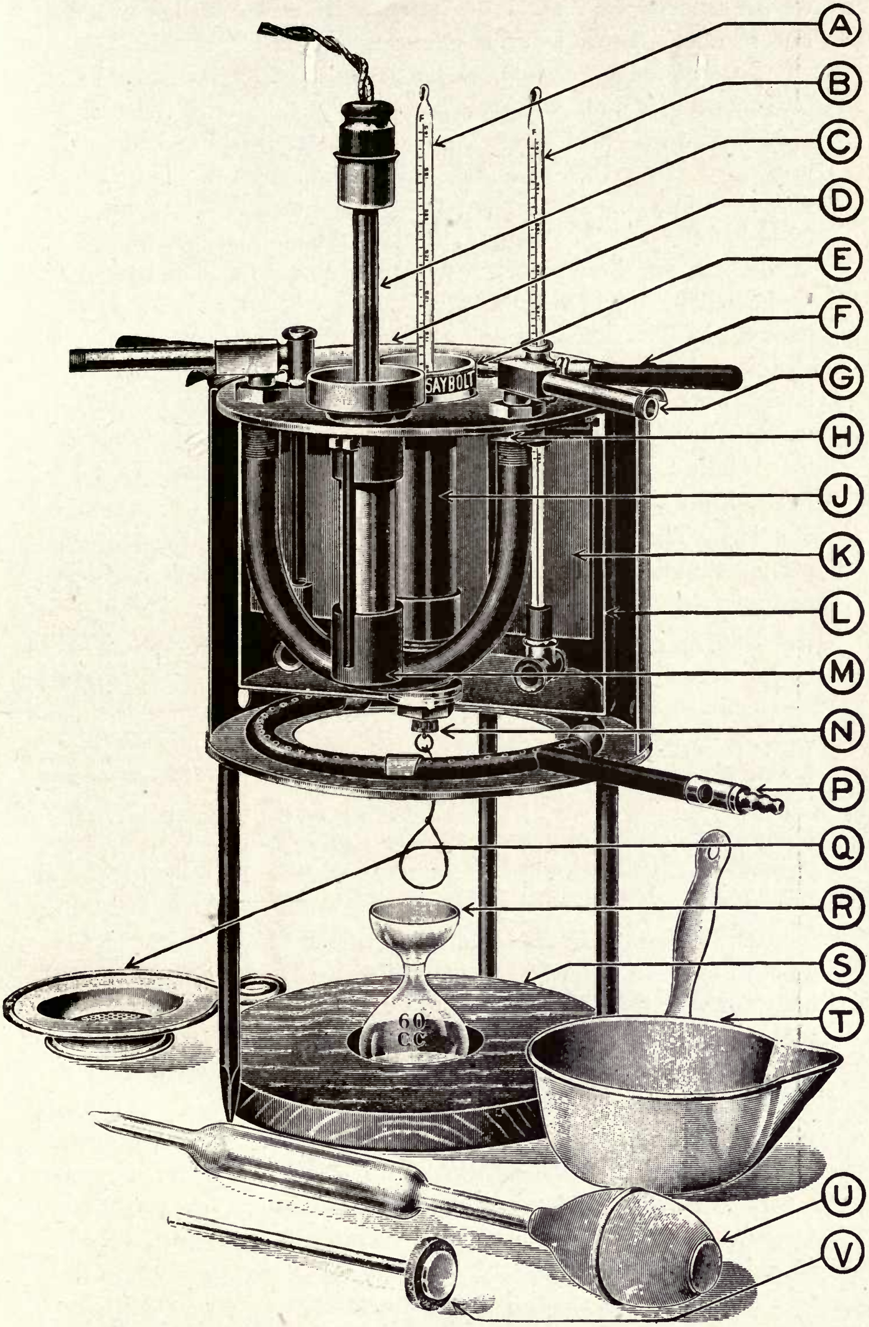

FIG. 4.—Saybolt Standard Universal Viscosimeter.

whose capacity to a mark on its neck is 60 (± 0.15) c.c. The lower end of the outlet tube is enclosed by a larger tube, which when stoppered by a cork, N, acts as a closed air chamber and prevents the flow of oil through the outlet tube until the cork is removed and the test started. A looped string is attached to the lower end of the cork as an aid to its rapid removal. The bath is provided with two stirring paddles, K, and operated by two turn-table handles F. The temperatures in the standard oil tube and in the bath are shown by thermometers, A and B. The bath may be heated by a gas ring burner P, steam U-tube H, or electric heater, C. The standard oil tube is cleaned by means of a tube cleaning plunger V, and all oil entering the standard oil tube shall be strained through a 30-mesh brass wire strainer Q. A stop watch is used for taking the time of flow of the oil and a pipette, fitted with a rubber suction bulb, is used for draining the overflow cup of the standard oil tube.

(b) The standard oil tube should be standardized by the United States Bureau of Standards, Washington, and shall conform to the following dimensions:

Dimensions.	Minimum CM.	Normal CM.	Maximum CM.
Inside Diameter of outlet tube	0.1750	0.1765	0.1780
Length of outlet tube	1.215	1.225	1.235
Height of overflow rim above bottom of outlet tube	12.40	12.50	12.60
Diameter of container of standard oil tube	2.955	2.975	2.995
Outer diameter of outlet tube at lower end	0.28	0.30	0.32

3. Viscosity shall be determined at 100° F. (37°.8 C.), 130° F. (54°.4 C.), or 210° F. (98°.9 C.). The bath shall be held constant within 0°.25 F. (0.14° C.) at such a temperature as will maintain the desired temperature in the standard oil tube. For viscosity determinations at 100 and 130° F., oil or water may be used as the bath liquid. For viscosity determinations at 210° F., oil shall be used as the bath liquid. The oil for the bath liquid should be a pale engine oil of at least 350° F. flash point (open cup). Viscosity determinations shall be made in a room free from draughts, and from rapid changes in temperature. All oil introduced into the standard oil tube, either for cleaning or for test, shall first be passed through the strainer. To make the test,

heat the oil to the necessary temperature and clean out the standard oil tube with the plunger, using some of the oil to be tested. Place the cork stopper into the lower end of the air chamber at the bottom of the standard oil tube. The stopper should be sufficiently inserted to prevent the escape of air, but should not touch the small outlet tube of the standard oil tube. Heat the oil to be tested, outside the viscosimeter, to slightly below the temperature at which the viscosity is to be determined and pour it into the standard oil tube until it ceases to overflow into the overflow cup. By means of the oil tube thermometer keep the oil in the standard oil tube well stirred and also stir well the oil in the bath. It is extremely important that the temperature of the oil in the oil bath be maintained constant during the entire time consumed in making the test. When the temperature of the oil in the bath and in the standard oil tube are constant and the oil in the standard oil tube is at the desired temperature, withdraw the oil tube thermometer; quickly remove the surplus oil from the overflow cup by means of a pipette so that the level of the oil in the overflow cup is below the level of the oil in the tube proper; place the 60 c.c. flask in position so that the oil from the outlet tube will flow into the flask without making bubbles; snap the cork from its position, and at the same instant start the stop watch. Stir the liquid on the bath during the run and carefully maintain it at the previously determined proper temperature. Stop the watch when the bottom of the meniscus of the oil reaches the mark on the neck of the receiving flask. The time in seconds for the 60 c.c. of oil is the Saybolt viscosity of the oil at the temperature at which the test was made.

Other viscosimeters in use are the Engler, Tagliabue, Scott, Redwood, Penn. Ry. pipet, McMichael, Lamansky-Nobel, Ostwald, Martens, Stormer, Ubbelohde, Lepenau, Kuenkler, Albrecht, Arvine, Barbey, Cockrell, Doolittle, Gibbs, Mason, Napier, Nasmyth, Phillips, Reischauer, Magruder. The Engler viscosimeter (See fig. 5) is used most extensively in Germany and its dimensions are as follows:

Inside diameter of the inside vessel for oil....	106 mm.
Height of vessel below overflow.............	25 mm.
Length of the oil jet......................	20 mm.
Inside diameter of the oil jet upper end......	2.9 mm.
Inside diameter of the oil jet lower end.......	2.8 mm.

Length of jet projecting from lower part of outer vessel	3.0 mm.
Width of jet	4.5 mm.

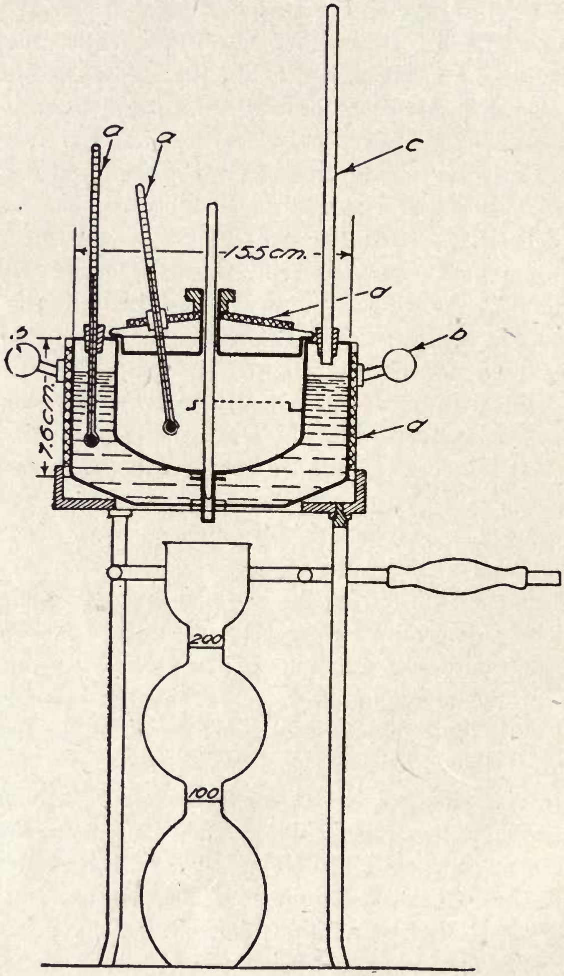

FIG. 5.—The Engler viscosimeter.

The quotient of the time of outflow of 200 c.c. of oil divided by the time of outflow of 200 c.c. of water is taken as a measure of the viscosity or is the so-called Engler degree. The Redwood viscosimeter is used extensively in England.

Table 6.—EQUIVALENT READINGS FOR THE SAYBOLT, REDWOOD AND ENGLER VISCOMETERS.

Saybolt Time.	Redwood Time.	Engler Number.	Saybolt Time.	Redwood Time.	Engler Number.
28.0	26.6	1.00	200	168	5.34
29.0	27.4	1.03	300	252	8.01
30.0	28.3	1.06	400	336	10.7
31.0	29.2	1.08	500	420	13.4
32.0	30.1	1.11	600	504	16.0
33.0	31.0	1.14	700	588	18.7
34.0	31.9	1.16	800	672	21.4
35.0	32.8	1.19	900	756	24.0
36.0	32.7	1.22	1000	840	26.7
37.0	34.6	1.25	1100	925	28.4
38.0	35.4	1.27	1200	1010	32.0
39.0	36.3	1.30	1300	1090	34.7
40.0	37.1	1.32	1400	1180	37.4
41.0	37.9	1.35	1500	1260	40.0
42.0	38.8	1.37	1600	1340	42.7
43.0	39.6	1.40	1700	1430	45.4
44.0	40.4	1.42	1800	1510	48.1
45.0	41.2	1.45	1900	1600	50.7
46.0	42.0	1.47	2000	1680	53.4
47.0	42.8	1.50			
48.0	43.6	1.52			
49.0	44.4	1.55			
50.0	45.2	1.57			
55.0	49.2	1.69			
60.0	53.2	1.81			
65.0	57.2	1.93			
70.0	61.2	2.05			
75.0	65.1	2.17			
80.0	69.0	2.29			
85.0	72.9	2.41			
90.0	76.8	2.54			
95.0	80.8	2.67			
100.	85.0	2.80			
110.	93.5	3.04			
120.	101.	3.29			
130.	109.	3.54			
140.	118.	3.80			
150.	126.	3.05			
160.	134.	4.31			
170.	143.	4.56			
180.	151.	4.82			
190.	160.	5.08			
200.	168.	5.34			

At and above 200 Saybolt, the Redwood time is obtained by multiplying by 0.84, and the Engler number by multiplying by 0.0267, thus: Redwood time = 0.84 X Saybolt time. Engler number = 0.0267 X Saybolt time. For Engler numbers 6.0 and over, Redwood time = 31.3 X Engler numbers.

Table 6 gives equivalents of Saybolt times, Redwood times, and Engler numbers.[a] Intermediate values can be obtained by interpolation. Fig. 6 is a chart[a] for the quick determination of these equivalents.

a. Compiled by Carl D. Miller, Ph.D., Associate Editor of Oil News.

Knowledge of the viscosity of fuel oil is valuable for determining the ease with which the oil can be pumped through pipe lines with or without heat. Although the viscosity of fuel oil increases with the density, tests have shown that oils of the same specific gravity from different localities often differ quite widely in viscosity.

Fuel oil, as regards viscosity, may be divided into two general classes, namely: Class 1. Asphaltic base crudes, residuums, or

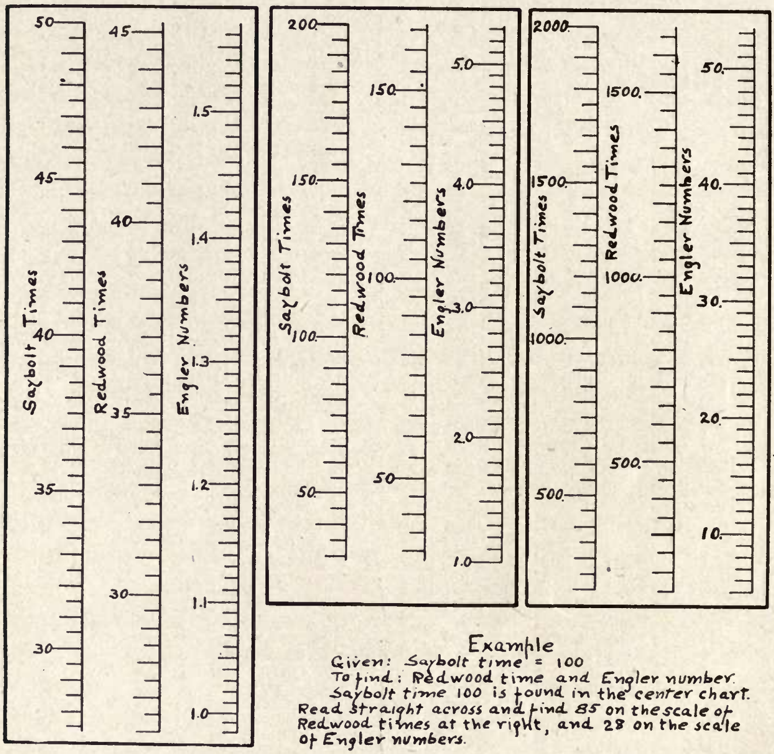

Fig. 6.—Chart for quick determination of Saybolt equivalents.

other oils which require heating facilities to reduce the viscosity in order that the oil may be handled by the storage and burning equipment. Class 2. Oils of a sufficiently low viscosity to make heating equipment unnecessary. In general, an oil in Class 1 should not have a viscosity above 2,000° Engler at 60° F. Oils of a higher viscosity than this can be used at plants provided with special equipment. It is imperative that oils of this class be heated to a temperature at which they have a viscosity of 12° Engler or lower before they reach the burner, in order to obtain proper atomization. It is desirable that this viscosity be obtained at a temperature below the flash point of the oil, in order to minimize fire hazards and to insure uniform feed to the burner. For an oil of Class 2, 12° Engler at 60° F. is the approximate maximum viscosity permissible.

Specific Gravity

Fuel oils are commonly sold and described as of a certain specific gravity or else as of a certain degree Baumé. Throughout the oil-burner industry the Baumé reading is generally used. The specific gravity of fuel oil is the relation by weight of a given volume of distilled water to the same volume of fuel oil when both are weighed at a temperature of 60° F. The specific gravity of fuel oil can be determined by the hydrostatic balance, by hydrometers, and by the specific gravity bottle. Throughout the oil industry the gravity as determined by the hydrometer is universally referred to. The principle of operation of the hydrometer is based on the law that a solid body floating in a liquid will displace a quantity of the liquid equal in weight to the floating body. Hence a body of constant weight and proportion will always sink to the same extent into a liquid of a certain density and will sink to a greater or less extent as the density decreases or increases. Because when a liquid expands or contracts with temperature, the density of the liquid varies accordingly, therefore, when the hydrometer is constructed the scale must be standardized for a certain temperature. As it is not always convenient to have the liquid at the temperature for which the scale of the hydrometer is arranged, it is often necessary to apply a correction for temperature variation.

The standard hydrometer used in the oil industry was evolved by Baumé. Baumé's hydrometer has an arbitrary scale. For liquids lighter than water, Baumé took for zero the point on the stem to which the hydrometer sank in a solution of 10 parts of salt and 90 of water. For the point 10 in the scale he took the level to which the hydrometer sank in distilled water. The space between the two marks he divided into 10 equal parts and called each space a degree and he continued the scale with the same intervals between the marks. The proper method of manipulating a hydrometer must be adhered to if accurate results are desired.

The following instructions are in line with those given by the U. S. Bureau of Standards.

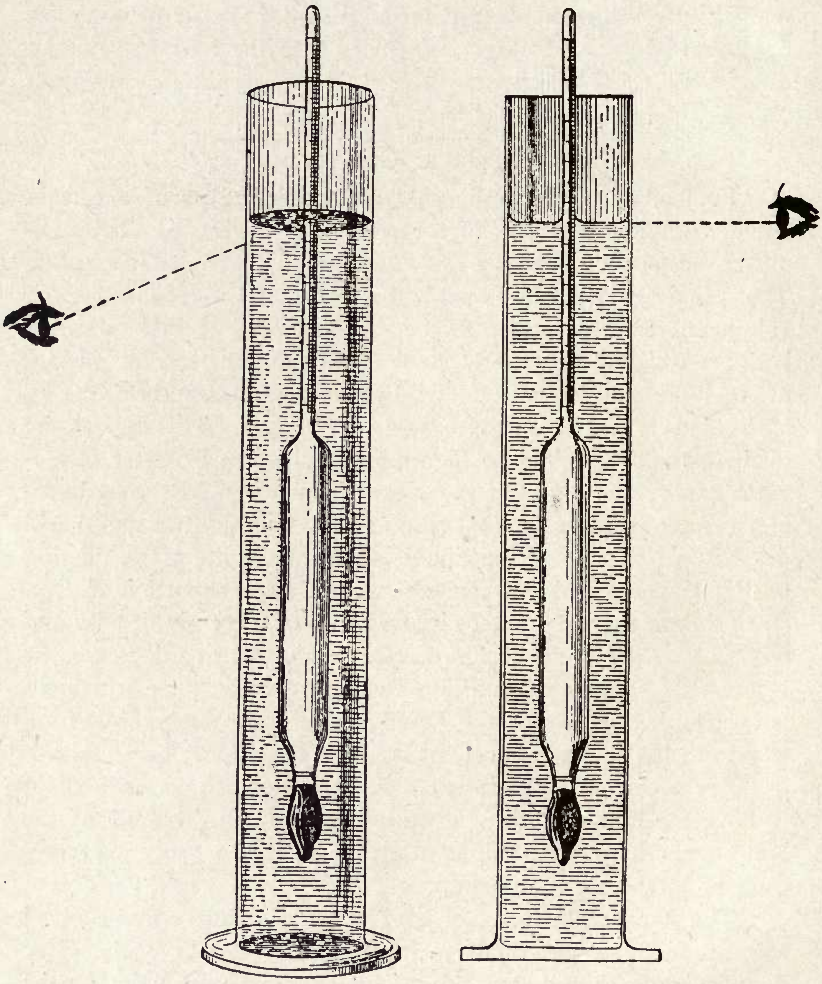

FIG. 7.—In reading the hydrometer the line of sight should first strike slightly below the plane of the oil surface (Left). The eye should then be slowly raised until the line of sight grazes from beneath the surface of the oil (Right).

It is essential that before it is used the hydrometer shall be thoroughly cleaned and dried. The liquids to be tested should be contained in clear, smooth, glass vessels of suitable size and shape. Thorough mixing of the liquids is requisite, before the hydrometer test is made, by means of a stirrer that reaches to the bottom of the vessel, so that the liquid will be uniform in density and temperature throughout. A perforated disc or a spiral at the end of a sufficiently long rod will give the best results as the up and down motion serves to disperse layers of the liquid of different density. The temperature of the surrounding atmosphere should be taken into account also and the temperature of the liquid being tested should be the same as the atmosphere, as otherwise its temperature will be changing during the test, thus causing not only differences in density, but also doubt as to the actual temperature. The temperature of the hydrometer itself should also be the same as that of the liquids being tested. When immersing the hydrometer it should be slowly sunk into the liquid slightly beyond the point where it floats naturally and then allowed to float freely. Surface tension effects on hydrometer observation are a consequence of the downward force exerted on the stem by the curved surface of the liquid or "meniscus" which rises on the stem and which affects the depth of immersion and consequent scale reading. The liquid for which the hydrometer is intended must be specified, therefore, because a hydrometer will indicate differently in two liquids having the same density, but different surface tensions. Hydrometers may be compared with each other if they are of equivalent dimensions, however, even if the liquid used differs in surface tension from the specified liquid, but comparisons of dissimilar instruments, in such liquid, must be corrected for the effect of surface tension. Spontaneous changes in surface tension occur in many liquids, due to the formation of surface films of impurities, which may come from the apparatus, the liquid, or the air. Errors from this source may be avoided by the purification of the surface by overflowing immediately before making the observation. Air bubbles must be allowed to disappear from the surface of the liquid before taking the scale reading. In reading the hydrometer scale, the eye is brought to the height of the level surface of the liquid and the point on the scale read, which appears to coincide with the level surface. In reading the thermometer scale, the errors of parallax are avoided by so placing the eye that near the end of the mercury column the portions on either side of the stem and that seen through the capillary appear to lie in a straight line. (See fig. 7.) The line of sight is then normal to the stem. The readings of the

Baumé hydrometer may be changed to those of absolute specific gravity as determined by a hydrostatic balance by the following formulas which hold for oil and for all other liquids lighter than water.

$$\text{Specific Gravity} = \frac{140}{130 - \text{Baumé reading}}$$

$$\text{Baumé} = \frac{140}{\text{Specific Gravity}} - 130$$

Example: What is Baumé of oil specific gravity .8092?

$$\frac{140}{.8092} - 130 = 43° \text{ Baumé.}$$

Table 7 gives the Baumé scale and specific gravity equivalents.

Flash Point

When oils are heated to a sufficiently high temperature, vapors are driven off which are inflammable and which create the danger of explosion. The temperature at which the oil gives off sufficient vapor to form a momentary flash when a small flame is brought near the surface of the oil is called the "flash point." The flash point is determined by heating the oil in a suitable device and testing with a lighted taper or with a spark. There are two types of flash testers, the open-cup and the closed-cup. There are many makes of both types on the market. The most common closed-cup testers are the New York State, the Pensky-Martens and the Abel, and the most common open-cup testers are the Tagliabue and the Cleveland. Figure 8 shows the Tagliabue closed-cup tester[a] which may be operated with either gas or oil to supply the ignition flame. The method of testing with the standard "Tag" closed-cup tester as outlined by the American Society for Testing Materials, Tentative Standards 1917, pages 445-6 are as follows:

The test must be performed in a dim light so as to see the flash plainly. Surround the tester on three sides with an inclosure to keep away drafts. A shield about 18 inches square and 2 feet high, open in front, is satisfactory. See that tester sets firmly and level. For accuracy, the flash point thermometers which are especially designed for the instrument should be used

a. Bulletin D 398, C. J. Tagliabue Manufacturing Company.

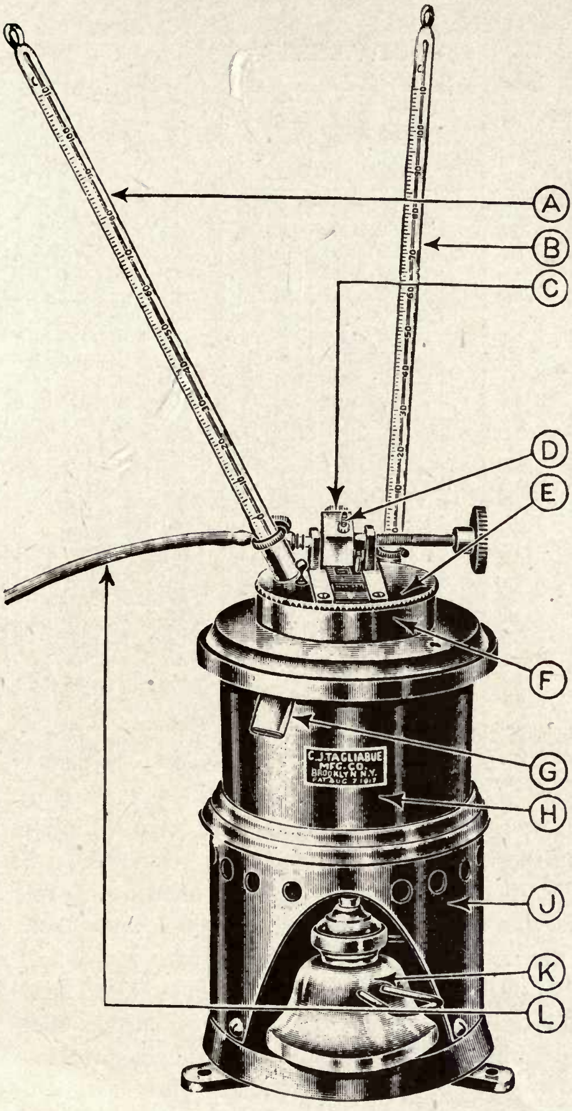

Fig. 8.—Tagliabue closed-cup tester. A. Thermometer, indicating the temperature ot the oil. B. Thermometer, indicating the temperature of the water bath. C. A miniature oil well to supply the test flame when gas is not available, mounted on the axle about which the test-flame burner is rotated, which axle is hollow and provided with connection on one end for gas hose and provided also with needle valve for controlling gas supply, when gas is available, the gas passing through the empty-oil well. D. Gas or oil tip for test flame. E. Cover for oil cap, provided with three openings, which are in turn covered by a movable slide operated by a knurled hand knob, which also operates the test flame burner in unison with the movable slide, so that by turning this knob, the test flame is lowered into the middle opening in the cover, at the same time that this opening is uncovered by the movement of the slide. F. Oil cup (which cannot be seen in the illustration) of standardized size, weight and shape, fitting into the top of the water bath. G. Overflow spout. H. Water bath, of copper, fitting into the top of the body, and provided with an overflow spout and opening in its top, to receive the oil cup and water bath thermometer. J. Body, of metal, attached to substantial cast metal base provided with three feet. K. Alcohol lamp for heating the water bath. L. Gas hose.

Table 7.—BAUME SCALE AND SPECIFIC GRAVITY EQUIVALENTS.[a]

°B.	Specific Gravity	Pounds in Gallon	° B.	Specific Gravity	Pounds in Gallon	° B	Specific Gravity	Pounds in Gallon
10	1.000	8.33	37	0.8383	6.99	64	0.7216	6.01
11	0.9929	8.27	38	0.8333	6.94	65	0.7179	5.98
12	0.9859	8.21	39	0.8284	6.90	66	0.7143	5.96
13	0.9790	8.15	40	0.8235	6.86	67	0.7107	5.92
14	0.9722	8.10	41	0.8187	6.82	68	0.7071	5.89
15	0.9655	8.04	42	0.8140	6.78	69	0.7035	5.86
16	0.9589	7.99	43	0.8092	6.74	70	0.7000	5.83
17	0.9524	7.93	44	0.8046	6.70	71	0.6965	5.80
18	0.9459	7.88	45	0.8000	6.66	72	0.6931	5.77
19	0.9396	7.83	46	0.7955	6.62	73	0.6897	5.74
20	0.9333	7.77	47	0.7910	6.59	74	0.6863	5.71
21	0.9272	7.72	48	0.7865	6.55	75	0.6829	5.69
22	0.9211	7.67	49	0.7821	6.51	76	0.6796	5.66
23	0.9150	7.62	50	0.7778	6.48	77	0.6763	5.63
24	0.9091	7.57	51	0.7735	6.44	78	0.6731	5.60
25	0.9032	7.52	52	0.7692	6.40	79	0.6699	5.58
26	0.8974	7.47	53	0.7650	6.37	80	0.6677	5.55
27	0.8917	7.42	54	0.7609	6.33	81	0.6635	5.52
28	0.8861	7.38	55	0.7568	6.30	82	0.6604	5.50
29	0.8805	7.33	56	0.7527	6.27	83	0.6573	5.47
30	0.8750	7.29	57	0.7487	6.23	84	0.6542	5.45
31	0.8696	7.24	58	0.7447	6.20	85	0.6512	5.42
32	0.8642	7.20	59	0.7407	6.17	86	0.6482	5.40
33	0.8589	7.15	60	0.7368	6.13	87	0.6452	5.37
34	0.8537	7.11	61	0.7330	6.10	88	0.6422	5.35
35	0.8485	7.07	62	0.7292	6.07	89	0.6393	5.32
36	0.8434	7.02	63	0.7254	6.04	90	0.6364	5.30

as the position of the bulb of the thermometer in the oil cup is essential. Put the water-bath thermometer in place. Place a receptacle under the overflow spout to catch the overflow. Fill the water bath with water at such a temperature that when testing is started, the temperature of the water bath will be at least 10° C. below the probable flash point of the oil to be tested. Put the oil cup in place in the water bath. Measure 50 c.c. of the oil to be tested in a pipet or a graduate and place in oil cup. The temperature of the oil must be at least 10° C. below its probable flash point when testing is started. Destroy any bubbles on the surface of the oil. Put on cover with flash point thermometers in place and gas tube attached. Light pilot light on cover and adjust flame to size of the small white bead on cover. Light

a. U. S. Bureau of Standards, United States Standard Tables for Petroleum Oils, Circular 57, 1916, p. 57.

Note.—Degrees Baume may be converted to specific gravity by adding 130 to the number of degrees Baume and dividing the sum by 140.

and place the heating lamp, filled with alcohol, in base of tester and see that it is centrally located. Adjust flame of alcohol lamp so that temperature of oil in cup rises at the rate of about 1° C. (1.8° F.) per minute or not faster than 1° C. (1.8° F.) nor slower than 0.9° C. (1.6° F.) per minute. Record the "time of applying the heating lamp," record the "temperature of the water bath at start," record the "temperature of the oil sample at start." When the temperature of the oil reaches about 5° C. below the probable flash point of the oil, turn the knob on the cover so as to introduce the test flame into the cup and turn it promptly back again. Do not let it snap back. The time consumed in turning the knob down and back should be about one full second, or the time required to pronounce distinctly the words "one thousand and one." Record the "time of making the first introduction of the test flame" and record the "temperature of the oil sample at time of first test." Repeat the application of the test flame at every 0.5° C. rise in temperature of the oil until there is a flash of the oil within the cup. Do not be misled by an enlargement of the test flame or halo around it when entered into the cup or by slight flickering of the flame; the true flash consumes the gas in the top of the cup and causes a very slight puff. Record the "time at which the flash point is reached," and the "flash point." If the rise in temperature of the oil from the "time of making the first introduction of the test flame" to the "time at which the flash point is reached" was faster than 1.1° C. or slower than 0.9° C. per minute, the test should be questioned and the alcohol heating lamp adjusted so as to correct the rate of heating. It will be found that the wick of this lamp can be so accurately adjusted as to give a uniform rate of rise in temperature of 1° C per minute and remain so.

Repeat Tests—It is not necessary to turn off the test flame with the small regulating valve on the cover, but leave it adjusted to give the proper size of flame. Having completed the preliminary test, remove the heating lamp, lift up the oil cup cover and wipe off the thermometer bulb. Lift out the oil cup and empty and carefully wipe it. Throw away all oil samples after once using in making test. Pour cold water into the water bath, allowing it to overflow into the receptacle until the temperature of the water in the bath is lowered to 8° C. below the flash point of the oil as shown by the previous test. With cold water of nearly constant temperature it will be found that a uniform amount will be required to reduce the temperature of the water bath to the required point. Place the oil cup back in the bath and measure into it a 50 cc charge of fresh oil. Destroy any bubbles on the surface of the oil, put on the cover with its thermometer, put in the heating lamp, record time and temperature of oil and water and proceed to repeat test as described above. Introduce test flame for first time at a temperature of 5° C. below flash point obtained on the previous test.

Precautions.—Be sure to record barometric pressure either from laboratory barometer or from nearest Weather Bureau Station. Record temperature of room. Note and record any flickering of the test flame or slight preliminary flashes when the test flame is introduced into the cup before the proper flash occurs. Record time and temperature of such flickers or slight flashes if they occur.

With the Cleveland open-cup tester, the oil is poured into the oil cup within 5 mm. of the top. The flame is then applied to the air bath in such manner that the temperature of the oil in the cup is raised at the rate of 5° C. per minute. The testing flame is made from a piece of drawn glass tubing, making a flame about 5 mm. in length. This flame is applied to the surface of the oil every half minute. A distinct flicker or flash over the entire surface of the oil shows that the flash point is reached and the temperature at this time is recorded.

Table 8.—CONVERSION OF BAROMETRIC PRESSURE IN CENTIMETERS TO INCHES.

	0	1	2	3	4	5	6	7	8	9
70	27.559	27.598	27.638	27.677	27.716	27.756	27.795	27.835	27.874	27.913
71	27.953	27.992	28.031	28.071	28.110	28.150	28.139	28.228	28.268	28.307
72	28.346	28.386	28.425	28.465	28.504	28.543	28.583	28.622	28.661	28.701
73	28.740	28.779	28.819	28.858	28.898	28.937	28.976	29.016	29.055	29.094
74	29.134	29.173	29.213	29.252	29.291	29.331	29.370	29.409	29.449	29.488
75	29.528	29.567	29.606	29.646	29.685	29.724	29.764	29.803	29.842	29.882
76	29.921	29.961	30.000	30.039	30.079	30.118	30.157	30.197	30.236	30.276
77	30.315	30.354	30.394	30.433	30.472	30.512	30.551	30.590	30.630	30.669

Table 8 gives figures for the conversion of barometric pressure in centimeters to inches[a] and Table 9 gives corrections of the flash point for normal barometric pressure.[a]

a. Bulletin No. 15, Kansas City Testing Laboratory, page 317.

Burning Point

The burning point of fuel oil is the temperature at which the vapor arising from the surface of the oil ignites and burns continuously. It is obtained both with the closed and open-cup tester by continuing the flash point test and noting the temperature at which the vapor gives a continuous flame.

Closed-cup testers are considered to give more reliable results for flash point determinations than do open-cup testers, because they permit better control of the rate of heat, uniformity of mixing the oil and exclusion of drafts. With a closed-cup tester lower results are always obtained than with open-cup testers, because the inflammable vapors given off by the oil are concentrated.

Calorific Value

In order to make a comparison between fuels, it is necessary to know the amount of heat which a given quantity of the fuel will give off when burned. The amount of heat which a given quantity of a fuel gives off is known as the calorific value or heat value. The standard measure of heat in this country is the British thermal unit. One British thermal unit is the amount of heat necessary to raise one pound of pure water from 62° F to 63° F. It is possible to calculate the calorific value of a fuel from its elementary composition, but calculations which are based upon the ultimate analysis of a sample may be very misleading because the heat of combustion is dependent upon the state of combination of the elements in the substance, and is never equal to the sum of those of its elements taken proportionately.

Determination of the calorific value of fuels is made by means of a calorimeter. In a calorimeter a weighed amount of fuel is completely burned, and the heat generated by the combustion is absorbed by a fixed weight of water, the amount of heat being calculated from the increase in the temperature of the water. A calorimeter, which has been accepted as the best for such work, is one in which the fuel is burned in a steel bomb filled with compressed oxygen. The function of the oxygen, which is ordinarily under a pressure of about 25 atmospheres, is to cause the rapid and complete combustion of the fuel sample. The fuel is ignited by means of an electric current, allowance being made for the heat produced by such currents and by the burning of the fuse wire. Among the standard calorimeters used are the

Atwater, Mahler and Kroeker bombs. Fig. 9 shows the Mahler calorimeter. The apparatus consists of: A water jacket, A, which maintains constant conditions outside of the calorimeter proper, and thus makes possible a more accurate computation of radiation losses; the porcelain-lined steel bomb, B, in which the combustion of the fuel takes place in compressed oxygen; the platinum pan, C, for holding the fuel; the calorimeter proper, D, surrounding the bomb and containing a definite weighed amount of water; an electrode, E, connecting with the fuse wire, F, for

Table 9.—CORRECTIONS OF FLASH POINT FOR NORMAL BAROMETRIC PRESSURES.

To correct readings made at other pressures to the standard barometric pressure of 760 mm.

Barometer Millimeters.	Correction Degrees C.	Barometer Millimeters.	Correction Degrees C.
700	— 2.1	750	— .3
705	— 1.9	755	— .2
710	— 1.7	760	0
715	— 1.6		
720	— 1.4	——	——
725	— 1.2	765	+ .2
730	— 1.0	770	+ .4
735	— .9	775	+ .5
740	— .7	780	+ .7
745	— .5	785	+ .9

igniting the fuel placed in the pan, C; a support, G, for a water agitator; a thermometer, I, for temperature determination of the water in the calorimeter. The thermometer is best supported by a stand independent of the calorimeter, so that it may not be moved by tremors in the parts of the calorimeter, which would render the making of readings difficult. To insure accuracy readings should be made through a telescope or eyeglass; a spring and screw device for revolving the agitator; a level, L, by the movement of which the agitator is revolved; a pressure gage, M, for noting the pressure of the oxygen admitted to the bomb. Between 20 and 25 atmospheres are ordinarily employed; an oxygen tank, O; and a battery or batteries, P, the current from which heats the fuse wire used to ignite the fuel.

The description of the operation of one bomb calorimeter is typical of all of them[a]. The lower half of the bomb is placed in

a. Bulletin No. 15, Kansas City Testing Laboratory.

the cast iron holder. About one gram of the oil is weighed to the nearest 0.0001 gram into the fuel pan and is placed in the bomb on the fuel pan holder. If the oil is volatile it is not advisable to pour the fuel directly into the fuel pan. For this purpose small gelatine capsules weighing .1 gm. are used and may be filled with ignited asbestos and into this the light oil is discharged from a weighing pipet. The capsule is immediately closed, leaving a minimum amount of air space. A similar capsule has been previously weighed and its calorific value determined. A stock of standardized capsules should be kept on hand in an airtight receptacle. The platinum fuse wire is cut equal in length to the taper pin wrench, which is connected to the terminal, being careful that it does not touch the pan. The wire is bent down so that it is covered by the oil or by the lips of the capsule. The upper half of the bomb is carefully fitted on the lead gasket to the lower half. The nut is screwed down over the upper half, being careful not to cross the threads. The bomb nut is now tightened by the use of the long wrench, being careful to cause no sudden jerking or vibrating which will throw the oil from the pan. The bomb is now carefully lifted out and placed on the swivel table and connected with the oxygen piping. The valve in the top of the bomb is opened about one turn and the valve in the oxygen cylinder is carefully and slowly opened so that the pressure in the bomb as shown by the indicator rises to 300 pounds. The bomb valve is now closed and the oxygen cylinder valve is closed. Exactly 1,900 grams of water at a temperature of about 4° below room temperature is weighed into the calorimeter water bucket. This is placed in the calorimeter container. The bomb is connected with the electric wire and is introduced into the water, being careful to place it in the center of the bucket. Two 100 watt lamps placed in parallel are in series with the fuse wire when a 110 volt circuit is used for firing. The stirring motor is placed in series with a 60 watt lamp on a 110 volt circuit. The cover is put on, the connections to the bomb wire are made and the stirrer is introduced as far down as it will go. It should not touch the bomb. The thermometer is introduced and stirring is continued for about 5 minutes. The temperature is read and the stirring continued for exactly 5 minutes and the temperature is again read and the charge is fired by quickly throwing in the switch and withdrawing it. The stirring is continued for 5 minutes, the temperature being read at minute intervals or at the end of 5 minutes, unless extreme accuracy is required. The stirrer is then run for an additional 5 minutes and the temperature is again read. The thermometer is corrected in accordance with the corrections furnished by the Bureau of Standards. The radiation corrections may be applied to each one-minute interval, but for

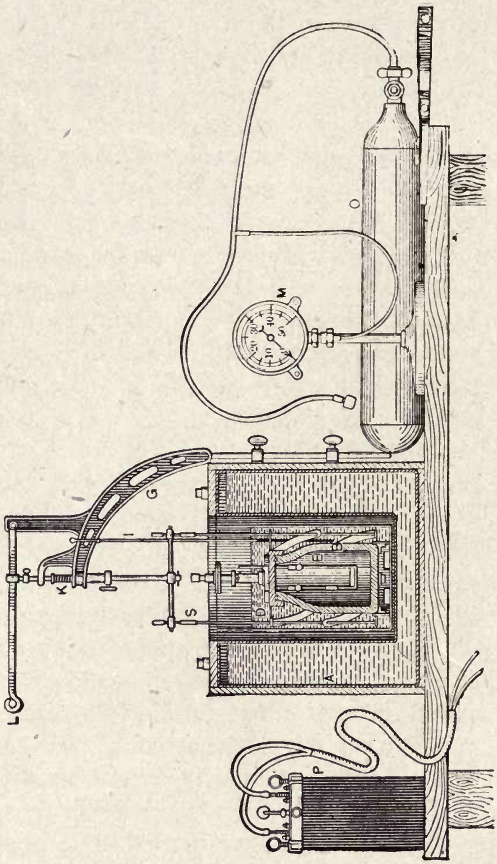

Fig. 9.—The Mahler calorimeter.

ordinary purposes 1/5 of the radiation for the 5-minute period before firing is applied on the 5-minute period immediately after firing and 4/5 of the radiation in the third 5-minute period is applied on the 5-minute period immediately after firing. The calorimeter constant (usually about 2,400) is determined by a blank test using exactly 1 gram of benzoic acid. This constant always remains the same with the same calorimeter, but must be determined each time a change is made in the calorimeter. In the case of oil in which it has been necessary to use the capsule the correction made must be applied for the calorific value of the capsule. This is most conveniently applied to the corrected net rise in temperature of the thermometer. To convert British thermal units per pound to calories per gram, multiply by 5/9. To obtain the water evaporative power, multiply the B.t.u. per pound by 1.035. To obtain the B.t.u. per gallon, multiply the B.t.u. per pound by the weight per gallon. An approximation of the heating value of fuel oil can be obtained by the following formula:

$$\text{B.t.u. in lbs. per gallon} = 18700 + 40\,(°\text{Bé} - 10).$$

A standard of 18500 B.t.u. to the pound of pure fuel oil is a good figure to be taken as a basis if the fuel oil is to be purchased on calorific determinations. A bonus may be paid for calorific value in excess of this figure and deductions made if the heat value of the fuel is below 18,500 B.t.u.'s per pound. The heat value of fuels is measured by the number of British thermal units contained in one pound of the fuel and this statement furnishes a direct comparison between fuels. Table 10 gives the calorific values of various oils.[a]

Water Content

Fuel oil should not contain more than 2 per cent by volume of water and sediment. The method of determining the amount of water and sediment in fuel oil is as follows: "A definite volume of the oil sample should be thoroughly shaken or 'cut' with an equal volume of gasoline of a specific gravity not greater than 0.74, and centrifuged. An appropriate tube that goes with a special machine is commonly used for this purpose. (See fig. 10).[b] Centrifuging should be continued until there is a clear line of demarcation between the water and sediment and oil in the bottom of the tube, and until a constant reading of water and sediment is obtained. From this reading the percentage by volume of water and sediment is computed. If the oil under consideration has a specific gravity greater than 0.96 one volume of oil to three volumes of gasoline should be used rather than equal volumes. When there is a question that the gasoline used

a. Fuel Oil and Its Uses, Tate-Jones and Company, Inc.
b. Courtesy of C. J. Tagliabue Company.

for thinning the oil in making this determination renders insoluble certain of its fuel constituents, then mixtures of gasoline and carbon disulphide, or of gasoline and benzol may be used for "cutting," providing the specific gravity of such mixtures is not greater than 0.74. If, after continued centrifuging, a clear line of demarcation between the impurities and the oil is not obtainable, the uppermost line should be read. If this procedure proves unsatisfactory, 100 C.C. of the sample may be distilled with an excess of hydrocarbons saturated with water and having boiling points slightly above and below that of water. Distillation is continued until all of the water has been distilled over into a graduated tube. The water in the oil is thus distilled over and readily collects at the bottom of this tube, where the percentage

Fig. 10.—An electrically driven centrifuge.

may be read off. The percentage of sediment in the oil may then be determined on the sample remaining in the distilling flask by "cutting" it with gasoline and centrifuging. The percentage of water obtained in the tube added to the percentage of sediment gives a total percentage to be deducted for moisture and impurities.

Sulphur Content

Appreciable sulphur content in a fuel oil is objectionable. However, a content of 4 per cent or less is not sufficiently objectionable to cause the rejection of a fuel oil for general purposes. (In general, experiments in burning fuel oils of various sulphur content have shown that the corrosive effects on the boiler tubes or heating surfaces are negligible. However, with steel stacks and low stack-gas temperatures, considerable corrosion in the stack has been noted.) In handling these oils, prior to burning, the corrosive action of the sulphur on steel storage tanks, piping, etc., is quite apparent and should be considered. If the oil is to be used for special metallurgical or other purposes where sulphur fumes are decidedly objectionable, it is necessary to specify a limiting figure for the sulphur content of the oil. The sulphur

Table 10.—CALORIFIC VALUES OF VARIOUS OILS[a].

Beaume°	Specific Gravity	Pounds in a Gallon	Calculated B. T. U. per Pound	Calculated B. T. U. per Gallon	Remarks
14	.9722	8.10	18810	152361	Mexico, California, Texas and Kansas Crudes and Fuel Oil. (14–27)
15	.9655	8.05	18850	151743	
16	.9589	7.99	18890	150931	
17	.9523	7.94	18930	150304	
18	.9459	7.88	18970	149484	
19	.9395	7.83	19010	148848	
20	.9333	7.78	19050	148209	
21	.9271	7.73	19090	147506	
22	.9210	7.68	19130	146918	
23	.9150	7.63	19170	146267	
24	.9090	7.58	19210	145612	
25	.9032	7.54	19250	145145	
26	.8974	7.49	19290	144482	
27	.8917	7.44	19330	143815	
28	.8860	7.39	19370	143144	Kansas, Oklahoma and Illinois Crudes, Pennsylvania Fuel Oil, California Refined Fuel Oil. (27–35)
29	.8805	7.34	19410	142269	
30	.8750	7.29	19450	141790	
31	.8695	7.25	19490	141303	
32	.8641	7.21	19530	140811	
33	.8588	7.16	19570	140121	
34	.8536	7.12	19610	139623	
35	.8484	7.07	19650	138926	

a. **Fuel Oil and Its Use, Tate-Jones & Co., Inc.**

Table 10.—CALORIFIC VALUES OF VARIOUS OILS.—*Continued.*

Beaume°	Specific Gravity	Pounds in a Gallon	Calculated B. T. U. per Pound	Calculated B. T. U. per Gallon	Remarks
36	.8433	7.03	19690	138421	Ohio, Pennsylvania and West Virginia Crudes. California and Kansas Refined.
37	.8383	6.99	19730	137913	
38	.8333	6.95	19770	137402	
39	.8284	6.91	19810	136887	
40	.8235	6.87	19850	136370	
41	.8187	6.83	19890	135849	
42	.8139	6.80	19930	135524	
43	.8092	6.76	19970	134997	
44	.8045	6.72	20010	134367	
45	.8000	6.68	20050	133934	
46	.7954	6.64	20090	133398	Kerosene and Gasoline.
47	.7909	6.60	20130	132858	
48	.7865	6.57	20170	132517	
49	.7821	6.53	20210	131971	
50	.7777	6.49	20250	131423	

content can be determined in the bomb calorimeter after the calorific value has been determined. The calorimeter is opened by gradually allowing the pressure to diminish and the bomb is carefully and thoroughly washed out with distilled water. The pan is placed in the beaker with the washings and about 10 cc. of hydrochloric acid is added. The contents of the beaker are treated with bromine, heated to boiling temperature for about 10 minutes, filtered and washed and the sulphur in the filtrate precipitated with 10 cc. of barium chloride solution. The precipitated barium sulphate is filtered, washed and weighed in the usual manner. The weight of the barium sulphate × 13,733 and divided by oil.

Fuel oil in this country is purchased by volume and not by weight. Table 10 shows that a gallon of oil of high specific gravity has a higher calorific value than a gallon of oil of low specific gravity. This fact should be remembered by users of oil fuel, because in buying fuel calorific value is sought. Individual conditions and requirements at the points of consumption influence to a large degree the specifications for viscosity, flash point and sulphur content. Definite specifications can be drawn for a fuel oil which will meet practically all requirements, but it can readily be seen that such specifications will exclude much of the fuel oil now available, and for most purposes the requirements need not be severe. Hence, it is advised that in purchasing fuel oil the individual requirements be studied, and that as lenient specifications as possible be written, which will insure an oil that will be satisfactory for the conditions for which it is intended.

CHAPTER III

COMPARISON OF COAL AND FUEL OIL

The term "Coal" as applied to fuel is very loosely used. The word is applied to a variety of substances ranging from turf through peat, lignite, semi-bituminous and bituminous coals to anthracite. It is obvious that no comparison can be drawn between coal and any other fuel unless the specifications of the coal are stated. The value of the chemical analysis of a sample of a given coal to an engineer, power-plant superintendent, or coal dealer, is a matter that has given rise to much discussion. The general weight of opinion seems to be that an analysis is often of the highest value, and that the time and labor involved in making it are well spent. However, it is clear that analyses are of greater value to some engineers or users of coal than to others; and that, at the present time, they cannot entirely supplant in all cases the information to be obtained from carefully conducted tests in boiler furnaces but should supplement such information, when the latter is obtainable.

In the testing of coals in the Government service the chief difficulties in the way of accepting or rejecting untried coals on the basis of chemical analyses alone have proved to be as follows:

(1) An ordinary analysis of a coal shows the percentage of ash, but does not indicate the extent to which this ash may fuse or slag on the grate bars of the furnace, and thus seriously interfere with the rate and completeness of the combustion. Though progress has been made toward the determination of the liability to clinker, through a study of the composition of the ash, the results obtained are not as yet altogether satisfactory.

(2) There seems to be a variability in the heating value of the volatile matter in the coal, which is not clearly indicated by the percentage of the volatile matter, as determined either by the usual methods, or by the ordinary calorimetric determinations.

(3) The caking of the surface coal in the fire box appears to interfere with the draft, and hence, with the rate and completeness of the combustion, and, therefore, impairs the fuel value of the coal to a degree that is not ordinarily indicated by chemical analyses.

For all practical purposes the coal produced in the United States may be divided into three classes, anthracite, bituminous and lignite. The great bulk of the country's coal supply, however, is bituminous or soft coal. Table 11 shows the production of coal in recent years in the United States.

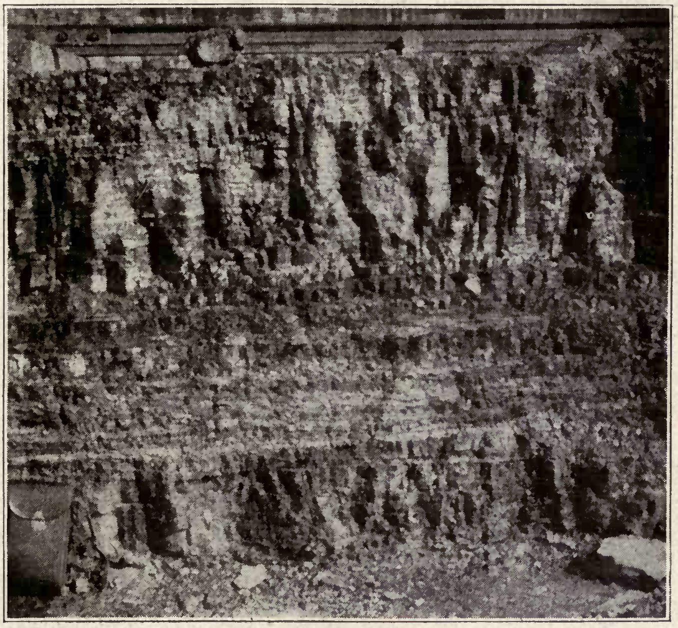

FIG. 11.—Bedded impurities in a seam of Illinois coal.

Table 11.—PRODUCTION OF COAL IN UNITED STATES.

Year	Total	Bituminous	Anthracite
	(In thousands of gross tons)		
1909-13 (5 year average)	457,716	380,515	77,201
1914	458,505	377,414	81,091
1915	474,660	395,200	79,460
1916	526,873	448,678	78,195
1917	581,609	492,670	88,939
1918	605,546	517,309	88,237
1919	508,000	432,000	76,000

Bituminous is the chief steam coal and when comparisons are made between coal and fuel oil, bituminous coal is used as a basis. Bituminous coal deposits are almost always underlain by fire clay and almost always are overlain by a stratum of shale. The fire clay is the residuum of the original soil in which grew the

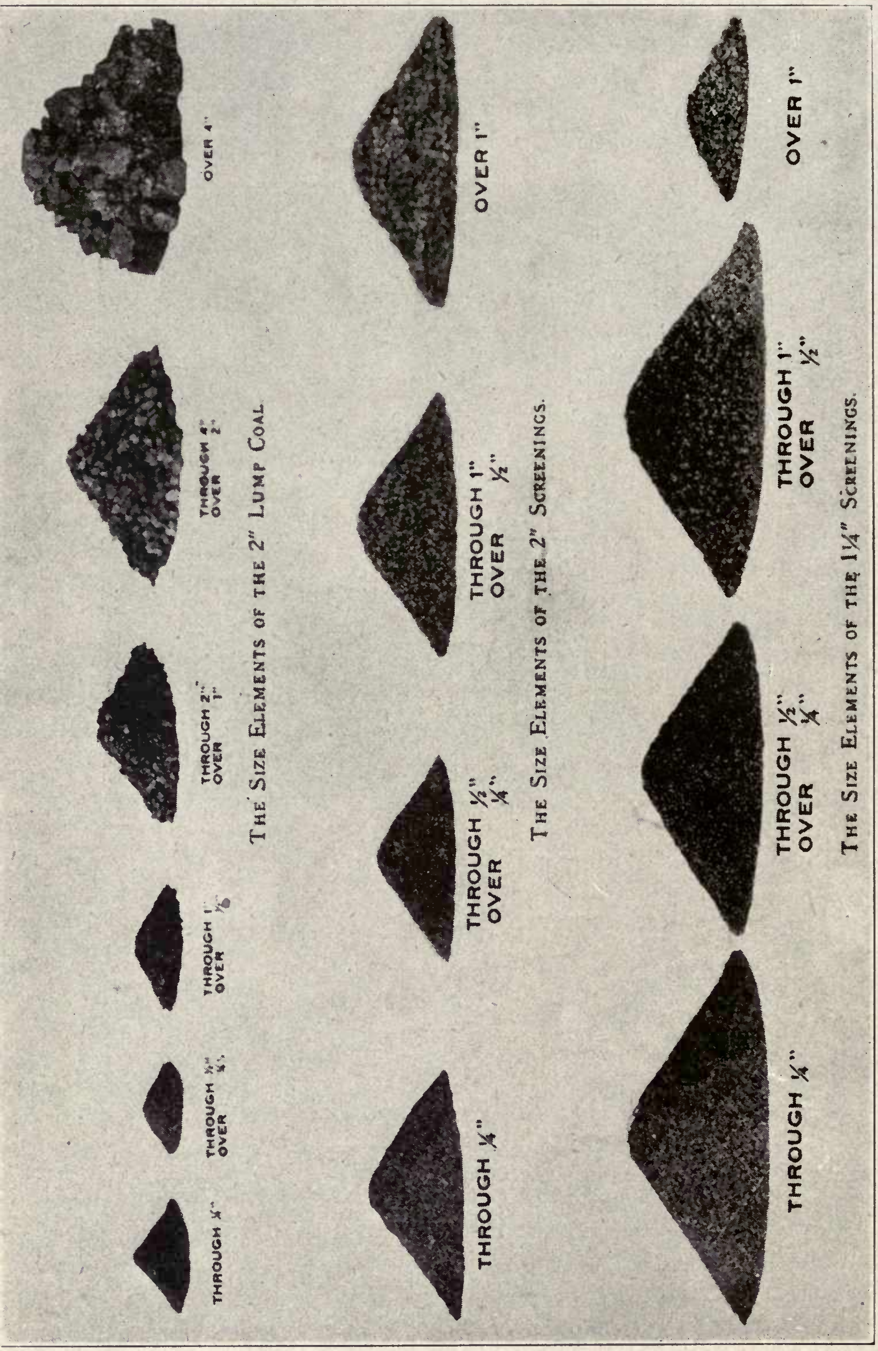

FIG. 12.—Size elements of lump coal and screenings.

luxuriant vegetation that supplied the material for the coal seams. When the swamps in which this vegetation grew subsided and when the water covering them grew deeper, a fine silt was deposited and this silt through pressure became the shale of today. In addition to the impurities such as bands of clay, shale or pyrites which, as shown in fig. 11, are found in the coal itself as it lies in the seam, the method of mining employed in the United States is responsible for the addition to the coal of fire clay from the floor and shale from the roof. A sample of coal taken at the face of a mine is only roughly indicative of the coal loaded in railroad cars at that mine. Although theoretically all pieces of fire clay, shale and pyrites or iron sulphide, are hand picked by the miner and thrown to one side, in practice great quantities of these impurities are loaded out by the miner and appear at the tipple on the surface. Inasmuch as these impurities are usually of small size, a greater percentage of impurity will be found in the small sizes of coal and the screenings or slack coal will contain a very high percentage of impurities. This is well illustrated in fig. 12, which shows the size elements of commercial 2-inch screenings and the size elements of 1¼-inch screenings. Of the 2-inch screenings, 66.8 per cent passed through a 1-inch screen, 41.1 per cent through a ½-inch, and 26.9 through a ¼-inch. Of the 1¼-inch screenings, 95.5 per cent passed through a 1-inch screen, 57.6 through a ½-inch, and 37.6 through a ¼-inch. (See fig. 13.)[a]

The sizes larger than screenings are used for domestic and special purposes. The screenings or slack coal are used for steam purposes, inasmuch as sized coal is much too expensive to be burned under industrial boilers. Slack coal which contains as low as 12 per cent ash is of extremely good quality and in practice many slack coals are burned which carry as high as 25 per cent ash.

Illinois is a representative industrial state. The varieties of fuel used in Illinois power plants are central bituminous coal, as represented by those of the coal fields of Illinois, Western Kentucky and Indiana and eastern bituminous and semi-bituminous or soft coals from the Pennsylvania, West Virginia and Eastern Kentucky fields. All of these coals are composed of the following materials in varying proportions:

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a. Proceedings of the Ninth Annual Convention of the International Railway Fuel Association, 1917, p. 133.

(1) Solid or fixed carbon which burns with a glow and without flame.

(2) Gases or volatile materials which escape from the coal when it is heated and which burn with a flame.

(3) Gases or volatile matter and water which escape from the coal when it is heated and which do not burn.

(4) Ash or mineral matter which does not burn and which remains as ashes after the coal is burned.

The bituminous coals of the central field (Illinois type) contain from 40 to 55 per cent of fixed carbon, 10 to 25 per cent of combustible gas, 5 to 15 per cent of non-combustible gas, 8 to 15

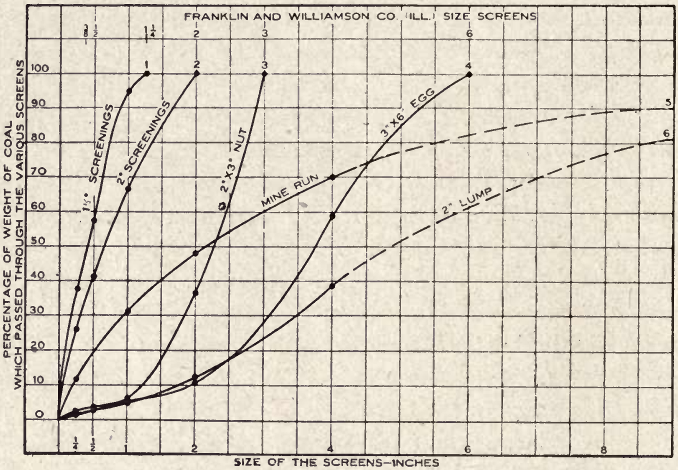

FIG. 13.—Percentage of weight of coal which passes through the various screens.

per cent of moisture, and 8 to 15 per cent of ash. When improperly fired or burned in furnaces not adapted to their use, central bituminous coals give off so large an amount of sooty material that flues are often quickly clogged. These unconsumed volatile products also represent a direct loss of heat value. Coals of the Illinis, type ignite easily and burn freely.

The moisture and non-combustible gases present in all coals are detected only by chemical analysis. They not only do not produce heat, but represent a definite loss because they absorb and carry off heat which would otherwise be available for useful purposes. The term moisture in coal does not mean the water adhering to the surface of the lumps, but that contained within the pores of the coal. A coal containing a high percentage of moisture by analysis may appear perfectly dry.

The ash content of different coals varies greatly. Ash is non-combustible mineral matter, which not only has no heating value, and therefore, represents a portion of the coal from which no return is received, but it may hinder the free burning of the combustible components of the coal. If the ash contains certain mineral substances, it may by clinkering greatly interfere with the process of firing and with the cleaning of grates. The ash normally is removed through the ashpit into which often passes also a certain amount of unburned coal. For this reason the amount of ashes removed from the pit usually represents a larger percentage of the fuel fired than the analysis of the ash content indicates.

The eastern bituminous coals contain from 5 to 10 per cent of ash, from 25 to 35 per cent of combustible gases, from 2 to 5 per cent of moisture and non-combustible gases, and from 55 to 65 per cent of solid carbon. They are more generally of the coking variety than are the Middle West coals. In general, they are higher in heating value and lower in ash. They are more friable and are not so well suited for transportation and repeated handling as are many of the central bituminous coals.

Table 12 gives the analysis of these coals.

Table 12.—ANALYSES OF COALS OF ILLINOIS, INDIANA AND WESTERN KENTUCKY.[a]

(Figures are for face samples and for coal "as received.")

ILLINOIS (AVERAGE ANALYSES).

District	Coal Bed	Moisture	Volatile Matter	Fixed Carbon	Ash	B. t. u. (Heating Value)
LaSalle	2	16.18	38.83	37.89	7.08	10,981
Murphysboro	2	9.28	33.98	51.02	5.72	12,488
Rock Island and Mercer Counties	1	13.46	38.16	39.75	8.63	11,036
Springfield-Peoria	5	15.10	36.79	37.59	10.53	10,514
Saline County	5	6.75	35.49	48.72	9.04	12,276
Franklin and Williamson Counties	6	9.21	34.00	48.08	8.71	11,825
Southwestern Illinois	6	12.56	38.05	39.06	10.33	10,847
Danville; Grape Creek coal	6	14.45	35.88	40.33	9.34	10,919
Danville; Danville coal	7	12.99	38.29	38.75	9.98	11,143

a. Engineering Experiment Station, University of Illinois, Fuel Economy in the Operation of Hand Fired Power Plants.

INDIANA (TYPICAL ANALYSES).

District	Coal Bed	Moisture	Volatile Matter	Fixed Carbon	Ash	B. t. u. (Heating Value)
Clay County	(Brazil block)	15.38	32.66	46.08	5.88	11,680
Green County	IV	13.53	33.54	45.38	7.55	11,738
Green County	V	10.30	36.31	41.64	11.75	11,218
Sullivan County	IV	12.15	33.48	46.23	8.14	11,722
Sullivan County	V	12.14	35.17	43.73	8.96	11,516
Sullivan County	VI	14.86	31.65	46.14	7.35	11,324

KENTUCKY (AVERAGE OF COMPOSITE SAMPLES).

District	Coal Bed	Moisture	Volatile Matter	Fixed Carbon	Ash	B. t. u. (Heating Value)
	9	8.17	36.82	45.17	9.83	11,867
	11	7.33	38.28	45.28	9.11	12,056
	12	9.67	34.86	46.46	9.01	11,695

"As received" samples represent the coal as taken from the mine. It is probable that the values given are fairly representative of the coal as purchased from local dealers.

Moisture in coal represents an appreciable loss in economy inasmuch as the coal may carry 16 per cent moisture and the heat required to evaporate it must be furnished by the coal itself, thus decreasing the amount available to heat water in the boiler. In excellent practice the per cent of the calorific value of coal as fired, which is lost by the evaporation of free moisture, is given by Gebhardt[a] as 0.5 per cent; in average practice, 0.6 per cent; and in poor practice, 0.7 per cent.

Fig. 14 is a chart[b] prepared by Mr. Joseph Harrington, combustion engineer, showing the influence of moisture in coal on its evaporative power as a fuel. With a moisture content of 30 per cent, slightly more than 10,000 heat units out of a total of 15,000 are available.

It is obvious that ash is simply a diluting material, but nevertheless when slack coal is burned the ash content of the coal has been transported from the mine to the industrial plant, which may be hundreds of miles away. Freight for the ash and moisture content of slack coal must be paid for, although they are not only of no value, but actually are an added expense in operation. (See fig. 15.) The loss of coal through the grates is a serious item. The refuse from a fuel is that portion which falls into the

a. Gebhardt, Steam Power Plant Engineering p. 65.
b. Hays School of Combustion, Instruction Book Number Two, page 12.

pit in the form of ashes, unburned or partially burned fuel and cinders. In steam boiler practice the unconsumed carbon in the ash pit ranges from 15 to 50 per cent of the total weight of dry refuse depending upon the size and quality of coal, type of grate and rate of driving. The loss resulting from this waste of fuel ranges from 1.5 to 10 per cent or more, of the heat value of the fuel. It is impossible to assign a minimum value because of the various influencing factors, but numerous tests of recent installations, equipped with mechanical stokers, indicate that actual loss ranges from 1.5 to 5 per cent of the heat value of the fuel at

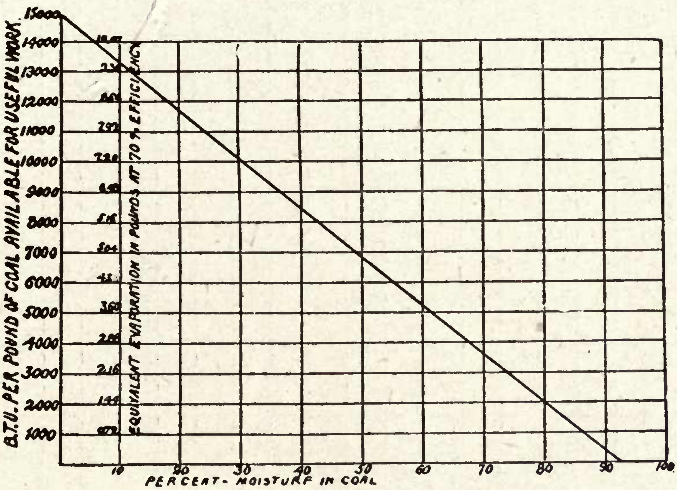

FIG. 14.—Influence of moisture in coal on evaporative power of the fuel.

normal driving rates. Coal which necessitates frequent slicing is apt to give greater losses from this cause than a free burning coal.

The losses of B.t.u. due to the combustible matter in the refuse per pound of coal as fired may be calculated by the following formula:

$$A \frac{C}{(1 - C)} \times 14600$$

Where A = chemical ash in coal

C = percentage of combustible matter in the refuse.

14600 = calorific value in B.t.u. of one lb. of carbon burned to CO_2.

At a coal-burning installation a continuous 24-hour full load test may show that 80 per cent of the heat of the coal is absorbed by the boiler, but when the heat represented by a month's evaporation is divided by the heat of the coal fed to the furnace during the same period the efficiency may drop to 70 per cent or lower. In an eight-hour day plant the fires must be banked at the conclusion of the day's run and this banking occasions a fuel loss

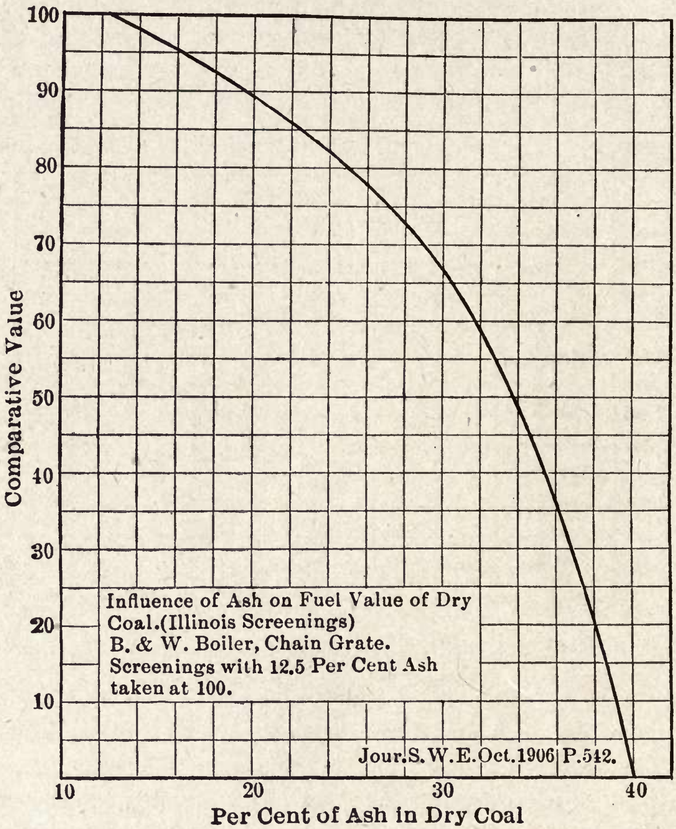

FIG. 15.—Influence of ash on fuel value of dry coal.

which is obviated when oil is used. Table 13 gives the coal burned during banking periods:

In hand-fired boilers another loss is occasioned by the opening of the fire box door, which admits a great inrush of cold air, reducing fire box temperatures and preventing the complete combustion of carbon so that the loss of heat units through the stack is greately increased.

Pulverized Coal

To overcome the obvious disadvantages in burning raw coal screenings, the idea was conceived of pulverizing the coal and introducing the pulverized coal into the furnace by air pressure. The early attempts to burn pulverized coal under stationary boilers were unsuccessful because the coal was not thoroughly dried and was not pulverized finely enough. In introducing the powdered coal into the furnace, too high pressures were used, resulting in a blow-pipe effect creating zones in the furnace in which the gases had high velocity. The impingement of these gases against the refractories caused a serious erosive action. Later experiments showed that seven feet per second is the maximum velocity which can be maintained without destruction of the refractories. The object of pulverizing the coal is to make a more complete mixture of the coal particles with the air in order that complete combustion may be obtained with a low percentage of excess air. All grades of coal can be burned in pulverized form with high efficiency, regardless of the percentage of ash. The additional cost of pulverizing the coal is, however, an important item. In an address recently delivered before the American Society of Mechanical Engineers, Mr. H. B. Barnhurst, chief engineer of the Fuller Engineering Company, gave the following estimate of the cost of pulverizing coal:

Table 13.—COAL BURNED DURING BANKING PERIODS.[a]

Rated Capacity of Boiler	Kind of Stoker	Ratio Heating to Grate Surface	Kind of Coal	Hours Banked	Coal Fed to Furnace, Lb. per BoilerHp.-Hr.		
					A	B	C
250	Stationary grate	35	Buckwheat	8	0.20	0.35	......
500	Chain grate	65	Bit. scrg.	13	0.40	0.52	1000
350	Chain grate	40	Bit. No. 3	9	0.32	0.62	1600
250	Chain grate	48	Bit. scrg.	7	0.35	0.71	1450
1200	Underfeed	82	Bit. scrg.	10	0.18	0.20	2600
550	Underfeed	66	Bit. scrg.	9	0.29	0.37	1165
150	Stationary grate	40	Bit. mine run	12	0.58	0.69	560
75	Stationary grate	48	Poc. lump	12	0.81	0.95	300
400	Murphy	52	Bit. scrg.	13	0.26	0.33	1350

(A) Coal fired during banking period.

(B) Coal fed to furnace during baking period including that required to put boiler into service at end of banking period.

(C) Coal fed to furnace to put cold boiler into service, pound.

a. Gebhardt, Steam Power Plant Engineering, p. 72.

"The following cost of pulverizing is made of a number of items as follows: Power, repairs, drier fuel and labor. The first two items are nearly constant. The drier fuel will vary slightly, according to the price at which coal is received. The cost of labor diminishes as the quantity of coal increases. In the following table the power is assumed as costing ¾-cent per kw-hr. Repairs at 7 cents per net ton. The dried fuel is based on coal at $5 per net ton delivered with an average moisture content of 7 per cent, assuming that 6 per cent of moisture would be driven off per pound of coal in the drier. The furnace labor is assumed at 50 cents per hour."

COST OF PULVERIZING AND DELIVERING THE PULVERIZED FUEL TO BOILER FURNACES.

Daily Capacity in Tons	Cost of Labor	Number Labor Hours	Repairs	Drier Fuel	Power	Cost of Pulverizing
20	30c	12	7c	6c	13	56c
30	30c	18	7c	6c	13	56c
40	25c	22	7c	6c	13	51c
80	20c	32	7c	6c	13	46c
120	18c	42	7c	6c	13	44c
160	17c	48	7c	6c	13	43c
240	13c	62	7c	6c	13	39c
320	11c	72	7c	6c	13	37c
400	10c	83	7c	6c	13	36c
480	9.5c	94	7c	6c	13	35.5c
640	8c	104	7c	6c	13	34c
800	6.75c	108	7c	6c	13	32.75c
960	6c	114	7c	6c	13	32c
1,120	5c	116	7c	6c	13	31c

No interest, depreciation, insurance or taxes have been included in the above total.

Although experiments in burning pulverized coal were begun as early as 1876, there has not as yet been any thoroughly satisfactory method of taking care of the ash resulting from the burning of the coal. When a slack coal with a high ash percentage is pulverized, the pulverized coal still contains the same percentage of ash as did the slack. Under the high heat developed in a fire box which burns powdered coal this ash forms a pasty slag which adheres to the sides and bottom of the fire box. The removal of this slag is accomplished with great difficulty and unless the slag is removed at frequent intervals, draft is interfered with and heat radiation to the boiler is decreased. Mr. C. F. Herrington, probably one of the highest authorities in the United States on the burning of powdered coal, makes in *Engineering News* the following comparison between oil and powdered coal:

"Of the three fuels, powdered coal, oil and water gas, fuel oil has come into use far more than any other. The U. S. Navy Yards have been consistent in their adoption of it. All now use fuel oil for heating operations, many to the complete exclusion of coal. Without a doubt, fuel oil is one of the easiest of fuels to handle; it can be carried in pipes anywhere so long as there is air pressure or pump pressure behind it. It requires only a comparatively small outlay for equipment—all that is necessary is a couple of storage tanks, a pump to fill the storage tanks from the cars, a piping system to the furnaces, and means to secure the necessary pressure. As a fuel for burning under boilers, powdered coal may some time be a success. The use of powdered coal in Portland cement manufacture has proven very economical and here it has come to stay. But when it is claimed that it is equally good for various heating operations, such as welding, shingling, annealing, riveting and forging, there is likely to be a difference of opinion."

In a recent article in an engineering paper the following advantages were claimed for powdered coal:

(1) "Complete combustion, doing away with losses due to the carbon contained in the ash and in the escaping volatile matter." This is not correct, for if one stands for an hour watching one of these furnaces working, as the writer did, he will be completely covered with fine, unburned powdered coal, which has escaped through the furnace doors. This has become such a nuisance to the surrounding machinery and workmen that attempts are now being made to relieve these conditions by placing a hood over the furnace door and connecting it into the furnace stack. This has not proven successful as yet, and probably will not until an exhaust fan is provided to discharge this unburned coal through the roof.

(2) "Total absence of smoke." Certainly this is not true inside of the shop, for powdered-coal furnaces, due to their non-uniform feed, smoke worse than oil. Powdered coal, as is well known, must be very dry to be pulverized and, when pulverized and allowed to remain quiet for 48 hours, it cakes and requires that a man knock on the bins to loosen it. This leads to uneven

combustion in the furnace with large quantities of smoke when there is a large amount of coal coming through the burner and no smoke when the coal is sticking back in the bins. No doubt this is largely due to inefficient handling of the feeder and burner; even so, a total absence of smoke cannot be claimed when such conditions are met.

(3) "A cheaper grade of coal may be used." The best coal for powdered fuel has a volatile content of not less than 30 percent, not more than 8 percent ash, and 1¼ percent sulphur. I think the readers will agree that coal meeting these specifications is of no very cheap grade. Pulverized coal must be handled with great care, for if it is mixed with any quantity of air, it is highly explosive, as the records of accidents in cement plants will prove.

Another very serious objection to powdered coal, due to the incomplete combustion of all the coal ejected into the furnace, is that this coal lies on the work, and when the work is taken out of the furnace, if not cleaned off, it is apt to be hammered into the work and make flaws which later are likely to be more or less serious according to the nature of the work. This is a fact seen from personal observation and cannot be denied. Powdered coal is not good for small furnaces, as it requires too large a chamber for combustion, and from the experience of users of powdered coal it is not desirable to have a combustion chamber separated by a bridgewall from the working chamber. It is found that the lesser of two evils is to remove the bridgewall and blow the powdered coal directly upon the work, which aggravates the condition mentioned above. If the large furnaces are changed from fuel oil to powdered coal, there will remain the small furnaces, and especially the portable ones, which will have to work on fuel oil. Then there would be the expense of handling two kinds of fuel where before there was but one. The pulverizing plant is to be considered. When it is reported that it costs only 30 to 50 cents a ton to perform a multitude of operations, I feel that some one has misplaced the decimal points, as will be shown later on.

Comparative Efficiencies

Now comes the debatable point of what is the efficiency of the furnace when using the different fuels. The powdered coal advocates will claim that the efficiency should be figured on the B.t.u. basis. That is, if a furnace burns, say 22 gallons of oil to do a certain piece of work and each gallon contains 140,000 B.t.u., 3,000,000 B.t.u. in all, it will take 3,000,000 B.t.u. in coal to do the same work, but the coal is cheaper. If oil were 5 cents a gallon, it would take coal at $10 a ton to equal the cost; so the reader will perhaps agree that this is not the proper method of comparing efficiencies, any more than saying that the cost of gasoline per gallon is the operating cost of running an automobile. The true way is to measure the efficiency of the furnace by the comparison of the input and output, and below are given results of some efficiency tests made for a well-known concern contemplating a revision of its furnace practice.

Powdered Coal—(Furnace using preheated air for combustion.)

Furnace cold at 60° F.
Steel and furnace heated to 2200° F.
Rise in temperature, 2140° F.
By test, 6.29 lb. of steel heated per pound of coal burned.
Specific heat of steel, 0.117.
$0.117 \times 2140 = 250$ B.t.u. per lb. of steel.
250 B.t.u. $\times$ 6.20 = 1572 B.t.u. output.
1 lb. of coal = 14,000 B.t.u., input.

$$\text{Efficiency} = \frac{1572 \times 100}{14{,}000} = 11.3\%$$

Fuel Oil—Same furnace with same rise in temperature and the same charge of work.

Heated 8.68 lb. of steel per pound of oil.
1 lb. of oil = 19,400 B.t.u. input.
25 B.t.u. $\times$ 6.29 = 1572 B.t.u. output.

$$\text{Efficiency} = \frac{2170 \times 100}{19{,}400} = 11.3\%$$

Another furnace using fuel oil. (Not using preheated air.)
Temperature rise from 1200° to 2200° = 1000° F.
Charge of wrought iron, 2150 lbs.
Oil required, 22 gal.
2150 lb. $\times$ 113 B.t.u. = 242,950 B.t.u. output.
1 gal. oil = 140,000 B.t.u.
140,000 B.t.u. $\times$ 22 = 3,080,000 B.t.u. input.

$$\text{Efficiency} = \frac{242{,}950 \times 100}{3{,}080{,}000} = 7.88\%$$

First Cost

In making comparison as to the relative first costs and operating costs, let us assume a plant now using fuel oil with a consumption of 50,000 gallons of oil per month at a cost of 5 cents per gallon, delivered at the shop. (These estimates were made for the company already mentioned.)

(1) Fuel Oil:	
Cost of equipment (storage tanks in place, auxiliary pressure tanks in place, piping and fittings in place, steam connections, furnace connections, tank car connections, tank pumps and air-blast outfit)	$21,100
Contractor's profit (15%)	3,165
	$24,265
Engineering and contingencies (10%)	2,435
	$26,700
(2) Powdered Coal:	
Pulverizing machinery, house, foundations, trestle and track, electric wiring, conveyors, walkways, motors, burners and controllers (30), furnace bins (30), furnace changes, hoods and connections, etc.	$68,100
Contractor's profit (15%)	9,900
	$78,000
Engineering and contingencies (10%)	7,800
	$85,800
(2A) Fuel Oil for Small Furnaces:	
Tank in place, auxiliary tank in place, piping and fittings, furnace connections, tank-car connections, pumps, air blast, etc.	$ 8,800
Contractor's profit (15%)	1,300
	$10,100
Engineering and contingencies (10%)	1,000
	$11,100
Summary:	
Fuel Oil	$27,000
Powdered coal with fuel oil	97,000

Fuel Consumption of Plants

For the fuel-oil plant, at 50,000 gallons of oil per month and 140,000 B.t.u. per gallon, 7,000,000 B.t.u. are consumed per month.

If we allow 10 pounds of coal at 14,000 B.t.u., equal to 1 gallon of oil, we have 500,000 pounds or 250 tons of coal used per month, for the powdered-coal plant. In addition, this plant consumes about 8,000 gallons of oil, the difference being compensated for by coal required in drying the main fuel supply."

TOTAL COSTS

Fuel Oil Plant (Estimated cost, $27,000):		
Fixed charges: Interest (5%)	$ 1,350	
Depreciation (12%)	3,240	
Taxes and insurance (1%)	270	$ 4,860
Operation: Oil (50,000x0.05x12)	30,000	
Labor, 1 man	1,000	
Electrical current, steam, air	500	
Miscellaneous supplies	200	31,700
Total yearly charge		$36,560
Powdered Coal Plant (Estimated cost, $97,000):		
Fixed charges: Interest (5%)	$ 4,850	
Depreciation (10%)	9,700	
Taxes and insurance (1%)	970	$15,520
Operation: Coal (250x2.50x12)	7,500	
Oil (8,000x0.05x12)	4,800	
Labor (1 operator, 2 assistants)	2,000	
Electricity for motors	5,000	19,300
Total yearly charge		$34,820

Advantages and Disadvantages of Liquid Fuel

From the foregoing it becomes evident that there are certain advantages which oil fuel has over coal when burned under boilers. These advantages may be summed up as follows:

(1) It is often found that it is desirable to push boilers far beyond their normal rating for a shorter or longer period of time. Tests that have been made by the United States Navy Department with fuel oil show that the heat absorptive powers of boilers is very great, and that this pushing can be accomplished with only a small drop in efficiency. In their tests with fuel oil the evaporation per square foot of heat surface has been increased from three pounds of water from and at 212 degrees F. to fifteen pounds of water. During this increase in rating, which is 500 per cent of the normal rating, there was a loss in efficiency of only two per cent. Boilers can be pushed twice as rapidly with oil as they can with coal.

(2) The loss of heat up the stack is diminished owing to

the smaller amount of air necessary for the complete combustion of oil over its equivalent in coal.

(3) A more equal heat distribution in the combustion chamber is possible inasmuch as the fire box doors do not have to be open for firing and as a consequence there is higher efficiency.

(4) The cost of handling fuel is reduced because it is done mechanically by pumps when fuel oil is used and the reduction in the number of firemen is in the proportion of five or six to one.

(5) A large increase in steam capacity is possible. The grate area absolutely limits the amount of coal that can be burned efficiently, whereas the amount of oil that can be burned efficiently is not affected by the grate size. The output of boilers can be augmented by 30 to 50 per cent by substituting oil for coal.

(6) Fires can be started and stopped instantly as required, avoiding standby losses, and this required head of steam can be rapidly obtained from a cold boiler and can be maintained with the utmost regularity. No fuel is lost through banking.

(7) The storage tanks for fuel oil can be located where desired, while coal bins must be near the boilers.

(8) The life of the boilers is prolonged because in hand-fired coal furnaces a combination of stresses on the furnace plates occurs when the furnace doors are frequently opened.

(9) Fuel oil can be burned to smokeless combustion without sparks.

While fuel oil will undoubtedly effect the economies claimed for it, there are several disadvantages attendant on its use. These may be enumerated as follows:

(1) Fire risk is increased and city ordinances, while becoming less stringent, still look with disfavor on its use.

(2) Under certain conditions the vapor from fuel oil forms an explosive mixture with air.

(3) Nearly all fuel oil burners make an objectionable roaring sound.

(4) Auxiliary apparatus is necessary to start an oil fire or to maintain it, or both.

(5) Fuel oil has a tendency to leak through valves and joints in the system.

CHAPTER IV

COLLOIDAL FUEL

Mr. Lindon W. Bates, in a paper read before the New York section of the American Society of Mechanical Engineers, has the following to say regarding Colloidal Fuel:

Colloidal Fuel is a combination of liquid hydro-carbons with pulverized carbonaceous substances, the components so combined and so treated as to form a stable fuel capable of being atomized and burned in a furnace. It is made in three forms, a liquid, a gel and a mobile paste. The new composite is intended primarily to be used as fuel. While the designation "Colloidal" is given it because so much of the combination is in the colloidal state, the name is not scientifically adequate, since much of the solid component is not reduced to colloidal dimensions. The title is, however, descriptive because of the important colloid-like characteristics of the composite. It is liquid up to the ratios of oil sixty percent and coal forty percent or thereabouts. It is a mobile paste up to the ratio of oil twenty-five percent and coal seventy-five percent. All kinds of oils and solid carbons may be used The cheap coal breakages and wastes are all available. The liquid is used in the self-same way as oil fuel and with the same apparatus. The coal particles are maintained in a state of suspension in the oil during the time required for the use of the fuel —days, weeks or months. (See fig. 16.)[a]

It is of interest to read the results of a special study made Jan. 3, 1920, by Messrs. Dow and Smith, Chemical Engineers, of New York City, to confirm certain technical aspects of Colloidal Fuel Grade 15, a typical grade, containing 38% mixed coal and coke, in Mexican Reduced Oil, made in August, 1919, and shipped to the Imperial Japanese Navy in Japan:

"We have examined your sample of colloidal fuel to determine whether electrolites cause a precipitation of any of the suspended particles.

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[a]Oil News, Feb. 20, 1920. P. 26.

"We first tested your fuel in a glass cylinder to determine whether or not there was any subsidation, with the following results:

"100 cc. of the colloidal fuel with a depth of 6″ was allowed to stand for 24 hours at a temperature of 115° F. At the end of the 24 hours the very top of the fuel was analyzed and that taken from the very bottom of the cylinder.

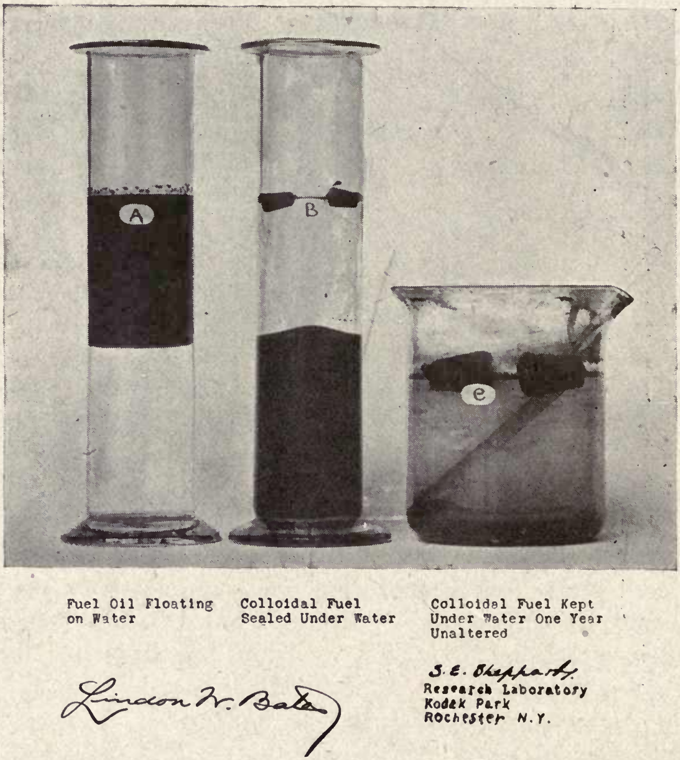

FIG. 16.—Colloidal fuel after standing one year under water.

"The top contained 33.8% insoluble in benzole.

"The bottom contained 36.4% insoluble in benzole, showing an increase of 2.6 of coal particles in the bottom over the top. This subsidation represents the particles of coal that have become destabilized since the sample was manufactured. It must not be inferred that a continuous and progressive subsidation would take place, that is, the subsidation in the second 24 hours would be only a fraction of a per cent, and would merely represent the particles which in that time had become destabilized. Some idea as to the quantity can be obtained from the fact that this sample, being five months old, shows only 2.6% of the particles had become destabilized in that time.

"Three lots of the fuel 100 cc. each were then shaken up with electrolites, sodium chloride, alum and copper sulphate, 5 grams of the powdered electrolite being used to this quantity of fuel. After the three cylinders had stood 24 hours there was no perceptible difference in the top and bottom, and therefore, no apparent precipitation by the electrolites.

"We have examined your colloidal fuel thinned with benzole under the ultra-microscope and find that it is filled with particles which have the Brownian Movement. We should judge that about half of the particles visible showed this action and they varied in size from those which were quiescent to others which had had an active range of 0.00325 mm.

"We also passed the benzole solution of your fuel through the finest hardened filter paper and found that the filtrate contained numerous colloidal particles.

"We examined your colloidal fuel under the microscope and measured the size of the visible particles with 1000 diameter magnification. We noted several particles in the field .001 of an inch across and .002 of an inch in length. There were numerous particles ranging from this down to invisibility. The majority of the particles appeared to be about .0001 of an inch in diameter. There is, of course, no doubt but that the particles diminish in size to that of molecules, as was shown by an examination under the ultra-microscope, and also from the fact that we know that portions of coal are soluble in mineral oils."

Colloidal Fuel enjoys several special qualities. The calorific value per unit volume is greater than that of straight oil unless coals of very low heat value and specific gravity are incorporated. The reason is that coal is heavier than oil though of less calorific content per pound, so that the coal content most frequently raises the calorific value per unit volume. The addition of coal is not an adulteration of the oil, but it makes an increase of the heat units in the resultant gallon of liquid fuel. Thus in a composite made up of 35% by weight of pulverized anthracite coal of 14,000 B.t.u. per pound and 1.6 specific gravity and 65% oil of 18,200

B.t.u. per pound and .96 gravity, a gallon of the composite has 165,000 B.t.u., while oil has 146,000 B.t.u. per gallon.

Owing to its coal content, Colloidal Fuel is heavier, while oil is lighter than water. The character of the composite is such that it may be stored under a water seal and its fire may be quenched with water. The feature is of vast importance since an oil fire cannot be extinguished with water, and hence the rules governing the use of fuel oil are justifiably drastic. Not less than 6.4% of all fires are caused by "Fuel Oil," according to the records of the National Fire Prevention Association.

The Board of Standards and Appeals of New York City adopted a set of rules, which became effective December 1, 1919, to admit liquid fuel into the city. Rule 1 contains the following provision:

"The term 'oil used for fuel purposes' under these rules includes any liquid or mobile mixture, substance or compound derived from or including petroleum."

The rule is phrased so as to admit Colloidal Fuel, which is a liquid or mobile mixture including petroleum. Colloidal Fuel is also in an exceptionally favorable situation under the Tentative Regulations of the National Fire Protection Association, adopted on November 3, 1919. These set the standard in the United States and Canada. "Oil burning equipments are those using only liquids having a flash point above 150° F. closed cup tester." The word "liquids" as selected includes the new fuel. Section 1, Paragraph A, provides: "For liquids of 20° Baumé and below, tanks may be of concrete," and Section 4, Paragraph 34, states: "Where it is necessary to heat oil in storage tanks in order to handle it, the oil shall not be heated to a temperature higher than 40° F. below the flash point, closed cup." This excludes several varieties of fuel oils which require preheating over or close to their flash point in order to flow. This is not the case in the Coloidal Fuel. The Laboratory of the National Board of Fire Underwriters has certified that Grade 13, a typical example of the new fuel, had a flash point of 266° F. and Grade 15 had 273.2° F. Grades 13 and 15 were preheated in practice to about 130° F and 180° F. respectively. The apparent ignition temperature was 779° F. and 788° F. respectively, while neither gave off volatiles at room temperature or at 104° F., nor gave evidence of spontaneous heating. It is for these reasons that Coloidal Fuel enjoys unusual safety features.

The combining of pulverized coal with oil and of tar with oil to make a liquid fuel has in the past had inventive devotees. As, however, petroleum does not ordinarily dissolve coal or tar, the problem was how to overcome the comparatively rapid and uncontrollable separation or settling out or sedimentation of some of the components. The present success was born immediately of the war efforts and was conceived to meet the possible shortage of liquid fuel in the Allied Navies.

The art of suspending as colloids in liquid hydrocarbons certain carbonaceous substances has been long practised. Lubricants are in use made of less than 1% of Acheson graphite of 2.1 specific gravity reduced so that the size of the particles is about 75 $\mu\mu$ (within colloidal limits) and suspended in oil by the addition of gallotannic acid. Colloids of charcoal and lampblack are known. It is also reported that if coal is reduced under high pressure or high speed disk-grinding and lengthy trituration in oil, the coal may be brought into the state of stable combustible colloid.

Suspension of high percentages of particles above colloidal sizes is found to be, however, quite without precedent. So also the peptization of carbonaceous matter in liquid hydrocarbons, producing a stable composite, is new. No prior art exists for producing a stable fuel of oils having carbonaceous matter as natural impurities, like the asphaltum and free carbon found in pressure still oil. In another field, that of rendering stable a compound of two or more unmixable or partly mixable liquid hydrocarbons for fuel needs, any prior art is also of little record. Many liquid hydrocarbons will mix. Others and these of the important burning liquid hydrocarbons have till this time proved obdurate to union—for instance, fuel oil and tar have heretofore refused to mix or have mixed only partially. Emulsions have been made of non-mixing liquid hydrocarbons for use in creosoting and disinfecting, but no such emulsions much less suspensions concerning unmixing liquid hydrocarbons for use as fuels have heretofore been created.

Up to 40% by weight of pulverized coal can be suspended with 60% by weight of oil, making liquid Colloidal Fuel. Up to 75% of carbon can be incorporated in the mobile pastes. Mobile gels can be made from either the liquids or the pastes. Colloidal Fuel may be a combination of any two or more of the forms. It will be understood, therefore, that between these states in varying blends and degrees of load, a large number of fuels either liquid or mobile, may be produced. Further, several of the forms have a natural tendency to transform themselves. For instance, liquid Colloidal Fuel stabilized for liquidity during a definite period of say, days or months, tends later to gel from the bottom of the container up. At that stage, the viscosities of the lower or gel stratum will be different from that of the thinner upper stratum. The fuel, nevertheless, has not given up the influence of its treatment. It remains atomizable, even though the gel be denser. In both layers and in the intermediate layers also, all the constituents are present and synchronize in burning. The gel thus formed is easily restored to a liquid state by heat or stirring or pumping. Sometimes even a tap upon the wall of the container will restore pristine liquid form. The colloidalizing treatment while artificially stabilizing the composite promotes also a gel formation. Conversely, the creation of a gel even in early stages helps to stabilize the compound since particles with more difficulty precipitate in a gel.

Colloidal Fuel is a composite whose particles are in three states of dispersion—solution, colloid and suspension. They give the characteristics of the three conditions. Some of the particles pass through a filter—many do not. Many are visible and measurable under microscopic inspection. Others are not. Some show active Brownian movement; others show slower movement; others no such motion at all. In considering the changes and stabilization under the treatment of Colloidal Fuel the division of the carbon surfaces must be noted. A cube of coal one centimeter on each side exposes a surface of six square centimeters. Such a cube pulverized so that 85% passes through a 200 mesh screen exposes surfaces of about 1872 square centimeters. The ratio of surface to volume has been multiplied over 300 times. Such a cube reduced to colloidal size (or .1μ diameter) develops a surface of 60 square meters—a multiplication of one hundred thousand. In Colloidal Fuel, most of the carbon particles are not reduced to colloidal sizes. Many remain much above these limits and above the colloidal borderland.

For the manufacture of the new fuel, the coal should be reduced so that about 95% passes through a 100 mesh screen and

85% through a 200 mesh screen. A finer pulverization, while of advantage, is not essential to the process. Coarser particles than those cited above may be temporarily or partly stabilized, serving sufficiently well certain fuel uses. For the reduction, mechanical, electric or chemical means may be used, but an ordinary coal pulverizing ball or tube mill is most economical.

To carry the load of a high percentage of carbon at normal and working temperatures the base oil employed should be in a certain range of viscosities which the treatment secures. While a lower viscosity does not hinder the creation of Colloidal Fuel, it lessens the load which the liquid hydrocarbon can stably carry. If the product sought is to be a gel or paste, the initial viscosity is of less concern. If the liquid medium provided is of over high viscosity to produce a liquid fuel with the percentage desired of load, a "cut back" can be introduced to lower viscosity. This "cut back" can be of another suitable hydrocarbon. If the medium provided is of over low viscosity, the process is reversed and the viscosity is raised by introducing a liquid hydrocarbon which adjusts the density. Several other ways, of course, exist for securing the right viscosity, such as, for instance, heat and emulsification.

With the right quality of fixateur or peptizing agent, stability is most readily and satisfactorily secured through its use. Varying the amount introduced makes adjustment simple. In general, the shorter the time, the less the degree of stability desired, the lower the temperature, the less the load and the finer the grinding, so much less fixateur or peptizing agent is needed. If a gel or paste is required, less of the agent is essential than if a liquid is sought. The introduction of more agent than is demanded for liquid stabilizing begets a tendency to early, complete and consistent gellification. The amount of the agent therefore introduced, must be a matter of knowledge from experimentation. It must be such a quantity and quality as will secure adequate stability at the temperature of storage and preheater. In practice, virtually, the maximum of a good quality of fixateur which has ever been employed to secure a stable liquid is an amount which adds 2% by weight of the essential substances to the fuel. The minimum producing an appreciable result is about .1%. Ordinarily between ¼% to 1½% is used. Higher percentages of certain peptizers or stabilizers are required than of others. If gaseous means are used these percentages do not hold. Between these outer limits the quality of fixateur and peptizer for particular products has been very accurately determined by experience and the effects recorded of different percentages blended with various ratios and kinds of components of the Colloidal Fuel.

Colloidal Fuel carrying up to 40 percent of carbon is practically equivalent to the class of heavy oil in relation to handling to the preheater stage. At 68° F. its viscosity will hardly be below 65° Engler, except when only the carbon particles found in pressure still oil are stabilized. The viscosity ordinary will range between 160° and 350° Engler, depending upon the components and other factors. At higher temperatures that obtain in the preheater, it behaves as do the lighter class of oils. Colloidal Fuel is really only a laden, stabilized oil and the problem of burning both is largely the same. Viscosity is under perfect control. The installations for burning oil, burn liquid Colloidal Fuel without any material change. Some slight modification is required for burning the pastes and gels since there must be sufficient pressure to carry the fuel to the atomizer. If the gel is broken up by pumping or if it becomes liquid in the preheater, pressure for conveying it alone is needed. Existing mechanical or steam, or air oil burners are adapted to Colloidal Fuel. Several varieties have been used.

CHAPTER V

DISTRIBUTION AND STORAGE

Oil refineries are built at points strategically located with respect to production and markets. From the refineries fuel oil is delivered to a station located in the center of the industrial district to be served and it is delivered from the refineries to these central stations by water or by rail. Many companies supply fuel oil to countries lying overseas. To these countries fuel oil is transported by ocean-going tankers and oil barges. There were in May, 1920, 93 steam tankers aggregating more than one million deadweight tonnage building in American shipyards for private companies. All but two of these ships burn fuel oil under their boilers for power and these two are equipped with Diesel engines.

Many of the tankers now in use carry fuel oil on outward voyages, but return to the United States laden with some other bulk liquid. The Philippine Vegetable Oil Company, for example, now has in operation two such tankers operating between San Francisco and Manila.[a] The two vessels now in operation are the "Nuuanu" and the "Katherine." They are specially equipped for carrying petroleum products, either bulk or case oil, for the Standard Oil Company from the Richmond refinery to Hongkong and returning via Manila, where a cargo of cocoanut oil is taken for delivery at the storage tanks of the Philippine Vegetable Oil Company at San Francisco. The "Nuuanu" was the first tanker to be placed in operation in this special service and has recently made her third round trip, each time carrying petroleum oil to Hongkong and returning via Manila, where a cargo of cocoanut oil was taken on. The auxiliary motor ship "Nuuanu" (See fig. 17) was before her conversion to an oil tanker the iron sailing vessel "Highland Glen" of the following dimensions: Length over all, 211 feet; breadth, 34 feet, and depth, 19 feet 6 inches. The power plant consists of a 320-b. horsepower model "M-11" Bolinder engine, the machinery being placed in an unused part of the ship and not interfering with the existing bulkheads.

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[a]Oil News, December 5, 1919, P. 28, C. W. Geiger.

This vessel has been able to make a speed of over seven knots. loaded, in ordinary weather without the assistance of sails. On her first trip from San Francisco to Manila via Hongkong the time occupied in making the voyage to Manila was 45 days. She

FIG. 17.—The oil tanker "Nuuanu."

arrived in San Francisco with a cargo of about 1,100 tons of bulk cocoanut oil, making the trip from Manila in 46 days. So well satisfied with the work of the "Nuuanu," the Philippine Vegetable Oil Company purchased the former British ship "County of

Linlithgow," renamed her the "Katherine" and converted her into a tanker for the same service. The "Katherine" was equipped with many features not included on the "Nuuanu," but these new features are now being installed on the "Nuuanu." The "Katherine" can carry about 2,600 tons. Both vessels carry sufficient fuel to make the round trip. Fuel is carried in two tanks, one tank being located in the engine room and the other in the cofferdam separating the cargo tanks from the engine room. The oil is delivered from these tanks to the engine by duplex pumps operated

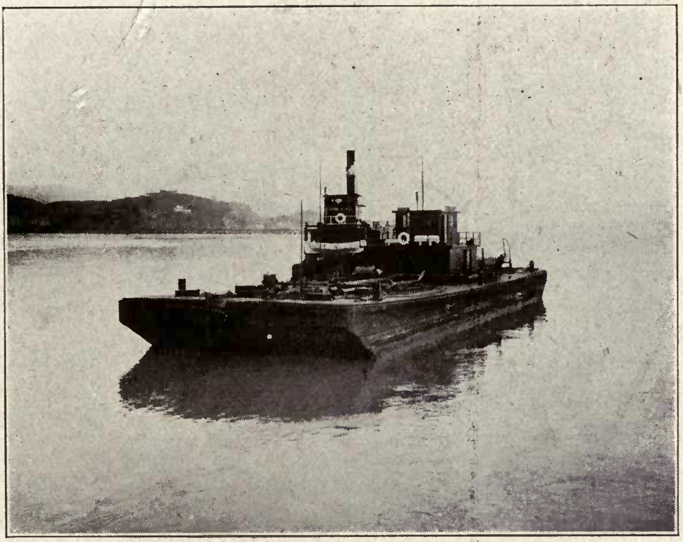

Fig. 18.—An Oil Barge on San Francisco Bay

by steam. The "Nuuanu" carries a crew of 30, including the chief engineer, first and second engineers, two wipers, captain, first and second mate and the usual number of sailors.

For delivering fuel oil to vessels either in the stream or at the dock a very extensive fleet of oil barges is operated on San Francisco Bay by the Standard Oil Company, Shell Oil Company, Union Oil Company, and the Associated Oil Company. In *Oil News,* September 20, 1919, page 11, the following account of the operation of these barges is given by C. W. Geiger:

"A large fleet of barges is maintained by the Standard Oil Company. Its units are principally barges with the steam tug Standard No. 1 in constant attendance, and working with them are the power barges Benecia and Contra Costa. The power barges are manned by both day and night crews, and are ready to make fuel oil deliveries around the harbor at any time during the entire twenty-four hours. The convenience of this service to steamship operators can readily be imagined, and the company has materially added to its fuel oil business because of it. The barge Contra Costa is propelled by a gasoline engine and has a capacity for carrying 7,500 barrels of oil in her tanks. The Benecia, which is also propelled by a gasoline engine, has a

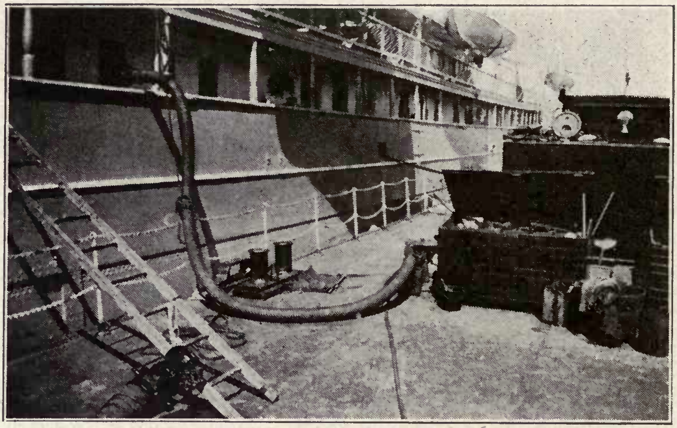

Fig. 19.—Delivering fuel oil to a mail steamer.

capacity for carrying 2,200 barrels. The carrying capacity of the remaining barges is as follows: Barge No. 1, 4,500 barrels; barge No. 2, 800 barrels; barge No. 3, 2,000 barrels; barge No. 4, 5,500 barrels; barge No. 5, which operates on the river, 2,000 barrels (See fig. 18); barge No. 6, 650 barrels; barge No. 7, 5,000 barrels; barge No. 8, 2,200 barrels. The following barges operate on the rivers: San Jose, stern wheel steamer, 500 barrels; Petroleum No. 3, stern wheel steamer, 1,500 barrels. The river trade demands a boat drawing not more than five feet of water, and here the stern paddle-wheel type of boat is necessary for carrying cargo and towing light-draft barges. Owing to the shallow water and many snags in the river, a propeller is out of the question.

Cargoes of fuel oil as high as 15,000 barrels are taken on by some of the trans-Pacific steamers (See fig. 19). All of the four oil companies mentioned maintain large storage tanks adjacent to the water front at San Francisco, with receiving and discharge pipes leading to the docks. In addition to supplying oil to the steamers in the bay, these barges deliver oil from the refineries operated by the various oil companies in the vicinity of San Francisco, to these oil storage tanks adjacent to the water front. These tanks supply fuel oil to the smaller vessels that tie up at the oil docks. The Standard Oil and the Shell Oil each maintain such storage tanks at the northerly end of the water front, from which point the numerous lumber schooners and fishing boats are supplied. At the southerly end

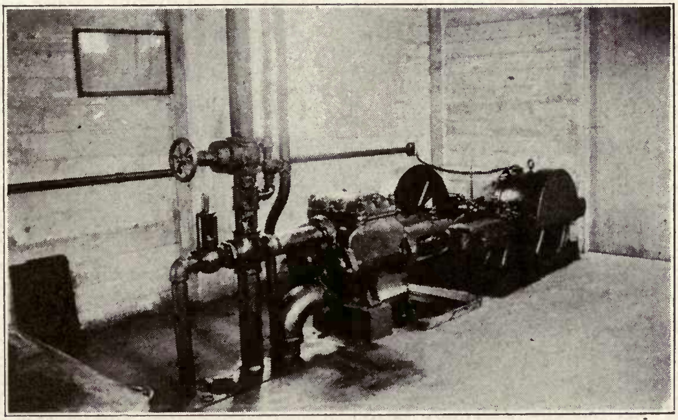

FIG. 20.—Pump for loading barges with fuel oil.

of the water front, in the vicinity of 16th and 17th streets, such storage stations are maintained by the Standard Oil, Union Oil, and the Associated Oil Companies. In addition to supplying oil to the smaller vessels, these storage stations supply the oil trucks that deliver oil through the City of San Francisco. The Shell Oil Company operates barges which take on oil at the loading station at Martinez and are towed to the San Francisco water front by a steam tug used for this exclusive purpose. During the busy seasons gasoline tugs are rented from the local launch companies. These barges have a carrying capacity ranging from 1,030 barrels to 3,000 barrels. The barges are all of wooden construction, being built especially for this type of service. Barge No. 4 is 148 feet in length, 35 feet in width and 6 feet 10 inches in depth. She draws 5 feet 6 inches when loaded and 3 feet 6 inches light. Barge No. 3 is 78 feet in length, 23 feet in width, and 6 feet 10 inches in depth, and draws 6 feet 6 inches when loaded and 2 feet 6 inches when light. Barge No. 1 is 116 feet in length, 32 feet in width and 10 feet 2 inches in depth, and draws 7 feet when loaded and 3 feet 6 inches light. She has a carrying capacity of 2,950 barrels of oil. The 250 horsepower steam tug Priscilla was built especially for tending these barges. They are operated on the tides, being towed from Martinez when the tide is going out aud returned with the incoming tide. Approximately 140,000 barrels of oil are handled monthly by these barges. Barge No. 4 is equipped with a gasoline-operated generator which pro-

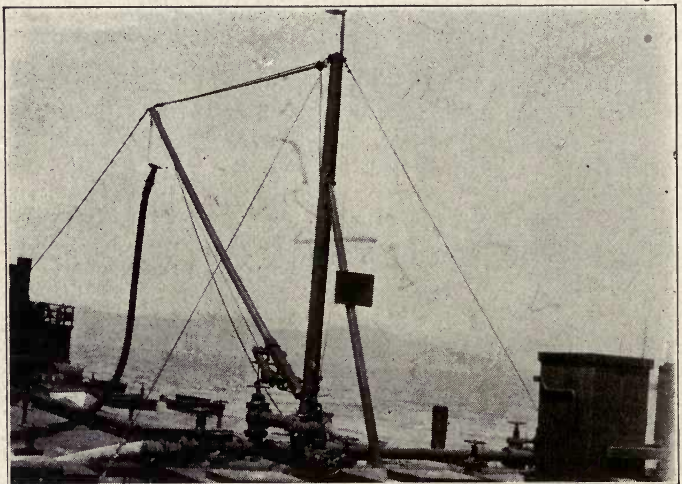

FIG. 21.—Derrick for handling heavy hose on barge.

vides electric current for lighting, which greatly facilitates night operations."

The railroads are among the principal users of fuel oil in this country. For filling the fuel storage tanks of the railroads the oil is transported in tank cars. Mr. Robert Clarke, Jr., describes the development of the tank car as follows:[a] "In 1865 the car tank, mounted on a railroad flat car, made its appearance. Mr. Lawrence Myers—who was represented as the patentee of this type of tank on wheels,—called it the "Rotary Oil Car." A number of the first tanks on cars were constructed of iron, but the majority were built of heavy pine planks, a material more readily obtainable and lower in cost. In shape these tanks were

a. The Petroleum Handbook, Andros, p. 151.

practically the same as the small iron-hooped wooden tank in use at the wells, being round and of smaller diameter at the top than the bottom and holding from 40 to 50 barrels each. On each flat car two of these tanks were mounted—one at each end over the trucks—making the capacity of the car between 80 and 100 barrels. The first of these "Rotary Oil Cars" arrived in Titusville, Pa., on November 1, 1865, where it received a cargo of oil at

Fig. 22. A Tank Car.

the Miller farm, the terminus of the first successful pipe line from Pithole. Miller farm was located four miles below Titusville on the banks of Oil Creek, Pa. This car was the property of the Eagle Transportation Company of Philadelphia, Pa., who owned the patent rights and who proposed to build and operate a tank line on all railroads for the transportation of crude and refined oils. With customary progressiveness we find the builders and users of tank cars soon making improvements in design and construction of the original car. Dillingham and Cole, a firm of machinists with shops located at Titusville, Pa., in 1866 received a contract for fitting 60 tanks on cars for the Oil Creek railroads—now a part of the Pennsylvania Railroad System—with a rather ingenious gate-valve or cock that could not be opened without having a wrench that was especially made for the purpose. These tanks were constructed of iron and mounted on flat cars at each end over the trucks, similar to those of the Eagle Transportation Company. The capacity of these cars was about 90 barrels. This new method of shipping was indeed a step in the right direction, for it eliminated a very considerable loss of oil resulting from leakage in transit, reduced the liability of serious conflagrations and did away with the necessity of a return of thousands of barrels to the producer, besides eliminating cooperage charges. Until 1870 this type of car, in which the iron-hooped wooden tank was employed, was used extensively in transporting crude oil to market. In the late sixties, however, the forerunner of the present type of tank car was introduced—a design of car in which a horizontal cylindrical tank replaced the two small wooden ones The first of these cars was shipped to the Oil Creek region in 1868 and sidetracked at the Boyd farm for loading. A radical change was made in the designing of these new tanks in that they were fitted with a dome which allowed the oil to expand without injury to the tank. These cars had a capacity of 80 to 90 barrels. Later this was increased to 100 barrels, which became the standard for that period. The advantages of this new type of car were quickly recognized by both oil and railroad men; in fact, its adoption was so general that by the end of 1872 the majority of the old type of cars had disappeared. About May 1, 1872, the Oil Creek and the Lake Shore Railroad companies issued orders that after that date none of the old type of tank cars would be accepted for transportation over their roads. With few exceptions, this ruling was generally adopted by other railways, although even as late as 1876 they were still accepted by the Allegheny Valley Railroad, extending from Oil City to Pittsburgh. By 1880 the last of the early wooden tank cars had disappeared from service. It is particularly true of American progressiveness and business acumen that the introduction of a new process or new method of doing something in one field is soon applied with equal success to other fields and so it has been with the tank car. Today there are thousands of tank cars in service carrying other products than petroleum and its by-products. The Master Car Builders' Association state in their specifications covering the design and construction of tank cars that a tank car is "any car to which one or more metal tanks, used for the transportation of liquids or compressed gases, are permanently fastened," and in order that these tank cars may be designed and constructed to meet the service requirements of a wide range of products they have designated that there shall be five classes of tank cars, classified as follows:

"Class 1.—Tank cars for general service, with steel underframes or without underframes, built prior to 1903.

"Class 2.—Tank cars for general service, with steel underframes, or without underframes, built between 1903 and May 1, 1917.

"Class 3.—Tank cars for general service, built after May 1, 1917.

"Class 4.—Tank cars for the transportation of volatile inflammable products whose vapor pressure at a temperature of 100° F. exceeds ten pounds per square inch, built after May 1, 1917.

"Class 5.—Insulated tank cars of specially heavy construction, built after January 1, 1918, for the transportation of liquid products whose properties are such as to involve danger or loss of life in event of any leakage or rupture of the tank."

The importance of good, strong, sound and thorough construction in tank car design cannot be overestimated. Upon these factors depends the life and efficient service of the car. A poorly designed and constructed tank car is not only a menace to the railroads hauling them, but also the shipper, consignee and the industrial centers through which the car may pass.

Fig. 22 shows a tank car.

In general the storage tanks erected by the railroads are steel cylinders. The size of a storage tank will naturally be a little in excess of a multiple of 6,000 gallons, for the reason that 6,000 gallons is the capacity of a regulation tank car. So, then, storage tanks will properly have capacities greater than 6,000, 12,000, 18,000 and so forth, gallons. Fig. 23 shows a 20,000-gallon fuel oil tank along the Mexican Railway,[a] and Fig. 24 shows locomotive loading tanks along the lines of the United Railways of Havana.[b]

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a. Reprinted by permission of Anglo-Mexican Petroleum Co., Ltd.

b. Courtesy of Sinclair's Magazine.

For the storage of fuel oil at small industrial plants and at hotels, apartment houses, and residences, the steel tank has been in general use. Mr. S. D. Rickard, Consulting Engineer, Wayne Oil Tank & Pump Company, gives the following advice concerning storage tanks:

"Too great care canot be used in the selection of the oil storage tank, or tanks. It is a great deal more difficult to con-

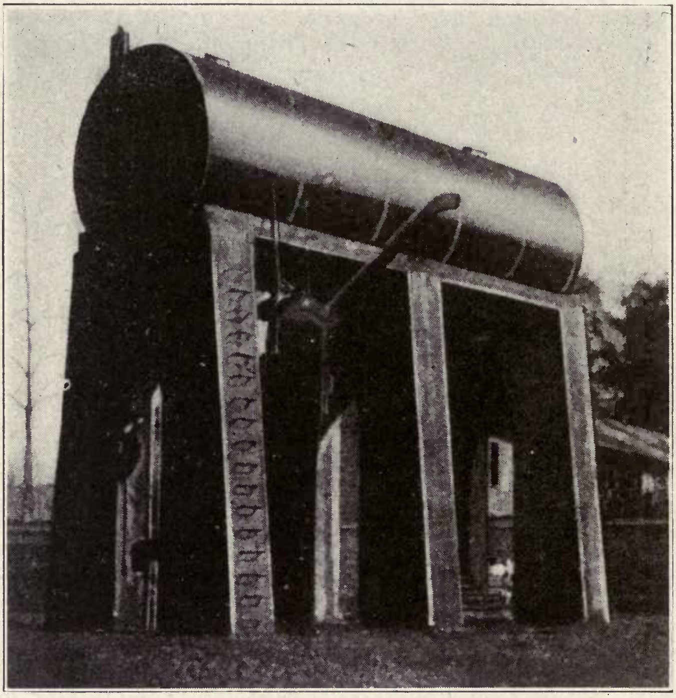

Fig. 23.—Storage tank along the Mexican Railway.
(Courtesy of Anglo-Mexican Petroleum Co.)

struct an oil-tight tank than to construct a tank simply for the storage of water. It is very difficult and sometimes impossible to repair a leaking tank, and a great deal of oil may be lost before the leak is discovered. All tanks should be inspected and labeled by the Underwriters' Laboratories of the National Board of Fire Underwriters.

Fuel oil storage tanks should be cylindrical in shape and placed underground so that the top of the shell is at least two feet below ground. These tanks should be of sufficient capacity to allow for a working supply in case deliveries are delayed, and so that tank cars can be entirely emptied as soon as they are received, avoiding demurrage charges. Where shipments are to be received in single carload lots, a 12,000-gallon tank is the smallest size that should be installed. However, many installations embody two or more tanks varying in capacities from 8,000 to 25,000 gallons.

It should be specified that the tank be fitted with all of the pipe flanges and the manhole at one end of the shell on top. In this way it is possible to build a box with a trap door over one end of the tank whereby all pipe connections and the manhole may be easily gotten at.

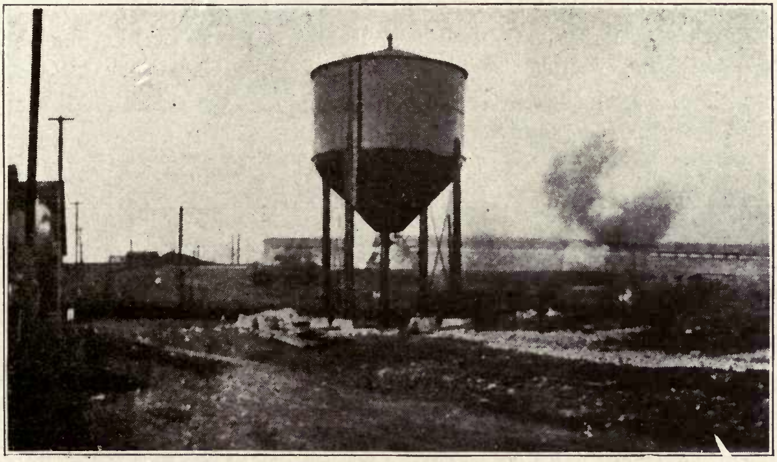

FIG. 24. Locomotive Loading Tanks Along Lines of the United Railways of Havana.
(Courtesy of Sinclair's Magazine.)

It is good practice to fit a fuel oil tank with the following flanges and manhole: one 10″ x 16″ manhole, one 3½″ suction flange, one 4″ fill flange, one 1½″ vent flange, one 1½″ return pipe flange, and one ½″ indicator flange.

Every fuel oil tank should be constructed with internal steam coils of proper design. Although it might be possible to obtain a light oil at the time the tank is installed, it may become necessary at any time to burn a heavy oil, which would require heating.

Each storage tank should be fitted with a tank gallonage indicator. These indicators show at a glance the contents of the tank. They may be placed inside of the nearest building, outside of the building against the wall, directly over the tank, or on the side of aboveground tanks."

When it is impossible to place the main storage tanks below ground or below the level of the burners, a small 5 or 10 barrel reservoir tank should be placed underground below the main storage. This reservoir tank is then fed by gravity from the overhead tanks. Just inside the small reservoir tank is placed a float valve, as shown in Fig. 25. This valve closes whenever the oil in the small tank reaches a certain level. The suction and return pipes should run from this small underground tank in the usual manner. In this way the danger of flooding a building with oil is avoided. Fig. 26 shows a typical steel storage tank for fuel oil.

The Butler Manufacturing Company, Kansas City, made the following quotations as of July 1, 1920, for storage tanks, f. o. b. Kansas City:

HORIZONTAL TANKS SUITABLE FOR UNDERGROUND USE BUT WITHOUT UNDERWRITER'S LABEL.

Size	Capacity	Weight	Gage Material	Dealer's Price	Retail Price
3 x 5	260 gal.	289	12 gage BA	$ 59.80	$ 74.70
3½x 5	350	352	12	67.40	84.26
4 x 5	460	416	12	78.60	98.20
4 x 6	560	473	12	84.05	105.75
5 x 5	725	565	12	94.20	117.50
5 x 6	870	635	12	102.00	127.40
5 x 7	1015	705	12	109.10	136.40
5 x 8	1160	775	12	116.70	145.90
6 x 6	1250	814	12	121.50	151.83
6 x 8	1675	980	12	139.00	173.80
6 x10	2100	1175	12	156.90	196.15

These horizontal tanks will be equipped with 4″ fill opening, 1″ vent, 2″ outlet; also, each tank will be given one coat of asphaltum paint.

VERTICAL WELDED STORAGE TANKS.

Size	Capacity	Weight lbs.	Gage	Dealer's Price	Retail Price
5x4	575 gal.	453	12BA	$ 95.40	$119.40
6x6	1250	747	12	129.30	161.63
7x6	1700	891	12	150.75	185.50
7x8	2280	1083	12	179.00	224.00
8x8	2975	1288	12	208.30	260.40
9x9	4240	1640	12	244.00	305.00

These vertical tanks have cone cover with 4″ fill openings and plug, a return bend and nipple screwed into plug for use as vent, a 2″ outlet tap in side near bottom, one coat of red paint to be applied.

On all tanks quoted above blue annealed steel is furnished, which is especially adapted for welding. All seams will be carefully welded and the tanks will be thoroughly tested under air pressure before leaving the factory to insure that they are oil-tight. If any tanks when first filled, are found to be leaking, necessary repairs will be made when the oil is removed.

In the event tanks of greater capacity, heavier material, or tanks bearing underwriter's label are required, quotations will be made on receipt of exact requirements.

It is only recently that concrete has been considered a suitable material for making containers for fuel oil. The knowledge of the desirability of concrete for oil storage tanks was acquired during the war through the practical elimination of steel plates.

Mr. H. P. Andrews, in a paper read before the American Concrete Institute, states that reinforced concrete has proved to be satisfactory in many ways, if intelligently handled. As it is necessary to install most fuel oil reservoirs underground, steel tanks rust if not protected. Concrete can be designed better to resist exterior stresses, as hydrostatic or earth pressures. It has

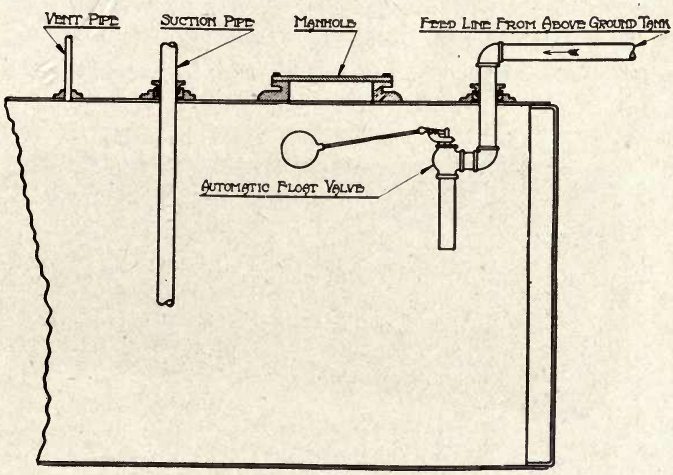

Fig. 25. Reservoir Tank with Automatic Float Valve.
(Courtesy of Wayne Oil Tank and Pump Company)

the dead weight to better resist upward hydrostatic pressure in soils which often are filled with water. It does not attract lightning like steel, nor if properly constructed is it affected by electrolysis. It is a non-conductor of heat and cold, thus retarding evaporation of oil in summer, and also retarding the lowering of the temperature of the oil in winter, an advantage in pumping. In case of a conflagration the oil is much safer in a concrete container than in steel. But, as previously stated, oil reservoirs of concrete must be designed correctly, the concrete proportioned correctly and mixed and placed correctly in order to get satisfactory results. And by satisfactory results it is meant that there shall be no leakage or seepage when built or, thereafter, to cause fire hazards or financial loss. When these necessities have been provided for, reinforced concrete reservoirs will contain fuel oil of a consistency up to 40° B., and practically all fuel oils are below this, the Mexican oils having a specific gravity as low as 16° B. For the lighter oils, including kerosene, gasoline or benzine, some provision should be made for a lining of special material, and the writer understands that the U. S. Shipping Board has been making some extended experiments along this line. The design and the location of a fuel oil reservoir may be considered from various standpoints. (1) Location. The reservoir should be located a safe distance from inflammable structures as far as possible consistent with pumping requirements, covered with at least 18 in. of earth, if near buildings, to decrease fire hazards and also to minimize oil evaporation. If distant from buildings it should

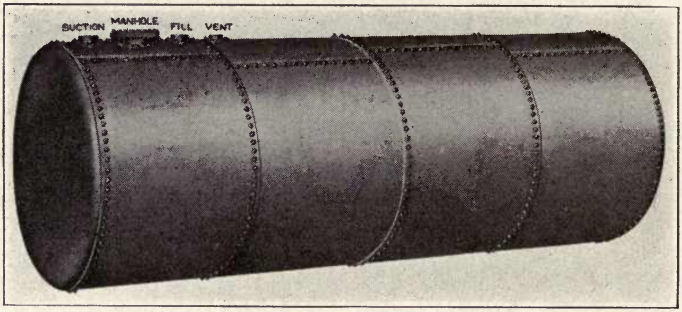

Fig. 26. Steel Storage Tank for Fuel Oil.
(Courtesy Wayne Oil Tank and Pump Company.)

be at least half underground, and if possible, the excavated material should be used in banking up around it. (2) Size. The reservoir should be limited in size for two reasons: First, the necessity of not exceeding a day's working limit in the operation of pouring concrete so that joints between operations may be eliminated; and secondly, so that in case of an accident or fire in any reservoir, that too much oil in storage will not be involved. This size limit should not be over 300,000 gallons under most conditions, and the majority of contractors have not the facilities to construct properly a reservoir of this capacity. (3) Shape. The reservoir should be circular in shape, the better and more directly to take care of involved stresses and to avert danger of tensile or temperature cracks. (4) It should be so proportioned and designed as to limit the number of pouring operations of

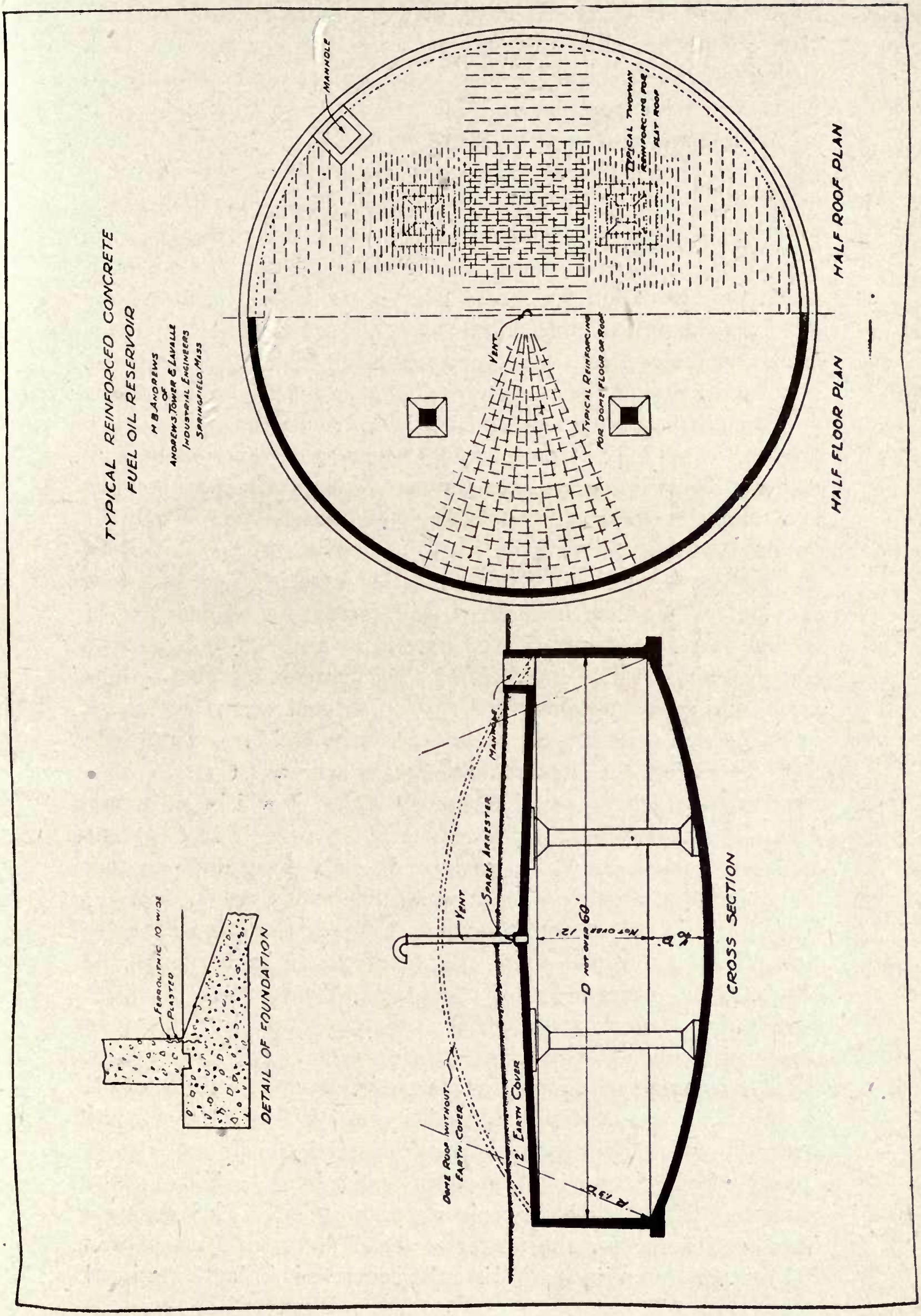

FIG. 27. A TYPICAL REINFORCED CONCRETE FUEL OIL RESERVOIR.

concrete, so as to avoid joints between these operations. (5) Care should be taken to provide for all exterior stresses, such as hydrostatic pressure from ground water, earth pressure on walls, and roof if reservoir is buried, and also to avoid as far as possible concentration of loads on walls or footings. Where joints are absolutely necessary they should be so protected that there will be no leakage through them. Regarding hydrostatic pressure, while engineers have found from tests that this pressure in soils is only about 50 per cent of the full head of water, it is not safe to design for stresses less than the full head, as any deflection in the concrete admitting a film of water between the earth and the concrete will produce the full hydrostatic pressure. (6) To so design the reservoir, piping and vents as to comply with municipal regulations and insurance requirements. (7) To protect temporarily or permanently concrete surfaces so that oil will not come in immediate contact with them if concrete is less than six weeks old. (8) To so design the false work for holding concrete temporarily in place that it will not fail or be distorted while placing concrete. It is especially necessary to provide for the firm holding of wall forms, as the pressure of several feet of concrete poured quickly as a monolith is intense, and any give of the forms after the concrete has obtained its initial set breaks up the crystals already formed, allows expansion of the concrete mass, with resultant porosity and loss of strength. (9) To design the concrete so that it will resist all exterior stresses to which it is subjected and so that it will be oil-proof. And one of the principal features of this design is to make the walls of circular reservoirs in tension, sufficiently thick so that the ultimate strength of the concrete in tension will not be exceeded. It is not meant, of course, to leave out the steel reinforcement so that the stress will theoretically be borne by the concrete, but, nevertheless it will actually be borne by it unless some unforeseen weakening of the concrete should throw it upon the steel. An extended investigation by the writer on high circular concrete standpipes for water showed that if the concrete in the wall was stressed beyond its elastic limit or ultimate strength, which is practically identical, vertical hair cracks will appear of sufficient width to admit water into the body of the concrete. This ultimate tensile strength in a 1:1½:3 concrete from tests made for the writer at the Watertown Arsenal was 203 lbs. per square inch. Where the concrete is in large sectional areas and reinforced, this tensile strength probably will be somewhat higher. If a stress not exceeding 150 lbs. per square inch is allowed in tension there will be no danger of these vertical cracks appearing. (10) To design the reinforcement so that it will take care of all interior and exterior stresses and with fittings to hold it rigidly in place while concrete is being poured. Steel in tension in walls should not be stressed over 10,000 lbs. per square inch to conform with insurance companies' requirements. Personally, the writer does not think that it is necessary to figure the stress as low as this, under usual conditions, having satisfactorily constructed many reservoirs using a stress of 14,000 pounds, but of course, the lower stress is an additional safeguard against inferior workmanship by inexperienced contractors and against any decrease in bond strength due to oil penetration of concrete. It is probably unwise to depart radically from insurance companies' recommendations. For other parts of the reservoir the recommendations of the Joint Committee on Concrete, Plain and Reinforced, should be followed. All reinforcing rods in concrete exposed to oil should be of a deformed section for better bending value. To carry out these requirements necessitates the employment of competent engineers, experienced in the work, to make the design and specifications and to superintend construction. The concrete should be no leaner than a mix composed of 1 part of cement, 1½ parts of sand and 3 parts broken stone or gravel. To this mix should be added a "densifier." Hydrated lime has been found economical and satisfactory for this purpose, using ten lbs. of dry lime to each bag of cement. The stone must be hard and clean, trap rock, granite or gravel being the best material. The sand must be free from any deleterious matter; and should be well graded. Cement should be of an established quality. The concrete should be deposited continuously in concentric layers not over 12 ins. deep in any one place. No break in time of over thirty minutes is permissible in depositing concrete during any one operation, and if any delay occurs, the previous surface must be chopped up thoroughly with spades before the next layer of concrete is deposited.

The different operations in pouring are:

1. The pouring of floor and footings.
2. The pouring of entire wall.
3. The pouring of roof.

In small reservoirs the wall forms may be supported so that the footings, floor and wall may be poured in one continuous operation. An approved joint or dam must be made between the floor and the wall. When the materials are obtained they should be mixed by a plant of sufficient size and power to carry out each separate pre-arranged operation without danger of delay during the process. The materials should be mixed at least 2 minutes in the mixer, using just enough water to obtain a plastic mix without excess water coming to the surface after concrete is deposited, and a measuring tank should be used so that the amount of water may be kept uniform. The concrete when deposited in forms should be well spaded by at least four competent laborers who are not afraid to use their muscle in compacting the concrete thoroughly and working out the trapped air bubbles. Reinforcement should be of round deformed bars conforming to "Manufacturer's Standard Specifications for Medium Steel." These bars should be bent or curved true to templates carefully placed in their predesigned location and rigidly maintained there by mechanical means. No laps should be less than 40 diameters and no two laps of adjacent rods should be directly opposite each other. The forms should be of a good material, strongly made and braced, or held in place by circumferential bands so that no distortion, allowing displacement of concrete during its initial set, is possible. The surface of the floor should be trowelled smooth as soon as it can be done properly. If all previously named precautions are taken, there should be no defects in the wall to correct. Concrete mixed and placed as recommended herein is practically oil-tight, but as oils are somewhat detrimental to fresh concrete, it is advisable to put on an interior wash or coating to protect the fresh concrete from the action of the oil for such a time as may be necessary for it to cure and harden sufficiently. Silicate of soda, while not a permanent coating, has been used satisfactorily for this purpose according to this specification for oil-proofing. The surface of the floor and the interior surface of the wall are to be coated with silicate of soda of a consistency of 40° B when applied as follows: First coat. One part of silicate of soda and three parts of water, applied with brush and all excess liquid wiped off with cloth before drying. Second coat. One part silicate of soda and two parts water applied as above. Third coat. One part of silicate of soda and one part water, applied with brush and allowed to dry. Fourth coat. Applied same as third. The dome roof is economical to construct where earth covering is not required and where all concentrated loads on walls are eliminated, which might tend to produce unequal settlement with resultant cracks. The inverted dome at the bottom gives additional storage capacity with only increased cost of excavation and lessens height of wall thus requiring less shoring of banks in loose soils. It allows a better drainage of the reservoir than a flat floor, and better resists upward exterior pressure. The recommended maximum dimensions for this type of reservoir are as follows: Diameter, 60 feet; height of wall, 12 feet, rise of roof dome, 1/6th to ⅛th dia; drop of inverted dome not over 1/10th dia. The floor and roof should be reinforced both circumferentially and radially to provide against temperature and other stresses. There are many details which might be added, but the information given is intended to cover the principal features." Fig. 27 shows a typical reinforced concrete fuel oil reservoir.

The Portland Cement Association in its Bulletin "Concrete Tanks for Industrial Purposes" is authority for the statement that at present there is in the United States concrete tank storage for over 790,000,000 gallons of oil. Concrete tanks for oil storage are not an experiment, but their use for such purposes has rapidly developed during the past three years because of unusual conditions during the war. There are examples of concrete oil tanks that have 15 years of service to their credit, thus proving their success in this field. The economy and advantages of the concrete oil tank have established it as a standard type of oil storage container, particularly as relates to the needs of industrial plants using fuel oil. Although such tanks can be built above ground, the greatest advantages are derived from placing them underground and covering with two or three feet of earth. Under such conditions the stored oil is maintained at a fairly even temperature, losses from evaporation of the lighter oils are reduced, and greater protection to tank contents is afforded against fire from lightning or other causes; therefore, the insurance on surrounding buildings is not increased because of the presence of stored oil. Insurance on contents of the tank is also less. In addition, there is the advantage that the storage container does not occupy valuable yard space necessary for plant operation or other storage, and the tank may be placed at any convenient location, even under a railroad sidetrack or plant driveway. So far as it has been possible to collect data, the following list, correct to August 1, 1919, shows industrial concerns in the United States and Canada using from 1 to 11 concrete oil storage tanks or reservoirs and the capacity of the storage listed:

Company	Location	Year Built	Capacity Gallons
ARIZONA			
Queen Laundry	Bisbee	1918	18,500
ARKANSAS			
Ozark Refining Co	Ft. Smith	1912	260,000
Lignite Products Co	Camden	1917	12,000
CALIFORNIA			
Associated Oil Co	San Francisco	1910-11	337,500,000
Union Oil Co. of Cal	San Louis Obispo	....	190,000,000
Kern Trading & Oil Co	Bakersfield	1913-14	100,000,000
Standard Oil Co	San Francisco	1906-15	60,000,000
Union Oil Co	Port Richmond	....	40,000,000
General Petroleum Corp	Los Angeles	1915	21,000,000
So. California Edison Co	Los Angeles	1911	2,000,000
W. H. Jameson	Corona	1913	110,000
Indian Valley Ry. Co	Paxton	1917	32,000
Libby, McNeill & Libby	San Francisco	1916	16 000
Napa Valley Electric Co	St. Helena	1912	10,000
CONNECTICUT			
American Brass Co	Torrington and Waterbury	1918	1,320,000
New Departure Mfg. Co	Bristol	1919	500,000
Lawton Mills Corp	Plainfield	1919	225,000
Yale & Towne Mfg. Co	Stamford	....	117,000
French River Textile Co	Mechanicsville	1919	110,000
Versailles Sanitary Fibre Co	Versailles	1918	72,000
Fafnir Bearing Co	New Britain	1919	36,000
FLORIDA			
St. Johns Electric Co	St. Augustine	1919	53,000
Southern Utilities Co	Miami	1919	50,000
Southern Utilities Co	Arcadia	1919	30,000
St. Augustine Ice Co	St. Augustine	1919	28,000
Southern Utilities Co	Palatka	1919	28,000
Southern Utilities Co	Ft. Lauderdale	1919	23,000
Southern Utilities Co	Ft. Myers	1919	23,000
Southern Utilities Co	Okeechobee	1919	23 000
Southern Utilities Co	Tarpon Springs	1919	23,000
Southern Utilities Co	Titusville	1919	23,000
ILLINOIS			
Symington Chicago Corp	Chicago	1918	750 000
American Steel Foundry Co	Granite City	1918	350,000
Cribben & Sexton Co	Chicago	1918	300,000
Pressed Steel Car Co	Hegewisch	1918	250,000
Rockford Drop Forge Co	Rockford	1912-18	175,000
Parlin & Orendorff Co	Canton	1918	125,000
Crescent Forge & Shovel Co	Havana	1917	110,000
Keystone Steel & Wire Co	Peoria	1919	85,000
Galesburg Coulter Dis. Co	Galesburg	1918	63,000
Greenlee Bros. & Co	Rockford	1918	63,000
A. Hershel Mfg. Co	Peoria	1919	55,000
Mt. Vernon Car Mfg. Co	Mt. Vernon	1918	50,000

Company	Location	Year Built	Capacity Gallons
Electric Wheel Co.	Quincy	1918	43,000
Octigan Drop Forge Co.	Chicago	1918	15,000
Whiting Fdry. & Equip. Co.	Harvey	1918	13,000
INDIANA			
Muncie Gear Works	Muncie	1918	24,000
IOWA			
Charles City Gas Co.	Charles City	1916	30,000
Moline Oil Co.	Clinton	1917	20,000
KANSAS			
Garden Sugar & Land Co.	Garden City	1907	2,000,000
Howard Oil Co.	Mt. Hope	1910	18,000
Williamson Milling Co.	Clay Center	1909	18,000
KENTUCKY			
Neha Refining Co.	Lexington	1918	150,000
MAINE			
Goodall Worsted Co.	Sanford	1919	600,000
Great Northern Paper Co.	Madison	1919	380,000
Wyandotte Worsted Co.	Waterville	1919	115,000
MASSACHUSETTS			
Pacific Mills	Lawrence	1919	1,300,000
American Steel & Wire Co.	Worcester	1918	1,000,000
Merrimac Chemical Co.	Boston	1918	690,000
Manufacturing Plant	Everett	1918	650,000
Thomas Plant Shoe Co.	Roxbury	1917-18	160,000
Holtzer-Cabot Electric Co.	Boston	1918	100,000
Osgood Bradley Car Co.	Worcester	1918	100,000
Christian Science Pub. Co.	Boston	1918	70,000
Pentucket Mills	Haverhill	1919	70,000
MICHIGAN			
Studebaker Corp.	Detroit	1918	825,000
American Car & Foundry Co.	Detroit	1918	400,000
Chicago Ry. Equipment Co.	Detroit	....	228,000
Detroit Steel Castings Co.	Detroit	1918	200,000
Timken-Detroit Axle Co.	Detroit	1918	200,000
Packard Motor Car Co.	Detroit	1918	127,000
Detroit Steel Products Co.	Detroit	1918	100,000
Great Lakes Eng. Works	Detroit	1918	100,000
Detroit Steel Casting Co.	Detroit	1918	78,000
Bower Roller Bearing Co.	Detroit	1918	75,000
Briscoe Motor Corp.	Jackson	1918	60,000
Buhl Malleable Co.	Detroit	1918	35,000
Russell Axle Co.	Detroit	1918	34,000
Detroit Twist Drill Co.	Detroit	1918	20,000
MINNESOTA			
City of Redwood Falls	Redwood Falls	....	20,000
MISSOURI			
Curtis & Co. Mfg. Co.	St. Louis	1917	1,500,000
No. American Refining Co.	Sheffield	....	840,000
Commonwealth Steel Co.	St. Louis	1918	240,000
Laclede Steel Co.	St. Louis	1918	240,000
American Brake Co.	St. Louis	1918	65,000
Kuhne Bros. Merc. Co.	Troy	1918	18,000
NEBRASKA			
Wells-Abbott-Nieman Co.	Schuyler	1917	70,000
So. Nebraska Power Co.	Superior	1916	26,000
T. F. Stroud & Co.	Omaha	1913	12,000

Company	Location	Year Built	Capacity Gallons
NEVADA			
Desert Power & Mill Co	Millers	1907	145,000
NEW HAMPSHIRE			
Clearmont Paper Co	Clearmont	1917	215,000
NEW YORK			
Titanium Alloy Mfg. Co	Niagara Falls	1917	110,000
Bossert Corp.	Utica	1918	60,000
NORTH DAKOTA			
Steele Light & Power Co	Steele	1917	16,000
OHIO			
Federal Glass Co	Columbus	1917	450,000
Aluminum Castings Co	Cleveland	1918	115,000
Wellman-Seaver-Morgan	Cleveland	1918	103,000
American Brass Co	Columbus	1918	100,000
Bonney-Floyd Co.	Columbus	1917	90,000
Shaw-Kendall Engineering Co	Lakewood	1918	88,000
City Light & Water Plant	Bryan	1918	40,000
Star Aluminum Co	Ashland	1918	20,000
Globe Mach. & Stamp. Co	Cleveland	1917	14 600
OKLAHOMA			
Muskogee Refining Co	Muskogee	1917	180,000
Oilton Refining Co	Oilton	1915	100,000
Anadarko Cotton Oil Co	Anadarko	1915	65,000
Baker Cotton Oil Co	Hobart	....	32,000
Shawnee Gas & Electric Co	Shawnee	1909	30,000
PENNSYLVANIA			
Westinghouse Air Brake Co	Wilmerding	1917-18	250,000
Amer. Brake Shoe & Fdry. Co	Erie	1918	182,000
Steel Car Forge Co	Ellwood City	1918	150,000
Union Switch & Signal Co	Swissvale	1918	150,000
Westinghouse Elec. & Mfg. Co	E. Pittsburgh	1918	125,000
General Electric Co	Erie	1918	100,000
Valley Forging Co	Verona	1918	86,000
H. H. Robertson	Cambridge	1918	80,000
Pittsburgh Seamless Tube Co	Beaver Falls	1918	70,000
Fort Pitt Spring Co	McKees Rocks	1918	52,000
Morris Bailey Steel Co	Wilson	1918	50,000
Erie City Iron Works	Erie	1918	30,000
Mathews Gravity Carrier Co	Ellwood City	1918	27,000
Union Iron Works	Erie	1918	26,000
Neely Nut & Bolt Co	Pittsburgh	1918	21,000
RHODE ISLAND			
International Braid Co	Providence	1918	600,000
Revere Rubber Co	Providence	1918	400,000
Gorham Mfg. Co	Providence	1918	305,000
Peace Dale Mfg. Co	Peace Dale	1918	300,000
Lonsdale Mfg. Co	Lonsdale	1918	280,000
Jenckes Spinning Co	Pawtucket	1918	150,000
National India Rubber Co	Bristol	1919	150,000
Alsace Worsted Co	Woonsocket	1919	110,000
Budlong Rose Co	Auburn	1919	100,000
Esmond Mills	Esmond	1919	100,000
Rosemont Dyeing Co	Woonsocket	1919	92,000
American Silk Spinning Co	Providence	1919	80,000
Montrose Worsted Co	Woonsocket	1919	45,000
TENNESSEE			
Davidson Co. Turnpike Bd	Nashville	1916	50,000

Company	Location	Year Built	Capacity Gallons
TEXAS			
Empire Gas & Fuel Co	Gainesville	1918	15,000,000
San Antonio Gas & Elec		1903-12	600,000
Lone Star Brewing Assn	San Antonio	....	228,000
Joyton Cotton Oil Co	Joyton	....	55,000
Winters Cotton Oil Co	Winters	1909	50,000
Texas Portland Cement Co	Harrisburg	....	44,000
Athens Brick & Tile Co	Athens	1917	27,000
Seymour Cotton Oil Co	Seymour	1906	12,000
VERMONT			
Wallingford Mfg. Co	Wallingford	1913	100,000
Jones & Lamison Mach. Co	Springfield	1918	30,000
WISCONSIN			
Newport-Hydro-Chemical Co.	Carrollville	1918	850,000
National Brake & Electric Co	Milwaukee	1918	265,000
Fairbanks, Morse & Co	Beloit	1916-17	175,000
State of Wisconsin		1917-18	146,000
Geo. H. Smith Steel Cast. Co	Milwaukee	1918	73,000
Dane County		1919	50,000
Appleton Water Works	Appleton	1918	25,000
Milwaukee Forge Machine Co	Milwaukee	1917	18,000
CANADA			
Leaside Munition Co., Ltd	Leaside	1918	280,000
Motor Trucks, Ltd	Brantford	1918	120,000
British Munitions, Ltd	Montreal	1918	100,000
Empire Mfg. Co., Ltd	London, Ont.	1917	70,000
Steel Co. of Canada	Swansea	1918	65,000
Massey Harris Co., Ltd	Toronto	1918	45,000
International Harvest Co. of Canada, Ltd.	Hamilton, Ont.	1917	42,000
Verity Plow Co., Ltd	Brantford	1918	42,000
Cockshutt Plow Co., Ltd	Brantford	1918	30,000
D. A. Brebuer Co., Ltd	Hamilton, Ont.	1918	12,000
Can. Shovel & Tool Co., Ltd	Hamilton, Ont.	1918	12,000
Dominion Sheet Metal Corp	Hamilton, Ont.	1918	12,000

The France & Canada Oil Transport Co., Aransas Pass, Tex., has two 55,000-bbl. cylindrical oil storage tanks of reinforced concrete, 110 ft. inside diameter and 33 ft. deep, which are probably the first concrete oil tanks of such large size to be built entirely above ground. While in many locations economy would be secured by building the tanks wholly or partly below ground, thus getting the advantage of added insulation as well as the outside earth pressure, these tanks were located on sand foundation not more than 1 ft. above water level and construction above ground was necessary. The nature of the location required that the tanks be supported by piling, which would have been equally necessary for steel tanks. Each tank is supported on some 600 piles cut off at water level and capped by a heavy reinforced concrete slab covering the entire area. The walls were built with sliding forms. Because of the intense summer heat in that section of the country and the desire for absolute insurance against temperature cracking, it was decided to make the walls double by constructing an outer shell separated from the main wall by a 5-in. air space. This decision was reached because no former experience was available as a guide for designing an entirely above ground oil tank of this size. As the result of experience with these tanks, however, the engineers are inclined to believe that the outer wall could be omitted with safety. The tanks were treated on the inside with an oilproof coating, for while they are built to hold a low gravity oil, it was felt that they might be used for very light oils at some future date and it would be wise to provide for this possibility. The tank roof supported by concrete beams and columns is a concrete slab covered with 1 ft. of sand. A gas-tight expansion joint is provided where roof joins the walls. Each tank was surrounded

FIG. 28. Concrete Oil Tanks Which Without Damage Withstood a Hurricane and Flood.

with an earthen dike to conform with insurance requirements and equipped with the usual filling and discharge lines, swing pipe and other fittings. During the severe Gulf hurricane of Sept. 14, 1919, the tanks were partly filled with oil, each containing about 30,000 bbls. The engineer who designed and built them says: "The water rose some 15 ft. accompanied by a 98-mile wind. The storm was the most severe ever experienced on the Texas coast, which means much. Our tanks were absolutely unprotected from the full fury of the hurricane. Apparently heavy timbers or possibly parts of the pipe lines were driven against the east tank, and slight damage to the outer wall in one place resulted. So severe was the storm that all of the surrounding sand was washed away, and at places near and even under the tanks, there is now from 10 to 18 ft. of water (See fig. 28). The pipe lines were demolished, valves broken off of the tanks, and the oil was lost but the concrete tanks remained intact. Had these tanks been of any material but concrete they would have been destroyed."

Mr. James B. Brooks,[a] General Superintendent of Buildings and Construction, for the Westinghouse Air Brake Company, refers to the company's fuel oil tanks at Wilmerding, Pennsylvania as follows: "During September, 1917, the Westinghouse Air Brake Co. constructed four concrete fuel oil tanks at Wilmerding, Pa., and during July, 1918, it constructed six more. The tanks were 15 ft. wide, 25 ft. long and 9 ft. deep with a capacity of 25,000 gals, each, or a total capacity amounting to 250,000 gals. The company has similar concrete tanks at Swissvale, Pa., with 300,000 gals. capacity, built like those at Wilmerding. The concrete in the tanks was made from one part cement, two parts sand and four parts pea gravel. The following method of construction was adopted. Excavating was done by crane and grab bucket and after squaring up the bottom, the reinforcing bars were placed for the floor slab, with ends of bars bent up 90 deg. so as to enter the wall. These rods were wired together and held in place by being suspended from 2 by 8-in. timbers placed several inches above the floor level. The entire floor slab for one tank was then poured, well tamped and finished rough. No. 16-gage galvanized iron strip, 6 in. wide, riveted and soldered at joints so as to make a continuous band, was then imbedded in the floor slab to a depth of 3 in. and placed so as to be on the center line of wall and projecting into it 3 in. The outside wall forms were then set up after which the reinforcing rods were placed, wired together and fastened to the form. In the meantime the forms and timbers for suspending rods for floor slab No. 1 were being set up and used for floor slab No. 2, the joint between the slabs being filled with pitch. The inside forms for wall, beams, and top slab were then set up and reinforcing rods placed for beams and top slab. Extreme care was taken in cleaning the slab at bottom of wall form, and, before pouring walls, a mixture of one part cement and one part sand was placed in bottom of form and around galvanized strip so as to make a tight joint. The side walls, beams, top slab and manhole are all cast in one piece, the only joint in the concrete being between the floor and bottom of wall. The inlet pipe cast into the top slab near the manhole is a 4-in. nipple and the outlet pipe is a 2½ in. brass pipe threaded its entire length, offering a rough surface for concrete to adhere to. The forms were removed in 3 or 4 days and the entire inside of tank was given a

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a. Engineering World, March, 1920, p. 278.

coat of plaster ½-in. thick, made up of one part cement and one part sand, troweled to a very smooth surface. The tanks are placed in a double row with a 3-ft. covered passageway between them, with manholes and ladders giving access to pipe and valves leading from tanks. Owing to the possibility of a slight weakening of the concrete due to the action of the oil, the tanks are heavily constructed and reinforced. Allowance was made for a weakening of 10 or 15 per cent. The top of tank is designed for a uniform loading of 400 lbs. per sq. ft., thus allowing this space to be used for the storing of miscellaneous material. The tops of tanks are 18 in. below yard grade and are covered with cinder so as to keep down excessive change in temperature. The tanks are filled from tank cars by gravity and piped so that oil can be directed to all or any one tank. They have given perfect satisfaction to date after continuous service and show no signs of seepage or cracks. Not even discoloration caused by oil penetration shows on the outside. It is the writer's opinion that it is unnecessary to use waterproofing material in the construction of concrete tanks where it is intended to store heavy fuel oil. The oil penetrates to a depth of 2 or 3 in., fills the pores and stops further penetration; therefore, the walls should be at least 8 in. thick to allow for this pore filling process whereas a 3 or 4-in. wall may possibly show seepage. Owing to the fact that the light oils, such as gasoline and benzine, are very penetrative and have little or none of the sealing qualities found in the heavy fuel oil, it would be necessary that a water-proofing compound in a paste form mixed with the water for mixing concrete should be used, and the interior of tank should have a ½-in. coat of plaster made up of one part cement and one part sand mixed with a first-class waterproofing compound upon which may be placed a solution of silica of soda, applied with a brush."

The fire hazard created by storage of fuel has generally been over-estimated by the insurance companies and until very recently the regulations for the storage and use of fuel oil in the larger cities have been much more stringent than is necessary for protection against fire risk.

NATIONAL FIRE PROTECTION ASSOCIATION RULES

The tentative regulations for the storage and use of fuel oil prepared by the National Fire Protection Association (revised November 3, 1919) are as follows:

Section 1.

SPECIFICATIONS FOR METAL TANKS.

UNDERGROUND TANKS.

1. Materials of Construction.

(a) Tanks shall be constructed of galvanized steel, basic open hearth steel or wrought iron of a minimum gauge (U. S. Standard) depending upon the capacity, as given in Tables 1 and 2. For liquids of 20° Baumé and below, tanks may be of concrete.

TABLE 1.

Capacity (Gallons)	Minimum Thickness of Material
1 to 560	14 gauge
561 to 1,100	12 "
1,101 to 4,000	7 "
4,001 to 10,500	1/4 inch
10,501 to 20,000	5/16 "
20,001 to 30,000	3/8 "

(b) In outlying districts to be prescribed by inspection departments having jurisdiction, tanks not exceeding 1,100 gallons in capacity, if located ten feet or more from any building, may be constructed as follows:

TABLE 2.

Capacity (Gallons)	Minimum Thickness of Material
1 to 30	18 gauge
31 to 350	16 "
351 to 1,100	14 "

2. Joints and Connections.

All joints shall be riveted and soldered, riveted and caulked, brazed, welded or made by some equally satisfactory process. Tanks shall be tight and sufficiently strong to bear without injury the most severe strains to which they may be subjected in practice. Shells of tanks shall be properly reinforced where connections are made and all connections made through the top of tank above the liquid level.

3. Rust Proofing.

All tanks shall be thoroughly coated on the outside with tar, asphaltum or other suitable rust resisting material, dependent upon the condition of soil in which they are placed. Where soil is impregnated with corrosive materials, tanks shall also be made of heavier metal.

4. Venting of Tanks.

(a) An independent, permanently open vent terminating outside of building shall be provided for every tank.

(b) Vent openings shall be screened (30 by 30 nickel or brass mesh or equivalent) and shall be of sufficient area to permit proper inflow of liquid during the filling operation and in no case less than two inches in diameter; shall be provided with weatherproof hoods and terminate twelve feet above top of fillpipe, or if tight connection is made in filling line, to a point one foot above the level of the top of the highest reservoir from which the tanks may be filled and never within less than three feet, measured horizontally and vertically, from any window or other building opening.

(c) Where a battery of tanks is installed vent pipes may connect to a main header, but individual vent pipes shall be screened between tank and header. The header outlet shall conform to the foregoing requirements.

5. Filling Pipe.

Filling pipe shall extend to within six inches of the bottom of tank and when installed in the vicinity of any door or other building opening, shall be as remote therefrom as possible and never within five feet; terminal shall be outside of building in a tight, non-combustible box or casting, so designed as to make access difficult by unauthorized persons.

6. Manhole.

Manhole covers shall be securely fastened in order to make access difficult by unauthorized persons. No manhole shall be used for filling purposes.

7. Test Well or Gauging Device.

A test well or gauging device may be installed, provided it is so designed as to prevent the escape of oil or vapor within the building at any time. Top of well shall be sealed and where located outside of building, kept locked when not in use.

8. Setting of Tanks.

(a) Tanks to be buried underground with top of the tanks not less than three (3) feet below the surface of the ground, and below the level of any piping to which the tanks may be connected, except that in lieu of the three (3) feet cover, tank may be buried 18 inches below the ground level and a cover of reinforced concrete at least 6 inches in thickness provided, which shall extend at least one foot beyond the outline of tank in all directions; concrete slab to be set on a firm, well tamped earth foundation. Tanks shall be securely anchored or weighted in place to prevent floating.

Where a tank cannot be entirely buried, it shall be covered over with earth to a depth of at least 3 feet and sloped on all sides, slopes not to be less than 3 to 1. Such cases shall also be subject to such other requirements as may be deemed necessary by the inspection department having jurisdiction.

If tank cannot be set below the level of all piping to which it is connected, satisfactory arrangements shall be provided to prevent siphoning or gravity flow in case of accident to the piping.

(b) Tanks shall be set on a firm foundation and surrounded with soft earth or sand well tamped in place, or encased in concrete as outlined in Section 12 (b).

(c) When located underneath a building the tanks shall be buried with top of tanks not less than 2 feet below the level of the floor. The floor immediately above the tanks shall be of reinforced concrete at least 9 inches in thickness, extending at least one foot beyond the outline of tanks in all directions, and provided with ample means of support independent of any tank.

ABOVE GROUND TANKS.

9. Materials of Construction.

(a) Tanks, including top, shall be constructed of galvanized steel; basic open hearth steel or wrought iron of a minimum gauge (U. S. Standard) as specified in Tables 3 to 7, inclusive. No open tanks shall be used.

(b) For liquids under 20° Baume', tanks may be of concrete.

TABLE 3.

Horizontal or vertical tanks not over 1,100 gallons capacity.

Capacity (Gallons)	Minimum Thickness of Material
1 to 30	18 gauge
31 to 350	16 "
351 to 1,100	14 "

TABLE 4.

Horizontal tanks over 1,100 gallons capacity.

Maximum Diameter	Minimum Thickness of Material — Shell	Heads
Not over 5 feet	10 gauge	7 gauge
5 feet to 8 feet	7 "	¼ inch
8 feet to 11 feet	¼ inch	⅜ "

TABLE 5.

Vertical tanks over 1,100 gallons capacity.

Under[a] in diameter and containing not more than 5,000 gallons.

Bottom No. 8 gauge,
Bottom Ring No. 8 gauge,
Other Rings No. 10 gauge,
Top No. 12 gauge.

TABLE 6.

Under[a] feet in diameter and containing more than 5,000 gallons, but not more than 10,000 gallons.

Bottom No. 8 gauge,
Bottom Ring No. 7 gauge,
Other Rings No. 8 gauge.
Top No. 12 gauge.

a. Dimensions omitted in printed form.—Author.

TABLE 7.

Other vertical tanks to be of thickness not less than indicated in the following table, the figures referring to U. S. Standard gauge:

Diameter Feet	Top	Top Ring	2nd Ring from Top	3rd Ring from Top	4th Ring from Top	5th Ring from Top	6th Ring from Top	Bottom
80	10	7	7	3	0	3–0	5–0	10
75	10	7	7	4	1	2–0	4–0	10
70	10	7	7	4	1	2–0	4–0	10
65	10	7	7	5	1	0	3–0	10
60	10	7	7	5	2	0	2–0	10
55	10	7	7	6	3	1	2–0	10
50	10	7	7	7	4	1	0	10
45	10	7	7	7	5	3	1	10
40 and less	10	7	7	7	5	3	2	10

(c) Tanks of capacity greater than given in Table 7 shall be of material sufficient in thickness to hold the contents, with a proper factor of safety.

(d) No vertical tank shall exceed 35 feet in height.

(e) Riveted joints shall have an efficiency of at least 60 per cent.

(f) Joints—See paragraph 2.

(g) Rust proofing—See paragraph 3.

10. Roofs or Tops.

No wooden or loosely fitting metal roofs or tops shall be permitted. Roof or top shall be without unprotected openings; shall be firmly and permanently joined to the tank, and all joints made as noted in paragraph 2.

11. Venting of Tank.

(a) A permanently open vent conforming to paragraph 4 shall be provided.

(b) A safety valve shall be provided, or a hinged, self-closing manhole cover kept closed by weight only.

(c) Approved explosion hatches having a combined area of not less than 1½ per cent. of the roof area shall be provided for every tank exceeding 200,000 gallons capacity.

12. Setting of Tanks.

(a) Tanks shall be set upon a firm foundation, and shall be electrically grounded

(b) Tanks with bottom more than one foot above the ground shall have foundation and supports of non-combustible materials, except wooden cushions.

13. Embankments and Dikes.

(a) In locations where above-ground tanks are liable, in case of breakage or overflow, to endanger surrounding property, each tank shall be protected by an embankment or dike. Such protection shall have a capacity of not less than one and one-half times the capacity of the tank surrounded, and to be at least 4 feet high, but in no case higher than ¼ the height of tank when height of tank exceeds 16 feet.

(b) Embankments or dikes to be made of earthwork or reinforced concrete. Earthwork embankments to be firmly and compactly built of good earth from which stones, vegetable matter, etc., have been removed, and to have a crown of not less than 3 feet and a slope of at least 2 to 1 on both sides.

(c) Embankments or dikes shall be continuous, with no openings for piping or roadways. Piping shall preferably be laid over embankments; where it is necessary to install pipes through embankments concrete wing walls shall be provided. Brick or concrete steps shall be used where it is necessary to pass over.

TANKS INSIDE BUILDINGS.

Note: Inside storage is regarded as much more hazardous than outside storage. Where used the following requirements shall be rigidly applied.

14. Setting and Heat Insulation of Tanks.

(a) Tanks shall not be located above the lowest story, cellar or basement of building.

(b) Tanks shall be located below the level of any piping to which they may be connected, or if this is impracticable, satisfactory arrangements shall be made to prevent siphoning or gravity flow in case of accident to the equipment or piping.

(c) Tanks shall be set on a firm foundation supported independently of the floor construction and completely enclosed with a heat insulation of reinforced concrete not less than 12 inches in thickness (8 inches for concrete tanks) with at least a 6-inch space between tank and concrete insulation filled with sand; for concrete tanks, a top insulation of 12 inches of sand without concrete covering shall be deemed sufficient.

(d) Walls of tanks, including those for insulating purposes, shall be constructed independently of and not in contact with the building walls. Eight inches of concrete and 6 inches of sand will be accepted as insulation for metal tanks when located in a fire-resistive oil room or special oil storage building. The space occupied by the sand insulation shall be drained through the insulating concrete wall by means of a pipe not greater than 2 inches in diameter.

15. Venting of Tanks.

See paragraph 4.

SECTION 2.

SPECIFICATIONS FOR CONCRETE TANKS.

Note: Concrete tanks are more susceptible to deterioration than metal tanks it there is any defect in the preparation of the cement as well as in the selection of the ingredients for the concrete and their mixing and pouring. The two most important features of tank design are the foundation and the reinforcing steel. Concrete tanks shall therefore be permitted only after detailed plans and specifications prepared by an engineer specially experienced in concrete tank construction have been approved by the inspection department having jurisdiction. Furthermore, it is essential that the construction work be entrusted only to thoroughly competent concerns.

16. Type of Construction.

The entire tank, including roof, shall be of reinforced concrete.

17. Reinforcement.

(a) Reinforcement shall be designed to take care of all interior and exterior stresses, and with fittings to hold it rigidly in place while concrete is being deposited. It shall be properly proportioned and located to reduce the shrinkage cracks to a minimum.

(b) The fiber stress in the steel shall not exceed 10,000 pounds per square inch.

(c) Reinforcement shall be of round, oval or square twisted, deformed bars. All bars shall conform to the Standard Specifications for Medium Steel of the American Society for Testing Materials.

(d) The bars should be bent or curved true to templates and carefully placed in their predesigned location. No lap splice shall be less than 40 diameters, and no two laps of adjacent rods shall be directly opposite each other.

18. Forms.

Forms shall be of good material, strongly made, tight and braced or held in place by circumferential bands, so that no distortion allowing displacement of the concrete during its setting is possible. The use of wires through the concrete is prohibited.

19. Material—Aggregates.

(a) The cement used shall meet the Standard Specifications for Portland Cement of the American Society for Testing Materials.

Sand shall be clean, well graded, and shown by colormetric test to be free from organic or other deleterious matter.

Coarse shall be clean, hard stone, preferably limestone or trap rock, ranging in size from 1/4" to 1". No quartz gravel or granite composed largely of quartz shall be used.

Water shall be free from oil, acid, strong alkalies or vegetable matter.

(b) The materials shall be so proportioned that concrete of the greatest density shall be obtained. A mixture not leaner than 1 part of cement, 1 1/2 parts of sand, and 3 parts of coarse aggregate shall be used.

20. Mixing.

(a) Mixing shall be done in a mechanical hatch mixer of sufficient size and power to carry out each prearranged operation without danger of delay during the process.

(b) Duration of mixing shall be at least two minutes, using just enough water to obtain a plastic mix without excess water coming to the surface after concrete is deposited. A measuring tank shall be used so that the amount of water may be kept uniform.

Note: Emphasis is laid upon the necessity of measuring the water content. With 1:1½:3 mixture, the water content should be 5½ gallons per bag of cement.

21. Depositing or Pouring of Concrete.

(a) The concrete shall, where possible, be deposited continuously in concentric layers not over 12 inches deep in any one place so that a monolithic structure will result.

(b) Where continuous pouring is impracticable, the pouring operations shall be in the following order:

1. The pouring of footings and floor.
2. The pouring of walls.
3. The pouring of roof.

(c) No break in time of over 30 minutes shall occur during any one operation. Where delays less than this interval occur, the previous surface shall be thoroughly chipped with spades, swept clean, and a mixture of 1:1 mortar brushed on before next layer of concrete is deposited.

(d) When deposited in forms, concrete shall be thoroughly spaded against inner and outer faces, so that will thoroughly compact and work out all trapped air.

22.

If walls and floors are not poured in one operation, an approved joint or dam shall be provided between the floor and wall. Two methods are suggested:

1. By means of a strip of galvanized iron 6 inches wide, with joints riveted and soldered so as to form a continuous band. This strip will be vertically embedded 3 inches in the floor slab, and on the center line of the wall. The floor slab under the walls shall be thoroughly cleaned, and before pouring the walls, a mixture of 1:1 mortar should be placed in the bottom of the forms and around the galvanized strip to make a tight joint.

2. Finish the joint of floor as nearly square as possible. Before depositing new concrete, the surface shall be thoroughly chipped with chisel, hammer or pick, and the surface thoroughly cleaned and wet down with water. A thick, creamy grout mortar composed of 1 part of cement and 1 part of sand shall then be deposited to a depth of at least 2 inches. Immediately following this operation, the new concrete shall be deposited. Method No. 1 shall be followed by all except those thoroughly experienced in the construction of concrete oil tanks.

23. Freezing.

During freezing weather all material used in making concrete, particularly the coarse aggregate, shall be heated, and precautions taken to prevent freezing during pouring. After pouring, the concrete shall be kept above 40° F., until it has obtained its final set, but such period shall be at least 72 hours. Walls and floor shall be trowelled smooth as soon as final setting occurs.

24. Aging or Curing.

The tank shall be aged or cured at least four weeks before being placed in use. Two methods for accomplishing this are suggested:

1. Fill tank with clear water.

2. Coat the floor, interior walls and under side of roof with 40° Baumé, Sodium Silicate and keep the exterior well dampened. A good method of applying the sodium silicate is as follows:

First Coat—1 part of sodium silicate and 3 parts of water. Apply with brush and wipe off all excess liquid with a cloth before drying.

Second Coat—1 part of sodium silicate and 2 parts of water, applied as first coat.

Third Coat—1 part of sodium silicate and 1 part of water applied with a brush and allowed to dry.

Fourth Coat—Same as third.

25. Venting of Tanks.

See paragraph 4.

26. Fill Pipe.

See paragraph 5.

27. Test Well or Gauging Device.
See paragraph 7.

28. Oil Proofing.
The interior of tanks shall be oil-proofed. This work shall be done only by concerns experienced in oil-proofing. A bond guaranteeing work for a term of years shall be furnished.

Section 3.

LOCATION AND CAPACITY OF TANKS FOR LIQUORS ABOVE AND BELOW 20° BAUMÉ (sp. gr. .933).

UNDERGROUND STORAGE.

29. Tanks shall preferably be located at least 50 feet from important buildings. When this cannot be done, the limit of individual tank capacity permitted shall be dependent on the location of tanks with respect to adjacent buildings, as follows:

(a) 15,000 gallons capacity if tank is so located that the top is *above* the lowest floor or pit of any building within 10 feet. In this case the tank must be entirely enclosed in concrete as outlined in paragraph 14 C.

(b) 15,000 gallons capacity if tank is so located that the top is *below* the lowest floor or pit of any building within 10 feet.

(c) 20,000 gallons capacity if the tank is so located that the top is below the lowest floor or pit of any building within 15 feet.

(d) 30,000 gallons capacity if tank is so located that the top is below the lowest floor or pit of any building within 20 feet.

(e) 40,000 gallons capacity if the tank is so located that the top is below the lowest floor or pit of any building within 25 feet.

(f) 60,000 gallons capacity if tank is so located that the top is below the lowest floor or pit of any building within 30 feet.

(g) 80,000 gallons capacity if tank is so located that the top is below the lowest floor or pit of any building within 35 feet.

(h) 110,000 gallons capacity if tank is so located that the top is below the lowest floor or pit of any building within 40 feet.

(i) Unlimited capacity may be permitted for underground tanks used only for the storage of liquids of 20° Baumé and below if tank is so located that the top is below the lowest floor or pit of any building within 50 feet.

(j) Quantities of liquids above 20° Baumé that may be stored at distances greater than 50 feet, shall be at the discretion of the inspection department having jurisdiction.

ABOVE-GROUND STORAGE.

30.

(a) The relation between gross capacity of tanks and the permissible distance from other property is shown in Table 8. No unprotected tank shall be within 60 feet of the nearest building.

(b) No tank shall be located closer to the building than a distance equal to the height of that wall of the building, facing the tank.

TABLE 8.

Minimum Distance to Line of Adjoining Property or Nearest Building (feet)	Capacity of Tanks (Gallons) Liquids above 20° Bé	Capacity of Tanks (Gallons) Liquids 20° Bé and below
60	80,000	100,000
75	96,000	128,000
85	150,000	200,000
100	200,000	266,000
150	300,000	400,000
250	500,000	666,000
300	1,000,000	1,333,000
350	2,000,000	2,666,000

31. Permissible Reduction in Distances.

(a) Where all buildings have standard, parapetted concrete or masonry exterior walls without unprotected openings on the sides facing tanks, or, where tanks are protected by concrete or masonry fire walls parapetted not less than 10 feet above top of tank and extending at least 10 feet beyond tank extremes, in both directions, the distance given in Table 8 may be reduced 50 per cent.; provided, however, that no tank shall be located closer to building than a distance equal to 80 per cent. of the height of exposed wall.

(b) Where openings in exposed walls are deemed a vital necessity, the inspection department having jurisdiction may permit openings dependent upon the construction and occupancy of the building. In this case openings shall be protected by fixed standard wired glass windows or standard fire shutters. In no case, however, shall the total area of such openings in any one store exceed 10 per cent. of the superficial area of the wall of one story, 15 feet in vertical height being considered the equivalent of one story.

32. High Water.

Tanks shall be so located as to avoid possible danger from high water.

33. Streams Without Tide.

When tanks are located on a stream without tide, they shall, where possible, be down stream from burnable property.

34. Tide Water.

On tide water, tanks shall be located, if practicable, well away from shipping districts.

STORAGE INSIDE OF BUILDINGS.

35. Liquids above 20° Baumé.

The storage within buildings of oils above 20° Be'. is prohibited.

36. Permanently Set Storage Tanks Inside Buildings for Liquids of 20° Baumé and Below.

(a) In ordinary buildings the gross capacity of tanks shall not exceed 5,000 gallons.

(b) In fire-resistive buildings the gross capacity of tanks shall not exceed 10,000 gallons.

(c) In any building, if cut off in a special fire-resistive oil room or oil storage building conforming to requirements given in paragraph 37, the gross capacity of tanks shall not exceed 50,000 gallons, with an individual tank capacity not exceeding 25,000 gallons.

Section 4.

FIRE-RESISTIVE OIL STORAGE ROOMS AND BUILDINGS.

37.

Special fire-resistive rooms within buildings for the storage of oil shall be constructed as follows:

Walls shall be not less than 12 inches if brick or 8 inches if reinforced concrete; floor and ceiling shall be of concrete at least 8 inches thick or its equivalent. Door openings to other rooms or buildings shall be provided with sills sufficiently raised to create a receptacle capable of containing twice the capacity of the largest tank or the full capacity if only one tank; said door openings shall be protected by an approved automatically closing fire door on each side of the wall; no combustible material shall be used in construction. Great care shall be taken to insure proper ventilation.

Section 5.

PIPING—GENERAL REQUIREMENTS.

38. Cross Connections.

Cross-connections permitting gravity flow from one tank to another shall be prohibited. This shall not be construed as prohibiting properly gated connections through subdivisions in any individual tank.

39. Workmanship.

All pipe connections to tanks and other oil containing or using devices shall be made in a substantial workmanlike manner.

40. Type of Material.

All piping shall be of the standard, wrought iron type. No pipe less than ½-inch internal diameter will be permitted.

41. Installation.

Piping shall be run as directly as possible, without sags, and so laid that pipes pitch toward the supply tank without traps; provision shall be made for expansion, contraction, jarring and vibration.

42. Tests.

Piping after installation shall be tested to a pressure of not less than 150 pounds.

43. Unions.

Unions, if used in place of right and left couplings, shall be of an approved type.

44. Protection to Piping.

(a) Piping between any separated oil containing or using parts of the equipment, shall be as far as practicable, laid outside of the building, underground, and if necessarily inside, it shall preferably be laid in a trench with proper metal cover, if on floor or subject to mechanical injury it shall be protected.

(b) Pipes leading to the surface of the ground or above the floor, particularly risers to furnaces, shall be eased or jacketed when necessary to prevent loosening or breakage.

(c) Fill and vent pipes shall be protected in a substantial manner against mechanical injury.

45. Outside Piping.

(a) All outside piping shall be laid in solid earth, or in a trench. Oil pipes shall not be located near, nor in the same trench with other piping, except steam lines for heating. Propping the pipes on wooden blocks shall be avoided.

(b) Openings for pipes through outside walls below the ground level shall be made oil-tight and securely packed with flexible material.

46. Valves.

(a) All valves shall be of an approved type.

(b) Shut-off valves shall be provided on both sides of any strainer which may be installed in pipe lines; in discharge and suction lines to pumps; in discharge and return lines to any tank, as near tank as practicable, and in branch lines near burners.

(c) A check valve of an approved type shall be installed in each air line near the burner.

(d) A pressure relief valve shall be installed in supply line to burners and so arranged as to return surplus oil to supply tank.

(e) The use of automatic shut-off valves for the oil supply is recommended.

47. Oil Level Indicating Device.

A device for indicating the level of the oil is desirable. Where used, such an attachment shall be connected through substantial fittings that will minimize exposure of the oil; no devices shall be used, the breakage of which will allow the escape of oil.

Section 6.

HEATING.

48. Heating of Tanks.

(a) Where it is necessary to heat oil in storage tanks in order to handle it, the oil shall not be heated to a temperature higher than 40° F. below the flash point, closed cup.

(b) Heating shall be done by means of properly installed coils within the tank, using only steam or water. Thermostatic control shall be provided for all heating devices.

49. Heaters, Other Than Those for Tanks.

(a) Heaters shall be of substantial construction, all joints shall be made oil-tight.

(b) Only steam or water shall be used for heating.

(c) Heater shall be by-passed so that in warm weather it will not be under constant pressure while not in use.

Section 7.

BURNERS.

50.

(a) The burner mechanism shall be so designed as to not enlarge the orifice, and so that the needle valve cannot be unscrewed and removed in operating.

(b) Where atomizing mediums are employed, the power supply to the oil pump shall be so arranged that the operation of the pump shall automatically stop, on cessation of flow of the atomizing medium at the burner.

(c) Burners shall be so designed as to be free from stoppage by carbonization, to not permit leakage of oil and so that they may be easily cleaned.

(d) Burners containing chambers which allow dangerous accumulation of gases shall be prohibited.

Section 8.

PUMPING SYSTEMS.

51. Systems employing gravity feed or pressure on tanks are prohibited.

52. Pumps.

(a) Pumps shall be in duplicate, of an approved design, and secure against leaks.

(b) They shall be located in a room cut off from oil burning devices and provided with entrance which can be reached without passing through room where burners are located; if this is not practicable, provision shall be made for remote control.

(c) Pumps used in connection with the supply and discharge of storage tanks shall be located outside the tank or embankment walls, and at such a point that they will be accessible at all times, even if the oil in the tank or reservoir should be on fire.

NEW YORK REGULATIONS

The Board of Standards and Appeals of the City of New York makes the following provisions for the storage and use of fuel oil:

FUEL OIL RULES.

Rule 1. Definition. Flash Point and Specific Gravity.

The term "oil used for fuel purposes" under these rules includes any liquid or mobile mixture, substance or compound derived from or including petroleum.

All oil used for fuel purposes under these rules shall show a minimum flash point of not less than one hundred and seventy-five (175) degrees Fahrenheit, in an open cup tester, or if closed cup tester be used a minimum of not less than one hundred and fifty (150) degrees Fahrenheit, and its specific gravity shall be not less than .933 (20 degrees Baumé) at a temperature of sixty (60) degrees Fahrenheit; and must not be fed from the tank to the suction pump at a pre-heat temperature higher than its flash point.

Rule 2. Manner of Storage.

Oil to be used as fuel for commercial, heating and power purposes on the premises where stored shall be at all times contained in metal tanks with all openings or connections through the tops of the tanks, except a clean-out plug in the bottom; and, when located inside of a building, must at all times be placed in the cellar or lowest story of such building, and at least two (2) feet in a horizontal direction from any supporting portion of the structure, and if practicable shall be buried underneath the lowest floor or ground.

Rule 3. Location of Tanks. Existing Buildings.

No storage of fuel oil shall be permitted in a building of frame construction within the fire limits, or in buildings of hazardous occupancy as so defined by the fire commissioner.

If placed in buildings already erected, if not buried beneath the lowest floor or ground, such tanks shall be placed in an enclosure the floor of which shall be at least three (3) feet below the surface of the cellar or lower story; or if by reason of water or foundation conditions, or if on rock bottom, the tank may be placed above the surface of the ground, but in any case subject to the conditions as hereinafter described under Rule 5.

Rule 4. Location of Tanks—New Buildings.

In buildings hereafter erected the bottom of the fuel oil service tanks shall be located in, or below the floor level of the cellar or lowest story as shall be determined by the Superintendent of Buildings under the provisions of Rule 2.

Rule 5. Enclosure of Tanks.

In either existing or new buildings such fuel oil service tanks shall be enclosed in an unpierced wall and floor of approved masonry or reinforced concrete, made oilproof and waterproof, and not less than twelve (12) inches in thickness; and also of sufficient thickness to properly support any lateral pressure, and to be of lateral dimensions at least one (1) foot greater on all sides than the outside dimensions of the tank. These walls are to be carried up to a height of at least one (1) foot above the tank, or the supply and feed connections thereto, and roofed over with reinforced concrete or its equivalent at least twelve (12) inches thick and capable of sustaining a live load of at least three hundred (300) pounds per square foot; and if not buried below the ground, placed so as to leave a clear and open space (except for pipe connections) of at least two (2) feet between such roof over the enclosure and the under side of the ceiling above. The roof of every enclosure shall contain a manhole with fireproof cover properly weighted, but not fastened, placed immediately above the supply and feed connections and the manhole in top of the tank.

Where found impractical to set the bottom of the tank three (3) feet below the floor of the cellar or lowest story, the tank shall rest on steel or masonry supports, and the bottom of the tank shall be at least one (1) foot above the floor of the enclosure, and the enclosure wall and floor as above specified shall be unpierced and the space below the horizontal centre line of the tank and within the enclosure formed by the surrounding unpierced walls shall have a capacity of at least sixty (60) per cent of the capacity of the tank.

The space within the enclosure surrounding the tank shall be at all times vented to the air outside of the building by iron or other fireproof conduit at least two and one-half (2½) inches diameter, connecting the enclosure at a point just above the floor level, and which shall finish above the street surface with proper connection at that point to permit the Fire Department to flood the enclosure.

A separate similar vent without Fire Department connection shall enter the enclosure just below its ceiling.

Rule 6. Capacity of Tanks.

In existing or new buildings of non-fireproof construction no fuel oil service tank containing over ten thousand two hundred (10,200) gallons, and in buildings of fireproof construction no tank containing over twenty thousand (20,000) gallons, shall be placed in any single portion of the cellar or lowest story unless such portion be separated from the rest of the cellar by walls of masonry or reinforced concrete with openings protected by automatic fireproof doors, with sills placed high enough above the cellar floor to contain capacity of tank located therein, in addition to the enclosure as already specified for the tank, and such portion be ventilated to the outer air. More than one such single tank may be installed if enclosed and separated as above.

When tanks are buried so that the top of the roof over the enclosure wall is level with the cellar floor, the capacity of any such tank may be increased by one hundred (100) per cent.

Rule 7. Service Tanks Located Outside of Buildings Within Fire Limits.

Within the fire limits, tanks to contain fuel oil for use on the premises, and of a capacity and at distances specified below, may be placed above ground outside of the building if such tank does not exceed fifteen (15) feet in height above the surface of the ground and if completely enclosed in the same manner as provided for in Rule 5.

Distance to Nearest Building in Feet Not Exceeding	Capacity in Gallons
40	71,400
30	40,800
20	30,600
10	20,400
5	10,200

If such service tanks are entirely buried and roofed below the surface of the ground, the capacity in gallons may be increased by two hundred (200) per cent.

Rule 8. Outside General Storage Fuel Oil Tanks Located Above Ground Within the Fire Limits.

Such general storage tanks located within the fire limits shall not exceed twenty-five (25) feet in height, shall be built of metal, and shall be surrounded with a dike of unpierced masonry or reinforced concrete not less than four (4) feet in height, with a capacity of at least that of the tank to be protected. The walls and floor of such dikes must be continuous, and oilproof and waterproof, and must not be built within ten (10) feet of the walls of the tank. If tanks are placed in battery the dikes shall be rectangular in shape, and the dike wall separating them as well as the dike wall within one hundred (100) feet of any structure, shall be carried up as a fire stop to a height of four (4) feet above the head of the tank and coped with stone or concrete, and any openings in walls above the dike shall have automatic fireproof doors.

The capacity of any such single general storage tank within the fire limits shall not exceed one hundred thousand (100,000) gallons, and the gross capacity of storage shall not exceed the following tables:

To line of adjoining property or nearest building (feet)	Gallons
75	100,000
100	150,000
150	250,000
200	500,000

Such general storage tanks may have extra fill and emptying connections as the Fire Commissioner may determine.

Rule 9. Outside General Storage Fuel Oil Tanks Located Outside the Fire Limits.

Such general storage tanks shall be protected by dikes and fire stops as provided under Rule 8, shall not exceed thirty-five (35) feet in height above the ground, and may be constructed either of metal or of concrete reinforced with steel in order to resist the oil pressure.

If built of concrete, the walls and floor of such tanks shall be continuous and shall be not less than eight (8) inches thick, mixed in the proportion of 1:1½:3 graded and mixed in accordance with the requirements of Chapter 5, Code of Ordinances. The walls shall be of sufficient thickness so that the tensile stress, disregarding the steel reinforcements, shall not exceed one hundred and fifty (150) pounds per square inch. The horizontal and vertical reinforcement shall be properly proportioned and placed to provide for expansion and shrinkage without leakage, and the stress in the steel shall not exceed ten thousand (10,000) pounds per square inch.

As soon as the concrete has hardened sufficiently to be self-sustaining, the forms shall be removed and all cavities filled with a one to one (1:1) mortar thoroughly rubbed in and all irregularities trowelled smooth.

The concrete shall harden at least twenty-eight (28) days before use, and the surface of the floor and the interior surface of the walls shall be protected by coating with a sodium silicate solution or other equally good protection to prevent oil coming in contact with the concrete.

The maximum gross capacity of any such single tank when situated outside the fire limits shall not exceed two hundred and fifty thousand (250,000) gallons, but the gross storage capacity may be double that specified in the tables under Rule 8; and when such tanks are placed at least two hundred and fifty (250) feet from the line of adjoining property or the nearest building, the gross capacity may be unlimited.

Rule 10. Material and Construction of Tanks.

1. All fuel oil storage tanks within the fire limits shall be constructed of wrought iron, galvanized steel, basic open hearth or electric steel plates of gauge corresponding to the capacity as specified in the following tables:

TANKS PLACED UNDERGROUND.

Capacity in Gallons	Thickness of Material U. S. Gauge
500	14
1,000	12
5,000	7
10,000	¼ inch
20,000	5/16 "
30,000	⅜ "

TANKS PLACED ABOVE GROUND. (Horizontal.)

Maximum Diameter in feet	Thickness of Material U. S. Gauge Heads	Shell
5	7	10
8	¼ inch	7
[illegible]	⅜ "	¼ inch

TANKS PLACED ABOVE GROUND. (Vertical.)

Diameter Feet	Top	Top Ring	2nd Ring from Top	3rd Ring from Top	4th Ring from Top	5th Ring from Top	6th Ring from Top	Bottom
	Thickness of Material, U. S. Gauge							
40 and less	10	7	7	7	5	3	2	10
45	10	7	7	7	5	3	1	10
50	10	7	7	7	4	1	0	10
55	10	7	7	6	3	1	2–0	10
60	10	7	7	5	2	0	2–0	10
65	10	7	7	5	1	0	3–0	10
70	10	7	7	4	1	2–0	4–0	10
75	10	7	7	4	1	2–0	4–0	10
80	10	7	7	3	0	3–0	5–0	10

2. Tanks of greater capacity than above shall be proportionately heavier and of sufficient thickness to safely hold the contents.

3. All joints shall be riveted and caulked, brazed, welded, or made by some equally satisfactory process, and the tanks braced sufficiently to withstand all stresses due to transportation or use. All riveted joints shall have an efficiency of not less than sixty (60) per cent.

4. The top cover shall be of the same material as used in the construction of the tank, permanently secured to the tanks without other openings than provided for in these rules. A safety valve shall be installed on all tanks placed outside of buildings.

5. All outlets and inlets shall be through the top or cover of the tank, except for the clean-out plug as provided for under Rule 2, and in general storage tanks a water drain not exceeding one (1) inch diameter may be permitted.

6. All metal tanks shall be thoroughly coated on the outside with tar, asphaltum, or other suitable rust-resisting protection. When buried in soil impregnated with corrosive materials, steel tanks shall be entirely covered with a two-inch thickness of cement mortar or shall be of heavier metal in addition to being protected as specified.

7. All above ground storage tanks exceeding two hundred thousand (200,000) gallons capacity shall be provided with approved explosion hatches having a combined area of not less than one and one-half (1½) per cent of the roof area of the tank.

8. All tanks shall be tested and must withstand a pressure of not less than twenty-five (25) pounds per square inch shop test.[a]

Rule 11. Vent and Fill Pipes.

1. Each fuel oil tank shall be provided with a separate steel vent pipe and a separate steel fill pipe of at least two (2) inches diameter placed in the top of the tank. The vents for enclosure around tank shall be as specified under Rule 5.

2. Vent pipes for fuel oil tanks located in the lower story or buried under buildings shall be run to a point outside the building, above the street surface and at least twelve (12) feet above the fill pipe and shall terminate in a weatherproof hood or a gooseneck, protected with non-corrodable screens of not less than thirty by thirty (30 x 30) nickel mesh or equivalent. Such vent shall not be located within five (5) feet either vertically or horizontally of a window or other opening or an exterior stairway or fire escape.

3. The receiver terminal of fill pipes shall be located in a metal box or casting provided with means for locking and the delivery terminal shall be connected through the top of the tank at a point furthest remote from the vent.

Rule 12. Fuel Oil Feed Systems.

1. Systems fed by gravity or force systems between tank and pump shall not be permitted.

2. Pump suction feed systems only will be approved and anti-syphon system must be provided.

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a. This requirement is extremely unreasonable and is not based on engineering principles. A pressure of five (5) pounds per square inch shop test for fuel oil tanks is acknowledged by all engineers to be ample security against leakage.—Author.

Rule 13. Pumps and Piping.

1. Feed pumps for fuel oils shall be of approved design, so arranged that dangerous pressures will not obtain in any part of the system and shall be located outside of enclosure walls around storage tanks, but so placed as to be accessible at all times, and provision shall also be made for remote control. They shall be installed in duplicate when directed by the Fire Commissioner and shall be provided with a by-pass to permit the draining of the oil for repairs.

A separate hand pump shall be provided for starting purposes.

2. Oil conveying pipes shall be carried above the tank outlet; if laid underground after leaving the tank to be carried in a separate trench enclosed in fireproof or non-conducting material. They shall be of extra heavy standard wrought iron, steel or brass pipe with substantial fittings and not less than one-half (½) inch in size and if covered it shall be with asbestos or other approved fireproof material. Overflow pipes shall be at least one size larger than supply pipes and shall be carried back to the receiver terminal.

3. All connections shall be tight with well-fitted joints. Unions shall have at least one face made of brass with conically-faced seats.

4. Connections leading to outside tanks shall be laid below the frost line and shall not be located near or placed in same trench with piping other than steam lines for heating. All pipes leading to the surface of the ground shall be cased or jacketed to prevent loosening or breakage. Openings for pipes through outside walls below the ground level shall be securely cemented and made oil-tight.

5. Piping shall be run as directly as possible, without sags, and be properly supported to allow for expansion, contraction, jarring and vibration and draining.

6. Piping between any separated oil container or using parts of the equipment, should be laid as far as practicable outside of the building, underground, and inside piping in a trench with metal cover or protected by not less than three (3) inches of concrete.

7. Piping under pressure must be designed with a factor of safety of not less than six (6), and shall in every case be tested to a pressure of not less than one hundred and fifty (150) pounds after installation.

Rule 14. Controlling Valves.

1. In fuel oil piping systems, readily accessible shut-off valves shall be provided in the supply line of fuel oils as near to tank as practicable, on both sides of any strainer which may be installed in pipe lines, in the main line inside the building, at each oil consuming device, and a gate valve in the discharge and suction pipes near the pump. Provision shall be made to insure the cessation of oil supply from tank to the burner when the pump is not in work.

Rule 15. Heating.

1. All heating to reduce viscosity of fuel oils in storage tanks in any building shall be only by means of hot water coils and the oil shall not be heated above one hundred and forty (140) degrees Fahrenheit.

2. All outside pipes subject to freezing shall be protected with a heating line of steam or hot water.

Rule 16. Fuel Oil Burners.

1. Burners containing chambers which allow dangerous accumulation of gases or containing oil-conveying pipe or parts subject to intense heat or stoppage from carbonization are prohibited.

2. Oil shall be supplied through orifices not larger than necessary to supply sufficient oil for maximum burning conditions when the controlling valves are wide open.

3. The mechanism shall be so designed that, where manual or automatic control is provided, operated at some distance from the burner, the flame cannot be extinguished except by closing the main shut-off valve in line to burner. Approved gas-pilot lights or equivalent will be acceptable.

4. A check valve of approved type shall be installed in each oil, steam and air line near the burner.

5. Smoke pipes shall be installed between the burners and chimney, and any dampers in smoke pipes shall not exceed eighty (80) per cent of the area of the pipe. Necessary regulation of draft shall be accomplished by dampers in the fire or ash pit doors.

6. Burners shall be installed with overflow attachment so arranged that surplus oil will drain by gravity from the burner into a substantially constructed reservoir. Such reservoir shall be constructed of brass, copper or galvanized iron plate not less than No. 18 U. S. gauge in thickness and shall be provided with a vent pipe with weatherproof hood leading outside the building.

7. The supply of oil and air or steam for atomizing shall be interlocked, so that if the steam or air should fail the oil will be automatically shut off.

Rule 17. Fuel Oil Fire Extinguishing Equipment.

1. Every tank with a capacity of over ten thousand (10,000) gallons shall be equipped with a system of steam pipes, blanketing gas or other approved system for use in case of fire, so arranged and installed as to adequately protect surrounding property.

2. When steam is used, the steam supply pipe shall not be less than one-half (½) inch in size, the boilers shall be conveniently located, and shall be controlled by valves outside the tank enclosure.

Rule 18. General Devices.

All devices used in connection, with oil-burning apparatus, such as indicators, gauges and burners, shall be of such character as to minimize leakage and exposure of oil, and shall be connected through substantial fittings. Devices which are subject to breakage and escape of oil shall be prohibited.

Thermometers with large clear reading scales, placed in approved thermometer wells with screwed top connections, shall be installed at convenient and prominent positions in the oil supply pipe lines between the service tank and the pumps and also between the pumps and the burner, to indicate the temperature of the oil.

Rule 19. Instruction Cards.

Cards giving complete instructions for the care and operation of the fuel oil system shall be permanently fixed near the apparatus.

Rule 20. Operation of Plant.

Such fuel oil-burning plants may be operated only by a licensed engineer or by a licensed operator who shall be a citizen of the United States, who can read and write the English language, and who is familiar with the practical working of such plant, as evidenced by the certificate of the Fire Commissioner.

Rule 21. Installation.

No installation of fuel oil plants shall be commenced until after the approval of plans by the Fire Commissioner, which plans shall be submitted to him for examination, together with the certificate of the Superintendent of Buildings that the proposed construction of the enclosure and the location of tanks is in accordance with the requirements of the Building Code and of these Rules.

Adopted, Nov. 6, 1919. JOHN P. LEO, *Chairman.*

WM. WIRT MILLS, *Secretary.*

CHICAGO REGULATIONS

Chicago's regulations for the storage and use of fuel oil are as follows:

STORAGE AND USE OF FUEL OIL AND THE CONSTRUCTION AND INSTALLATION OF OIL BURNING EQUIPMENT

Section 76. Large supply or storage tanks for oils having a flash point above 150 degrees Fahrenheit shall be constructed in the manner hereinafter set forth.

CAPACITY AND LOCATION OF TANKS.

(a) Tanks shall be so located as to avoid undue exposure of adjacent combustible property, and in all cases where a doubt exists as to the proper location of same under the terms of this ordinance the location shall be subject to the approval of the Chief of Fire Prevention and Public Safety. The distances specified in the following table are for plants or storage tanks located outside the districts defined in Section 37 of this ordinance:

TABLE 1.

MINIMUM DISTANCE OF TANKS

Capacity in gallons	To line of adjoining unprotected building or property which may be built upon	To line of adjoining protected building	To line of any existing frame building	To any other tank
1,000	10 feet	5 feet	20 feet	2 feet
2,000	20 feet	10 feet	40 feet	2 feet
16,000	25 feet	15 feet	50 feet	2 feet
24,000	30 feet	20 feet	60 feet	2 feet
36,000	40 feet	25 feet	80 feet	3 feet
48,000	50 feet	35 feet	100 feet	3 feet

Provided, that the aggregate capacity of all tanks in any one yard, enclosure or plant shall not exceed 300,000 gallons, and no one tank shall contain in excess of 48,000 gallons.

(b) Each above ground tank shall be surrounded with an embankment or dike not less than four feet in height and having a capacity not less than fifty per cent greater than the tank to be protected.

(c) Embankments or dikes shall be made of reinforced concrete or brick and shall have a crown of not less than one foot and a slope of at least one and one-half inches to the foot on both sides.

(d) Embankments or dikes shall be continuous, with no openings for piping or roadways. Piping shall be laid well below the foundation of the embankment. At points where it is necessary to pass over the embankment, properly built steps or concrete roadways shall be provided.

(e) Adjacent tanks shall be protected against danger from each other by fire walls of brick or concrete not less than 12 inches thick and extending not less than 3 feet above and beyond each tank. Each such fire wall shall have a fender or return wall of the same height and thickness at each end, and extending 3 feet on each side of said wall.

Section 77.

HEIGHT OF TANKS.

(a) Vertical tanks shall be so constructed as not to exceed thirty feet in height.

MATERIAL AND CONSTRUCTION OF TANKS.

(b) Tanks shall be constructed of iron or steel plates of a gauge depending upon the capacity as specified in the following table:

TABLE 2.

THICKNESS OF METAL FOR ABOVE GROUND TANKS.

Horizontal.

Maximum Diameter	Minimum Thickness — Heads	Minimum Thickness — Shell
Not over 5 feet	$\frac{3}{16}$ in.	$\frac{9}{64}$ in.
5 feet to 8 feet	$\frac{1}{4}$ in.	$\frac{3}{16}$ in.
8 feet to 11 feet	$\frac{3}{8}$ in.	$\frac{1}{4}$ in.

Vertical.

Capacity 5,000 gallons or less; diameter less than 40 feet:

Bottom,	No. 8 U. S. Standard Gauge
Bottom Ring,	No. 8 U. S. Standard Gauge
Other Rings,	No. 10 U. S. Standard Gauge
Top,	No. 12 U. S. Standard Gauge

Capacity 10,000 gallons or less; diameter less than 40 feet:

Bottom,	No. 8 U. S. Standard Gauge
Bottom Ring,	No. 7 U. S. Standard Gauge
Other Rings,	No. 8 U. S. Standard Gauge
Top,	No. 12 U. S. Standard Gauge

(c) Other vertical tanks shall be of material having a thickness of not less than indicated in the following table, in which the figures in all columns, excepting the first, refer to U. S. Standard Gauge:

Diameter Feet	Top	Top Ring	2nd Ring from Top	3rd Ring from Top	4th Ring from Top	5th Ring from Top	6th Ring from Top	Bottom
80	10	7	7	3	0	3–0	5–0	10
75	10	7	7	4	1	2–0	4–0	10
70	10	7	7	4	1	2–0	4–0	10
65	10	7	7	5	1	0	3–0	10
60	10	7	7	5	2	0	2–0	10
55	10	7	7	5	3	1	2–0	10
50	10	7	7	7	4	1	0	10
45	10	7	7	7	5	3	1	10
40 and less	10	7	7	7	5	3	2	10

All riveted joints shall have an efficiency of at least 60 per cent.

Tanks of greater capacity than as specified above shall be of material of sufficient thickness to safely hold the contents and proportionately heavier, subject to the approval of the Chief of Fire Prevention and Public Safety.

(d) Materials to be used in smaller tanks shall be as required in Table 3, Section 43 of this ordinance.

(e) All joints of such tanks shall be riveted and soldered, riveted and caulked, brazed, welded or made by some equally satisfactory approved process. Tanks must be tight and sufficiently strong to bear without injury the most severe strains to which they are liable to be subjected in transportation or use. Tanks shipped complete must be suitably reinforced to prevent injury to joints.

(f) All tanks shall be provided with a vent pipe terminating in a weatherproof hood containing a non-corrodible screen. In case such vent pipe is not permanently open a suitable safety relief must be provided. In all cases where, in order to provide a means for relieving pressure, manhole covers are not provided with bolts or clamps the openings must be protected by a non-corrodible wire mesh screen of not less than 20x20 meshes per square inch, which may be removable but must be normally securely held in place.

(g) Outside surfaces of tanks shall be thoroughly protected against corrosion by a suitable rust-resisting paint.

SUPPORTS FOR TANKS

Section 78. All tanks shall be set upon a substantial foundation, and, when elevated above the ground level, supports shall be of non-combustible material, with the exception of suitable wooden cushions. All above ground tanks shall be thoroughly grounded electrically.

MEANS FOR EXTINGUISHING FIRES IN TANKS

Section 79. Tanks and dikes shall be equipped with suitable means or devices, satisfactory to the Chief of Fire Prevention and Public Safety, for extinguishing or retarding fire in such tanks or dikes.

PUMPS

Section 80. All pumps used in connection with the supply and discharge of any tank constructed under the provisions of this chapter shall be located outside of the reservoir walls, and at such a point that they will be accessible at all times, even if the oil in the tank or reservoir should be on fire.

PIPE CONNECTIONS

Section 81. (a) All oil conveying pipes shall be laid underground and such pipes shall not, under any circumstances, break through the reservoir walls above the surface of the ground.

(b) The above provision does not apply to pipes laid well below the surface of the ground.

CONTROLLING VALVES

Section 82. (a) There shall be a gate valve located at the tank in each oil conveying pipe. In case two or more tanks are cross-connected there shall be a gate valve at each tank in each cross-connection.

(b) There shall be a gate valve in the discharge and suction pipes near the pump and a check valve in the discharge pipe, located underground.

INDICATOR.

Section 83. There shall be a reliable indicator provided for each tank to show the level of the oil in the tank. Such indicator shall be of such a form that its derangement will not permit the escape of oil.

PLANS AND SPECIFICATIONS.

Section 84. A complete set of plans and specifications of any proposed installation under the provisions of this chapter shall be submitted to the Bureau of Fire Prevention and Public Safety before beginning construction.

CHAPTER VIII.

INDIVIDUAL OIL-BURNING EQUIPMENTS FOR OTHER THAN HOUSEHOLD PURPOSES.

Section 85. CAPACITY AND LOCATION OF TANKS.

(a) Within the districts defined in Section 37 of this ordinance, all tanks constructed under the provisions of this chapter shall be located underground with the tops of such tanks not less than 2 feet below the surface of the ground and below the level of the lowest pipe in the building to be supplied. Such tanks may be permitted underneath a building if buried at least two feet below the lowest floor, if such floor is of concrete not less than six inches thick. All tanks shall be set on a firm foundation and surrounded with soft earth or sand, well tamped into place. No air space shall be allowed immediately outside of such tanks. Any such tank may have a test well, provided such test well extends to near the bottom of the tank and the top end shall be hermetically sealed and locked except when necessarily open. When any such tank provided with a test well is located underneath a building, the test well shall extend at least 12 feet above source of supply. The limit of storage permitted shall depend upon the location of such tanks with respect to the building to be supplied and adjacent buildings, in accordance with the following table:

TABLE 3.

PERMISSIBLE AGGREGATE CAPACITY IF LOWER THAN ANY PORTION OF A BUILDING WITHIN RADIUS SPECIFIED.

Capacity	Radius
30,000 gallons	50 feet
20,000 gallons	30 feet
15,000 gallons	20 feet
11,500 gallons	10 feet
10,000 gallons	Less than 10 feet

(b) When located underneath a building, no tank shall exceed a capacity of 10,000 gallons, and the basement floors of such building are to be provided with ample means of support independent of any tank or concrete casing of same.

(c) Outside of the district defined in Section 37 of this ordinance, above ground storage tanks may be permitted as specified in Table 1, Section 76, of this ordinance: Provided, that drainage away from combustible property in case of breakage of tanks shall be arranged for same or that dikes shall be built as provided for in Section 76 of this ordinance.

(d) When above ground tanks are used all piping must be so arranged that in case of breakage of such piping the oil well will not be drained from the tanks. This requirement shall be understood as prohibiting the use of any gravity feed from storage tanks.

MATERIAL AND CONSTRUCTION OF TANKS.

Section 86. (a) All such tanks shall be constructed of iron or steel plate of a gauge depending upon the capacity as specified in the following tables:

TABLE 4.

Underground tanks inside of the districts defined in Section 37 of this ordinance, or within 10 feet of a building when outside such districts.

Capacity—Gallons	Min. Thickness of Material
1 to 560	14 U. S. Standard Gauge
561 to 1,100	12 U. S. Standard Gauge
1,101 to 4,000	7 U. S. Standard Gauge
4,001 to 10,500	¼ in.
10,501 to 20,000	5/16 in.
20,001 to 30,000	⅜ in.

TABLE 5.

Underground tanks outside of the districts defined in Section 37 of this ordinance, provided the tanks are 10 feet or more from a building.

Capacity—Gallons	Min. Thickness of Material
1 to 560	18 U. S. Standard Gauge
31 to 350	16 U. S. Standard Gauge
351 to 1,100	14 U. S. Standard Gauge
1,101 to 4,000	7 U. S. Standard Gauge
4,001 to 10,500	¼ in.
10,501 to 20,000	$\frac{5}{16}$ in.
20,001 to 30,000	⅜ in.

Tanks of greater capacity than 30,000 gallons must be made of proportionately heavier material, subject to the approval of the Chief of Fire Prevention and Public Safety.

(b) All joints of such tanks shall be riveted and soldered, riveted and caulked, welded or brazed together or made by some equally satisfactory approved process. Tanks must be tight and sufficiently strong to bear without injury the most severe strains to which they are liable to be subjected in practice. The shells of tanks shall be properly reinforced where connections are made, and all connections shall, as far as practicable, be made through the upper side of tanks above the oil level.

(c) All such tanks shall be thoroughly coated on the outside with tar, asphaltum or other suitable rust-resisting material.

FILL AND VENT PIPES

Section 87. (a) Each underground storage tank having a capacity of over 1,000 gallons shall be provided with a vent pipe at least 1 inch in diameter extending from the top of the tank to a point outside of the building. Such vent pipe shall terminate at a point at least 12 feet above the level of the top of the highest tank car or other reservoir from which the storage tank maybe filled. The terminal of such vent pipe shall be provided with a hood or gooseneck protected by a non-corrodible screen and shall be located remote from fire escapes, and never nearer than 3 feet, measured horizontally and vertically, from any window or other opening. Vent pipes from two or more tanks may be connected to one upright, provided the connection is made at a point at least one foot above the level of the source of supply.

(b) Tanks having a capacity of less than 1,000 gallons may be provided with combined fill and vent pipes, if the same are so arranged that the fill pipe cannot be opened without opening the vent pipe, and such pipes terminate in a metal box or casting provided with a lock.

(c) Fill pipes for tanks which are installed with permanently open vent pipes shall be provided with metal covers or boxes which are to be kept locked except during filling operations.

(d) Fill and vent pipes for tanks located under buildings shall be so constructed that they will run underneath the concrete floor to the outside of the building.

FILTERS.

Section 88. Suitable approved filters or strainers for the oil stored or used in any such tanks shall be installed and the same shall, wherever practicable, be located in the supply line before reaching the pump. Filters shall be arranged so as to be readily accessible for cleaning.

FEED PUMPS.

Section 89. (a) All feed pumps used for any installation under the provisions of this chapter must be of approved design, secure against leaks. Any stuffing box in connection therewith, if used, shall be provided with a removable cupped gland designed to compress the packing against the shaft and arranged so as to facilitate removal. Packing affected by the oil must not be used.

(b) Such feed pumps shall be arranged so that dangerous pressures will not be obtained in any part of the system, and such feed pumps shall be inter-connected with the pressure air supply to the burners in order to prevent flooding.

GAUGE GLASSES AND PET COCKS.

Section 90. Glass gauges, the breakage of which would allow the escape of oil, are hereby prohibited. Pet cocks shall not be used on oil carrying parts of the system.

RECEIVERS OR ACCUMULATORS.

Section 91. (a) Whenever receivers or accumulators are used, they shall be designed so as to secure a factor of safety of not less than 6 and must be subjected to a pressure test of not less than twice the working pressure.

(b) The capacity of oil chamber must not exceed ten gallons.

(c) Such receivers or accumulators shall be equipped with pressure gauge.

(d) They shall also be provided with an automatic relief valve set to operate at a safe pressure and connected by an overflow pipe to the supply tank, and so arranged that the oil will automatically drain back to the supply tank immediately on closing down the pump.

AUXILIARY TANKS.

Section 92. (a) Wherever auxiliary tanks are used, their capacity shall not exceed ten gallons.

(b) They shall be of substantial construction, equipped with an overflow, and so arranged that the oil will automatically drain back to the supply tank on shutting down the pump, thereby leaving not over one gallon where necessary for priming, etc.

(c) If such auxiliary tanks are vented, the opening shall be at the top, and such opening may be connected with the outside vent pipe from the storage tank above the level of the source of supply.

PIPING.

Section 93. (a) Standard full weight wrought iron, steel or brass pipe with substantial fittings shall be used and shall be carefully protected against injury. Piping under pressure must be designed to secure a factor of safety of not less than 6, and after installation the same must be tested to a pressure not less than twice the working pressure.

(b) All piping shall be run as directly as possible, and laid so that the pipes are pitched toward the supply tanks without traps.

(c) Overflow and return pipes shall be at least one size larger than the supply pipes, and no pipe shall be less than one-half inch in diameter.

(d) All connections shall be perfectly tight with well-fitted joints. Unions, if used, shall be of approved type, having at least one face of the joint made of brass and having conically faced seats, obviating the use of packing or gaskets.

(e) Pipes leading to the surface of the ground shall be cased or jacketed wherever necessary to prevent loosening or breakage, and proper allowance shall be made for expansion and contraction, jarring and vibration.

(f) Connections to outside tanks shall be laid below the frost line and shall not be located near nor placed in the same trench with other piping.

(g) Openings for pipes through outside walls shall be securely cemented and made oil tight.

VALVES, ETC.

Section 94. (a) Readily accessible shut-off valves shall be provided in the supply line as near to the tank as practicable and additional shut-offs shall be installed in the main line inside of the building and at each oil consuming device.

(b) Controlling valves in which oil under pressure is in contact with the stem shall be provided with stuffing boxes of liberal size containing removable cupped glands designed to compress the packing against the valve stem, and arranged so as to facilitate removal. Packing affected by the oil must not be used.

(c) Approved shut-offs for the oily supply in case of breakage of pipes of excessive leaking in the building shall be installed.

Section 95. It shall be the duty of the Chief of Fire Prevention and Public Safety to enforce all the provisions of this ordinance, and he shall have full power to pass upon any questions arising under the provisions of this ordinance, subject to the conditions, modifications and limitations contained therein, and he shall have similar power and authority in and about the enforcement of this ordinance as is now granted to him by the terms and provisions of an ordinance "Creating a Bureau of Fire Prevention and Public Safety," passed by the City Council on the 22nd day of July, 1912, and appearing on pages 1543 to 1620, inclusive, of the Journal of the Proceedings of said date, and all ordinances amendatory thereof and supplementary thereto.

Section 96. Article XVII of an ordinance "Creating a Bureau of Fire Prevention and Public Safety," passed by the City Council on the 22nd day of July, 1912, and appearing on pages 1543 to 1620, inclusive, of the Journal of the Proceedings of said date, and all ordinances amendatory of and supplementary to said Article XVII are hereby repealed, and Sections 1683 to 1692, both inclusive, and Sections 691 to 694½, both inclusive, of The Chicago Code of 1911, and all amendments thereto, are hereby repealed.

Section 97. Penalty. Any person, firm or corporation that violates, neglects or refuses to comply with, or resists the enforcement of, any of the provisions of this ordinance, shall be fined not less than twenty-five dollars ($25) nor more than two hundred dollars ($200) for each offense, and every such person or corporation shall be deemed guilty of a separate offense for every day on which such violation, neglect or refusal shall continue.

Section 98. This ordinance shall take effect and be in force from and after its passage and due publication.

Fuel oil is being used as a substitute for coal in so many small industrial plants, office buildings, hotels, apartment houses and residences that a distribution problem has been created which only the motor truck can solve and at the present time the motor truck supplements railways, waterways and pipe lines in the delivery of fuel oil from the refinery to the ultimate consumer. Competition in the oil business is very keen and the retaining of customers depends very largely upon the service rendered. Transportation from central stations to the ultimate consumer must be reliable, elastic and economical. The use of the motor truck in fuel oil delivery is described by Mr. Alfred F. Masury[a] as follows: "What rail and waterways are to the industry so far as the long haul is concerned, the motor truck is to the delivery of supplies and products in and between communities. The operation or administration of each distributing center is independent of the other; that is, each center is a unit, yet a part of the whole. The area of each distributing center, the frequency of comparatively long hauls, repetitive delivery of large loads, the necessity of rapid and certain distribution regardless of climatic or road conditions, have called the motor truck into general use and subordinated, if not eliminated, the use of the horse. It has been demonstrated that a 1½-ton truck will replace not less than two 2-horse-drawn wagons of 700-gallon capacity, while the capacity of the tank or motor truck is 650 to 675 gallons. In some instances, however, larger trucks will displace from six to nine horses and two or three horse-drawn wagons and effect a considerable saving in labor. A 2½-ton truck is usually operated by one man. Larger units usually have a helper. This, however, does not hold true in every case. In a well-regulated concern a study is made by a traffic man of the conditions under which

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a. The Petroleum Handbook, Andros, p. 158.

each truck operates and the labor supplies depend on delivery conditions. While it is usually admitted that in a short radius of ten miles the teams, from a money standpoint, are the most economical to operate, it is true that it is much easier to obtain individual help to operate motor trucks than it is to drive teams. The truck has the advantage of being able to perform the work more satisfactorily in the heat of the summer and in the intense cold of the winter season. In other words, a truck is a more flexible unit and meets more of the conditions. For this reason it gives better service to the trade. These considerations are

Fig. 29. A Tank Truck.

causing trucks to replace horses in most instances. The motor truck takes up the delivery of oil where the railway, the waterway and the pipe line leave off. Only when a station runs out of a supply and it is impossible to deliver a new supply in time by rail, is the motor truck called into use where the railroad would otherwise be used. The type of truck used in hauling from refineries to the central stations is a 5½ or a 7½-ton capacity, the size depending upon the road conditions and local road regulations or city ordinances. The most economical unit for hauling from a central station in the country or smaller cities covering a mileage of 60 to 65 per day is a 2½-ton truck, whereas in the larger centers the 3½-ton truck is the one mostly used, covering a radius of 35 to 40 miles per day. In the delivery of fuel oil in what is known as bulk deliveries, motor trucks of the following capacities are advisable: 2½-ton truck, 650 gallons; 3½-ton truck, 1,000 to 1,200 gallons, depending on road conditions; 5½-ton truck, 1,350 to 1,500 gallons; 7½-ton truck, 1,800 to 2,000 gallons. With the present road and bridge conditions the 2,000-gallon tank is too large. On good roads and pavements the larger capacities can be used successfully and economically. During the war one or two concerns used tanks of this capacity when the deliveries from refineries to central points were held up by the congestion on the railroads.

In some cases where the tanks are in inaccessible locations, it is necessary to deliver the oil to containers on a higher level than the vehicle. In such cases a pump is usually installed upon the truck which is operated by power delivered from the motor, otherwise no special loading equipment is required in the handling of oil. Delivery hours run from 7:00 a. m. to 6:00 p. m. In some cases they may be a little earlier. Another advantage of the motor truck is that it cuts down the number of hours a man has to work, because it shortens the time necessary to make deliveries of oil. It is very seldom that an old employe who has driven a team for a number of years and is broken in on a motor truck wishes to go back to the old type of vehicle. He finds the truck an interesting study and takes much interest in and care of it. It has been proved in most instances that the old time horse driver, who is broken in and carefully instructed, makes a much better motor truck driver than a professional chauffeur. The motor truck occupies a prominent place in the delivery of fuel oil, a place which cannot be filled by any other method of delivery. The motor truck possesses the speed, capacity and endurance, regardless of weather or other conditions, and is far more economical than any other method. In fact, the motor truck generally proves to be the most economical unit to handle. The saving effected by units of this character is usually reflected in the ultimate cost to the consumer." Fig. 29 shows a motor tank wagon.

CHAPTER VI

HEATING, STRAINING, PUMPING AND REGULATING

For the most effective atomization all fuel oil should be heated in order to increase its fluidity and all fuel oil below 20 degrees Baume gravity must be heated in order to insure the proper flow of oil through the burners. Certain crude oils at the ordinary temperature of the atmosphere are of great viscosity, which viscosity increases as the temperature gets lower. At 30° to 40° F., which is not an unusual outdoor temperature, the fluidity of the oil is so slight that it is almost impossible to pump the oil or to force it to the burner. It is therefore necessary where fuel oil is to be used in regions which are subjected to severe winter temperatures that there should be means for heating the oil so that the oil may more readily flow to the pumps. The usual manner of accomplishing this is not to attempt to heat the whole tank or bunker of oil, but simply to heat the oil immediately surrounding the suction pipe to the pumps. This can be easily accomplished by placing a coil of a few turns of steam pipe about the suction pipe. In all pipes intended for the transmission of crude oil it is desirable that connections should be made to them so that steam can be turned into the pipes after shutting off the oil. These pipes can be thus cleaned by the heat and the force of the blowing steam, and any deposited asphalts, paraffins, or condensed hydrocarbons can be cleared out before the pipes become choked so as to impair their efficiency. The heating of the oil should be always recommended as an aid to secure better operation of pumps and burners, but, this heating should never be carried to such a degree of temperature as will cause decomposition of the hydrocarbons of the oil. Heating fuel oil above its flash point increases the fire hazard and should be avoided.

One of the best methods of providing for uniform fluidity throughout the system is to parallel the oil pipe lines with steam lines. When this is done and when a suitable pre-heater is also installed a uniform flow of oil is provided. Exhaust steam has nearly as great a heat content as live steam and is usually used for heating oil. The fluidity necessary to be obtained for perfect atomization depends upon the capacity of the burner. Fig. 30 shows a temperature capacity curve for a mechanical oil burner. In the case of oil as heavy as 10 to 12 degrees Baume' or lower, a separate heater should be used with live steam and exhaust steam.

Various types of heaters are on the market. The heater shown in fig. 31 can be used with exhaust or live steam or with both. The oil enters at the bottom and passes up through the heater in a thin film as the oil passage is formed by the space between two thin cylinders placed concentrically. Steam is admitted at the top, surrounds the outer cylinder, and also flows into the inside of the inner cylinder thus keeping the oil surrounded on all sides by a steam jacket. The oil travels up and out the top while the steam enters at the top and exhaust from the bottom so that the hot oil leaving the heater is always drawn from that part of film nearest the hottest steam. The outer steam space is made by a large-sized pipe of suitable length which surrounds the outer cylinder mentioned above. This large pipe is insulated by means of asbestos and magnesia pipe covering which reduces the radiation loss from the sides of the heater.

Fig. 32 shows a spiral oil heater. The oil entering this heater unit between the two shells takes a spiral course upward to the space between the two shell heads from whence it flows down through the seamless steel coil and out to the discharge header. In the event of an operator closing the inlet and outlet oil valves without cutting out the steam to heater, thereby causing the dead oil in the unit to heat and expand to a pressure which might create a rupture, a safety valve "A" is provided for each unit and set to operate before an excessive pressure can be attained. Steam is admitted and condensate carried off as shown.

Fig. 33 shows the installation of pumps and heaters at the City and County Hospital power plant, San Francisco.

When using air either at high or low pressure as a spraying medium it is exceedingly desirable that the air be superheated before passing to the spraying tip, as thereby a considerable gain in efficiency can be anticipated.

Inasmuch as crude oils have been obtained from the earth they necessarily carry more or less sand or grit. The more viscous the oil the easier the sand and grit are held in suspension. In any installation of an oil burning plant special provision should be made for straining out all sand and foreign matter. Sand in oil not only clogs the burner openings but also wears out the small annular nozzles. Nearly all of the strainers inserted in oil burning systems are simple in construction and are often formed of a wire-gauze gasket set in the joints of the oil pipe. In order to take out the strainer for cleaning, however, it is necessary with such an installation to unbolt the joints of pipe and the

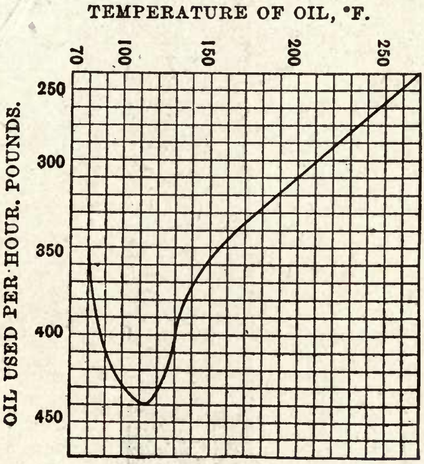

FIG. 30. Temperature-Capacity Curve for Mechanical Oil Burner. Texas crude oil (gravity, 18° B., flash point, 240° F.) used in a Peabody burner producing a round flame at 200-pound pressure.

more satisfactory arrangement is to use some strainer of the type shown in Fig. 34. Strainers of this type can be easily removed without tools or wrenches. The wire-gauze used in strainers should be made of wires of a width of mesh work equal to about one-half the width of the oil orifice in the burner. In the best practice a strainer is placed on each side of the oil pump, serving the two purposes of preventing sand from entering the pump and keeping any particles of old packing or other material from the pump itself from going through the system into the burner.

Fig. 35 shows another type of strainer. By simply removing one cap screw the strainer can be withdrawn from the casing and thoroughly cleaned.

Any water entering an oil storage tank will settle to the bottom of the tank. When the oil is drawn from a fixed outlet at the tank bottom, this water will enter the system.

There is no practicable device that will directly separate the

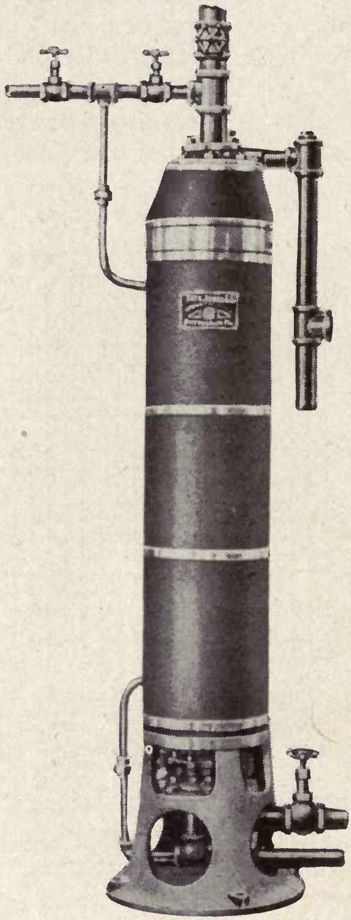

FIG. 31. Heater Used with Live or Exhaust Steam.
(Courtesy of Tate, Jones & Co., Inc.)

water from the oil. This separation can only be satisfactorily effected by allowing the water to settle to the bottom of the tanks by gravity. It therefore follows that if the suction to the oil pumps are placed in the bottom of the tanks, water will be often drawn when only oil is desired. A thread of water blown into

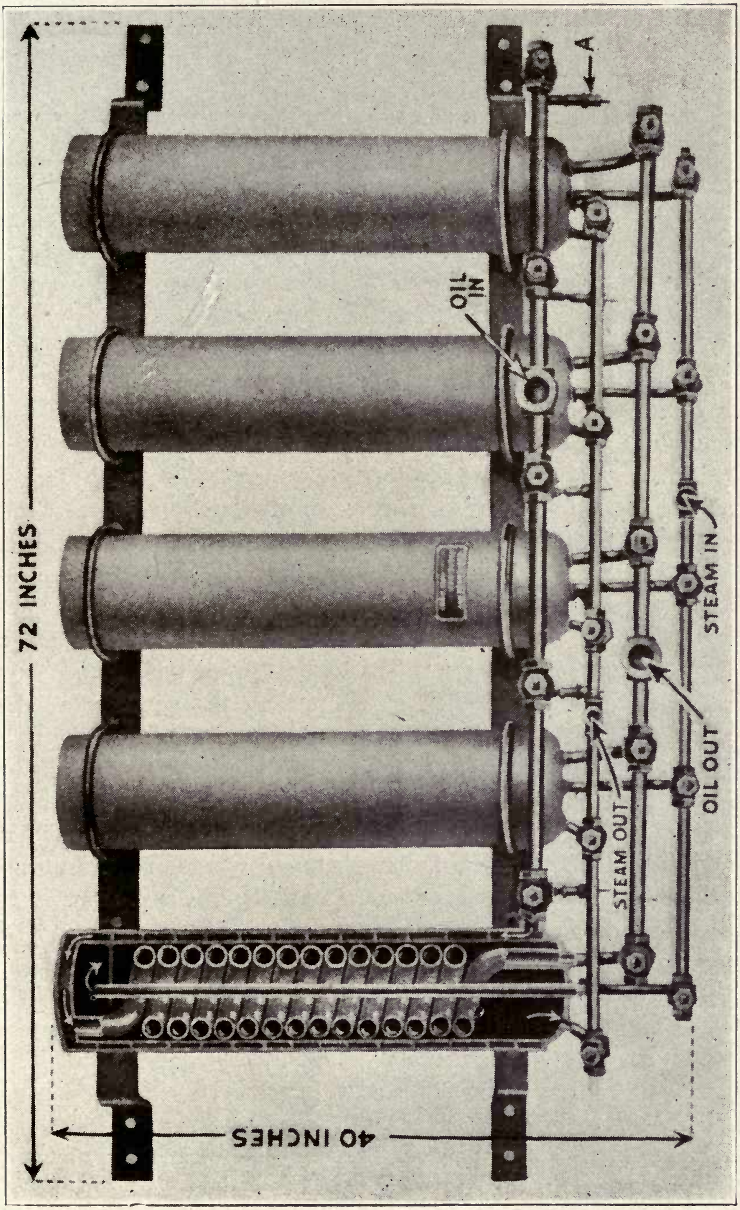

Fig. 32. A Type of Spiral Heater.
(Courtesy Coen Company, Inc.)

the oil burner effectually extinguishes the flame in the furnace, and if oil does not soon follow the water, there may be difficulty in relighting without introducing an outside flame.

With most burners it is desirable that a uniform pressure should be maintained on the oil circuit to the burner. If it were possible to keep the pumps automatically and perfectly regulated, a uniform pressure could be secured. There are many devices on the market which set out to secure this uniformity of action. Oil-pressure regulators similar to those used as regulators on steam mains have been tried, but in general have been found to be unsatisfactory, owing to the fact that the moving parts become clogged with sand or hydrocarbon. A so-called oil pressure regulator used as a single device is seldom satisfactory. A reliable plan is to provide the oil chamber of the pump with what would correspond to an air chamber on the water pump, or to provide a separate tank or chamber in which a constant air pressure is maintained on top of the oil by additional means. There are a number of designs of apparatus on the market which contain this feature of an oil air chamber, and corresponding regulating apparatus, which have given satisfaction. Many of these installations contain automatic arrangements whereby the change of level of the oil in the chamber effects a control of the steam supply to the oil pump, and thus affords an automatic method of controlling the quantity of the oil supply to the burner system. In all oil installations it is very important that the control of the oil pump and of the steam to the burner or of the compressed air, where air is used, should be so arranged that in case the delivery of any one of these fluids is reduced, or interrupted, a corresponding reduction or shutting off should be effected in the supply of the other elements. It is especially important that oil should in no case continue to be forced or pumped to the burners when the steam or air required for spraying is shut off, as in such an event the unsprayed oil is liable to flood in upon the hot brickwork and a furnace explosion is sooner or later likely to occur. The underwriters' regulations in many cases specifically require that in the event of the stoppage of the oil flow to the burner all the other functions shall be caused automatically to cease. These are precautions dictated by considerations of ordinary safety, and various applications of valves and devices are in the market whereby these results can be attained.

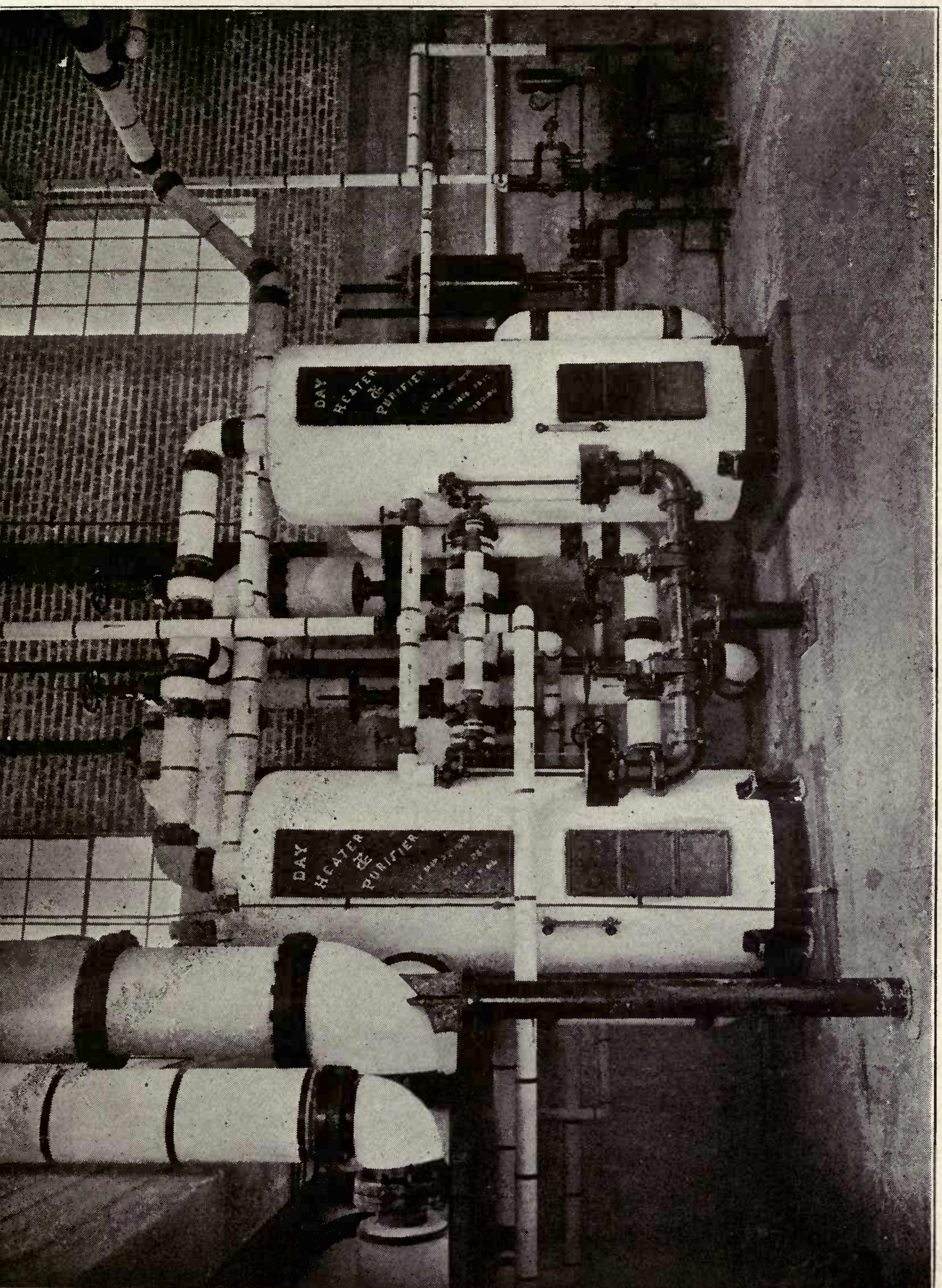

FIG. 33. Pumps and Heaters at City and County Hospital Power Plant, San Francisco.

Fig. 36 shows a specially designed pumping system for supplying fuel oil in uniform quantity and at even pressure. It consists of a duplex pump and receiver mounted on a cast-iron drip pan supported at a convenient height on cast-iron legs. The pump takes the oil directly from the storage tanks and at set pressure automatically forces it through the receiver to the

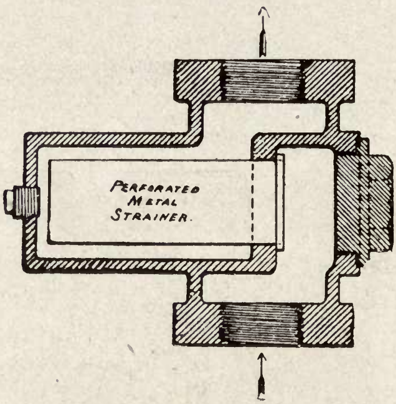

FIG. 34. A Simple Oil Strainer.
(Courtesy G. E. Witt Co.)

burners, through suitable pipe lines, the machine serving one or any number of burners within its capacity with equal uniformity. The receiver contains a coil of pipe, which can be connected with the exhaust of the pump, heating the oil, if necessary, through a medium of water. A special governor is furnished which automatically stops and starts the pump as the pressure in the receiver rises and falls. The receiver is specially equipped with the glass

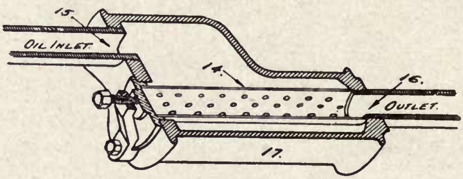

FIG. 35. Another Type of Strainer.

gauge, pressure gauge, thermometer, etc. This pumping system is constructed both of single and double type. In the double type one pump is operated at a time, and the other is held in reserve in case of breakdown. Fig. 37 shows another type of pumping system.

A pulsometer should be installed in the line between pump and furnace so as to prevent variation of pressure due to piston action. For a 3″ feed line, a 15″ pipe 5′ long with a provision at the bottom for the removing of sediment will be found beneficial. Fig. 38 shows a pulsometer.

Mr. C. D. Stewart writing in Oil News[a] states as follows:

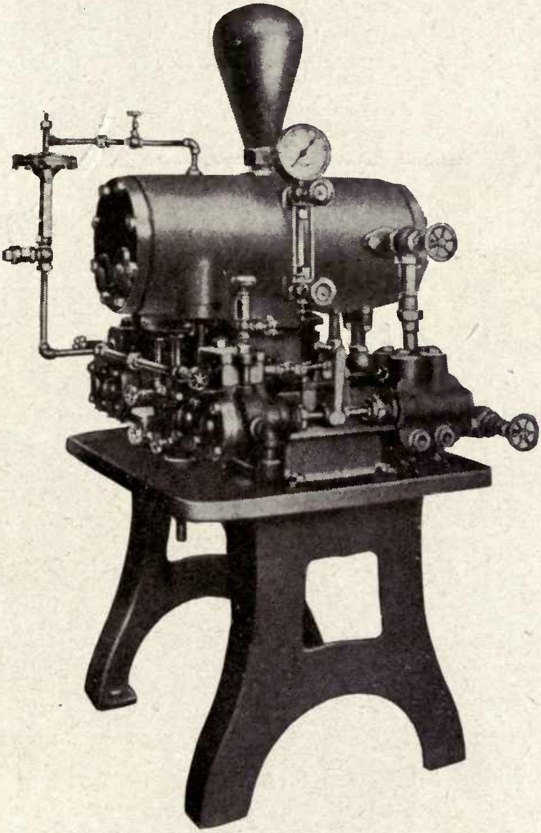

FIG. 36. A Modern Pumping System.
(Courtesy W. N. Best, Inc.)

"On the Pacific Coast where oil burning was first practiced to any large degree automatic apparatus has been devised and developed since the use of fuel oil began, and today most of the plants in that territory are equipped with mechanical oil stokers. Automatic systems are firing boilers at high efficiency in plants

a. Oil News, November 20, 1919, page 12.

of nearly every character, including power stations, sugar refineries, canneries, spinning mills, smelters, ferry boats, river boats, etc. It may be of interest to describe a stoking system operating on the step principles and providing for the accurate control of the three (3) elements of combustion in every step.

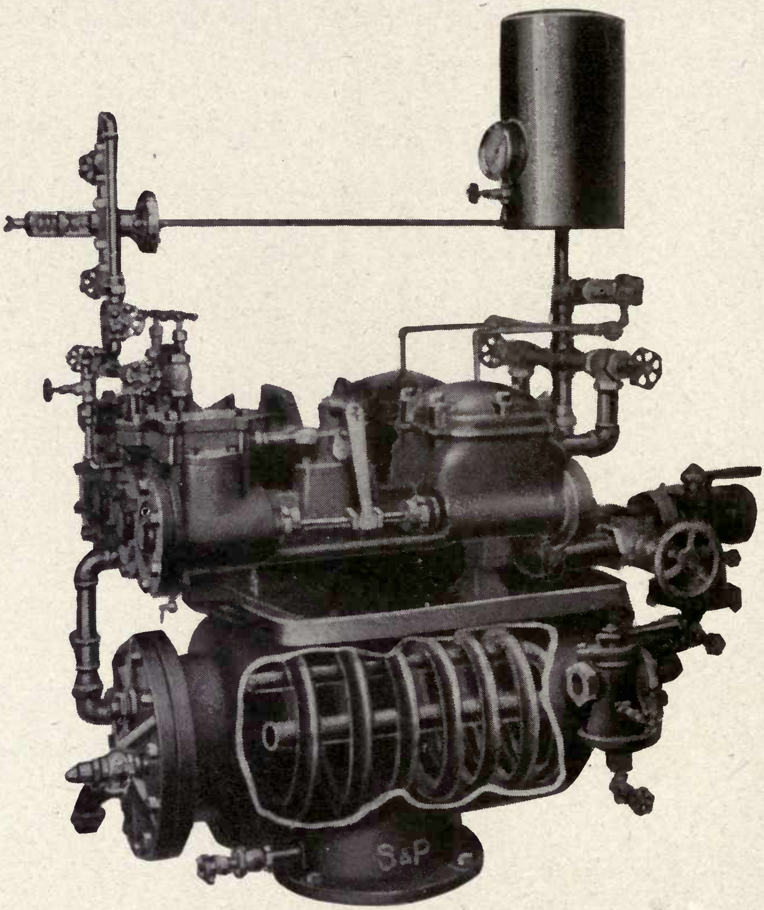

Fig. 37. Another Type of Pumping System.
(Courtesy of Staples & Pfeiffer.)

Atomizing steam, fuel oil and drafts are changed in each step of the fire in proportions that give the highest possible CO_2 throughout the entire range. Line drawings, as shown, illustrate the apparatus as applied to these installations.

Fig. 39 is a diagrammatic view of the burner regulator, one of which is applied to each burner.

Fig. 40 is a diagrammatic view of the Master Controller Set, controlling the entire plant, whether one or fifty boilers.

Fig. 41 is a cross sectional view of the Interlocking Damper Device, the number per plant varying according to the work to be done.

Briefly, the operation of this apparatus is as follows:

Boiler steam pressure present at all times above the diaphragms of the Master Controller Set causes it to function so as to step up the fires in case of a drop in steam pressure and to

Fig. 38. A Pulsometer.
(Courtesy W. N. Best, Inc.)

step down the fires in case of a rise in steam pressure. Fuel oil, which is under pressure to the burners, is also used as the actuating medium to perform the work of opening and closing the oil and steam valves to the burners and closing the dampers. Weights, as a safety measure, are used to open the dampers. The Master Controller Set, acting under the influence of boiler steam pressure, admits fuel oil pressure to the interlocking damper devices to close the dampers and releases it from the damper devices to permit the opening of the dampers by the weights. The Interlocking Damper Device was so named because of its construction, which is an application of the principle used in railway switch and interlocking plants. In the performance of its functions a step up in the fire cannot be brought about until the dampers are open an amount that will give correct combustion for that step of the fire, and a step down in the fire is made before the dampers close an amount to give the correct combustion for a lower fire.

The individual burner regulator, as illustrated and described in this article, provides for a three (3) stage fire on each burner,

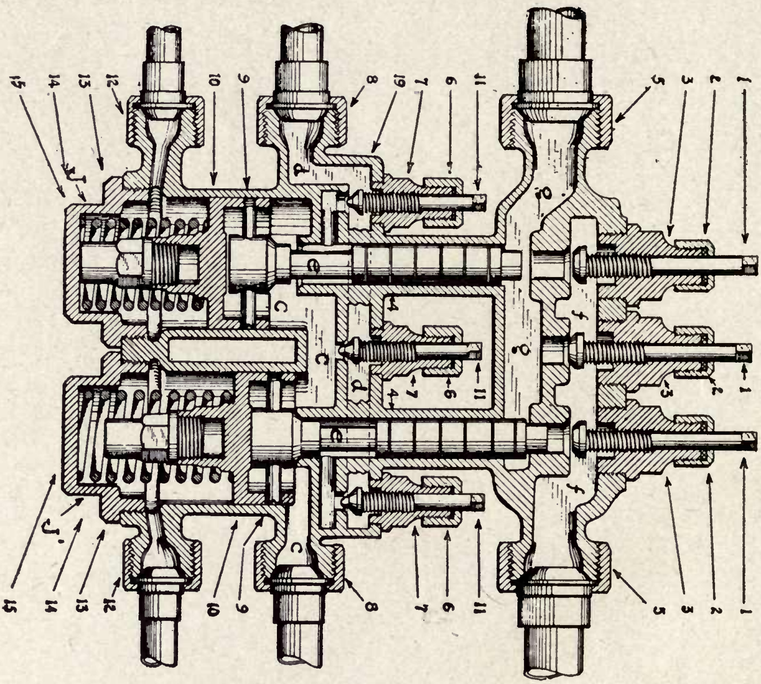

FIG. 39. The Burner Regulator.

however, more or fewer steps can be provided where conditions make it desirable. The regulator consists of three main portions: One portion comprises fuel oil and atomizing steam orifice valves, which regulate the amount of fuel and atomizing steam that flows to each burner in each stage of the fire. Another portion comprises plunger valves which govern two stages of the fire. A third portion comprises actuating pistons which open and close the plunger valves. The three stages of the fire are known as pilot, medium and maximum fires. The pilot fire is not automatic and, therefore, not governed by a plunger valve. The size of this fire is determined by the opening of the pilot orifice valves which consists of one oil and one steam valve. The medium fire

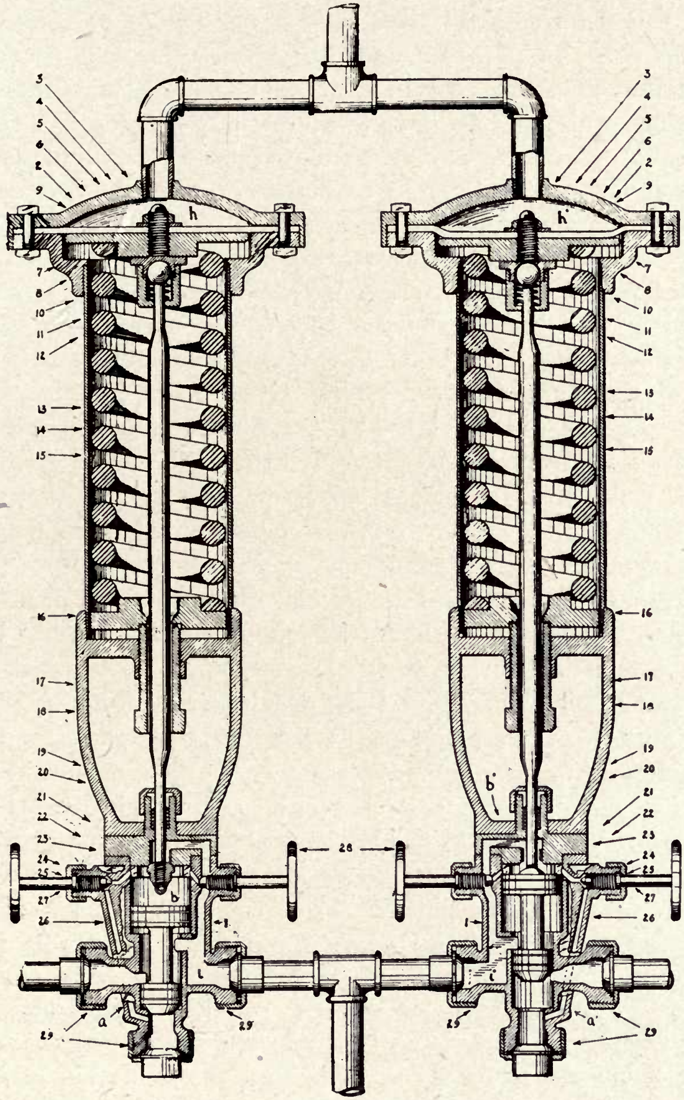

FIG. 40. The Master Controller.

orifice valves govern the size of the fire in the second stage, but no flow takes place by these orifice valves until the medium plunger valve is unseated. The maximum fire orifice valves do the same for the maximum fire and the maximum fire plunger valve starts and stops the flow by the orifice valves. When the installation is completed, each step of the fire is set according to the needs of the plant and the drafts adjusted to give the maximum efficiency in each stage, and with the fluctuation in steam pressure, the apparatus will function day after day without variation in efficiency. The Master Controller Set is designed to maintain steam pressure within 3 lbs. of the maximum at all times. The Master Controller, as illustrated, comprises two (2) portions, but in a number of large power plants, the Master Controller Set comprises four (4) portions and the plant so piped that a group of boilers sufficient to carry the normal load of the plant is on one portion of the Master Controller and these boilers are fired at their maximum rating. Other boilers are connected in series with the Master which functions only in case an abnormal load develops and these boilers are used only for the peak load. In this way still higher efficiency is realized by keeping a certain group of boilers operating normally at their designed capacity. There are a number of applications to this principle which have been made on the Pacific Coast due to the flexibility of the unit principle. Still another refinement that is interesting has been worked out in one or two large power plants which are used as standby plants to pick up the electric load in case of an interruption on the hydro lines. When this interruption comes, it is necessary to have the steam plant on the line in the shortest possible time, as every second counts. Accordingly the Master Controller Set, instead of being connected to the steam pressure at the boiler, is tapped into the steam mains at the turbine, with the result that the instant the load comes on the turbines, the Master Controller feels the steam drop instantly and has the fires under the boilers before the steam gauges have recorded any variation. As a result, one of these plants has gone from zero to maximum load instantly with a maximum drop in steam pressure of only six pounds."

Fig. 42 shows a fuel oil pump set controlled by a spring-control diaphragm regulator.

Fig. 43 shows a fuel oil pumping, heating and regulating system for power boilers.

1. Body
2. Cylinder
3. Cylinder Cap
4. ¼" Union
5. Piston
6. Piston Nut
7. Piston Rod
8. Piston Valve
9. Piston Valve Stop
10. Spring
11. Bonnet
12. Bonnet Nut
13. Stop Guide
14. Stop
15. Sprocket Chain
16. Sprocket
18. Gland

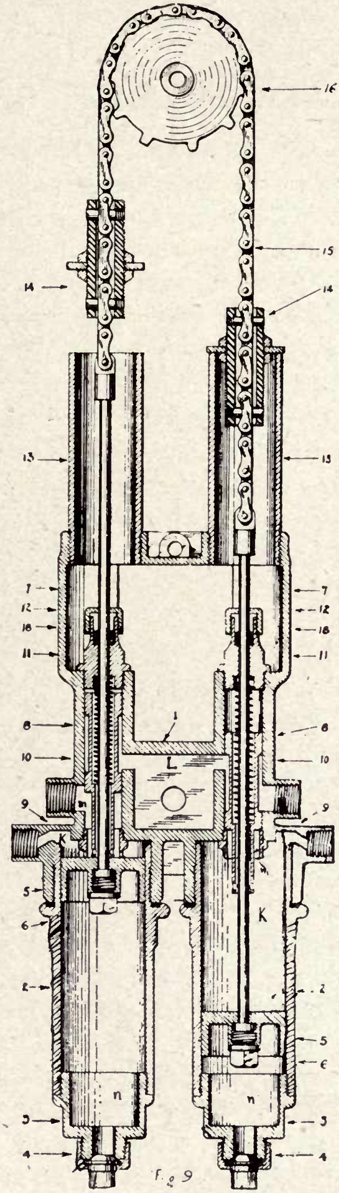

FIG. 41. THE INTERLOCKING DAMPER DEVICE.

CHAPTER VII

ARRANGEMENT OF BOILER FURNACES

The only object of burning fuel under a boiler is to convey heat to the water inside the boiler. Any furnace arrangement which allows the heat provided by the combustion of the fuel to escape up the stack is an inefficient arrangement. It is, of course, impossible to attain 100 percent efficiency in the burning of fuel in furnaces. It should be emphasized, however, that the furnace is simply a means of transferring to the water the heat units contained in the fuel.

In burning fuel oil under boilers, all of the oil should be consumed before it reaches the boiler surface because the impingement of the flame upon the boiler surface retards or arrests combustion. Practically all of the modern oil burners introduce the oil into the furnace in finely divided particles for the purpose of shortening the duration of the burning and the oil spray is thoroughly mixed with air before it is raised to the furnace temperature. Careful attention to the design of the furnace is of much more importance than is the selection of a burner.

Incandescent brick work around the flame is, of course, desirable, but in many cases a satisfactory compromise is effected by using a flat flame burning close to the white-hot floor through which air is steadily flowing. Even in a cold furnace a good burner will maintain a suspended clear and smokeless flame. The path of the flame should be such that heat is uniformly distributed over the boiler heat-absorbing surface without direct flame impingement. The linings of furnaces should be kept tight and there should be no openings except those necessary for the introduction of the mixture of fuel oil and air. Improper insulation results in radiation of heat from a furnace. Each square foot of exposed wall or arch surface represents a loss of heat through radiation. The refractories used should be the best obtainable, of uniform thickness, and as mechanically perfect as possible. Under ordinary firing the first pass of the boiler should be located directly over the furnace in order that the heating surface may absorb the radiant heat from the incandescent fire brick. Generally speaking, it is not desirable to have fire brick arches and target walls because they localize the heat with a resultant burning out of tubes or bagging of shell on account of the limited overload capacity.

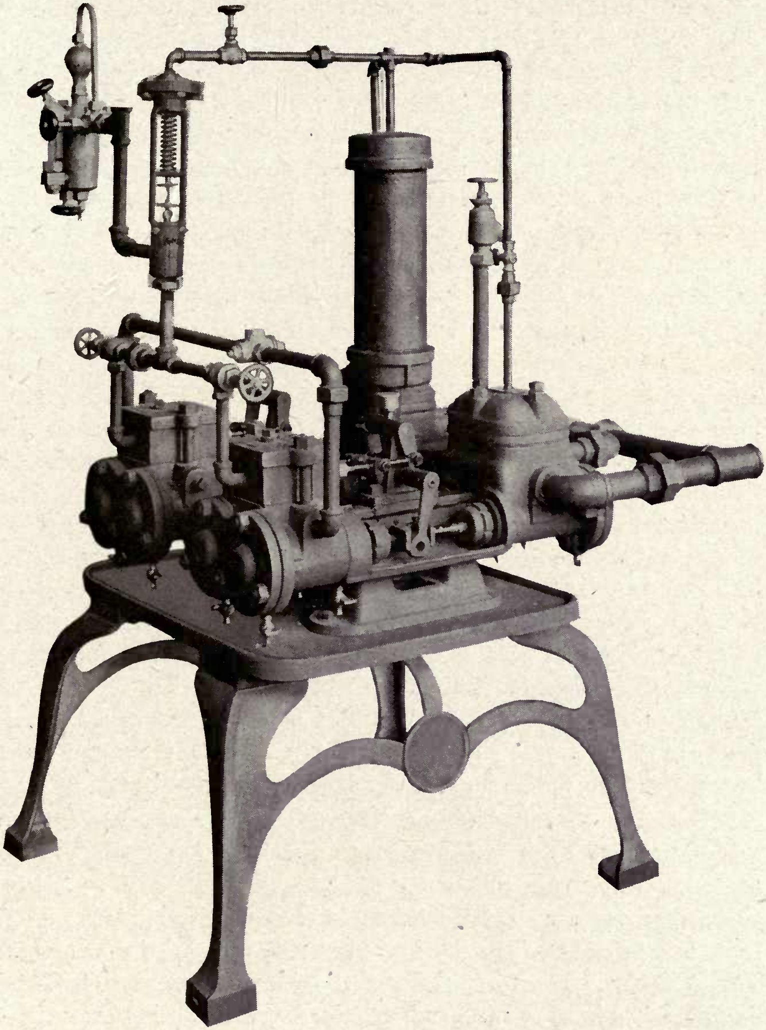

FIG. 42. Fuel Oil Pump Set, Controlled by a Spring-Control Diaphragm. (Courtesy Fisher Governor Company)

The velocity of the gases in their passage through the furnace should not be so high that complete combustion of the oil does not take place. The problem of obtaining complete combustion is comparatively simple. Sufficient oxygen must be supplied to burn the hydrocarbons contained in the fuel oil and excess air must be avoided.

The following statement in the Report of the U. S. Naval "Liquid Fuel" Board gives concisely the fundamentals of furnace design: "A liquid fuel such as crude petroleum requires an ample combustion space, more indeed than does almost any other sort of combustible material. The relative dimensions—length, breadth, and depth—of the combustion spaces are of minor importance. The primary requisite is volume, and that alone, provided all parts of it are traversed by the same quantity of gas in a given time; in other words, provided the gases are not short-circuited through or across some parts of the space to the neglect of others. Thus, if a current of gas flows through a cubic foot of space at the rate of 1 cubic foot per second, each particle of gas will spend one second within the space, regardless of whether the space is long and narrow or short and wide. In a long and narrow space there is less chance of the gases taking a short cut, and herein lies the sole utility of introducing baffles in the combustion space. Indeed, there is a strong objection to their introduction arising from the fact that the narrower the passage the greater will be the velocity of flow and the greater the distance to be traversed. Since the resistance that the draft pressure must ovrcome is proportional to the square of the velocity of flow and to the length of the passage, it follows, that for a given volume of combustion space the draft resistance will be proportional to the cube of its length. The advantages are, therefore, in favor of the combustion space of large cross section and short in the direction of the flow of the gases.

As to the difficulty arising from the tendency of the gases to follow the path of least resistance and to flow, for instance, with too great velocity at the center of the space and too little at the sides, that can always be checked by means of retarders placed so as to equalize the velocity over the cross section of the current. The difficulty, therefore, reduces itself to the mere trouble of finding out where to place the retarders, and this is obviously a question to be settled by experiment. What is true in this matter of the combustion space is also largely true of the tube space. The process of diffusion, so important to combustion, continues after the combustion is complete, and must have a good deal to do with the rate at which heat is abstracted from the gases by the

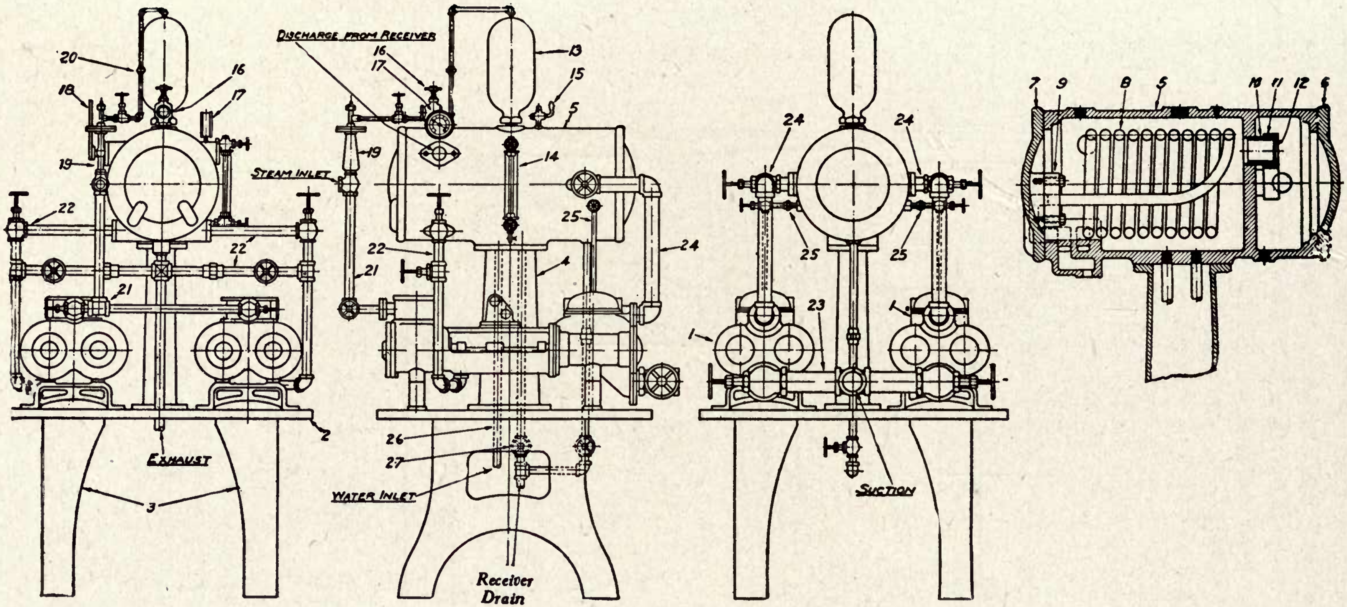

FIG. 43. FUEL OIL PUMPING, HEATING, AND REGULATING SYSTEM FOR POWER BOILERS

Guide to Part:

1. Pumps.
2. Base Plate.
3. Legs.
4. Receiver support.
5. Receiver.
6. Receiver Head. (Oil End).
7. Receiver Head (Coil End).
8. Heating Coil.
9. Heating Coil Flanges.
10. Oil Strainer Body.
11. Oil Strainer Cap.
12. Oil Strainer.
13. Air Chamber.
14. Gauge Glass, complete.
15. Air Cock.
16. Relief Valve.
17. Pressure Gauge.
18. Thermometer.
19. Fuel Oil Governor.
20. Fuel Oil Governor Piping and Valve.
21. Steam Piping and Valves.
22. Exhaust Piping and Valves.
23. Suction Piping and Valves.
24. Discharge Piping and Valves.
25. Air Relief Piping and Valves.
26. Water Inlet Pipe.
27. Receiver Drain Piping and Valves.

(Courtesy of Wayne Oil Tank and Pump Company) heating surfaces. As affecting the necessary amount of draft pressure, a tube space short in the direction of flow of the gases and of large cross-sectional area is better than one of small area and long in the direction of flow; but on account of the lesser velocity of flow through the short space the gases within it will be less thoroughly mixed by eddying, and the importance of arranging the heating surfaces so as to permeate all parts of the space will be increased."

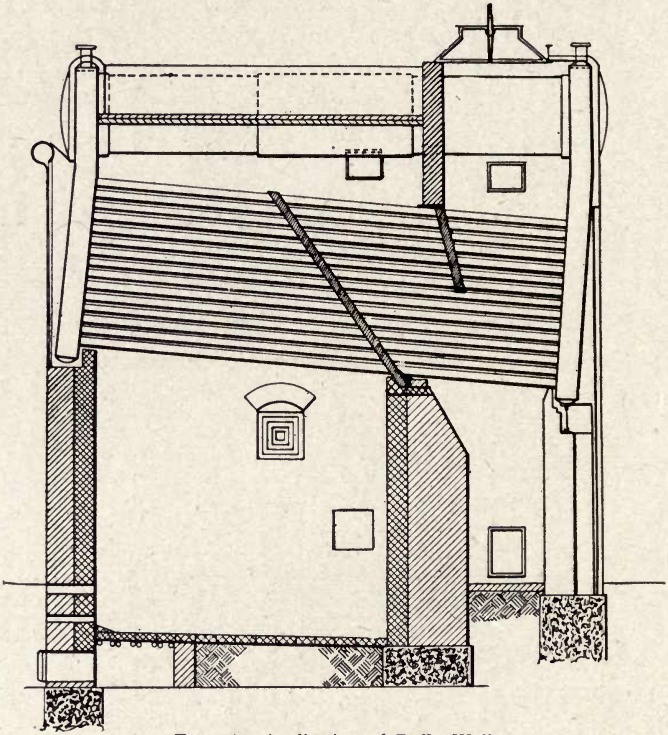

FIG. 44. Application of Baffle Wall.

The following essential requirements govern boiler and furnace design, according to the U. S. Bureau of Mines[a]: "(1) The heating surfaces must be arranged in such a way that the gas passages are long and of small cross section so as to give a small hydraulic mean depth, the hydraulic mean depth being defined as "the quotient of the area of the cross section of the gas stream divided by the perimeter formed by the boiler heating surface touched by the gases." An increase of the ratio of the length

a. Efficiency in the Use of Oil Fuel, Wadsworth, U. S. Bureau of Mines, Page 15.

of gas path to the hydraulic mean depth of the cross section of the path increases the efficiency of the boiler, because the hot molecules of gas will strike the heating surface oftener and will have to travel smaller distances to reach this surface. The

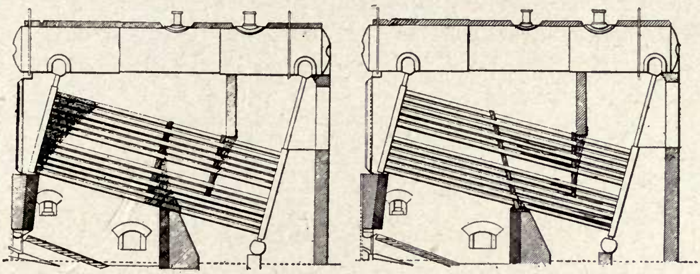

FIG. 45. Eliminating Dead Spaces with Baffles.

amount of heat given up to this surface by a given volume of gases will therefore be greater, and both boiler and furnace efficiency will be higher. This ratio can be increased, either by increasing the length of the gas path, or by reducing the hydraulic

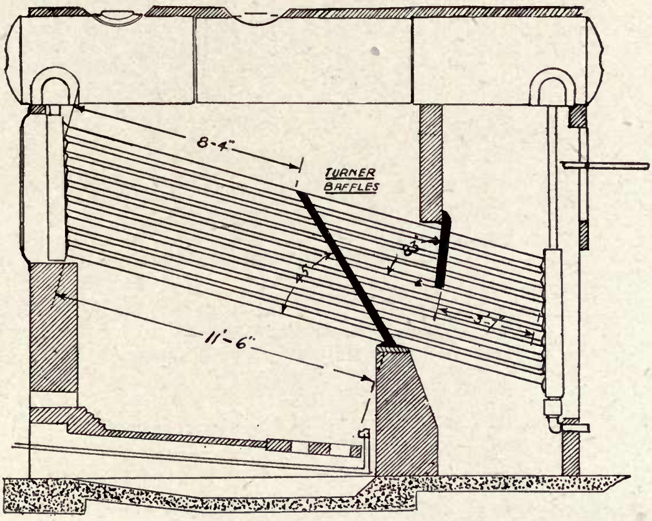

FIG. 46. An Inclined Baffle.

mean depth. The length of the gas path can be increased by either increasing the length of the boiler or by placing baffles and thus putting parts of the heating surface in series with one another. (2) The heating surface should "see" as much of the furnace as possible in order to increase the amount of heat imparted to it. This effect should not be so pronounced that the heat will be radiated to the heating surface too rapidly, for the furnace temperature would then be reduced below that required to support combustion. (3) The combustion space of the furnace must be so constructed that the burning particles of fuel shall be completely consumed before they can touch the relatively cold boiler surface; also this space should enlarge in the direction of the

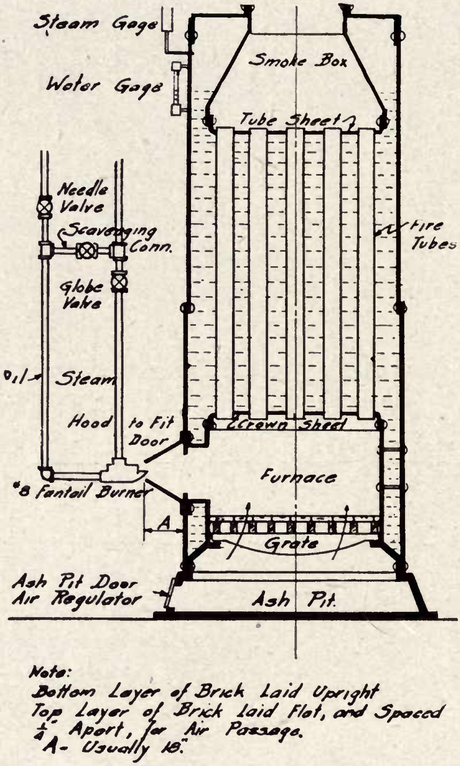

FIG. 47. An Oil-Burner Under a Vertical Tubular Boiler.
(Courtesy of John Foerst and Sons.)

flow of the heated and expanding gases, as the capacity of a furnace for burning oil is limited almost entirely by the furnace volume. The furnace should be lined with refractory brick, which when very hot radiate heat and assist the combustion of the fuel."

Mr. K. L. Martin, writing in Oil News,[a] discusses furnace

a Oil News, April 20, 1920, p. 17.

design for burning fuel oil as follows: "An authority on oil burning recently stated that the selection of a burner, while important, was secondary to the proper design of the furnace. Nine-tenths of the trouble experienced in the installation of oil burners could be avoided if the proper attention were paid to getting the combustion space large enough and to locating the walls opposite the burner far enough away so the flame does not strike them. A study of the best stationary boiler practice using steam atomizing furnaces would indicate that a ratio of one cubic foot of furnace volume should be provided for every boiler horsepower to be developed. In other words, a 500-horsepower boiler which is ex-

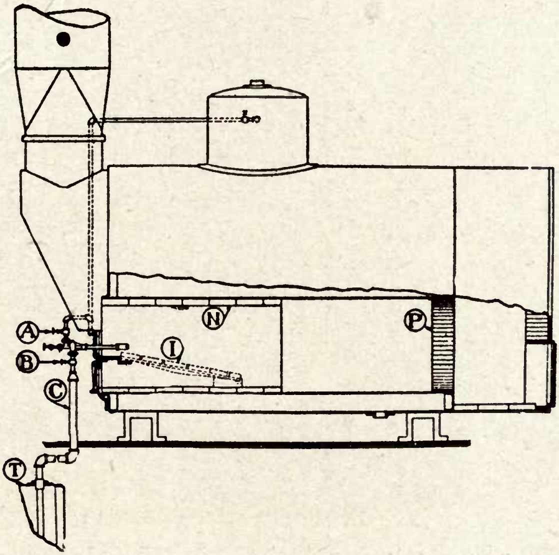

FIG. 48. Oil Burning System for Scotch Marine Boilers. (Courtesy of Vulcan Engineering Co.)

pected to run at 200 percent of rating should have approximately 1,000 cubic feet of space below the tubes. Furnaces have unquestionably been operated with proportionately smaller combustion space but the constant tendency of all furnace design, not only for oil but for powdered coal, and modern stokers is decidedly for larger combustion space.

This has resulted in higher boiler settings, fourteen feet from the floor to the bottom of the front header being common, and in the moving back of the bridge wall to a point ten, eleven, or even more feet from the front wall. As installations are frequently made in boilers where the height is fixed and usually too low, the most common way to get the necessary furnace volume is to move back the bridge wall. Until recently this has made necessary the laying of a horizontal shelf of T-tile on the lower row of tubes to joint the old cross baffle with the top of the bridge wall in its new position. This practice had several objections:

1. The T-tile must necessarily be small in order to get them in place and the resulting mosaic is full of open joints through

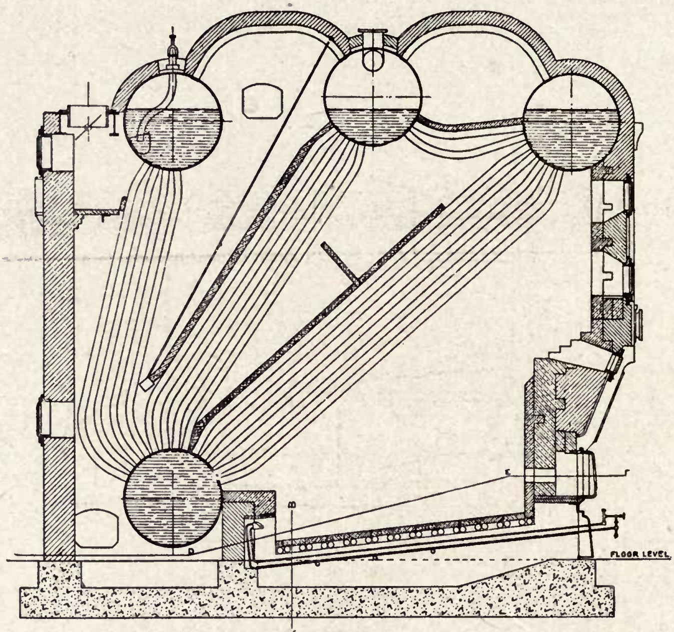

FIG. 49. Application of Oil-Burning System to the Stirling Watertube Boiler.
(Courtesy of Hammel Oil Burner Company.)

which a quantity of hot gases short circuit directly from the furnace chamber to the third pass and escape up the stack.

2. Those gases which do not escape travel along underneath the baffle until they meet the elbow formed by the horizontal and vertical baffles. The tubes at this point are already exposed to the radiant heat of the flame and to the gases rising directly from the front of the furnace, and the resulting concentration of the heat is often too much for the tubes and failures are frequent.

3. The horizontal baffle forms a shelf on which the soot is deposited and while this deposit is not as troublesome as in coal

burning boilers, it still has to be reckoned with. These troubles have been remedied by the design of a baffle wall so constructed that, while absolutely gas tight, it can be built at any desired inclination and the horizontal baffle entirely eliminated. One of the first applications is shown in fig. 44. This boiler was originally coal burning and was converted to oil burning in a manner all too frequent—by taking out the grates, laying a checker work and inserting a couple of burners through the front wall. At the end of six months they had replaced over a hundred tubes, the

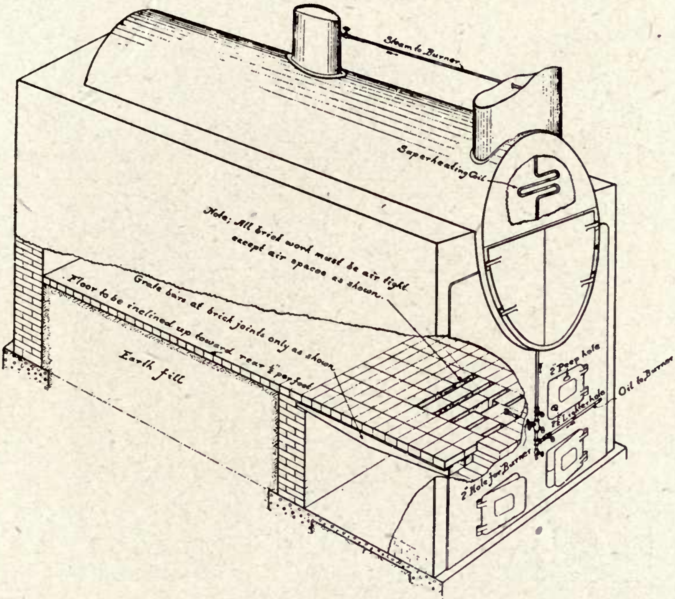

FIG. 50. Oil Burning System Applied to Return-Tubular Boiler. (Courtesy of Staples and Pfeiffer.)

remainder were bent so that the tubes in some rows were down on the tube in the next, the furnace linings had been replaced several times and complaints from the authorities as to the smoke were insistent. Neither the ratings nor the economies anticipated had been obtained. Realizing the opportunity for better design made possible by the new type of baffle wall, the bridge wall was moved back to a point ten feet from the front wall so that the flame no longer played upon it. The horizontal shelf and right angle baffle was replaced by a long inclined baffle wall starting from the top of the wall and making an angle of 45° with the tubes. At the same time the floor of the furnace was lowered 42 inches.

This furnace has now been in continuous service for nearly three years and the original linings are in the furnace. No tubes have been renewed except about three months ago. A few of the worst of the bent ones left in when the change was made, with the expectation they would soon burn out, were replaced. High ratings and satisfactory economy have been realized. No repairs to the baffles have been necessary. It will be noted that the wide

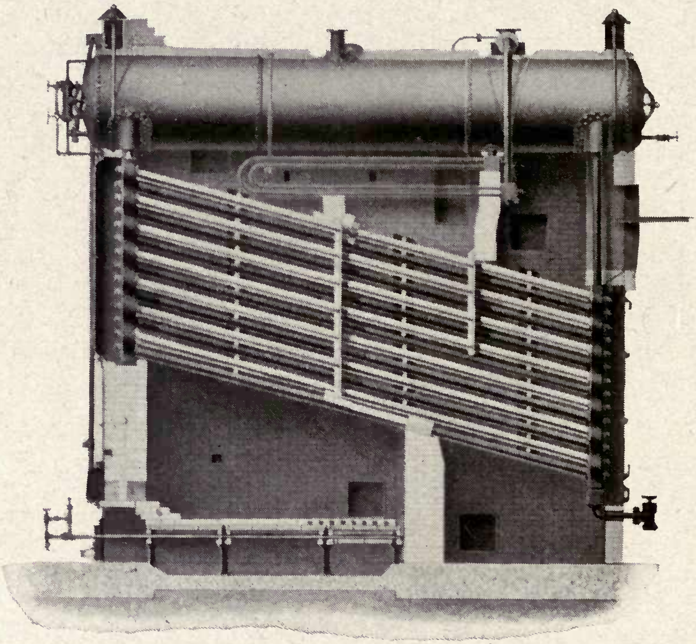

FIG. 51. A Babcock and Wilcox Oil Furnace, Patented.

open throat of the first pass gives every opportunity for the radiant heat from the flame and the reflected heat from the furnace walls and floor to strike the tubes. The wide opening also means a low velocity for the gases and abundant time for their heat to be transmitted through the steel walls of the tubes to the water inside.

The gases are cooled as they pass by the tubes and naturally shrink in volume and tend to draw away from the front header, leaving a dead space at its top. The inclined wall contracts the space as the gases cool, so that they need every cubic inch of space to get through and every square inch of heating surface is flooded with hot gas. This action is continued through the second and third passes. The result is shown in fig. 45.

In another installation a low setting had been used in connection with coal fires. Before the existence of the new baffle was known, the bridge wall was moved back, a horizontal shelf built and a back shot burner installed. At the end of 54 days they had been unable at any time to develop more than rating for the boiler, and they had lost 12 tubes. The inclined baffle (fig. 46) was installed in a similar boiler alongside the first as an experiment and at the end of 57 days no tubes had been replaced and they had carried a load averaging 200% of rating. As this meant a development of 100,000 more horsepower per year per boiler, the first boiler was immediately rebaffled and has since given equally good results."

The application of fuel oil burners to any type of furnace is easily performed. Fig. 47 shows an oil burner under a vertical tubular boiler. Fig. 48 shows an oil-burning system for Scotch Marine boilers. Fig. 49 shows an oil-burning system applied to the Stirling water-tube boiler and fig. 50 to a return-tubular boiler. Fig. 51 shows a Babcock and Wilcox Oil Furnace, patented.

CHIMNEY DESIGN

The same procedure is gone through in the design for stacks for oil fuel firing as for coal burning. The required draft in the furnace at maximum overload in each case is obtained by the necessary height and the maximum volume of gases generated determines the proportion of the area of the stack. When coal is burned there is seldom any danger of too much draft, but the economy of oil-fired furnaces is greatly affected by excessive draft and for this reason the various draft losses through the boiler and breaching must be estimated very carefully. A bed of coal on the grate occasions loss of draft, but with oil fuel this loss is negligible and in addition on account of the smaller volume of gases discharged per boiler horsepower hour, the pressure loss through the boiler will be less than with coal. To a more or less degree the action of the burner itself acts as a forced draft. For this reason both the height and area of a stack for any given capacity of boiler will be less for oil firing than for coal firing. Mr. C. R. Weymouth[a] has prepared the most authoritative table for proportioning stacks for oil fuel. The data prepared by Mr. Weymouth are given in Table 14.

TABLE 14.—STACK SIZES FOR OIL FUEL

Stack Diameter, Inches.	Height in Feet Above Boiler-Room Floor					
	80	90	100	120	140	160
33	161	206	233	270	306	315
36	208	253	295	331	363	387
39	251	303	343	399	488	467
42	295	359	403	474	521	557
48	399	486	551	645	713	760
54	519	634	720	847	933	1000
60	657	800	913	1073	1193	1280
66	813	993	1133	1333	1480	1593
72	980	1206	1373	1620	1807	1940
84	1373	1587	1933	2293	2560	2767
96	1833	2260	2587	3087	3453	3740
108	2367	2920	3347	4000	4483	4867
120	3060	3660	4207	5040	5660	6160

Figures represent nominal rated horsepower; sizes as given are good for 50 per cent overloads. Based on centrally located stacks, short direct flues and ordinary operating efficiencies.

[a]Trans. A. S. M. E., Vol. 34.

CHAPTER VIII

TYPES OF FUEL OIL BURNERS

The first recorded attempt to use oil as a fuel was in 1861, when Werner, a mechanic employed in a refinery in Russia, burned the residuum obtained from the refinery in an open furnace. The desirability of a liquid fuel was obvious and subsequent to Werner's attempt, each year produced its quota of designs for oil burners until at the present time there are on file in the United States, British and Continental patent offices several thousand designs of oil fuel burners. Very few of these patents were designed in accordance with the fundamental principles which should underlie such devices. The main function of a burner is to atomize the oil thoroughly so that it is broken up into very small particles forming a mist in which each particle of oil is surrounded with an envelope of air ready for immediate and complete combustion. The thousands of designs of fuel oil burners which differ from each other in minor respects may be divided into three major classifications:

(1) Vapor burners.
(2) Mechanical burners.
(3) Spray burners.

VAPOR BURNERS

The report of the U. S. N. "Liquid Fuel Board" states that the impossibility of successfully operating burners designed on the principle of superheating the oil to a point bordering on gasification, has been both theoretically and practically demonstrated. The conclusions in regard to such burners expressed by Commodore Isherwood many years ago holds true now as then. The liquid oil has, in all cases, to be transformed into oil gas before it can be burned. This transformation can be made by the direct application externally of heat to the liquid, but the temperature of the oil on the vaporizing surface is higher than the temperature required to decompose it, the result being deposition of solid carbon in the form of coke, which soon fills the vaporizing vessels and renders them useless. This coke is frequently so hard that cold chisels can scarcely detach it, and if thrown into a fire even in small fragments it burns with excessive slowness, like graphite. Whenever the vaporizing vessel is subjected to a high temperature, like that of a boiler furnace, the decomposition of the oil and deposition of coke go rapidly on, so that in the course of a few hours any vessel of practicable size is filled by it. All apparatus exposed to anything like furnace or flame temperature will inevitably fail from these causes in the future, as they have in the past.

MECHANICAL BURNERS

Among the thousands of oil burners which have been designed there are many which affect vaporization by entirely mechanical means. Since the early days of oil burning, various plans have been proposed to effect vaporization by entirely mechanical means. Early inventions contemplated the use of oil running over surfaces exposed to the action of flames and the burning taking place directly on the exposed surface of the oil.

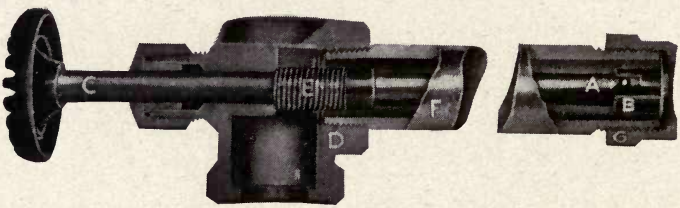

Fig. 52. A Mechanical Oil Burner.

All such plans proved decidedly inefficient owing to the fact that the air supply could never be brought to the burning surfaces of oil in quantities sufficient to effect complete combustion. Consequently all mechanical burners operating on that plan have been long since abandoned. The next field of invention that gave indication of success was to design burners in which the oil would be sprayed positively by mechanical action. Mechanical action can be resorted to, for the purpose of spraying oil by two general methods: First, to force oil outward under considerable pressure from a properly formed orifice, by the action of a special pump; second, by whirling or flinging the oil outward from a rapidly revolving mass or burner head. Figure 52 shows a mechanical burner which can be regulated very closely by means of the adjusting rod. With all mechanical burners the tips are required to be very small in the diameter of orifice, usually not over $\frac{1}{16}$ of an inch. The objection to burners of this type, as compared with the steam-atomization type, is the equipment required. Also, the general conical shape of the flame and the tendency toward blast action frequently requires change in the furnace to insure successful use. Professor Jiles W. Haney of the Department of Mechanical Engineering, University of Nebraska, writing in Oil News,[a] has the following to say concerning mechanical burners: "A mechanical burner atomizes the oil by giving it a centrifugal throw through small slots tangentially placed in the burner. The air is fed in around the burner so that it assists in breaking up the oil. The oil, heated almost to its flash point, is pumped to the burner under pressure and as it passes a central spindle, spirally grooved, a rotary motion is given to the oil causing it to fly into a spray by centrifugal force on issuing from the nozzle. The particles of oil are burned when they come in contact with the necessary air to effect combustion. This type of burner has the prime advantage of returning the steam used by the pumps and heaters as feed water to the boilers. The steam used for operating it is much less than that for other burners, ranging from ¼ percent to 1 percent of the total steam generated. These considerations have made its use in marine work quite general, and in stationary plants where feed water is an important item. The ease of control is another important advantage of the mechanical burner. For a given boiler capacity a greater number of these burners are installed than in the case of steam atomizing burners; the number of burners in operation varying as the load on the boiler. This scheme can be worked very satisfactorily since each burner has its individual air supply, which also can be shut off with the burner. This cannot be done when the main air supply comes through a checkerwork at the bottom of the furnace. Another control method is that of changing the pressure of the oil supplies to the burner. A good burner will atomize moderately heavy oil with an oil pressure varying from 30 to 200 pounds per square inch; then since the rate of flow of the oil discharged through a given orifice is proportional to the pressure on the oil at the orifice, a low rate of flow will occur with a low pressure and a high rate of flow will result with a high pressure. The pumping equipment can be connected up so that it will automatically control the rate of flow of the oil to the burners as the load varies."

a. Oil News, February 20, 1920, page 16.

SPRAY BURNERS

In spray burners the oil is atomized by a blast of steam or compressed air. The most efficient burner for any purpose is the simplest possible piece of mechanism using the least possible amount of steam or air for atomizing purposes. An analysis of the various types of spray burners made by the U. S. N. "Liquid Fuel Board" shows that five general classes will cover practically

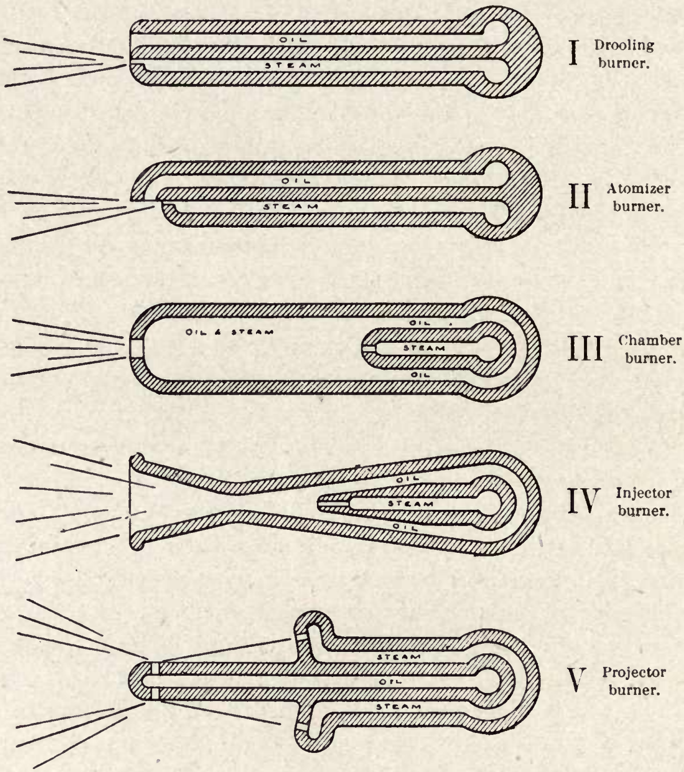

FIG. 53. Classes of Spray Burners.

all the main features of construction. These five classes of oil burners may be thus grouped:

1. Drooling burner.
2. Atomizer burner.
3. Chamber burner.
4. Injector burner.
5. Projector burner.

These five classes are shown by fig. 53, in which each burner is pared down to its very simplest elements of construction, leaving out all unnecessary features of manufacture or detail which might be regarded as merely accessory.

1. Drooling burner.—The name selected for this burner, while perhaps unusual, best expresses its function as seen from the diagram; the oil simply oozes out, or properly "drools" out, at the orifice over and on to the steam jet. In this case the drooling oil is simply carried away on a jet of flaring steam. The action is supposed to be as follows: As the steam issues forth it expands within the layer or film of oil which is being carried into the air by the fire box. It may be thought that this rather rough method of effecting vaporization would hardly be possible or satisfactory; yet as large numbers of these burners have been and are in actual use, they can not be regarded as crude or unsatisfactory.

2. The Atomizer burner.—In this burner the oil is brought through an orifice from which it is swept off by a brush of steam or air. It is, in short, a principle made use of in an ordinary cologne sprayer. This form of spraying or atomizing is a very old invention, and its capabilities for spraying into a fine mist have long been appreciated.

3. Chamber burner.—In this burner the oil and steam are more or less mingled within the body of the burner and pass out from the tip or nozzle as a mixture, and then, owing to the expansion of the steam, the oil is rapidly broken into minute particles. Burners of this type are simple in construction and have been carried through a large range of design.

4. Injector burner.—Burners of this type are analogous to the injector often used for boiler feeding and similar purposes. Here the steam and oil rising, each through its own passage, mingle within cone-shaped passages, and as a mixture passes through a contracted nozzle, and then outward through a reversed flaring cone. Burners designed on these lines have the principle common to injectors in general, that they can draw or suck the oil to them and force the mixture of steam and oil outward at considerable velocity. Burners of this type have been in use for forty years or more on the railroads of Russia and have become with that nation what might be regarded as a standard type.

5. Projector burners.—In burners of this type the oil is pumped to the oil orifice and from there is caught by a passing gust of steam and blown off. This might be regarded as a sub-

classification of No. 2, the atomizer burner, except for the fact that the brush of steam is located some distance from the oil orifice, and this sweeping brush of steam, as usually constructed,

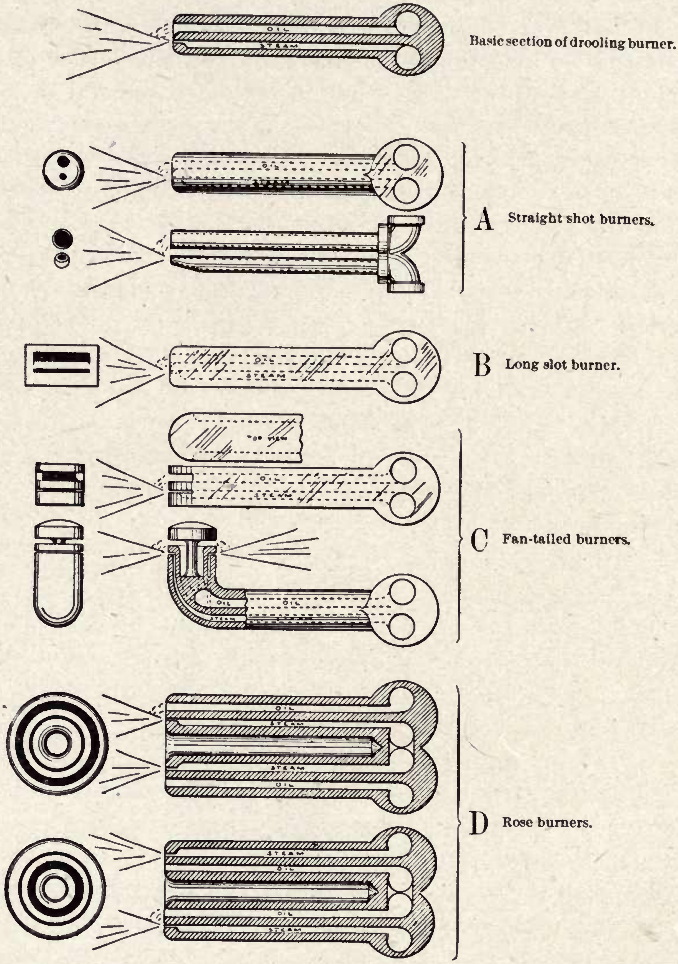

FIG. 54. Possible Modifications of the Drooler Burner.

is arranged to entrain a certain amount of air further to aid in spraying and in combustion.

By changing the pressure on the atomizing medium or by some slight variation of construction a long or short flame of special advantage for some particular purpose, may be produced in the first four of the types described above. As an example, the possible modifications of the drooling burner are shown in fig. 54. In this illustration the first sketch shows the basic form of the drooling burner. This subdivides into four special classes designated as A, B, C, and D. In form A is shown the drooling burner made in its simplest possible form, the upper view showing simply two drilled holes, the larger for oil and the smaller for steam, while the lower view shows two pipes in a double T-elbow, the larger pipe being for oil and the smaller for steam. Burners have often been made in this exceedingly elementary form, and will give results without any further recourse to mechanism. For convenience, this subdivision A is termed as "straight shot burners," due to the fact that the flame formed will have considerable length. In form B the basic section of the drooling burner is developed into a class which gives two long slots. In this form a large number of burners have been constructed, and in another part of this report results of tests are given on the Santa Fe burner, which has been largely used on a railroad of that name. In this simple form of a box-shaped casting these burners have gained a wide use, especially for railroad work. The construction is of course crude, but the results from a practical standpoint have been quite satisfactory, due to the fact that there are no complicated parts, and it is almost impossible to choke up any of the openings even with quite a dirty oil. Where burners are required to use a very heavy oil or residuum, or even a tar, these burners will always operate. This form B, which, for convenience, has been termed the long-slot burner, can be developed into the additional form C, or a fan-tailed burner. In form C there are two burners which can be devised. The first form, in which the fan-tailed effect spreads through but a small arc of a circle, and the second form, in which the fan-tailed effect is extended so as to cover the arc of the entire circle. The first form will cover a large amount of surface in a wide or square firebox, while with the second form the burner can be placed in the center of a grate and the flame will extend outward in the form of a continuous sheet and cover the entire firebox or grate area, such uses being desirable, for example, in the fire box of vertical boilers, such as fire engines, etc. The last form or modification, form D, can be developed from the basic section of this drooling burner by conceiving that the section is revolved around an axis parallel with the burner axis. By revolving the section around an axis on the steam side there will be derived a burner of the style shown in the upper part of the pair of form D, or by revolving the basic section around an axis near the oil side we get a form of burner shown as the lower one. Either of these two burners, while apparently very different in form from the basic section, yet are nothing more or less than a development of the original type. Burners of this style should probably only be used where very heavy consumption of oil is required. In heavy metallurgical operations, brick kilns, and where a large volume of flame is desired such burners have a wide field of usefulness.

Practically all of the basic types can be further modified by special design of their tips or orifice, thus leading to still greater variety and often to greater improvement in their spraying qualities. These modifications of tips can be reduced to a series of classes independent of the other possible mechanical arrangements of the burners. Fig. 55 shows types of burner tips. Form 1: The design of the tip is in itself a matter of much moment, as the configuration of the tip edges has a very important physical effect on the formation of the spray, and whether the material which it is intended to spray is forced through by steam, compressed air, or even by the effect of its own pressure supplied by a pump, the edge over which the spray last passes has a determining effect on the state of subdivision of the spray. In form 1 is represented an ordinary nozzle with a sharpened edge at the point of exit. If a proper angle is selected for this edge, and the edge itself is well sharpened, the outgoing stream instead of passing out in a straight line, as from a hose nozzle, is caused to diverge, and if divergence ensues, of course there follows an expansion in the volume of the outgoing liquid which causes a condition of more or less subdivision of the particles of the fluid. In form 2 is shown a design of orifice in which this effect is heightened by introducing a cone in the center of the conical orifice. The physical reason why this increased divergence is secured is due to the fact that the cone takes the place of any streams of oil which in the first case had the tendency to travel in the straight lines of the solid core of fluid. All the lines of fluid traveling down the cone surface meet in collision at the edge and tip of the cone and rapidly expand owing to the pressure which was behind them. In form 3 there is again indicated the same type of sharpened cone-shaped orifice, but outside of this is placed a diverging cone upon which the outgoing spray strikes and receives a greater amount of divergence than the orifice edges would alone have produced. This diverging cone is usually placed with its stem extending within the orifice, although at the right of the diagram is shown a case where the diverging cone is supported from the outside. The amount of divergence effected

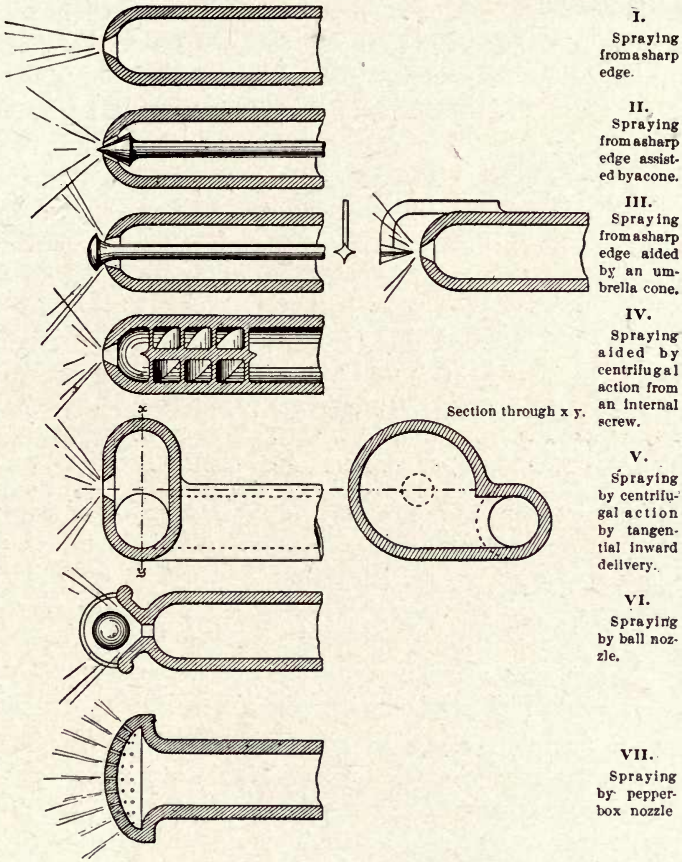

FIG. 55. Types of Burner Tips.

by this cone can be controlled to any extent by the position or shape of the diverging surface of the cone. In form 4 there is shown an orifice similar to form 1, but increased divergence of the cone of spray is obtained by circulating the fluid in a rotary manner before issuing from the sharpened orifice, the physical result of which is that as soon as the fluid leaves the orifice the effect of centrifugal action is manifested to fling the oil tangentially outward to some distance. In the diagram, as shown, this centrifugal effect is obtained by passing the fluid through spiral passages. Form 5 represents the original style of orifice, but the casing is so shaped as to obtain the rotational effect of the previous tip by admitting the fluid tangentially to the interior of the chamber. The effect on the resulting cone or spray is the same as in the previous example. Form 6: The type of nozzle is changed by inserting a ball in the outgoing current of spray, thus mechanically breaking up the action by requiring the spray to strike the ball, this being nothing more or less than the old familiar type of the dancing ball, long made familiar in water nozzles and pneumatic nozzles as a curiosity. Its effectiveness as a spraying agent is probably no greater or as great as a well-designed and proportioned orifice of form 3. Form 7 represents a class widely different from any of the preceding, which for lack of any other properly designative term might be called the "pepper-box nozzle." Its effectiveness for a certain class of burners may be made very great, but it always suffers under the great disadvantage of a multitude of small holes, which are exceedingly liable to become choked up by foreign matter or by the hydrocarbons formed at the tip of a burner while in action.

It is understood, of course, that in the description of types of burners just given either steam or air may be used as the atomizing agent. Steam is generally employed for stationary boilers and locomotives. When steam is used as the atomizing agent no auxiliary apparatus such as air compressors or oil pumps are required. Compressed air is most valuable in the case of a battery of boilers where high efficiency is essential.

Discussing the subject of atomization, W. N. Best says:[a] "Compressed air or steam is preferable to low pressure air because it requires power to thoroughly atomize liquid fuel. With low pressure or volume air, you are limited to the use of light oils, whereas with compressed air or steam as atomizer, you can use any gravity of crude oil, fuel oil, kerosene or tar which will flow through a ½-inch pipe. For stationary boilers, steam at boiler pressure is ordinarily used to atomize the fuel. In furnaces the most economical method of operation is the use of a small quantity of compressed air or dry steam through the burner to atomize the fuel, while the balance of the air necessary for perfect com-

a. Science of Burning Liquid Fuel, Best.

bustion is supplied independently through a volume air nozzle at from 3 to 5 oz. pressure. Every particle of moisture which enters a furnace must be counteracted by the fuel and it is therefore essential, if steam is used as atomizer, that it be as dry as possible. It is folly to attempt to use steam as atomizer on a small furnace, especially if the equipment is located some distance from the boiler room, for oil and hot water do not mix advantageously. Numerous tests have proven that with steam at 80 lbs. pressure and air at 80 lbs. pressure, by using air there is a saving of 12 percent in fuel over steam, but of this 12 percent it costs 8 percent to compress the air (this includes interest on money invested in the necessary apparatus to compress the air, repairs, etc.), so there is therefore a total net saving of 4 percent in favor of compressed air."

Spray burner systems are classed as "high pressure" when the oil and steam (or air) are supplied to the burners under a pressure of over 2 lbs. per sq. in. and as "low pressure" when the pressure is less than 2 lbs.

Mr. S. D. Rickard, writing in Oil News,[a] says that the most essential points in an oil-burning system are: "1. That it supply oil in sufficient volume to the burner in a clean and properly heated condition, and under a constant and automatically regulated pressure, free from pulsations.

2. That it supply air in sufficient volume to the burners (when of that type) in a clean and fresh condition, and under a constant and automatically regulated pressure, free from pulsations.

3. That it supply steam to the burners (when of that type) in a dry, hot state, and under sufficient pressure.

4. That the air and oil supply be connected, or co-ordinated, in some way so that should the air supply fail, the oil supply will be instantly cut off.

The burning of oil is in reality the continuous feeding of two ingredients (oil and air) in proper proportion into the combustion chamber in such a manner that a chemical mixture will be secured and good combustion will be the result. It will be appreciated that whenever the oil or air pressures are not constant, or pulsate, it is impossible to secure good combustion. In short, whenever the oil or air supply pulsates, it is safe to say that just

a. Oil News. May 5, 1920, p. 18.

50 percent of the time good combustion is not obtained. The pressures of oil and air must also be automatically regulated; or otherwise, whenever a burner is started up or shut down it will be necessary to adjust all of the other burners in the system. It will also be appreciated that when wet steam is fed to a burner an excess of oil must be burned to overcome the cooling effect of this water and convert it into steam."

CHAPTER IX

FUEL OIL IN STEAM NAVIGATION

Dr. George Otis Smith, Director of the U. S. Geological Survey, in an address before the American Iron and Steel Institute, May, 1920, states that the requirements of the American Navy and the new Merchant Marine present a priority demand on fuel oil. Dr. Smith said: "Admiral Griffin, the chief of the Bureau of Steam Engineering of the United States Navy, informs me that the oil-burning vessels ready for service aggregate more than 6,000,000 horsepower and that other vessels under construction will bring this total up to nearly 9,000,000 horsepower. The navy now needs 8 million barrels of fuel oil a year, yet this figure is small compared with the requirements of the Shipping Board, which are stated by Mr. Paul Foley, its Director of Operations, as 40 million barrels for 1920 and 60 million for 1921. If the American flag is to fly on the seven seas the motive power to carry it must be assured, and here is one demand for fuel oil which alone equals the present output of our refineries for about four months. Surely no American with vision wishes to contemplate even the possibility of a shortage of fuel oil that would endanger the immediate availability of these battleships, cruisers, and destroyers or interfere with the successful operation of the passenger and freight steamers in the construction of which our Nation has invested so many million."

All of the advantages inherent in oil burning on shore are applicable to its use in steam navigation. On an equivalent bunker weight the higher calorific value of fuel oil as compared to coal increases the ship radius of action by 50 percent. A ton of coal occupies 43 cubic feet, while a ton of oil occupies 36 cubic feet, and, consequently, with equivalent bunker space the ship's radius of action is increased 80 percent and this advantage can be greatly increased by carrying fuel oil in double bottom tanks. Ship Building and Shipping Record states that during the war it was found possible to utilize the double bottom for storing oil without any great alterations. But there are stringent rules laid down by the registration societies and the Board of Trade which must be conformed with. The flash point of oil fuel is not to be less than 150° F., according to the former, while the latter require a minimum of 175° F. in the case of passenger vessels. Any double-bottom, peak, or deep ballast tank which is able to pass the

FIG. 56. "Coaling Ship."

ordinary watertightness tests can be used. Owing, however, to the spacing of rivets, they will probably not be oiltight, but if steps are taken to deal with any leakage which may occur, they can be accepted. To limit the wash from side to side the center line division must be reasonably oiltight, but it is sufficient merely to close the drainage holes by bolted plates. Lloyds require that the tanks should stand a head of water to the top of the filling pipes, the load waterline, or 12 ft., whichever the greatest. Special attention is required for all the piping and pumping arrangements, with the intention of preventing oil from finding an entrance into the machinery space, and draining the compartments as completely as possible. Coal bunkers will usually be found unsuitable in construction; it is, however, suggested that electric welding might be used with advantage. Both the B. O. T. and Lloyds require that special precautions be taken for dealing with leakage; the double bottom must be sheathing, with ceiling standing on grounds at least 2 in. above the tank top, and bulkheads must be closely sparred to prevent cargo from touching the plating and to allow leakage to drain freely to the gutters and wells. Oil must not be stored in a compartment adjacent to crew or passengers, and cofferdams must be fitted between oil and fresh-water tanks. Thus, although the details require careful treatment, the difficulties of conversion of existing ships are not great. From experience gained during the war, it is found that on no occasion has the cargo been deleteriously affected if the details have been thus considered."

The ability to force boilers with oil-fired furnaces to 50 per cent above normal rating without a great strain on the personnel is a decided advantage, and the quickness with which an oil-burning ship can get under way is a very important point in its favor for naval use. The U. S. Shipping Board, in announcing that 636 of the 720 vessels now under construction for the Emergency Fleet Corporation will burn oil fuel, justify their abandonment of coal as follows:

1. Less bunker space required, a barrel of oil being equal to one ton of coal, and occupying four-sevenths of the space. 2. Oil can be carried in spaces, e. g., the double bottom, not available for cargo. 3. Cargo can be carried where coal is now. 4. Greater despatch in bunkering, of special advantage in view of the shortage of ships. 5. No labor or machinery required to handle ashes. 6. No stoking, reducing the number of crew and labor costs. 7. Uniform pressure is easily maintained, insuring a steady speed, and reducing boiler depreciation due to uneven temperature.

In a 5,000-ton D. W. ship, 16 engineers are required for coal and 12 for oil; in an 11,000-ton ship, 27 and 18 men are required respectively.

The Shipping Board fleet of steamers is composed of approximately 10 million deadweight tons, of which 8 million tons are oil-fired. The Shipping Board has established bunkering stations at St. Thomas, Rio Janeiro, St. Vincent, Bermuda, the Azores, Brest, Dizerta, Constantinople, Colombo, Singapore, Manila, Shanghai, Durban, Sidney, Wellington, Honolulu and Panama.

The Tide Water Oil Company in "Fuel Oil" gives the following data from a report to the Naval Advisory Board: "A 5,000-ton deadweight coal burning ship, 2,000 rated H. P., steaming at 12 knots per hour, will require approximately 37 days' time and 1,060 tons of coal to make a round trip between New York and French channel ports. This shows that 21 percent of the ship's deadweight capacity would be required by her fuel. The same ship burning oil could make the trip in 34 days, and requiring only 584 tons of oil, or less than 12 percent of the ship's deadweight capacity for fuel. Thus an oil-burning ship's cargo capacity is increased 9 percent or 468 tons per voyage. By storing the oil in double bottoms, which is standard practice, a 5,000-ton deadweight capacity ship can carry 689 tons, or 27 per cent more general cargo per trip, than a coal-burning ship of equal deadweight. The speed of a 5,000-ton boat in continuous service has been increased 10 percent by changing its fuel to oil. This is largely due to steady steam and increased boiler capacity affording maximum and constant propeller speed. Hence, a further 10 percent of cargo goes to the credit of oil-burning ships during their steaming time only, all of which is a net gain The cost of handling oil fuel is about 70 percent less than that of coal, owing to the fact that the oil is handled mechanically and the ash handling is entirely eliminated. The fire-room crew is materially reduced, generally by one-half to two-thirds of the crew necessary for coal firing. Efficiencies of boilers are increased by 8 to 10 percent and steaming capacities from 35 to 50 percent, which is due to more rapid and perfect combustion obtainable. All of the foregoing saving features figure materially in the dollars and cents column."

"Coaling Ship" has always been regarded as a most arduous duty (see fig. 56). Ships of the "Wyoming" class in the navy

TABLE 15.—COMPARATIVE PERFORMANCES OF OCEANIC STEAMSHIP MARIPOSA, USING OIL AS FUEL.

OUTWARD TRIP.

Date	Voyage No.	Knots per day	Knots per hour	Revolutions per minute	Barrels oil per day	Oil per day, in tons of 2,240 pounds	Oil per hour, in pounds	Pounds of oil per knot	Knots per ton of oil	Distance per barrel of oil, in knots	Slip, per cent	Average temperature uptake (°F.).	Average temperature, superheater (°F.).
July, 1902.........	1	312.7	13.12	65.2	254.8	36.40	3,412	260.9	8.585	1.22	13.14	......	......
August, 1902......	2	309.9	12.96	63.4	226	32.28	3,013	233.3	9.60	1.37	9.9	548	360
February, 1904....	17	302.2	12.80	61	217	31	2,893	229.7	9.716	1.39	7.3	425	388
HOMEWARD TRIP.													
August, 1902......	1	332.7	14.05	70.91	302.0	43.18	4,026	286.3	7.818	1.111	12.8	......	......
September, 1902...	2	304.9	12.7	65.7	241	34.46	3,212	252.6	8.87	1.27	13.01	546	360
March, 1904.......	17	308.4	12.8	61.9	221	31.57	2,946	229.3	9.76	1.395	9.1	463	383

carry as much 3,000 tons of coal, which is lifted aboard by large electric and steam winches after large bags have been filled in the lighters or colliers. Coaling a ship is usually an all-day job and an "all hands" detail, whereas fueling on an oil burner is both clean and speedy. Fig. 57 shows the method of fueling with oil, and Fig. 58 shows a fueling station in the Orient.

Although oil had been successfully used under ship's boilers for a long time prior to 1904, it was the favorable report of the U. S. Naval "Liquid Fuel" Board in that year which gave a decided impetus to the use of fuel oil on the sea. The investigation of this Board was conducted with such scientific accuracy and its report was so comprehensive that the Board's findings still are regarded as irrefutable. The Board made an extended series of tests for the purpose of determining the relative value of coal and liquid fuel for naval purposes and, in addition, it made a careful study of the performance of the S. S. Mariposa of the Oceanic Steamship Company and of the S. S. Nebraskan of the American-Hawaiian Steamship Company, both vessels being fitted for oil burning. Table 15 gives the comparative performances of the Ocean Steamship "Mariposa" using oil as fuel.

It is interesting to compare the test of the Mariposa with tests of the 8,800-ton steel steamer West Conob. The report of the Conob's test was submitted to the author by Mr. C. W. Geiger and covers the six hours' builder's trial off San Pedro, California, on May 20, 1919. On this trial trip the West Conob's three boilers were under steam pressure of 200 lbs. The temperature of the oil to burners was 205 degrees, and that of the stack 460 to 475 degrees. The temperature of boiler feed water was 200 to 215 degrees. An average of 411.1 gallons of oil was consumed per hour.

The following data are taken from the log of the S. S. West Conob, on voyage 1, San Francisco to Honolulu:

Departure 9:14 a. m., San Francisco Lightship, June 13, 1919.

Arrived 4:26 a. m. Honolulu, June 21, 1919.

Average knots per hour, 11.1.

Average fuel per day, 211.2 barrels.

Average fuel per knot, .8.

Revolutions per minute, 79.5.

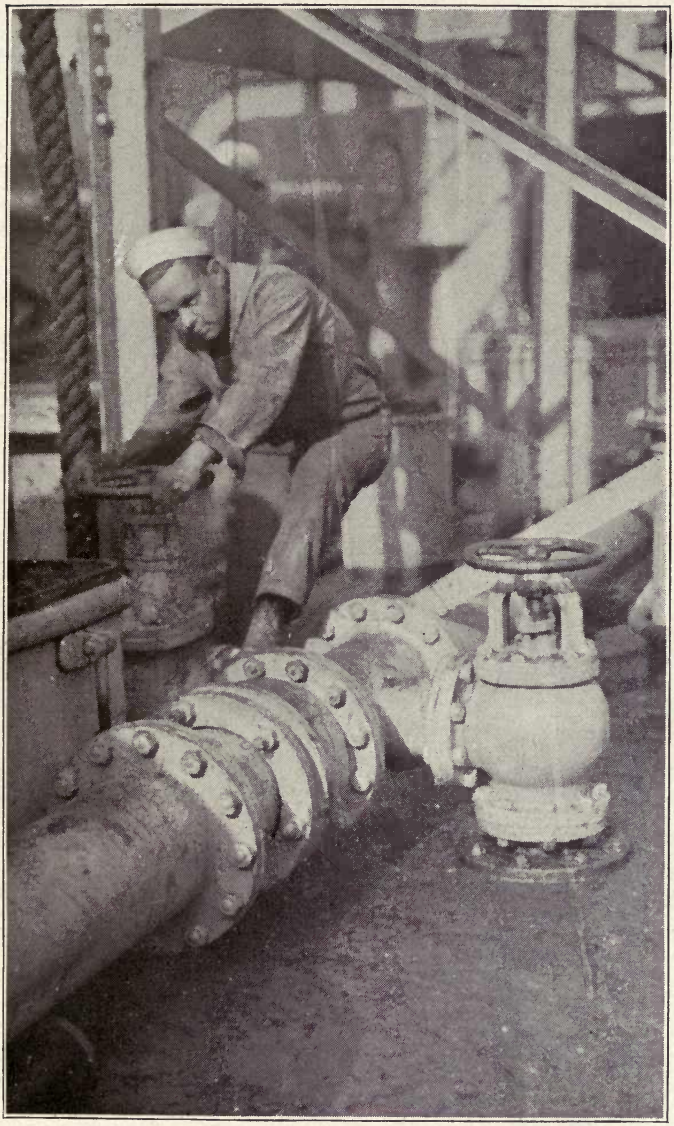

Fig. 57. Fueling With Oil.
(U. S. Navy Official Photograph)

The fuel oil capacity of the West Conob is 6,359 barrels in double bottoms; 1,100 barrels in after peak; 2,141 barrels in each of two deep bottom tanks; and 320 barrels in the two settling tanks, making a total of 12,060 barrels. The oil storage tanks were filled to capacity when the vessel started on her first voyage to Hong Kong. Nineteen hundred and ninety-three barrels of oil were taken on at Honolulu; 3,850 barrels were taken on at Hong Kong. On the return trip 2,100 barrels were taken on at Honolulu, the vessel having 1,047 barrels in the tanks when she arrived at San Francisco.

The West Concb is 423 ft. 9 inches in length over all, 29 ft. 9 in. depth and beam molded of 54 feet. Her displacement, light,

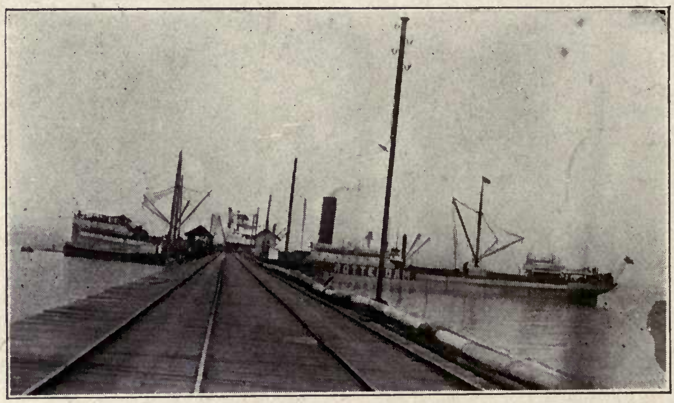

FIG. 58. A fueling station at Palik Papan, Dutch Borneo.

is 3,751 tons; loaded, 12,401 tons. She is equipped with a triple expansion reciprocating engine of the inverted type of 3,500 h. p. The cylinders are 28½ in. by 47 in. by 78 in. with 48-in. stroke. There are three Foster water tube boilers, each having a heating surface of 4,150 square feet, and 827 2-inch tubes and 52 4-inch tubes. The propeller is 17 ft. 1 in. diameter with a pitch of 15 ft. 3 in. and a developed area of 102 square feet. The designed speed is 11 knots an hour.

The vessel is equipped with the Coen system of mechanical oil burning equipment. There are two duplex oil pumps 6 in. by 4 in. by 6 in. with a capacity of 30 gallons each per minute. These pumps are mounted one above the other, each being large enough to supply all the burners, thus one set is always held in reserve. They draw their supply from the settling tanks through a 4-inch pipe. The oil is pumped from one settling tank at a time. The discharge pipes leading to the heaters are 3 inches in diameter reduced to 1 inch at the heater, of which there are three sets,

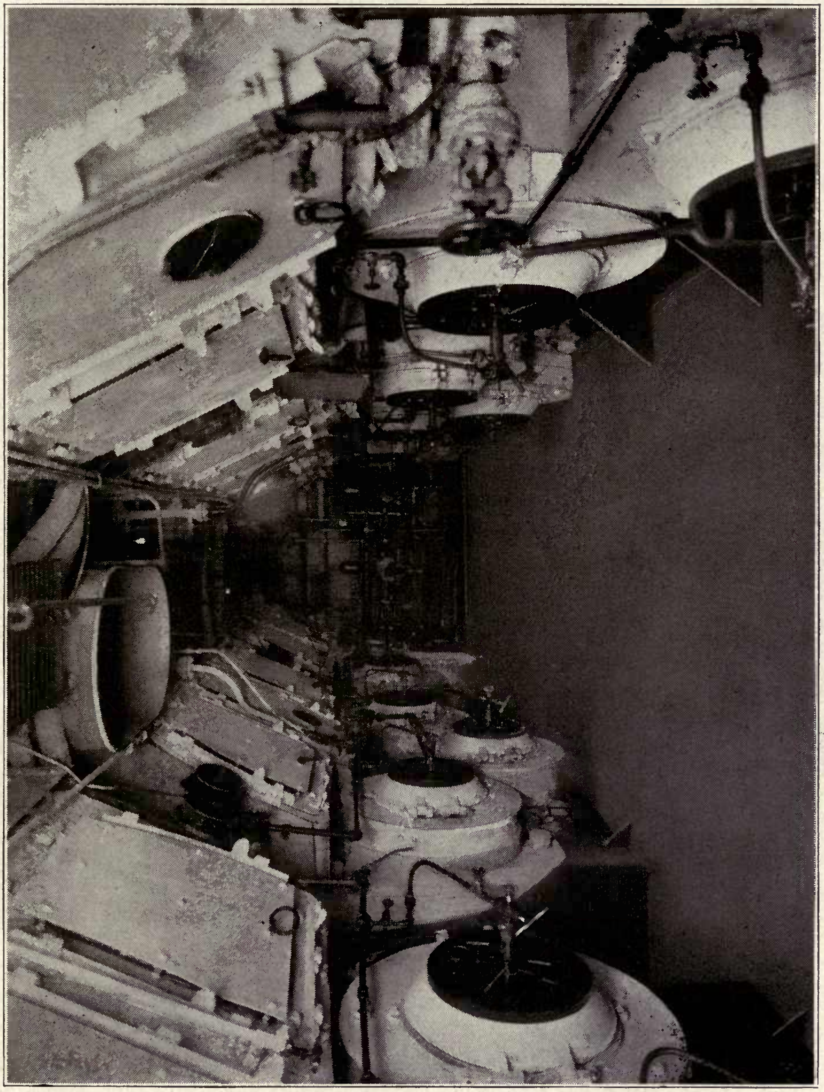

Fig. 59. Fire Room of S. S. Manoa.

with five heaters to a set. Two sets are operated at a time, the third being held in reserve.

The oil enters the heater unit between two shells and takes a spiral course upward to the space between the two shell heads from whence it flows down through the seamless steel coil and out to the discharge header. In the event of an operator's closing the inlet and outlet oil valves without cutting out the steam to the heater, thereby causing the dead oil in the unit to heat and expand to a pressure which might create a rupture, a safety valve is provided for each unit and set to operate before an excessive pressure can be attained.

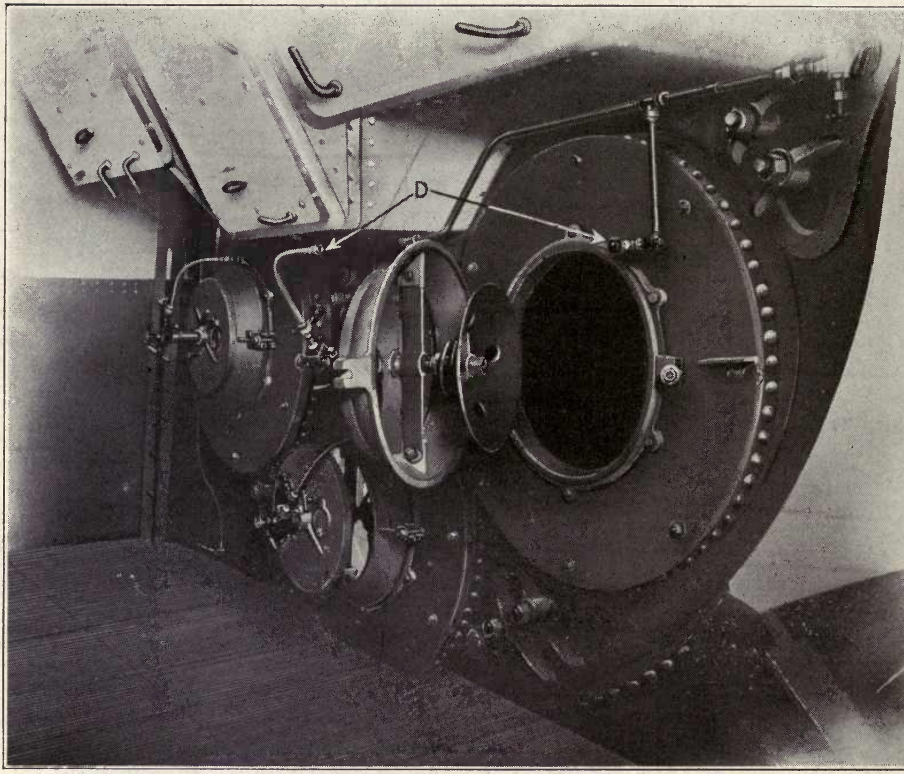

FIG. 60. Coen Hinged Firing Front for Scotch Marine Boilers.

Each individual coil is under control and can be cut in or out independent of the others. No cleaning is required except blowing out with steam. The inner shell being a floating member eliminates expansion and contraction strains. The cold oil entering and circulating between the inner and outer shells acts as an insulator, making covering of the units unnecessary.

A standard temperature for all fuel oils cannot be fixed for the "efficient temperature" will vary as the different oils vary in viscosity and gravity. However, a temperature ranging from 210 degrees F. to 230 degrees F. has been proven to be the most efficient stage for residuum fuel oil. Lighter oils require a much lower temperature. Heavy Mexican oils require a temperature ranging from 275 to 300 degrees F. The steam pressure to the heaters is reduced to 100 lbs. For stand-by the oil is maintained at a pressure of 30 to 35 lbs. and for full speed ahead 125 lbs. There are five burners to each boiler. The oil pipes leading from the heaters to the burners are 1½ inches in diameter and reduced to ⅜-inch at the burner. The burner consists of a special angle valve, a short piece of tubing, a tip, a cap to hold the tip in place and a steel rod running through the burner to provide means for regulating the discharge from the tip. With this burner, the fireman has at his immediate command not only means for regulating the size of his operating fire, but means whereby he can instantly substitute a stand-by and vice versa, with one quick turn of the burner valve wheel. During the noon hour when tied up at dock, all burners are shut off except one.

In starting a fire in a cold boiler, the fireman first sees that all valves in the burner feed lines are closed. He then cracks the valve in the return line, and starts the oil pump. He then admits steam to the oil heater and allows the oil to circulate through the lines until the thermometer shows the proper temperature. When the oil has attained the proper temperature, he closes the valve in the return line, and opens the dampers in the firing front and stack. He inserts a lighted torch directly in front of the burner tip and opens the burner valve wide. He then opens the valve in the burner feed line wide when the fire readily lights. Fig. 59 shows this system of burners which is installed in the Matson Navigation Company's steamer Manoa, and Fig. 60 shows the hinged firing front for a mechanical burner.

The Matson Navigation Company operates 7 oil burning steamers of their own between San Francisco and Hawaiian Islands, and nine Shipping Board steamers. The company's own steamers consume about 600,000 barrels of fuel oil yearly. The Matson steamer Matsonia has a fuel oil capacity of 21,000 barrels. This steamer consumes 10,000 barrels on the round voyage between San Francisco and Honolulu. The steamer takes on oil to her full capacity at San Francisco, and delivers the surplus into tanks at Honolulu for use by the steamers operated by the company for the Shipping Board, and for use of the company's own steamers in case they need it. The Manoa, with a capacity of 16,500 barrels, consumes 6,500 barrels on the round trip. This vessel also delivers the surplus into tanks at Honolulu for the same purpose as the Matsonia. Fig. 61 shows the oil-burning French S. S. Lieutenant de Missiessy, of the Compagnie des Messageries Maritimes.

The Staples and Pfeiffer oil-burning system has been in operation on a large number of steamers on the Pacific for many years. This system is somewhat different in operation from the Dahl and Coen systems, as the system atomizes the oil by means of steam or compressed air. The oil is heated and forced through the burners by pumps, and in addition steam or compressed air is introduced into the burner which atomizes the oil. (See fig. 62.) The following data are from the steam trials of the U. S. R. C. Golden Gate, which is equipped with the Staples & Pfeiffer oil-burning system:

Run, November 23, 1911.
BABCOCK & WILCOX WATER TUBE BOILER, TRIPLE-EXPANSION ENGINE.

Duration, hours		1.50	1.00
Water evaporated, totals for run lbs		8332.00	8013.00
Total equivalent, from and at 212 deg. F. lbs		9798.43	8098.76
Fuel oil corrected for moisture—total lbs		614.90	600.00
WATER PER HOUR—			
Main engine and aux	lbs	5320.66	7664.50
Oil pump	lbs	87.00	98.00
Oil burners	lbs	147.00	250.50
Total for all purposes	lbs	5554.66	8013.00
Total equivalent, from and at 212 deg. F	lbs	6532.29	9098.76
Fuel oil corrected for moisture per hour	lbs	409.90	600.00
Evaporation, lbs. water per bbl. oil	lbs	13.55	13.35
Factor of evaporation		1.176	1.135
Evaporation, lbs. water per lb. oil, equivalent	lbs	15.99	15.16
Total heating surface	sq. ft	2034.00	2034.00
Evap. per sq. ft. head surface, per hour, equivalent		3.21	4.47
Percent of total equiv. evaporation for atomizing oil		2.25	2.75
Efficiency of boiler	percent	82.55	78.50
PRESSURE BY GAUGE—			
At boiler	lbs	145.00	144.00
At engine	lbs	135.00	133.00
First receiver	lbs	21.00	36.00
Second receiver	lbs	1.00	4.00
Vacuum	inches	23.00	23.00
Oil to burner	lbs	45.00	45.00
TEMPERATURES F., DEGREE, AVERAGE—			
Feed	Deg. Fahr.	89.00	125.00
Stack	Deg. Fahr.	453.00	516.00
Fuel oil to burner	Deg. Fahr.	124.00	128.00
Main engine revolutions per minute		125.90	147.60
Total h. p. mach. eng. and aux		253.92	396.85
Horsepower of auxiliaries, estimated		17.10	19.54
Water per hour per H. P., equivalent	lbs	24.65	21.82
Fuel oil per hour per H. P., total		1.61	1.51
Fuel oil per hour per I. H. P		1.73	1.58

FUEL OIL—

Specific Gravity	0.952	Fire point	280.00
Degrees, Baume'	17.00	Calorific value B. t. u	18648.00
Flash point	190.00	Moisture	.005

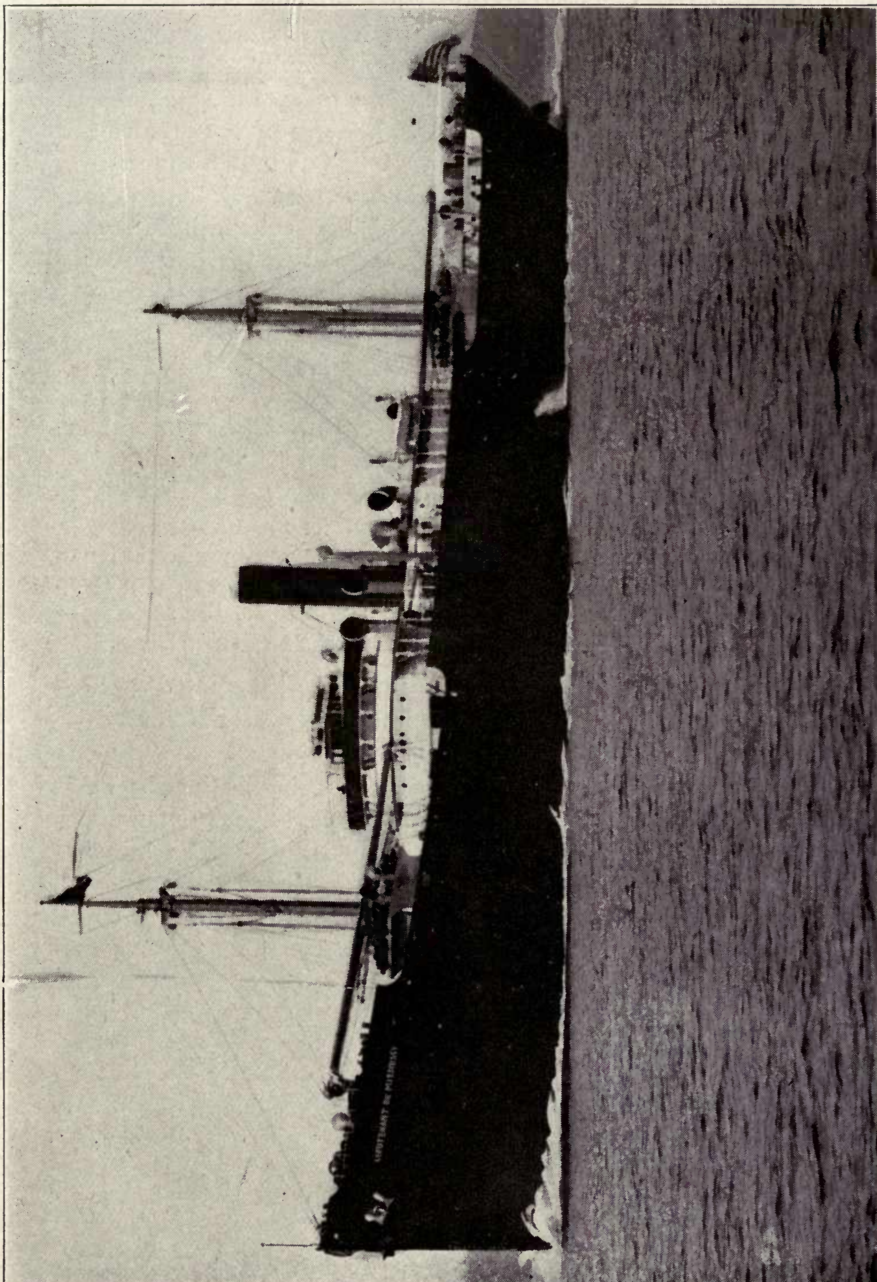

FIG. 61. The Oil-Burning French S.S. Lieutenant de Missiessy.
(Courtesy Coen Company, Inc.)

Probably nothing can illustrate the superiority of oil over coal as fuel for steamers, more clearly than the history of the Oceanic Steamship Company's steamers Ventura and Sonomo. These vessels were originally coal burners operating between San Francisco and Australian ports. Because of the disadvantages of coal as fuel these steamers were tied up in San Francisco Bay for over two years. They were converted to oil burners in 1915 by the Union Iron Works of San Francisco, and have been in operation between San Francisco and Australian ports ever since. It has never been necessary during these six years of operation to make any repairs to boilers.

The Ventura is equipped with eight boilers, 24 furnaces, 8,000 H. P. The Sonoma is of similar equipment. These steamers burn from 19,000 to 21,500 barrels on the round voyage, the distance for the round voyage being 13,475 miles. The total tank capacity is 18,290. This amount is taken on at San Francisco. At Honolulu a sufficient amount of oil is taken on so that the supply will total 16,500 barrels when leaving that port, and on the return trip sufficient oil is taken on at Honolulu so that there will be 4,500 barrels in the tanks, which is ample to bring the vessel to San Francisco, and still have a three days' supply on hand. These steamers are of 10,000 tons displacement each. The rated speed is 17 knots an hour, but they only maintain a speed of 15½ knots an hour on the trip to Australia and return.

The Shipping Board steamers are now being equipped with heating coils in the double bottoms so that the steamers may use the heavy oil which is found at certain points. The heavy Mexican oils especially require these coils so that the oil may be heated in order to be handled by the oil pumps. This will enable the steamers to be operated on any kind of oil.

CHAPTER X

OIL-BURNING LOCOMOTIVES

In 1882 Thomas Urquehart, Superintendent of Motive Power of the Griazi-Tsaritzin Railway of Russia converted 143 of the locomotives of this railroad from coal-burners to oil-burners and made service tests on them which showed that one pound of oil equaled 1.78 pounds of coal. The oil had a calorific value of 18,600 B. t. u. and the coal used, a Russian anthracite, contained 24,920 B. t. u.

In the year 1888, Dr. Charles B. Dudley presented to the Franklin Institute of Philadelphia a comprehensive paper dealing with the subject of oil fuel for locomotives. Dr. Dudley founded his conclusions largely on a series of experiments which had been conducted by the Pennsylvania Railroad Company. He determined that, based on the relative heat values of the fuels, one pound of oil was equivalent to one and three-quarters pounds of coal; while taking into account the various incidental economies due to the use of oils, one pound of the latter was practically equivalent to two pounds of coal. Dr. Dudley pointed out the following advantages which oil has over coal as a fuel for locomotives:

1. Less waste of fuel: First, from smoke and unburned gases which go out the smoke stack; second, cinders, which are carried through the tubes and deposited in the smoke box or exhausted from the stack; third, fuel, which escapes through the grates.
2. Economy in handling fuel.
3. Economy in handling ashes.
4. Economy in cleaning locomotives, the absence of smoke and cinders in using oil being the source of this saving.
5. Less waste of steam at the safety valve. The oil is under positive and practically instantaneous control, and with proper attention the working steam pressure of the boiler may be maintained under all conditions of operation without the safety valve being allowed to open. Steam lost through the safety valve simply means so much fuel gone

to waste. The occasional raising of safety valves cannot be prevented with the best handling of an ordinary coal fire.

6. Economy in cleaning ballast. The cinders thrown out of the smoke stack of coal-burning locomotives are not only a loss on account of not being burned, but also because they fall on the track and choke the ballast, especially where rock ballast is used, thus interfering with the drainage.
7. Economy of space in carrying and stowing fuel, as a pound of oil does not occupy as much space as a pound of coal and a higher heat value is obtained per pound of oil than of coal.
8. No fire from sparks.
9. Very little smoke and no cinders.
10. Possibility of utilizing more of the heat.

A report of the Indian Government on a comparison of oil and coal on the Northwestern Railway of India gives the following advantages of burning oil in locomotives: (1) Release of engines and rolling stock required for carrying coal; (2) saving cost of unloading and stacking coal and putting on tenders; (3) locomotives cleaner and more comfortable for the staff, and easier work for the firemen, also there is a saving of one fireman per engine, as Indian locomotives as a rule carry two; (4) saving of fuel during period locomotives are standing at stations or in yards; (5) rapidity with which steam can be raised; (6) larger blast pipes can be used to reduce back pressure in cylinders; (7) less wastage of fuel in transit and in stock and probably considerably less stolen; (8) absence of sparks and smoke when the admission of air, steam and fuel are properly regulated. No ashes to be removed from ashpan or smoke-box, no ashpits to be cleaned."

The recent determinations made by the Missouri, Kansas, and Texas Railroad of Texas are of interest.[a] This road figures its 1918 fuel (coal) cost around $6,250,000, and its 1920 fuel (oil) cost at less than $4,750,000, or a saving by substitution of oil for coal of approximately $1,500,000. Detailed investigation by experts have shown that 3½ barrels of oil are the equivalent of one ton of coal, and the cost of handling the oil is one cent a barrel.

a. Oil News, Sept. 5, 1919, p. 44.

Cost of movement of coal from mines to point of use averaged 4 mills per ton per mile last year. Fuel coal consumption aggregated 630,000 tons at average cost of $3.50 f. o. b. mines, or $2,200,000, and average handling cost was approximately 17.95 cents per ton, or nearly $111,000, and average transportation cost was 83.1 cents or around $513,500, a total of over $2,800,000. Oil cost is figured initially as follows, in round figures: Cost of oil, $1,320,000; handling, $21,500; transportation, $854,000; cost of oil used in heating, $65,800; total, $2,261,300 for 2,226,000 barrels. A report to this railroad on the waste of coal in locomotive consumption follows: "Coal in the first 24 hours after it leaves the mines will depreciate 2 percent on account of evapora-

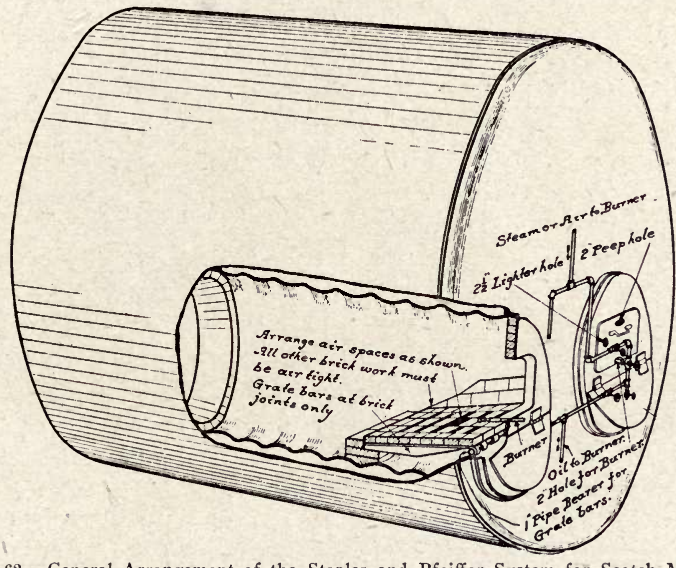

Fig. 62. General Arrangement of the Staples and Pfeiffer System for Scotch Marine Boilers.

tion of the moisture it contains. Investigation heretofore made also shows that the average 100,000 capacity car, in addition to running 2 percent short on account of evaporation, will average 1,000 pounds additional shortage on account of discrepancies in tare weights, mine weights, etc. There are further losses due to theft and loss in transit. No figures are available to show just what coal loses through deterioration in handling, and through storage, but it has been thoroughly established that every time coal is handled or moved it loses heat-producing value. Various authorities have agreed that there is an average loss equivalent to 5 percent between the mine and the locomotive due to the causes above enumerated, i. e., evaporation, theft, loss in transit, deterioration in handling, storage, etc."

Among the many foreign railways which have converted all or part of their locomotives from coal-burners to oil-burners are: The Austrian State Railways, Western Railway of France, Paris, Lyons, and the Mediterranean, Paris and Orleans Railway, South Russian Railway, Roumanian State Railway, Los Angeles Railway, Taltal Railway, Mexican Railway, Chilian Railway, Tehuan-

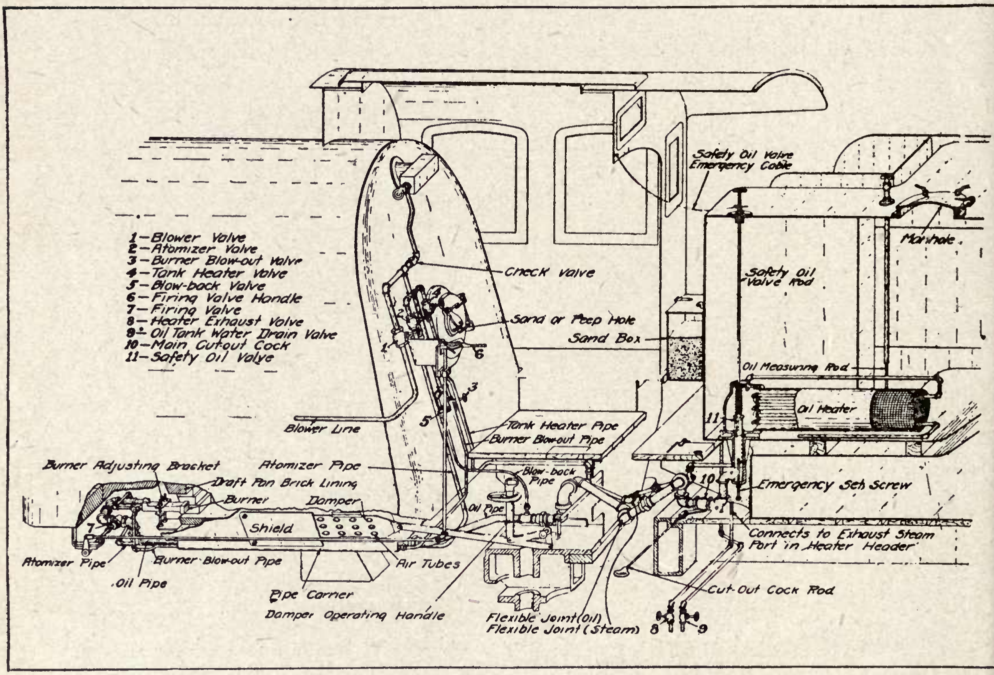

FIG. 63. Oil Burning Equipment as Applied to Santa Fe Locomotives.

tepec National Railway, and the Mexican National and Inter-oceanic Lines.

The United States Geological Survey[a] names the following railways in the United States which use fuel oil in their locomotives:

Arizona:
- Atchison, Topeka & Santa Fe Railway System.
- Southern Pacific Company.

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a. Petroleum in 1917, by John D. Northrop.

Arkansas:
- Kansas City Southern Railway Co.

California:
- Atchison, Topeka & Santa Fe Railway System.
- Los Angeles & Salt Lake Railroad.
- Northwestern Pacific Railroad Co.
- San Diego & Arizona Railway Co.
- San Diego & Southeastern Railway Co.
- Southern Pacific Co.
- Tonopah & Tidewater Railroad Co.
- Western Pacific Railroad Co.

Florida:
- Florida East Coast Railway Co.

Georgia:
- Central of Georgia Railway Co. (on Tybee district).

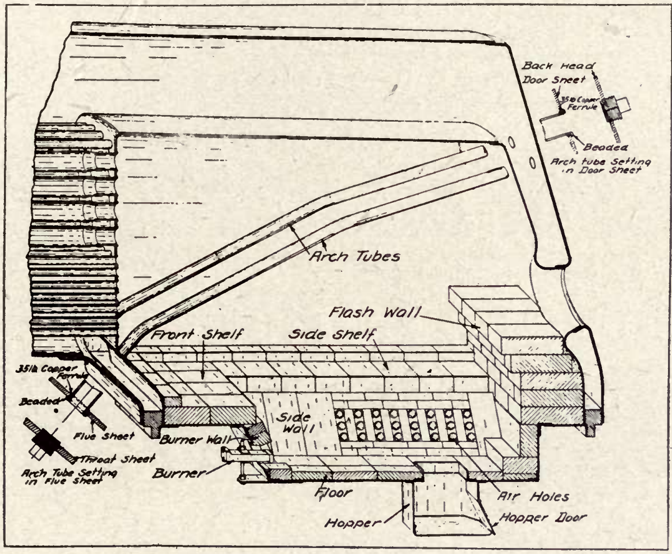


FIG. 64. Locomotive Firebox and Fire Pan Arrangement with Oil Burners.

Idaho:
- Chicago, Milwaukee & St. Paul Railway Co.
- Great Northern Railway Co.
- Oregon Short Line Railroad Co.
- Oregon-Washington Railroad & Navigation Co.
- Washington, Idaho & Montana Railway Co.

Kansas:
- Atchison, Topeka & Santa Fe Railway System.
- Kansas City Southern Railway Co.

Louisiana:
- Atchison, Topeka & Santa Fe Railway System.
- Houston & Shreveport Railroad Co.
- Kansas City Southern Railway Co.
- Louisiana Railway & Navigation Co.
- Louisiana Western Railroad Co.
- Morgan's Louisiana & Texas Railroad & Steamship Co.
- New Orleans, Texas & Mexico Railway.

Missouri:
- Kansas City Southern Railway Co.

Montana:
- Chicago, Burlington & Quincy Railroad Co.
- Chicago, Milwaukee & St. Paul Railway Co.
- Great Northern Railway Co.
- Oregon Short Line Railroad Co.

Nebraska:
- Chicago & Northwestern Railway Co.

Nevada:
- Atchison, Topeka & Santa Fe Railway System.
- Bullfrog Goldfield Railroad Co.
- Las Vegas & Tonopah Railroad Co.
- Los Angeles & Salt Lake Railroad.
- Southern Pacific Co.
- Tonopah & Goldfield Railroad Co.
- Tonopah & Tidewater Railroad Co.
- Western Pacific Railroad Co.

New Mexico:
- Atchison, Topeka & Santa Fe Railway System.
- El Paso Southwestern System.
- Southern Pacific Co.

New York:
- Delaware & Hudson Co. (in the Adirondacks).
- New York Central Railroad Co. (in the Adirondacks, including Old Forge and the Fulton Chain).

Oklahoma:
- Atchison, Topeka & Santa Fe Railway System.
- Kansas City Southern Railway Co.

Oregon:
- Great Northern Railway Co.
- Northern Pacific Railway Co.
- Oregon Trunk Railway.
- Oregon-Washington Railroad & Navigation Co.
- Southern Pacific Co.
- Spokane, Portland & Seattle Railway Co.

South Dakota:
- Chicago, Burlington & Quincy Railroad Co.
- Chicago & Northwestern Railway Co.

Texas:
- Atchison, Topeka & Santa Fe Railway System.
- Beaumont, Sour Lake & Western Railway.
- Fort Worth & Denver City Railway Co.
- Galveston, Harrisburg & San Antonio Railway Co.
- Galveston, Houston & Henderson Railroad Co.
- Houston, East & West Texas Railway Co.
- Houston & Texas Central Railroad Co.
- International & Great Northern Railway Co.
- Orange & Northwestern Railroad.
- St. Louis, Brownsville & Mexico Railway.
- San Antonio & Aransas Pass Railway Co.
- Texarkana & Fort Smith Railway Co.
- Texas & New Orleans Railroad Co.
- Texas & Pacific Railway.
- Trinity & Brazos Valley Railway Co.

Utah:
- Los Angeles & Salt Lake Railroad Co.
- Southern Pacific Co.

Washington:
- Bellingham & Northern Railway Co.
- Chicago, Milwaukee & St. Paul Railway Co.

Great Northern Railway Co.
Northern Pacific Railway Co.
Oregon Trunk Railway.
Oregon-Washington Railroad & Navigation Co.
Spokane, Portland & Seattle Railway Co.
Washington, Idaho & Montana Railway Co.

Wyoming:
Chicago, Burlington & Quincy Railroad Co.
Chicago & Northwestern Railway Co.

The quantity of fuel oil consumed by all railroad companies that operated oil-burning locomotives in the United States in 1917 was 45,707,082 barrels, a gain of 3,580,665 barrels, or 8.5 per cent over 1916, and a larger consumption than in any other year.

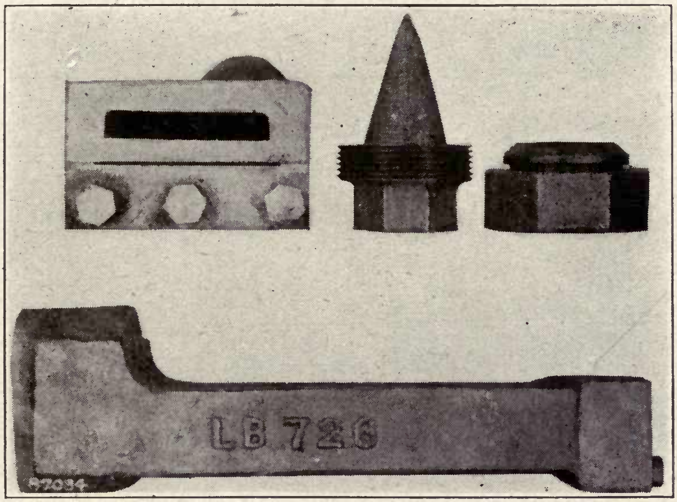


Fig. 65. The Booth Oil Burner used as a standard on the Santa Fe. The oil falls on the steam jet and is atomized and carried to the flash wall of the firebox. The edge of the steam jet extends ⅛-inch beyond the edge of the oil opening on each side, so all the oil is atomized, money being permitted to fall in the pan unburned.

The total distance covered by oil-burning engines was 146,997,144 miles, and the average distance covered per barrel of fuel oil consumed was 3.2 miles. Oil-burning locomotives were operated in 1917 over 32,431 miles of track in 31 states.

The Santa Fe Railway System has at the present time (June, 1920) approximately 3,160 locomotives, of which two-thirds use coal and one-third use oil. The general arrangement[a] of oil-burning equipment representing present practice on the Santa Fe Railway is shown in figs. 63 and 64. Fig. 65 shows the Booth oil burner used as standard on the Santa Fe. Mr. Bohnstengel

a. Oil Burning Practice on Locomotives. Walter Bohnstengel, Proceedings of Twelfth Annual Convention, International Railway Fuel Association.

gives the following data on Santa Fe locomotives: "The burner is made and tested in the Santa Fe shops. Good results are obtained from 1½-inch burners on small locomotives, while the larger power is provided with 2 and 2½-inch burners. For the Mid-Continent oil, a 1½-inch pipe is used to convey the oil from the tank to the firebox, while with California and Mexican oil, 2-inch piping is used to the firing valve. Both the oil and steam connections between engine and tender must be flexible to follow the curves and variations; the older types were rubber hose and are still used to some extent, but as rubber is not durable for either oil or steam, it has been largely replaced by flexible metallic joints."

The number of barrels of oil required to produce a locomotive boiler evaporation equivalent to one ton of coal for various conditions is shown by Table 16.

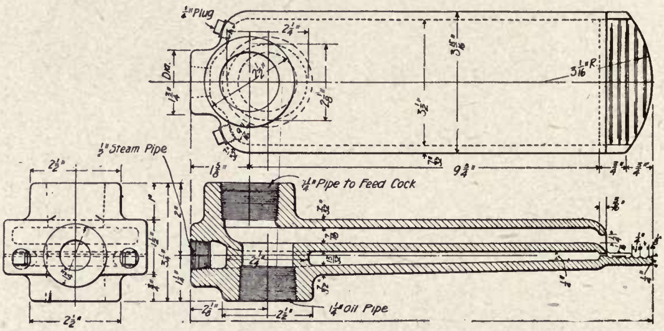


FIG. 66. Von Boden-Ingalls Burners.

TABLE 16. FACTOR FOR EQUIVALENT EVAPORATIVE VALUES, COAL VS. OIL

Coal, Heat Value, B. t. u. Per Pound	Barrels California Oil To One Ton Coal		Barrels Mid Continent Oil To One Ton Coal	
	Hand Fired	Stoker Fired	Hand Fired	Stoker Fired
11,500	2.95	2.56	3.07	2.66
11,600	2.97	2.58	3.10	2.68
11,700	3.00	2.60	3.13	2.71
11,800	3.03	2.62	3.15	2.73
11,900	3.05	2.64	3.18	2.75
12,000	3.08	2.66	3.20	2.78
12,100	3.10	2.69	3.23	2.80
12,200	3.13	2.71	3.26	2.82
12,300	3.15	2.73	3.28	2.85
12,400	3.18	2.75	3.31	2.87
12,500	3.20	2.77	3.34	2.89

Locomotive Furnace Efficiency—Oil Burner, 75 per cent. Coal, hand fired, 60 per cent. Coal, stoker fired, 52 per cent.

California Oil—Heat values, 18,550 B. t. u. per lb. Weight, 8.0 lb. per gal.

Mid Continent Oil—Heat value, 19,000 B. t. u. per lb. Weight, 7.5 lb. per gal.

Oil—42 gal. per bbl. Coal, 2,000 lbs. per ton.

The figures in Table 16 hold only for the relations stated.

The average cost of coal and oil for locomotive use from 1909 to 1919 inclusive, are shown in Table 17.

Table 17. Average Coal and Oil Costs

Year	Cost of Coal Per Ton	Cost of Oil Per Barrel
1909	$1.530	$.....
1910	1.650	0.527
1911	1.630	0.472
1912	1.690	0.532
1913	1.800	0.500
1914	1.900	0.446
1915	1.745	0.400
1916	1.820	0.580
1917	2.380	0.697
1918	3.140	0.997
1919	3.510	1.424

The general average for all locomotives on the system is shown by Table 18.

Table 18. Locomotive Fuel Results
A. T. & S. F. Railway System

Year	Gross 1000 Ton Miles		Total Fuel—Lb.		Fuel Per 1000 Ton Mile—Lb.	
	Coal	Oil	Coal	Oil	Coal	Oil
1909	16,040,276	8,070,236	3,648,196,030	1,189,504,930	227	147
1910	18,824,990	9,868,037	4,126,982,270	1,492,019,110	219	151
1911	19,292,704	11,310,659	3,991,532,000	1,660,989,870	207	147
1912	18,278,168	12,842,472	3,814,399,600	1,850,896,400	209	144
1913	20,626,718	12,095,065	3,942,891,200	1,704,359,263	191	141
1914	21,036,407	10,678,616	3,818,514,710	1,414,208,050	181	132
1915	21,962,754	13,655,095	3,779,843,000	1,677,782,860	172	123
1916	22,455,557	17,587,327	3,759,233,600	2,139,531,200	167	122
1917	25,015,575	20,195,544	4,296,203,900	2,380,453,820	171	118
1918	24,324,979	19,094,296	4,135,067,900	2,190,272,735	170	115
1919	25,556,469	17,353,521	4,113,172,500	1,950,162,870	161	113

The gross ton mileage figures on which the fuel consumption is based are arrived at by multiplying the miles run by locomotives by the total gross weight of the trains hauled. The weight of the locomotive is not included.

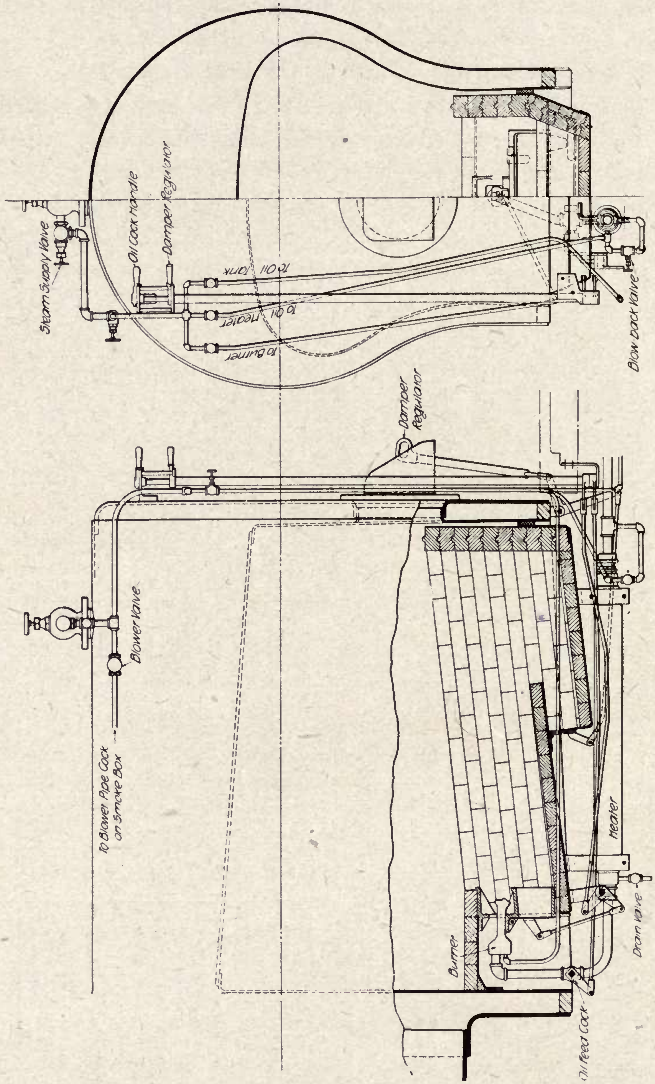


Fig. 67. Arrangement of Oil Burning Equipment as Used by The Baldwin Locomotive Works.

The oil is usually brought to the division and to intermediate storage tanks in tank cars, from which the oil is drained into sumps by pits or pipes and is thereafter pumped by means of centrifugal, rotary or reciprocating pumps into storage or service tanks.

The oil is taken on the tender from the service tank through a crane similar to water cranes. At terminals these cranes are frequently some distance apart but at fuel stations on the road the water and oil cranes are usually so located that water and oil may be taken at the same time, resulting in a minimum consumption of time for taking fuel and water. There is always danger of explosion resulting from igniting the gases coming from the oil and hence precaution is essential in oil handling. Proper sign boards are placed wherever necessary. Some places are simply marked "Danger—keep lighted torches or lanterns away," at other places more elaborate signs which give reasons for precaution are evident. To lessen this danger to a certain minimum, the flash point is specified in purchasing oil. The oil must also be free from dirt and water that would cause poor combustion.

The amount of atomizer required is an item that requires judgment. One locomotive requires little steam, another more to properly atomize the oil. In connection with some recent tests, a pressure gauge was placed in the atomizer line next to the burner on two freight locomotives, the one carrying 200 pounds, the other 225 pounds boiler pressure. The atomizer steam is supplied by a ¾-inch pipe line, the steam being regulated by means of a ¾-inch globe valve. The average pressure at the burner for different valve openings was as shown in Table 19.

TABLE 19. ATOMIZER PRESSURES

Atomizer Valve Handle	Pressure—Lb. Per Sq. In.	
	Boiler	At Burner
"Cracked open"	200 to 225	5 to 10
⅛ turn	200 to 225	15 to 25
¼ turn	200 to 225	30 to 40
⅜ turn	200 to 225	50 to 70
½ turn	200 to 225	130 to 150
Wide	200 to 225	160 to 180

These locomotives had 2½-inch Booth burners with standard $\frac{1}{32}$-inch steam atomizer opening."

The Southern Pacific Railway has a large number of oil-burning locomotives in service on its lines. The Southern Pacific uses the Von Boden-Ingalls burner[a] shown in fig. 66. In front of the oil outlet is placed a corrugated lip, which retains any drippings from the burner, and is said to assist in atomizing the oil. The burner is placed in the front end of the fire-pan. Admission of air takes place through a number of horizontal tubes, placed under the burner, and these tubes can be covered by an external damper operated from the cab. The Von Boden-Ingalls burner is so arranged that oil may be taken in either at the top or bottom of the oil chamber, as is the more convenient. The opening not in use is closed by a plug.

Fig. 67 shows the arrangement of oil-burning locomotive equipment as used by the Baldwin Locomotive Works. It was formerly their practice to place the burner in the rear end of the furnace and burn the oil under a brick arch. In service, however, when the engine was being heavily worked, the draft frequently lifted the flame over the arch, thus causing incomplete combustion and an excessive amount of smoke. The horizontal draft arrangement with burner placed in the front end of the furnace has been found in practice to give very much better results.

Mr. Charles E. Kern is authority for the following statement: "The 80,000,000 barrels of fuel oil now used annually on the steam railroads of the country is reported to the Interstate Commerce Commission as 20,000,000 tons of coal and is equivalent to one-seventh, speaking roughly, of the entire fuel requirements of the railroads of the United States. This estimate is made upon the basis of statistics for the first six months of 1919. During these six months the steam railroad freight service used 35,302,800 tons of coal or equivalent in fuel oil. The passenger service used 14,770,000 tons, switching service 10,187,000 tons, mixed special service 1,001,000 tons and stationary plants 8,200,000 tons. Double these figures and we have a total of about 140,000,000 tons of coal or its equivalent in fuel oil, and of the entire amount 20,000,000 tons was, in fact 80,000,000 barrels, of fuel oil. Thirty-six of the great steam railroad systems of the United States use in whole or in part fuel oil. The Central Western Division consumes annually about 21,500,000 barrels of fuel oil. This division includes the Santa Fe, Chicago, Burlington & Quincy, Northwestern & Pacific, Los Angeles, Salt Lake, Rock Island, Colorado Southern, Fort Worth & Denver City, Southern Pacific and the Arizona Eastern. The Northwestern region con-

a. Oil Burning Locomotives, The Baldwin Locomotive Works.

sumes about 6,250,000 barrels of oil as follows: Chicago & Northwestern, 1,000,000 barrels; Chicago, Milwaukee & St. Paul, 1,250,000 barrels; Great Northern, 1,900,000 barrels; Southern Pacific, 1,300,000 barrels; the Spokane, Portland & Seattle, 750,000 barrels; and the Northern Pacific, 275,000 barrels. The New York Central normally uses approximately 4,000,000 barrels of fuel oil annually and the Delaware & Hudson about 1,800,000 barrels. The Long Island road uses fuel oil. The Florida East Coast requires about 1,000,000 barrels; the Wichita Falls & Northwestern requires about 1,250,000 barrels; the Missouri, Kansas & Texas, 1,250,000 barrels; Gulf, Colorado & Santa Fe, 7,000,000 barrels; the Galveston Wharf, 250,000 barrels; Trinity & Brazos Valley, 900,000 barrels; Morgan's Louisiana & Texas, 6,000,000 barrels; Houston, Belt Terminal, 750,000 barrels; Texas & Pacific, 10,000,000 barrels; Gulf Coast Lines, 5,000,000 barrels; St. Louis Southwestern, 5,000 barrels; Kansas City Southern, 1,000,000 barrels; International & Great Northern, 1,500,000 barrels; Fort Worth Belt Line, 50,000 barrels; St. Louis & San Francisco, 900,000 barrels; Missouri, Kansas & Texas Railway of Texas, 3,000,000 barrels, and the Gulf, Colorado & Santa Fe, 80,000 barrels."

CHAPTER XI

THE MANUFACTURE OF IRON AND STEEL

The importance of a nation depends upon its agricultural resources, its fuel deposits, and its iron deposits. It is a difficult matter to determine which of these resources is the most important or which has contributed most largely to the advance of a country. Undoubtedly the great industrial predominance

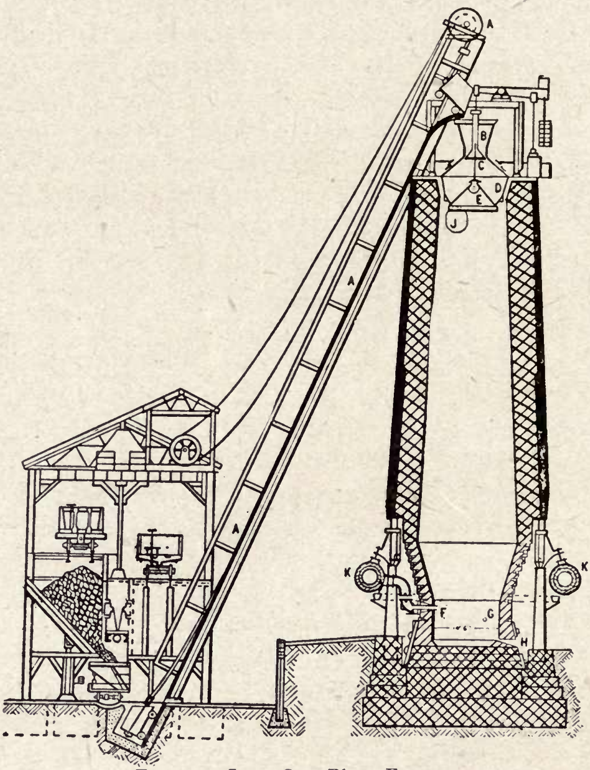


Fig. 68. Iron Ore Blast Furnace.

of the United States is due to the fact that this country is rich in all three resources. It is, however, possible that industrial prominence depends more upon iron deposits than upon the other two factors, because the foundation of our present industrial structure is steel. Steel is the most important of all manufactured products, and the development of special grades is largely responsible for the enormous amount of building construction, the great extension of railroads, and the great multiplication and expansion of industry that has occurred in recent years. Steel is a finished product of which iron is the raw material. The ores of iron are red hematite (Fe_2 O_3), brown hematite, the limonite of the mineralogist (2 Fe_2 O_3 and 3 H_2O), magnetite (Fe_3 O_4), and siderite (Fe Co_3), these being mixed with more or less silica, clay, etc., besides containing a small percentage of manganese, phosphorus and sulphur.

To extract the metallic content from any ore, it is necessary to get rid of the impurities. With all metals this is done by melting the ore by intense heat and adding what is known to the metallurgist as a flux. A flux is any mineral, usually lime, which

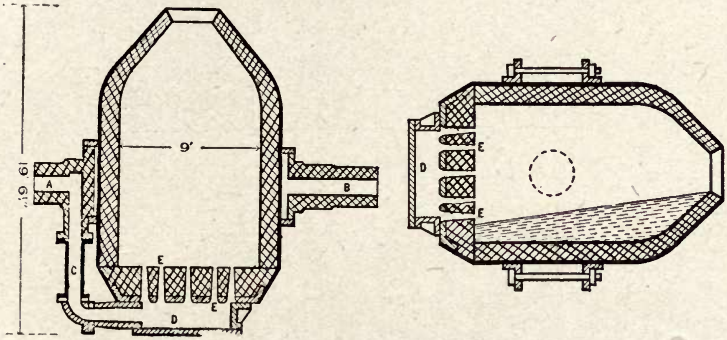


Fig. 69. The Bessemer Converter.

unites with the impurities of the ore to form a liquid slag which floats upon the molten metal. The metal can then be drawn off from the bottom of the furnace, but is still in a more or less impure state and needs to be refined. This is the case with iron. Crude iron is made in very large circular vertical blast furnaces (see fig. 68), which are lined with refractory fire brick. In the blast furnace ore and limestone, which is used as a flux, together with the coke necessary for providing the intense heat, are raised to the top of the furnace by a hoist (A) and discharged into the hopper (B) and these materials fall into the hopper (D) at the top of the furnace by lowering the bell (C). When the bell (E) is lowered the materials are dropped into the furnace. The two bells and hoppers are provided to prevent the escape of large volumes of gas from the top of the furnace. In order to provide sufficient air for combustion of the coke enormous volumes heated to 1,100 to 1,500 degrees F. are blown through a set of pipes called "tuyeres" near the bottom of the furnace at a pressure of 12 to 15 pounds per square inch. The burning coke melts the charge, producing intense local heat. About three-quarters of a pound of coke is used per pound of pig iron made. The air blast coming through the tuyeres is heated by passing it through

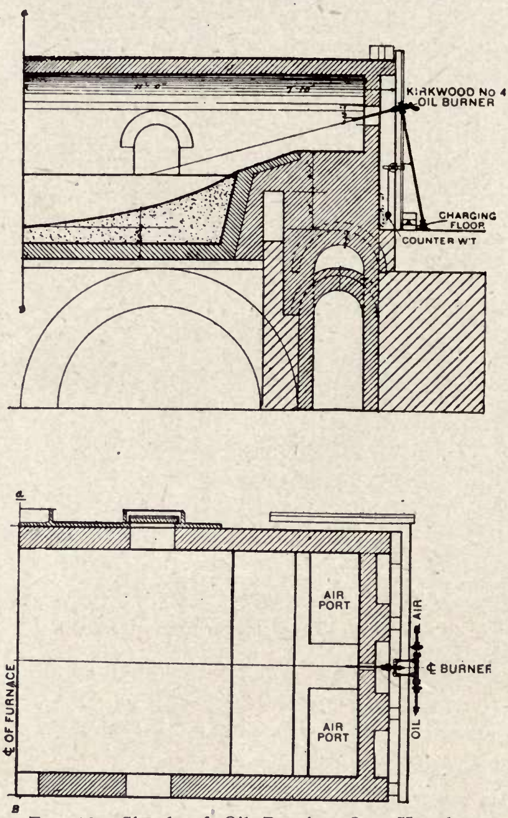


FIG. 70. Sketch of Oil Burning Open-Hearth.
(Courtesy of Tate-Jones & Co., Inc.)

"stoves" which are large cylindrical structures filled with a checker-work of fire brick. One blast furnace usually has three or four "stoves." After the chemical action is completed within the furnace the crude iron is drawn off into moulds called "pigs." Pig iron, however, contains impurities which must be burned away before a good quality of steel is produced. Of the impurities found in iron, graphite is unique, inasmuch as it is rarely found in other metals. It is present in the form of flakes or thin

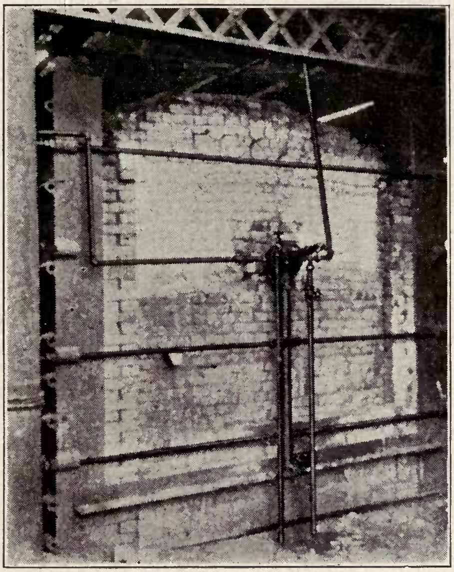


FIG. 71. Water Cooled Oil-Burner in Open-Hearth Furnace.

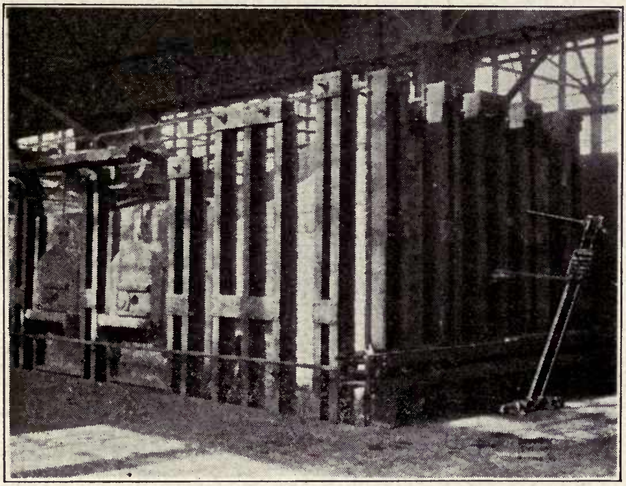


FIG. 72. Swinging Oil Burners in Open-Hearth Furnace.
(Courtesy of Tate-Jones & Co., Inc.)

plates in sizes varying from microscopic proportions to approximately ⅛ sq. in., disseminated throughout the body of the metal and forming an intimate mechanical mixture. It is necessary that the iron from which steel is to be made be low in sulphur and low in phosphorus, but both of these impurities are always present and must be burned away. When sulphur is present in too

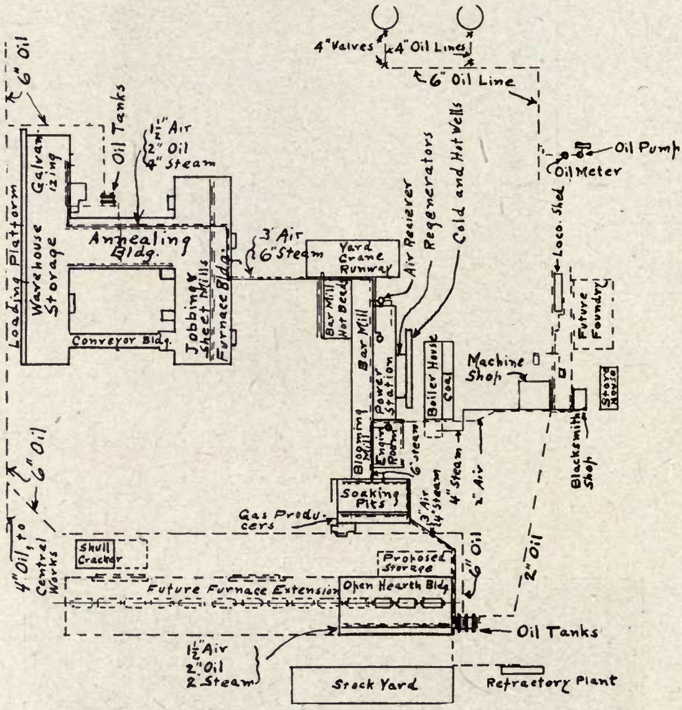
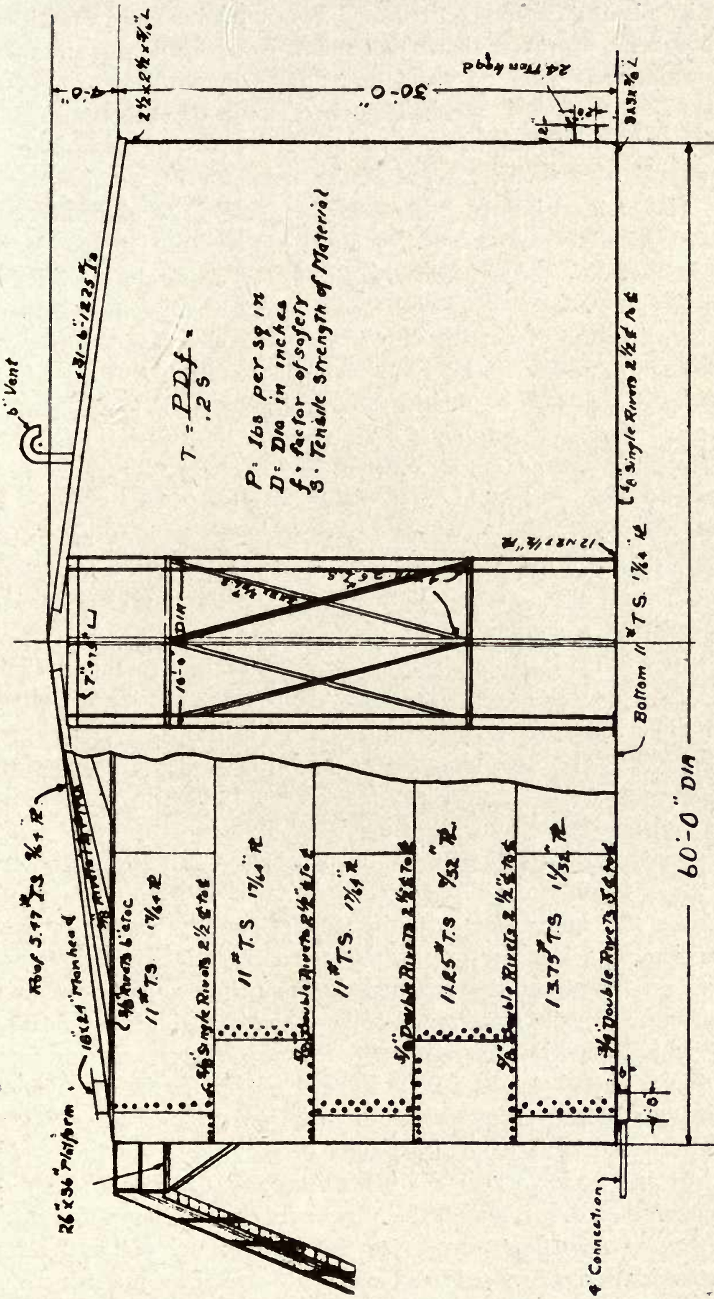


Fig. 73. Layout of Oil System at Middletown Plant of American Rolling Mill Co.

great quantities in steel, the steel is rendered hot short, that is, when heated, on account of the presence of the sulphur the steel will bend or break. The amount of sulphur present for good results should not exceed 0.06 percent. It is much better to keep the sulphur content below 0.04 percent, which is the generally accepted specification for open hearth steel. Phosphorus increases the strength of steel but renders the metal cold short or brittle. For constructional purposes steel should be specified with phosphorus not to exceed 0.04 percent, which is the general specification for open hearth steel.

Steel, like cast iron, is an alloy of iron and carbon, or iron, carbon and other metals. The dividing line between steel and



CAPACITY 635040 GALLONS

FIG. 74. Construction of Oil Storage Tank.
(Courtesy of American Rolling Mill Co.)

cast iron is at a carbon content of 2.2 per cent, i. e., all iron with a carbon content greater than this amount is cast iron, and all under this amount is steel or wrought iron. The physical properties of steel are greatly influenced by the amount of carbon, alloying elements and impurities present. The process of manufacture has much to do with the value of the metal for various purposes.

The general influence of carbon on steel is to give the steel greater tenacity and also to render it harder and stiffer. Manganese increases the tensile strength of steel while the ductility is probably somewhat decreased. Silicon, as an alloying element, tends to increase the tensile strength, but to decrease the elongation and reduction of area. Nickel has a strengthening effect without decreasing the ductility. Chromium tends to make steel intensely hard and to give it a high elastic limit in the hardened or suddenly cooled state, so that it is neither deformed permanently nor cracked by extremely violent shocks. Chromium accelerates the case hardening process. Vanadium seems to render the steel more homogeneous and to render the effects of the other elements greater than in steels without vanadium, but otherwise of a similar composition.

Steel is made from pig iron by four different methods. The Bessemer process is the cheapest and produces the largest quantity. The Bessemer process is conducted in the converter shown in fig. 69. The crucible process and the cementation process produce only small quantities of steel supplying the demand for fine tools, watch springs, needles, etc. For constructional work the most reliable method is the open hearth. In the open hearth process a flame playing upon the open bath of the molten metal removes the impurities. In the open hearth process pig iron, scrap iron and iron ore are melted in regenerative, reverberatory furnaces. Without the regenerative principle a sufficient temperature cannot be maintained to keep the charge properly fused after the impurities are oxidized. For this reason, air for combustion is heated to over 1,000° F. before it enters the combustion chamber. Measured quantities of ore, iron scale or other oxides added to the bath of molten metals react with the impurities present and serve to keep the mass thoroughly agitated. Silicon, manganese and carbon of the pig having a greater affinity for oxygen, oxidize first, protecting the iron of the pig and scrap from oxidation. Any oxidized iron will form slag on coming into contact with silica.

The carbon is oxidized by reaction with the iron ore. Figure 70 shows an open hearth furnace equipped with an oil burner. Oil as a fuel for open hearth furnaces has many advantages. The repair cost of the fuel oil burner is about 40 percent less than when gas is used. A more even temperature may be maintained because the heat of the furnace is easily regulated. When oil is used a different chemical reaction takes place in the furnace and a superior quality of steel is produced and a lower grade of scrap iron can be used. For these reasons many large steel plants in the East have equipped their furnaces with fuel oil burners. Fig. 71 shows an open hearth furnace at Erie, Pennsylvania, equipped with a water-cooled oil burner. Fig. 72 shows an open hearth furnace in Pittsburgh, Pa., using swinging oil burners.

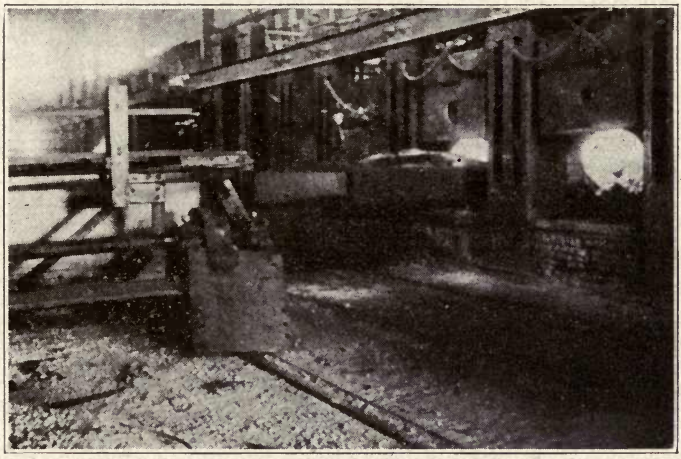


FIG. 75. Charging an Oil-Burning Open-Hearth Furnace. (Courtesy American Rolling Mill Co.)

The equipment of open hearth furnaces with oil burners is inexpensive. One open hearth furnace having one burner for each end of the furnace must have a reversing stand for reversing the flow of the oil and when the furnace is acting as the atomizing agent. This reversing stand is located on the charging flood. It must also have a pumping system for pumping oil from the storage tank and regulating the supply to the burner. In addition, it must have a reducing valve for regulating the atomizing and the necessary valves, tank and pipe. For firing open hearth furnaces a swinging burner is commonly used. A water-cooled burner is used when the end of the furnace is so near to the wall of the building that there is no room for a swinging burner or when the furnaces are close together. A circulation of water through a ¾-inch pipe prevents the burner from being melted off by the heat of the furnace.

The pressure at which the oil is fed to the burner varies considerably at different plants but oil at 45 pounds and air or dry steam for atomizing at 40 pounds will probably give the best results under the average conditions. The question of whether compressed air or dry steam is best for atomizing seems to be an open one. About one-half of the plants use steam and the other half air as an atomizing agent. It is very important, however, that the steam be dry and it is usually well to put a drip in the steam line near the furnace and in some cases provide for superheating the steam before it enters the burner. An air or steam pressure reducing valve should be put in the line to cut the compressor or boiler pressure down to the proper point for atomizing.

The American Rolling Mill Company of Middletown, Ohio, in the manufacture of its Armco Iron uses fuel oil in many of its operations. Fig. 73 shows the layout of its plant with respect to fuel oil distribution. Fig. 74 shows the method of construction of its oil storage tank. Fig. 75 shows the method of charging open hearth furnaces at this plant.

CHAPTER XII

HEAT TREATING FURNACES

Heat treatment, it is generally understood, comprises the heating of steel to a temperature slightly above the critical point; quenching in oil or water; re-heating to some temperature to give the desired physical properties and cooling slowly. Mr. James H. Herron in the Journal of the Cleveland Engineering Society, September, 1914, says that "the importance of determining the correct temperature and exercising the greatest care in heating cannot be over emphasized. This is especially true of the higher carbon and alloy steels. If the value of the steel is not actually impaired, a resulting condition may occur which would render the treatment valueless.

"One of the most important forms of heat treatment is case carbonizing or so-called case hardening. Steel to be carbonized is packed in some carbonaceous material and heated for a given length of time at temperatures varying from 1600 to 1750 degrees F., depending upon the depth of penetration of the carbon desired.

"It has become common practice to give case carbonized parts a double heat treatment, i. e., heat for the refinement of the core, quench in oil, subsequently heat at a lower temperature for the refinement of the case and quench in water, after which the material may be drawn to the extent necessary for the physical properties desired.

"In the heat treatment of steel castings, proper annealing is of the greatest importance. Unfortunately commercial annealing is not what it should be, and if much is expected from the material it should be properly annealed or heat treated. By heat treating large steel castings with the carbon range of 0.20 to 0.60 percent the elastic limit can be increased about 50 percent with little decrease in the ductility."

Mr. E. J. Janitzky, Metallurgical Engineer, Illinois Steel Company, in the Journal of the American Steel Treaters Society, December, 1918, gives the following discussion of the theories of heat treatment: "Although not going too deeply into the history of the theories that have been developed in regard to hardening, it might be interesting to describe in non-metallurgical phraseology their contents. There are several theories for the

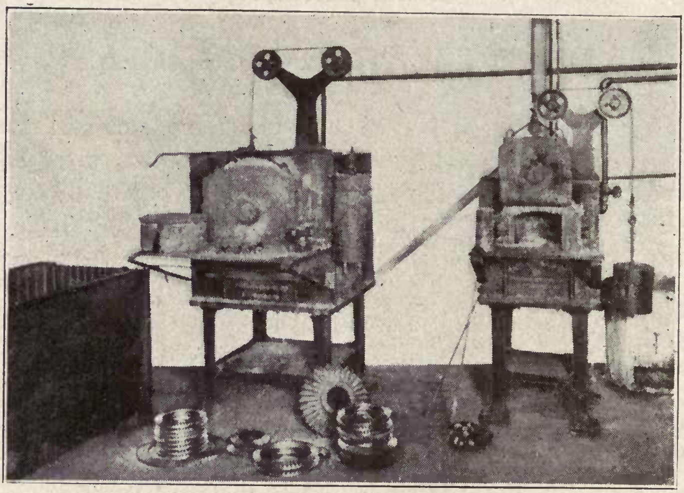


Fig. 76. A Furnace for Case Hardening and Heat Treating Gears. (Courtesy of Tate, Jones and Co., Inc.)

hardening of steel, the more important one being the stress theory, the carbon theory and solution theory. The stress theory basis its contention on the high stressing of the outer shell of the

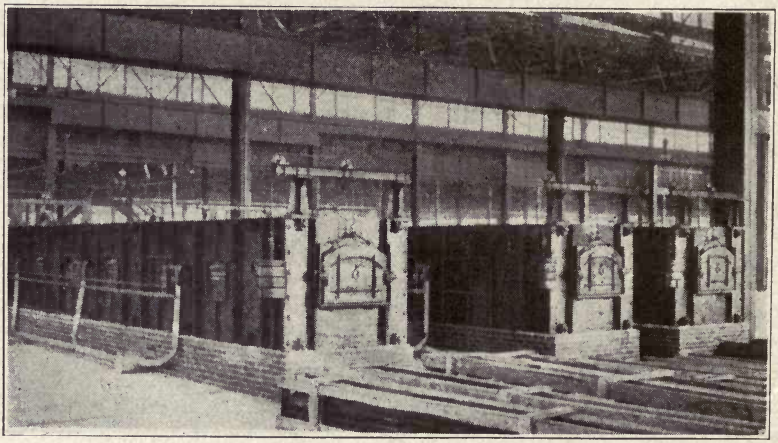


Fig. 77. Continuous Rod-Heating Furnace. (Courtesy of Tate, Jones and Co., Inc.)

steel when shrinking onto the interior and the stress set up in the crystal change from the hot to the cold metal. The fact that

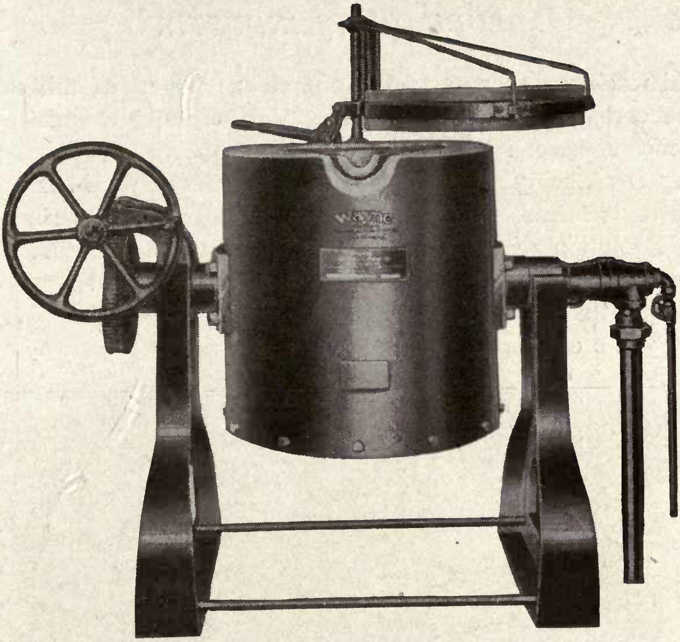


FIG. 78. Oil-Burning, Tilting Crucible Type, Brass Melting Furnace. (Courtesy Wayne Oil Tank & Pump Company)

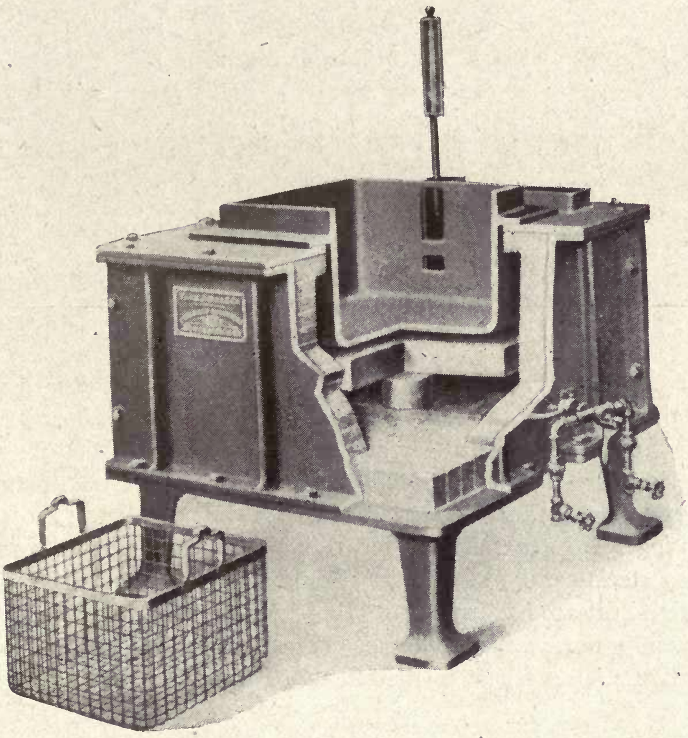


FIG. 79. Tempering Bath Furnaces.

cold working hardens steel is offered in support of this theory. The carbon theory contends that the hardness resulting from quenching steel is due to the condition the carbon exists in in the steel, it being recognized that carbon can easily exist in several allotropic forms. The solution theory contends that carbon is in solid solution with the iron. This seems to be the most logical and all phenomena can be explained by it. It will likewise be obvious that no theory so far presented fully satisfies for an acceptable explanation of the phenomena involved and that new

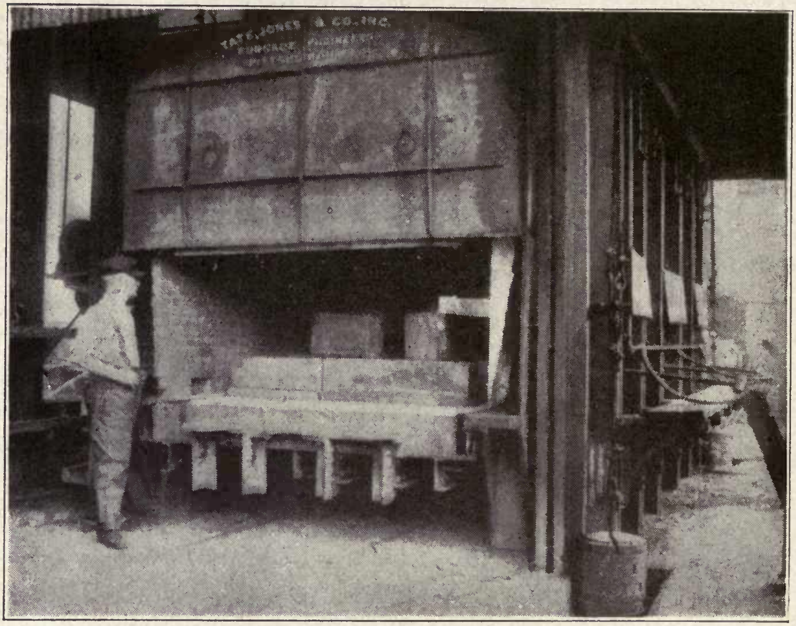


FIG. 80. A Large Car-Type Furnace.

avenues of approach must be found to obtain a correct answer to this apparent enigma. The most progress in heat treatment has been attained with the advent of alloy steel. With few exceptions all alloy steels are heat treated for use, the treatment developing in them physical properties they are capable of possessing. No general laws regarding the effects of treatment of alloy steels can be laid down. Some steels when quenched from a high heat are hardened and others are softened, the latter being generally those with the higher contents of certain of the alloying elements. In respect to the effects of heat treatment, each steel is considered by itself. Developments in the manufacture of alloys steel and in the heat treatment of steel have occurred somewhat simultaneously during the past thirty years. The highest merit is obtained from the adoption of both developments together, that is, the use of heat treated alloy steels. Usually heat treatment has contributed more to the superior properties of the metal than has the use of alloys. The effect of alloying elements in alloy steels are various, thus nickel increases the elastic limit compared to tensility, chromium increases hardness of quenched steel, and manganese destroys magnetic susceptibility effects, all of which are valuable for certain purposes."

Most of the advantages of fuel oil under boilers are retained in its use for furnaces. Oil is especially desirable in furnaces because it gives a clean heat and one which is very readily kept uniform. Forging and heating furnaces of all kinds can be started and shut down instantly with fuel oil and an early attainment of the maximum temperature is reached with accurate and easy regulation. In enameling and japanning work, especially, where dust must be avoided, fuel oil is being used more and more. Fuel oil is in common use in all heat treating furnaces, especially in those for large and small annealing, tool dressing, bolt heading, drop forging, heavy forging, rivet rod, nut punching, continuous rod, plate and flanging, flue welding, pipe bending, pack hardening, case hardening and tempering. Figs. 76, 77, 78, 79 and 80 show oil burners applied to various types of furnaces.

CHAPTER XIII

FUEL OIL IN THE PRODUCTION OF ELECTRICITY

The production of electricity in the United States in 1919, according to the U. S. Geological Survey, totaled 38,900,000,000 kilowatt-hours, of which 24,160,000,000 kilowatt-hours, or 62.1 percent, were produced by fuel power. During the year 1919 the total fuel consumption for the production of electricity by public utility plants was as follows: Coal, 35,000,000 short tons; oil, 11,050,000 barrels; gas, 21,700,000 M. cu. ft. The quantities of fuel consumed in January, February and March, 1920, by states, in the production of electric power are given in Table 20. From this table it will be seen that California, Texas, Florida, and Arizona depend chiefly upon oil as a source of power. Table 21 shows the source of power in the United States for these three months.

The figures for January, February and March are based on returns received from about 2,800 power plants of 100 kilowatt capacity, or more, engaged in public service, including central stations, electric railways, and certain other plants which contribute to the public supply. The capacity of plants submitting reports of their operation is about 90 percent of the capacity of all plants listed. The average daily production of electricity in kilowatt-hours for the three months was as follows: January, 124,600,000; February, 119,800,000; and March, 121,800,000. Of this electricity, 33 percent in January and February and 38 percent in March were produced by water power.

The mean daily output for the first quarter in 1919 was 105.3 million kilowatt-hours and the mean daily output for the first quarter of 1920 was 122.2, an increase of 16 percent.

In 1918 in California, $4,742,000 was spent for fuel oil by companies engaged in the production of electricity. The following description of California oil-burning installations in central stations is of interest[a]:

"It has been found necessary in line with the Pacific Gas & Electric Company's policy of continuous service to maintain

a. C. W. Geiger, Oil News, April 5, 1920.

TABLE 20.—FUEL CONSUMED IN PRODUCTION OF ELECTRIC POWER IN FIRST THREE MONTHS OF 1920.

QUANTITIES OF FUEL CONSUMED.

	Coal—Short tons			Petroleum and Derivatives Barrels			Natural Gas Thousands of Cubic Feet		
	January	February	March	January	February	March	January	February	March
Alabama	29,211	17,654	17,819	1,255	8,516	8,437	0	0	0
Arizona	198	317	271	29,449	29,851	30,182	0	0	0
Arkansas	8,675	7,654	8,710	4,888	4,049	3,933	218,596	207,185	232,834
California	0	0	0	551,126	539,986	416,354	179,563	190,449	165,474
Colorado	43,345	38,968	40,545	110	100	110	0	0	0
Connecticut	77,311	68,269	72,176	4,374	3,722	2,425	10,236a	15,133a	14,155
Delaware	9,139	9,834	10,214	0	0	0	0	0	0
District of Columbia	23,237	21,104	22,171	0	0	0	0	0	0
Florida	2,333	2,342	2,423	59,095	62,579	64,049	0	0	0
Georgia	19,556	10,875	10,268	19,605	27,702	27,366	0	0	0
Idaho	150	60	150	10	10	10	0	0	0
Illinois	411,719	394,151	386,629	472	593	237	0	0	0
Indiana	197,186	184,174	182,658	270	277	428	2,025	2,025	2,025
Iowa	92,871	89,141	90,682	576	555	608	0	0	0
Kansas	39,710	36,935	36,417	90,198	73,345	74,242	76,283	68,560	93,187
Kentucky	43,181	39,521	40,127	188	295	310	5,622	8,308	10,402
Louisiana	7,589	11,855	12,073	60,528	36,029	34,453	68,510	58,276	74,109
Maine	8,410	3,523	813	49	0	3,984	0	0	0
Maryland	39,552	34,251	30,391	0	0	0	1,500	1,400	1,500
Massachusetts	172,978	156,334	149,803	1,764	1,542	1,122	0	0	0
Michigan	180,901	168,530	171,993	139	131	140	0	0	0
Minnesota	64,060	56,286	56,024	620	490	1,610	0	0	0
Mississippi	14,028	12,887	13,645	11,841	5,242	10,548	0	0	0
Missouri	91,446	92,867	101,512	90,657	55,986	39,086	0	0	0
Montana	4,551	4,353	4,276	22	26	29	1,257	1,098	1,119
Nebraska	37,926	38,939	36,305	16,503	8,331	10,621	0	0	0
Nevada	247	232	248	1,890	1,798	1,208	0	0	0
New Hampshire	6,768	5,780	3,645	0	10	39	0	0	0
New Jersey	156,280	129,816	135,009	136	112	92	280a	0	0
New Mexico	4,788	4,288	4,688	866	851	849	0	4	0
New York	479,109	411,625	402,866	763	825	788	72,579	57,834	8,997
North Carolina	21,612	18,609	20,097	34	32	36	0	0	0
North Dakota	19,362	16,007	14,266	150	194	207	0	0	0
Ohio	400,696	361,882	373,608	697	530	578	161,065b	119,409	284,616
Oklahoma	8,413	8,889	10,643	71,940	53,904	49,556	275,926	250,514	666,617
Oregon	190	197	635	3,657	1,752	798	0	0	0
Pennsylvania	532,963	493,081	507,925	5	343	37	49,437	27,267	71,454
Rhode Island	35,196	32,624	28,675	7,560	8,764	11,492	0	0	0
South Carolina	11,649	9,630	11,202	0	0	0	0	0	0
South Dakota	7,827	7,645	6,522	1,936	2,576	2,697	0	0	0
Tennessee	24,216	22,486	23,953	25	23	25	0	0	0
Texas	57,104	53,650	32,818	212,316	197,665	236,014	48,227	48,307	48,355
Utah	3	15	40	0	0	0	0	0	0
Vermont	1,748	2,250	441	2,146	2,121	1,753	0	0	0
Virginia	43,269	37,575	33,737	132	119	129	0	0	0
Washington	3,348	2,722	3,230	15,612	11,209	11,054	0	0	0
West Virginia	107,133	98,010	106,963	50	45	48	227,900	207,691	207,352
Wisconsin	77,051	79,203	83,752	544	518	516	0	0	0
Wyoming	13,718	13,516	13,380	9,685	8,348	8,563	3,300	2,980	3,190
Total	3,631,953	3,299,556	3,316,438	1,273,883	1,151,096	1,056,763	1,401,406	1,266,436	1,885,386

(a) Artificial gas. (b) Includes 61,520 M. cubic feet of artificial gas steam-generating plants in the larger load centers, each plant being capable of carrying all the connected load, in the district

TABLE 21.—SOURCES OF ELECTRIC POWER. THOUSANDS OF KILOWATT-HOURS PRODUCED

State	By Water Power			By Fuels		
	January	February	March	January	February	March
Alabama	34,864	36,780	39,354	14,452	7,929	9,736
Arizona	8,567	6,883	8,899	6,276	5,708	6,423
Arkansas	132	120	130	9,290	8,326	9,056
California	166,806	148,839	203,595	113,446	111,797	92,222
Colorado	12,784	12,082	12,665	22,811	19,282	20,416
Connecticut	9,069	8,553	17,607	59,256	49,801	52,120
Delaware	0	0	0	6,807	6,138	6,263
District of Columbia	0	0	0	23,317	20,763	21,356
Florida	965	818	1,024	10,897	10,461	11,210
Georgia	43,816	42,016	43,697	10,696	8,260	8,770
Idaho	48,564	43,336	43,065	1,348	1,133	1,315
Illinois	14,831	14,147	14,588	260,723	239,928	246,478
Indiana	2,943	2,741	3,637	91,817	71,503	73,351
Iowa	55,538	49,415	54,417	31,733	30,337	38,846
Kansas	1,741	1,240	1,598	35,913	32,391	32,916
Kentucky	0	0	0	23,449	21,768	22,711
Louisiana	0	0	0	18,126	16,755	17,884
Maine	23,491	20,866	23,658	1,577	1,614	918
Maryland	284	327	131	31,261	26,889	21,530
Massachusetts	21,987	16,248	34,367	147,914	129,365	123,042
Michigan	51,749	47,291	64,503	138,379	129,875	130,523
Minnesota	28,053	26,705	32,889	36,157	30,083	25,681
Mississippi	0	0	0	5,848	4,783	5,075
Missouri	5,720	3,987	4,916	54,143	52,672	53,740
Montana	89,574	90,411	104,991	596	540	515
Nebraska	909	662	668	20,436	17,305	18,028
Nevada	3,416	3,420	3,180	852	845	882
New Hampshire	4,322	4,001	5,223	5,166	4,289	2,319
New Jersey	143	102	161	101,478	88,120	94,975
New Mexico	53	57	59	1,593	1,447	1,529
New York	227,033	203,282	248,218	382,194	338,960	328,475
North Carolina	52,880	45,576	57,560	10,745	9,040	9,670
North Dakota	0	0	0	2,718	2,270	2,170
Ohio	1,490	2,101	3,222	259,335	234,061	252,803
Oklahoma	217	182	231	17,163	15,245	15,935
Oregon	32,359	28,323	32,125	7,845	8,624	7,788
Pennsylvania	45,359	43,500	56,881	329,625	294,483	326,074
Rhode Island	355	436	719	37,114	32,599	26,876
South Carolina	60,531	52,212	55,165	5,768	4,563	4,976
South Dakota	477	474	1,162	3,382	3,258	2,789
Tennessee	39,443	31,664	40,125	9,926	11,581	9,818
Texas	74	231	380	55,424	49,651	53,266
Utah	13,932	14,635	18,565	0	8	12
Vermont	15,467	11,732	18,969	786	1,038	344
Virginia	13,809	16,441	21,310	30,435	24,240	22,219
Washington	103,981	94,907	98,839	4,480	2,849	3,450
West Virginia	1,776	2,334	2,101	96,221	83,501	94,479
Wisconsin	37,843	32,321	43,585	42,336	43,606	43,733
Wyoming	152	145	154	4,585	4,178	4,162
Total	1,277,499	1,161,543	1,418.233	2,584,839	2,313,862	2,358,869
Total by water power and fuels				3,862,338	3,475,405	3,777,102

In some of the States electricity is produced by the use of wood as fuel. During March about 17.0 million kilowatt-hours, or 0.4 percent of the total for the month, were produced by wood-burning plants. The following list gives the States and their output in millions of kilowatt-hours, which produces the larger amounts of electricity by the burning of wood: Oregon, 7.4; Minnesota, 1.7; Wisconsin, 1.3 Idaho, 1.3; Washington, 1.1; California, 0.5; Louisiana, 0.6; and Florida, 0.4.

which it is meant to supply; thus Station A in San Francisco, with four turbines of capacity of 57,000 kilowatt, Oakland with 21,000 kilowatts and Sacramento with 5,000 kilowatts. Ordinarily the steam turbines are connected in parallel with the transmission line and then if the line goes out of service the turbines automatically pick up the load. Station A in emergency cases has generated one-third of the company's entire output. It is operated 365 days yearly.

Probably no other electric light and power plant in the world can handle its fuel in such large quantities and so quickly as Station A. The oil is stored in two steel tanks, one of 25,000 barrels capacity and one of 10,000 barrels capacity. Two separate pipe lines lead from the tanks to the company's wharf, through which oil may be discharged from steamers.

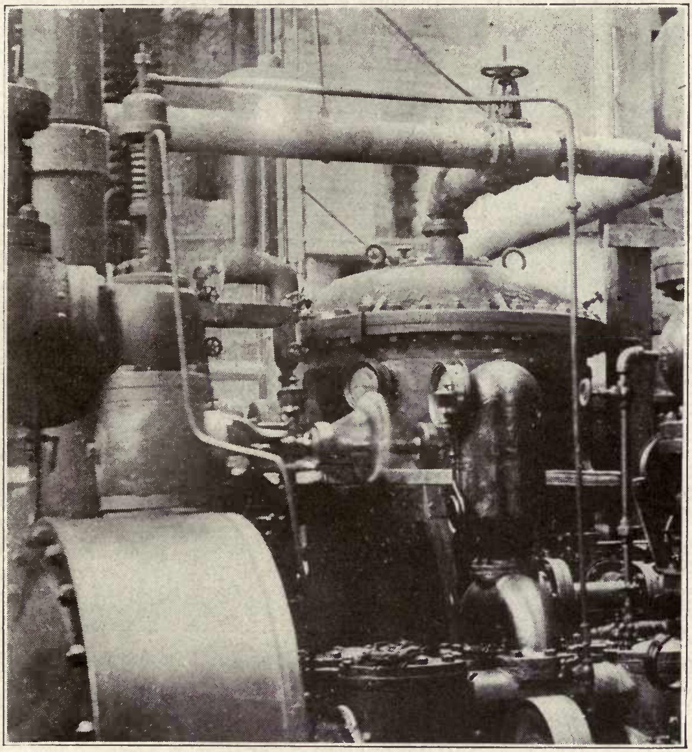


FIG. 81. Oil Heaters and Pumps in California Electric Plant.

The plant uses 5,000 barrels of fuel oil a day at the maximum and 2,500 barrels a day on the average. The oil is heated to a temperature of 165 to 175 degrees and fed to the furnaces at a pressure of 65 lbs. The fuel oil pumps discharge into a common pipe 4 inches in diameter that leads to the burners. (See fig. 81.) The burners are of special design, and were made by the company's workmen. Steam for atomizing the oil is supplied to the burners at normal load of 200 lbs., through a $\frac{3}{16}$-inch hole, but on a heavy load the steam is by-passed through a ½-inch hole. The plant originally was equipped with 27 boilers, but with the installation of a new 15,000-kilowatt turbine in July, 1919, four of the original boilers were removed and eight 822 horsepower vertical water tube boilers were installed. There are four fuel oil pumps and four oil heaters in the boiler room. (See fig. 82.)

In December, 1908, a 9,000 kilowatt turbine was installed in the Oakland steam plant of the Pacific Gas & Electric Company,

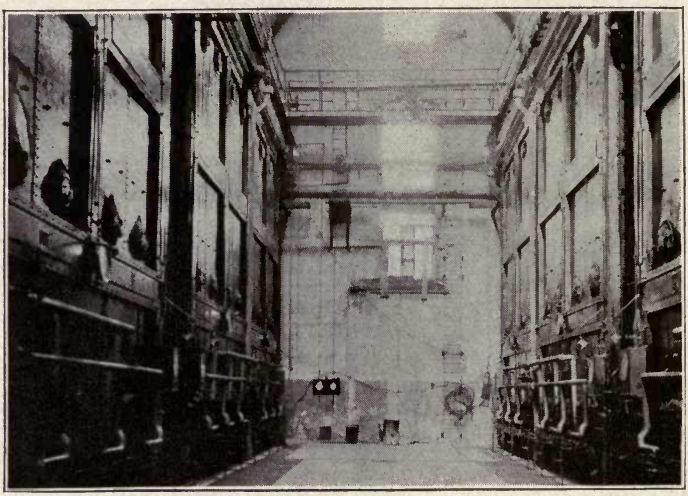


FIG. 82. Boiler Room Showing Piping for Oil Burners in California Electric Plant.

but in 1911 it was deemed advisable to further protect the consumers of the company by installing a sister unit of greater capacity to meet any emergency that might arise, so in 1911 a 12,000 kilowatt vertical turbine was installed. This new turbine is supplied with steam from four 773-horsepower water tube boilers of the Parker type, each boiler containing 366 four-inch tubes 20 feet long, heating surface 7,734 square feet and grade surface 48 square feet.

The turbine can be operated in parallel with the main transmission lines of the company or separately on the Oakland load. The arrangement of the plant is such that extension can be made

TABLE 22.—EVAPORATIVE TEST OF OIL-FIRED BOILER AT ELECTRIC PLANT.

Date of Test (1910)		Aug. 8	Aug. 9	Aug. 10	Aug. 11	Aug. 12.	Aug. 13	Sept. 5	Average of all Tests
Test Number	No.	1	2	3	4	5	6	7	
Duration of Test	Hrs.	7	7	7	7	7	7	7	7
Steam Pressure	Lbs.	184.9	184.9	186.0	184.7	183.5	184.6	184.9	184.8
Steam Temperature	Deg. F.	473.3	457.4	468.8	465.1	473.8	493.8	526.7	479.8
Superheat	Deg. F.	91.8	76.0	86.9	83.7	93.0	112.5	144.3	98.3
Temperature, Feed Water	Deg. F.	90.6	92.6	92.7	93.4	90.8	94.6	101.2	93.7
Factor of Evaporation		1.237	1.225	1.232	1.229	1.237	1.245	1.259	1.238
Average Water Level	Ins.	4	4	4	4	4	4	4	4
Barometer	Ins.	29.97	30.00	30.00	30.09	30.08	30.04	29.68	29.97
Temperature Boiler Room	Deg. F.	88.7	86.6	84.4	85.2	87.3	86.7	84.4	86.2
Temperature Flue Gases	Deg. F.	385.3	397.5	409.1	406.2	429.0	477.1	537.5	434.5
Draft: In Ash Pit	Ins.	.025	.035	.055	.044	.071	.127	.230	.084
Draft: In Furnace	Ins.	.01	.005	.025	.014	.060	.130	.188	.062
Draft: In Rear Pass	Ins.	.005	.014	.061	.046	.133	.296	.471	.147
Carbon Dioxide	%	12.2	13.4	13.3	14.3	14.2	13.3	12.1	13.2
Oxygen	%	3.6	2.7	2.4	1.8	1.7	2.8	6.8	3.1
Excess Air	%	28.7	17.7	18.5	10.6	11.3	18.5	43.0	21.2
Smoke		None	None	None	None	None	None	Light Haze	
Position of Ash Pit Doors			Doors Wide Open Throughout all Tests.						
Temp. in First Pass Above Third Tube	Deg. F.	1100	1090	1160	1180	1240	1300	1600	1240
Temp. Top First Pass	Deg. F.	640	640	700	680	780	940	1170	793
Temp. Top Second Pass	Deg. F.	570	540	620	610	650	740	820	650
Temp. Bottom Second Pass	Deg. F.	500	500	520	510	550	600	700	554
Temp. Bottom Third Pass	Deg. F.	450	450	505	495	530	570	660	523
Total Water Actually Evaporated	Lbs.	85766	111988	129628	129609	156622	191290	226558	147351
Total Water Evaporated from and at 212° F.	Lbs.	106092	137185	159702	159289	193741	238156	285236	182771
Water Per Hour Evaporated from and at 212°F.	Lbs.	15156	19598	22814	22756	27677	34022	40748	26110
Steam Used. (Pounds per Hour.)	Lbs.	34	441	549	549	624	708	873	568
By Burners. (Per Cent of Total Steam)	%	1.54	2.25	2.40	2.40	2.25	2.08	2.13	2.15
Steam Pressure to Burners	Lbs.	48.2	74.7	99.7	102.6	120.4	142.5	167.6	122.2
Oil Pressure to Burners	Lbs.	11.4	15.2	24.4	25.4	38.3	46.1	61.6	31.6
Temp. of Oil to Burner Line	Deg. F.	131.3	134.3	133.5	142.3	140.1	142.1	141.7	137.9
Kind of Oil Burned				Oil from Los Angeles Fields.					
Specific Gravity of Oil at 60° F.	S. G.	.9770	.9770	.9763	.9770	.9776	.9776	.9797	.9776
Specific Gravity of Oil, Beaume, at 60° F.	S. G.	13.3	13.3	13.4	13.3	13.2	13.2	12.9	13.2
Moisture in Oil	%	.4	.5	.45	.4	.8	.65	.6	.54
Heat Value of Oil as Fired	B.T.U.	18280	18256	18131	18253	18214	18171	17985	18184
Heat Value of Oil Corrected	B.T.U.	18353	18347	18212	18326	18357	18289	18093	18281
Total Oil as Fired	Lbs.	6913	8758	10322	10115	12602	16580	20205	12213
Total Oil Corrected for Moisture	Lbs.	6885	8714	10276	10075	12501	16472	20084	12144
Oil Per Hour as Fired	Lbs.	987	1251	1474	1445	1800	2369	2887	1745
Oil Per Hour Corrected	Lbs.	983	1245	1467	1439	1786	2353	2869	1735
Water Evaporated F. & A. 212°F. per Sq. F.H.S.	Lbs.	2.58	3.24	3.78	3.77	4.58	5.63	6.74	4.32
Boiler Horse Power Builders' Rating	B.H.P.	604.	604.	604.	604.	604.	604.	604.	604.
Boiler Horse Power Developed	B.H.P.	439.3	568.0	661.3	659.6	802.2	986.2	1181.0	756.8
Per Cent. Builders' Rating	%	72.7	94.0	109.4	109.2	132.8	163.3	195.5	125.3
Water Evaporated per Lb. of (Oil as Fired)	Lbs.	15.35	15.66	15.47	15.75	15.37	14.37	14.12	15.15
Oil from and at 212° F. (Corrected for Moisture).	Lbs.	15.41	15.74	15.54	15.81	15.49	14.46	14.20	15.23
Boiler Efficiency	%	81.1	82.8	82.4	83.3	81.5	76.4	75.8	80.47

in the future without in any way interrupting the service. The efficiency of the turbines either when floating on the line and used for voltage regulation or in giving assistance to the transmission lines has been fully demonstrated. Their ability to quickly take a load in cases of emergency renders them invaluable when viewed from the standpoint of auxiliaries to the hydro-electric system.

The steam-generating station of 5,000 kilowatt capacity at Sacramento is connected with the transmission lines from Colgate, Alto, and Folsom systems as well as the main transmission line from Oakland. With its installation of 5,000 kilowatts, this plant is capable of carrying the full Sacramento district load. In normal operation a machine is kept floating on the line, using a minimum amount of steam, but with enough boilers under steam to respond instantly to emergency calls. Although designed as a stand-by or auxiliary, the fact that all the hydro-electric stations are taxed to the full capacity will put the steam plant in constant commission as a generating station.

The building has a structural steel frame, with walls, floors and roof of reinforced concrete. The building is L-shaped, having a total length of 156 feet, width 100 feet at the generation end, and 71 feet at the boiler end of the building. The boiler room is one story high, the height to the roof being 40 feet above the first floor level.

The boiler room is large and well lighted and airy. The light is from above a glass-covered monitor or weather-board Three batteries composed of two Sterling boilers each are installed with room for an additional battery. The boilers are of the water tube type, each containing 600 3¼-inch tubes, three 42-inch drums and one 18-inch mud drum. Each boiler is rated at 822 horsepower. The high pressure steam pipes are designed for 200 pounds steam pressure with 125 degrees superheat. Each battery of boilers supports one smoke stack 7 feet 6 inches in diameter, mounted on breeching. These stacks stand 100 feet above the floor and 60 feet above the roof.

The fuel oil is fed through Peabody back shot burners, three to each boiler. Fuel oil pumps are of the Worthington duplex type. Provision is made to carry a full month's supply of oil for fuel. Storage tanks are placed on the extreme east end of the property, about 450 feet east of the building. These are two riveted steel tanks, the capacity of each being 10,000 barrels. The tanks are about 50 feet in diameter and 30 feet high. The tank walls and top are supported inside by timber bracing to prevent the tank collapsing when empty in a high wind. Each tank is supported on a reinforced concrete pad 30 inches deep and about 50 feet in diameter. A reinforced concrete retaining wall 12 feet high and 95 feet in diameter surrounds each tank. This is a safety precaution to hold the oil in case of a fire or of the tank's failing. The capacity of the concrete retainer is made equal to that of the tank.

Oil is brought to the tanks through 8-inch standard screw piping. Provision is made for the delivery of oil from barges on the river or from cars. On the oil wharf there is an oil manifold with four 6-inch connections. Along the spur railroad which runs in front of the building is a car manifold with four 4-inch connections. The service oil is brought to the building through an 8-inch pipe line encased in sawdust with a 2-inch steam line to heat the oil. Just outside the south end of the boiler room are two rectangular oil service tanks of 200 barrels capacity each. These are encased in reinforced concrete. They are placed below the ground level and are accessible through manholes.

Table 22 gives an evaporative test made at the Redondo plant of the Pacific Light and Power Company. The data are given through the courtesy of the Hammel Oil Burner Company. The test was made on a 604-horsepower Babcock and Wilcox boiler equipped with Hammel Patent Furnace and Oil Burners, the boiler being in regular service and under the usual plant operating conditions.

CHAPTER XIV

FUEL OIL IN THE SUGAR INDUSTRY

Although sucrose or cane sugar ($C_{12}H_{22}O_{11}$) is found in many plants, its extraction is often unprofitable because it is usually found in association with other substances. Only a comparatively small quantity of the sucrose will crystallize if dextrin, glucose, "invert sugar," or dissolved mineral salts are present in considerable quantities. Sugar is obtained commercially from various sources, the most important of which are sugar cane, sugar beet, sugar maple and the date palm. Although the sorghum plant contains considerable sugar it has not been possible to obtain from it a satisfactorily crystallized product, even after much experimentation, because its sugar content varies and in addition it contains a large percentage of gums and dextrin. As a commercial product, in the peculiar flavor of maple sugar lies its only value. When maple sugar is refined it cannot be distinguished from ordinary cane sugar, because it loses the maple sugar taste. Date palm sugar is shipped for refining and is produced in India as a low-grade crude sugar, where it is known as "jaggary."

Practically all commercial sucrose is obtained from the sugar cane and the sugar beet. A warm and moist climate is necessary for the growth of the sugar cane and there must be periods of hot and dry weather. Sugar cane is a member of the grass family and it is propagated by budding. A plant and several shoots are produced from each bud and these shoots form cane clumps. The height of the stalks varies; some being only four or five feet high, while some attain the height of twenty-five feet.

Practically all of the supply of sugar comes from Louisiana, Brazil, the West Indies, the Sandwich Islands, the Philippine Islands, Java, and Mexico. The climate suitable for sugar cane is not suitable for sugar beets, which require a temperate climate. Germany, France, and the United States raise great quantities of sugar beets.

In the growing cane plant, as is the case with many fruits, it is not until the plant reaches maturity that sucrose is secreted.

Ripe sugar cane has about the following analysis:

Sugar	18 %
Fibre	9.5%
Water	71 %

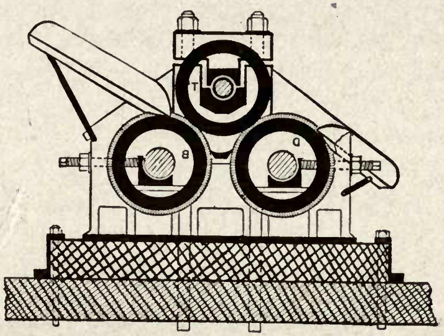


Fig. 83. Mill for Crushing Sugar Cane.

Other matter	1.5%

After the juice is squeezed from the ripe cane its analysis is about as follows:

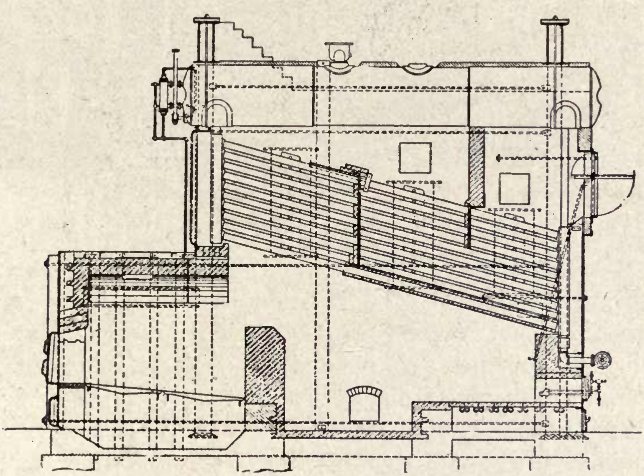


Fig. 84. A Furnace Burning Begasse and Oil.
(Courtesy of Babcock & Wilcox Co.)

Water	80 %
Sucrose	18 %
Glucose	0.30%
Gums	1.40%
Mineral Salts	0.30%

The actual yield of sugar, however, is not equal to the analysis, because ordinarily 16 to 20% of the juice cannot be extracted from the waste cane pulp, which is called "begasse." The mineral salts can be decreased in the mature cane if the soil in which it grows is plentifully limed, because the lime precipitates salts deposited by surface water and the decomposition of the soil. The preparation of raw sugar from the cane is divided into four operations:

(1) Extraction of the juice.
(2) Clarification of the juice.
(3) Evaporation of the juice to crystallization.
(4) Separation of the crystals from the liquor.

In the field the leaves are stripped from the cane and the

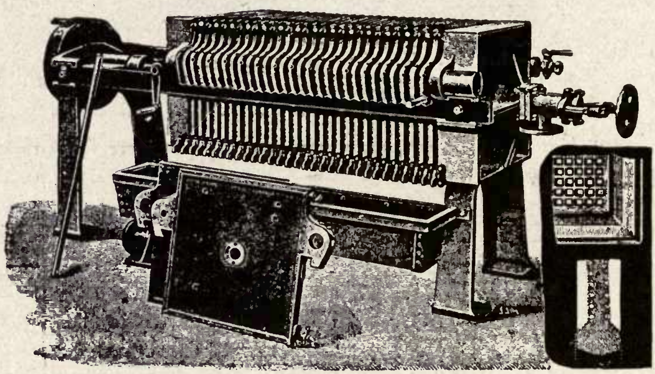


FIG. 85. A Typical Filter Press.

stripped cane is taken to the mill, where it is crushed and all of the juice extracted which it is possible to squeeze out. A great deal of the sugar is lost if fermentation begins, and consequently the crushing must be done very soon after the cane is cut. The crushing mills are very simple and are made up of two or three horizontal rolls having a diameter of 30 to 60 inches (see fig. 83). The axes of the rolls are parallel and the bearings of the rolls are adjustable. If the mill contains three rolls, the cane passes between the top roll and the first bottom roll and then between the top and the second bottom rolls. The second bottom roll is set nearer to the top roll than is the first, so that the crushing is done in two stages. The cane is ordinarily passed through two or three of these crushing mills and about sixty to seventy percent of the juice is extracted. In Louisiana shredder machines are used which consist of toothed wheels that revolve at different speeds. The cane is put through these wheels before it is taken to the mills and is broken up into a soft and pulpy mass. When cane is shredded before being sent to the mills the extraction of the juice averages a little over 75% of the total content of the cane. After the cane has come from the crushing mills it is put into about ten or twelve percent of cold or hot water to which milk of lime has been added. It is then passed through the crushing mill again and an increase of two or three percent more juice is obtained. The extracted juice runs off in the trough and the begasse or "trash" is used for fuel under the boilers. This waste fibre when used alone as a fuel requires elaborate and expensive equipment for burning. In many instances begasse is the sole

TABLE 23—ANALYSES AND CALORIFIC VALUES OF BEGASSE

Source	Moisture	C	H	O	N	Ash	B. t. u. per lb. Dry Bagasse
Cuba	51.50	43.15	6.00	47.95	....	2.90	7985
Cuba	49.10	43.74	6.08	48.61	....	1.57	8300
Cuba	42.50	43.61	6.06	48.45	....	1.88	8240
Cuba	51.61	46.80	5.34	46.35	....	1.51	....
Cuba	52.80	46.78	5.74	45.38	....	2.10	....
Porto Rico	41.60	44.28	6.66	47.10	0.41	1.35	8359
Porto Rico	43.50	44.21	6.31	47.72	0.41	1.35	8386
Porto Rico	44.20	44.92	6.27	46.50	0.41	1.90	8380
Louisiana	52.10	....	....	....	....	2.27	8230
Louisiana	54.00	....	....	....	....	....	8370
Louisiana	51.80	....	....	....	....	....	8371
Java	....	46.03	6.56	45.55	0.18	1.68	8681

fuel used, but in the more modern plants fuel oil is used to supply the necessary additional heat units. Table 23 gives the analyses and calorific values of begasse.[a]

In Hawaii, where there are modern furnace installations only 1½ to 2 gallons of oil are required per ton of cane treated, but the plants in Mexico and Louisiana which have not this modern equipment, use as much as 10 gallons of oil per ton of cane treated. The average horsepower required for each ton of cane handled per twenty-four hours is 1½. This means that a plant handling 2,000 tons of cane in twenty-four hours requires 3,000 boiler horsepower. The begasse, owing to the condition in which it comes from the mills, supplies only two-thirds of the heat units required, and fuel oil supplies the additional horsepower.

A special design of furnace for burning fuel oil in conjunction with begasse is not necessary, because the oil burner can be inserted above the fire doors through a hole in the boiler front.

a. Steam, Its Generation and Use, Babcock & Wilcox Co., p. 206.

The burner can be pointed so that its flame passes through the flame from the begasse. The oil flame will form carbon if it is cooled by coming in direct contact with the begasse. A very satisfactory method of installing auxiliary oil burners is to place them at the rear of the furnace so that the flame passes towards the front. Before the introduction of fuel oil the additional heat units necessary were supplied by coal, but fuel oil used in conjunction with begasse shows an increase of about 20.8 percent of boiler horsepower over that obtained by the use of coal and begasse. Fig. 84 shows a furnace for oil and begasse.

When the juice comes from the mills it contains small pieces of cane and these are removed by straining the juice through wire screens. In addition to the pieces of cane the juice also contains

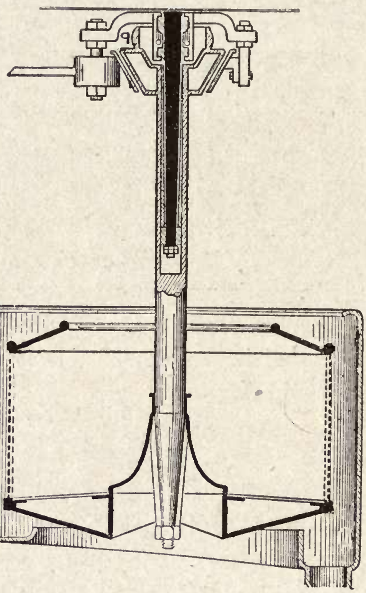


FIG. 86. A Centrifugal Separator.

organic acid, nitrogenous bodies, and invert sugar in solution. These are all very susceptible to fermentation and must be removed. The process of removal is called "defecation." The juice is passed through a heater which is placed in the vapor pipe of the vacuum pan and thence into the defecator tanks, heated by steam coils. In these tanks milk of lime is added for neutralizing the acids. After neutralization, the juice is left slightly acid and turns litmus paper red. Another function of the lime and of the heat is to coagulate the albumin and a portion of the gums. The juice is rapidly boiled and the coagulated material rises to the top. The scum, consisting of lime salts which hold all the impurities entangled in it, is usually about 2 inches thick. The scum is allowed to stand about three-quarters of an hour when it begins to crack. At this point the scum is either skimmed off or else the juice is drawn off beneath it. The scum is run into tanks where it is mixed with more lime and sawdust. The purpose of the sawdust is to make the cake more porous in the subsequent filter-pressing. The juice obtained from the filter-press (see fig. 85) is run into the juice from the defecators and the entire quantity of juice is now ready for evaporation. On the successful work of defecation depends the amount and the quality of the sugar produced.

In all modern sugar houses enormous pans are used for evaporation. The juice is generally concentrated three times, after which the solution will contain about fifty percent of solids, at which point crystallization begins. The liquor is then transferred to a simple vacuum pan called the "strike" pan, where the evaporation is continued slowly under a high vacuum with the object of building up the crystals on the crystal points.

When the crystals have reached the desired size in the "strike" pan, the mixture of crystals and syrup is run into storage tanks where it is slightly cooled. From these tanks it is run into centrifugal separators (see fig. 86), where the molasses is separated from the sugar. The sugar obtained in the centrifugal machine is called the "first sugar" and is at once packed for shipment. The first sugars, if they are of good quality, contain 95 to 97 percent pure sugar and are light colored. The molasses separated from the first sugar is called "first molasses," which contains about 50 percent of sucrose. The molasses is diluted and again defecated with lime and the clarified syrup thus obtained is again boiled in the vacuum pans yielding a "second sugar." The second sugar crystallizes slowly and it is necessary for the concentrated syrup to stand from three to seven days in a room kept at a temperature of sixty degrees C. until crystallization is completed. The mass is then put through the centrifugal separator and yields a "second" or "molasses sugar" and second molasses. The sugar thus obtained is not uniform in quality and can either be shipped for what it will bring on the market or it can be dissolved in water and the resulting syrup added to the juice going to the vacuum pan.

It does not pay to attempt to recover the forty percent of sugar contained in the second molasses, although it is sometimes fermented to make rum or alcohol. It also has a fuel value and is often injected into the furnace in a fine stream. The second molasses is not suitable for table use or for cooking purposes.

From whatever source raw sugar is derived it is always more or less colored and impure. To obtain pure white sugar the raw sugar must be refined. Refining is not usually done in the same countries that produce the raw sugar. Sugar refining is a simpler

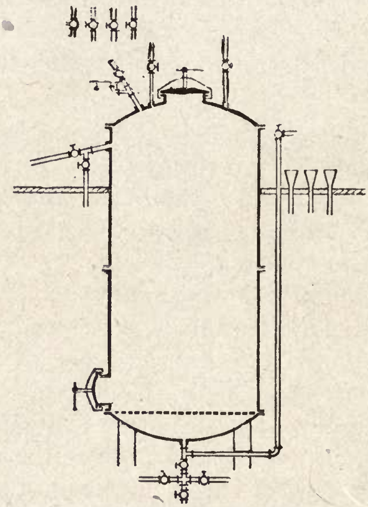


FIG. 87. Type of Char-Filter.

process than the preparation of the raw sugar, but much expensive machinery and careful attention to detail are necessary. The process consists in dissolving the crude sugar, separating the impurities from it, and re-crystallizing it. Refineries usually have the melting tanks on the ground floor. Ordinarily each tank has a capacity of 16,000 lbs. of sugar, to which water is added to form a syrup of 1.25 specific gravity. This syrup contains about 55 percent of solids. The melter which contains an efficient mixer or stirring apparatus has a false bottom which retains the coarse impurities such as straw, pieces of cane, leaves, sticks and stones. Heat is supplied to the melter by closed steam coils. The melter is filled about one-third full of water at a temperature of 170° F., after which the stirrer is put in motion and the first charge of sugar is dumped in. The sugar dissolves in about 15 minutes and the liquor, which now is a light straw to dark brown color is pumped directly to the "blow-ups." The blow-ups are defecators which hold about 16,000 lbs. of sugar. These defecators are also heated by closed steam coils, but each defecator also has a perforated coil through which air is forced for the purpose of agitating the liquid. For centrifugal sugars the temperature is kept at 160° F., but more heat is necessary for lower grades of sugar. This defecation removes any fine suspended dirt, gums, organic acids and impurities.

The temperature is now raised to boiling and the air blast is turned on for about 20 to 30 minutes. When deep cracks appear

FIG. 88. Oil-Driven Tractor Pulling Plows on Sugar Estate. (Courtesy of Sinclair's Magazine.)

in the scum, the liquor is poured off and passed into bag filters. The liquid from these filters must be perfectly clear if the sugar is to be white.

The bag filter is a long narrow bag of twilled cotton which is supported by an outside cover of coarse, strong netting, which can sustain a considerable weight. These bags are often five to six feet long and eight inches in diameter. The bags are suspended in a closed room which is about 12x6x8 feet. The room contains an open steam coil which heats the bags to 180° F. before the liquor is allowed to run into them. First runnings are always re-filtered because they are muddy. When the liquor runs clear it is collected in tanks which are placed above the char-filters. It is customary to allow the filtration to continue for about 24 hours because the bags become clogged with slimy mud making the filtration very slow. At the end of 24 hours the bags are flushed with pure water, which is drawn out by a suction pipe and returned to the defecators. The bags are then flushed with hot water until the liquor draining from them contains only two percent of solids. In order to get rid of the soft mud the bags are then turned inside out in a tank of hot water and are thoroughly washed and dried. The mud which is washed from the bags contains about 20 percent sugar and is sent to special tanks where the liquid is made strongly alkaline by lime and is then filter-pressed. The clear liquor from the filter-press is used to flush the bag filters and to mix with the melting water for raw sugar. The straw colored liquor contained in the tanks above the char-filter is now passed through the char-filter. The char-filter is shown in fig. 87. These filters are about 24 feet deep and 8 feet in diameter and contain bone-char in grains passing a No. 16 sieve and remaining on the No. 30 sieve. About one pound of bone-char is used for each pound of sugar melted. Because the filter becomes clogged at times, it is often necessary to use compressed air to force the liquor through the char. The filtered liquor from the char-filter is now delivered to copper vacuum pans, which are about 12 feet high and 10 feet in diameter. Each pan is connected with a condenser by a goose-neck. For granulated sugar the boiling is carried on at about 160° F., and is continued until grains appear, at which time some syrup is added slowly until the crystals have reached the desired size. When the crystals are large enough, air is slowly admitted to the vacuum pan and the vacuum pumps are started. The magma of sugar and syrup is drawn off through the bottom valve into coolers or mixers, which are directly beneath the vacuum pans. In order to prevent the grains from growing again into a mass, the magma is stirred while cooling. The sugar and the syrup are now separated in centrifugal machines. In the separator the sugar is washed for the purpose of removing any adhering syrup and it is then dropped into a storage bin, from which it is carried by a belt conveyor to the granulator. The granulator is heated by steam and is a long iron cylinder set at a slight incline. The cylinder is made to rotate slowly which prevents the grains of sugar from sticking together. During its passage through the granulator the sugar is thoroughly dried and is then conveyed to a series of sieve reels, where it is separated into three or four sizes.

In addition to its use in furnaces in the preparation of raw sugar, fuel oil is also often used under boilers at the refineries. A more recent development has made it adaptable to the preparation of ground for the planting of sugar cane and for the transportation of the cane to the mills. In order to prepare sugar land for the crop it must be plowed, cross-plowed, harrowed, rolled, and furrowed. Before tractors using fuel oil were employed many mule-teams and much labor were necessary. With the introduction of oil-driven tractors the work is performed at less than one-third the former cost. Figure 88 shows an oil-driven tractor drawing plows on one of the sugar estates in the Philippine Islands.

CHAPTER XV

FUEL OIL IN THE GLASS INDUSTRY

Glass beads have been found in early Egyptian mummy cases which are at least 3,000 years old. The glass industry also flourished in Rome, but in the middle of the thirteenth century Venice became the center of the industry and later Bohemia took the lead in glass manufacturing.

The necessary materials for making glass are silica, some alkali, and lime or lead. Glass is known in commerce under various names, but it is always a mixture of silicates. The silica was formerly derived from quartz or flint, but on account of the expense of preparation of these raw materials, quartz sand and soft quartzites are now used except for glass of a very fine quality. Alkali is derived from the carbonate or sulphate of soda or potash.

The first process in glass manufacture is grinding the raw materials and thoroughly mixing them. In some instances to insure perfect mixing the batch is reground. When a thorough mixture is assured the batch is shoveled into the furnace together with a certain amount of broken glass called "cullet," which melts at a very low temperature and assists in starting the fusion of the ground raw materials. Care must be taken that iron is present in only minute quantity, because it turns the glass a dark green. Where color is no objection as in common bottle glass and other cheap grades, a larger amount of blast furnace slag can be used.

The fuel for glass making should yield a long flame without smoke or soot. Furthermore, delicate heat control is essential. With the use of fuel oil the losses sustained by reason of varying and unreliable temperatures have been materially reduced. The discovery of natural gas had a great influence on the glass industry and most of the largest plants are located in and around Pittsburgh, because it was the center of the gas territory. Fuel oil is now most generally used in glass making. In the burners used in glass making only high pressure should be used for atomizing the oil.

There are several forms of glass furnaces. The common pot furnace has a central opening through which the flame and hot gases come up from the grate which is below the hearth. The pots are placed in a circle around this opening and the flame is deflected down to the pots by a flat arch roof. Pots for glass making must be made of only the best material, and must be very

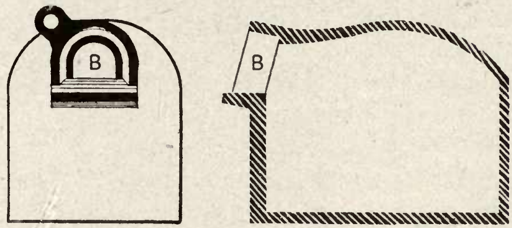


FIG. 89. Typical Closed Pot.
(From Outlines of Industrial Chemistry, Thorp.)

carefully constructed. There are two kinds of glass pots, open and closed. Open pots are usually slightly greater in diameter at the top than on the bottom. The diameter of the top is from three to five feet and the pots are usually three to five feet deep. They give a quick melt, but are expensive and fragile. The dimensions of closed pots (see fig. 89) are: Length, 5 feet; width,

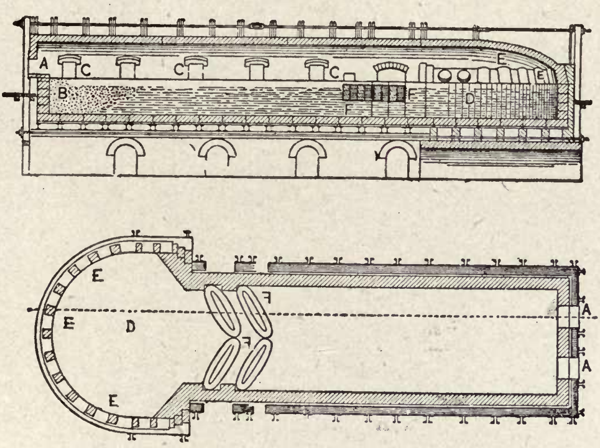


FIG. 90. Regenerative Furnace.
(From Outlines of Industrial Chemistry, Thorp.)

3½ feet; height, 4 feet. Through the construction of the neck built into the wall of the furnace neither fire gases nor flame can come in contact with the glass. Closed pots are always used for lead glass. Before putting pots in the glass furnace they are heated in a special furnace with a slow rise of temperature. The life of pots is very uncertain, but sometimes they last for months.

The regenerative type of furnace shown in fig. 90 has the air for combustion passing through one flue in the combustion cham-

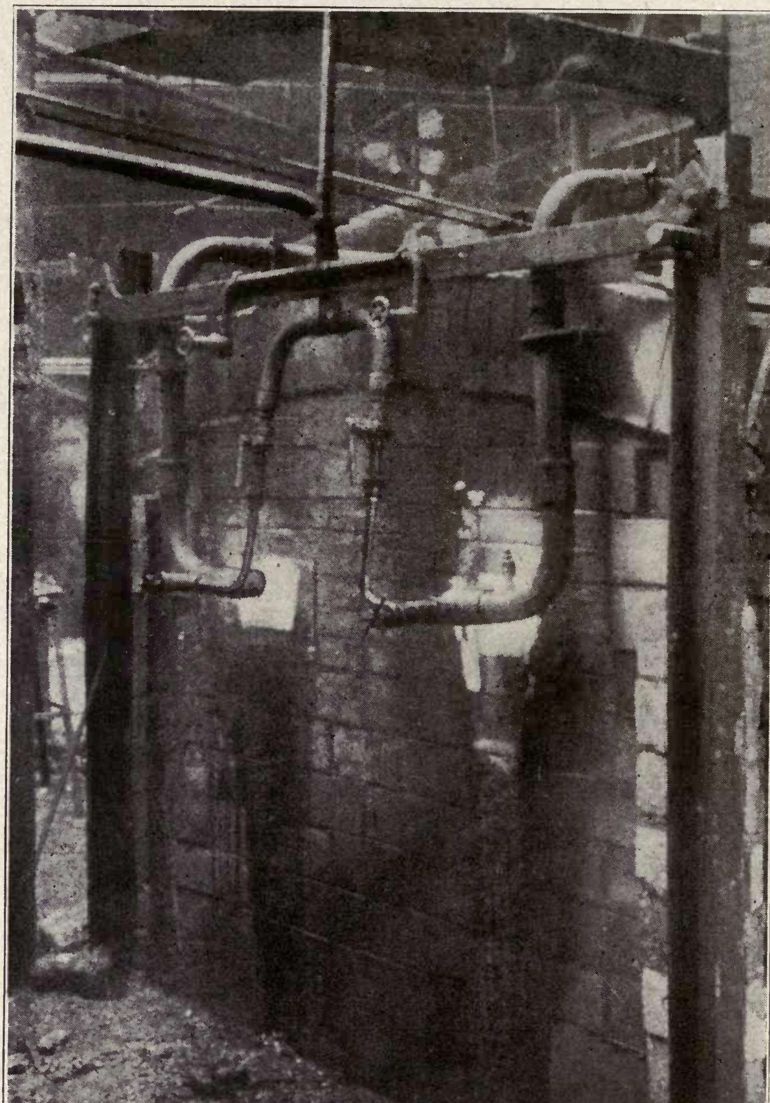


FIG. 91. Glass Tank Holding 6½ Tons Equipped with Oil Burners. (Courtesy of Anglo-Mexican Petroleum Products Co., Ltd.)

ber then through the furnace and down the other flue. The intake chamber heats the incoming air and the escaping gases heat the lining of the exhaust chamber which is made of checker-work brick. At twenty-minute intervals the air current is reversed and so the intake air is always well heated. The oil burner at one of these furnaces used compressed air for atomizing the oil at 40 pounds pressure and 140° F. The walls of this type of furnace would crack with uneven expansion and it requires approximately three weeks to bring the furnace up to its proper working tem-

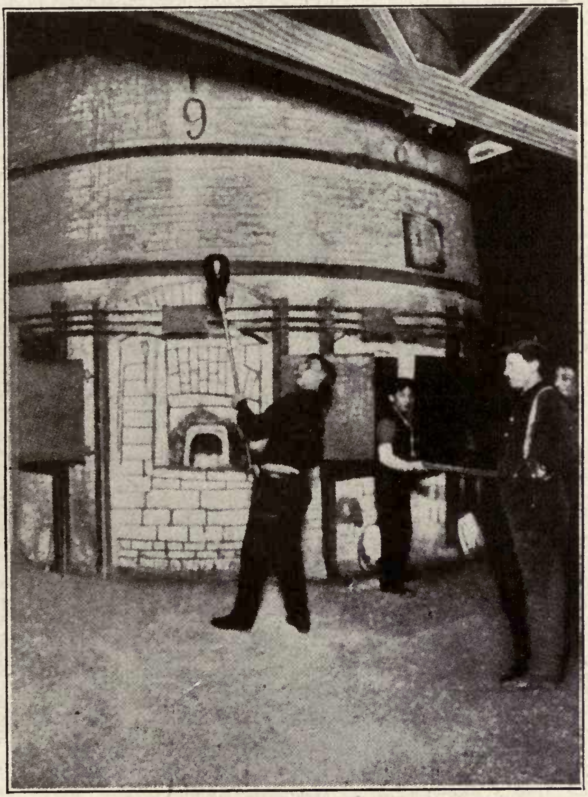


Fig. 92. Blowing Window Glass.
(Courtesy of Tide Water Oil Co.)

perature. This furnace can also be used as a tank furnace when a large quantity of one kind of glass is to be made. A large deep tank replaces the pots. At one end of the tank the raw materials are continually introduced and from the other end the glass is constantly withdrawn. Fig. 91 shows an oil-burning glass tank holding 6½ tons.

When the raw materials have become melted and the gases formed by fusion have escaped in bubbles and the melt has come to a state of high fusion, the liquid glass is allowed to stand at a raised temperature. The object of this is to free the glass entirely from bubbles and this part of the process is called refining. When allowed to cool after having been fused, the glass first becomes pasty and then rigid. Without passing through this pasty stage, glass blowing would be impossible, and only cut or molded

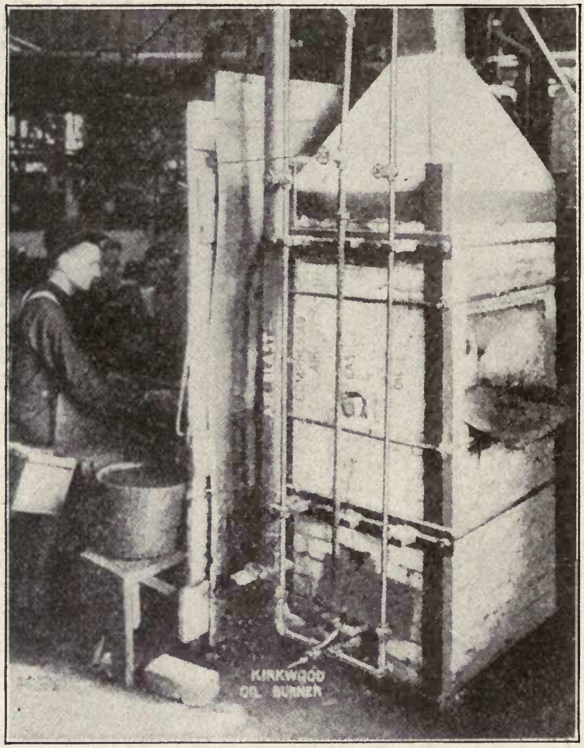


FIG. 93. Glory Hole Furnace.
(Courtesy of Tate-Jones & Co., Inc.)

ware could be manufactured. As a rule, the higher the percentage of silica the more difficult the glass is to fuse and the harder and more brittle it becomes.

In the manufacture of plate glass the melted glass is poured on a table made of thick, narrow segments of cast iron, bolted together and planed on top. To smooth the surface of the glass and to give the plate uniform thickness, a heavy iron roller is passed over the pasty mass. As soon as the plate is rolled, it is transferred to a furnace which is directly in front of the table and which has been heated to the temperature of the glass. This is called the annealing oven. When the plate has been transferred to the annealing oven it is closed and the burners are extinguished and the plate is allowed to cool for a number of days very slowly. Upon again removing from the annealing oven, the plate is uneven and rough. It is placed on a table and heavy cast iron rubbers slide over its surface with a whirling motion while water and coarse sand are sprinkled on it. About half the thickness of the plate is cut away during grinding and polishing.

Window glass is always blown. After the refining, the glass is allowed to become pasty and then the blower begins his work, as shown in fig. 92. The pipe of the glass blower is a straight piece of iron tubing 4 or 5 feet long. A lump gathers on the end of the pipe and by blowing through it while whirling it between the hands, the blower forms a hollow globe of glass. The hollow globe is again heated in the furnace called the glory hole (see fig. 93) and when soft is rolled on a flat surface and then swung in a vertical circle. In order to allow room for vertical swinging, the blower stands on a plank or bridge placed across a deep pit. While swinging, the blower occasionally blows through the pipe until the globe becomes a hollow cylinder closed at one end and opening into the pipe at the other. The closed end of the cylinder is re-heated until soft and then blows out. A hollow cylinder open at both ends is thus formed and with a diamond is cut lengthwise and put into the flattening furnace which maintains a temperature sufficient to soften the glass. The cylinder slowly opens and spreads out on the floor of the furnace in a flat sheet.

The regenerative tank furnace is particularly adapted to the manufacture of bottle glass.[a] A typical furnace of this kind may be 75 feet long, 16 feet wide, and the depth to the level of the door may be 5 feet. As the glass comes from the doors it is taken by the bottle machine and made into bottles which are then passed through the annealing furnace. They are carried by an endless chain gear into the furnace to a revolving table and are conveyed into the hottest part of the furnace, which is usually at a temperature of about 100° F. At this degree the bottles come in direct contact with the flame and then pass out the door by another endless chain gear. The entire operation requires about 36 hours.

a. Outlines of Industrial Chemistry, Thorp.

Bottle glass is melted and refined in this tank furnace at a consumption of 140 gallons of oil per ton of glass.

Fuel oil is very generally used now by the large glass factories because the flame can come in direct contact with the glass without producing any discolorization or injuring the glass in any way. In addition, the temperature control is perfect and many articles that were formerly ruined by fluctuations in temperature can now go through the process without injury, due to the maintenance of an absolutely uniform temperature.

CHAPTER XVI

FUEL OIL IN CERAMIC INDUSTRIES

In the manufacture of clay products any fuel which causes discoloration by uneven heating, soot or smoke, is undesirable and unprofitable. Coal is out of the running in the manufacture of ceramic products, such as vases and dishes, and oil is the preferable fuel even in manufacturing enameled, vitrified, fire and common brick.

Many enamel ware manufacturers use the muffle kiln. Whenever it is necessary to treat the ware with two or more coats of enamel, it is necessary to apply all but the first coat at a higher temperature. In burning common brick about five days are required to water smoke and burn and 35 to 50 gallons of crude oil per thousand bricks are required. A longer time, higher temperature and greater consumption of oil per thousand bricks are necessary in the burning of fire bricks, but the process is similar to that used for common brick.

In burning brick with oil the amount of fuel required varies with the quality of clay or shale used. One large plant in Kansas is burning brick using 100 gallons of oil per 1,000 brick. This includes fuel for running their boilers to operate the plant. The presence of carbon in clay is always a serious problem where coal is the fuel, because in case the carbon is ignited and burns freely, the fires in the furnace have to be drawn, all air supply shut off and the carbon allowed to smolder until completely burned out. In pulling a coal fire, the doors must be open and an excess of air rushes into the kiln before it can be daubed, not only checking the ware but supplying large quantities of oxygen for combustion of the carbon in the clay which might overburn the entire kiln. An oil fire does away with these dangers. It can be instantly turned off or turned down and the air inlets closed without loss of fuel or danger to kilns. Fig. 94 shows an oil-burning brick kiln of a capacity of 500,000 brick.

Limestone as quarried is calcium carbonate, and its composition expressed chemically is $CaCo_3$. To make quicklime, which is CaO, it is necessary that the carbon dioxide, CO_2, be driven off by heat. Carbon dioxide begins to come off at a temperature of about 750 degrees F., but a temperature of over 1,300 degrees is required to completely reduce the stone to calcium oxide. There are always some impurities present in the original limestone and the actual yield of quicklime varies from 30 to 55 percent of the limestone. The different quarries produce limestone of different densities and consequently the difficulty of reducing the stone to quicklime varies. The dense and compact stones yield the best quality of lime.

The old method of burning lime in the "periodic" kilns is wasteful of fuel and time. This type of kiln is shown in fig. 95.

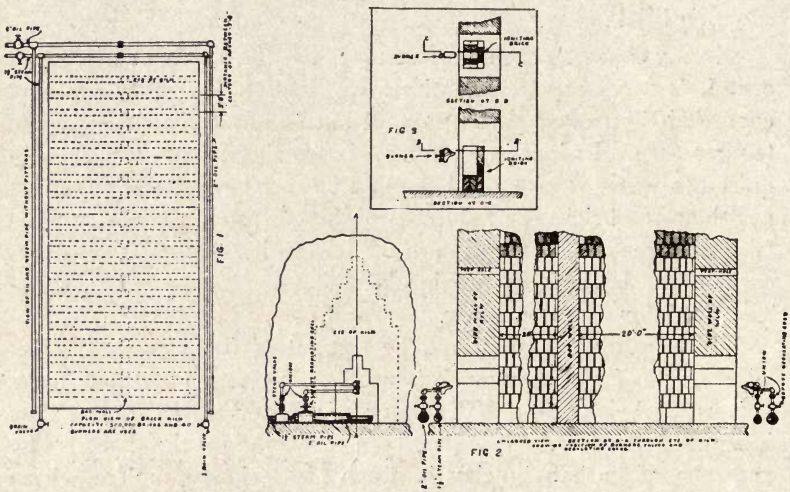


FIG. 94. An Oil-Burning Brick Kiln. (Courtesy of W. N. Best, Inc.)

The kiln is made of large blocks of limestone or of brick. Two or three feet from the ground an arch (A) of large blocks of limestone is turned. The fire is built under the arch and the limestone is piled on top of the arch, the lumps varying in size from that of a cocoanut just above the arch to that of a goose egg at the top of the kiln. After the fire is started, the temperature is raised very slowly for six or eight hours to prevent the limestone arch from crumbling. After this interval the temperature is kept at a full red heat for two days or more when the fire is allowed to burn out and the kiln cools. During the time of cooling, discharging and recharging, the kiln is idle and much time is lost. Moreover a large amount of fuel is wasted in heating the walls of the kiln after each recharging.

When fuel oil is used in burning lime all the disadvantages of the periodic kiln are eliminated because the production is continuous. Furthermore, oil burned lime commands a ready market because of its greater cleanliness. There are two types of kiln

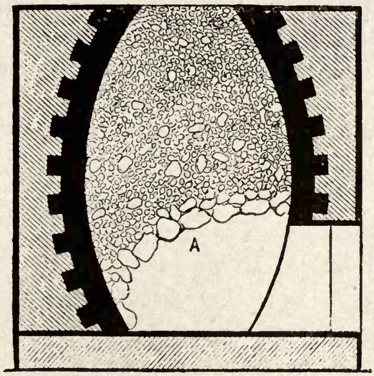


FIG. 95. A Periodic Lime Kiln.

which have proven remarkably successful with fuel oil. One, the "continuous" kiln, is vertical and this kiln should be charged with lumps of stone about the size of a man's head. If the temperature is too low or the lumps too large, the stone will not be calcined to the center and the lumps will not slake. At the burning zone the width of the kiln should not exceed eight feet, because with a

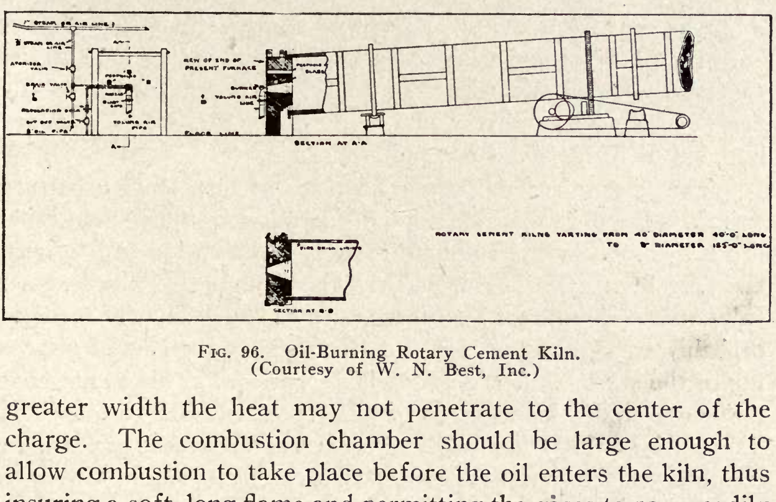


FIG. 96. Oil-Burning Rotary Cement Kiln.
(Courtesy of W. N. Best, Inc.)

greater width the heat may not penetrate to the center of the charge. The combustion chamber should be large enough to allow combustion to take place before the oil enters the kiln, thus insuring a soft, long flame and permitting the gases to pass readily to the center of the kiln. A low pressure air burner is preferable for this purpose and it should be so constructed as to thoroughly atomize the oil. Air should be admitted around the burner, giving complete combustion by passing through the flame.

The second type is called the "rotary" kiln, shown in figs. 96 and 97. This type had been universally adopted for the burning of Portland cement, and its proven efficiency showed its adaptability to lime burning when the lime is to be ground and hydrated. The lime produced in the rotary kiln is broken into fine pieces and consequently is not desirable for building lime. The size of the rotary kiln for lime burning is regulated to a great extent by the desired capacity, and there is a difference of opinion as to the proper diameter and length to secure the most economical results. The idea of the rotary kiln was first conceived by Crampton in 1877, but no practical application was made till Ransom patented his design in England in 1885. The rotary kiln is really nothing more than a plain cylindrical tube supported by four or five sets of heavy roller bearings and driven by a train of gear wheels The revolving speed is controlled by regulators and is from 1 to 2½ R. P. M., depending upon the material to be burned. The tube is inclined towards the discharge end at an inclination of one to twenty-five. The rotation of the cylinder by reason of its inclination slowly advances the material toward and out of the lower end. The most popular sizes of rotary kilns for the larger plants are 7 to 7½ feet in diameter by 100 to 125 feet in length.

The great Air Nitrates plant at Muscle Shoals, Alabama, built by the government, has 8 by 125 ft. rotary kilns for burning the lime used in the electric furnaces in the first step of the process. Repairs are very low in the moving parts of a rotary kiln and its life is about 20 years.

The disposal of the large quantities of lime sludge that are daily produced in the causticizing operation by those pulp mills using the soda or the sulphate process and by the alkali works, has long been a serious problem. The lime has so much actual value that it should not be thrown away. The price paid for lime probably averages $4 per ton f. o. b. plant, and the cost of disposing of the waste sludge is at least 25c per ton. This means that the waste sludge has a value of $4.25 per ton if burned back to lime. About 1900 the western beet sugar plants began to use the rotary kiln for re-burning their spent lime. The results have been perfectly satisfactory and today such installations are common. Lime sludge can be re-burned far more cheaply than new lime can be bought. It is, of course, impossible to re-burn the same lime indefinitely, as it gradually becomes contaminated from constant use, mainly from the linings of the kilns. The customary practice is to introduce a certain quantity of new lime into the circuit periodically. This usually amounts to about 15% of the lime used. The quality of the recovered lime depends to a great extent on the quality of the original stone from which it was produced.

Portland cement is manufactured from a mixture of materials containing lime and silica in definite proportions. The raw materials are usually limestone in some form and clay or

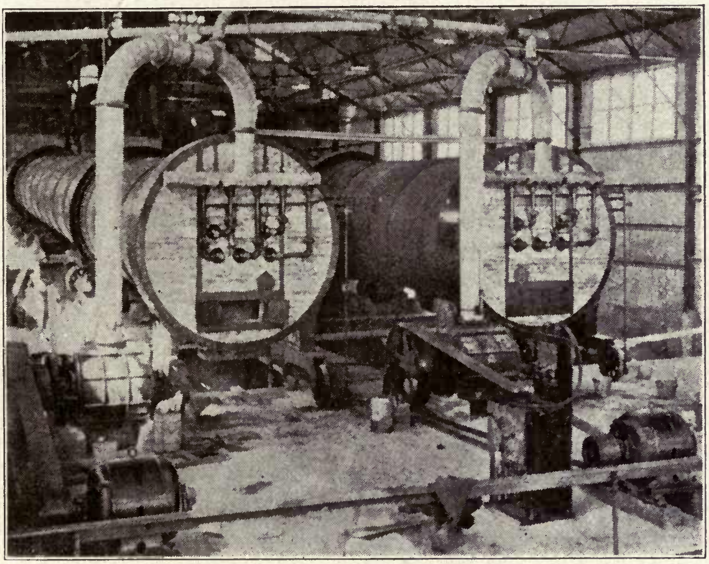


Fig. 97. Oil-Burning Rotary Cement Kiln.

shale. The materials are pulverized raw and mixed either in the form of a dry powder or in a wet condition and are then delivered to the rotary kiln in which the required chemical changes take place. The temperatures required for burning cement clinker are from 2,800 to 3,000 degrees F. To withstand these high temperatures a lining having high refractory qualities must be employed. It must also have the quality of withstanding decomposition by the chemical action taking place within the kiln.

During the passage of the mixed material through the kiln there are two stages of physical and chemical changes. Water and carbon dioxide are driven off at an average temperature of

1,800 degrees F. in the first stage and in the second the burned mass is fused to clinker at high temperatures.

The rotary kilns used in cement plants vary in dimensions, but the tendency is toward greater length and diameter. In 1890 they were about 4 feet in external diameter and 40 feet long. At present they are 8 to 12 feet in diameter and 200 to 275 feet long. The economy of the kiln has been greatly increased by increasing its length and this is in part due to the carbon dioxide being driven off from the materials before they reach the combustion zone in the kiln and in part to the reduction of heat losses. With long kilns the average amount of oil required to burn one barrel of cement is 11 gallons.

In handling oil for fuel it is necessary to provide storage tanks of sufficient capacity to keep the plant running for a reasonable period of car blockade or other possible failure of the source of supply. They must also be erected far enough from the rest of the plant to avoid fire hazard and yet sufficiently near to eliminate long pipe lines. For unloading from tank cars it is usual to provide a steel or concrete sump, to which the oil is emptied directly and from which it flows by gravity or is pumped to the storage tanks. The latter in turn connect with, say, 1,000-gal. "measuring tanks," from which the daily supply is taken into the plant. Further pumps, then, must be provided to send the oil to the kiln burners under pressure, or the same effect can be produced by gravity if a side hill unloading and storage sufficiently above kiln level is feasible. Where oil pumps are used, it is desirable to have them in duplicate, and also to have a duplicate or ring system of piping, so that any section can be cut out or by-passed if repairs become necessary.

Before being admitted to the burner spray nozzles, the oil must have its temperature raised sufficiently for atomizing in a steam heater designed for this purpose. The low-pressure system requires a blower, but the high-pressure system takes a compressor, about the same actual volume of free air being drawn through the intake in either case. The high-pressure system effects a much better atomizing of the oil but, of course, it costs considerably more for the compressor, motor, electric current and other running expense.

For each rotary kiln two oil burners or multiples thereof are ordinarily used, one being equipped with a round-point nozzle and the other with a flat nozzle. The former is designed to throw the flame to the rear of the kiln and the latter to hold the flame near to the front. By this arrangement of nozzle units and proper regulation of the burner, the temperature can be accurately controlled at any point in the kiln.

The competitors of fuel oil at cement plants are natural gas, producer gas, and powdered coal, of which the last competes most actively. The advantages of oil over coal are obvious. It can be transported with much greater facility; no coal drying, grinding, or conveying machinery is necessary; the kiln can receive its supply of fuel in a minimum of time simply by turning a valve; and the supply can be regulated with the greatest ease.

CHAPTER XVII

HEATING PUBLIC BUILDINGS, HOTELS AND RESIDENCES

The increasing cost of coal and the uncertainty of obtaining a supply when it is most needed have brought about a steadily increasing use of fuel oil for the heating and lighting plants of public buildings, hotels, apartment houses, and private residences and for many domestic purposes.

A direct comparison of the cost of one million B. t. u. of coal and one million B. t. u. of oil is not an index to the desirability of burning oil under the boilers of these plants. It is necessary to consider also the freedom from smoke and dust which fuel oil burning insures and it is also necessary to remember that during the spring and fall months very little heat is required to provide a comfortable temperature in buildings. If coal is used, the consumption of fuel must continue after this temperature is attained, but oil burners can be shut off, stopping fuel consumption, when the desired temperature is reached. Table 21 gives the percentages of total fuel for the season required for the different months.

TABLE 24—MONTHLY FUEL REQUIREMENTS IN PERCENTAGES OF TOTAL FOR SEASON

State	October	November	December	January	February	March	April	May
New York.....	3	7	15	25	22	20	5	3
Michigan......	5	12	15	18	21	17	8	4
Pennsylvania..	8	12	13	15	16	19	12	5
Ohio..........	3	12	18	21	19	14	11	2
Missouri......	3	11	18	22	20	13	10	3

The ease with which fuel oil burners respond to peak load demands for heat and light makes them especially desirable for office buildings. Elimination of the expense of ash removal when burning oil is also a point to be considered.

Fig. 98 shows the oil burner installation at the San Francisco Hospital. The San Francisco Hospital consists of ten buildings, costing $3,500,000, and is maintained by the City and County of San Francisco for the treatment of its sick poor. It has accommodations for 1,000 patients. It is the practice at the hospital plant to heat the oil to a temperature of about 270 degrees, forcing it through the burner tip at about 130 pounds pressure. The system consists primarily of two duplex oil pumps and two oil heaters and burner. Two pumps and two heaters are provided, so

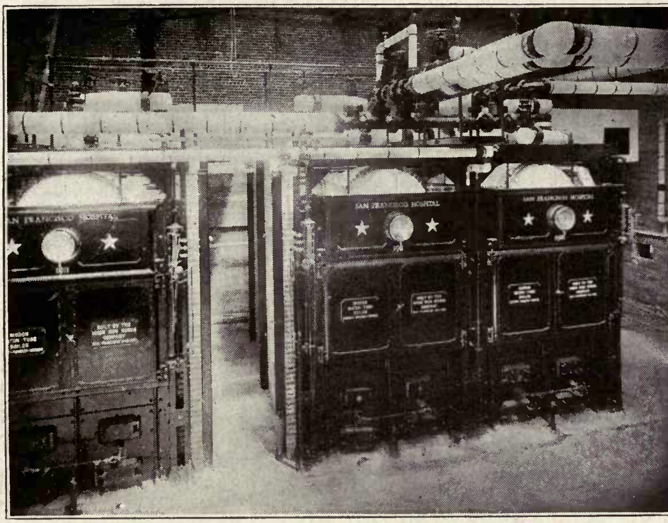


FIG. 98. Oil-Burner Installation at San Francisco Hospital.

that in case of a breakdown, or in case of overflow, there will always be one pump and one heater in reserve. About 50 barrels of fuel oil are used each day, the supply being carried in a 12,000-

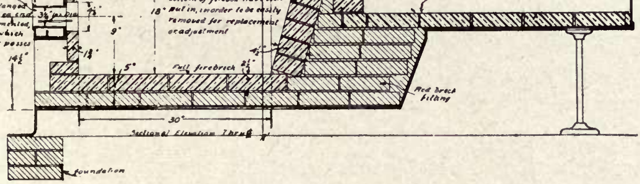


FIG. 99. Sectional View of Firebox Construction of a Schoolhouse Hot-air Furnace. (Courtesy of Fess System Co.)

gallon steel tank placed under the floor of the fire room. As a protection the steel tank is surrounded with a brick wall. The power plant consists of four 250-horsepower Heine boilers, and the entire boiler room is looked after by one fireman. Since the plant was installed six years ago, it has never been shut down. It is absolutely necessary that this plant be in constant operation because the hospital is completely isolated from all outside sources of power. Electricity for power and light are generated by four 125 kilowatt Curtis turbine generator units. There are 138 motors throughout the hospital which operate the equipment of the hospital. All steam and hot water for the hospital is supplied by the power plant.

Fuel oil is peculiarly adapted to school power plants. Fig. 99 gives a sectional view of a schoolhouse hot-air furnace. Fig. 100 shows the oil-burning equipment now installed in all new San Francisco schools.

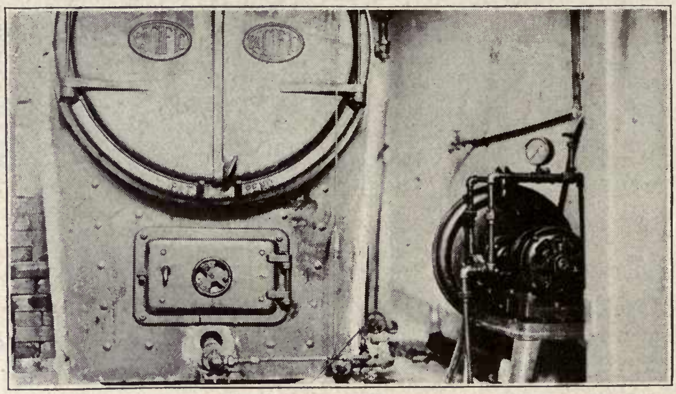


FIG. 100. Oil-Burner Equipment Installed in San Francisco Schools.

During the coal famine in Chicago in the winter of 1919, many of the Chicago schools installed fuel oil burners. The oil-burning systems were installed and burning in four days.[a] The installation provided at the schools has the steam-atomizing pressure system of supplying oil to boiler firing. For conditions such as obtained at the schools selected, this was the quickest and most economical, as well as the simplest installation that could be made. The equipment consisted of storage tank, or tanks, duplex steam-driven oil pump, steam and oil piping, oil burners, and a small auxiliary boiler. The following description, with minor variations, will outline a typical installation:

Two horizontal, steel storage tanks, 6 ft. in diameter by 12 ft. long, each having a capacity of 2,000 gallons of oil, were installed.

a. Oil News, Jan. 5, 1920, p. 38.

These tanks were so inter-connected by piping as to permit of either tank being drawn from or filled separately, thereby insuring an uninterrupted service of oil to the burners. Inside each tank and surrounding the suction pipe, a pipe coil was placed, through which the exhaust steam from the oil pump is discharged for the purpose of heating up the oil sufficiently to keep it in a

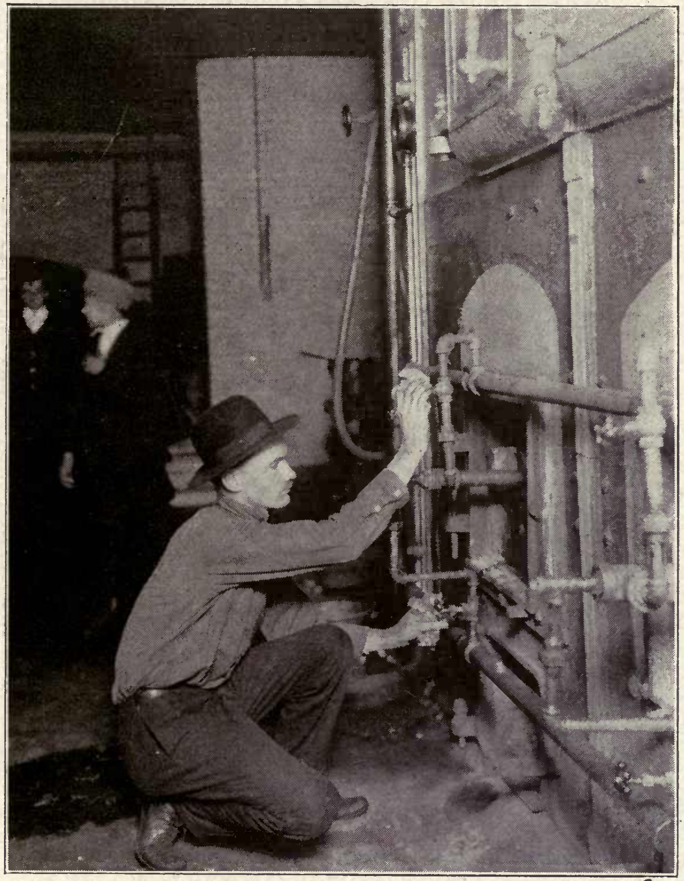


FIG. 101. Fuel Oil Burner Installation in Chicago Schools.

free-flowing condition during cold weather. As the tanks are located outdoors and exposed to all degrees of weather, they were insulated with hair felt and a weather-proof covering in order to conserve the heat supplied from the exhaust-steam coil and to keep the whole mass of oil in as free-flowing condition as possible. A by-pass from the live-steam line to the exhaust-steam line was provided, so that when occasion requires live steam can be used for heating the oil.

A two-inch pipe was run from the tanks to the oil pump to provide suction to the pump, and a pipe 1¼ in. in diameter was run from the pump and along the front of the boiler, from which a connection was provided to each burner. A pressure relief valve was installed in the discharge line from the pump and releasing into the suction line. This valve affords relief in case the pressure on the discharge line should go higher than desired. A pressure gauge was installed on the discharge line so that the operator can know at all times the pressure of oil supplied to the burners.

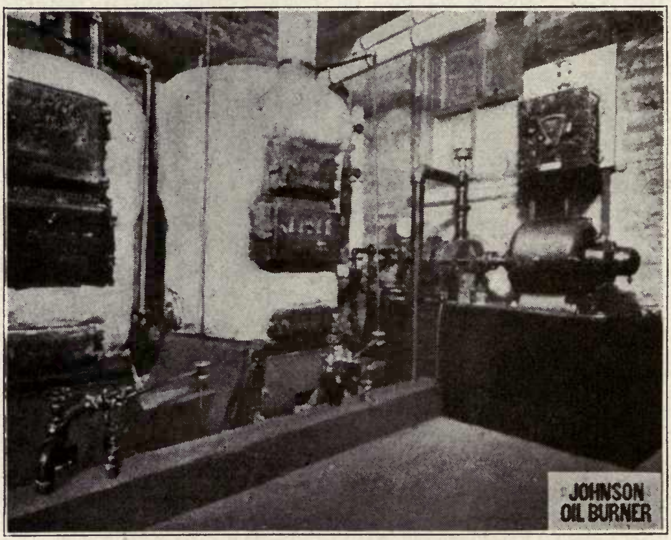


FIG. 102. Boiler Room of a Modern 60-Room Apartment Hotel.

The main steam header in the boiler room was tapped and a connection made for the branch steam line to supply steam for operating the oil pump and for atomizing the oil at the burners. A connection was made from this branch line to each burner.

The pump for supplying oil under pressure to the burners is an ordinary duplex, piston-type steam pump, equipped with a control governor for maintaining a steady pressure on the oil discharge line.

To furnish steam for operating the oil pumping system when the main boilers are cold, an auxiliary upright "Donkey" boiler of 6 to 10 H. P. capacity was provided. As soon as steam is raised on the main boilers this auxiliary boiler is cut out of the

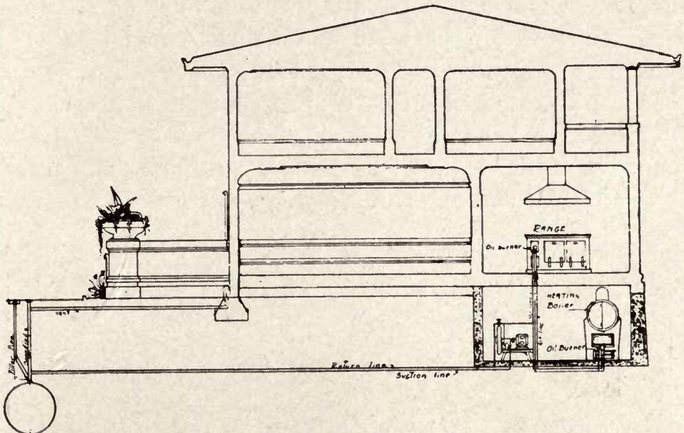


FIG. 103. Fuel Oil Heating a Residence Boiler and a Brick Kitchen Range.
(Courtesy of The Fess System Co.)

system and the fire allowed to die out. Fuel for firing the small boiler is largely furnished by the paper and refuse collected from the school rooms on the preceding day.

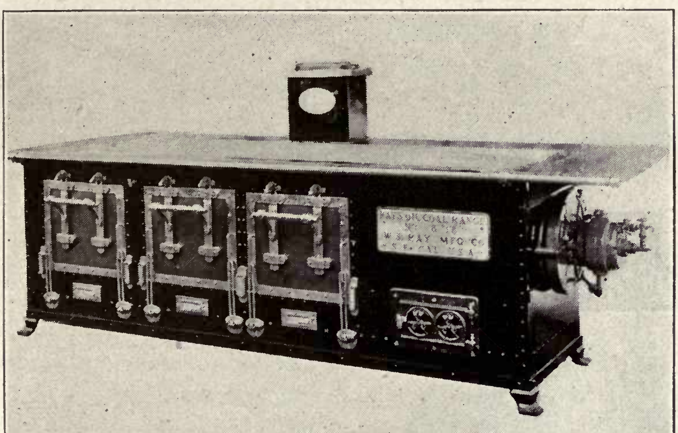


FIG. 104. Oil-Burner Applied to Hotel Range.
(Courtesy W. S. Ray Mfg. Co.)

Fig. 101 shows the installation in the Chicago schools.

Owners of large and small apartment houses have been quick to see the advantages and the ultimate economy of burning fuel oil. Fig. 102 shows the boiler room of a modern 60-room apartment house. The oil is pumped from an underground tank 100 feet distant. This equipment operates one low-pressure steam-heating boiler and one water heater. This building is furnished with a steady steam pressure automatically regulated at four pounds gauge pressure, and with hot water at 140°.

Steam heating companies usually estimate that each square foot of direct steam radiation will require 500 lbs. of steam per season. In Federal buildings with a heating and ventilating apparatus, each 7,000 cu. ft. of contents will require 1 boiler horse-

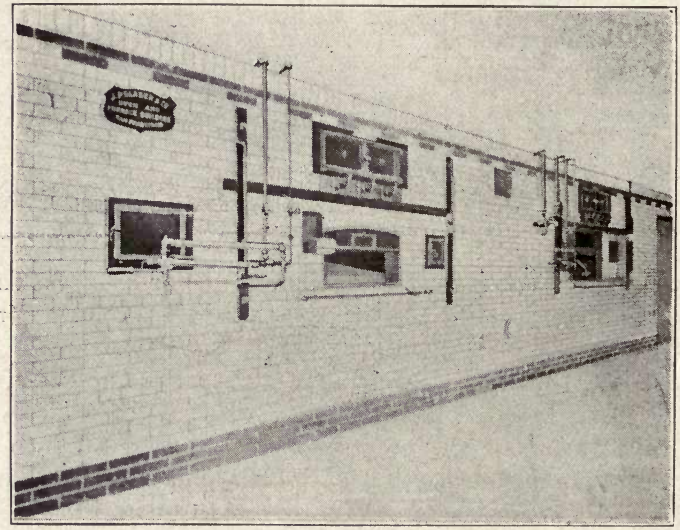


FIG. 105. Oil-Burner Applied to Bakers' Ovens.
(Courtesy of S. T. Johnson Co.)

power. Under normal conditions 1 B. H. P. will supply 138 sq. ft. of radiation. One square foot of steam radiation gives off about 260 B. t. u. per hour and 1 square foot of water radiation gives off about 160. One B. t. u. will raise the temperature to 55 cu. ft. of air 1 degree F. One pound of oil will evaporate approximately 12 lbs. of water per hour in a heating boiler and 100 sq. ft. of radiation will require 33 1/3 lbs. of water per hour.

Fig. 103 shows a sectional view of a residence where fuel oil is used for the heating boiler and in a brick set kitchen range. Fig. 104 shows a fuel oil burner applied to a hotel range. The close regulation of heat possible with an oil burner makes fuel oil an ideal fuel for ranges and for bakeries. Fig. 105 shows a bakers' oven burner. When firing is finished this burner swings back out of the way and lies flat against the side of the oven.

CHAPTER XVIII

OIL IN GAS-MAKING

William Murdock of London, first employed coal gas for illuminating houses, and his system was introduced for lighting the streets of London in 1812 and for lighting the streets of Paris in 1815. Since the introduction of Murdock's system, gas lighting has developed remarkably.

The gas produced during the carbonization of coal is a mixture of fixed gases, vapors of various kinds, and at times also globules of liquids held in suspension and carried forward by the gas. Water-gas is produced by the action of steam on incandescent carbon and is composed chiefly of hydrogen and carbon monoxide. Water-gas is not luminous, but has a high heat value. The luminosity of a gas depends upon the presence of hydrocarbons, and in order to render water-gas luminous it is carbureted with gases derived from oil which are rich in illuminants. Illuminating water-gas can be made by two general methods:

(1) The carburetted gas is made in one operation.

(2) Non-luminous gas is prepared and then carburetted by a second process.

There are several systems for making oil-gas which are distinguished from those known as carburetted water-gas systems. Among these may be mentioned the Pintsch, the Blaugas, and the Peebles process. In all of these the oil gas is made by cracking the oil in retorts. In the Pintsch process a transverse partition divides the retort into an upper and lower chamber. In the upper chamber the oil is cracked and vaporized, the vapor passing into the lower compartment, which is heated to nearly 1000 C., where permanent gases are formed. In the Peebles process the oil is only partly cracked, and only the very volatile hydrocarbons leave the apparatus. In the Blaugas process gas-oil is conducted into the retorts just as it is in the manufacture of Pintsch and other oil gases and is vaporized and decomposes in this retort under the temperature of about 550 to 600 degrees C., this low temperature being employed to prevent the production of a large percentage of fixed gases. After the oil has thus been distilled the gas is conducted in the usual manner through coolers, cleaners and scrubbers in order to remove the tar from the gases, and the gases are then conducted into large holders for storage.

From the holder the gas is drawn into a three-stage or four-stage compressor, where it is compressed to 100 atmospheres. Under this pressure the oil gas is reduced to 1/400th of its volume, the gas so obtained being of a specific gravity approximately the same as atmospheric air. It has a calorific value of about 1,800 B. t. u.'s per cu. ft., or approximately three times the heat value of ordinary city gas.

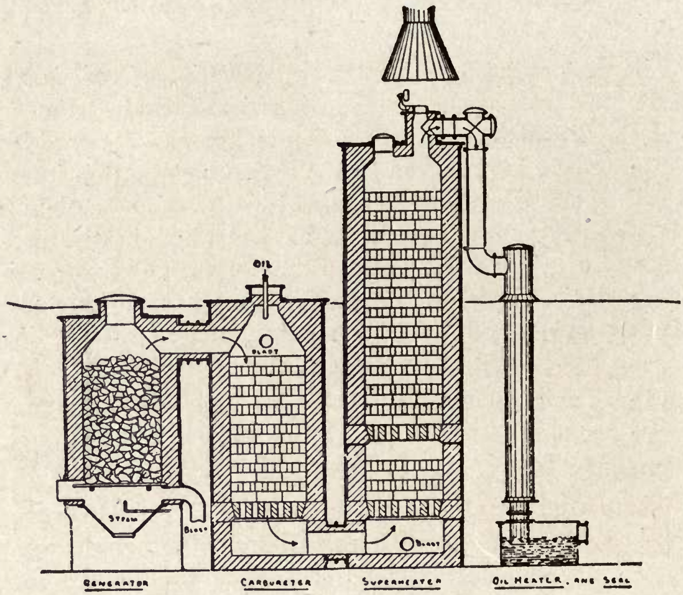


FIG. 106. Apparatus for Gas Making by Lowe Process. (From Outlines of Industrial Chemistry, Thorp.)

The manufacture of oil-gas by the three processes mentioned is for the purpose of transporting it for the lighting of railway cars or isolated buildings, and also for steel and cast iron welding, brazing, soldering and for all other purposes where a uniform gas with high heat units is essential. About eight gallons of oil are required per 1,000 cu. ft. of gas.

By far the greatest consumption of oil in gas manufactured is in the manufacture of carburetted water-gas. The process for the manufacture of carburetted oil-gas was devised by Prof. Lowe in 1874. The Lowe process is carried out as follows:

The generator (Fig. 106) is filled with anthracite coal or coke, which is brought to incandescence by a blast of air. The gases from the generator, at this time consisting mainly of carbon monoxide and nitrogen, enter at the top of the carburetor, a circular chamber lined with firebrick, and containing a "checker-work" of the same material; while passing down through this, the gas is partly burned by an air blast which enters the apparatus near the top, and the checker-work is heated white hot. The gases pass on to the "superheater," a taller chamber, also filled with checker-work. At the bottom of this an air blast is introduced to complete the burning of the producer gas and to raise the temperature of the checker-work to a very bright red heat.

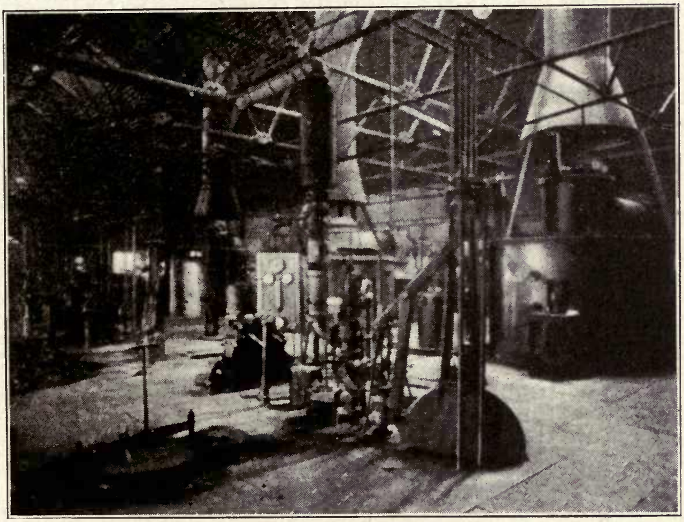


FIG. 107. Charging Floor of Gas-Generating Apparatus in which Oil Is Used for Enrichment.
(Courtesy Tide Water Oil Company.)

From the top of the superheater, the waste gases escape into a hood leading into the open air. When both the carburetor and superheater have reached the desired temperature, the air blasts are cut off, and the steam is introduced into the generator, where it is decomposed by the incandescent fuel, according to the reactions. The water-gas thus formed passes into the carburetor, while a small stream of oil is being introduced through a pipe at the top. The oil is decomposed by contact with the hot checker-work, forming illuminating gases which mix with the water-gas, and, passing into the superheater, are completely fixed as non-condensable gases.

It is customary to run the air blast for some eight minutes, when the fuel reaches a temperature of about 1100° C. The steam, superheated before entering the generator, is run about six minutes, until the temperature of the generator and carburetor has fallen below the point at which decomposition occurs. In order to economize heat, the hot carburetted gas is passed through a pipe surrounded by a jacket, within which the oil is circulating, thus heating it before it enters the carburetor. The lower end of the pipe leading from the superheater is closed by a water seal to prevent any backward rush of the gas during the operation of the air blast. It is customary to lead the gas from the superheater into a storage holder, from which it is drawn through the purifying apparatus. In this process, the blowing of air and of steam are intermittent, but the actual formation of gas is accomplished in one operation. The impurities in the water-gas are essentially the same as those in coal gas, and the method of washing and purifying are the same.

In the making of carburetted water-gas of 535 B. t. u.'s per cu. ft. about three gallons of gas oil are required. As the B. t. u.'s per cu. ft. increase the amount of oil necessary for the manufacture of the gas increases, and if gas of 600 B. t. u.'s per cu. ft. is required, approximately 3.75 gallons of oil per 1000 cu. ft. are necessary. Generally gas-makers assume a consumption of 3½ gallons per 1000 cu. ft. of carburetted water-gas. Fig. 107 shows the charging floor of a gas generating apparatus in which oil is used for enrichment.

APPENDIX

USES OF FUEL OIL

Feul oil has come into general use in the industries and its use is not limited geographically. A list of the purposes for which fuel oil may be used would comprise every known industry. It is in common use, however, for the following purposes:

Annealing Furnaces
Asphalt Mixers
Assay and Fusion Furnaces
Babbit Melting
Billet Heating
Bake Ovens
Boiler Making
Bolt Furnaces
Brazing and Dip Brazing
Breweries
Brick Making
Bullion Melting
Candy Furnaces
Canneries
Case Hardening
Cement Works
Cement Kilns
Cloth Singeing
Continuous Heating
Cook Stoves
Copper Melting
Core Drying
Cranes
Cremating
Crucible Furnaces
Cupellation Furnaces
Cycle Making
Drop Forging
Electric Power Plants
Enamelling
Fire Engines
Foundries
Galvanizing
Gas Making
Glass Making
Glass Melting
Glass Bending
Gold Cyanide Smelting
House Heating
Incinerators
Japanning
Ladle Heating
Lead Baths
Lead Melting
Locomotives
Nut Making
Ore Smelting
Petroleum Distillation
Pipe Bending
Plate Heating
Pottery Baking
Pumping Works
Ranges
Rivet Heating
Rivet Making
Rolling Furnaces
Rotary Kilns
Sand Drying
Screwmaking
Shaft heating
Shipbuilding
Shovel Making
Smelting
Silver Refining
Smithy Work
Spring Tempering
Steam Cranes
Steam Shovels
Steam Boilers
Steel Melting
Sugar Refining
Tea Drying
Tempering
Tilting Furnaces
Tinplate Making
Tin Smelting
Tractors
Tool Making
Tube Making
Tire Heating
Water Heaters
Welding
Wire Annealing
Wire Making
Zinc Distillation

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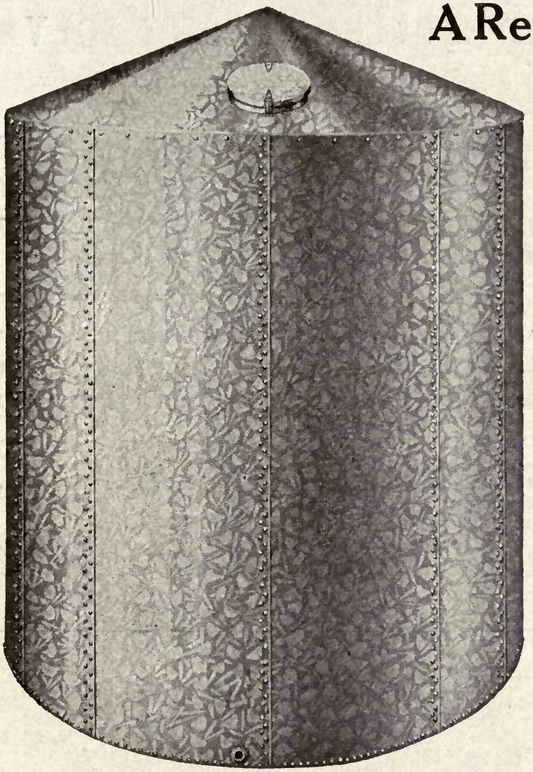

A Real Tank For Real Burners

One of the problems that confronts the users and the sellers of oil burners alike is the storage of the fuel.

A leaky tank means a dissatisfied customer, regardless of the satisfaction of the burner.

Everyone Is Satisfied With Butler Tanks

Butler Fuel Storage Tanks are not experiments; they have stood the test from every angle.

Butler Tanks are constructed with lapped seams, double riveted, with the exception of seam around the bottom where rivets are very closely set. The solder is sweated entirely through the seam, and the spacing of the rivets is closer than in any other tank we know of. Every Butler Tank is inspected and made oil tight before it leaves our factory. The special construction of the cover makes it vapor tight and dust proof. Each top is strongly reinforced inside with an angle riveted to the tank. The cone cover fits closely inside the tank and is tightly riveted to this angle. The top edge of the side is flanged over and down against the cover tightly all around, then carefully soldered.

NOTE: Butler Fuel Tanks can also be furnished knocked down. This type is ideal for long shipments and is of particular value where tank is desired in basement. It is not necessary to remove walls or make special excavations in such instances if Butler Bolted Fuel Tanks are installed. Simply erect tank in allotted space.

This type of tank comes completely knocked down. It is easily erected, being put together with bolts at the seams. The fabrication is accurate and all parts fit together readily and easily. When erected, Butler Bolted Fuel Tanks are rigid and strong, they are constructed vapor-proof and are satisfactory in every way.

Such tanks as Butler makes are a boon to the Fuel Oil Industry. Butler Tanks have friends throughout the entire country.

Ask for special bulletins and prices. They can be furnished up to 1,500 gallons when desired.

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Kansas City, Mo. Minneapolis, Minn.

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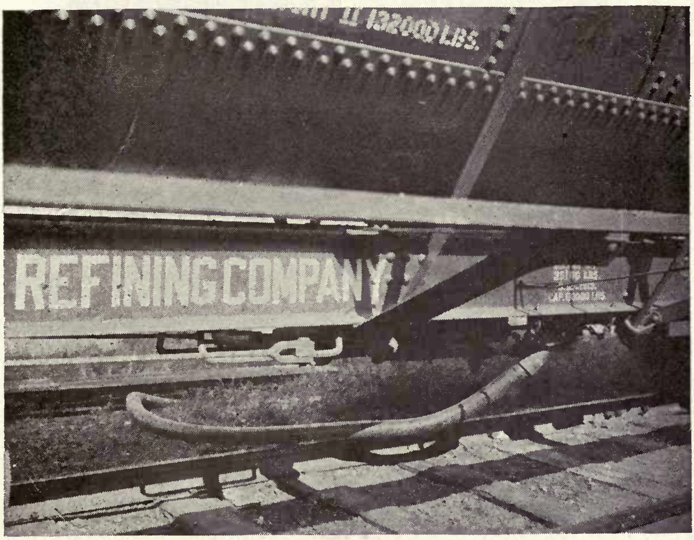

FUEL OIL IN INDUSTRY

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Pennsylvania Flexible Metallic Tubing Company

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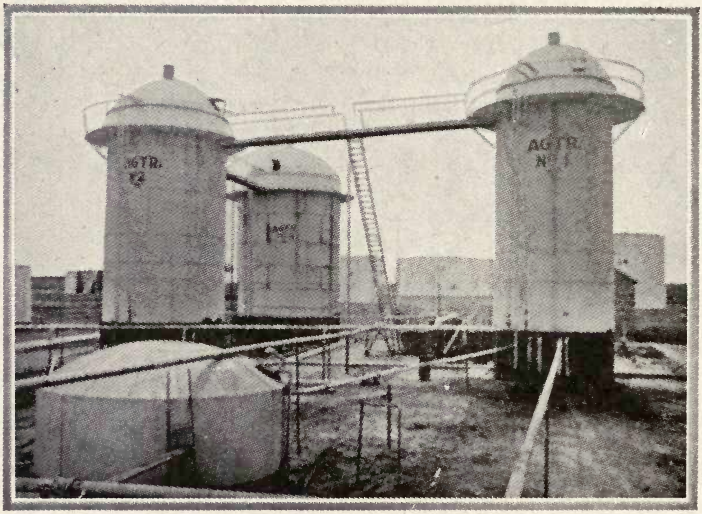
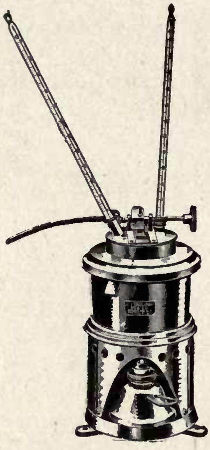
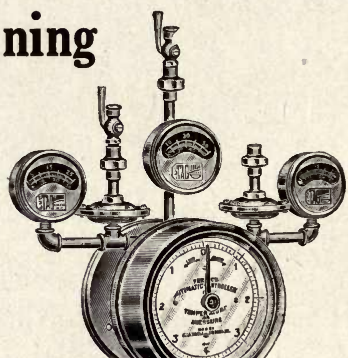


A Group of Agitators at the Southern Oil Corporation's Refinery at Yale, Okla.

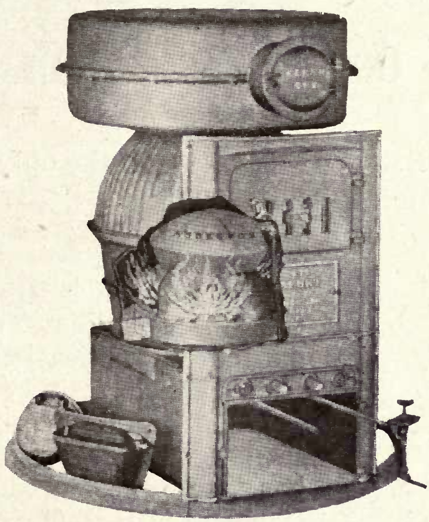




The Worthington Company

123 W. Madison Street
Chicago, Ill.

Product: Oil burners for homes, apartment buildings, store and office buildings. These burners are made to fit any type of heating system, steam, water or vapor. Installations require no change or remodelling of heating plant, and can be made by any efficient plumber in a short time.



Description: Worthington Burners are gravity feed burners and are made in various sizes. They have been tested for over four years. In Kansas City, Missouri, alone there are over 1,000 installations, and every burner is giving full satisfaction. The fuel used is distillate of 36 degrees Baume. This fuel is vaporized and thoroughly mixed with air before burning. This accounts for the high quality of the heat produced and for the fact that there is no smoke or soot. The burners do not carbonize and require no attention after starting. Two special advantages are, (1) the burner heats at the grate line and, (2) it is an "over-feed" burner with flame spreader which will not burn out the furnace dome. This burner is of especial value to owners of private homes, and to those who appreciate cleanliness and convenience.

Representatives: Information can be secured from representatives in nearly every large city, or the company will be glad to put those interested in touch with the nearest office. All inquiries promptly answered.

Prices and full description on request.