AMERICAN LUBRICANTS

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From the Standpoint of the Consumer

BY

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PREFACE.

The purpose of this book is to aid the user and the buyer of lubricants in a more intelligent selection of oils and greases. The point of view throughout is that of the user rather than that of the refiner.

An effort has been made to include such facts and figures in regard to lubricants as will best serve to bridge the gap between the refiner or manufacturer and the consumer. Of almost equal importance, a conscientious effort has been made also to *exclude* irrelevant matter so as not to obscure the main facts.

In a book of this character it is of the utmost importance that the refiner, the seller, the buyer and the user of lubricating oils speak the same language.

The language of the American oil trade, so far as viscosity is concerned, is that of the Saybolt Universal Viscosimeter; consequently all viscosities given in this book are with this viscosimeter at 100° F. unless otherwise specified, except that the viscosity of cylinder oils is taken at 210° F. Likewise the Flash and Fire Tests are with the Cleveland (or similar) Open Cup. Unless otherwise stated, all temperatures are Fahrenheit, and the Baumé gravity is based on the Bureau of Standards scale at 60° F.

The specifications given are in all cases the latest obtainable.

The author takes this occasion to acknowledge his indebtedness, directly and indirectly, to the published data on petroleum oils which has been drawn upon freely.

He trusts that the book will prove of practical aid, especially to the buyer and the consumer of lubricants.

L. B. Lockhart.

Atlanta, Ga., June 1, 1920.

CONTENTS.

LIST OF ILLUSTRATIONS.

CHAPTER I.

CRUDE PETROLEUM.

The Shift in Production.—The American Petroleum Industry began with the sinking of the first oil well in Pennsylvania in 1859, two years after oil had been struck in Roumania. The production in the United States was confined to Pennsylvania and New York until 1876. In 1891 the Pennsylvania fields reached their maximum production of 33,009,236 barrels which was 61 per cent. of the country's production for that year. The Appalachian field as a whole reached its maximum production of 36,295,433 barrels in 1900 which was 57 per cent. of the output for that year.

In 1918 the Appalachian field produced only 25,833,000 barrels of petroleum, or 8 per cent. of the total for that year, and of this amount only 8,800,000 barrels were actually produced in Pennsylvania and New York. The estimated production for Oklahoma in 1917 was 107,507,471 barrels which is greater than the production for the whole United States for any year prior to 1907. In 1917 Oklahoma and California together produced 60 per cent. of the country's petroleum, the total for that year being 335,315,601 barrels. The above figures refer to the marketed production. The estimated actual production for 1918 was 345,896,000 barrels for the United States, of which nearly 60 per cent. was used for fuel oil.

In January, 1919, the United States Geological Survey, after an exhaustive study of the known fields in the United States, estimated that the fields are 40 per cent. exhausted. The Appalachian field is 70 per cent. exhausted. Additional statistics are given at the end of this volume.

Characteristics of Crude Petroleum.—Petroleum or crude mineral oil is a dark brown liquid made up of a mixture of compounds, some of which would be gases and solids if separated from the mixture. Small amounts of sulphur, oxygen and nitrogen are usually present.

There are two well known types of crude petroleum: (1) Paraffin-base oil which contains much light oil or gasoline and considerable paraffin wax, like the Pennsylvania oils, and (2) asphalt-base oils which contain very little light oil, or paraffin wax, but contain much heavy, low cold test oil, like the Texas oils. A third type is also recognized, called mixed-base oil, which is intermediate between the other two types. Paraffin-base oils consist largely of compounds containing relatively more hydrogen than is present in the asphalt-base or naphthene oils.

Crude oils are valued largely on the basis of their distillation products. Oils which yield much gasoline and kerosene on simple distillation, and which are rich in paraffin, bring the highest prices at the wells, though the amount and nature of the sulphur impurities are of much importance.

Crude oils from the different fields of the United States have the following characteristics:

Oils from the Appalachian field (New York, Pennsylvania, West Virginia, Kentucky, and eastern Ohio) are mainly paraffin base, free from asphalt and objectionable sulphur, and they yield by ordinary distillation high percentages of gasoline and burning oils. The gravity ranges from 34° to 48° Bé.

Oils from the Lima-Indiana field (Indiana and northwestern Ohio) consist chiefly of paraffin hydrocarbons, though containing some asphalt, and are contaminated with sulphur compounds which require special treatment for their removal—usually with copper oxide and lead oxide. Some lubricating oil distillates are produced in this field. The Canadian oils belong to this group.

Illinois oils are of mixed asphalt and paraffin base and differ much in specific gravity and distillation products. The sulphur which is generally present can be removed without special treatment. The gravity varies from 28° to 39° Bé.

Mid-Continent oils (from Kansas, Oklahoma, northern and central Texas and northern Louisiana) vary in composition within wide limits, ranging from asphaltic oils poor in gasoline and kerosene, to paraffin oils of low asphalt content which yield much gasoline and kerosene. Sulphur is present in varying quantities in the low grade oils which in certain instances may necessitate special treatment. The gravity varies from 27° to 42° Bé.

Oils from the Gulf field (the Coastal Plain of Texas and Louisiana) are high in asphalt and low in gasoline. Much of the sulphur is present as sulphureted hydrogen which can be removed by steaming. The gravity varies from 15° to 27° Bé.

Oils from Wyoming and Colorado are mainly paraffin base, though there are some heavy asphaltic oils in Wyoming.

California oils are chiefly asphaltic with practically no paraffin and with more or less sulphur. The chief products are fuel oils, kerosenes, lubricants and oil asphalt, with a little gasoline from the lighter southern oils. The gravity ranges from 12° to 30° Bé. (See "Petroleum in 1917;" p. 690, U. S. Geol. Survey.)

Mexican oil, like the oils from the Gulf field, are of low gravity, 14° to 19° Bé., and they are high in sulphur compounds. The oil is largely used as fuel oil.

The oils may be arranged roughly in the order of their gravities, beginning with the lightest oil (highest Baumé gravity): Pennsylvania, Illinois, Caddo (Louisiana), Kansas and Oklahoma, and some oil from California. Very heavy oils come from the Gulf field (southern Texas and Louisiana), from Mexico and from most California fields.

Chemical Composition.—Petroleum or crude mineral oil is made up chiefly of a mixture of compounds known as hydrocarbons, having a composition of from 12 to 14 per cent. of hydrogen and 84 to 86 per cent. of carbon. These numerous hydrocarbons vary markedly in boiling point, from the light hydrocarbons like methane (CH_4) and ethane (C_2H_6), found in natural gas, to heavy solid bodies like paraffin, or asphalt and viscous oils which cannot be distilled without decomposition.

The hydrocarbons in petroleum belong to several different chemical series, depending on the amount of hydrogen present with the carbon or on the way the carbon is combined with itself. Pennsylvania petroleum is made up largely, but not entirely, of "paraffin" hydrocarbons which have the general formula C_nH_{2n+2}. The paraffin-base oils are more likely to yield important percentages of gasoline and kerosene on simple distillation, than the asphalt-base oils, as these light oils belong chemically to the "paraffins."

The hydrocarbons in the asphalt-base oils consist largely of unsaturated hydrocarbons or of hydrocarbons of the naphthene series (polymethylenes). These hydrocarbons have the general formulas $C_n H_{2n}$ and $C_n H_{2n-2}$. Sometimes still less hydrogen is present as in some California oils which consist partly of aromatic compounds similar to those from coal tar with the general formula $C_n H_{2n-6}$. Besides having less hydrogen than is present in the "paraffins," the naphthenes (polymethylenes) are cyclic compounds while the paraffins are "chain" compounds. In these cyclic compounds, the carbon is united to form at least one ring, usually of the polymethylene type, such as,

$$\underbrace{CH_2.CH_2.CH_2.CH_2.CH_2}_{\text{ring}}$$

while in the chain compounds, the carbon is united in an open chain, such as,

$$CH_3.CH_2.CH_2.CH_2.CH_3.$$

The above discussion does not cover the field by any means, as the subject is very complex, several series being present in most oils in varying proportions. Heavy oils, like the Texas oils, usually contain a large proportion of naphthenes. The fact that oils are different in composition from the Pennsylvania oils does not condemn them for any use, but necessitates finding out exactly what they are suitable for without forcing them to meet certain artificial requirements which were devised for use with other oils.

Heavy Pennsylvania lubricating oils consist largely of naphthenes or hydrocarbons of the $C_n H_{2n}$ and the $C_n H_{2n-2}$ series and not of paraffins as generally supposed. In other heavy oils the series $C_n H_{2n-4}$ may also be present. The true unsaturated hydrocarbons of the olefine series are not present to any important extent in crude petroleum, but are present in ordinary cracked distillates. Aromatic hydrocarbons are present in limited amounts in most petroleums, and in considerable amounts in California petroleums.

Prof. Mabery, who has done valuable work on the composition of American petroleums, has shown that the paraffin hydrocarbons have a low lubricating value. He has also shown that the viscosity of hydrocarbons increases very rapidly with increase in molecular weight, so if high viscosity products are to be made, distillation must be conducted with as little decomposition as possible. (*J. Am. Chem. Soc.*, pp. 992-1001, 1908).

The separation of the individual compounds from petroleum is practically impossible on account of the boiling points of the compounds being modified by presence of the other hydrocarbons in the mixture. Separation into groups of compounds with certain boiling limits is carried out on a large scale for the producton of such commercial products as gasoline, kerosene and the various lubricating oils.

Hydrocarbons resist chemical action to a considerable degree, and so petroleum oils show little tendency to attack metals. Animal and vegetable oils show considerable tendency to form acid.

Origin of Petroleum.—Since different petroleums have very different compositions, there is naturally a great variety of theories to account for the origin of crude petroleum. Of the inorganic theories, which depend largely on the action of water on heated metallic carbides somewhat as acetylene is produced commercially, Clarke says (Data of Geo-Chemistry, p. 737, 1916) that "There is no evidence to show that any important oil field derived its hydrocarbons from inorganic sources."

The theories which accord with most of the facts are the theories of organic origin from the decomposition of animal and vegetable remains. Doubtless all types of organic matter have contributed their quota in varying amounts. Some oils, as in certain Texas fields, show evidence of marine animal origin. The considerable percentages of nitrogen compounds present in some oils strongly indicate animal origin.

The original differences in petroleums have been further modified by the migration of the oil, or its filtration through different strata which changes the composition of the oil.

Field Production, Storage and Transportation.—Oil is reached by bored wells varying in depth in different fields from 100 to over 4,000 ft. It the gas pressure is sufficient, a flowing well or "gusher" may result, particularly when the well is first brought in. The maximum flow is usually immediately after oil is struck, some wells coming in with a flow of thousands of barrels per day, as the famous Beaumont well with 70,000 per day. The Mexican well (Potrero del Llano No. 4) produced 100,000,000 barrels of oil in eight years before it was finally ruined by salt water.

The oil is run into large metal or concrete storage tanks in the field, and is sent to the refineries by means of tank cars or pipe lines. Pipe lines run from the Oklahoma fields to the Atlantic Seaboard by way of Chicago. The Oklahoma fields are also tapped by pipe lines from the Gulf.

CHAPTER II.

THE REFINING OF PETROLEUM.

For the manufacture of lubricating oils and other valuable commercial products, crude petroleum is refined by distillation and by filtration or chemical treatment. Distillation separates the hydrocarbons into groups of different boiling points which find various commercial uses.

When petroleum is heated, it becomes more fluid by melting certain substances present in the petroleum, or by decreasing the cohesion between the liquid particles. If the temperature is sufficiently high, some of the crude petroleum will evaporate and can be condensed so as to yield gasoline, kerosene, and various distillates. During the process of heating, some of the hydrocarbons may be decomposed or "cracked" by the heating, yielding products of lower boiling point than those present in the original petroleum. Such decomposition is especially likely to occur if there is over-heating or prolonged heating, or if certain sulphur compounds are present. Distillation of even the lightest of the petroleum products cannot be effected without evidence of some decomposition. The heaviest part of the petroleum cannot be distilled without decomposition with the formation of free carbon or "coke."

In distilling lubricating oils, the best lubricants are obtained by processes which prevent prolonged heating or overheating of the oil, and which therefore cause the least amount of decomposition or "cracking" of the compounds originally present in the crude oil.

There are two processes in general use for the distillation of petroleum: Fire distillation and steam distillation. Steam distillation will be described first and in some detail as the best lubricants are made by it and as certain lubricants, such as steam-cylinder oils, can be made in no other way.

Steam Distillation.—The crude petroleum is put into large horizontal, cylindrical stills of 250 to 1,200 barrels capacity, made of sheet steel supported on brick-work. Heat is applied by means of direct fire under the still, and as soon as the heating has begun steam is introduced by means of perforated pipes reaching nearly to the bottom of the oil in the still. The steam stirs the oil and so prevents local over-heating, and at the same time the escaping steam carries off the oil vapors as soon as formed so that they do not condense and drop back into the hot oil. The oil vapors go out through large pipes in the dome of the still and are condensed in a vertical tower condenser. In this condenser the heavy oils condense first near the bottom and the light oils condense last near the top. Thus with this type of condenser the oil may be separated into groups during the first distillation. With other types of condensers the distillates may have to be redistilled for this separation into groups.

The groups so collected are, in the order of their boiling points, (1) crude naphthas, (2) illuminating oils, (3) gas oil, (4) light lubricating distillate, (5) heavy lubricating distillate, and (6) undistilled residue. The distillation is usually stopped just above 600° F. The residue in the still is suitable for cylinder stock if Pennsylvania or other paraffin-base stock has been used. The various distillates are distilled to rid them of light and heavy ends and to render the removal of the paraffin from the lubricating distillates less difficult.

The use of steam causes the distillation to proceed at a temperature of at least 100° F. below what would be required without the use of steam. Since "cracking" is largely prevented, the yield of gasoline and kerosene is greatly reduced by the use of steam. Steam distillation is applied to paraffin-base oils mainly, but may be used with other oils as well. Paraffin-base petroleums may also be fire distilled instead of steam distilled in order to increase the yield of gasoline and kerosene.

The use of steam not only gives better grades of lubricants, but it increases the yield of lubricating oils as well, particularly of cylinder stock. A partial vacuum may be used along with the steam to aid further in the distillation for special products, as for the production of vaseline or special filtered cylinder stocks. Vacuum stills and continuous stills have not had a wide use in this country. The use of steam can effect distillation at

150° to 250° F. lower than the actual boiling point of the distillates.

Instead of the "tower" condenser for separating into groups during the first distillation, the "cut" is often made for the different groups on the basis of the gravity of the distillate.

The groups obtained by steam distillation may be treated as follows:

Gasoline.—The crude naphthas are treated in turn with strong (66°) sulphuric acid, washed with water, then with caustic soda solution, and finally with water again. They are then distilled with steam to make the light and heavy gasolines or naphthas of commerce. The heavy ends are added to the crude kerosene distillate.

Kerosene.—The crude kerosene is steam distilled, the first part of the distillate being added to the crude naphtha distillate and the last part or "tailings" being added to the gas oil distillate. The main distillate is chemically treated (see gasoline) and is then filtered through fuller's earth to make the commercial grades of kerosene. Only "water white" kerosene is made by steam distillation, but the first part of the kerosene distillate from fire distillation of petroleum is also "water white" oil.

Some of the oils heavier than kerosene may be collected separately and made into special burning oils, such as mineral seal oil for railroad use.

Lubricating Oil Distillates.—These are distilled a second time from fire stills by the aid of steam, the undistillable residue going into fuel oil. The oils are chilled and filter-pressed to remove paraffin wax. They may be partly distilled again or "reduced" to remove the light oils and so raise the viscosity and the fire test. The light oils distilled off in this reducing process may be run into the gas oil distillate or made into thin lubricating oils called non-viscous neutrals. The reduced lubricating oils are filtered through fuller's earth or bone-black to improve the color and remove impurities and are then ready for use as "viscous neutrals."

Cylinder Stock.—The residue in the still, if a paraffin-base crude has been used, is a steam refined cylinder stock. If the temperature has been carried well above 600° F. during the distillation most of the paraffin has been distilled off. To make a filtered cylinder stock, the residue is "cut back" with crude naphtha, chilled and filter-pressed or otherwise filtered, and the gasoline finally recovered. The product is a filtered, low cold-test cylinder stock.

Fire or Destructive Distillation.—The more usual method of distillation has been to distil without the aid of steam, as this gives not only the gasoline and kerosene actually present in the crude oil, but additional light distillates formed by "cracking" much of the heavy hydrocarbons.

The cracking is accomplished by partly drawing the fire after the regular gasoline and "water white" kerosene distillates are off, so that the oil vapors are not removed from the still as soon as formed but condense on the upper part of the still and run back into the hot oil. The prolonged and excessive heating to which the oil is thus subjected breaks down the heavy hydrocarbons into lighter hydrocarbons which distil at a lower temperature, greatly increasing the yield of illuminating oil and somewhat increasing the gasoline output. The kerosene thus made has some color and a low flash point, and much of it goes into the export trade as low test oil or is used as "standard white" oil. Considerable unsaturated hydrocarbons, or olefines, are present from the cracking. These light distillates are chemically treated and redistilled with steam as stated above for steam distilled oils.

After the burning oils are all off, the "tar" residue, amounting to 10 or 15 per cent. of the original crude, is run into "tar-stills" of some 250 barrels capacity and is destructively distilled by fire until only dry coke remains in the still. The distillate is pressed to remove paraffin wax and the liquid portion is used as paraffin oils after chemical treatment and final steam fractionation.

The residue from the distillation is coke instead of cylinder stock.

Yields.—The amount of the different products varies considerably with the crude used and with the details of the refining process.

The percentage yields of products from the various fields is given by the Oil, Paint & Drug Reporter 1819 Year Book (p. 247):

Field	Naphtha & Gasoline	Illuminating oil	Lubricating oil	Fuel oil	Paraffin wax
Appalachian	14	67	12.5	4	2
Illinois	13.2	31.2	15	35	2
Lima-Indiana	11.5	43	15	25	2
Mid-Continent	11	41	—	45 (a)	–
Colorado	3.5	35	3	55	–
Gulf	3	15	6	28 (b)	–
California	6	18	1.5	72	–
Mexican	15	35	—	47	–

(a) 20% fuel oil; 25% gas oil.

(b) And 45% gas oil.

The present tendency is to cut deeper into the illuminating oil fraction than shown by the above table with a corresponding increase in yield of gasoline.

Recalculation of statistics issued by the Bureau of Mines shows the following percentage of refined products for the entire country: Gasoline 20.3%, kerosene 13.0%, gas and fuel oil 44%, lubricating oil 5.8%, wax 2.1%, coke, 1.8%, asphalt 4.1%, miscellaneous oil 5.6%, loss 3.6%. Of the gasoline 2.44% came from cracking processes, the remainder being straight run. (G. Egloff, *Met. Chem. Eng.*, 17, p. 680 (1917), and *Ch. A.*, p. 421 (1918)).

Western Lubricating Oils.—The so-called western oils are made from crudes which contain little paraffin. The procedure is similar to the refining of Pennsylvania oils, except as the procedure may be modified by the character of the merchantable products possible. Most of the California crudes, and much of the Oklahoma and Texas crudes are "topped" for the removal of gasoline and illuminating oils, and the undistilled residue is sold directly as fuel oil without further refining. Very little lubricating oil is produced west of the Mississippi River.

Oklahoma crude, and some heavy crudes from Texas and California, are now worked up for the manufacture of certain lubricants, such as cylinder oil, red engine oil and lighter lubricating distillates. The distillates have higher gravities, lower flash points, higher viscosities at low temperatures (70° or 100° F.), and lower cold tests, than do Pennsylvania products of the same class.

By combined steam and fire distillation very viscous distillates may be produced from certain heavy Texas oils. (Cf. H. R. Heyne: "Comparison of Gulf Lubricating Oils with Paraffin-base Oils," *Fuel Oil Jour.*, 7, pp. 140-142, 1916).

The residue from asphalt-base oil is asphalt instead of cylinder stock, but mixed base oil may yield some cylinder stock by proper treatment.

On account of the high Baumé gravity of Oklahoma crude and the large percentage of gasoline and kerosene, the value of some Oklahoma oils ranks close to Pennsylvania crudes.

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CHAPTER III.

THE REFINED PRODUCTS.

A. LIGHT DISTILLED OILS.

Gasoline or Naphtha.—The light naphtha of 88° Bé. is known as petroleum ether. It distils at a lower temperature than does gasoline.

Gasoline, motor fuel, or heavy naphtha has a gravity between 56° Bé. and 70° Bé. It is obtained by the simple distillation of petroleum, or by "cracking" petroleum oils by some of the recent processes for producing "synthetic" gasoline. It is also produced by blending certain gases from natural gas with heavy gasoline to make the so-called casing-head gasoline. Commercial gasoline may contain products ranging from 40° to 90° Bé. While a large amount of very volatile constituents facilitates explosion in the motor, the extremely volatile products increase the hazard in using and in shipping, and so the Bureau of Explosives specifies maximum pressure limits for gasoline shipped by common carriers.

Kerosene.—The gravity of kerosene ranges from 40° to 48° Bé., the distillation range being from 150° to 300° C. (302° to 572° F.). For Pennsylvania water white oil the gravity is usually above 46° Bé. and a slightly higher boiling point limit can be used, but with the removal of more of the lighter oils for incorporation into gasoline, some of the heavier oils above 275° C. must also be left out in order to give a product of good candlepower.

Several grades of kerosene are generally recognized: Water white oil made by straight distillation of the crude, and prime white oil made by cracking the crude during distillation. The former commands the higher price and is considered the more satisfactory product. Much of the latter goes into the export trade as low flash oil. The flash point of kerosene is adjusted largely to meet State requirements. Water white kerosene is usually 150° fire test with the open cup.

Mineral Sperm Oil or Mineral Seal Oil.—These heavy illuminating oils, of 300° F. fire test, distil off after the kerosene. They are used for railroad and similar illumination where steady burning and only small illuminating power are necessary. The gravity ranges from 34° Bé. to 42° Bé.

Gas Oil.—The oils distilled between the illuminating oils and the light lubricating oils are used for carbureting water gas and other gas to improve the illuminating power. This gas oil is a cheap product. In re-distilling the lubricating oil distillates, the light ends are run into the gas oil. This product is sometimes used for fuel oil.

B. DISTILLED LUBRICATING OILS.

Paraffin Oils.—These oils are manufactured by fire distillation (without steam) and are decolorized or bleached by treatment with sulphuric acid. The final colors are yellow or red. Some of the better grade products are filtered instead of acid treated. The gravity seldom goes above 30° Bé. even for the thinnest oils, and the viscosity is low as compared to the gravity as the method of distillation tends to break down the more viscous portion of the oil. The viscosity ranges from that of heavy kerosene to 300 Saybolt at 100° F. The light oils can be used for spindle oils in the place of the usual non-viscous neutrals. The heavy oils are used for engine oils, loom oils, motor oils, etc. These oils are not so expensive as are neutral oils. The high viscosity paraffin oils are made by "reducing," that is, by distilling off the lighter oils by means of steam and fire.

Neutral Oils.—These oils are manufactured by steam distillation, and are of high viscosity in proportion to their gravity. After the wax has been removed from the mixed lubricating oil distillate, the oil is "reduced" by steam distillation to remove the lighter oils. These light oils constitute the "non-viscous" neutrals, while the residue from this final distillation constitutes the "viscous" neutrals.

The non-viscous neutrals usually have a gravity well above 30° Bé. and a low viscosity, suitable for light spindles. These oils are considered the best spindle oils as they do not stain like paraffin oils if properly filtered. These oils are not usually acid treated. The viscosity is 45 to 65 at 100° F.

The viscous neutrals are usually slightly above 30° Bé. and have viscosities ranging from 80 to 200 at 100° F. These oils are suitable for motor oils, turbine oils, gas engine oils, air compressor oils, and for the highest grade service. The color is reduced by repeated filtration through fuller's earth instead of by acid treatment. In order to make the heavier oils, the viscous neutrals are blended with small amounts of high-flash, filtered steam-cylinder stock. Blended oils of high viscosity may have gravities as low as 27° Bé., even when from Pennsylvania stock. Viscous neutrals are also made from other stocks than Pennsylvania stocks, in which case the gravities will be much lower and the viscosities much higher than can be obtained from Pennsylvania distillates alone.

Spindle Oils.—These are low-viscosity oils, of 45 to 100 Saybolt at 100° F. They may be light paraffin oils, but are usually and preferably the non-viscous neutrals.

Loom Oils.—Neutral oils are used, but the use of paraffin oils similar to light engine oils, is common practice. The oils have been acid treated in most instances.

Engine Oils.—Commercial engine oils are usually the heavier paraffin oils. The heavier oils are nearly always red, but the amount of color depends on the amount of acid treatment or of filtration. The color is not an index to the lubricating quality. The heavier engine oils may be built up by the addition of cylinder stocks to heavy distillates. Viscous neutrals were formerly much sold as engine oils, but high-gravity neutrals now go largely into the motor oil trade. Low-gravity western neutrals are still sold as engine oils. For circulating oil systems, neutral oils are more satisfactory than paraffin oils as they separate from water better.

Motor Oils.—For lubricating gasoline engines of all kinds, the viscous neutrals are considered most suitable. While Pennsylvania products are generally given preference, oils can be made by the same process from other crudes with equal success. For western oils, the gravity is lower and the viscosity may be higher. The heavy motor oils are made by the addition of special steam-cylinder stocks to viscous neutral oils. Paraffin oils make less desirable motor oils.

Turbine Oils.—These are similar to the lighter motor oils. The neutral oils separate from water better than do the paraffin oils and so are more desirable in actual service.

Air Compressor Oils.—These are similar to the lighter motor oils.

Paraffin.—Solid paraffin, though not used as a lubricant, comes over with the lubricating oil distillates and has to be removed by chilling the oil and filter pressing. Ordinarily the oil distillates have to be vaporized twice in order to get the paraffin in condition to filter from the oil. The crude "scale wax" is further treated to make the paraffin of commerce, the treatment consisting of "sweating" to remove oil and filtering to remove tar and asphalt.

C. UNDISTILLED OILS.

Cylinder Stocks (Steam Refined).—By steam distillation of Pennsylvania oils and other paraffin-base oils, a heavy undistilled oily residue is left in the still. This can be used as a cylinder stock after removing some of the solid impurities. Steam refined stocks of high fire test (over 600° F.) are not filtered as filtration is difficult and the high temperature has removed most of the paraffin. The flash test ranges from about 550° to 600° F. and the fire test from 600° to 700° F. Low fire test stocks are more likely to contain paraffin and high test stocks to contain tarry matter. Cylinder stocks should be free from tar, so the color should be green or brown and not black.

The viscosity of Pennsylvania stocks runs from 140 to 280 at 210° F. for the steam refined stocks. The highest viscosity Pennsylvania stocks do not run below 24° Bé. in gravity.

Cylinder Stocks (Filtered).—Steam refined stocks can be cut back with crude gasoline and filtered through fuller's earth or boneblack to remove carbon and coloring matter. The highest fire test stocks are never filtered, the fire test of filtered stocks rarely being over 600° F. Also stocks of over 160 viscosity are rarely filtered. Pennsylvania stocks do not run less than 26° Bé. Filtering reduces the viscosity of cylinder stocks.

Bright stocks are generally low cold test stocks made in the preparation of petrolatum.

Cylinder Oils.—See Compounded Oils below.

Petrolatum (Vaseline).—Special Pennsylvania oils are carefully distilled, with steam and vacuum, until the solid uncrystallizable paraffins are reached. The product is then filtered through boneblack after cutting back with gasoline. The light colored residue, after driving off the gasoline, is a pasty mass called vaseline. The darker colored oils which filter later are used as cylinder stock.

Car Oils (Black Oil, Reduced Oil, Well Oil).—The residue left after distilling off the lighter lubricating oils by fire distillation is a black oil which is sold in the unrefined condition as car oil. For winter car oil, the distillation can be stopped earlier, or the residue can be cut back with some light distillate.

Fuel Oils.—Many of the western crudes, as from California, are sold for fuel, either as they come from the wells, or after "topping" or "stripping" to remove the light oils. Also light and heavy ends from redistilling lubricating oils are run into the fuel oil. Distilled fuel oils are really heavy gas oils.

In 1917, it has been estimated that 204,000,000 barrels, or 61 per cent. of the entire marketed production of petroleum in the United States, was used for fuel oil.

D. MIXED OILS.

Blended Oils.—Blended oils are made by mixing mineral oils either distillates or cylinder stocks. Sometimes oils are "cut back" by addition of a small amount of low viscosity oil to reduce the viscosity of an oil. An example would be the addition of a distillate to a cylinder stock to lower its viscosity or the addition of a distillate to car oil to change a "summer" car oil to a "winter" car oil. Sometimes the viscosity of light oils is "built up" by the addition of heavy oils, as in adding cylinder stocks to engine oil distillates to make heavy motor oils.

In mixing or blending oils it is well to remember that the viscosity of the mixture is always decidedly lower than would be calculated from the viscosities of the two oils and the proportions taken. Where the oils are very different in viscosity the variation from the expected viscosity is greatest. The viscosity of the mixture may be as much as 30 per cent. below the expected viscosity, but it is usually from 5 to 15 per cent. lower than the calculated viscosity.

The gravities are as would be expected, but the flash point is lower than the mean of the mixture. (See Sherman, T. T. Gray and Hammerschlag on "A Comparison of the Calculated and Determined Viscosity Numbers [Engler] and Flashing and Burning Points in Oil Mixtures," *J. Ind. & Eng. Chem.*, pp. 13-17, (1909); also T. T. Gray on "A Comparison of the Engler and Saybolt Viscosities of Mixed Oils," *8th Int. Cong. Appl. Chem.*, X, pp. 153-158, 1913).

Compounded Oils.—Compounded oils are made by mixing or blending a mineral oil with a fatty oil. The chief compounded oils are cylinder oils made by dissolving animal oil or other fatty oil in cylinder stocks, and marine engine oils, made by dissolving rape oil or blown rape oil in mineral oil. Compounded oils for other purposes are now seldom used.

The viscosity of a compounded oil is much less than the theoretical viscosity calculated from the oils used in compounding.

E. MISCELLANEOUS OILS.

Rosin Oils.—These are the heavy oils from the distillation of rosin. They are used for grease making, for transformer oils, in printing inks, in paints, and in the purified condition as lubricating oils. After the rosin acids have been largely removed, the rosin oils are chiefly special hydrocarbons.

Coal Tar Oils.—These belong to the aromatic series of hydrocarbons ($C_n H_{2n-6}$) which are cyclic compounds. They are sometimes used in lubricating greases. The heavier tars may be used in special thick greases for chains, etc.

Thickened Oils.—Oils may be thickened by the addition of certain soaps to form greases, or with certain aluminum soaps to form mineral castor oils. Caoutchouc is also added to oils to increase their apparent viscosity.

Shale Oil.—Shale oil, from the destructive distillation of oil-shales, has been produced to an important extent in Scotland and elsewhere. The large quantities of oil-shales in Colorado and other states may be similarly developed for lighting, power and lubricating purposes.

The United States Geological Survey has estimated that the high-grade shales of Colorado, Utah, Wyoming and Nevada alone contain 75 billion barrels of oil, or over ten times the present known petroleum reserves of the entire country. (See *U. S. Geol. Survey Bull. 641,* pp. 139-198, etc., 1916, on "Oil Shale in Northwestern Colorado and Adjacent Areas.")

F. SPECIAL PROPERTIES OF MINERAL OILS.

The advantages of petroleum lubricating oils over animal and vegetable oils are the lower cost of the mineral oils, the non-oxidizing and non-gumming character of mineral oils and their general stability, and the great range of viscosity obtainable. This wide range in viscosity of the products available makes a knowledge of the viscosity of the various mineral oils not only desirable but necessary to meet different lubricating conditions. The chief disadvantage of mineral oils consists in the non-adherence of the oils in presence of hot water, and in the rapid decrease in viscosity under heat. Animal and vegetable oils also lose viscosity rapidly under heat. By proper attention to the temperature at which an oil is to be used, a mineral oil can be obtained which will meet all viscosity requirements at the desired temperature.

Coefficient of Expansion.—Oils expand rapidly with rise of temperature and so decrease in specific gravity, the amount of expansion for oils of the same specific gravity being the same. The expansion for gasolines is from 0.0006 to 0.0007 for each degree F.; for kerosenes 0.0005; for spindle oils 0.00045; and for lubricating oils of 0.890 to 0.950 specific gravity (17° to 27° Bé.) 0.0004. In filling cars and barrels sufficient space must be allowed for expansion (see *Bureau of Standards Circ. No. 57*).

Specific Heat of Oils.—This is important in oil refining or wherever oils have to be heated. It is of special importance in relation to the cooling action of oil on bearings. Oils do not vary greatly in this particular, the specific heat usually being between 0.45 and 0.50 as compared to water at 1.

Heat of Combustion.—The heat of combustion varies from about 16,000 to 22,000 B. t. u., the average being about 19,000. The heat of combustion is higher for the light oils. (See under specifications, etc., for Gasoline and Fuel Oils.)

CHAPTER IV.

FRICTION AND LUBRICATION.

A large percentage of the power applied to all kinds of machines and manufacturing plants is used in overcoming friction. This power, which is largely lost or wasted so far as doing useful work is concerned, generally amounts to from 20 per cent. to 80 per cent. or more of the total power developed.

Unnecessary Stresses.—Important sources of power losses are improperly aligned shafting or bearings, and tight belts, which cause excessive pressures and stresses which can only be reduced by mechanical adjustment. Properly aligned machinery, bearings that do not bind, and large pulleys with loose belts will greatly reduce power waste and depreciation of machinery. The first step in the reduction of friction is to remove unnecessary stresses by the best possible adjustment of the moving parts.

Two Kinds of Friction.—In the operation of most machinery two kinds of friction have to be overcome by the expenditure of power: Solid friction which results from actual contact of the moving surfaces, and fluid friction which is due to the resistance the lubricant offers to motion. Since solid friction is much greater than fluid friction, lubricants are used to separate the moving parts of machines, and so substitute fluid friction for solid friction. With smooth bearings at high speeds and under moderate pressures, this substitution is practically complete with a suitable oil, and the friction developed is proportional to the true viscosity of the oil.

Solid Friction.—More or less solid friction results where the lubrication is deficient either in quality or quantity. On account of the minute irregularities of bearings and journals, and on account of the tendency of metals to weld or "sieze" under the influence of pressure, the resistance to motion is high where the metals are in actual contact. Excessive initial power is required in starting a machine as much of the oil has been squeezed from between the bearings so that the surface depressions and projections interlace somewhat like cogs. After the machine is in motion, if the lubricating film is not sufficiently thick, or if the bearing is not smooth, the solid projections still strike or press against each other and consequently varying degrees of solid friction result.

The effects of solid friction are relatively large power losses, heating of the bearing, lowering of the viscosity of the oil by heating, and wear. As the bearings may be continually roughened by the sliding contact, the conditions become ideal for increased frictional losses. In extreme cases, serious seizing of the bearing and journal may occur so that proper lubrication becomes impossible and the removal of the bearing becomes necessary. In most cases, the effect will be continued wear and continuous waste of power through excessive solid friction. With good lubrication, serious abrasion is entirely absent, and wear and solid friction are reduced to a minimum.

Solid and Fluid Friction.—While for heavy, slow-moving machines solid friction is generally an important factor in power consumption, in the usual bearings and journals at normal speeds and pressures, relatively more power is used in overcoming resistance due to the oil. This is contrary to the popular belief which ascribes most of the power losses to wear resulting from actual contact of the bearing and journal. If the lubricant does not keep the bearing and journal apart almost entirely during normal running, there is something wrong with the lubricant or with the bearing.

Fluid Friction.—In perfect lubrication, the moving part is entirely supported or "floated" on a film of oil which is of sufficient thickness to keep the journal and bearing apart under all reasonable conditions. To maintain such a film, the oil must have sufficient viscosity or "body." Pressure, speed, working temperature, condition of the bearings and method of oil feed determine the most advantageous oil to use, the effect of these different factors being as follows:

(1) With other conditions the same, high pressures require oils of higher viscosities than do low pressures, as high pressures tend to squeeze the oil from between the friction surfaces.

(2) With the same pressures, a fast moving journal can be satisfactorily lubricated with a thinner or less viscous oil than can a slower journal. This is because the speedier journal sucks or pulls in more oil between the moving parts and so aids in maintaining the film.

(3) For bearings that operate at high temperatures, as on electric motors, an oil of greater viscosity is required than for lower working temperatures under similar speeds and pressures. Raising the temperature greatly reduces the viscosity of an oil.

(4) For rough bearings, an oil of high viscosity is required in order to maintain a thick film which will reduce actual contact of the bearing and journal to a minimum.

(5) With a circulating oil feed, or force feed, oil of lower viscosity can be used on account of the increased amount of oil reaching the bearing which partly compensates for the oil squeezed out. The excess of oil also tends to reduce the temperature of the oil film and cool the bearing so that the working temperature is lower and the working viscosity is higher than where less oil is fed.

In general, for low pressures and high speeds a thin oil is desirable; for high pressures and low speeds, a thicker, more viscous oil is necessary. Pressure per square inch is meant and not the total pressure on the bearing, while speed refers to the friction speed of the contact surfaces and not to the actual rate of rotation. For rubbing speeds of less than 100 feet per minute, the oil film does not form properly for satisfactory oil lubrication.

With good lubrication, or practically perfect lubrication, the friction is chiefly fluid friction, and the main factor in determining the amount of friction, is the viscosity of the oil, so far as lubrication is concerned. Obviously then, an oil which has just sufficient viscosity to carry the load under all reasonable conditions, but no greater viscosity, is the ideal lubricant.

Viscosity.—By the viscosity of an oil is meant its internal friction or its resistance to flow. It refers to the same property as do the terms body and cohesion. For true liquids viscosity varies inversely as fluidity.

Viscosity is usually measured by noting the time required for a given volume of an oil to flow through a definite sized opening or tube under a definite pressure. With commercial viscosimeters, such as the Saybolt and the Engler, the tube is too wide and too short for the real friction of the oil to be accurately registered, consequently such instruments do not show the true viscosities of oils, though such instruments serve to classify oils in the order of their viscosities. For high viscosity oils, above 300 Saybolt, the true viscosities are practically proportional to the Saybolt viscosities, but for low viscosity oils the viscosities observed are not relatively proportional. Thus an oil of 50 Saybolt viscosity has considerably less than one-fourth of the absolute (true) viscosity of an oil which reads 200 Saybolt. Also, the difference between two low viscosity oils, for instance of 50 and 60 Saybolt, is much greater than the two figures would indicate.

Friction and Viscosity.—It is generally accepted that under good lubrication conditions, the frictional resistance necessarily varies with the pressure, with the velocity of the friction parts, and with the viscosity of the oil at the working temperature. It is, however, not so generally accepted that under definite conditions of speed and pressure, the coefficient of friction is solely dependent on the viscosity of the oil. This is Ubbelohde's theory which he has substantiated by calculating the actual coefficient of friction for many oils, including American oils, from the true viscosities of the oils (*Pet. Rev.*, 27, pp. 293 and 325-326; *Petroleum*, 7, pp. 773-779, and 882-889; cf. *Chem. Abs.*, pp. 1986, 2521, and 2839, 1912; and pp. 248 and 2678, 1913). Ubbelohde states that the reason this relation has not been generally recognized before is due to the fact that commercial viscosimeters do not give the true viscosity, or readings relatively proportional to the true viscosities. It has been the practice also to make viscosity readings at temperatures which did not accord with working conditions and so the relation was further obscured.

The value of oils as lubricants has been explained by many observers on the basis of such properties as "oiliness," or "body" The only tangible evidence of the existence of "body", as separate from viscosity, is in connection with the known superiority of lard oil over mineral oils for cutting purposes where the unit pressures are exceedingly high. Factors which are important are adhesion (outer friction) and capillarity, but according to Ubbelohde all oils possess sufficient adhesiveness for lubricating purposes as all oils cling to or "wet" all solid bodies. (See also Report of Sub-committee on Lubrication at Spring Meeting of American Society of Mechanical Engineers, 1919, or Power, p. 119, July 15, 1919). The question of "body", or adhesion, is now being investigated by the U. S. Bureau of Standards and by the Department of Science and Industrial Research (London). The matter may be related to the increase of viscosity under high pressure, or to surface tension effects due to adsorption. Thus the addition of a very small amount of fatty acids to mineral oils has an effect practically equal to the addition of a large percentage of fatty oil for use with high pressures. (See "The Theory and Practice of Lubrication: The 'Germ' Process," by H. M. Wells and J. E. Southcombe, *J. Soc. Chem. Ind. 39*, pp. 51t-60t, 1920; or *Ch. A.*, p. 1074, 1920, and *Pet. Times, 3*, pp. 173-5, pp. 201-3, 1920; also "Discussion on Lubrication," by D. R. Mountford, et al., *Proc. Phys. Soc.*, London, 32, Pt. II, pp. 1-34S, *Ch. A.*, p. 1475, 1920).

For further discussions on the relation of "body" and viscosity, see: "Lubrication" [under high pressures], T. E. Stanton, L. Archbutt, J. E. Southcombe, et al., *Engineering, 108*, pp. 756-760, 1919, (*Ch. A.*, p. 491, 1920); "Lubricants: Memorandum on Solid Lubricants," T. C. Thomsen and L. Archbutt (28 pp.) H. M. Stationery Office, London; "Notes on Lubrication," by S. Skinner, *Ch. A.*, p. 1971, 1919; "Note on Static Friction and on the Lubricating Properties of Certain Chemical Substances," W. B. Hardy and J. K. Hardy, *Phil. Mag.*, Cambridge, 38, pp. 32-49, 1919, (*Ch. A.*, p. 2805, 1919); also, "A Problem in Lubrication," W. B. Hardy, *J. Soc. Chem. Ind., 38*, p. 7t, 1919, (*Ch. A.*, p. 808, 1919.)

In connection with this contention that adhesion is always adequate, and that there is no "slip" of the oil in contact with the metal, it is of interest to note the statement of Prof. Gill (Rogers and Aubert's Industrial Chemistry, Ist Ed., p. 563) that in per-forming friction tests with a friction machine the effects of the oil previously used on the machine persist for about eight hours. This indicates that the oil in actual contact with the metal is difficult to dislodge even when the "pores" of the metal surface are at a minimum.

Ubbelohde's experiments prove that oils of the same viscosity, whether refined oils or unrefined oils, distilled oils or undistilled oils, have the same coefficient of friction, without regard to the origin of the oil.

Viscosity and Temperature.—As the temperature rises, viscosity decreases rapidly. This makes it especially important that the viscosity be taken at the working temperature, or sufficiently near the working temperature to make possible an adequate comparison of the working viscosities of the oils used. The viscosity of most oil distillates is now taken at 100° F. and this is usually sufficiently high for all such oils, except possibly for heavy engine oils. Western oils lose viscosity faster below 100° F. than do Pennsylvania oils, but at temperatures above 100° F. the drop in viscosity is not much greater for western distillates than for Pennsylvania distillates.

When power acts to overcome friction, heat is generated as will be noted from the rise of temperature of any bearing when the journal is in motion. The highest temperature observed in a bearing is necessarily much less than the temperature of the oil film actually supporting the load, and the true working temperature of the oil film is higher than generally supposed, with a correspondingly decreased viscosity for the oil.

In practice, high temperatures from friction accompany great power losses either by solid or fluid friction. Low temperatures above surrounding temperatures indicate small power losses.

Rise of temperature, even of a few degrees, greatly lowers the observed viscosity and the lowering of the true viscosity is even greater than indicated by the reading, on account of the defects previously noted in commercial viscosimeters.

Fatty oils (animal and vegetable oils) retain their viscosity somewhat better under heat than do mineral oils. This is especially true of sperm oil, although the viscosity of sperm oil is relatively low. Castor oil and blown oils are the only fatty oils having high viscosities at elevated temperatures.

One of the functions of a lubricant is to cool the bearing by absorbing and carrying off the heat from the friction surfaces. Lubricating oils vary very little in their heat absorbing capacity, consequently where considerable heat is developed, as in bearings around a steam engine, the temperature can be best kept down by a force-feed or by a circulating oil feed which feeds more oil to the bearing.

While the working viscosity of an oil is primarily the viscosity corresponding to the actual temperature of the supporting film, the viscosity of the oil at the other temperatures of use, such as the temperature at which steam cylinder oils are handled and fed, may be important and should receive proper consideration.

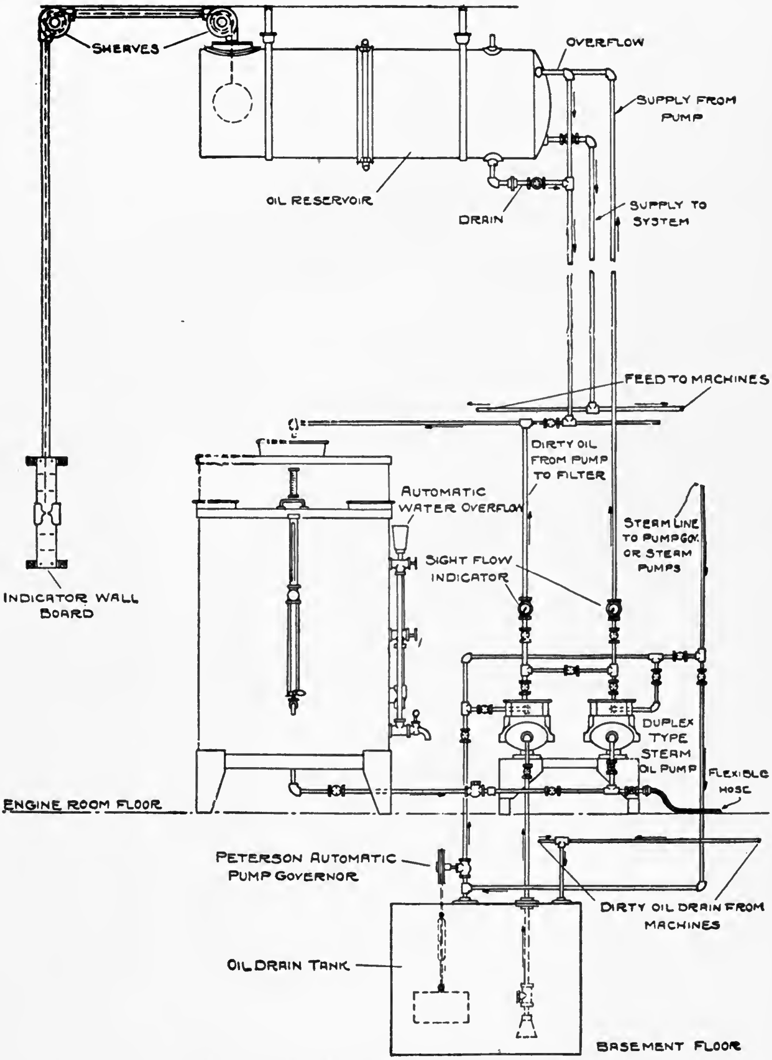
For a further discussion of viscosity and its determination see Index.

Oil Lubrication.—The above statements in regard to the relation of friction and viscosity apply primarily to oil lubrication. Successful oil lubrication is based on two fundamental principles:

(1) The use of an oil of sufficient viscosity to maintain a film of adequate thickness under normal working conditions plus sufficient additional viscosity to prevent the bearings coming in contact during abnormal conditions. Since solid friction is so much greater than fluid friction, if the bearings come together appreciably, power will be used up and more or less wear result. A lubricant which does not keep solid friction and wear to a minimum does not meet the primary requirements of a lubricant.

(2) The use of an oil of only sufficient viscosity to meet the above conditions, as all additional viscosity results in the useless consumption of power. At high speeds, not only can an oil of lower viscosity be used, but any additional viscosity results in much greater power losses than would result at lower speeds. Fluid friction is roughly proportional to the square root of the velocity of the friction surfaces.

Imperfect lubrication with solid friction results where friction speeds are too low, or too little oil is fed, or the load is too great for the viscosity of the oil under the working conditions. Con-



Typical Central Oiling and Filtering System with Filter on Engine Room Floor and Receiver and Automatic Pump Governor in Basement.

(By courtesy of The Richardson-Phenix Co., Milwaukee).

sequently for heavy shafting where the friction speeds are low, and in similar circumstances with other machinery, an oil of sufficiently high viscosity should be used. If the speed is low a reasonable excess of viscosity will result in little lost power.

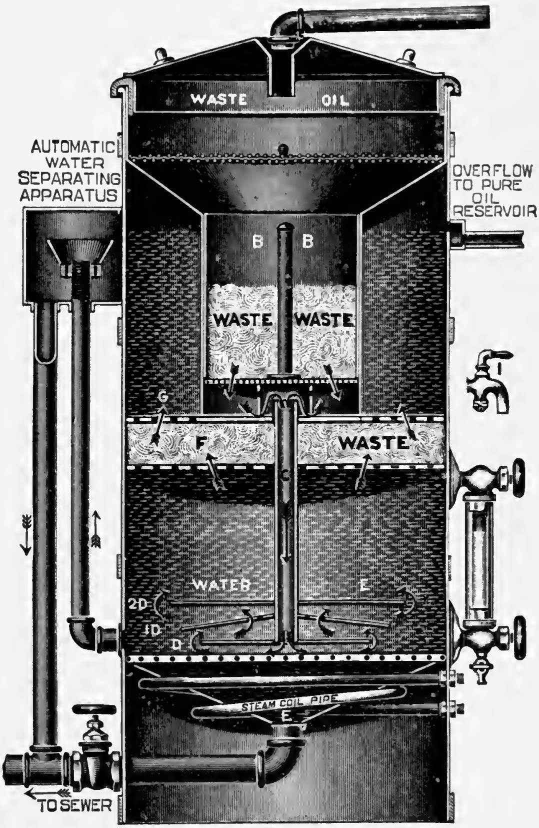
Purity of Oils.—Numerous other tests are applied to oils besides the viscosity tests. These are necessary to insure an oil that will be safe to use, or that can be used without undue loss from evaporation or decomposition, or without developing materials which would interfere with the oil feed or change the viscosity. Refining tests are applied to protect the bearings from the presence or the formation of injurious or gumming materials. These tests ordinarily have no direct bearing on the value of the oil so far as reducing friction is concerned, but are tests of the stability and suitability of the oil for the special conditions under which it is to be used.

Oil Testing Machines.—Tests made on the usual testing machines are generally unsatisfactory as the machines do not duplicate working conditions. Satisfactory results can be had by selecting an oil from the physical tests, especially the viscosity tests at the working temperatures, and checking the selection of the oil in service or on a service bearing.

Important contributions have been made by Prof. R. H Thurston to the science of lubrication through his development and use of testing machines. Much of his work is given in his "Friction and Lost Work in Machinery and Mill Work," published in 1879, which is still the standard treatise on this subject.

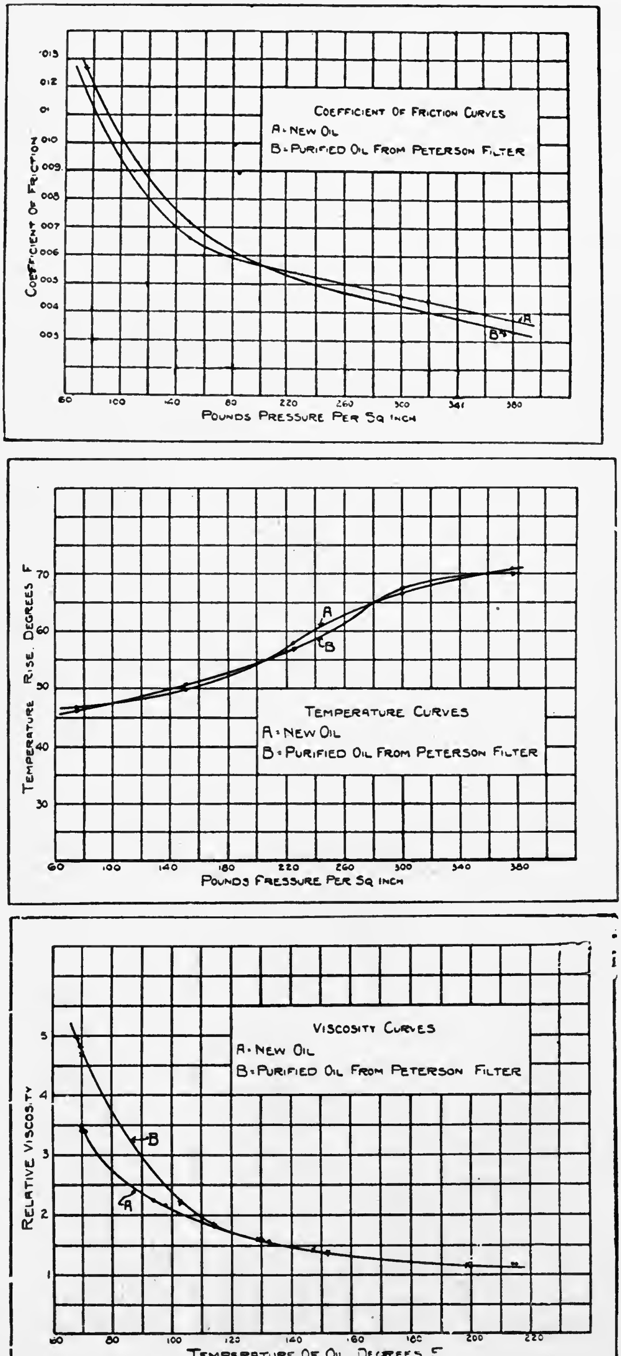
Circulating Oil Systems.—With the development of complex, heavy machinery, automatic oiling devices have come into use which feed the oil where needed without continued attention. Circulating oil systems, operated by motors or by steam pressure, feed oil to the many friction points of Corliss engines, turbines, and dynamos, collect the excess oil as it flows from the bearings, separate entrained water by appropriate means, filter off dirt and precipitated matter, and continue the oil in service with little loss. Such oil may circulate through the system 500 times or more and still be in good usable condition, as a good oil does not wear out, though it naturally darkens in service even with proper filtration. A poor oil may develop acid under exposure to heat and air, or may emulsify with water and increase in viscosity.

In circulating systems, and with ring oilers and other devices for flooding bearings with excess oil, an oil of lower viscosity can be used than where just sufficient oil is fed, as the surplus oil serves to cool the bearing.



The Cross Oil Filter "Style B."
(By courtesy of Burt Mfg. Co., Akron, O.)

The importance of ample lubrication, such as afforded by flooded bearings and by bath lubrication; can hardly be stressed



Curves Showing the Relation Between New and Filtered Oil.
(By courtesy of The Richardson-Phenix Co., Milwaukee).

too much on account of the great reduction in friction losses through the free use of an oil of the right viscosity.

In connection with forced-feed lubrication, the following quotations from Technological Paper No. 86 of the Bureau of Standards, by W. H. Herschel, are of interest:

"Lubricating oils are used to reduce friction, and their effectiveness depends upon the manner in which they are applied as well as upon their quality. To obtain the best results there must be an abundant supply of the lubricant. It has thus become recognized as good practice, especially for high speed machinery, to use a forced-feed lubricating system, the oil being pumped from a settling tank through the bearings and allowed to flow back to the tank. A filter is included in the circuit.

"It has been found that oils do not wear out mechanically and may be used over and over again. Thurston says, 'A mineral oil is usually just as good after use as before, apart from the impurities, which are removed by filtering.' Similarly Sabatié and Pellet conclude, 'The apparent result of all these different tests is that a used oil, received in good condition and *filtered with care* to rid it of the material which it may contain in suspension, preserves its different properties almost intact."

"It is on account of the necessity for filtering, upon which emphasis has been laid, that an emulsifying oil cannot be used in a circulatory system. An emulsion may clog the filter and result in damage to the bearings, due to the failure of the oil supply."

(See also Emulsification Test.)

The accompanying curves show tests made on oil after use in a circulating system for one and one-half years of continuous day-and-night operation. The circulation was at the rate of 150 gallons per hour, or 1,800 barrels per month, three barrels of new oil being added to the system per month. The oil was used to lubricate 134 points on several engines and compressors. The upper curve shows the coefficient of friction on a Thurston Railroad Lubricant Tester at 360 revolutions per minute for new oil and for filtered oil. The middle curve shows the temperature of the bearings in this test with the two oils. The bottom curve shows the viscosities of the new and the filtered oil at various temperatures with an Olsen viscosimeter. The oil increased in gravity from 0.895 to 0.903 during the period of use. The increase in gravity is without special significance.

For additional tests on changes in oils used in force-feed circulating systems, see "Examination of Oils from the Atlantic

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Fleet, before and after Use," by J. G. O'Neill, *J. Am. Soc. Nav. Engrs.*, *29*, pp. 325-338, May, 1917.

For references on breaking oil emulsions, see *J. Ind. Eng. Chem.*, pp. 180-181, 1920.

Bearings.—The design and fit of bearings greatly influence the quality of the lubrication. Bearings should be so constructed, by proper grooving or otherwise, and by proper location of the oil feed, that ample oil is drawn in or sucked in by the moving journal. In order to secure the best possible conditions for lubrication, the bearing should be smooth and of softer metal than the journal. While an excessively soft bearing would not offer sufficient resistance to the load, a soft bearing soon beds or flows to fit the journal so as to support the load at all points.

The area of bearings is designed to secure proper load per unit area. The area of the bearing should be just sufficient to maintain the load successfully under all conditions with the grade of oil to be used, as any excess area will increase the friction loss unless a thinner oil is substituted. For high speeds, the friction is practically independent of the load and is proportional to the area of the friction surfaces.

The proper fit of bearing for the lowest coefficient of friction is obtained by having the radius of the journal slightly less than the radius of the bearing to give space for the oil film which is usually 0.0002 to 0.003 inch thick.

Ball bearings and roller bearings are generally lubricated with oil and thin grease, respectively, and offer less frictional resistance than do other bearings. The oils used may have viscosities ranging from 100 to over 500 Saybolt at 100° F., depending on speed and pressure requirements. (See "The Lubrication of Ball Bearings," *Power*, *50*, pp. 848-9, 1919, or *Mech. Eng.*, *41*, pp. 811-5, 1919).

Grease Lubrication.—Good lubrication with oils is difficult to attain with slow moving machines under high pressures on account of the tendency of the lubricant to squeeze from between the friction surfaces faster than it is fed in by the motion of the journal. Since greases do not squeeze from bearings readily, but maintain a relatively thick film under pressure even when the journal is still, they are especially suited for slow or intermittent work where the loads are heavy. Sometimes oils of high viscosity can be used successfully for such work. For use on gears, greases are especially adapted as the unit pressures are high and the rubbing speeds slow.

Greases are not suitable for high friction speeds on account of their greater frictional resistance as compared to oils, though they do not offer excessive resistance to flow at low speeds. The coefficient of friction is higher for greases than for oils, which is another way of saying that greases offer more resistance to motion than oils do. Thin greases and greases of low melting point do not offer as great frictional resistance as stiff greases of high melting point.

Greases are also often used instead of oils for lubricating inaccessible parts of machines, for general convenience in application, for reducing the consumption of lubricant, to prevent splashing and to secure automatic feed.

Graphite as a Lubricant.—Flake and amorphous graphite have been widely used in conjunction with oils and greases for lubrication. The function of the graphite seems to be to build up the depressions in the friction parts and so make a smoother bearing. The effect is to reduce the friction, to make possible the use of a much thinner oil and to reduce the consumption of lubricant. For very heavy work and slow speeds, graphite is extremely valuable in preventing abrasion and seizing, and for reducing solid friction, as in steam valves and cylinders.

Graphite also seems to form a veneer or coating which carries heavy loads without offering much resistance to motion. Only very finely divided graphite should be used, especially with bearings having small clearance. Very small amounts of graphite give the best results.

Considerable work has been done by Prof. Mabery on the effect of graphite on the coefficient of friction of lubricants, using oils mixed with 0.35 per cent. of deflocculated (Acheson) graphite, with favorable results (*J. Ind. & Eng. Chem.*, pp. 115-123, 1910, and pp. 717-723, 1913; also *J. Frank. Inst.*, Vol. 169, pp. 317-328). Other authorities also report decreased frictional resistance where graphite is added to oils.

Mica as a Lubricant.—In general, the action of mica in a suitable state of fineness is similar to the action of graphite in being a surface evener. Mica has been used largely in certain greases.

CHAPTER V.

LUBRICATION OF INTERNAL COMBUSTION ENGINES.

Most explosive engines using liquid fuel work on the four cycle principle. The oil reaches the cylinder wall either by being splashed or sprayed on the wall below the piston. In some cases the oil is supplied by a force feed, but usually the oil is largely splashed by the moving parts in the crank-case. The oil gets into the cylinder above the piston either by being rubbed up by the piston, or by being sucked in past the piston rings during the stroke preceding the compression stroke, that is, during the inlet stroke. In the stroke succeeding the explosion or firing stroke the lubrication must be effected solely by the small amount of unburned oil remaining on the cylinder walls and by the oil actually left on the piston rings.

In order to secure proper lubrication an oil must be used which resists decomposition at a high heat, which leaves little undesirable residue when exposed to heat or when burned, and which has sufficiently high viscosity to lubricate but not sufficient viscosity to prevent the rapid formation of an oil film or seal. While at the high temperatures which the oil attains the viscosity is very greatly reduced, yet the very high speed of the piston and the relatively small pressure exerted by a vertical piston against the cylinder wall makes an oil of very high working viscosity unnecessary.

Excessive viscosity will prevent the oil film from forming rapidly after the firing stroke. However, owing to the fact that the oil is used to seal the gap between the cylinder wall and the moving piston or piston rings, as well as for actual lubrication, an oil of a little too high viscosity gives better results than an oil of too low viscosity. A low viscosity oil, especially with loose piston rings, does not seal the cylinder properly and so results in hot gases leaking past the piston rings and contaminating the oil in the reservoir or sump, exposing the oil, which is repeatedly splashed on the cylinder wall below the piston, to fairly high temperatures for long periods. Also the use of an oil of low viscosity may make necessary the use of excessive amounts of oil with the possibility of increased carbon formation in the cylinder.

So far as temperature conditions are concerned, the oil has two kinds of temperature to withstand: the temperature just below the flash point of the oil (200° to 400° F.) repeatedly for long periods of time as the oil is splashed on the cylinder walls below the piston and runs back into the oil reservoir, and temperatures of 200° to 800° F. in the cylinder above the piston where the oil is readily consumed. The first condition results in more or less decomposition and blackening of an unstable oil so that good results can hardly be expected when such an oil finally gets into the cylinder. The second condition must finally result in the more or less complete combustion of the oil as no oil could stand the excessive temperatures within the cylinder, but doubtless the oil remains partly unconsumed for a somewhat longer period than generally supposed. This would be due to the fact that the metal on one side of the oil film is a good conductor of heat and the oil itself is a poor conductor of heat, consequently the layer of oil next to the metal is partly protected from the heat by the outer layer of oil. This could not result in delaying actual combustion of the oil very long, but a fraction of a second's delay means the difference between actual lubrication and an absence of lubrication. When the oil finally burns, little carbon residue should be formed.

Except for the smaller high-speed pistons, as in automobile engines with small cylinders, the oil seal is relatively as important as actual lubrication and should be so considered. In fact, with a proper oil seal formed on the piston rings, sufficient lubrication will usually result.

Automobile Engines.—See chapter on Automobile Lubrication.

Stationary Gasoline Engines.—The oil used should ordinarily have a flash test of about 400° F., and should preferably be a straight distillate (viscous neutral). This mineral oil distillate may be blended with a very small amount of filtered cylinder stock, or well-refined cylinder stock, for use in heavy engines. Distillation of the oil should therefore show very little carbon residue unless the oil is for extra large engines which require an extra heavy oil. The gravity is preferably, but not necessarily, above 26° Be., though oils of any gravity may be used successfully if of the proper viscosity.

Oils which turn black on heating to their flash points for 15 minutes or show considerable sediment on subsequent standing will tend to form excessive amounts of carbon in use (see Heat Test). All oils show some darkening when heated to high temperatures.

Medium oils of 220 to 270 viscosity at 100° F. are suitable for small gasoline engines. For large gasoline engines heavy oils of 250 to 450 viscosity should be used. For engines operating in cold climates the cold test should be sufficiently low to meet practical conditions. Engines having force feed can use the higher viscosity oils to advantage, while the high viscosity oils are required for air-cooled engines.

Gas Engines.—The regular medium and heavy oils just mentioned are suitable for explosive gas engines. See "Horizontal and Vertical Gas Engines" (3 Bulletins), by Vacuum Oil Co., 1916.

Railroad Section Cars.—In these cars the oil is usually fed by mixing with the gasoline. An oil of at least 350 viscosity at 100° F. is required. Usually about 5 per cent. of the oil is added to the gasoline.

Motor Boats.—The engines are either two-cycle or four-cycle. For the two-cycle engines, medium motor oils of 200 to 270 viscosity at 100° F. are required. Where the oil is fed by mixing with the gasoline an extra heavy oil of 350 viscosity or over is necessary. For the four-cycle engines a somewhat heavier oil should be used than is necessary for the two-cycle engines, such as a medium oil of 220 to 350 viscosity, depending on the size of the engine cylinder. Where the oil is fed separately from the fuel a thinner oil can be used than with automobile engines on account of the efficient water cooling.

Motorcycle Engines.—The cylinder oil is fed by mixing with the gasoline or by some other method. Usually about 1 pint of the lubricant is added to 5 gallons of gasoline. The oil should be a heavy or extra heavy motor oil of 350 to 800 viscosity at 100° F. Such an oil is suitable for all types of feed.

Gasoline Tractors.—Such tractors usually require heavier cylinder oils than the correspondingly rated automobile engines, on account of the continuous heavy duty required of tractors. Oils of about the grade specified for stationary gasoline engines above work satisfactorily.

Kerosene Engines.—Explosive engines using kerosene as fuel require heavy oils for lubrication. Owing to the necessity of pre-heating the fuel charge and the introduction of water into the cylinder to aid combustion, the consumption of oil is heavy. The temperature of the gases rises to nearly 3,000° F., while the temperature of the cylinder walls and piston head ranges from 300° to 800° F.

Suitable oils for kerosene engines should have a viscosity of 450 to 650 at 100° F. and a flash test of 400° F. The viscosity of these cylinder oils might preferably be taken at 210° F., as the oil in the crank-case is usually kept this hot, but of course a correspondingly lower figure for the viscosity would then be required. A suitable oil can be made by blending a large amount of cylinder stock of good grade with a suitable heavy distillate. Where the engine is constructed for using water in the cylinder with the fuel, the effect is to reduce the amount of "carbon" which would otherwise be formed by such a heavy oil and at the same time to keep the remaining carbon in such a condition that it is continually removed through the exhaust.

Much of the difficulty experienced in lubricating kerosene engines has been due to lubricants of too low viscosity. The introduction of water into the cylinder makes a different condition from that present where no water is introduced as in the regular gasoline engine. Much of the kerosene is burned in a finely atomized condition instead of being actually exploded.

Kerosene Tractors.—The same cylinder oil is used as for kerosene engines above. For the lubrication of other tractor parts, medium (No. 3) cup greases are suitable for the various cups and for the axle bearings. The transmission is lubricated with transmission oil or a suitable cylinder stock of 175 viscosity at 210° F., or with a semi-fluid gear or transmission grease. The same dark grease may be used on the rear axle bearing if desired.

Regular and systematic cleaning of the cylinder and all wearing parts will pay well in lengthened life of the tractor.

Aeroplane Engines.—On account of the extreme lightness of the motors, the high speeds, the air-cooling and the absolute necessity for the motor to operate continuously at full capacity, the use of only the highest grade oils is absolutely necessary. These are usually of the same type as the very best of the automobile motor oils. The gravity should be high (30° Bé.), the flash test well above 400° F., the cold test not more than 15° F., and the carbonization test at 250° C. (482° F.) for 2½ hours should show only a minimum amount of material insoluble in petroleum ether or light gasoline (see Heat Test). The oils should be straight mineral oil distillates, or heavy distillates mixed with only small amounts of well-filtered high-grade cylinder stock, and should show little carbon residue on distillation to dryness. These tests are to insure an oil which will give the minimum amount of carbonization in use, as carbon would not only reduce the capacity of the engine, but might cause the engine to stop with all the hazard involved.

The viscosity of the oil should be high, a heavy-bodied oil of 400 to 950 viscosity at 100° F. being required. Vegetable castor oil is used extensively for lubricating certain cylinders, as in the Gnome rotary motor.

Although castor oil is of high viscosity and low cold test, it is used primarily for rotary motors on account of the method of fuel feed which requires an oil insoluble in gasoline.

While many of the newer aeroplanes have water-cooled engines, and consequently require somewhat less oil than the air-cooled engines, the conditions in both types of engines are excessively high piston speeds, extra high pressures and temperatures, particularly for long flights.

Diesel Engines.—The Diesel engine does not operate on the explosive principle of the usual gasoline engine, but burns an atomized liquid fuel. The air in the cylinder is compressed to a much higher degree than in the gasoline engine, so that it becomes heated above the ignition temperature of the fuel oil. The finely atomized oil is consequently ignited as it is introduced into the cylinder toward the end of the compression stroke. Any liquid fuels, even heavy distillates can be readily used. The engines are usually built in large units and operate with a low fuel consumption for the power developed. Fuel oils can be burned which are not suitable for use in other internal combustion engines.

The lubrication is usually by a forced-feed or a circulating system. For the cylinders, use a medium or heavy automobile oil of 250 to 800 viscosity at 100° F. This oil should have a flash of 400° F. or over and should ordinarily have a low cold test, and a low carbonization test when heated for 2½ hours at 250° C. (482° F.). (See Heat Test.) On account of the high compression of the air in the cylinder (500 pounds per square inch) and the resulting high temperature before, during and after the combustion, the oil is subjected to such a high temperature that only a good grade of oil will stand up. In case heavier oils are required they can be prepared by blending a well-filtered high-grade cylinder stock with a larger amount of a high viscosity distillate. A 250 horse-power Diesel engine uses about one quart of oil per hour.

A high-grade oil as given above will usually meet all requirements so far as emulsifying is concerned. In certain Diesel engines where moisture is present in the cylinder the cylinder oil can be used compounded with 5 to 10 per cent. of a suitable animal or vegetable oil. It is preferable to use straight mineral oils wherever possible, as in the regular Diesel engines.

The oil used for the air compressors in connection with Diesel engines should in general meet the conditions stated above for Diesel engine cylinders. The oil should separate readily from water, should have a high gravity (above 30° Bé.), and should be a straight distillate of 200 viscosity or over. The oil should be filtered, and only just enough oil should be used. Oils sometimes form acid by oxidation under the influence of heat, and H.

Moore (*Engineer,* 120, p. 176, 1915, and *Ch. A.,* p. 1093, 1916) has shown that this is somewhat dependent on the iodine number of the oil.

In connection with the fuel oil consumption for a Diesel engine, it is interesting to note that the Bureau of Mines (*Tech. Paper* 37) states that 1 pound of fuel oil will generate the same power that 2½ pounds of oil or 4 pounds of coal would generate in a steam turbine. It takes from 0.525 to 0.721 pound of fuel oil per brake horse-power for a Diesel engine.

On account of the unusually high efficiency of the Diesel engine, its use is rapidly increasing.

(Cf. "Diesel Engine Lubrication" by J. L. Wilson, *Petroleum World,* 13, p. 338, 1916; and "Talks on Diesel Engines", by L. H. Morrison, *Power,* 49, p. 640-3 etc., 1919).

CHAPTER VI.

AUTOMOBILE LUBRICATION.

A. MOTOR LUBRICATION.

Mechanical Considerations.—In any discussion of automobile lubrication, the conditions to be met in cylinder lubrication naturally receive first attention, owing to its importance and to the special difficulties involved.

The various designers and manufacturers of automobiles have adopted slightly or radically different systems of supplying the lubricant to the cylinder. The most usual systems are splash feed, force feed, circulating feed, and modifications or combinations of these separate systems. In the splash systems all or a large part of the lubricant is carried in the crank case and is splashed on or fed indirectly to the cylinder walls below the piston, any excess oil being wiped off by the piston and running back into the crank-case reservoir or sump. In the other systems the oil is either sprayed directly on the cylinder walls below the piston, or it is fed directly to the friction edge of the piston where it is needed.

In any case, the lubrication is effected by means of the oil which actually gets between the piston head and the walls of the cylinder. With the four-cycle engine, used in all automobiles, the pressure is higher in the cylinder than it is outside the cylinder during three of the cycles. This tends to prevent the oil entering the cylinder past the piston head, and also causes a tendency to press the oil from between the piston head and the walls of the cylinder. During the remaining cycle the pressure in the cylinder is lower than it is outside, consequently there is more or less leakage of oil into the cylinder above the piston head. Most of the oil entering the cylinder is thus introduced immediately before the compression stroke. This is the oil which does most of the work and causes most of the trouble in cylinder lubrication.

The conditions are not materially different whether the motor has four cylinders or twelve, the important conditions being the size and weight of the pistons and the clearance or fit of the piston rings. With the new V-type motors used on eight- and twelve-cylinder cars, the lubricating system has to be more elaborately worked out to secure proper distribution of the oil, but this is a problem for the automobile designer rather than for the automobile user. Ordinarily a working idea of the size of the cylinder can be had from the horse-power capacity per cylinder.

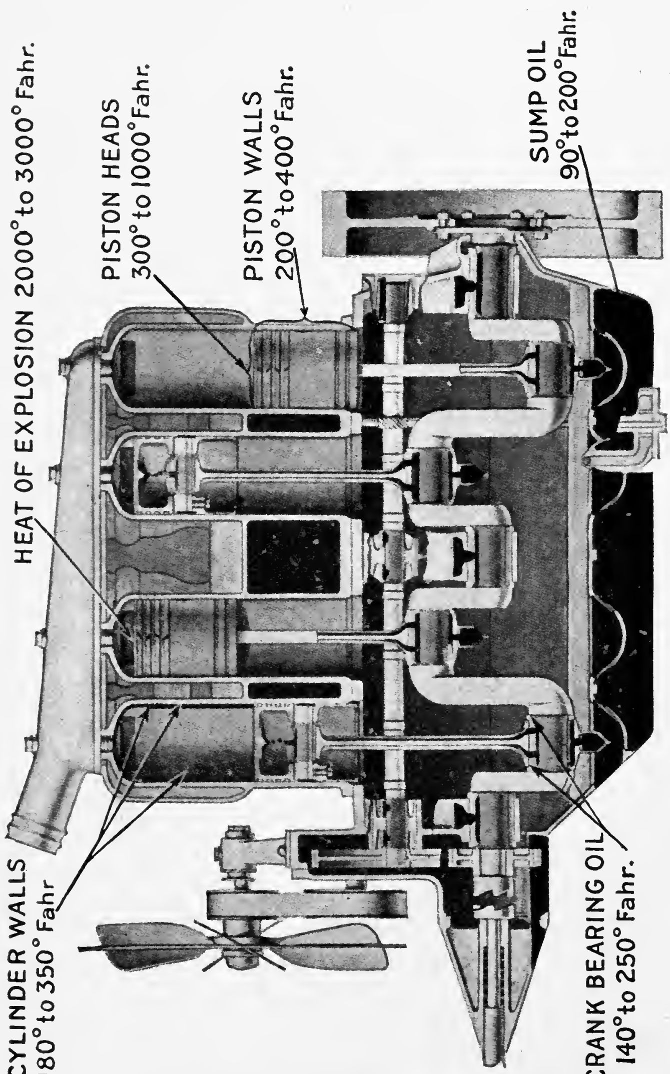
Temperature Conditions.—While exactly the same amount of heat is developed in burning a given amount of the same gasoline completely, irrespective of the motor speed, yet the temperature attained may be very different with different motors. Small cylinders have more cooling surfaces in proportion to their capacity than large cylinders, consequently the temperature of the cylinder walls is usually lower for small cylinders. Thus, the temperature of the cylinder walls of a twelve-cylinder motor will ordinarily be lower than the temperature of the cylinder walls of a four-cylinder motor of the same power.

The following figures will give some idea of the temperature conditions in a water-cooled motor:

	Degrees F.
Oil in crank-case	100-225
Explosion temperatures	2,000-2,800
Temperature of piston	200-400
Temperature of piston head	300-900
Temperature of cylinder walls	200-350

It can be readily seen that the temperatures to which the oil on the cylinder walls and piston head is exposed will not only greatly reduce its viscosity but will rapidly vaporize and burn the oil. Fortunately the large cylinders are always installed in a vertical position so that the weight of the piston does not come directly on the cylinder wall, otherwise much heavier oils would have to be used.

What Happens to the Oil.—With a properly working motor having close-fitting pistons, and using suitable oil, only small amounts of oil get past the piston rings. Even with close-fitting piston rings, an oil of too low viscosity would get into the cylinder in greater quantity than necessary. With a thin film of oil on the cylinder walls and on the piston head, part of the oil



Operating Temperatures of Motor Parts.
(By courtesy of Platt & Washburn Refining Co., New York.)

is vaporized and burned during each explosion, leaving a part of the oil still in working condition on the cylinder wall. Part of the oil may be burned without vaporizing. The small amount of carbon formed is readily blown out through the exhaust unnoticed.

If the oil happens to be thin, an extra amount of oil gains admission to the cylinder. This oil is vaporized and burned, or else burned without vaporizing, forming more carbon than the proper amount of oil would have done and at the same time leaving the cylinder and piston with insufficient lubrication. Oils of too low flash test would also vaporize unnecessarily fast and so reduce the quality of the lubrication.

If the oil happens to have sufficient viscosity, but is made by blending a large percentage of steam cylinder stock with some light distillate, as is often the case, the steam cylinder stock will not readily vaporize, but will accumulate on the piston head and on the cylinder walls. It will then be burned, or vaporized from the piston head, leaving considerable deposits. Steam cylinder stocks have not been vaporized in the process of manufacture and cannot be vaporized or distilled without partly breaking down with carbon formation. The heavy motor oils always contain considerable amounts of added steam cylinder stock.

In addition to the carbon formed by "cracking," carbon is also formed by the action of heat on the oils, the amount of such carbonization being determined by the chemical nature of the particular oil. The carbon deposits consist only partly of free carbon, the major part of the deposit being made up of grindings from the cylinder walls, road dust, and asphaltic or resinous matter formed by oxidation and polymerization of the oil under the intense heat.

Dr. C. E. Waters (*Tech. Paper No. 73* of the Bureau of Standards) states that the carbonization is due chiefly to this formation of asphaltic substances rather than to actual cracking. He recommends the heat test as an indication of the ability of motor oils to stand up under the conditions of use. Different oils heated for two or three hours to 250° C. (482° F.) show different amounts of material insoluble in petroleum ether. He does not consider longer heating necessary, but higher temperatures show even greater differences between "good" oils and "bad" oils. The amount of "carbonization" found for eight well-known brands of motor oil after heating for 2½ hours at 250° C. varied from 0.02 per cent. to 0.70 per cent. Oils which had been exposed for several days to sunlight showed increased tendency to form carbon under heat. It is interesting to note that the oils which were tested for vaporization loss showed from 17 to 24 per cent. loss in three hours at 250° C. (482° F.), but this has no direct bearing on the amount of "carbon" formation.

The presence of an excess of oil not only tends to the formation of unusual amounts of carbon, but some of the excess oil or heavy residues from it may act to prevent blowing out much of the carbon that is formed and so aid in its accumulation in the cylinder. Too rich a gasoline mixture also tends to increase the deposition of carbon in the cylinder.

The Effect of Carbon Deposits.—The cylinders are designed for a certain charge and an optimum compression. While the designer has allowed for the accumulation of a small amount of carbon, yet any marked accumulation of carbon will not only cut down the capacity of the cylinder and so decrease the horsepower obtainable, but it will cause the compression to increase to such a point that the charge will be over-heated resulting in spontaneous ignition. Pre-ignition troubles may also result from highly heated carbon actually firing the charge. Some of the other effects are choking up of valves, spark plugs and piston rings. Carbon may result in "knocking," in abrasion of the cylinder and piston, in wasted fuel, in decreased power, or even in actual stoppage of the motor.

The Removal of Carbon Deposits.—The asphaltic matter usually makes up a large part of the deposit. Where the deposits are soft and powdery they can be readily removed mechanically. Harder deposits could be chiseled out. Deposits can also be burned out to advantage by the oxygen or oxy-acetylene process. Deposits can sometimes be loosened by leaving the cylinders full of kerosene over night and then operating the motor so as to blow out the softened accumulations through the exhaust. Various other light solvents besides kerosene have been used for this purpose.

Motor Oil Tests.—The most important single test is for the viscosity at 100° F. or at some higher temperature. The real lubricating value of the oil depends primarily upon its viscosity at the temperature of use. The flash test in the open cup should be taken. Under certain conditions, the cold test, the fire test, the vaporization test and the color test should be made, but they are not usually important. The gravity is an indication of the source of the oil; if around 30° Bé., it is probably a Pennsylvania product and will probably retain its viscosity somewhat better under heat than other oils do. If the oil is not of Pennsylvania or similar origin it is well to allow a little extra viscosity as shown at 100° F. If the addition of excessive amounts of steam cylinder stock is suspected, the distillation test can be made; a high carbon residue will indicate such additions. These stocks are added to cheap, light oils to make heavier motor oils, and they are also used as a legitimate addition to heavy motor oils to make extra heavy oils.

The carefully filtered oils may also be tested by heating to 250° C. (482° F.) for 2½ hours and determining the asphalt content by dissolving in petroleum ether and filtering off the undissolved asphalt. An asphalt content of 0.50 per cent. would indicate an unsatisfactory oil so far as carbon formation is concerned.

Cylinder Oil Specifications.—The oils should be straight distillates known as viscous neutrals, except the heavy motor oils which can be blended with a minimum amount of well filtered cylinder stock. The flash point should be approximately 400° F. or higher. An oil of proper flash consistent with its viscosity will usually be free from low boiling constituents and will give correspondingly good results in use. The gravity test may be of value in indicating the source of the oil, an oil of high Baumé gravity most likely being of Pennsylvania or similar origin. The fire test, the cold test and the color test usually give no added information so far as actual lubricating value is concerned. The oil when heated for 15 minutes to its flash point should not turn black and should show very little deposit on standing 24 hours. The oils should have been purified by filtration and not by acid treatment.

With light new cars, oil of 140 viscosity can often be used, but there is no advantage in using an oil below 160 viscosity at 100° F. A so-called "light" motor oil should have a viscosity of about 180 to 225. Such an oil will usually lubricate all light cars in average condition, and all medium weight cars in good condition. It is preferable, however, to use the regular "medium" oil of 240 to 260 viscosity for the average medium weight car as the oil consumption will be considerably less than with the light oil and the resulting carbon formation will also be less. Cars in poor condition, as with loose piston rings, will require heavier oil for proper lubrication. For heavy trucks or heavy motors an oil of 350 viscosity or over can be used. The heaviest oils offered for the very heaviest work rarely exceed 700 viscosity at 100° F. Heavier oils are desirable for air-cooled cars than for water-cooled cars. Knight motors require extra heavy oils.

Analyses of Some Motor Oils.*—The following analyses show the properties of some oils actually in use for motor lubrication:

	Gravity	Flash (°F) Open cup	Viscosity	Remarks
Light motor oils:				
Sample No. 1...	26.6	405	162	
" No. 2...	27.0	390	183	
" No. 3...	30.0	415	195	
" No. 3a..	22.0	380	215	
Medium motor oils:				
Sample No. 4...	25.5	415	196	
" No. 5...	26.3	385	206	A blended oil shows 14.8% residue (liquid) on distillation.
" No. 6...	25.6	400	207	
" No. 7...	25.8	400	228	A blended oil shows 2.8% residue (liquid) on distillation.
" No. 8...	26.8	430	285	
Heavy motor oils:				
Sample No. 9..	24.5	420	262	
" No. 10..	29.0	420	310	
" No. 11..	27.2	430	435	

Analyses of a large number of motor oils made in 1917 show gravities ranging from 19.5° to 28.5° Bé., and viscosities as fol-

* For further analyses, see Index.

MOTOR OIL CHART.

The Viscosity figures indicate suitable oils for engines in average working condition. The minimum figures are for new cars, or for engines with close fitting piston rings, where the lubricating conditions are otherwise favorable. For summer use, and for engines in poor condition, the oils of higher viscosity are adapted. The figures represent the maximum ranges usually required for modern cars (1919 and 1920 models).

Automobile or truck.	Viscosity of cylinder oil at 100° F.	Automobile or truck.	Viscosity of cylinder oil at 100° F.
Allen	225-375	Kline	200-275
Apperson	300-400	Lexington	200-250
Atlas	225-375	Liberty	200-275
Auburn	200-275	Locomobile	200-350
Blair	225-375	Lozier	225-350
Briscoe	225-375	Mack	250-400
Buick	200-275	Marmon	275-425
Cadillac	250-350	Maxwell	200-275
Case	200-275	Mercer	300-425
Chalmers	250-375	Metz	225-325
Chandler	200-275	Mitchell	225-375
Chase	250-400	Moline (Knight)	700-900
Chevrolet	250-375	Monroe	250-350
Cole	300-400	Moon	200-275
Crow-Elkhart	225-350	Nash	225-375
Dart	200-300	National	250-350
Davis	200-275	Oakland	300-400
Dayton	225-325	Oldsmobile	275-375
Dodge	225-350	Overland	200-275
Dorris	250-400	Packard	300-400
Dort	225-350	Paige, 6-cyl	225-325
Elcar	200-275	Peerless	275-375
Elgin	225-350	Pierce-Arrow	275-375
Empire	200-325	Premier	325-425
Federal	200-325	Pullman	200-275
Ford	185-275	Regal	225-275
Franklin	275-400	Reo	225-375
Garford	250-400	Roamer	200-275
Glide	225-375	Saxon	185-250
Haynes	250-400	Scripps-Booth	300-400
Henderson	200-275	Selden	225-325
Hollier 8	250-350	Stearns-Knight	700-900
Hudson	225-350	Studebaker	250-400
Hupmobile	225-400	Stutz	325-425
I. H. C. (water cooled)	250-375	Velie	200-300
Indiana	225-400	Westcott	200-275
Jackson	250-350	White	250-325
Jordan	200-275	Willys-Knight	700-900
King 8	250-350	Winton	250-325
Kissel Kar	225-350		

lows: Light motor oils 190 to 220 Saybolt at 100° F., and medium motor oils 250 Saybolt and higher. The heavy and the extra heavy motor oils have considerably higher viscosities, but do not offer any regular basis for comparison so far as the viscosity at 100° F. is concerned. Where the working conditions are severe and a heavy oil is required, the tendency is to supply oils of higher viscosity than was formerly considered necessary under similar circumstances. In winter, it is necessary to use oils of low cold test to avoid difficulty in starting the engine, consequently oils of lower viscosity are needed in winter than in summer, as the heavier oils usually have relatively high cold tests particularly if from paraffin-base oils.

The tabulated analyses are not all for high grade oils. Owing to competitive conditions in the oil trade, and to the higher cost of the heavier oils, the tendency is to substitute low viscosity oils under the name "heavy" motor oils, and similarly for "medium" motor oils. While this may apparently be to the interest of the oil manufacturer, it is certainly not to the interest of the consumer. His interest demands an oil of somewhat too high viscosity in preference to an oil of too low viscosity.

Oil Consumption.—Most motorists waste their cylinder oil. With an oil of proper viscosity and with proper piston clearance as in new cars, the oil consumption can be cut to 25 per cent. of the average per mile consumption. Cars which normally require a gallon of oil for each 150 to 200 miles can be run with proper motor conditions for 600 to 800 miles on the same amount of a suitable oil. With proper oil-feed, carbon troubles would be a thing of the past. The blue smoke from the exhaust is not always due to a low grade gasoline; it is often due to an excess of cylinder oil.

With loose "leaky" piston rings a heavier oil is needed and more of it. More gasoline is also required and the results are in general less satisfactory. The proper clearance of pistons is not over 0.002 inch per inch of cylinder diameter. The crankcase reservoir should be cleaned out at frequent intervals. This becomes more necessary if there is leakage of contaminated and sooty oil past the piston head. A proper oil seal on the piston rings is as important as actual lubrication in saving power and in protecting the oil in the reservoir from contamination by hot gases and wastes from the cylinder.

The secret of successful motor lubrication is to keep the motor in good mechanical condition and use an oil of good (high) viscosity somewhat sparingly. It is not necessary to have an oil of quite as high viscosity for winter use as for summer use.

The two most important and necessary characteristics of motor oils are proper viscosity at the working temperatures and low carbon formation. The excessive high engine speeds, 2,600 to 3,400 revolutions per minute in some modern automobile engines, and the attendant high rubbing speeds in the cylinders make an oil of just the right viscosity absolutely necessary, otherwise the oil film will not have time to form and the power out-put of the engine will also be reduced.

B. GENERAL CHASSIS LUBRICATION.

Transmission Lubrication.—Where the transmission is suitably housed to retain oil, a good steam refined cylinder stock of 160 to 220 viscosity at 210° F. is a satisfactory lubricant. The lubricant should have enough body to adhere to and cushion the gears without wiping off from the teeth under the great pressure. Such an oil should be from 25° to 26° Bé., 30° F. cold test, 550° to 600° F. flash in the open cup and 600° to 675° F. fire test.

Where an oil does not have enough body, as in heavy cars and trucks, a transmission grease can be used. The true transmission greases are usually dark in appearance, being made from cylinder stocks, and are semi-fluid. The body of such a grease can be made sufficiently high for any properly designed transmission while the ability of the grease to stick to the gears is retained. If the grease is not semi-fluid, but stiff and heavy, the gears will cut "tracks" through it without being properly lubricated. If the grease is too thin, as would be the case if a thin oil were used in making the grease, the gears will not be cushioned properly.

Light cars are often lubricated with cup greases or similar light greases, either alone or mixed with steam refined cylinder stock. The light greases alone are hardly to be recommended as the greases have to be fairly stiff in order to do the work properly, particularly if made from the usual grades of thin oils, but a stiff grease may fail to lubricate also by having the gears cut tracks through it.

Differential Lubrication.—A dark semi-fluid transmission grease of good body is suitable. The grease can be somewhat stiffer than described for the transmission. It should be made from cylinder oil stock. Cup greases should not be used, except possibly for light cars.

Some manufacturers use graphite or mica to assist in cushioning the gears. Excessive amounts of these substances act as cheapeners, although reasonable additions are legitimate.

Poorly designed or poorly cut bearings on heavy cars or trucks may require lubrication with a special heavy grease containing solid fiber, either asbestos or wood. Such a grease may reduce rattling, but it also increases power losses.

Worm Drives.—A special heavy gear grease is used on worm drives. The oil in the grease should be a suitable cylinder stock. For some drives an extra heavy cylinder stock of 220 to 250 viscosity at 210° F. is preferred instead of the grease. The use of tar or asphalt-thickened oils or greases is inadvisable for any of the gears of automobiles or trucks.

Roller Bearings.—For automobiles a medium to soft grade of fiber or cup grease can be used. For heavy trucks, it is necessary to use a tough, stringy grease made from a good cylinder stock. Fiber or sponge greases are preferable to cup greases as there is less tendency for the oil to separate from the grease. Gear compounds, which should only be made from sponge or fiber greases combined with heavy oil, are least likely to leak out.

The bearings of the rear axle are partly lubricated by the waste lubricant from the differential.

Greases loaded with much graphite or mica should not be used on the roller bearings in the wheels.

The Use of Cup Greases.—The chief use for cup greases in automobile lubrication is in connection with the various compression cups. For this work various consistencies are available, the most usual grade being a medium grease of No. 3 body.

Electric Road Vehicles.—For the transmission and gears a high-grade steam refined cylinder stock of 170 to 240 viscosity at 210° F. is suitable. The oil should have a fairly low cold test for winter use. Such a high viscosity oil will have sufficient adhering power to cling to the gears under pressure. In the rare cases where there is a tendency for the oil to work out, a thin, semi-fluid gear grease made from a high-viscosity cylinder stock can be used successfully. For general lubrication of the electric motors, etc., an oil of 300 to 350 viscosity at 100° F. can be used.

ADDITIONAL REFERENCE.

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CHAPTER VII.

THE LUBRICATION OF ELECTRICAL MACHINERY.

Dynamos and Motors.—Most of these machines are equipped with ring-feed bearings, or with circulating feed. The usual conditions are high speeds and a fairly high operating temperature due to the heat generated by the electric current in the adjacent coils. The function of the oil is to give sufficient lubrication and to aid in cooling the bearings. Since the oil is used over and over again, a thin oil is decidedly preferable. Such an oil circulates more readily and permits the impurities to settle out more quickly.

Where the oil-cooling reservoir is not sufficiently large an oil of higher viscosity becomes necessary. Such an oil is more likely to form gummy material and give trouble than would a thinner oil kept at the proper temperature by an efficient cooling system. In starting a dynamo or motor, particularly the larger machines after long standing, the bearings can often be hand-oiled to advantage. The oiling-rings should be regularly inspected to see that they are revolving and so feeding the oil properly.

For lubricating the bearings of very small machines heavy spindle oils or non-viscous neutral oils can be used. These oils should have a viscosity of 70 to 110 at 100° F.

For small dynamos and motors, of 5 to 35 horse-power, viscous neutral oils are required. Engine oils of good grade and light automobile oils are suitable. The oils should preferably be straight distillates purified by filtration rather than by chemical treatment, and of low enough cold test to meet the conditions of use. The gravity of the best oils will ordinarily be above 30° Bé., but good oils can be had of 27° Bé. The flash point will be above 380° F., the cold test below 20° F., and the viscosity 140 to 180 at 100° F. The oils should be free from gummy or tarry matter as shown by the gasoline test.

For large dynamos and motors, over 50 horse-power, viscous neutral oils at 160 to 220 viscosity at 100° F., are suitable. These oils should preferably be straight distillates, have a flash test of

400° F., and be pure mineral oils as shown by the tests just given for purity.

Transformer Oil.—The function of a transformer oil is to act as a non-conductor, chiefly between the primary and the secondary coils, and to carry off the large amount of heat generated by reason of the electrical resistance in the coils. To be able to maintain the proper dielectric conditions, the oil must be absolutely free from acid, alkali and mineral salts, and free from any trace of moisture or mechanically suspended impurities.

Even one part of water in 100,000 parts of oil greatly reduces the dielectric strength of the oil. For use in high tension transformers the oil is subjected to a test at 30,000 volts. The suspended water is usually removed by filter-pressing; for example, through several hundred thicknesses of "blotting" paper. Water can also be removed by filtering through freshly burned lime. A simple method for testing for the presence of water in the oil is by shaking the oil with a little anhydrous copper sulphate. The white powder turns blue if there is a trace of moisture present. The anhydrous copper sulphate can be prepared for use by gently heating a little of the ordinary blue copper sulphate so as to drive off the water. The presence of water in any appreciable amounts can also be detected by heating a quantity of the oil in a test tube immersed in a boiling salt-water bath. If water is present in the oil a series of small bead-like bubbles will form on the surface of the oil where it is in contact with the tube.

In order to circulate freely the oil should be of low viscosity, preferably a non-viscous neutral of 80 to 120 or 140 viscosity at 100° F. The oil circulates by gravity or by means of a pump. The cold test should be below 20° F.

Since the oil is subjected to high temperatures almost continuously, up to 100° C., the flash should be over 340° F. The oil should not lose over 0.2 per cent. when heated at 100° C. (212° F.) for 5 hours, and should not contain asphaltic or tarry matter originally or after heating for several hours in the presence of air at 250° F. The gravity should be above 32° Bé.

Holde ("Examination of Hydrocarbon Oils," p. 81) states that special rosin oils and heavier distillates, of approximately 300 viscosity, are also used. Rosin oils show much greater volatility than do the mineral oils, while the heavier mineral oil distillates show very little evaporation loss. The heavier oils show greater tendency to form the undesirable asphalt.

The "Report of the Sub-committee of the Institute of Electrical Engineers" on the suitability of an oil for a cooling-insulating medium gives a detailed account of the tests required. (*J. Inst. Elect. Eng.*, 54, p. 497, 1916; and *J. Soc. Chem. Ind.*, 35, p. 625; also *Chem. A.*, p. 2633, 1916.) For methods of making the evaporation test for transformer oil see Waters, *J. Ind. & Eng. Chem.*, pp. 394-398, 1913.

Electric Elevators.—For suitable oils for lubricating the motors, see specifications under electric motors of the proper capacity. The worm-gears can be lubricated with a steam refined cylinder stock of 170 to 220 viscosity at 210° F. Heavy, dark gear greases when not too stiff, or similar semi-fluid greases made by blending fibre or sponge grease with cylinder stocks can be used. For the compression cups a medium grease will answer if the grease contains an oil of sufficient viscosity. Small additions of graphite or of high-grade mica may be beneficial in the worm-gears.

For lubricating the metal cables and for preventing rusting, a very heavy engine oil distillate of 300 viscosity at 100° F. can be used, or a good cylinder stock, or cylinder stock blended with a distillate. The guides can be lubricated with similar heavy oils.

Rotary Converters.—The same type oil, or slightly heavier oils are used as for heavy dynamos and motors.

Vertical Electrical Generators.—These are mounted on a water-driven shaft which usually floats on an oil film maintained by a circulating force-pump. The oil should have the same general characteristics as specified for large dynamos and motors and should have a viscosity of at least 200 at 100° F.

Electric Railways.—The various bearings and journals are likely to become badly contaminated with dirt and grit sucked up from the road-bed. Regular, systematic inspection and regular cleaning are necessary to prevent destruction of the bearings and to keep the packing in place so as to feed the lubricant to each bearing. The waste should be well moistened, but not soaked, in order to lubricate without wasting the oil.

The motor axle bearings and the bearings of the armature are subjected to considerable heating from the electric current and so should preferably be lubricated with a heavy engine oil of 280 to 400 viscosity. The flash test should be approximately 400° F. and the cold test 10° or 25° F. depending on the season and the climate.

Air compressors (see Index) are lubricated with a good light cylinder stock or cylinder oil.

For lubricating the journals a cheap car oil is satisfactory. Suitable black oils or car oils should have the following characteristics: For summer, 80 to 90 viscosity at 210° F., 300° to 325° F. flash test and free from excessive amounts of tarry sediment; for winter, about 65 viscosity at 210° F., 275° to 300° F. flash test, 10° F. cold test, and free from excessive sediment (not over 5 per cent. by the gasoline test).

It has been customary for some of the oil companies to rate black car oils on the basis of their viscosity at 130° F.

Street railways are often furnished lubricants on a per mile basis, but this is not always to the interest of the railway companies.

For the motor gearing of electric railway cars, heavy greases of high melting point are used. These greases should be made from heavy oils so as to cling to the gears properly. Sometimes greases containing a heavy residuum combined with tar are used on account of their ability to cling to the gears under the conditions of use, but the solid grades of this grease, similar to "hot neck" greases for rolling mills, are too thick for advantageous use on car gears. One reason for using such greases in preference to regular gear greases, is on account of the higher cost of the regular gear greases.

Curve greases, for application to the tracks, are made from crude, heavy residuum, from various grades of tar or pitch, or from combinations of tar and residuum.

CHAPTER VIII.

THE LUBRICATION OF STEAM CYLINDERS AND STEAM ENGINES.

Saturated Steam Conditions.—When steam is generated in a closed space, as in a steam boiler, the pressure rises to a definite point corresponding to the temperature of the steam. This is the usual type of boiler, the steam pressure being automatically released by a safety valve whenever it reaches a predetermined maximum. The temperature of saturated steam is exactly proportional to the pressure, so if the correct, effective gauge pressure is known the temperature can be read off by means of a table such as the following:

Effective gauge pressure (lbs. per sq. in.)	Temperature °F.	Effective gauge pressure (lbs. per sq. in.)	Temperature °F.
10	238	120	350
20	260	130	356
30	276	140	360
40	288	150	365
50	297	160	370
60	307	170	375
70	316	180	379
80	323	190	383
90	332	200	387
100	337	225	397
110	344	250	406

It will be noticed that, even with the highest pressures used, no importance need be attached to the flash point of cylinder oil for use with saturated steam as practically all cylinder oils now offered for sale flash above 500° F.

The viscosity of the oil is important as well as the amount of fixed oil and the method of feeding the oil to the cylinders. Pressures below 60 pounds are usually called low pressures, while high pressures refer to pressure of 125 pounds per square inch and over.

Superheated Steam Conditions.—Superheated steam is steam which has a higher temperature than corresponds to its pressure, owing to having been subjected to direct heating after being generated in the boiler. The number of degrees the steam is above that of saturated steam at the same pressure is called the "degrees of superheat." The extra heating is usually accomplished by having a large number of small pipes making a number of turns in the firebox, the steam having to move through these pipes on the way from the boiler to the steam chest. The turns in the pipes are necessary in order to "break the core" of the steam which is moving at an extraordinary velocity and so insure its coming into contact with the hot pipe.

The economy in the use of superheated steam comes from the facts that a very large amount of heat is required to change water into steam, and less heat is required to raise steam one degree than to raise water one degree. Steam, like any other gas or vapor, expands rapidly when heated. This expansion of the steam in the pipes in the firebox does not result in increased pressure over that in the boiler, but has the effect of increasing the volume of the steam and so raising the capacity of the boiler equipment.

Superheated steam has many advantages over high pressure saturated steam, especially for locomotives. The temperature of superheated steam may rise to 600° or 700° F. While the steam may reach such temperatures for certain engines, at the moment of introduction into the cylinders, the most usual practice is to give just a sufficient degree of superheat to insure the steam reaching the steam chest without condensation. Normally, the steam is introduced into the cylinders with more or less superheat. The actual cylinder pressure is more nearly the boiler pressure than with saturated steam as the loss of pressure from condensation is largely overcome. With saturated steam, condensation not only acts to lower the pressure but also to waste steam which has already been generated before it has had a chance to do useful work.

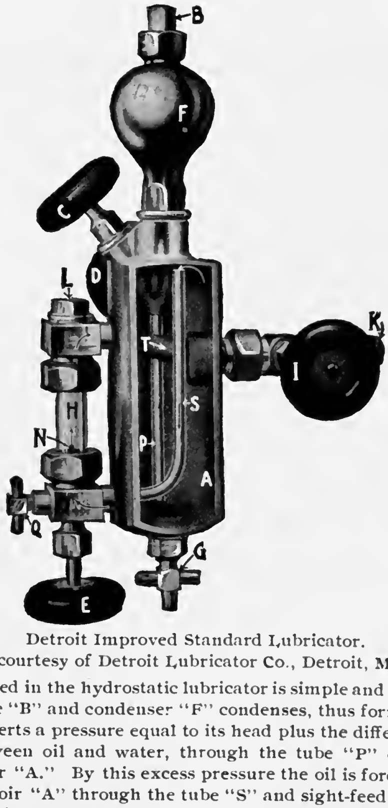
In any case, whatever the degree of superheat, the steam may be so reduced in temperature during its expansion in the cylinder, by reason of work done and loss of heat through conduction and radiation from the cylinder, that condensation takes place and a wet steam results. Most of this water is ordinarily vaporized during the exhaust or it is vaporized by the subsequent inrush of more superheated steam. With a high degree of superheat, compound cylinders are used, the high-pressure cylinder working dry and the low-pressure cylinder fed by the exhaust steam, working wet as a regular saturated steam cylinder.

The conditions in a superheated steam cylinder as compared to a saturated steam cylinder, are higher working temperature, higher working pressure, and dryer steam for the former. In order to meet these conditions, a higher viscosity oil is required with a better flash and fire test. Except in rare cases compounded oils are necessary. Superheated cylinders and valves, except on locomotives, require very little fatty oil in the cylinder oil.

Methods of Applying Cylinder Oils.—The kind of cylinder oil to use is largely dependent on the method of lubrication. Where the oil is warmed before pouring into the lubricator and where the oil in the lubricator is kept warm by the aid of steam or condensed water, a low cold test is of slight importance except for convenience in handling.

In the hydrostatic or sight-feed lubricator, such as the widely-used Detroit or similar lubricator, the oil floats on warm water supplied by condensation from a vertical steam pipe, the condensed water in the vertical pipe serving to force the oil through a small tube into a sight-feed glass. Here the oil feeds up through water, drop by drop, then goes by a short pipe well into a special steam pipe leading to the cylinder or steam-chest. The passing steam catches the oil drop and shoots it to the steam chest in a finely atomized condition. The cylinders and valves may be lubricated by separate pipes or by the same pipe. If the oil has too high viscosity for the steam pressure available it will not be properly atomized for good lubrication. Low flash oil and oil high in fatty oils seem to be more completely atomized than high flash oils or straight mineral oils.

The sight-feed glass should be kept clean so as to feed perfect drops, and the cup of the lubricator should be frequently drained and cleaned. In starting the lubricator, the oil feed should not be opened until the oil in the cup has reached a proper working temperature, which is usually about 140° to 150° F. Also the feed water in the vertical pipe should be sufficiently high to feed the oil. The rate of feed is judged by the number of drops of oil per minute. Cylinder oils vary from about 3,000 to 8,000 drops per quart of oil, depending on viscosity, amount of tar, etc., as well as on lubricator conditions.



Detroit Improved Standard Lubricator.
(By courtesy of Detroit Lubricator Co., Detroit, Mich.)

The principle employed in the hydrostatic lubricator is simple and positive. Steam being admitted into pipe "B" and condenser "F" condenses, thus forming a column of water which exerts a pressure equal to its head plus the difference in specific gravity between oil and water, through the tube "P" on the oil in reservoir "A." By this excess pressure the oil is forced from reservoir "A" through the tube "S" and sight-feed nozzle "N" into the sight-feed chamber "H." The sight-feed chamber being filled with water, the drop of oil floats to the top and passes to the point to be lubricated through the passage "T" and support arm "K."

Force-feed lubricators, worked mechanically by the moving parts of the engine, are not so generally used as the sight-feed lubricators, but heavier oils can be fed with the force-feed lubricators. These lubricators can be used advantageously with heavy engines for intermittent service, the flow of oil stopping and starting automatically when the engine is stopped or started. They can also be used to advantage with variable speed engines. The manufacturers of mechanical lubricators claim that better lubrication is obtained by feeding a little of the oil at each stroke of the piston than can be had with the usual hydrostatic lubricators.

Cylinder Stocks.—For the methods of manufacture and for actual analyses of cylinder stocks see Index. These stocks are straight undistilled petroleum products. The light oils present in the original petroleum have been removed, usually by steam distillation, and the residue left in the still is purified by more or less complete filtration. The residues from the distillation of many crudes are unsuitable for making cylinder stocks, and are not so used, but are used as car oils, fuel oils, etc. Sometimes a low viscosity cylinder oil is made by cutting back a heavier cylinder stock with a very limited amount of heavy engine oil, but such a blended oil will have a low flash test. The cylinder stocks are treated for the removal of paraffin so as to improve the cold test. However, high viscosity stocks, as for valves, will have a pasty character particularly in winter.

Western stocks have a lower gravity than Pennsylvania stocks, so, unless Pennsylvania stock is used, a high gravity stock should not be required. Much of the difficulty in using western stocks comes from insisting that they comply with the gravity standard of Pennsylvania oils, whereas the important consideration is the viscosity of the oil at 210° F. and higher. Pennsylvania stocks have a gravity of 25° to 29° Bé. with viscosities ranging from 90 to 250 or over at 210° F. The higher viscosity oils (170 and over) are rarely filtered. Western stocks have gravities as low as 18° Bé. and lower flash tests than Pennsylvania stocks.

The most important consideration is the viscosity at the working temperatures. The working temperatures are about 140° to 150° F. for the lubricator, and above 210° F. for the cylinder. While the viscosity in the cylinder is lower than the viscosity as determined at 210° F., yet the working viscosity in the cylinder is directly proportional to the viscosity taken at 210° F., and so oils can be correctly compared and judged on that basis.

In order to feed properly, the stocks should be free from tar. Green stocks are usually free from excessive amounts of tarry matter, but all stocks should preferably be tested by the gasoline test. Any asphaltic or tarry matter will fail to dissolve in the gasoline and will settle out so that it can be readily seen.

Cylinder Oils.—Cylinder oils are made by compounding (mixing) cylinder stocks with animal or vegetable oils. Cylinder stocks are never used alone for lubricating saturated steam cylinders except where the condensed water is to be used again for some purpose, and are rarely used alone for lubricating superheated steam cylinders, at least in this country. A certain amount of fixed oil (fatty oil) is necessary to keep the wet steam from displacing the oil from the friction surface of the cylinders and valves. A straight mineral oil will not form or maintain an oil film on metal in the presence of hot water, that is, it will not "wet" the metal, and so will not lubricate. Fatty oils will "wet" metal in the presence of hot water and they have the property of keeping this valuable characteristic even when mixed with mineral oils.

Varying amounts of fixed oils are required, ranging from 2 to 12 per cent. or over, the lower per cent. being sufficient for very dry steam and the higher per cents. being required for very wet steam, as is present in low-speed cylinders. The usual cylinder oils contain less than 12 per cent. of fatty oil, the amounts ordinarily present being from 4 to 10 per cent.

Practically all kinds of animal and vegetable oils have been used at times for compounding cylinder oils. The most generally preferred is tallow oil, but neatsfoot oil, lard oil, degras, degras oil, rape oil, blown rape oil, cottonseed oil and even linseed oil have been used. The animal oils are preferred on account of their non-gumming character. Rape oil is popular abroad, and blown rape oil is used as it has a high viscosity which makes the viscosity of the compounded oil not much lower than the viscosity of the stock from which it was compounded. The addition of fatty oil greatly lowers the viscosity of the cylinder stock to which it is added, even more than would be expected.

Excessive amounts of fatty oils, above that actually required, should not be added to cylinder stocks as the fatty oils break down somewhat under the action of steam, forming free fatty acids which attack the metal of the cylinder. Carefully compounded oils do not give any trouble in this particular.

The oils used for compounding cylinder oils should be "acidless," as acidless tallow oil, that is, they should contain less than 2 per cent. of free acid calculated as oleic acid.

If the exhaust steam is to be condensed and used over again it is important that the amount of fatty oils be reduced to a minimum so that the oil can be separated from the water readily. This is true in the case of cylinder oils for ice plants and for marine engines which are often operated with straight cylinder stocks.

It may be said that the high viscosity cylinder stocks have better adherence to hot, wet metal than have lower viscosity stocks, and so require no more fixed oils than do cylinder oils for lower pressures. The high-flash, high-viscosity oils are more difficult to atomize, but proper location of steam pipe and proper installation of the lubricator will result in good atomization with the higher pressure steam.

For superheated cylinders, oils are compounded from high firetest, high viscosity stocks and 3 to 11 per cent. of animal oil, usually tallow oil. As much as 11 per cent. is not usually required for stationary engines, but may be in locomotive practice on account of greater condensation from cooling in winter or to make possible the lubrication of the low-pressure cylinders of compound engines, with the oil carried by the exhaust steam from the high-pressure cylinders. The viscosity of the finished oil is rarely as low as 140, and is usually between 160 and 220 at 210° F. Cylinder oils for saturated steam have viscosities from 100 to 220 at 210° F.

Filtered cylinder oils are not usually required for either saturated or superheated steam cylinders.

Analyses of Some Cylinder Oils.—The following analyses were recently made by the author:

No. of oil	1	2	3	4	5	6
Kind of oil	Pasty filtered stock	Bright filtered stock	Bright filtered stock	Steam refined stock	Filtered railroad super-heater	Filtered railroad saturated
Baumé gravity....	22.0	23.1	26.2	25.6	25.5	26.0
Flash test (°F.)...	(550)	510	545	585	535	(530)
Viscosity at 150°F.	—	458	435	—	—	406
Viscosity at 210°F.	183	138	141	168	180	128
Fatty oils (%)....	1.5	(0.4)	2.6	0.9	11.2	10.6
Iodine No. (Hanus)	—	—	12.0	—	21.7	22.1
Maumené No. (°C.)	3.5	3.0	4.5	4.5	11.5	11.0
Volatile at 350 °F. in 2-hours (%)..	1.0	—	1.0	0.8	1.5	1.7
Acid as oleic (%) .	—	—	0.22	—	—	1.06

No. of oil	7	8	9	10	11	12
Kind of oil	Dark low pressure	Low pressure	High pressure	Special low pressure	High pressure	Special low pressure
Baumé gravity....	27.0	22.5	24.5	25.0	22.4	22.6
Flash test (°F.)...	485	530	570	455	550	525
Fatty oils (%)....	9.5	3.6	5.3	3.3	7.0	4.8
Viscosity at 150 °F.	281	465	696	341	666	463
Viscosity at 210 °F.	100	141	220	115	187	136

Sample No. 7 had a viscosity of 975 at 100°F., and 572 at 120°F.

Cylinder Greases.—These greases require special type lubricators so that the greases melt to oils before they are fed to the cylinders. These greases consist of high cold test cylinder stocks compounded with enough tallow, degras or solid fat to make them fairly firm at ordinary temperatures. Pasty cylinder stock of the valve oil type may be used or vaseline may be added to the "grease" along with the fats. These greases melt easily and lubricate substantially in the same way that the oils do and so would be tested for viscosity and amount of fats in the same way cylinder oils are. Excessive amounts of fats should be absent and no soaps should be present.

Poor Lubrication.—Indications of poor lubrication, either through insufficient amount of lubricant reaching the cylinder and valves or by the use of an unsuitable oil, are groaning of the valves and vibration, as in heavy Corliss engines and in engines used for air compressors. More oil should be used, and if this does not quickly correct the trouble, the valves and cylinders should be inspected for scoring or a heavier oil should be used. Poor lubrication is also indicated by difficulty in manipulating the valves, as in locomotives. The use of graphite in the cylinders or in the cylinder oil, or of a very little high-grade mica, has been found to improve the tendency of the valves to stick.

Scoring and groaning may be due to poor lubrication for which the oil is in no way responsible, but may sometimes be traced to adjustment of the lubricator which results in insufficient lubricant reaching the cylinders, or by poor adjustment of the pipe conveying the oil into the steam pipe so that the oil is not properly atomized by the steam. Any scoring of the cylinder would naturally continue to prevent proper working regardless of the character of the subsequent lubrication. The proper remedy would be to overhaul such cylinders promptly.

Good lubrication is indicated by easy working of the valves, and by the presence of oil on the piston rods as evidenced by holding a piece of white paper against the rod. By removing the cylinder head, proper lubrication will be shown by the presence of the oil film and by the absence of appearance of wear.

Cylinder Deposits.—These deposits may form on account of mineral matter brought over from the boiler by "foaming," especially in connection with the use of excessive amounts of boiler compound. In this case they should contain large percentages of lime and magnesia compounds, or compounds derived from the boiler treatment.

Deposits may be due to wear from insufficient clearance of the rings or from allowing the edges of the rings to get sharp. In this case a magnet will show a large amount of metallic iron present.

Where the cylinder oil is to blame, considerable carbon is likely to be present from cracking of the fatty oils present, and excessive amounts of iron rust or iron oxide show the action of fatty acids on the metal. The fatty acids could be present in the original oil or be formed from excessive amounts of fatty oils in the cylinder oils under the action of steam. Iron oxide, however, may at times come over with muddy water from the boiler. Fatty acids are active at high temperatures and rapidly corrode iron and other metals.

If an asphalt base mineral oil has been used asphalt may have been formed by the heat, in which case an analysis of the deposit would show considerable organic matter insoluble in gasoline. With superheater engines, particularly locomotives during "drifting" immediately after a hard pull, the admission of oxygen to the hot cylinders may carbonize the oil remaining in the cylinder.

General Engine Lubrication.—For lubricating the moving parts of steam engines, other than cylinders and valves, a good grade of engine oil should be used. This oil is preferably a straight mineral oil distillate of 400° F. flash test, 27° to 31° Bé. gravity, and a viscosity of 180 to 250 at 100° F. For large engines with circulating oil systems, the viscosity need not usually be over 220 at 100° F. as an oil of lower viscosity can be used with a circulating system which floods the bearings than without a circulating system where the oil must be fed sparingly. The excess oil tends to cool the bearings and so maintain the viscosity of the oil.

As more or less water comes in contact with the oil it is necessary to separate out this water in the oil-filtering process. A good quality of filtered oil should therefore be used, and it should be protected in every way from other contaminating oils. If an oil too high in fatty oil is used in the steam cylinder, some of this oil may finally work into the circulating oil supply and cause it to emulsify with the water to an objectionable extent. For large engine installations it is desirable that oils be tested for emulsification with water, and an oil chosen which shows little emulsification.

Marine Engines.—Marine engines are often operated without any lubricant to the cylinder other than the condensed water, where the water is needed for further use. Upon entering port cylinder oil is fed to the cylinder to prevent the idle cylinder from rusting. Small amounts of steam refined stocks, without the addition of fatty oils, can sometimes be used satisfactorily. but the addition of 2 or 3 per cent. of acidless tallow oil improves the lubrication. By using an oil of low viscosity (125 to 140 at 210° F.), of low fatty oil content, and low acidity, excessive emulsification of the oil with the exhaust water can usually be prevented.

For superheater marine engine cylinders, straight high viscosity refined cylinder stocks may be used, either alone or compounded with not over 3 per cent. of acidless tallow oil. The finished oil should have a viscosity of 180 to 250 at 210° F.

For general engine lubrication, it has been a long established custom to use a heavy engine oil compounded with 20 to 30 per cent. of blown (thickened) rape oil. This increases the viscosity of the oil to over 350 at 100° F. It is important that the oil be free from fatty acids and it is sometimes advantageous to add some other fatty oil in addition to the rape oil to overcome the tendency of blown rape oil to separate from the mineral oil.

Steam Turbines.—Lubrication is usually by a gravity or force-feed circulating system which makes it possible to use a thin oil. High-grade, pale engine oils, known as viscous neutrals, are generally used. They should have a gravity of over 30° Bé., be straight mineral oil distillates free from acids, and have a flash point around 400° F. Where an asphalt base oil is used the flash and gravity will not be so high. The oil should always be tested for its emulsifying properties as the oil should separate readily from water in practice.

In order to continue to separate from water properly and maintain a suitable viscosity without the development of acidity, the oils should be practically free from sulphur. The nature of the sulphur compounds is important. For examples of oils which thickened and changed in use, see Conradson, *J. Ind. & Eng. Chem.* p. 179, 1910, and Herschel, *Tech. Paper* No. 86 of the Bureau of Standards, p. 35-36.

The oils should be non-carbonizing when tested as for motor oils and should be free from undistilled residue. In practice the amount of oil in the circulating system should be ample to prevent any great increase in the temperature of the bulk of the oil. Sulphur and continued high temperature of the oil tend to develop acids which would attack the bearings and cause emulsification. The maximum working temperatures are ordinarily from 130° to 140° F., but according to Herschel some of the more recent turbines run at 175° F.

The oils used have from 120 to 400 viscosity at 100° F. The most important single test, after the viscosity test, is the emulsification test which gives a better indication of the behavior of the oil in use in a circulating system than can be obtained by any other physical or chemical tests. (See Emulsification test.)

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CHAPTER IX.

THE LUBRICATION OF STEAM RAILWAYS.

Locomotive Cylinders and Valves.—The cylinder oils are applied to the cylinders, valves and air compressor by means of a triple feed, and sometimes by a five-feed, sight-feed lubricator. The usual method is by means of a triple-feed lubricator feeding to the slide valves or steam chest on either side, and to the air compressor, the cylinder getting its lubrication more or less indirectly from the steam chest.

The conditions outlined in the previous chapter for cylinder oils for superheated and saturated steam apply also to the lubrication of locomotives. The opportunity for cooling of steam pipes and cylinders is much greater with a rapidly moving locomotive than with a stationary engine, particularly in winter, and so, with saturated steam at least, sufficient condensation is likely to occur to make the use of the minimum amounts of fatty oils inadvisable. Good locomotive cylinder oils contain from 7 to 12 per cent. of saponifiable or fatty oil so as to be reliable under all working conditions, the most usual amount being around 10 per cent. There are doubtless conditions for small, or poorly operated engines, where as much as 15 per cent. fatty oil will be needed, but this is the exception.

Saturated Steam Cylinders.—In saturated steam practice it is unnecessary to stress a high flash or fire test oil, as practically all oils have sufficiently high tests to meet all requirements, and unnecessarily high flash or high viscosity oil does not atomize with the steam quite so readily as does somewhat lower flash oil. It is usually a mistake to use oils of high viscosity for saturated steam locomotives, oils from 115 to 135 viscosity at 210° F. meeting all requirements for successful lubrication and low oil consumption. Cylinder oils, in order to feed properly, should be free from tar as shown by the gasoline test. A cold test of 50° or 60° F. is usually satisfactory. If western oil is used the gravity should not be seriously considered, as an effort to get a certain gravity oil would result in the sacrifice of some more vital property, for example, a lowering of the viscosity shown at 210° F.

It is customary to use the same oil for the cylinders and the air compressors. A high flash oil of the cylinder oil type is necessary for locomotive air compressors as they are air-cooled which permits compression temperatures of 500° F. or over.

Cylinder Deposits.—These may be caused by foaming in the boiler, as with excess of boiler compound or with certain waters containing much dissolved matter, in which cases the deposit will show much lime and magnesia, and sometimes iron oxide from muddy water. Scoring of the cylinders will be detected by metallic iron in the cylinder deposit as evidenced by a magnet. The oil may be to blame in certain rare cases, either by decomposing under the heat with carbon and asphalt formation, or by the breaking up of the fatty oils which yields corrosive fatty acids. The latter condition may result where the oil is compounded with fatty oil which is not "acidless" or where too large a percentage of fatty oil is used in compounding, the valves, etc., being pitted or corroded with the formation of much red iron oxide or rust.

With superheater locomotives, the practice of "drifting" or coasting with air admitted to the cylinders, particularly just after a hard pull, will result in actually burning up the oil and forming a carbonaceous residue. This leaves the cylinder and valves without lubrication after steam is re-admitted to the cylinder as some time is required to form a new film of the oil. Burning of the oil does not seem to take place much below 550° F. or in the presence of steam, so if the air is not introduced until a moment or two after the severe pull is ended, the oil is less likely to be destroyed. The introduction of the hot front end gases at any time is likely to consume the oil as well as introduce cinders and ashes which destroy the oil and form very undesirable deposits. During drifting, the low-pressure exhaust steam could be used to advantage in the superheated cylinders.

Superheated Steam Cylinders.—The pressures are not necessarily any greater than with saturated steam cylinders, but the temperatures are much higher, possibly as high as 600° or 700°

F. at times. Consequently a large percentage of the oil is finally vaporized. Much of it is vaporized by the superheated steam after atomization in the steam pipe, in which case the oil vapor seems to "lubricate" the steam and condense on the walls of the cylinder during the cooling of the steam in the cylinder. While a high flash test is desirable, an unduly high flash or fire test will prevent proper atomization and volatilization of sufficient oil to give the best results. Superheated steam is dry and has no lubricating value as wet steam has.

Cylinder oils for use in superheated locomotive cylinders should be able to stand a good heat, say 5 or 6 hours in an air bath at 500° to 550° F. without developing material insoluble in gasoline. When an engine can run 50 or 75 miles on a pint of valve oil, as in general practice, the quality of the oil is much more of a consideration than the price per gallon. Excessive amounts of oil are not desirable.

On account of superheated steam being dry, and on account of the greater adhesive properties of the high viscosity petroleum oils, very small amounts of fatty oils are really necessary. However, it is customary to use from 5 to 10 per cent. of fatty oil, usually the latter amount in order to meet the varied requirements of locomotive service. There are likely to be times when the cylinders work wet. It is also desirable to lubricate the low-pressure cylinders in compound locomotives with the waste oil brought over by the steam from the high-pressure cylinders. For the lubrication of these low-pressure cylinders, the same amount of fatty oil is necessary as for other saturated steam cylinders. The viscosity of superheater oils varies from 135 to 180 at 210° F. Saturated valve oils with viscosities of 135 to 140 at 210° F. will generally lubricate superheater valves and cylinders satisfactorily under normal conditions.

While the tendency is generally toward rather high pressures and a high degree of superheat in American locomotive practice, for example, 220-pounds pressure and 230° of superheat (equivalent to about 625° F. actual steam temperature), there are some types of locomotives using a low degree of superheat. These locomotives show only about 30° of superheat at the cylinder which is about enough to insure the steam being dry at the time it enters the cylinder, consequently the lubrication conditions are practically the same as for saturated steam cylinders.

American practice is toward heavier locomotives, and more exacting service conditions with longer trains and heavier cars. The increase of superheater locomotives from almost none to 30,000 in a total of 80,000 locomotives in the last ten years has rendered a more careful study of cylinder lubrication necessary.

Special Apparatus for Studying Cylinder Oils.—A valuable apparatus for studying the behavior of cylinder and valve oils with saturated and superheated steam has been devised by Dr. P. H. Conradson. For description of apparatus, method of operation, results obtained and discussion of results, see papers by Dr. Conradson in *J. Ind. & Eng. Chem.*, Vol. IV, pp. 744-745 (1912); *8th Int. Cong. of Appl. Chem.*, Vol. I, pp. 127-129, and Vol. XXVII, pp. 13-17; also address before the Cincinnati Railway Club, May, 1915.

This apparatus is essentially a small boiler equipped with gauges, superheater, thermometers, hydrostatic or sight-feed lubricator for feeding the oil when the steam has reached the desired temperature, a horizontal glass cylinder for observing the oil-steam mixture or for heating a weighed amount of oil in a dish, and a condenser for recovering the oil and steam. The steam rate is judged by the amount of condensed water.

The apparatus can be used with temperatures up to 1,000° F. which is 300° or 400° F. higher than required in the most exacting service conditions for superheater locomotives. Admission of air into the apparatus at 550° F. or higher shows the carbonization and destruction of oils which results from the practice of "drifting" or coasting with air admitted into hot steam cylinders.

Dr. Conradson says:

"It is interesting to note that cylinder oils containing rather a large percentage of saponifiable fats or fat oils generally come over at much lower temperatures than the main portions of the petroleum stock oils that are commonly used in compounding first-class cylinder oils.

"The cylinder oils may leave a residue in the dish at steam temperatures below 700° F.; if so, such residue should give a clear solution in 90 cc. of 0.65 specific gravity (87° Bé.) petroleum ether (Pennsylvania) and show no precipitate on standing. At steam temperatures of 850°-900° F., all the oil has usually been volatilized with the steam; good oils should leave no carbonaceous or coky residue."

The accompanying table of comparative tests of five samples of cylinder oils, A, B, C, D, E, and F, a petroleum distillate, is of particular interest in connection with the study of cylinder oils in superheated steam. (From *8th Int. Cong. App. Chem.*, XXVII, pp. 13-17, paper by Dr. Conradson.)

	A. Fahr.	B. Fahr.	C Fahr.	D. Fahr.	E. Fahr.	F. Fahr.
Flash point (open cup)	545°	550°	605°	595°	550°	365°
Burning point	610	630	695	680	630	415
Gravity at 60°F. Baumé	26.4	26.1	24.7	25.9	—	33.5
Sp. gr. at 15°C.	0.895	0.897	0.905	0.898	—	0.856
Color	Light	Dark	Dark	V. dark	—	Yellow
Gas. test bef. fire test	Good	Good	0.5 cc.	4.0 cc	—	—
Gas. test after fire test	Good	Good	Good	3.0 cc.	—	—
Cold test flows	+55°F.	+32°F.	+45°F.	+34°F.	+30°F.	Zero
Saponifiable fats	Trace	Trace	Trace	Trace	15%	None
Vis. Saybolt at 212° F. (60cc.)	133 sec.	146 sec.	215 sec.	216 sec.	—	—
Barbey ixomit 500° F. (180 units = 30cc.)	45 sec.	51 sec.	61 sec.	60 sec.	—	—
Hot air test at 540° F. (loss)	15%	11%	2.5%	5.5%	—	—
Gas test after	Good	Good	0.5 cc.	3.5 cc.	—	—
Carbon test residue	2.51%	2.70%	4.90%	5.10%	—	—
SO_3 in residue	0.023%	0.03%	0.03%	0.04%	—	—
Loss super. steam 400°F.	0.0%	0.0%	0.c%	0.0%	0.0%	32%
Loss super. steam 500°F.	5.0	4.0	1.5	1.0	5.0	67
Loss super. steam 600°F.	18.5	18.0	6.5	8.5	21.5	—
Loss super. steam 700°F.	44.0	34 0	32.5	40.5	—	—
Total loss up to 700°F.	67.5	56.5	40.5	50.0	—	—
Gas. test of oil residue from 700° test	Good	Good	1.5 cc.	3.0 cc.	—	—

"Hot Air Test: 13 grams of oil in shallow, round, flat-bottom iron dishes exposed 6 hours at 540° F. in a specially designed air bath.

"Gasoline Test: 10 cc. oil, 90 cc. petroleum ether 0.65 sp. gr. (from Pennsylvania crude) in graduated flat precipitating tubes, taking reading after 1 hour's standing.

"Carbon test using 35 grams oil according to Conradson's apparatus and method.

"Superheated Steam Test: 13 grams of oil used.

"Sample 'A' in a superheated steam test at 800° F. (427° C.) left no residue. Sample 'C' left 2.5 per cent. dry carbonaceous residue.

"Sample 'E' containing 15 per cent. of saponifiable fats subjected to the superheated steam test lost 26.5 per cent. up to 600° F.; the oil residue from this test contained 17.5 per cent. saponifiable fats. This indicates that the petroleum oil stock (B used) goes off with the steam somewhat faster in proportion to the fat oil up to 600° F. (350° C.).

"The steam pressures used in these tests were about 10 to 12 pounds per square inch. A large volume of superheated steam passed through the apparatus during the tests (about 40 cc. condensed steam per minute).

"In these superheated steam evaporating tests about 13 grams of oil were weighed into the small dish placed inside the steam vessel D. (The capacity of the small iron dish is 50 cc. having a diameter of about 48 mm. and 30 mm. high, with flat bottom.)

"The steam vessel with the oil in the dish was heated up to about 350° F. (176° C.), passing a slow current of natural gas through the apparatus, then superheated steam was admitted, the gas shut off, and the temperature raised up to the required degree and kept constant for about 75 minutes; the volatile matter in the oils at the given test temperature generally were carried over with the steam inside of 60 minutes, allowing about 15 minutes extra steaming. At the end of each given temperature test the steam and heat were shut off; after cooling, the dish containing the oil was weighed and replaced into the steam vessel and the operation repeated for the next temperature test and so on."

For a critical study of conditions to be met in superheated practice see papers by C. D. Young on "Locomotive Superheaters and their Performance" in the *J. of the Franklin Inst.*, July, 1914, pp. 1-83, and Aug., 1914, pp. 181-194, and Prof. Goss's investigations on "Superheated Steam in Locomotive Service," published by the Carnegie Institute; Washington, D. C., in 1910.

It is interesting to note that the German railways use oils of 110 to 185 Saybolt viscosity at 210° F. for saturated steam. These oils have a gravity of 18° to 28° Bé., a flash point of 540° F. or over (open cup) and contain from no fatty acids up to

10 per cent. For superheater locomotives, oils of the following characteristics are used: Saybolt viscosity 180 to 300 at 210° F., gravity 17° to 27° Bé., flash point around 600° F. (open cup), fatty oil content 0 to 10 per cent. (Cf. Holde, Exam. of Hydrocarbon Oils, Eng. Ed., pp. 182-183). The superheaters used have higher degrees of superheat than those used in this country until comparatively recently. The crude petroleums used may be very different from the Pennsylvania oils and stocks used in this country, although much of the oil has been imported from the United States.

For actual specifications of locomotive cylinder oils see Index.

Locomotive Journals.—The journals of most locomotives are now equipped with "cellars" below the driving axle to feed grease to the journal. A large amount of grease, from 80 to 125 pounds, is required to pack an engine completely, most of it being required for the journals of the driving axles. The hard grease is packed into the removable cellar so that the cellar is filled completely and the upper part of the grease is beaten into shape to fit the axle. The cellar is then fastened below the axle. A strong spring pushes up a false bottom in the cellar and so keeps the grease pressed against the lower side of the axle. Owing to the spring pressure and the friction of the warm, moving axle, the grease wears off from the top to fit the axle.

On account of the strong spring pressure in the cellars and the great pressures on the journals, the grease must be exceedingly hard to give good results in service. It is customary to use a grease made from a heavy oil and a large percentage of soda soap, with some water and an excess of caustic. A grease containing too much water, or insufficient soaps would feed too freely to be economical in use, necessitating delays for frequent repacking. With a single packing an engine should make a large number of trips as the springs are arranged to feed most of the grease from the cellar with a little attention occasionally. Greases containing suitable solid lubricants, as graphite or mica, have been found to give good results in practice.

The pressures on locomotive journals are enormous on account of the immense weight required to secure the necessary tractive effort to move trains of 60 to 100 modern cars, some of 90 tons capacity, or a train of 1,200 tons or more. Also on account of the gauge of American railroads the journals must be made shorter than would be considered good practice for the same total pressures in other bearings. When it is considered that the pressures may amount to over 1,200 pounds per square inch, the difficulties of lubricating a large journal on a fast-moving through train, freight or passenger, with its attendant high temperatures from friction and boiler heating, are readily apparent.

To meet these abnormal conditions, the journals are well fitted with suitable bearing metal which soon adjusts itself so that the fit is perfect, making a bearing ideal for lubrication. The bearings normally work at a temperature of 130° to 150° F. as at least this much heat is required to cause the heavy grease to soften sufficiently to lubricate.

The waste grease from the locomotive journals is usually taken out before repacking the cellars. This grease is trimmed to remove any adhering grit or impurities, and is used for packing cellars on branch lines or on switch or yard engines, either directly or after heating and straining to further purify the used grease.

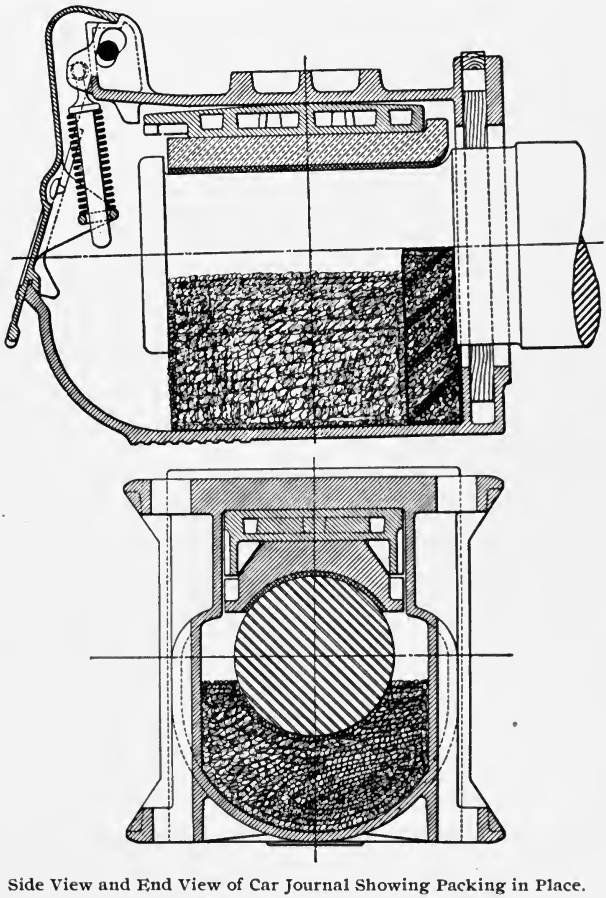
Many smaller engines have not been fitted with cellars for using journal grease or journal compound, and for these a suitable cylinder stock is required. Cylinder oil could be used but is not necessary as it is more expensive. A cylinder stock of 160 to 220 at 210° F. usually answers all requirements.

Crank Pins.—For lubricating the pins on driving wheels, a grease somewhat like journal grease is required, although a grease of somewhat lower soap content and a little lighter oil may be used satisfactorily. The grease is forced into a small (2-inch) cylindrical grease cup in the driving shaft, and a screw which just fits this opening is screwed in until it presses on the grease sufficiently hard to force grease into the bearing below. As the bearing warms up soon after starting, the grease begins to soften a little and lubricate the driving pins. If the grease is too soft, or of too low melting point, or if the operating conditions get too severe from any cause, the grease will all melt out. Also if the heat from the pins gets higher than 212° F. the water in the pin grease will vaporize and force out all the grease. It then becomes necessary to cool the engine somewhat, as the addition of more grease would have a similar result. Normally, as the grease is used up, the screw is given another turn, as in a compression cup, to force the grease down to the pins.

A hard grease is required as the pressures are exceedingly high, up to 3,000 pounds per square inch at starting. The lubricating conditions are favorable as the pressure is intermittent, first on one side of the pin, then on the other, so that the grease has an opportunity to get in between the rubbing surfaces.

General Engine Lubrication.—For general lubrication about the engine and tender a good engine oil of 220 to 270 viscosity at 100° F. gives good results. Some roads use regular car oil for the tender, or even for the locomotive, but the latter is hardly good practice. Systematic, frequent oiling, as is generally practiced is important. It is better to use small amounts of oil frequently than to flood the bearings at infrequent intervals.

Car Journals.—The great difficulty in the lubrication of car journals is not in getting an oil thick enough, but in getting an oil that will feed to the journal properly under the working conditions. In an ordinary bearing the pressure is on the lower side of the journal and so oil will feed by gravity to the point where it is needed. With car journals, the friction and pressure surface is on top of the axle, and the journal is equipped with a box to be packed with oil-soaked cotton waste. This waste should be frequently inspected, and loosened up or repacked, so that it presses against the moving axle, else there is no way for the oil to get to the friction surface of the journal. Many journals are cut with suitable grooves to hold some oil, but this does not take the place of careful packing and regular inspection. One journal not properly lubricated may heat sufficiently to do serious damage to the car and its content, or to delay the whole train. The present high state of railway car lubrication has only been attained by rigid inspection of all cars before and at frequent intervals during the run. Well fitted journals are also the rule which has made possible exceedingly low lubricating costs per car mile.



Side View and End View of Car Journal Showing Packing in Place.
(By courtesy of McCord & Co., Chicago.)

In preparing waste for use in the journal boxes, it should be soaked for several days and then squeezed slightly so as not to drip, or allowed to drain well. It is then packed into the box loosely except the part next to the inner end of the box which is well packed. The waste should come up against the lower half of the journal. The waste acts as a wick to feed the oil to the moving axle which carries it to the bearing.

Car journals are also equipped with lubricating pads instead of waste, or even with mechanical force-feed lubricators. A thinner oil can be fed with these devices.

Car Oils.—Car oils, well oils, black oils, or reduced oils, are the still residues from crudes which were originally unsuitable, or have been rendered unsuitable by the method of treatment, for use as cylinder stocks. Usually only the gasolines, kerosene and other light oils have been removed. Car oils have ordinarily never been distilled. The winter car oils are made by removing less of the lighter oils, or by cutting back the summer grade of car oil with some light distillate.

The following analyses of car oils were made by the author:

Sample No.	1.	2.	3.	4.	5.
	Summer car oil	Summer car oil	Winter car oil	Winter black oil	Black engine oil
Gravity (°Bé.)	21.4	20.0	25.7	27.4	24.0
Viscosity at 210°F.	80	95	65	66	61
Flash point (°F.)	—	400	375	—	—
Sediment	—	V. dirty and tarry	Little sed.	Black sed.	Black sed.

The viscosity of winter black oil is high enough for summer use, so far as actual lubrication of the journal and bearing is concerned, but a higher viscosity oil is required in summer so as to feed properly by means of the waste. The friction loss is greater with the heavier oil than it would be with the lighter winter oil.

It has been customary to specify the viscosity of car oils at 130° F. instead of at 210° F., but the tendency is to depend more on the figures at 210° F.

The cold test of summer oil is not important, but the cold test of winter oil should not exceed 10° F. except for southern climates. Tarry matter should not exceed 5 per cent. by the gasoline test. This includes all sediment. The gravity is not important as the cost is an important consideration and specifying gravity would probably make it necessary for some roads to go to distant fields to meet the specification. The viscosity for winter oil should be between 60 and 65 at 210° F., and for summer oil 80 to 100 at 210° F. The flash point should be above 250° F. in winter for northern climates and over 325° in summer; for southern climates the flash point might advantageously be 50° higher in each instance.

Freight cars do not stay on one road long, so it is not so much to the interest of the railway company to furnish a high-grade expensive oil. Most roads use about the same grade of oil and standard methods of packing.

Passenger coaches usually stay on the owner's lines, and are lubricated either with black oil, or oil of a somewhat better grade, or with an oil made by blending cylinder stock with black car oil.

Shop Oil.—For air-cooled compressors use a high grade cylinder stock, for water-cooled compressors use a regular air compressor oil (see Index).

For engine lubrication use a good cylinder oil of 115 to 135 viscosity as for saturated steam locomotives. Not over 10 per cent. of fatty oil is usually required.

Oil Supplies.—Most American railroads are lubricated on a car-mile and engine-mile basis. Since the railroad companies have to keep a close account of the supplies issued under these contracts, and the amounts of such supplies which can be issued are rigidly restricted, engineers are at times in real need of extra oil or grease for their engines. It is not uncommon for this to result in losses of thousands of dollars in upkeep of engines without any corresponding saving in lubricant. It ought to be to the advantage of roads not to be too strict with engineers in regard to the amount of valve oil and other lubricant issued to them. Such a condition as is often present on many railroads would not be tolerated if the purchaser of oil supplies was the person responsible for the cost of up-keep of engines. It is not unusual for over 10 per cent. of the engines to be constantly in the shops for repairs.

Oil supplies should be kept clean, both in the store-room and in the hands of the operating engineers. The custom of keeping the cylinder oil in the tallow pot warm before using in the lubricator no doubt serves to settle out anything which might choke the lubricator. Highly filtered oils are not usually required for steam cylinder lubrication.

ADDITIONAL REFERENCES.

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CHAPTER X.

THE LUBRICATION OF COTTON MILLS AND OTHER TEXTILE MILLS.

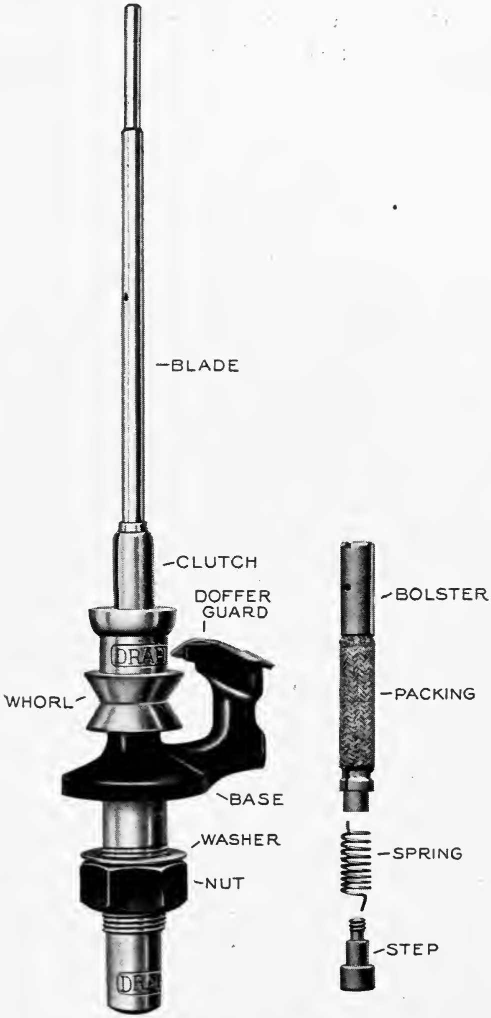
Cotton mills, in common with other plants having a large number of quick-moving machines, require the use of oils with as low viscosity as is consistent with minimum wear, otherwise the preventable power losses may be enormous.

The total cost of lubricants used in a large mill is not burdensome, but the preventable losses through the use of improperly selected lubricants may easily amount to many times the sum paid for the lubricants. A mill with 60,000 submerged spindles operated at 11,000 revolutions per minute requires 1,000 net horsepower for the spindles. A mill using spindles of the same type at 7,000 revolutions per minute requires barely half as much power for the same number of spindles. A saving in power consumption of 10 per cent., or of 20 per cent. as is sometimes possible, amounts to a considerable sum at $20.00 per horse-power-year.

The bulk of the preventable power losses in cotton mills, so far as lubrication is concerned, is connected with the more scientific lubrication of spindles, looms and shafting.

Spindle Lubrication.—An oil of just the proper viscosity is more necessary for spindles than it is for any other class of machinery. The light weight, the speed, the special design and the smooth construction of the spindle make possible the use of a very thin oil. The faster the spindle the more fluid the oil should be.

Spindles will normally run from 10° to 15° F. above the room temperature. This increased temperature does not indicate wear, for the substitution of a thinner oil would in many cases result in a temperature only 6° or 7° above room temperature, showing a power saving with the thin oil. A thicker or more viscous oil would ordinarily give a higher temperature with a correspondingly higher power consumption per spindle. The most satisfactory spindle lubrication usually accompanies the smallest temperature rise. A 5-degree reduction in the temperature of the



A Modern Ring Spindle.
(By courtesy of the Draper Corporation, Hopedale, Mass.)

spindle by a change of oil may be equivalent to a saving of over 10 per cent. of the power required to operate the spindle. The extra power has been consumed in stirring the oil, the lost power being turned into heat.

Spindle oils must have sufficient viscosity, or body, to keep the bearings apart under all reasonable conditions and so prevent wear; but with such high speeds less viscosity is required to keep the bearings of light spindles apart than is generally supposed.

Spindle oils are usually pure mineral oil distillates which have been rendered nearly colorless by filtering through fuller's earth or boneblack. They should be free from mineral acid and from tarry or gummy matter, and they should usually have a flash test over 300° F. in order to reduce the fire hazard. As a further indication of their safety so far as starting fires or spreading fires otherwise started is concerned, the low-flash spindle oils should not show over 4 per cent. evaporation in 8 hours at 150° F. The viscosity should be as low as is consistent with a safe flash point and with the prevention of wear.

The analyses of some typical spindle oils now used in cotton mills are given below:

	Submerged spindle oil	Light spindle oil No. 1	Light spindle oil No. 2	Regular spindle oil	Heavy spindle oil	Special heavy spindle oil (?)
Baumé gravity at 60° F.	33.8	33.0	32 6	34.1	32.6	27.0
Flash test (° F.)	275	275	285	325	345	355
Fire test (° F.)	320	320	325	380	390	395
Viscosity at 70° F.	61	68	74	101	174	202
" " 100° F.	46	49	53	64	93	104
" " 120° F.	41	43	45	52	68	75

These samples gave a Maumené number of 3 or 4, showing pure mineral oils unmixed with animal or vegetable oils. The submerged spindle oil lost 3.1 per cent. in 8 hours at 150° F., and 21 per cent. in 6 hours at 210° F. It showed a loss of 1.7 per cent. in 24 hours at 70° F. The light spindle oil No. 2 showed a loss of 2.7 per cent. in 8 hours at 150° F. These figures showing evaporation loss may be taken as indicating in a general way present day practice so far as safety is concerned, but these figures should be taken as approximating the maximum permissible loss for the conditions under which spindle oils are used. It is hardly practicable for the oil manufacturer to furnish an oil of much lower viscosity than the thinner oils given above, without at the same time lowering the flash point unduly or increasing the evaporation loss to a point inconsistent with adequate safety from a fire standpoint.

The cold test of spindle oils should not exceed 15° F., but this is a condition easily met.

The Lubrication of Special Spindles.—For the lubrication of heavy spindles, such as mule spindles or twister spindles, more viscous oils are necessary than for the lighter ring spindles. The lubrication of mule spindles would generally be done by means of such oils as the light spindle oils and the regular spindle oils shown above, but much depends on the weight and speed of the spindle, heavy spindles requiring the heavier oil and the higher speed spindles requiring the lighter oils.

Twister spindles require light or medium oils of 125 to 220 viscosity at 100° F., an oil of 150 to 175 viscosity being suitable in most cases. Such oils will usually show from 26° to 28° Bé. gravity (very expensive oils may show 31° Bé. gravity) and a flash point of 370° to 420° F.

It might be well to mention at this point, in connection with saving power through correct lubrication, that considerable excess power may be required to operate the spindle when the band pull is greater than necessary. It is as important that all bearings and moving parts be correctly fitted and adjusted as that a suitable oil be used. Spindles should be oiled regularly, every two weeks at most, and should be cleaned as often as regular inspection indicates may be required. Gummy material, if present, may be removed by rinsing with kerosene.

Stainless Oils.—The so-called "stainless oils" are alleged to be more readily removed from the fabric, or to be less objectionable than the heavier spindle oils. There are no absolutely stainless straight mineral oils as the complete removal of these oils from the fabric is impracticable, particularly if the spot is not removed at once. The best method of removal is to treat the oil spot with olive oil or other fixed oil, let soak in and then scour with caustic soda solution or with soda ash.

The true stainless oils are altogether or largely (50 per cent. or over) animal or vegetable oils. Various mixtures of these have been used, such as sperm oil, lard oil, olive oil, cottonseed oil, neatsfoot oil, etc., alone or in mixtures. These oils are often used in lace mills or mills producing fine fabrics where the value of the manufactured product is sufficient to stand the added cost. Spots from such oils can usually be removed completely by treatment with suitable alkali solutions.

It is generally recognized as the best practice to take the necessary precautions to prevent the formation of oil spots on the cloth so that the difficulties connected with the removal of oil spots is largely obviated.

Sewing Machine Oils.—In general, the same type of neutral, paraffin or "stainless oils" are used as given for spindles. Some mills add up to 20 per cent. of sperm oil or other fixed oil to the mineral spindle oil. The viscosity generally ranges from about 50 to nearly 100 Saybolt at 100° F., the heavier oil being used for heavy sewing machines.

Loom Oils.—Owing to the character of work done by looms and the different types of looms, a large range in viscosity is necessary to meet the different requirements. The oils used are generally of the engine oil type, and range from heavy spindle oils for the light looms to heavy engine oils for the heavy looms. The viscosities range from about 100 to 225 or over. The analyses of some loom oils are as follows:

Sample No.	1	2	3	4	5	6	7	8
Baumé gravity	26.5	27.3	20.6	24.2	30.6	31.0	25.5	20.1
Flash test (°F.)	370	370	320	410	385	415	415	330
Fire test (°F.)	425	430	—	450	425	470	—	—
Viscosity at 70°F.	246	209	413	543	398	350	495	481
" " 100°F.	126	102	165	221	176	160	196	196
" " 120°F.	86	72	103	136	115	108	124	118

The oils are straight mineral oils as shown by the Maumené test, the Maumené number ranging from 4 to 6. Oils of the type of the first four are most generally used.

Oils like No. 4 and No. 5 are suitable for looms in woolen mills, but the lighter oils are generally preferred.

Neatsfoot oil, lard oil or olive oil, either alone or compounded with mineral oils, is often used for lace machines.

The cold test of loom oils should generally be below 20° F.

General Mill Lubrication.—In order to avoid mistakes in the use of oils, the number of oils used in the mill should be reduced to a minimum. A spindle oil, a medium or heavy loom oil, a very heavy engine oil for lubricating shafting and for general heavy lubrication, a steam cylinder oil, and a turbine oil should be ample for most practical conditions. The whole scheme of lubrication should be planned so as to have oils of the proper type and proper viscosity to meet the actual conditions in the mill and then each oil should be used for lubricating in its own special field. It is of real importance that the oiling be in charge of one man whose sole or principal duty is to see that all machinery under his care is regularly and systematically oiled and cleaned as often as necessary. This is the most certain way to reduce the number of mistakes, and to save oil and machinery. By such a procedure it is not necessary to flood the bearings and so waste the oil.

Spoolers, speeders, pickers, rolls on the spinning frames, twister spindles, and miscellaneous machinery other than shafting can usually be lubricated satisfactorily with the medium or heavy loom oil used for the looms in the mill. In special cases, some of this machinery may need a heavier oil in which case the engine oil used on shafting can be used, but it is preferable to use the lighter loom oil on the faster machinery wherever practicable.

Oils used with success on the various classes of machinery have viscosities as follows:

Spoolers	180–220	Saybolt viscosity at 100° F.
Speeders	160–220	" " " "
Pickers	110–220	" " " "
Combs	160–220	" " " "
Cards	160–220	" " " "
Beaters	175–220	" " " "

Shafting Lubrication.—For shafting a very heavy engine oil is necessary. Oils with a viscosity of 220 to 290 are suitable. Generally oils from 220 to 250 can be used with satisfactory results. Oils have been used with a viscosity as low as 140 at 100° F., but this is not to be recommended.

In order to prevent constant loss of power it is necessary that all shafting be aligned properly and lubricated thoroughly. The same oil can be used for shafting and for general engine lubrication, such as bearings, slides, etc., but not for steam cylinder lubrication.

Cylinder Oils.—Cylinder oils are compounded from cylinder stocks and varying amounts of fixed oils, such as tallow oils or neatsfoot oil. The Pennsylvania stocks are preferable, cylinder oils from such stocks rarely being below 24° Bé. If oils other than Pennsylvania oils are used, the gravity should not be considered at all. The important property of a cylinder oil is the viscosity at 210° F. Light cylinder oils, for low-pressure engines, can be used with a viscosity as low as 100 at 210° F., but it is usually inadvisable to use an oil having a viscosity below 120. For high-pressure cylinders the oils should have a viscosity of 140 to 220 at 210° F. Low-pressure cylinder oils should be compounded with at least 4 per cent. of tallow oil or other fixed oil, and high-pressure cylinder oils should have 6 to 10 per cent. or more of fixed oils. When cylinders work very wet, more fatty oil is required. The flash test is always above 500° F. for Pennsylvania cylinder oils of the required viscosity.

Other uses of cylinder oils in cotton mills are for very heavy bearings, such as water wheels, on certain heavy winders and for application to overheated bearings, especially heavy engine bearings, in an emergency.

The bearings and slides of an engine can usually be lubricated with an engine oil of 160 to 220 viscosity at 100° F.

Turbine Lubrication.—For use on turbines as thin an oil as possible should be selected. Turbines normally work at 130° F. and above, so the viscosity of the oil given at 100° F. is higher than actually present under working conditions. Well-filtered, pale Pennsylvania oils of high gravity and low viscosity are preferred as they separate from water more readily and completely. An oil which emulsifies with water is unsuitable for turbine lubrication. Satisfactory turbine oils should usually have a gravity above 30° Bé., a flash point of 400° F., and a viscosity from 125 to 160 at 100° F. Some turbines may require heavier oils, but this is seldom the case in cotton mill practice, as the engines work at high speeds. The use of turbines for cotton mills is increasing. For a further discussion of turbine oils and the emulsification test, see Index.

Dynamo Oil.—Oils for dynamos and electric motors should be high-grade engine oils, preferably above 30° Bé., flash 400° F. or above, and viscosity from 120 to 200 at 100° F., depending on horse-power developed. Light electric motors, below 15 horse-power, can be lubricated with a good medium loom oil or even with a heavy spindle oil.

Lubricating Greases.—Cotton mills use greases ranging from the soft, pasty "non-fluid" oils to grease of No. 3 body.

The non-fluid oils and the very soft greases are often used for lubricating looms and cards where the tendency of an oil to splash would be undesirable. Such greases are made by compounding certain heavy metal soaps with light mineral oils. The pasty character of the oil or grease also prevents too rapid consumption and consequent waste of the lubricant. The soft "comb-box" greases are finding many uses in cotton mills, for lubricating top rolls, drawing frames, speeders, spinning frames, comb-boxes on cards, loom cams, etc.

The heavier grades of this pasty type of grease are also employed in rod cups where the copper rod serves to heat up and melt the grease so as to feed to the bearing as needed. While this cuts down the amount of lubricant consumed, a loss of power may easily result from deficient lubrication if the grease is not very easily melted. The fact that these greases are widely used indicates that they have real value in preventing undesirable oil-splashing and in reducing the amount of damaged fabrics.

The regular cup greases of No. 3 body are used on certain heavy, closed bearings, such as for beaters and cards. All of the above greases contain light, paraffin oils. The greases containing heavy oils, similar to the greases used for heavy automobile transmission, apparently are seldom used. Graphite and mica greases find a more or less limited use for heavy work.

The Lubrication of Knitting Mills.—Ordinarily about two grades of oil are sufficient. For the small running parts a spindle oil of not over 100 viscosity is suitable. For the heavier needle plates a paraffin or neutral oil of 140 to 180 viscosity usually proves satisfactory. These two oils should usually serve for lubricating a mill operated by small electric motors, the spindle oil being suitable for lubricating small motors with ring bearings and the heavier oil (engine oil) could be used with satisfactory results on the larger electric motors.

CHAPTER XI.

THE LUBRICATION OF MISCELLANEOUS PLANTS AND MACHINES.

A. FLOUR MILLING MACHINERY.

The heavy rolls in the grinding machines revolve at high speeds and are subjected to grinding friction and grinding pressure throughout their whole length. Consequently the bearings always run warm which greatly increases the tendency to squeeze out the oil. It is, therefore, usual to lubricate the bearings of the rolls with a very heavy engine oil of 220 to 260 viscosity at 100° F. Some operators prefer to use an extra heavy mineral castor oil which seems to give ample lubrication while at the same time resisting the tendency to squeeze out of the bearings. Where rod cups have been tried the bearings seem to run hotter than where oil is used, as the increased temperature is required to make the grease flow regularly. Only soft greases should be used where the bearings are equipped with cups for grease lubrication. Generally a No. 3 grease is much too solid for this use.

The light rollers and smaller bearings are lubricated with mineral castor oil or with a light engine oil of 160 to 180 viscosity. All the rolls should be systematically oiled daily by a regular, competent oiler who is not burdened with too many other duties.

Certain small inner rollers whose bearings are in contact with the flour are lubricated perfectly without the addition of any lubricant besides the flour.

The large amount of heavy shafting requires special attention. A very heavy engine oil of 220 to 275 viscosity is required.

For the lubrication of a modern flour mill, only a very few oils are required. Besides the steam cylinder oils, there is usually needed a light engine oil of 140 to 180 viscosity for light machinery, such as fans, motors, small rolls, etc., a mineral castor oil for the grinding rolls, and a heavy engine oil of about 250 viscosity for the shafting and for general engine lubrication. On account of the large amount of dust, bearings should be inspected and cleaned regularly.

The bearings of conveyer-carriers are lubricated with a heavy engine oil of 225 to 270 viscosity.

For the lubrication of high- and low-pressure steam cylinders see Index. General engine lubrication can be had with a heavy engine oil.

In all cups where greases are to be used, whether light cup greases or heavier gear greases are employed, better lubrication can usually be had by using the softer grades of grease.

The large number of expensive belts of large size render careful attention to their condition necessary in order to prevent deterioration. By using comparatively large pulleys and oiling with suitable oils, such as vegetable castor oil, so as to keep the belts pliable and cause them to cling to the pulleys properly, satisfactory service can be had for 30 to 50 years or even longer.

B. COTTON OIL MILLS.

For all rod cups, a soft semi-grease is used. This pasty grease shows a big saving in amount of lubricant required as compared to oil, but the cost of the grease is on a somewhat higher basis than the oil. Although the bearings run warmer than with oil, the lubrication seems to be satisfactory. This grease should have a sufficiently low melting point in order to feed freely when needed. On account of the large amount of dust and lint all cups and bearings should be regularly inspected and cleaned to insure proper lubrication. Cups should be kept covered.

For general lubrication, not many oils are necessary. A heavy red engine oil of 220 to 270 viscosity at 100° F. is suitable for general lubrication of shafting, delinters, hullers, crushers and separators. In some of the heavier bearings, as on the crusher rolls, a heavy mineral castor oil would doubtless give good results over either engine oil or grease since it would not be readily squeezed out of the rolls. The bearings on the crusher are often lubricated solely by means of crude cottonseed oil.

For some of the lighter bearings, as for conveyors, etc., a medium engine oil of 160 to 180 viscosity is used.

Belts should be kept pliable by the regular use of limited amounts of vegetable castor oil or some high-grade belt oil. Excessive use of sticky belt preparations would catch an unnecessary amount of lint.

For engine lubrication, use the heavy engine oil above for the moving parts. For the cylinders, use a good cylinder oil made from a steam refined cylinder stock and 6 to 8 per cent. of acidless tallow. The finished oil should have a viscosity of 105 to 140 at 210° F., the lower viscosity being necessary for low-pressure cylinders where force-feed lubricators are not available and the higher viscosity oil being required for high-pressure cylinders.

For electric-motor lubrication see Index.

Hydraulic presses may be lubricated solely by means of crude cottonseed oil, by means of graphite or by the use of soapy water. The presence of mineral oil aids in preventing rusting of the valves. Air compressors are lubricated with a light, high-flash oil (see below).

C. ROLLING MILLS.

Hot Neck Rolls.—The conditions to be met for the successful lubrication of the large bearings or necks of rolls are enormous pressures suddenly applied, sudden stoppage and sudden reversal of the rolls, and very high temperatures of the necks due to the heating of the rolls by contact with the heated metal which is being rolled. On account of the large size of the "necks" the friction speeds are very high. The ends of the rolls are usually housed so as to protect them from dust, etc.

For the lubrication of these rolls a heavy grease of high melting point is necessary. The most generally used greases are made from heavy petroleum residuum either alone or combined with heavy tar or heavy pitches. The pitches used are mineral pitches, coal tar pitch, stearin pitch and wool pitch. The heavy tars are coal tar, pine tar, etc. The heavy petroleum oils, such as are present, in good residuum, have high adhesive properties. The addition of suitable pitches or tar increases the adhesive properties of the grease. This is very necessary on account of the high temperatures and the high pressures. The adhesive properties are greatly reduced by the presence of small amounts of water in the grease. The grease must maintain a high viscosity at temperatures of 600° or 700° F. without vaporizing or decomposing readily.

Hot neck greases are sometimes thickened with rosin, or with solid materials like talc, lime, mica and graphite. All of these greases must be melted before swabbing on the rolls, otherwise they are too heavy for easy application. Sometimes the greases are heated in a bucket and then dipped out and poured into the housing of the bearing. Used grease can be melted to free it from grit and can then be re-used.

Soap products, particularly products high in soda soaps, such as extra heavy gear greases, could be used successfully and would doubtless be used more extensively were it not for their higher cost. These greases should also be free from any water.

Cold Neck Grease.—This grease is used on the neck of rolls which are kept cool by running water. Firm greases containing soda soaps are suitable, but light tarry compounds, or pinions greases, are more often used on account of the lower cost. Sometimes heavy oils are used combined with rosin, tallow or waxes, These make greases of low melting point compared to the other greases. Suitable grades of residuum can be used without the addition of other substances.

Roll Gears.—The driving gears of rolls can be lubricated with a medium grade of light cylinder stock (105 to 140 viscosity at 210° F.) or with light residuum. The more usual practice is to use a light pinion grease, containing tar and residuum, or a dark gear grease or "dope." This is swabbed on the open gears, and should be stringy and adherent enough to cling to the gears without being squeezed off.

Cylinder Oils.—For the steam engines, unless of very high pressure, an oil of 105 to 135 viscosity at 210° F. will usually answer all purposes. Such an oil should be made from a steam refined cylinder stock free from tarry matter and should contain from 5 to 15 per cent. of tallow oil or other fixed oil. Not over 10 per cent. of fixed oil is required unless the cylinders work very wet. These low viscosity oils will generally lubricate the yard locomotives satisfactorily. For high-pressure engines, or engines using superheated steam, oils of 140 to 180 viscosity at 210° F. should be used.

Yard Cars and Locomotives.—For cylinder oils, see above. For the locomotive journals and pins, a solid soap product containing heavy oils should be used. Ordinary grades of grease will not be satisfactory on account of the lack of resistance to the pressure springs under the journal boxes. Where the locomotives are not fitted with journal boxes for grease lubrication, a good cylinder stock of 140 to 180 viscosity at 210° F. is generally used.

The cars used in the plant and in the yard are usually lubricated with black oil or car oil. This oil should have a viscosity of over 60 at 210° F. for winter use, and a satisfactory cold test. For summer use, the oil should have a viscosity of 75 to 90 at 210° F., and should be free from excessive amounts of tarry deposit. The packing should be regularly inspected and kept in place so that the journal is actually reached by the oil. Sometimes a thin black grease or "dope" is used to lubricate the car journals.

General Lubrication.—For the lighter, faster work a good light cylinder stock of 100 to 125 viscosity at 210° F. will answer. If a cheaper oil is required, the above black car oil can be used. Various grades of thin gear greases and thin pinion greases are also available for this work.

For general engine lubrication, a heavy engine oil of 210 to 270 viscosity at 100° F. is satisfactory.

Compression cups, on cranes, etc., are usually lubricated with a medium, No. 3, cup grease.

Chain and cable greases often contain graphite, mica or talc, combined with petroleum oils and certain solidifying substances such as fats, wax, rosin, pitch, tar, and soaps.

D. MISCELLANEOUS.

Air Compressors.—On account of the great increase in temperature when air is strongly compressed, it is usual to compress in two or more stages with intermediate cooling. If no radiation or cooling took place, air taken at 60° F. and compressed under

50 pounds pressure would have a temperature of 339° F. Similarly, under 100 pounds pressure the temperature would be 485° F. and under 150 pounds the temperature would be 580° F. But as cooling always occurs the real temperatures run considerably lower.

On account of the high temperature, carbonization tends to take place as in motor oils, therefore, compressor oils should be tested for tendency to carbonize, or for sulphur which seems to influence the amount of carbonization. For safety the oil should have a flash point well above 400° F. Only straight mineral oil distillates of low cold test and high gravity (above 30° Bé.) should be used. A low viscosity oil is generally preferred, from 160 to 200 for average pressures and 200 to 250 for high pressures. A simple test for comparing these oils is the amount of darkening or deposit (insoluble in gasoline) formed on heating to the flash point for several hours. There should not be much darkening or deposit. (See Heat Test.)

If the oil is too thick it adheres to the valves where it carbonizes from the dry heat. It is important to use the minimum amount of oil and to use clean air. Low flash oils have caused a number of explosions, so the oils might very well be tested for amount of loss under heat.

Soapy water mixed with flake graphite is said to give good lubrication without causing sticking of valves, but it is necessary to feed oil just before shutting down in order to avoid rusting.

For air-cooled compressors, as on street cars and locomotives the temperatures get very high (up to 450° F. for street cars and 550° F. for electric locomotives according to Conradson). For such compressors it is necessary to use cylinder stocks, or cylinder oils.

(Cf. W. H. Callan: "Lubrication of Air Compressors," *Power*, 48, p. 229, 1918; also "Lubrication of Air Compressor Cylinders," *Power*, 47, p. 417, 1918; and H. V. Conrad: "Lubrication of Air Compressors," *Eng. & Min. J.*, 107, pp. 392-4, 1919; or *Text. Wld. J.*, 55, p. 79, 1919.)

Compressed Air Machinery.—Pneumatic tools such as drills, etc., operated by compressed air require oils of very low cold test on account of the drop in temperature of the expanding air. The cold test should be below 10° F., the gravity above 30° Bé., and the viscosity should be low as determined at 100° F.

Mine and Quarry Machinery.—For the journals of cars, summer black oil of 85 viscosity at 210° F., or winter black oil of 65 viscosity at 210° F. are generally used. The journals should be kept properly packed, should be inspected and cleaned regularly and should be protected from all gritty material as much as possible. Cheap, thin greases, called "black dope," are used to some extent for car journals.

For the lubrication of air compressors, electric motors, steam cylinders and small locomotives, see Index. Pneumatic drills and other similar tools can be lubricated with a high-grade engine oil of 180 to 260 viscosity at 100° F. The oil should have a low cold test and the wearing parts should be kept clean and free from grit.

Hoisting ropes (metal) are lubricated with coal tar containing up to 20 per cent. of lime to neutralize the tar acids. A mixture of tar and engine oil is used, alone or mixed with graphite, mica or talc. The tar aids in the exclusion of water and so prevents corrosion of the metal. Solid fats and waxes are also used with oils for the same purpose.

Ice Machinery.—For the ammonia compressors, the oil should have a low cold test (0°F.) and a flash of at least 375° F. A western oil is suitable on account of having a natural low cold test while the Pennsylvania oils require special treatment to get a satisfactory cold test. The loss on the evaporation test should be low as the carrying over of oil by the ammonia will reduce the rate of refrigeration. A high-grade spindle oil of 50 to 90 viscosity at 100° F. will give good results if it also satisfies the above condition. The gravity of western oils may be as low as 27° Bé.

For lubricating the steam cylinders, a high-grade steam refined cylinder stock should be used, either alone or compounded with not more than 2 or 3 per cent. of acidless tallow oil. A practically pure mineral oil is necessary in order to separate the condensed steam from the oil in condition for use in ice making.

The emulsion of oil and water does not "break" so readily in the presence of the fatty oil. The minimum amount of oil should be fed to the steam cylinder and to the ammonia compressor.

(Cf. E. W. Miller: "Hints on Ammonia Compressor Lubrication," *Power,* 46, 697, 1917.)

Printing Presses.—For small and medium presses a medium to heavy red engine oil of 220 to 270 viscosity is suitable.

For heavy presses, used for newspaper work, a heavy engine oil of 300 viscosity at 100° F. is usually heavy enough for use on the cylinders. Where a heavier oil is needed a good cylinder stock of 105 to 125 viscosity at 210° F. may be used satisfactorily, but where there is any tendency to come into contact with the paper, filtered stocks are preferable to steam refined stocks. For the gears a light gear grease can be used. For lubricating electric motors, see Index.

Cutting Tools.—The office of cutting oil is to cool the cutting tool and at the same time lubricate the face of the tool. The pressure on the cutting edge is great and no lubrication is possible or desired at this point.

Mineral oils, such as kerosene oil or paraffin oils, can be used as cutting oils. They are more often compounded with 20 to 25 per cent. of fixed oil, such as lard oil or cottonseed oil, or even corn oil. Kerosene seems to work well on cast iron, but the presence of lard oil or some similar oil seems to make a cleaner, smoother and faster cut on steel and copper. The paraffin oil can be compounded with other fixed oils with similar results.

Emulsions of water, soap and mineral oils, with or without soda, are also used for cutting purposes. These so-called soluble oils are made by combining soluble soaps with light mineral oils, such as paraffin oils. The soaps may be made from fats, rosin, etc. The product emulsifies permanently, if properly made, when brought into contact with water. The emulsion is also made by dissolving a suitable soft soap in water and then stirring in a mixture of lard oil and paraffin oil. The presence of the oils and soap tends to reduce the amount of rusting which might be caused by the water. These water soluble oils are better cooling agents than the pure oil products on account of the fact that the heat absorbing capacity of water is about twice as great as that of oils.

Special merit is claimed for the suspension of graphite in water known as "aquadag."

Where a purification system is used and the oils are available for re-use, the more expensive cutting oils can be used to advantage.

The following analyses of soluble cutting oils have been compiled from a paper by C. W. Copeland on "Cutting Oils: Their Properties, Examination and Industrial Application." (*J. Met. & Chem. Eng.*, Vol. 17, pp. 25-32, 1917):

Number of oil	1	2	3	4	5	6	7
Mineral oil	72.12	59.27	75.50	76.26	61.15	67.25	79.08
Volatile mineral oil (additional)	—	18.30	—	—	14.07	—	—
Neutral fatty oil	1.35	0.62	5.80	4.03	2.17	9.31	0.83
Free fatty acids	6.20	15.34a	0.13	4.68	19.87a	5.08	4.23
Soap	12.08	—	10.40	8.26	—	7.88	8.36
Water & vol. matter	8.26	7.05b	8.40c	7.00c	3.30b	10.68c	7.60c

(a) Sulpho-acids from sulphonated oil.
(b) Including ammonia. (c) Including alcohol.

Of the above oils, Nos. 1 and 3 were not recommended as the original oils show segregation and they emulsify poorly. No. 6 was recommended on account of its good emulsification, although it showed some segregation. The other oils (Nos. 2, 4, 5 and 7) gave excellent emulsions.

The following analyses of straight cutting oils are quoted from the same source:

Number of oil	8	9	10	11
Saponifiable oil	12.11	28.05	8.50	16.80
Mineral oil	74.72	67.60	88.00	81.00
Free fatty acids (additional)	12.76	4.15	3.10	2.08
Specific gravity at 60° F.	0.892	0.889	0.900	0.883
Baumé gravity at 60° F.	26.9	27.5	25.4	28.5
Flash test (open cup) °F.	355	396	360	410
Fire test (open cup) °F.	390	440	410	455
Viscosity at 100° F.	111	192	164	176

Oil No. 8 was rejected for excessive fatty acids and low viscosity. Oil No. 10 was rejected for poor composition as it was compounded from inferior animal oils. The other two oils were recommended.

For further information on Cutting Oils see the following: "Lubricating Oils and Cutting Compounds for Shop Use", *Am. Machinist*, Vol. 44, pp. 993-8, 1916; "Emulsion Lubrication of Cutting Tools" by J. A. DeCaw, *Am. Machinist*, Vol. 49, p. 433, 1918; "Cutting Lubricants", *Sci. Am. Supp.*, 87, p. 350, May 31, 1919; "Twist Drill Lubrication", recommendations of the *Eng. Exp. Sta.* of the Univ. of Illinois; also "Memorandum on Cutting Lubricants and Cooling Liquids and Skin Diseases", *Bull. 2, Dept. of Sci. & Ind. Research,* London, (Advisory Council, 1918), abstracted *J. Ind. & Eng. Chem.*, 11, p. 155, 1919; and "Analysis of Lubricating Greases Emulsifying in Water", by L. R. Voris, *Chem. Analyst* 22, 12-13, 1917; *Ch. A.*, 574, 1918.

For cutting oil specifications, see Index.

CHAPTER XII.

PHYSICAL METHODS OF TESTING LUBRICATING OILS.

From the large number of tests and methods available an effort has been made to give tests which meet present day requirements.

The only standard tests which have so far been officially adopted by the American Society for Testing Materials are Specific Gravity, Cloud and Pour Tests for Petroleum Oils except Steam Cylinder and Black Oils, Cold Test for Steam Cylinder and Black Oils, Free Acid Test and the Carbon Residue Test. These official tests, together with the Viscosity Test (Tentative), are given in this and the two following chapters.

The Committee on Standardization of Petroleum Specifications (Bull. No. 4, April 16, 1920) of the Bureau of Mines has adopted the Official Tests of the American Society for Testing Materials, and additional tests which are also given in these three chapters.

A statement of the meaning or value of each test is usually given as an aid to its use and in interpreting the results obtained.

VISCOSITY.

By viscosity is meant the internal friction or "body" of an oil. In commercial instruments, the viscosity is determined by the rate of flow of the oil through a small tube, but the figures obtained are not in exact proportion to the true viscosity particularly for thin oils. Viscosity in true liquids is inversely proportional to the fluidity.

The viscosity of an oil is the most important property of the oil from a lubrication standpoint. The relation of viscosity to friction and lubrication is discussed elsewhere in this volume. The coefficient of friction has been shown to be proportional to the true (absolute) viscosity of oils at the temperature of use. The real importance of the viscosity determination has been obscured by the fact that determinations have been made at temperatures which did not represent the working temperatures, and by the fact that the viscosities as read by commercial viscosimeters do not show the true viscosity or even the exact relative viscosity, particularly for oils of less than 200 Saybolt viscosity. Thus, the real viscosity of an oil of 100 Saybolt is considerably less than half the viscosity of another oil reading 200 Saybolt. This becomes of greater importance when it is recalled that the viscosity as read decreases rapidly with rise of temperature and the true viscosity decreases more rapidly still than is indicated by the reading; also the temperature of the oil film actually doing the lubricating is higher than the temperature shown by any part of the bearing.

The commercial methods of taking viscosity are based on the time required for a given volume of the oil to flow through a certain size opening or tube under specified conditions. In order to make a single instrument answer for all types of oils, the opening is made too large, or the tube too short, for thin oils to register their true relative viscosities as compared to the thicker oils. The recognition of this fact will greatly extend the usefulness of the viscosity test. The Bureau of Standards has recently (1918) thoroughly standardized the dimensions of the Saybolt viscosimeter and determined the absolute (true) viscosities for the Saybolt and Engler viscosimeters, thus making possible a sound interpretation of viscosities on a scientific basis. Ubbelohde has published tables for conversion of Engler viscosities into absolute viscosities. Tables have been published by the Bureau of Standards showing the relation of the standard Saybolt and the Engler viscosimeters. (See Index). All previous tables for the Saybolt instrument are incorrect as they were based on unstandardized instrument.

The Saybolt universal viscosimeter, which is the only type of Saybolt viscosimeter now used, requires only a small amount of oil for the determination. The time of outflow of 60 cc. of oil expressed in seconds is taken as the viscosity of the oil at the temperature used. This viscosimeter requires about 28 seconds for 60 cc. of water to flow out at 68° F. (20° C.).

TENTATIVE TEST FOR VISCOSITY OF LUBRICANTS.*

Report of Committee D-2 on Lubricants, American Society for Testing Materials.

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

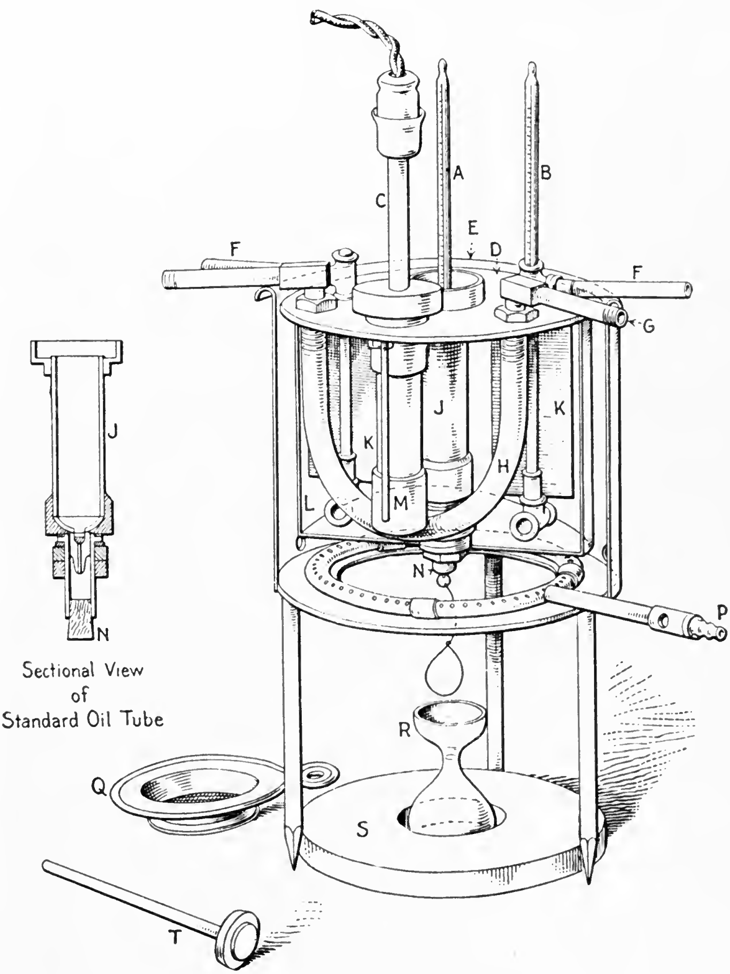
* This test will doubtless be officially adopted during 1920, without substantial change.

"**Apparatus.**—2.(*a*) The Saybolt Standard Universal Viscosimeter (see Fig.) 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*, whose capacity to a mark on its neck is 60 (±0.15) cc. 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 *T*, 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, *J*, should be standardized by the U. S. Bureau of Standards, Washington, D. C., 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

"**Method.**—3. Viscosity shall be determined at 100° F. (37°.8C.), 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



A	Oil Tube Thermometer.	K	Stirring Paddles
B	Bath Thermometer.	L	Bath Vessel.
C	Electric Heater.	M	Electric Heater Receptacle.
D	Turntable Cover.	N	Outlet Cork Stopper.
E	Overflow Cup.	P	Gas Burner.
F	Turntable Handles.	Q	Strainer.
G	Steam Inlet or Outlet.	R	Receiving Flask.
H	Steam U-Tube	S	Base Block.
J	Standard Oil Tube.	T	Tube Cleaning Plunger.

Sectional View of Saybolt Standard Universal Viscosimeter.
(By courtesy of American Society for Testing Materials.)

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-cc. 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 in 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 delivery of 60 cc. of oil is the Saybolt viscosity of the oil at the temperature at which the test was made."

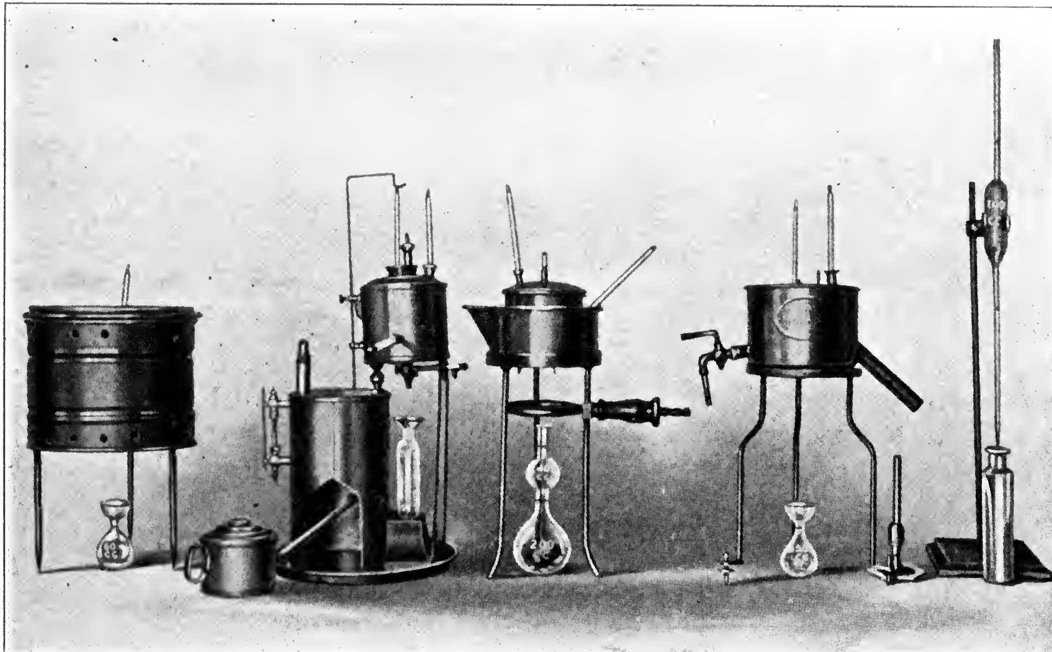
The Engler viscosimeter, used in Continental Europe and largely by the United States Government, requires practically 51 seconds (50 to 52 seconds) for 200 cc. of water to flow out at 20° C. (68° F.) when 240 cc. of water is used in the instrument. The viscosity of an oil is taken by using 240 cc. of the oil in the viscosimeter, adjusting the temperature to the desired point by means of the water bath which is part of the instrument, and noting the number of seconds required for 200 cc. of the oil to flow out. The Engler viscosity or Engler number for the observed temperature is calculated by dividing the time of outflow of the oil (in seconds) by the time of outflow of water at 68° F. (in seconds).

The Engler viscosimeter requires a large amount of oil for a complete determination, but where only a small amount of oil is available, or it is desired to shorten the time, the time of outflow of a smaller amount of oil may be taken in seconds, using a smaller amount of oil in the viscosimeter. The factors given below are used to multiply the seconds noted to find the time of outflow of 200 cc. if 240 cc. of oil had been used in the instrument. The errors are somewhat larger than for a regular determination.

See *Ch. A.*, p. 304, 1912, Offerman, also Holde and Ganz. Cf. Bur. of Stand. Tech. Paper 100, pp. 39 and 43.)

Amount of oil used cc.	Amount run out cc.	Multiplying factor
25	10	13.
45	20	7.25
45	25	5.55
50	20	7.3
50	40	3.62
60	50	2.79
120	100	1.65
240	100	2.35

The Dudley, or Pennsylvania Railroad pipette, is sometimes used to get comparative viscosities of oils where a standard viscosimeter is not available. An exact standardization of such an instrument is impossible, so the results are valuable only for the direct comparison of oils at room temperatures.



Saybolt Universal — Tagliabue — Engler — Redwood — Dudley or Pennsylvania R. R. Pipette

Viscosimeters

(By courtesy of Platt & Washburn Refining Co., New York.)

The Saybolt universal viscosimeter is now used generally in the United States, superceding the older types of Saybolt viscosimeters and the Tagliabue viscosimeter which were formerly used to more or less extent. The Engler viscosimeter is used in Germany and generally in Continental Europe and has been used in the United States, notably by the Government. The Redwood viscosimeter is standard in England. The Dudley pipette is a simple instrument for comparing oils directly at ordinary temperatures.

The old practice of taking viscosities at 70° F. is indefensible as oils are practically never used at that temperature. So long as Pennsylvania oils only were used the results at 70° F. were roughly proportional for oils of the same class at 100° F. or higher. Lubricating oils from other sources may show greater viscosities at 70° F. than Pennsylvania oils and less viscosity at 100° F. or at working temperatures, owing to more rapid thinning under heat. After this preliminary thinning, the viscosities do not vary so differently upon further heating. The determination of viscosity at 100° F. has now become general in this country, except for car oils which are tested at 210° F. and sometimes at 130° F., and for cylinder oils and stocks which are tested at 210° F. The Government, following foreign practice, sometimes takes the viscosity of engine oils at 50° C. (122° F.) which seems to be good practice as this is near the possible working temperature of the oil.

The practice of taking the viscosity of engine oils and heavy motor oils at 130° F. should be encouraged, since a better basis for comparison of the true working viscosities of different types of heavy oil can be obtained at this temperature than at 100° F.

The practice of taking the viscosity of cylinder oils, as is frequently advocated, at temperatures above 212° F. is of no value for routine testing or for specifications as the viscosity at higher temperatures can be correctly inferred from the viscosity at 210° F.

The presence of soaps and other oil thickeners dissolved in an oil interfere with a correct determination of the viscosity. Such thickeners must first be removed, or the viscosity determined at a sufficiently high temperature to render their effect of minor importance, otherwise the viscosity reading will be misleading. Such oils give a "fictitious" viscosity reading.

For change of viscosity with change of temperature, see analyses under spindle oils, loom oils and cylinder oils.

Absolute Viscosities.—In commercial viscosimeters arbitrary scales have been adopted which do not give proportional viscosities for different oils even with the same instrument. This is because the outflow tube is too large and too short to register the whole energy of outflow, particularly for the thin oils. Absolute viscosities are expressed in "dynes per square centimeter" and the specific gravities of the oils are taken into account as a heavier oil will give a slightly shorter outflow time than a lighter oil of the same absolute viscosity. Corrections are also made for the energy of flow not used in overcoming resistance within the outflow tube. The units used are not familiar to the oil trade, but will doubtless become so.

Standardization of Viscosimeters.—The standard dimensions of the Saybolt Universal Viscosimeter, as agreed on by Mr. George Saybolt and the Bureau of Standards in 1918, give the following relations between Saybolt viscosity and kinematic viscosity:

$$\frac{\mu}{\gamma} = 0.00220t - \frac{1.80}{t}$$

where

$\frac{\mu}{\gamma}$ = kinematic viscosity
μ = viscosity in poises
γ = weight of 1-cc. in grams
t = Saybolt reading in seconds.

The poise is the absolute unit of viscosity. The fraction $(1.80/t)$ is the correction required for unutilized energy of flow. This correction is large for oils below 100 Saybolt, and practically negligible for oils above 200 Saybolt.

As an example of how the true viscosity varies much faster than shown by the Saybolt reading, it may be stated that an oil of 77 Saybolt has practically twice the true viscosity of an oil of 50 Saybolt. Similarly an oil of 50 Saybolt has twice the real viscosity of an oil of 37 Saybolt. These examples serve to indicate the real need for a more rational expression of viscosity measurements, especially for thin oils, or the necessity for a more rational basis for interpreting commercial viscosities.

The Bureau of Standards has prepared limit gauges and is now prepared to certify any Saybolt instrument. Based on the tolerances permitted in the agreed dimensions of the Saybolt instrument, the following extreme variations are still possible, though not likely:

TIMES OF DISCHARGE FOR STANDARD SAYBOLT UNIVERSAL VISCOSIMETERS.

Liquid	Temperature	Kinematic viscosity	Time of discharge		
			Minimum	Normal	Maximum
	°C		Sec.	Sec.	Sec.
30 per cent. ethyl alcohol..	20	0.02841	34.6	35.7	37.4
" " " ..	25	0.02292	33.2	34.2	35.7
50 per cent. ethyl alcohol..	20	0.03144	35.4	36.6	38.4
" " " ..	25	0.02636	34.2	35.2	36.8
A heavy oil	—	1.00	428.0	455.	490.0

For "Standard Substances for the Calibration of Viscosimeters," see Scientific Paper No. 298 of the Bureau of Standards. This paper, by Bingham and Jackson, gives exact data for the use of sugar solutions and alcohol-water mixtures. A mixture of 45 per cent. by volume of ethyl alcohol and water has a viscosity which is almost exactly four times that of water at 0° C. Since the viscosity of ethyl alcohol-water mixtures passes through a maximum at this concentration, the viscosity does not change rapidly with the concentration, which is a marked advantage. Also the surface tension of such an alcohol-water mixture at the temperature of calibration (15° C.) is practically identical with that of oils. (Bur. of Stand. Tech Paper No. 112, p. 13.)

The absolute viscosity of water at 20° C. (68° F.) is given as 1.005 centipoise, but water is not recommended as a good calibrating liquid.

It is probable that the best calibrating liquid for high viscosities is castor oil, in spite of slight differences between samples of different age and origin. Probably the most accurate determinations of the viscosity of castor oil have been made by Kahlbaum and Raber. (Tech. Paper No. 112, p. 24.) For table see Index under Castor Oil.

MECHANICAL TESTS.

The usual oil testing machines give little information of value to the user of oils. The conditions of use on testing machines do not duplicate the actual service conditions, so the tests are chiefly valuable as tests of the working conditions used, or as a test of the general principles of lubrication involved, or of bearing design, rather than a test of the suitability of the oil for a definite purpose.

Much has been learned about the science of lubrication by the use of testing machines, such as the coefficient of friction to consider as a working ideal for given pressures and speeds. Ubbelohde (Petrol. 7, p. 773, 882 and 938, 1912; see *Chem. Ab.*, p. 1986, and 2521, 1912, also pp. 248, 1121, and 2678, 1913) has shown by experiment that the coefficient of friction of an oil can be calculated from the absolute viscosity of the oil (Holde, Eng. Ed., p. 125). The Saybolt and Engler viscosities are not directly proportional to the true or absolute viscosity of the oil, and this fact together with the practice of taking the viscosities of oils at unsuitable temperatures has tended to obscure the important relation between viscosity and the coefficient of friction.

High viscosity oils have high coefficients of friction and so the best oil to use in practice is an oil of just sufficient viscosity at the working temperature to keep the bearings apart with certainty under all conditions. The viscosity test, in conjunction with the available information on lubricating principles, is a sufficent guide to successful lubrication. Actual service tests can be used to confirm the accuracy of the conclusions from the viscosity determination.

Thurston and others have studied the principles underlying lubrication, and in this way the use of testing machines have proved of great service.

REFERENCES.

"Standard Substances for the Calibration of Viscosimeters," *Sci. Paper No. 298,* Bur. of Stand., by E. C. Bingham and R. F. Jackson, 1917.

"Determination of Absolute Viscosity by Short-Tube Viscosimeters," *Tech. Paper No. 100,* Bur. of Stand., by W. H. Herschel, 1917.

"Standardization of the Saybolt Universal Viscosimeter," *Tech Paper No. 112,* Bur. of Stand., by W. H. Herschel, 1918.

"The MacMichael Torsional Viscosimeter," by W. H. Herschel, *J. Ind. & Eng. Chem.,* pp. 282-6, 1920.

"Tentative Test for Viscosity of Lubricants," Report of Comm. D-2, *Am. Soc. Test. Mat.,* 1919.

"Viscosity and its Relation to Lubricating Value," by Alan E. Flowers, *Power,* Jan. 11, 1916, pp. 37-40.

CHAPTER XIII.

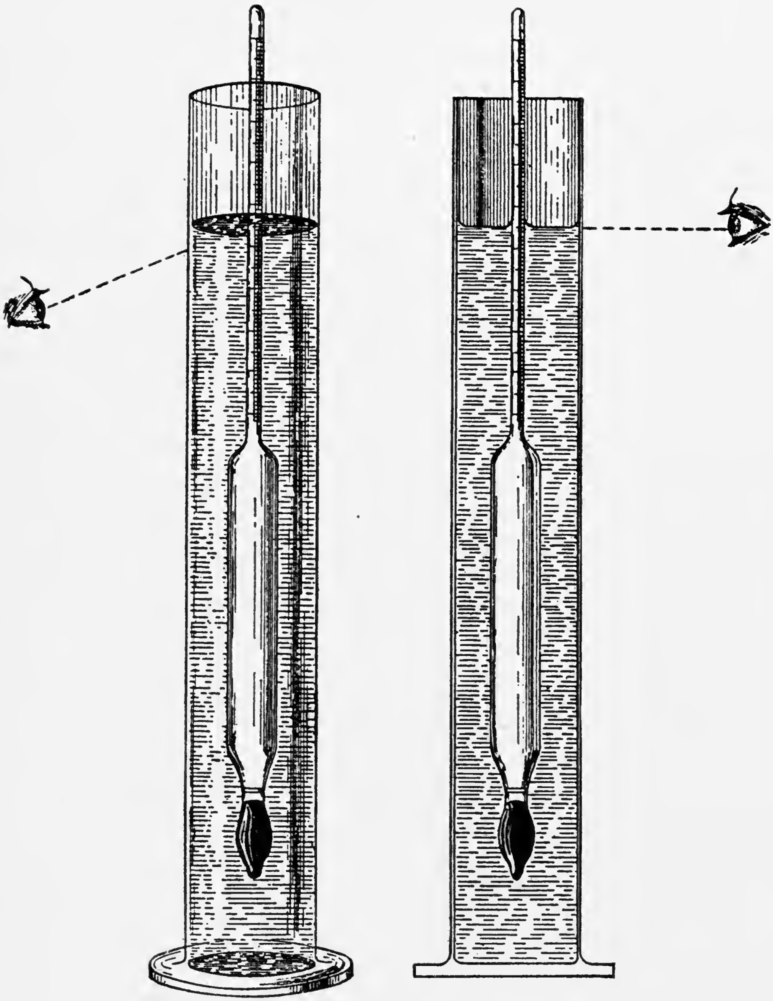
PHYSICAL METHODS OF TESTING LUBRICATING OILS.

(Continued.)

A. GRAVITY TESTS.

The gravity test has been accorded too much weight in judging the lubricating value of oils, consequently oils have often been found unsuitable because some more vital test, such as viscosity, has been sacrificed to meet an impracticable gravity requirement. It has great value in the refinery as a quick method of judging when to make the "cuts" or changes in distillation. So long as Pennsylvania crude was the only oil used, the gravity was an index to the viscosity and was, therefore, of real value to the user. With the production of lubricating oils from other crudes, the gravity test has lost much of its value unless taken in conjunction with other tests. The gravity is of value in judging the type of crude from which the oil was refined. Thus high viscosity oils (viscous neutrals) do not run over 30° Bé. unless from Pennsylvania or similar crude. For a given crude the viscosity is generally proportional to the gravity, but this is not necessarily true for oils of the same type from different crudes. All mineral oils contain about 85 per cent. actual carbon, so a possible variation of 1 or 2 per cent. in the carbon content of an oil as evidenced by a lower gravity can hardly be of any practical significance.

It has long been a trade custom to use the Baumé gravity (° Bé.) instead of the specific gravity. The simplest way to take the gravity is with a hydrometer as shown in the accompanying illustration. Hydrometers are made which read either Baumé gravity (degrees Baumé), or specific gravity, or both. Hydrometers can also be had in sets so that more exact readings can be made than where the whole scale is on a single spindle. Since the gravity must be taken at 60° F., or be corrected to 60° F., hydrometers may be equipped with thermometers. Sufficient time should be allowed for the thermometer to register the true temperature of the oil. For most lubricating oils the correction for temperature is approximately 0.06° Bé. for each degree Fahren-



Showing Correct Method of Reading Hydrometer.
(From Bureau of Standards Circular No 57.)
In taking the reading the eye should be placed slightly below the plane of the surface of the oil and then raised slowly until this surface becomes a straight line. The point at which this line cuts the hydrometer scale is taken as the reading of the instrument. With an oil not sufficiently clear to allow a reading as described, the reading can be made above the oil surface and a suitable correction made.

heit above or below 60° F., the correction to be subtracted when the reading is made above 60° F. Tables are given (See Index) for correcting the gravity where the observation is not made at 60° F. (or see Bureau of Standards Circ. No. 57).

The Specific Gravity test as officially adopted by the American Society for Testing Materials (D-47-1918) is as follows:

"Specific Gravity may be determined by hydrometer, Westphal balance, or pycnometer, provided these instruments are verified. The observation shall be taken with the sample at 15.56° C. compared with water of the same temperature. Correction for the buoyant effect of the atmosphere shall be made when necessary."

The specific gravity correction is about 0.00036 for each degree Fahrenheit above or below 60° F. (equivalent to 0.00065 correction for 1° C.), the correction to be added for temperatures above 60° F. The correction is slightly higher for lubricating oils of low specific gravity. Tables are given for converting specific gravity into degrees Baumé, etc.

The Baumé scale is unscientific in that it was arbitrarily chosen and bears no obvious relation to the weight as does the specific gravity. There are a number of Baumé scales for liquids lighter than water, but the Bureau of Standards has sanctioned the scale based on the following formula:

$$\text{Sp. gr. } 60°/60° = \frac{140}{130 + \text{deg. Bé.}}$$

The specific gravity shows the weight of an oil as compared to water as unity at 60° F. Since 1 gallon of water at 60° F. weighs 8.32823 pounds, the weight of 1 gallon of oil can be calculated by multiplying this value by the specific gravity of the oil at 60° F. Heavy oils have low Baumé gravities, but high specific gravities.

B. FLASH TEST.

The flash point of an oil is the lowest temperature at which the oil gives off sufficient vapors to form an inflammable mixture with air. The flash point varies with the conditions of testing and with the apparatus used.

The flash point does not indicate the value of an oil for lubricating purposes, except in a very general way. Thus very high flash oils, such as cylinder oils, must usually have a high viscosity, and light oils such as spindle oils cannot have as high flash points as engine oils have. Also oil made from western crude may show a lower flash point than the same class of oil from Pennsylvania crude.

The chief value of the flash test is to determine the safety of an oil with respect to the fire risk and as an indication of the freedom of the oil from excessive evaporation loss during use. The fire hazard of lubricating oils is of importance where the oils are for use on fast-moving machinery, such as spindles, or for use in compressors for air, ammonia and other gases. The flash test is of special importance in connection with motor oils and other oils exposed to high temperatures. For oils not exposed to high temperatures, the flash point is usually sufficiently high, except for very low viscosity oils like spindle oils.

While many testers have been used in the United States, the best known testers for lubricating oils are the Cleveland open-cup tester, the Tagliabue open-cup tester, and the Pensky-Martens (closed-cup) tester. The flash point with the open testers may be as much as 40° F. higher than with the closed testers, such as the Pensky-Martens. The open tester has been used in the United States to the exclusion of other testers.

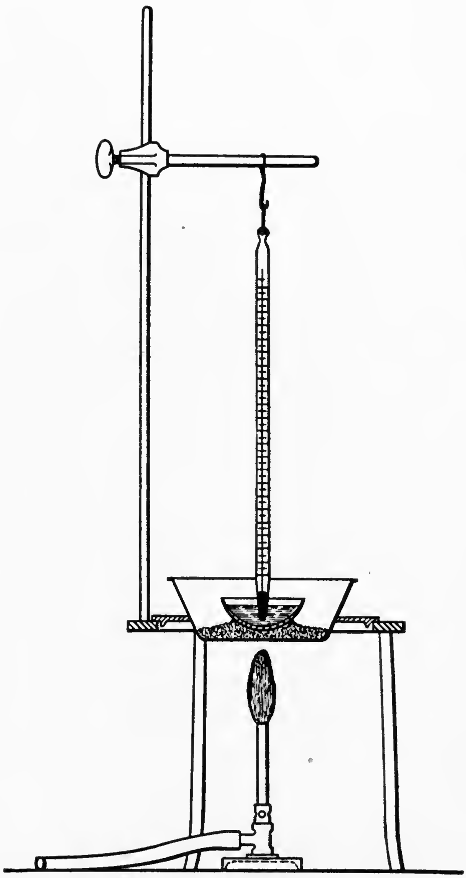
The flash test method, adopted by the Committee on Standardization of Petroleum Specifications (April 16, 1920) is as follows for lubricating oils:

"This test shall be made in the Cleveland Open Cup Tester, the apparatus being used without any bath or outer cup surrounding the oil cup. The oil cup should have two marks on the inside, the first, one-quarter inch below the top, and the second, three-eighths inch below, the first to be used when testing oils with a flash point below 425° F. and the second when testing oils with a flash point at or above 425° F. The clean oil cup should be inserted into the tripod ring, which must be level, and the cup filled to the proper mark with the oil to be tested. Care should be exercised not to spill any oil on the sides or top of the cup, and if this accident should happen, all such oil must be carefully removed. A "bulb immersion" thermometer should then be inserted into the oil and suspended from a suitable support. The bulb of the thermometer should be three-eighths to five-eighths inch in length. During the test the bulb must be fully covered by the oil and the bottom of the thermometer must not be less than one-fourth inch from the bottom of the cup. The thermometer must be suspended in the oil midway between the center and inside edge of the cup. The alcohol or gas burner is then placed under the oil cup so as to heat it uniformly. The oil may be heated rapidly at first but the rate of heating should be 8 to 10 degrees F. (5° C.) per minute during the last 80 degrees of heating prior to attaining the flash point. As the flash point is approached, a test is made for every 5 degrees F. rise in temperature (on the readings which are multiples of 5) by slowly passing a small bead-like test flame, not exceeding one-eighth inch in length, across the center of the cup one-fourth inch above the surface of the oil, the movement occupying one second.

"The temperature when a flame first jumps from the test flame to the oil is called the flash point of the oil. The test must be made where the cup is free from draughts and must also be made in a subdued light.

"After the flash point has been obtained, the same method of testing shall be continued until the oil takes fire and continues to burn. The temperature at which the oil continues to burn is the fire point of the oil."

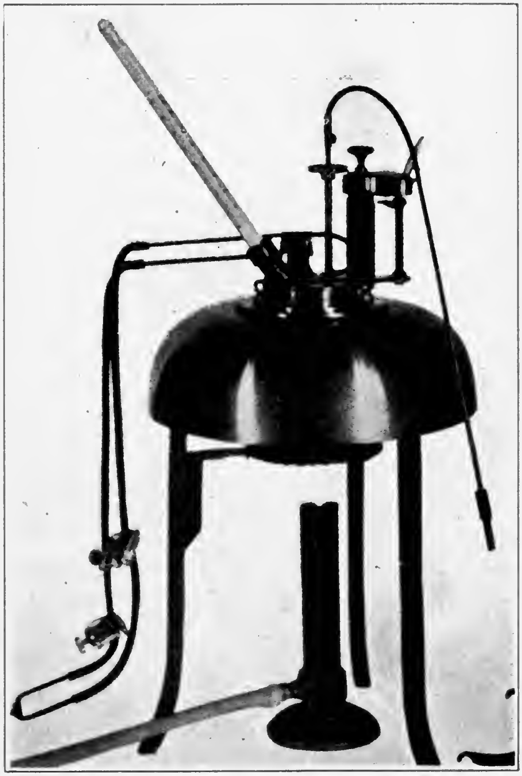
Similar results to those with the Cleveland open-cup tester are obtained by heating the oil in a porcelain crucible or evaporating dish, or in a glass beaker, or a sand bath (see illustration). A 50 cc. crucible or dish is suitable for the oil vessel, the oil being filled to within ¼ inch of the top only. The thermometer is adjusted so that the bulb is completely covered but does not touch the bottom of the dish. The apparatus should be protected from air currents and from the breath of the operator. The heating flame is adjusted so that the temperature rises at the rate of 10° to 12° F. per minute, and a small test flame is applied every 7° F., beginning at least 50° below the supposed flashing point of the oil. The test flame can be a small lighted splinter, or preferably a gas flame burning on a pointed glass tube, but should not be more than ¼ inch long in any case. The flame is applied by passing it slowly entirely across the dish, about ½



Apparatus for Determining the Flashing and Burning Points of Combustible Liquids as used by the Pennsylvania Railroad.

The porcelain dish is 2¾ inches in diameter and 1 inch deep.

inch above the level of the oil and just in front of the thermometer. The flash point is the temperature read at the moment the vapor ignites with a slight flash. The heating may be continued, applying the flame as before, until the oil vapor continues to burn after the test flame is removed. The temperature observed is called the burning point or the fire test.



Modified Pensky-Martens Tester, Ready for Test.
(From Tech. Paper 49, Bureau of Mines.)
This flash tester has been adopted by the National Fire Protection Association and the Independent Petroleum Marketers' Association of the United States. This tester without the modified bath, is the official standard for testing lubricating oils in most European countries. This is the most accurate form of tester.

The rate of heating and the method of applying the flame are very important. The results are sufficiently exact for commercial purposes.

Thermometers are usually standardized with the bulb and stem at the same temperature, so a correction should be applied to the thermometer reading as found above. The following corrections are to be added to the thermometer reading to get the true flash point and are sufficiently exact for most purposes:

Flash-point reading (°F.)	Correction to be added (°F.)
275–300	5
300–325	6
325–350	7
350–375	8
375–400	10
400–425	11
425–450	13
450–500	16
500–550	20
550–600	23
600–650	27
650–700	30

The effect of various factors on the flash point as determined with the closed cup testers is discussed fully in Tech. Paper No. 49 of the Bureau of Mines (37-pp. with bibliography, 1914) and in a paper by the same authors, Allen and Crossfield, *J. Ind. & Eng. Chem.*, pp. 908-910, 1913. See index for railroad methods of testing given in this volume.

C. FIRE TEST.

The fire test or burning point of an oil is the lowest temperature at which the oil gives off sufficient vapor to continue to burn after the vapor is ignited. The method of making the fire test has been given above.

Oils, particularly steam cylinder oils, have been largely sold by their fire test, which is from 40° to 50° F. above the flash test for motor oils or engine oils, and from 60° to 80° F. above the flash test for cylinder oils. The fire test has the same general significance as the flash test and gives little additional information.

D. EVAPORATION TEST.

The amount of oil that will vaporize at any given temperature is somewhat proportional to the flash and fire tests of the oil. A low flash oil will lose weight faster than a high flash oil.

The evaporation test gives more definite information as to the extent of the loss by vaporization under definite conditions than can be inferred from the flash and fire tests. This is especially true where the oil tends to decompose under the influence of heat. The usual procedure is to use temperatures of 212° F. or higher, up to the flash point of the oil, for a period of not more than 6 hours, the temperatures used and the time of heating being chosen with reference to the type of oil and the conditions under which the oil is to be used. Generally an air bath is used for the heating, though the heating may be conducted on a water bath for the loss at 212° F., or on an electric hot plate for losses at higher temperatures. Comparative results can be had by using the same type of dish and the same conditions for a series of tests. The form of the dish, the depth of oil in the dish and the amount of oil surface exposed greatly influence the result as does also circulation of the air to remove the vapor formed. Waters (*J. Ind. & Eng. Chem.*, pp. 394-398, 1913) recommends brass vessels 0.5 millimeter thick, 5 centimeters internal diameter and 3 centimeters high, and 5 grams of the oil.

This test is of value in determining what flash test to specify, as for spindle oils or motor oils, and for testing such oils as air-compressor oils, turbine oils, transformer oils and superheater cylinder oils. In these tests the condition of the residue, as determined by its appearance and by its behavior in the gasoline test, is of more importance than the actual loss on evaporation. (See heat test and gasoline test.)

For example of evaporation losses for various oils see Index for analyses of spindle oils, cylinder oils, railroad cylinder oils and motor oils.

"**Evaporation.** [Comm. on Stand. of Pet. Specif., April 16, 1920.]—Twenty grams of the oil is placed in a weighed flat-bottomed glass crystallizing dish having a diameter of approximately 3¾ inches. The dish is then placed in an oven at a temperature of 212° F. for two hours, cooled in a desiccator, and weighed."

E. COLD TEST (CLOUD TEST, POUR TEST).

The cold test is the lowest temperature at which the oil will still flow. Methods of making the test vary and the temperature found has many names besides the cold test, such as cloud test, pour test, flow test, chill point, freezing point, setting point, etc., etc. The oil does not solidify as a whole, but becomes solid from the freezing out of some constituent, such as paraffin.

The cold test is valuable where oils are to be exposed to low temperatures, such as on freight cars in winter, for use on pneumatic tools, etc. In general a lower cold test is required in winter than in summer. For general lubrication the cold test should be sufficiently low to give a free flowing oil under the most severe service conditions, otherwise serious trouble may result from freezing of the oil.

The cold test has no special bearing on the lubricating value of an oil except at low temperatures. The cold test of western oils is naturally lower than the cold test of Pennsylvania oils on account of freedom from paraffin.

The usual method of making the test is to put 30 cc. (1 ounce) of the oil in a 4-ounce sample bottle fitted with a stopper carrying a thermometer, and chill the oil by immersion in a freezing mixture. The chilling is gradual and the oil is stirred during the freezing. The bottle is removed from the freezing mixture every few degrees and the temperature noted at which the oil ceases to flow in the bottle or from the thermometer bulb, this temperature being recorded as the cold test of the oil. The Pennsylvania Railroad method is to freeze the oil solid, remove the bottle from the freezing bath and note the cold test as the point at which the oil softens sufficiently to flow from one end of the bottle to the other (see Index).

Cloud and Pour Tests for Petroleum Oils except Steam Cylinder and Black Oils.

(American Society for Testing Materials: Standard Tests, D 47-1918.)

"**Cloud Test.**—The cloud test indicates the point at which paraffin wax or other solid substances crystallize out or separate from solution in the oil.

"Put the oil to be tested in a glass jar or bottle, approximately 1¼ in. in inside diameter and 4 to 5 in. high, to a height of about 1¼ in. or sufficient to reach ¼ in. above the mercury bulb of the thermometer. The thermometer used is the so-called cold-test thermometer, which is specially made for this purpose and has a bulb ¼ to ⅜ in. long. Insert the thermometer through a tight-fitting cork so that it is held centrally in the jar, with the lower end of the bulb ½ in. from the bottom of the jar. Then place the cold-test jar in a metal or glass jacket 4 to 5 in. high, having inside diameter ½ in. larger than the outside diameter of the test jar. A disk of felt, cork or wax, ¼ in. in thickness, is placed in the bottom of the jacket. Care should be taken that the test jar is placed in the center of the jacket, so that it does not touch the sides at any point. Then put the whole apparatus into the refrigerating mixture and at every drop in temperature of 2° F. when near the expected cloud test, remove the jar from the jacket and inspect, being careful not to disturb the oil by moving the thermometer or otherwise. When the lower half of the sample becomes opaque through chilling, read the thermometer. This reading shall be taken as the "cloud test" of the oil.

"**Pour Test.**—The pour test indicates the temperature at which a sample of oil in cylindrical form of specified diameter and length will just flow under specified conditions.

"In making this test the same bottle and quantity of oil are used as for the cloud test, and the pour test may, if desired, be made after the cloud test has been determined; in the great majority of cases the cloud test being the higher. In making the pour test, place the jar containing the oil in a close-fitting metal jacket provided at the bottom with a disk of felt or cork ¼ in. thick. Place this in the freezing mixture. At each drop in temperature of 5° F. remove the bottle from the jacket and tilt it until the oil begins to flow; just sufficiently tilted but no more. In the extreme case, the bottle should be tilted to the horizontal. When the oil has become solid around the thermometer and will not flow, the previous 5° point shall be taken as the "pour test" of the oil.

"Preferably, the cold should be applied so that the pour test will be completed in approximately one-half hour. The materials used in the freezing mixture may be ice, calcium chloride or sodium chloride, or solid carbon dioxide with acetone, depending upon the temperature desired in making the tests. For oils congealing or solidifying above +35° F. pounded ice is used. From +35 to +15° F., a mixture of pounded ice and a small addition of salt, 1 : 20 by volume, may be taken. For temperatures from +15 to —5° F., also use an ice-and-salt mixture, adding about one-third salt. The salt should be very dry and granulated fine enough to pass through a 20-mesh-sieve. From zero to —25° F., a mixture of ice and calcium chloride is used. For temperatures lower than —5° F., however, it will be found very convenient to use solid carbon dioxide and acetone, by which any desired temperature down to —70° F. can be obtained, or even lower. This freezing mixture is made as follows:

"Take a sufficient amount of dry acetone and put it into a covered metal beaker, copper or nickel; put the beaker into an ice-salt mixture and when the temperature of the acetone reaches +10° F., or below, add by degrees solid carbon dioxide, until the desired temperature is reached. To get the solid carbon dioxide, take an ordinary liquefied carbon-dioxide cylinder and invert it, open the valve carefully and let the gas run out into a chamois-skin bag. By the rapid evaporation the dioxide becomes solid.

Cold Test for Steam Cylinder and Black Oils.

(American Society for Testing Materials. Standard Tests D 47-1918.)

"The object of the cold test is to determine the lowest temperature at which oil will flow from one end of a container to the other, in case it should become frozen and the resulting solid oil stirred till it has assumed a sufficiently pasty consistency to flow. The test is conducted by freezing an ounce of the oil solid in an ordinary 4-oz. oil sample bottle, using a freezing mixture if necessary. A thermometer should then be introduced into the frozen mass, and after it has become cold, the bottle containing the congealed oil is removed from the cooling medium. The frozen oil is thoroughly stirred with a thermometer until the mass will run from one end of the bottle to the other, and at this moment the temperature as indicated is recorded. The reading is the cold test of the oil.

"If the figures indicating the cold test are inside the bottle and covered by the softened oil, the reading can be obtained by grasping the bottle by the neck with one hand, having in the same hand a piece of waste, which encloses the thermometer. The thermometer is then withdrawn through the waste with the other hand for a sufficient distance to enable the operator to see the end of the mercury column and read the temperature."

F. COLOR AND APPEARANCE.

The color of an oil is no indication of its lubricating value. Heavy oils have deeper colors than light oils, such as the paraffin oils or non-viscous neutrals. Oils should not be darker than their viscosity warrants as such a condition is evidence of incomplete or improper refining. Highly filtered oils are paler than other oils of corresponding viscosity, but the color of oils can be lightened by acid treatment.

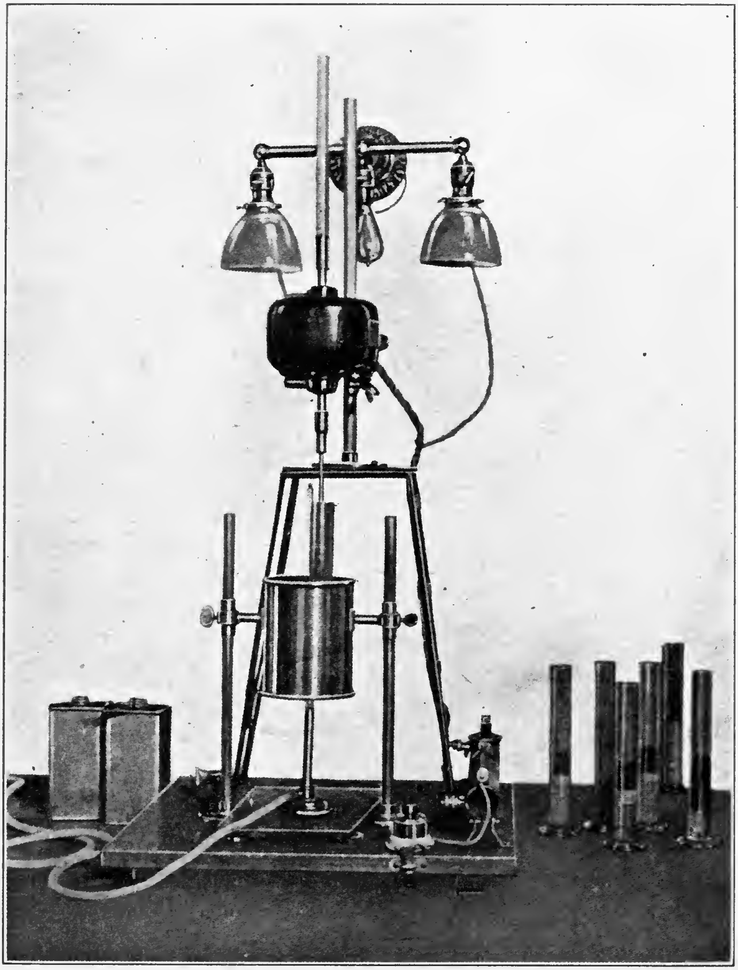
Red engine oils should be clear when viewed toward the light in a sample bottle. Oils should be free from any turbidity which might indicate the presence of water, paraffin, glue or other impurities.

Cylinder oils, if free from tar, are green in color instead of black, but the gasoline test is more reliable for detecting tar.

All mineral oils show more or less "bloom" or fluorescence unless the bloom is artificially removed by the addition of nitrobenzene (oil of mirbane), or by nitro-naphthalene.

G. EMULSIFICATION TEST.

For oils used in circulating systems where the oil must be used repeatedly, such as in steam turbines, the oil must be able to separate from water readily and must retain this property during use. The tendency to emulsify seems to be related to the presence of certain sulphur compounds, soaps and fatty oils or or-



Emulsifier in use at the Bureau of Standards.
(From Bureau of Standards Tech. Paper No. 86.)

ganic acids. The most important single test for a turbine oil or similar oil, after the viscosity test, is the emulsification test. The thickening of an oil in service prevents proper circulation and lubrication, and failure to separate from water makes an early rejection of the oil necessary.

The test is made by vigorously stirring a definite quantity of the oil with a definite quantity of water. Dr. Herschel (Bureau of Standards Tech. Paper No. 86) makes the test as follows:

> "Twenty cc. of oil and 40 cc. of distilled water are placed in a 100 cc. cylinder having an inside diameter of 26 millimeters and heated in a water bath to 55° C. The liquids are then stirred with a paddle for 5 minutes at a speed of 1,500 revolutions per minute. The paddle is simply a metal plate 89 by 20 by 1.5 millimeters submerged in the liquid. The cylinder is allowed to stand for a time not exceeding 1 hour at a temperature of 55° C., and from each of the readings, taken as frequently as necessary, of the volume of oil settled out from the emulsion, there is calculated the average rate of settling between the time of stopping the paddle and the time of observation. The maximum rate of settling thus obtained is called the demulsibility, and is used as a measure of the resistance of the oil to emulsification. The maximum possible demulsibility is 1,200, as the first reading is taken 1 minute after stopping the paddle."

Small variations in the size of the paddle do not make any great difference in the result. The "demulsibility" is calculated as follows when a cylinder is used which is graduated from the bottom up: If the reading at the upper surface of the emulsion is 50 cc. at the end of 15 minutes, the rate of settling or demulsibility $= (60 - 50) \times \frac{60}{15} = 40$ cc. per hour; for a reading of 45 cc. and a time of 10 minutes, demulsibility $= (60 - 45) \times \frac{60}{10} = 90$ cc. per hour. A high demulsibility shows a good oil. The majority of the oils on the market are either very good or very bad. Oils of high ash content show little resistance to emulsification.

The color of an oil has no real connection with the demulsibility, though highly filtered oils show high resistance to emulsification. Small amounts of impurities, too small to determine chemically, may cause an oil to emulsify, but the engineer is more concerned with the fact of emulsification than with its cause. The General Supply Committee, which makes contracts for purchasing supplies for various departments of the Government, has specified a demulsibility of 300 for turbine and spindle oils. This is approximately the value that would be obtained with a half and half mixture of kerosene and olive oil, with a volume of water equal to twice that of the kerosene and olive oil together.

Owing to the temperature and exposure to air, oils develop acid which causes the demulsibility to decrease. Dr. Herschel (pp. 34 and 35) gives the following figures for new and used oils:

DEMULSIBILITIES OF STEAM-TURBINE OILS

Section I.—New Oils

No.	Demulsibility	Comment
1	1200	Proved satisfactory.
2	192	Best satisfaction in use of any oil of this type.
3	{ 1200 400 }	These two oils are in use.
	71	We have been asked to try this oil.
4	600	Proves to be very satisfactory.
5	1200	We have been using this brand for 10 years.
6	300	Satisfactory for our use.

Section II.—Used Oils

No.	Demulsibility	Months in use	Comment
7	81	36	So far is very satisfactory.
8	85	1	Have practically no difficulty.
9	41	12	Results considered as satisfactory.
10	3	24	Contemplating a change of oil.
11	81	5	Has proven satisfactory.
12	39	12	
12	98	10	
12	87	3	
13	75	7	

Section III.—New and Used Oils of Same Brand

No.	Demulsibility		Months in use	Comment
	New	Used		
14	150	74	2	
15	280	93	12	This grade of oil has proved satisfactory.
16	600	102	24	
17	68	1	29	Oil still doing satisfactory service.
18	168	0	120	25 per cent. of fresh oil added since July, 1906.
19	1200	12	11	Discoloration due to babbitt bearings.
20	41	4	6	Deposit after 6 months' use.
21	1200	114	60	
22	94	32	10	
23	80	23	20	
24	120	102	2	Used this brand a great many years.

"If oils of sufficiently high demulsibility are used, no trouble is experienced with emulsification. It has been found also that oils of high demulsibility will last longer in use before becoming unserviceable from the formation of deposits. It seems probable that for any particular turbine in a given plant a value for the demulsibility could be found beyond which it would be unsafe to go, and that it would be an aid to the operating engineer to keep record of the demulsibility, as well as of the amount of sediment, in determining when the oil becomes unfit for use."

The method as approved by the Committee on Standardization of Petroleum Specifications (April 16, 1920) is as follows:

"**Emulsifying Properties.**—*Essential Features of Emulsifier.*—The oil and water to be emulsified are contained in an ordinary commercial 100 cc. graduated cylinder, 1 1/16 to 1 2/16 inches inside diameter. An oil or water bath is provided for maintaining the contents of the cylinder at a temperature of 130° F., except when a different temperature is specified, both during the stirring and subsequent settling out of the oil from the emulsion. The paddle used in stirring is a copper plate 4¾ inches long, between ¾ and ⅞ inches wide, and 1/16 inch thick. Means are provided for revolving this paddle about a vertical axis parallel to and midway between its two longer edges, and for keeping the speed fairly constant at 1500 r. p. m. Some form of holder for the cylinders is a convenience but not a necessity, since on account of the ample clearance between paddle and cylinder, and the fact that a sample is stirred for only 5 minutes, a cylinder may be held by hand during the stirring. A stop should be provided so that when the paddle is lowered into the cylinder (or bath raised), the distance from the bottom of the paddle to the bottom of the cylinder will be about ¼ inch. To save time otherwise lost in waiting for the filled cylinders to come to the temperature of the bath, it is desirable that the bath should be large enough to contain several cylinders.

"**Emulsion Test.**—Forty cc. of the emulsifying liquid is placed in a clean 100 cc. graduated cylinder and 40 cc. of the oil to be tested is added. The cylinder is then placed in the bath and when the contents have reached the temperature required for the test, they are stirred by the paddle for 5 minutes. The paddle is stopped, withdrawn from the cylinder, and wiped clean. The cylinder is then allowed to stand for the specified time and is then inspected.

"**Demulsibility Test.**—Pour 27 cc. of the oil to be tested and 53 cc. of distilled water into a cylinder, place cylinder in bath and heat to 130° F. Submerge the paddle and run it for 5 minutes at a speed of 1500 r. p. m. Stop the paddle, withdraw it from the cylinder and use the finger to wipe off the emulsion clinging to the paddle and to return it to the cylinder. Wipe off the paddle with paper so that it will not contaminate the next sample. Keep the temperature of the cylinder constant at 130° F. and take readings every minute of the position of the line of demarcation between the topmost layer of oil and the adjoining emulsion. The first reading is taken one minute after stopping the paddle. With oils which act normally, the rate of settling out of the oil increases up to a maximum and then decreases, and the maximum value, in cc. per hour, is called the 'demulsibility' and is recorded as the numerical result of the test. Each rate of settling is the average rate calculated from the time of stopping the paddle to the time of reading, as shown in the following condensed table.

Time	Time since stopping paddle	Reading at interface between oil and emulsion	cc. of oil settled out	Rate of settling cc. per hour
9.50	0	80	0	0
9.55	5	77	3	36
10.02	12	67	13	65
10.05	15	63	17	68
10.10	20	61	19	57

"The demulsibility in this case would be 68, the highest value in the last column. In case where the maximum rate of settling has not been reached at the end of one hour, the test is discontinued and the demulsibility taken as the number of cc. which settled out in the hour."

Phillips (*J. Soc. Chem. Ind.*, pp. 697-701, 1915) uses 500 cc. of oil and 500 cc. of water at 100° C., stirring being accomplished in a special apparatus by means of a high speed motor, the speed and time being specified. The oil-water mixture is run into graduated cylinder and the amount of separated oil read off after 24 hours' standing. The "demulsification value" is calculated from the percentage of oil separated as compared with the amount of oil taken. He states that in actual practice with over 700 samples a demulsification value of over 90 per cent. always proved satisfactory for turbine service. This "demulsification value" is not the same as Herschel's "demulsibility." An apparatus on the same principle as the two above is used by Bryan (*J. Am. Soc. Naval Engrs.*, 26, p. 559, 1914).

Conradson's method (*J. Ind. & Eng. Chem.*, pp. 166-167, 1917, and *Proc. Am. Soc. Test. Mat.*, Vol. XVI, Pt. II, 1916) is somewhat simpler, steam being conducted from a copper retort by means of a delivery tube to the bottom of a 250 cc. graduated glass cylinder containing 20 cc. of water and 100 cc. of oil. The oil is churned up by the steam for 10 minutes. The amount and condition of the oil, the emulsion and the water are noted after standing for one hour in a water bath at 130° F.

Emulsification tests have been made by shaking oil and water together in sample bottles or in test tubes, but the results are not satisfactory as the shaking is not vigorous enough unless a special mechanical shaker is used.

Holde and Schwarz have given emulsification tests for steam cylinder oils, in which equal parts of oil and water are shaken for one minute in a wide test tube at 185° F. Not over 1 millimeter of emulsion should remain after one hour at this temperature when 10 cc. of oil are used. Unless the condensed water is to be separated from the oil after use, the chief value of the test would be as an indication of the presence of soaps which might throw doubt on the accuracy of the viscosity test. Ashing the oil would give the same information. It is not known whether an emulsification is desirable or undesirable in the actual lubrication of a steam cylinder.

H. SPECIAL TESTS.

"**Wick Feed Test.** [Comm. on Stand. of Pet. Specific., April 16, 1920].—An oil container made of brass capacity of about one quart is fitted in the center with a brass tube of ½ inch internal diameter, which serves as an oil-way and which feeds into a graduated glass cylinder, where the quantity of oil fed by eight strands of worsted zephyr is measured. At the beginning of the test the wick should be dipped in the oil and the lift of the wick should be maintained at from ½ to ¼ inch. The wick should be supported by a copper wire bent in a hock which grips the outlet end of the wick below the level of the oil, as is the usual manner in a wick feed.

"The worsted zephyr shall be of the best quality, pure, long fibre, cream white fine wool, thoroughly washed, scoured and carded. It shall be in its natural condition; not dyed nor subjected to any chemical process. Strands shall be four ply soft spun and twisted. The separate plies shall be of uniform thickness throughout their entire length."

"**Protection.**—[Comm. on Stand. of Pet. Specif., April 16, 1920].—A clean polished steel plate 2 inches long, ½ inch wide, and ⅛ inch thick, is coated by immersing in the lubricant which has been heated to a temperature of 212° F. The plate is removed while still hot, allowed to cool in a vertical position, and suspended vertically within a ten per cent. salt solution."

CHAPTER XIV.

CHEMICAL METHODS OF TESTING LUBRICATING OILS.

Chemical methods are used to determine the nature and amount of impurities in oils, the true character of oils, and the behavior of oils under certain conditions of treatment, such as prolonged and excessive heating. Absence of chemical action and a high resistance to chemical change are desirable in lubricating oils.

A. FREE ACID.

Free acid, or acidity, is due to the presence of sulphuric acid from improper refining, to the presence of fatty acids in cylinder oils or other compounded oils, or to the development of acid in oil from exposure to heat and air. Straight mineral oil should show no acidity. Properly treated mineral oils are either neutral or slightly alkaline or show an alkaline ash. Compounded oils may develop acid by the decomposition of the fatty oils under heat.

Acids should not be present as they corrode iron, brass and other metals. Mineral acids are especially active in this particular, although fatty acids become very active and corrode metals rapidly at high temperatures. Not more than 0.2 per cent. of SO_3 or 2 per cent. of oleic acid should ever be present.

The American Society for Testing Materials Standard Test for Free Acid (D 47—1918) is as follows:

"Accurately weigh 10 g. of the oil into a flask, add 50 cc. of 95-per-cent. alcohol which has been neutralized with weak caustic soda, and heat to the boiling point. Agitate the flask thoroughly in order to dissolve the free fatty acids as completely as possible. Titrate while hot with aqueous tenth-normal alkali, free from carbonate, using phenolphthalein, alkali blue or tumeric as an indicator, agitating thoroughly after each addition of alkali.

"Express results either as percentage of oleic acid or as acid number (milligrams of potassium hydroxide required to saturate the free acids in 1 g. of fat or oil).

"1 cc. of tenth-normal alkali = 0.0282 gram of oleic acid. Alkali, 1 cc. of which is equivalent to 0.0099 g. of KOH, and 1 cc. of which is equivalent to 0.5 per cent. of oleic acid, may be used."

To calculate the "acid number" where N/10 alkali is used, multiply the number of cubic centimeters used in the titration by 5.6 and divide the result by the number of grams of oil used. If the acidity is to be reported in per cent. of SO_3, as for mineral acids, divide the acid number by 14. To calculate the acidity to "free oleic acid," as for compounded oils, divide the acid number by 2.

Sulphuric acid can be detected by shaking some of the oil with warm water and adding a few drops of barium chloride solution containing a little hydrochloric acid. A fine white precipitate shows the presence of sulphuric acid.

"**Corrosion.** [Comm. on Stand. of Pet. Specific., April 16, 1920].—A clean strip of pure copper about ½ inch wide and 2 inches long is heated to redness in a Bunsen flame and while red hot dropped into alcohol. The strip is then allowed to dry as quickly as possible in the air and dropped into a sample of the oil contained in a test tube. About half the length of the copper strip should be submerged. The test tube is then closed with a stopper and left to stand for 24 hours. At the end of this time, the copper strip is removed and washed clean with proper solvents. It is then compared with a similar strip freshly cleaned as previously described. No discoloration of the test strip should be shown by this comparison."

B. ASH.

Ash is only present in appreciable quantities in oils containing soaps, either as added soaps or naphthenic soaps unremoved in the refining. Well refined engine or motor oils do not contain over 0.02 per cent. ash, and cylinder oils seldom as much as 0.1 per cent. ash which should be practically free from alkali. If the ash is red it is chiefly iron oxide from the stills.

The ash is determined by carefully burning 20 grams of the oil in a platinum or silica dish and igniting until the carbon is burned out. Final ashing may be hastened by cooling the dish, adding a little solid ammonium nitrate and reheating. A platinum dish should not be used if the presence of lead soaps is suspected.

Mineral castor oil will contain weighable ash in proportion to the amount of aluminum or other soaps present.

C. SOAPS.

Lime or aluminum soaps can be detected by shaking the oil with weak hydrochloric acid solution and evaporating the solution before making the usual qualitative tests.

Alkali soaps are indicated by a pink color when the oil is shaken with water containing phenolphthalein, also by the tendency to form emulsions with water, and to "string" or "rope" when the stopper is removed from the bottle. Alkaline soaps yield an alkaline ash which can be titrated as given under greases.

Soaps can be determined quantitatively (*a*) from the ash by titration if alkali or lime is present, (*b*) by shaking the oil with dilute hydrochloric acid and determining the ash in the acid extract, or (*c*) the free acids liberated in the oil by shaking with the hydrochloric acid may be determined after thoroughly washing out all the mineral acid. This last is the better method as a very small amount of ash corresponds to a large amount of soap, particularly aluminum soaps. The free, fatty acids are not soluble in water but are soluble in oil, while the hydrochloric acid can be completely removed by shaking the oil with warm water. Emulsions formed by the warm water can be broken up by the addition of light solvents such as ether or gasoline. The acidity of the original oil as well as of the treated oil should be determined and the soap calculated from the difference between the two determinations.

D. HEAT TEST.

This test is used for oils which are to be subjected to heat, such as air compressor oils, turbine oils, motor oils, transformer oils and steam cylinder oils (for superheater). The oils are heated for six hours just below their flash points, usually 400° to 550° F., the temperature being kept at a definite point previously decided upon. The oil to be tested is put into dishes as for the Evaporation Test, or into glass sample bottles which are heated in an air-bath while air is blown through the bath. The oil is allowed to cool and any change in color is noted as well as the formation of any deposit. A very dark color with a heavy black precipitate on standing indicates much decomposition due probably to the presence of sulphur in an undesirable form. The oil is also dissolved in 88° Pennsylvania gasoline after heating and the amount of precipitate noted on standing. The best oils will dissolve clear without the formation of any sediment.

The higher temperatures (500° F. and over) are used for cylinder oils and steam may be blown through instead of air using an apparatus similar to Conradson's (see Index).

The heat test is supposed to have great value for motor oils as an indication of the amount of carbonization in practice. Studies have been made by Waters of "The Behavior of High-Boiling Oils on Heating in the Air" (*J. Ind. & Eng. Chem.*, pp. 233-237, 1911); on "The Effect of Added Fatty and Other Oils upon the Carbonization of Mineral Lubricating Oil" (*J. Ind. & Eng. Chem.*, pp. 812-816); and on the Oxidation of Automobile Cylinder Oils (*J. Ind. & Eng. Chem.*, pp. 587-592, 1916).

Waters conducts the carbonization test or heat test at 250° C. (482° F.) for two and one-half hours, and filters off the precipitate formed with petroleum ether after standing over night.

In connection with a modified Waters' Heat Test or Oxidation Test, as applied to Motor Oils, the following is quoted from C. W. Stratford (*Nat. Pet. News*, pp. 18, 24 and 26, March 20, 1918):

"In the light of the most recent study and exhaustive experimentation, the oxidation test appears to be the only dependable and satisfactory method by which the stability of oils can be predicted when they are used in service. The main facts shown by this test are the evaporation loss and the rate at which solid hydrocarbons are formed by polymerization or precipitation when oils are exposed to working conditions of an engine.

"In the oxidation test oils are exposed to a uniform high temperature and the surface of the oil under test is swept by a continuous current of air, thus duplicating actual conditions to be met with in an engine."

Oxidation Test.

"The apparatus for making the oxidation test consists of a cubical box constructed of heat-insulating material. Through the vertical axis of this box passes a shaft, at the corner of which is attached a disk of about 11 inches diameter. This disk and shaft are rotated at a speed of 25 r. p. m. The containers for oil samples are steel cups cut from the solid, 50 mm. inside diameter, plus or minus 0.04 mm.; and 50 mm. high, plus or minus 0.4 mm. The cup wall is 1 mm. thick. The oven is electrically heated by resistance coils, and the temperature is maintained constant and regulated by a thermostat. Air circulation is provided through holes in the bottom of the sides of the oven and through the top. The determinations made in this oven are:

1. Evaporation loss.
2. Petroleum ether insolubles.
3. "Varnish."

"Fifty grams of the oil are weighed into the cups, and these are placed at equal distances at the outer edge of the rotary disk. The temperature is brought to 225° C., and the test is continued at this uniform temperature for twelve hours, in two periods of six hours. The samples are then removed and allowed to cool, weighed, and the loss in weight (per cent.) recorded as evaporation loss. The contents of the cups are then washed through a Gooch crucible with standardized petroleum ether (see below) until the filtrate is colorless. From the crucibles on which remain the insoluble residue the petroleum ether is allowed to evaporate, after which they are introduced into a Freas oven and thoroughly dried at a temperature of 105° C. The weight of the residue is then determined and the percentage recorded as petroleum ether insolubles.

"When the metal cups have been thoroughly washed with petroleum ether there still remains a varnish-like residue, which clings to the upper walls. The weight of this substance is determined and recorded as 'varnish.'

"The real significance of 'varnish' values has not been clearly established up to the present. Poorly refined oils, however, also those from some mid-continent and from California crudes, usually show high "varnish" values.

"The maximum variation of checked results on evaporation loss and petroleum ether insolubles should not exceed 2 per cent.

"It has been found that the evaporation loss of an oil does not always coincide with its boiling-point range; therefore, it seems permissible to conclude that the evaporation loss is a measure of the decomposition of an oil, as well as of its volatility. In judging oils it is important to observe carefully the relation between the boiling-point range and the evaporation loss. For example, an oil may have a high boiling-point range, and yet, owing to its instability, may readily decompose when exposed to heat, and thus show a high evaporation loss.

"The petroleum ether insolubles indicate, on the one hand, the solid carbonaceous matter formed in an oil, which splits up, when exposed to heat, into light volatile ends and solid products. On the other hand, these insolubles may indicate the precipitation of coloidal carbon or other products in improperly refined oils. Values of petroleum ether insolubles may be entirely independent of those of boiling-point range or evaporation loss."

For the determination of petroleum ether insolubles the petroleum ether should be from Pennsylvania crude, of 77 to 80 Bé. gravity; initial boiling-point (Saybolt) 110°-120° F.; final boiling-point, 220° to 245° F.; unsaturated hydrocarbons not over 4 per cent. by absorption in sulphuric. (Bureau of Mines Method).

E. GASOLINE TEST.

This is a test for tarry matter, asphalt, gummy material, and other impurities. These substances may be present in the original oil or formed in some of the heat tests. Usually 5 cc. of the oil are dissolved in 95 cc. of Pennsylvania gasoline (88° Bé.) by shaking and the amount of turbidity noted as well as the amount of precipitate on standing one hour or longer. No precipitate or turbidity should be noticed with the best oils.

Steam cylinder oils and stocks should be found free from tar or suspended matter by this test. The gasoline test on the oil after heating often affords valuable information as to the changes which heat will cause in the oil.

"**Precipitation.** [Comm. on Stand. of Pet. Specific., April 16, 1920.]—Five cc. of the oil is mixed with 95 cc. of petroleum ether in a tall stoppered graduated cylinder and allowed to stand.

The petroleum ether must be freshly redistilled and the portion boiling above 150° F. discarded. It must not show perceptible solubility in concentrated sulphuric acid."

F. CARBON RESIDUE TEST.

This test, called also the carbon test, fixed carbon or coke test, is of no great value though it gives some information when used on oils which must eventually vaporize or burn, such as superheater cylinder oils, air compressor oils and motor oils. The figures obtained bear no relation to the amount of carbonization that will take place in an automobile cylinder, the heat test previously described being more closely related to actual carbon formation in practice.

"The carbon found in this test is formed from the cracking of heavy or non-volatile oils and indicates to some extent the stability of the oil under heat and the amount of undistilled oil present in the original oil.

"The American Society for Testing Materials Standard Test for Carbon Residue[1] (Conradson Method) (D 47—1918) is as follows:

"*Apparatus.*—The apparatus (see Fig.) consists of:

"(*a*) Porcelain crucible, wide form, glazed throughout, 25 to 26-cc. capacity, 46 mm. in diameter.

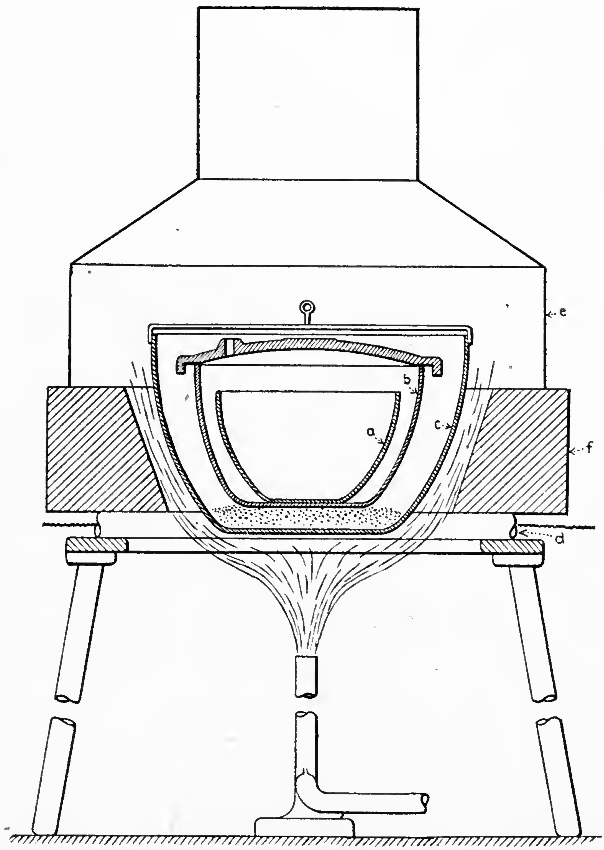
"(*b*) Skidmore iron crucible, 45-cc. (1½ oz.) capacity, 65 mm. in diameter, 37 to 39 mm. high with cover, without delivery tubes and one opening closed.

"(*c*) Wrought-iron crucible with cover, about 180 cc. capacity, 80 mm. diameter, 58 to 60 mm. high. At the bottom of this crucible a layer of sand is placed about 10 mm. deep or enough to bring the Skidmore crucible with cover on nearly to the top of the wrought-iron crucible.

"(*d*) Triangle, pipe stem covered, projection on side so as to allow flame to reach the crucible on all sides.

[1] This method is a modification by P. H. Conradson of his original method and apparatus for Carbon Test and Ash Residue in Petroleum Lubricating Oils. See *Proceedings*, Eighth International Congress of Applied Chemistry, New York, September, 1912, Vol. I, p. 131. Also reprint in the *Journal of Industrial and Engineering Chemistry*, Vol. 4, No. 11, November, 1912.

"(*e*) Sheet iron or asbestos hood provided with a chimney about 2 to 2½ in. high, 2⅛ to 2¼ in. in diameter to distribute the heat uniformly during the process.



Apparatus for Determining Carbon Residue.

"(*f*) Asbestos or hollow sheet iron block, 6 to 7 in. square, 1¼ to 1½ in. high, provided with opening in center 3¼ in. in diameter at the bottom, and 3½ in. in diameter at the top.

"*Method.*—The test shall be conducted as follows:

"Ten grams of the oil to be tested are weighed in the porcelain crucible, which is placed in the Skidmore crucible and these two crucibles set in the larger iron crucible, being careful to have the

Skidmore crucible set in the center of the iron crucible, covers being applied to the Skidmore and iron crucibles. Place on triangle and suitable stand with asbestos block and cover with sheet iron or asbestos hood in order to distribute the heat uniformly during the process.

"Heat from a Bunsen burner or other burner is applied with a high flame surrounding the large crucible, as shown in Figure, until vapors from the oil start to ignite over the crucible, when the heat is slowed down so that the vapor (flame) will come off at a uniform rate. The flame from the ignited vapors should not extend over 2 in. above the sheet iron hood. After the vapor ceases to come off the heat is increased as at the start and kept so for five minutes, making the lower part of large crucible red hot, after which the apparatus is allowed to cool somewhat before uncovering the crucible. The porcelain crucible is removed, cooled in a desiccator and weighed.

"The entire process should require about one-half hour to complete when heat is properly regulated. The time will depend somewhat upon the kind of oil tested, as a very thin, rather low-flash-point oil will not take as long as a heavy, thick, high-flash-point oil."

G. DISTILLATION TEST.

The author has found this test of value for determining the general nature of an oil. An ordinary Engler distilling flask, about 125 cc. capacity is used, as for kerosene and gasoline distillation, using a medium sized glass tube as a dry condenser. The flask can be wrapped in asbestos cloth if desired, though a very strong flame is necessary toward the end of the distillation. The addition of as much as 12 or 15 per cent. of steam cylinder stock to a distillate can be detected by noting the temperature at which the last portion distils. Another procedure would be to distil off 90 per cent. of the oil and note the character of the residue.

The following quotation and method for motor oils are from C. W. Stratford (*Nat. Pet. News,* pp. 18 and 24, March 20, 1918):

"The distillation of finished oils under a high vacuum offers an unfailing means of determining their constituents; that is, of what groups of hydrocarbons, highly volatile or less volatile, the finished oils may consist. This test is a useful supplement to the oxidation test.

"Fractionation under conditions of high vacuum is an excellent method of making an approximate analysis of finished lubricating oils, since it permits of separating the volatile from the less volatile portions in graduated fractions. When oils show high evaporation loss the oxidation test alone cannot explain the reason for this loss. Evaporation may occur because of natural volatility or because of the occurrence of "cracking," that is, decomposition of the oil into light portions and heavy liquid or solid hydrocarbon residuals."

Boiling-Point Range.

"The apparatus for making this test consists of a special steel still and vapor tower, a special water-cooled condenser and chamber for the distillate receivers. The position of these receivers can be adjusted from the outside without alteration of the pressure in the distillation system. The distillation system is connected with a pump capable of maintaining a vacuum of 2½ mm. absolute and having a capacity of 6 cubic feet per minute.

"The still is charged with 2,000 cc. of the oil under examination. The standard vacuum, 40 to 50 mm. absolute, is established throughout the closed system, and heat applied to the bottom of the still. For the purpose of specification it will be necessary to carry the distillation only to the point at which the still temperature has reached 300° C. (572° F.) The percentage of distillate up to 300° C. has been arbitrarily taken as a basis for judging the relative volatility of different lubricating oils. However, for the ultimate analysis of finished lubricating oils, the distillation may be continued up to the point where nine-tenths of the total charge will have passed over, the rest being allowed to remain in the still, and estimate as residual.

"The fractionation of finished lubricating oils under high vacuum is a satisfactory way of determining boiling-point limits with the least decomposition. The quantity of law-boiling-point fraction varies widely in lubricating oils intended for use in different types of internal-combustion engines. All engines that operate under approximately full load and at high temperatures (aviation engines should contain a minimum quantity of low boiling point fractions, say 4 per cent. distilling under 300° C. The results obtained by actual tests in aircraft engines clearly demonstrate this point. On the other hand, passing from such conditions of high operating temperatures to those of widely varying and comparatively low operating temperatures (passenger cars and trucks), it is necessary to increase materially the quantity of low-boiling point fractions to prevent serious carbonization. There is a limit, however, to the addition of low-boiling point fractions, for the reason that too large a quantity will greatly increase the specific consumption of the lubricant in service, hence some mean value must be fixed upon, a permissible balance being struck between carbonization and high consumption. An analysis of the most successful automobile oils now sold shows that not over 30 per cent. of the oil should distill below 300° C. in the vacuum distillation apparatus described. This volatility is a guarantee of a reasonably low specific consumption, good lubrication and minimum carbonization within the explosion chamber."

H. SAPONIFIABLE FATS.

A determination of the Saponification Number, as given for Fatty Oils, is made on a 5-gram sample, using 25 cc. of the alcoholic potash solution and 25 cc. of benzol to aid solution. Since the average saponification number of most oils is 190, the per cent. of fatty oils can be calculated by dividing the saponification number by 1.9. The saponification number of mineral oils is zero.

This method is suitable for getting the per cent. of fatty oil used in compounding cylinder oils and marine engine oils. Where unblown rape oil is used for compounding, or where rosin oils are present, the results are not exact. For the detection of rosin or rosin oils, see Index.

For heavy or dark cylinder oils, 50 cc. of benzol and an extra 25 cc. of alcohol may be required to get the oil properly dissolved for complete saponification.

A working knowledge of the kind of fatty oils used in compounding cylinder oils can be gained by a comparison of the per cent. of fatty oil found with the results by the Maumené test or by the iodine number. Also the mineral oil can be dissolved out with ether after converting the fatty oils to soaps by means of caustic potash and tests made as given under Greases.

"**Fatty Oil.** [Comm. on Stand. of Pet. Specif., April 16, 1920.] —Solutions required: (*a*) Approximately half-normal alcoholic potassium hydroxide. Dissolve 33 grams of potassium hydroxide sticks (or an equivalent amount of sodium hydroxide sticks) in 1000 cc. of purified 92-95 per cent. ethyl alcohol. Allow to settle and filter.

"(*b*) Purified Benzene. This may be prepared as follows: To 1000 cc. of '90 per cent. benzol' add a stick of sodium hydroxide, boil for an hour, using a condenser loop inside the neck of the flask. Transfer to a large separatory funnel and add sufficient water to cause the liquid to separate into two zones. Draw off the lower zone and discard. Wash the benzene with water once. Transfer the washed benzene to an Engler distillation flask and distill up to 82 degrees C., discarding the residue.

"(*c*) Standard solution of half-normal hydrochloric acid.

"(*d*) Phenolphthalein Indicator. Dissolve one gram of phenolphthalein in 100 cc. of 95 per cent. ethyl alcohol.

"(*e*) Neutral gasoline.

"*Saponification:* Weigh 10 grams of oil into a 350 cc. Erlenmeyer flask. Add from a pipette 50 cc. of the alcoholic potassium hydroxide solution followed by 25 cc. of the purified benzene (C_6H_6). Connect with a condenser loop. Boil on steam bath or electric hot plate for 90 minutes, shaking occasionally. Remove and add 25 cc. of neutral gasoline, and titrate with the half normal hydrochloric acid solution, after adding 2 or 3 drops of the phenolphthalein indicator solution until the pink color is destroyed. The absence of the pink color may be determined after the titration has begun, by allowing the solution to stand at rest, approximately a minute and noting the color of the lower zone. Run two blanks with the same mixture of alcoholic potassium hydroxide solution and purified benzene. From the difference between the number of cubic centimeters of half-normal acid required for the blanks and for the determination, the percentage of fatty oil may be calculated as follows:

$$\frac{\text{No. of cc. N/2 acid used x .02805 x 100}}{\text{.195 x weight of oil taken}} = \text{per cent. of fatty oil.''}$$

I. MAUMENÉ NUMBER.

This is the rise in temperature (in °C.) when 10 cc. of strong sulphuric acid are run into 50 cc. of oil. (For method, see Index.) The Maumené number of mineral oils is usually from 3 to 8. The addition of fatty oil raises the Maumené number in proportion to the amount and character of such added fatty oil. The test is short and can yield considerable information, as in distinguishing cylinder stocks from compounded oils.

J. IODINE NUMBER.

The determination is made by the Hanus method on a 1-gram sample as given under Fatty Oils (see Index). The iodine number of uncracked mineral lubricating oils varies from 6 to 15. Sometimes iodine numbers of 20 are met with for pure mineral oils, the value increasing with the amount of cracking. The iodine value is increased by the addition of fatty oils in proportion to their amount and nature.

(See paper on "Iodine Number of Linseed and Petroleum Oils" by Tuttle and Smith, *J. Ind. & Eng. Chem.*, pp. 994-998, 1914, or *Tech. Paper No. 37* of the Bureau of Standards).

H. Moore (*Engineer*, 120, p. 176, 1915) considers the iodine number a good indication of possible acid formation in Diesel air compressor oils in use.

K. SULPHUR.

The amount of sulphur seems to have an important bearing on the breaking down of motor oils and the development of acidity and emulsifying properties in oils used in circulating systems, such as turbine oils.

Sulphur may be determined by burning 10 grams of the oil, absorbing the products of combustion in standardized sodium carbonate solution and titrating the excess of alkali with standard mineral acid in the presence of methyl orange. Since much of the sulphur remains in the wick, the wick should be ashed with a little dry sodium carbonate, concentrated nitric acid and magnesium nitrate and determined gravimetrically after further oxidization in solution by means of bromine. Conradson considers the nature of the sulphur of as much importance as its amount. (See "Apparatus and Method for Determining Sulphur in Petroleum Illuminating and Lubricating Oils," *J. Ind. & Eng. Chem.*, pp. 842-844, 1912; also pp. 175-176, 1912; and *8th Int. Cong. Appl. Chem.*, I, pp. 133-136, and XXVII, pp. 19-20).

For Allen and Robertson's method for sulphur see Bureau of Mines Tech. Paper No. 26. For Water's "New Method for the Determination of Sulphur in Oils," see *J. Ind. & Eng. Chem.*, pp. 482-3, 1920.

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CHAPTER XV.

LUBRICATING GREASES.

Greases are used for lubricating bearings where the pressures are too great for successful oil lubrication; for lubricating difficultly accessible parts of machines; for preventing undesirable splashing as in certain greases for cotton mills; for preventing waste of lubricant from poorly housed bearings; and for reducing the cost of lubrication by reducing the attention required and the amount of lubricant fed to the bearings.

Greases are made in varying consistencies, or in varying degrees of hardness, to suit different purposes, from the soft compression cup or rod cup greases to the solid greases used for locomotive journals.

The most usual type of lubricating grease to-day is the soap-thickened mineral oil type. Practically all the greases met with in general lubricating practice are made by combining mineral oils of different grades with varying amounts of lime soaps, soda soaps, or other soaps. The texture of these greases is influenced by the character of the mineral oil, the kind of soap (as soda or lime), the amount of soap, the kind of fatty oil from which the soap was made (such as tallow, etc.), by the presence of free fatty oils, by the presence of water in the grease, and by the process of manufacture.

Cup Grease.—Cup greases are nearly always lime-soap greases, from 12 to 23 per cent. of lime soaps being present combined with a mineral oil distillate of low or medium viscosity. The general practice is to use very thin oil which may not give enough lubricating body to the grease for heavy work. Water is generally present from traces up to 1 per cent. The small amount of emulsified water, usually less than 0.4 per cent., is added to give the proper consistency to the grease and to prevent ultimate separation of the lime-soap and the mineral oil. The effect of much water is to make the grease softer, so excessive amounts of water are seldom found since the addition of the water is not economical to the manufacturer. Water also makes the grease opaque and lighter in color.

In connection with the colloidal character of greases, see paper by Holde on "The Physical Condition of Machine Greases, Oil Solutions of Lime Soaps and Heavy Mineral Oils" (*Z. angew. Chem.*, 31, pp. 2138-44; or *Chem. Abs.*, pp. 123-125, and 726-727, 1919.) See also *Chem. Abs.*, p. 1476, 1920.

In making cup greases it is important that only sufficient lime be used to saponify the fat or fatty oil used, otherwise the grease will contain free lime which might attack some kinds of bearings, *e. g.*, brass bearings. There should be no uncombined fatty acids in the grease, but fatty oils have only a beneficial effect on the bearings in the absence of fatty acids.

The cup greases, or lime-soap greases, are somewhat more generally used than the soda greases. Cup greases are often blended with graphite or mica. This may or may not be good practice depending on the amount and nature of such additions and the purpose for which the grease is to be used. For heavy machinery, mica and graphite are often advantageous, though the tendency is to use excessive amounts .

Soda Grease.—These greases are made by dissolving soda soaps in hot mineral oils. Heavier oils are generally used than in the cup greases, although light oils are also used. The oils used are paraffin oils, engine oils and cylinder stocks. Soda greases have a better reputation than lime-soap greases on account of the presence of heavier oils and on account of freedom from any tendency to separate into soap and oil. Where soda greases are free from water they can be melted and cooled down without separation.

The soda greases are generally known as "fiber" or "sponge" greases on account of their peculiar texture.

Gear greases or gear compounds are soda greases or sponge greases in which the soap is of a stringy character and the oil is a heavy, dark oil or cylinder stock. On account of the viscous nature of the oil these greases show good adhesive properties and a good cushioning effect.

For special purposes, some of the stiff, heavy soda greases may contain up to 50 or even 60 per cent. of soaps for heavy bearings or journals carrying heavy loads.

Soda greases should not contain any uncombined caustic. Ordinarily, however, there is no special difficulty involved in making a neutral product.

Greases should not ordinarily be stiffer than absolutely necessary as stiff greases use up power to a marked extent.

Non-Fluid and Soap-Thickened Oils.—The non-fluid oils or solidified oils are made by combining from 0.5 to 7 per cent. of suitable soaps (lime, aluminum, lead or soda soaps, alone or mixed) with light mineral oils, such as paraffin oils. These treated oils vary in consistency from the soft pastes used for rod cups down to thick oils. Mineral castor oil is made by dissolving from 2 to 5 per cent. of aluminum soaps in a light paraffin oil, the effect being to give a stringy character to the oil and greatly increase its apparent viscosity. The real viscosity of such oils cannot be determined at low temperatures without first removing the soap.

Thickened oils and grease pastes or jellies have many advantageous applications as they can be made of fairly low melting points for use in cups where a slight increase in temperature will cause them to flow to the bearing. One of the special uses is for "comb box" grease and non-splash oils in cotton mills to prevent the lubricant from damaging the fabric.

Axle Grease.—This grade of grease is usually made from lime and rosin oil, with or without the addition of mineral oil. The lime combines with the acids in the rosin or rosin oil forming a "soap" which thickens the oil so as to form a grease. Usually more lime is used than is required to combine with the rosin acids, the excess lime remaining as a filler. Mica, talc, soapstone, and other powdered substances are also added to this grade of grease. Axle grease is only suitable for rough work, such as for use on iron bearings.

Rosin consists mainly of organic acids and is soluble in hot petroleum oils. Rosin oil, made by distilling rosin at a high temperature (above 360° C.), contains up to 40 per cent. of organic acids. The oil high in acids is most suitable for grease making. The method of manufacture is either to stir the dry slaked lime into the cold rosin oil and let it "set" without any further stirring or agitation, or to make a cream of the slaked lime with water, this cream being stirred into the rosin oil. In this latter case the water is expelled during the rapid setting of the mix and mineral oil is then stirred in after running off the water.

Rosin greases usually contain either small amounts of water or about 20 per cent. of water.

Petroleum Grease.—Heavy petroleum residuum, after the lighter oils are distilled off to a very high temperature, is more or less solid at ordinary temperatures, has a very high fire test and a high viscosity even at elevated temperatures. It can be used directly as a hot neck, cold neck, or pinion grease, or it can be mixed with various pitches and tars for similar uses. The pinion greases are the thinner grades. These grades have high adhesive properties, particularly in the absence of water.

The thinner products containing tar, pitch, rosin and similar substances, find many applications, such as for ropes, chains, cables, gears, etc., where a cheap material is essential. They are not suitable for light fast-moving gears on account of power losses.

Petroleum grease may also be made by blending solid petrolatums, such as vaseline, with high viscosity mineral oil. Such products, whether blended with vaseline, paraffin, or tallow, have low melting points and are not to be compared with the soap-thickened greases for general uses.

ANALYSES OF GREASES.
(By the author.)

	Medium cup grease	Cup grease	No. 3 cup grease	Soft comb-box grease	Rod-cup grease	Trans-mission gear grease
Flash point (°F.)	365	345	355	360	305	540
Melting point (°C.)	83	85	83	77	—	High
Water (%)	0.4	tr.	Pres.	0	0	0
Lime soaps (%)	19.7	21.2	13.4	0	7.5	0
Soda soaps (%)	0	0	0	2.3	0	12.5
Fatty oils (%)	2.4	9.1	—	0	0	0
Gravity (°Bé.)	—	—	—	25.2	28.2	—
Gravity of oil (°Bé.)	27.7	—	—	—	31.4	25.6
Viscosity of oil (100°F)	104	—	—	—	58	High

Analyses of other greases showed from 3.2 per cent. of lime soaps for a non-fluid oil and 3.9 per cent. soda soap in a pale yellow elevator grease to 48.4 per cent. soda soap in a grease for use on laundry machinery.

COMPOSITION OF SOME GREASES.
(Gillett.)

	Flash point °C. (Open cup)	Melting point, °C.	Consistency Gms., 20 °C.	Water (%)	Calcium soap (%)	Other thickeners (%)	Mineral oil	Fatty oil	Free acid	Maximum rise in bearing temp. (°C.)	Average coefficient of friction
Graphite	195	93	18	tr.	11	16	56	17	0	53	0.097
Summer motor	160	87	170	tr.	38	—	36	25	tr.	39	0.075
Winter motor	175	86	7	tr.	23	—	40	37[5]	6.1	42	0.063
K_1	193	85	24	0.2	16	—	67	16	0	38	0.057
K_2	195	93	66	0.3	20	—	60	20	0.3	39	0.054
Auto	190	79	11	1.0	19	—	60	20	tr.	32	0.046
Tallow A	210	52	(150)	2.5	—	1.4[1]	22	73	0	22	0.022
Tallow XX	215	49	200	tr.	30[7]	2.1[1]	20	48	0	25	0.029
Lead rosin oil	240	102	7	24.7	—	1.7[2]	—	0	0	40	0.067
Lime rosin oil	198	77	31	tr.	—	9.9[3]	—	0	0	42	0.048
Lime rosin oil	198	75	4	20.0	—	7.8[3]	—	0	0	29	0.036
Soda grease	215	83	35	0	—	22.[4]	78[6]	0	0	17	0.019
Non-fluid oil	210	76	27	0	9.8	12.9[4]	70	7	0	25	0.026
No. 4 petrolatum	247	47	6	0	—	—	100	0	0	16	0.018
Lard oil	265	5	0	0	—	—	0	100	—	7	0.011

[1] Potash soap. [2] Lead (soap). [3] CaO. [4] Soda soap. [5] Mainly palm oil. [6] Oil of 24.2°Bé. [7] Paraffin.

Gillett ("Analysis and Friction Tests of Lubricating Greases," *J. Ind. & Eng. Chem.*, pp. 351-360, 1909), classifies commercial greases as follows:

"A. The tallow type: These greases are made up of tallow and more or less of an alkali soap, commonly the sodium or potassium soaps of palm oil, mixed with a smaller amount of mineral oil. These were the principal types of lubricating grease ten or twenty years ago, but to-day are less used than the greases of type B.

"B. The soap-thickened mineral oil type: These are the most common journal greases to-day, and are composed of mineral oil of various grades made solid by the addition of calcium or sodium soaps. Calcium soap is more used than sodium.

"C. Types A or B with the addition of a mineral lubricant—usually graphite, mica, or talc.

"D. The rosin-oil type: These consist of rosin oil thickened by lime, or less commonly, litharge, to which is added more or less mineral oil, either paraffin or asphalt oils being used. These are sticky, usually contain 20-30 per cent. of water, and find their chief application as gear greases where true lubrication is not so essential as prevention of wearing and rattling of the gears. Some very heavy bearings are occasionally lubricated with this type of grease. Tar, pitch, graphite and such fillers as wood pulp and ground cork are often put into these gear greases.

"E. Non-fluid oils: These are thin greases stiffened to some extent with aluminum oleate or a mixture of soaps, as sodium and calcium.

"F. Special greases, such as mixtures of wood pulp and graphite, thin greases of any of the above types mixed with wool or cotton fibers, hot-neck greases, freak greases containing rubber, etc.

"Of these A, B and C are the most important as lubricants.

"The analysis of a lubricating grease may have one of two objects in view: to duplicate the grease, or to determine its value as a lubricant. Without resorting to mechanical tests of the actual friction reducing power of the grease in question, the first is probably the easier problem."

Gillett gives the analysis of a number of greases (see above) and the friction tests on a small Thurston testing machine fitted with a compression grease cup. In connection with these tests which were made at a pressure of 60 pounds per square inch of projected bearing area and a speed of 310-320 revolutions per minute, he makes the following statements:

"The general behavior of a grease during the run (3 hours) was as follows: At first the coefficient of friction would be high, and the temperature would rise rapidly. In the case of a hard grease, as a rule, this would continue until the thermometer showed some certain temperature, nearly up to the melting point of the grease. The surface of the bearing probably did reach that temperature, although the thermometer did not register quite that temperature, as there was some chance for radiation.

"After the grease had apparently melted, and the bearing was then in the state of an oil-lubricated bearing, the coefficient of friction would momentarily fall off, sometimes to a very low figure, and the temperature would drop rapidly. Then the grease would seem to stiffen again, and the coefficient and temperature would immediately rise again. The graphite grease shows this behavior to the greatest extent. This would go on for perhaps an hour, when a condition of equilibrium would be established, and a fairly constant reading would be attained.

"Since the friction cannot be reduced till the temperature of the bearing has risen enough for the grease to melt, or at least to be softened so it can flow over the bearing, it follows that other things being equal, the grease with the highest melting point will produce the highest coefficient of friction. Hence the lowest melting grease that will stay on the bearing will have the lowest coefficient of friction, which is only another way of saying that a grease already melted, *i. e.,* an oil, will give the best results wherever it can possibly be used.

"There is no direct proportionality between the results of the determination of any one analytical constant and the lubricating power, though there seems to be an approximate relation between the melting point and the friction reducing power, as would be expected. The relation, however, is not close enough to allow us to predict the lubricating value from the melting point without taking the chemical composition and the physical constants into consideration.

"The graphite grease showed an unexpectedly low lubricating power, and would be best fitted for a gear grease. The rosin oil greases, which are usually considered to be very poor lubricants, showed high friction at first, but after the bearing had warmed up enough to soften them somewhat, they compared well with the more expensive greases. The high moisture content of most of these greases would seem to be no drawback, but rather an advantage in rendering them less sticky.

"It will be noted that the lime soap greases, the most common type to-day, do not give as good results as the older, though more expensive tallow greases. It will also be seen that the greases compounded with soda soaps are better lubricants than those compounded with lime soaps."

In connection with the above tests, it might be well to caution the reader against drawing too sweeping conclusions, either for or against any one of the greases mentioned, when used under radically different conditions of pressure and friction speed than those used in the tests. (Cf. also Gillett, Power & Engineer, 32, 1998-2000; Ch. A. **5**, 991, 1911.)

The following quotations are taken from pages 5, 11, 61, 62 and 63 of The University of Missouri Bulletin, Eng. Exp. Sta., Vol. 4, No. 4, 1913, by A. L. Westcott on "Friction Tests of Lubricating Greases and Oils:"

"While grease lubrication is applicable to all sorts of machinery except steam and gas engine cylinders, it has its own special field where it has a marked advantage over oil. This field is machinery whose operation is intermittent, such as cranes and hoisting machinery. Grease cups of proper design will supply ample lubrication to the bearings of such a machine. They require no attention except to fill with grease when empty and, if of the hand compression type, to force grease into the bearing perhaps once or twice a day. No lubricant is wasted when the machine is not in operation, as is likely to be the case if sight feed oil cups and liquid lubricant are used.

"The effect of a rise of temperature upon the coefficient of friction is almost always the same. The curves show this very clearly. The fluidity of a lubricant is increased by warming it, and its viscosity is decreased. This results in decreased friction up to that point where the bearing pressure is sufficient to overcome the tenacity of the oil film, so that there is contact between the rubbing surfaces. The tests do not indicate that, within the limits of bearing pressure which obtained, there is any disadvantage or danger of cutting the bearing incident to a temperature of 150 degrees F. In some instances the temperature was carried as high as 200 degrees, and as long as there was an ample supply of lubricant to the bearing, no harmful effects were noted. The "hot box" of practice occurs because the lubrication of the bearing has failed; the former being the effect of increase of friction due to the latter. There is nothing intrinsically objectionable in a bearing temperature much higher than is commonly permitted in practice, if good lubrication obtains; and these experiments show that much may be gained in the way of decreasing the lost work of friction.

"The tests of series C served to show that the oil hole method of applying grease to the bearing is inferior to the method of forcing it in by means of a grease cup, the coefficients of friction in the former case being much larger than in the latter."

"Lubricating oils are compared by means of certain physical tests; prominent among these is the test for viscosity. The viscosity of an oil is determined by means of a viscosimeter, several forms of which are in common use. A common form consists of a vessel to contain the oil, surrounded by a space which may be filled with water for the purpose of controlling the temperature. At the bottom of the vessel is a nozzle, through which a measured quantity of oil is permitted to flow. The viscosity is proportional to the time required for this quantity to flow through the nozzle.

"It seemed to the writer that a similar scheme might be employed for the purpose of comparing greases as to their consistency, or density. As grease is a solid and therefore will not flow of itself, some compulsion must obviously be used to force the grease through the nozzle. After some preliminary experimentation, the apparatus shown in fig. 40 was constructed. This consisted of an ordinary grease cup supported upon an iron framework. A plunger was made to fit the cup closely. To insure perfect freedom of motion, the plunger was made slightly spherical. The plunger rod was carried through a guide, and supported weights placed upon its upper end. A scale graduated in twentieths of an inch was scribed on the rod, so that the time of descent over a measured distance might be noted. A nozzle of about ¼-inch diameter was placed in the bottom of the cup.

"Experiments with this instrument gave results that were, to the writer, decidedly surprising. It was found that the density of a given grease, as indicated by this means, is a very variable quality. Successive passages of the same grease gave constantly decreasing lengths of time for the same distance. The grease became softer and more fluid by the process of forcing it through the nozzle. This was particularly true of the harder greases. After several passages, the grease became oily in appearance. The change may be due to a more thorough mixing of the ingredients composing the grease.

"The results of a number of tests of grease with this instrument are given below.

DENSITY TEST, X GREASE, No. 1 DENSITY.

The same grease sample was passed repeatedly through the nozzle. The weight on the plunger was 20 lb.; temperature of grease, 71 deg. F.

No.	1	2	3	4	5	6	7	8	9	10	11	12	13
Seconds to descend 1 in.	3750	235	95	66.2	57.4	36	27.2	23	19	19	16	24	15

The time became nearly constant after eight passages; the mean of Nos. 9, 10, 11, 12, 13 is 18.2 seconds.

A second test was made several days later, on the same grease sample as the preceding; load on plunger, 20 lb.; temperature of grease, 68 to 72 deg. F.

No.	1	2	3	4	5	
Seconds to descend 1 in.	17	12.6	14.2	13.8	14	mean time of last four, 13.6

The load was changed to 10 lb. and continued on the same grease sample as above; temperature of grease, 62 to 65 deg. F.

No.	1	2	3	4	
Seconds to descend 1 in.	572	670	597	593	mean time, 608

DENSITY TEST, Y GREASE, No. 3 DENSITY.

A sample of the grease was passed through the nozzle 18 successive times with weights of 20, 15 and 10 lb. The temperature of the grease was 82 deg. F. at the start, increasing to 92 deg. F. at the end.

LOAD, 20 LB.

No.	1	2	3	4	5	6	7	
Seconds to descend 1 in.	50	17.4	13	3.4(?)	6.4	6.8	5.2	mean time of last three, 6.1

LOAD, 15 LB.

No.	8	9	10	11	12	13	
Seconds to descend 1 in.	15.8	16	12	11.4	11.6	9.6	mean time of last four, 11.1

LOAD, 10 LB.

No.	14	15	16	17	18
Seconds to descend 1 in.	159	131	129.6	97.8	95

DENSITY TEST, Y GREASE, No. 1 DENSITY.

No.	1	2	3	4	5	6	7	8	9	10	11	12	13
Load, lb.	10	5	5	5	5	5	5	5	4	4	3	3	3
Seconds to descend 1 in.	3.2	23.6	31	18	27.4	25	23.8	19.8	57	59.4	273	250	267

"Tests numbers 2, 3, 4, and 5 were made on successive samples of grease taken from the can. Numbers 6 and 7 were repetitions of grease that had been passed once through. Similarly, 11 and 12 were new grease, while 13 was the second passage. It will be noted that for this very thin grease, no very great change occurs with successive repetitions of the test on the same sample. The time for number 6 is almost exactly the same as the mean of the preceding four.

"The consistency of grease as shown by the experiments described above becomes nearly constant after several passages through the apparatus at a constant load; but it appears that when the load is changed, the grease again requires a number of passages before coming to a constant condition of consistency. It is interesting to note the great effect produced in the time of flow of the grease by a small change in the weight. Thus, in the last test, Y grease No. 1, the time was increased about 450 per cent. by decreasing the load from four to three pounds.

CONCLUSIONS

"Grease lubrication compares favorably with oil where the form of bearing is such as to favor the retention of the film of lubricant, and provision is made for an ample supply to the bearing. But, as shown by the experiments of series A, oil will give better results in a bearing which is short in proportion to its diameter.

"Grease of soft consistency is a much better lubricant than the harder densities of the same grease. The advantage of the softer grease is especially marked at low temperatures such as usually obtain in a well lubricated bearing.

"The best method of applying grease to a bearing is by a forced feed and a constant rate of flow. This agrees with the best practice in oil lubrication, where the bearing is flooded with oil, which passes to a filter and is then used over again. The drawback in case of grease, is the problem of cleaning it after it has passed once through the bearing, so that it could be used over again.

"Grease cups with spring actuated plunger are designed to give a constant flow of grease. They are far from accomplishing this purpose, however. When such a cup is full of grease, the spring is compressed to its maximum amount and the pressure upon the grease is therefore much greater than when the cup is nearly empty. Provision is made to regulate the flow by means of a small cock placed in the outlet of the cup, but this needs adjustment as the cup empties and is apt to be neglected. If the setting is right when the cup is filled the bearing will be insufficiently supplied when it is partly emptied. The experiments upon grease consistency show what a great difference in flow is produced by a small change in the pressure upon the grease. A design of cup is desirable which will deliver the grease at a constant rate from the time it is filled until it is empty."

CHAPTER XVI.

METHODS FOR TESTING AND ANALYSIS OF GREASES.

On account of the great variety of greases much must be left to the judgment and ingenuity of the analyst. Reference should be made to the chapters on Methods of Testing Lubricating Oils and Animal and Vegetable Oils for the identification of oils extracted from the grease. The kind of fatty oil used in making up the grease can be determined with reasonable certainty where only one kind of fatty oil has been used. If a mixture of fatty oils has been used the identification is much more difficult and less certain.

Preliminary Examination.—Much may be learned by noting the color of the grease, and by noting its odor particularly during the determination of the flash point. The presence of tallow, of rosin and rosin oil and of certain other oils may often be detected by the odor of the warm grease. Greases made from low grade fats or tar oil often have some scenting material added, such as oil of mirbane (nitro-benzol). Very pale greases ordinarily contain thin oils, such as low viscosity paraffin oils. If the grease is completely soluble in ether or gasoline, no soaps are present, and water would be shown by a turbidity of the solution if present in appreciable quantities. The presence of soap can also be detected easily by burning a little of the grease on a platinum crucible lid, or in a crucible. If any ash is present soap is indicated and the kind of soap (lime or soda, etc.) can be found by testing in a flame on a platinum wire with hydrochloric acid.

The taste of grease is often characteristic, but misleading tastes may develop on the surface exposed to air and light.

PHYSICAL TESTS.

The chief physical tests are determination of the melting point, flash point, consistency, and the water content.

Melting Point.—This is the most important single determination, particularly for all kinds of cup greases. The melting point is chiefly dependent on the amount of soap present, the kind of soap (lime or soda, etc.), the kind of fat from which the soap was made, the nature of the mineral oil used (if very heavy), and the amount of water present and its condition. Greases of high melting point show high coefficients of friction on testing machines and in service.

Gillett uses the following method: A piece of open glass tubing 8 centimeters long and about 0.4 centimeter internal diameter is stuck into the grease so that a plug of grease 1 centimeter long is left in the glass tube. The tube is then attached by a rubber band to a thermometer so that the grease plug is even with the bulb. The thermometer with the tube attached is then immersed in a beaker of water so that the bottom of the plug is 5 centimeters below the surface. The water is then heated at the rate of 3°-4° C. per minute. When the melting point is reached, the plug, which is under a pressure of 5 centimeters of water, slides upward in the tube. Checks can be obtained to 0.5° C., and slight variations in diameter of tube, depth of immersion, length of plug, and rate of heating would rarely cause more than 1° variation from that obtained by the prescribed procedure.

The melting point can also be determined by putting the grease in a capillary tube closed at one end and noting the temperature at which the grease becomes transparent when heated in a water bath. If the grease is melted in order to get it into the tube the melting point determination should not be made for several hours, as a freshly melted grease would give a different result from the original grease. The so-called dropping point can be determined roughly by smearing some of the grease on the bulb of a thermometer and heating the thermometer in an air bath. The reading can be taken when the grease runs down to the end of the bulb or when it actually drops from the bulb. The amount of grease used causes variation in the temperature reading.

Greases do not melt sharply as a rule, so that the temperature at which they soften sufficiently to flow under a suitable small pressure seems the most logical and definite point to designate as the melting point.

Often much information of value may be obtained by putting some of the grease on a wire gauze and holding high over a gas flame. The melting point is roughly indicated, and any tendency for the grease to separate will be shown by the oil running through the gauze leaving most of the soap behind.

Flash Point.—The flash point can be taken with any good open-cup tester, or by putting the grease in a 50 cc. porcelain crucible which is placed in a sand bath and heated at the rate of 5° C. per minute, a small testing flame being applied every 3° C.

The flash point gives an idea of the grade of mineral oil used without going to the trouble of actually extracting the oil. Ordinarily the thin oils have correspondingly low flash points.

Consistency.—This property of a grease or fat is determined by using a special apparatus which is essentially a pointed rod of a certain weight and shape, and noting the weight required to cause the rod to sink 1 centimeter into the grease at 20° C. (68° F.). Sometimes the reading is obtained by taking the time required for the rod to sink a certain distance into the grease under a definite weight. This test has no special bearing on the lubricating value of the grease, but has importance in connection with the use of the grease in compression cups, etc. (See Index).

Water.—The water content of greases is important and necessary in order to give them the proper texture. This is particualrly true for lime-soap greases, but only very small amounts of water are necessary if properly emulsified. The moisture can be determined by heating in an air bath at 110° C. until all frothing ceases. On account of the presence of volatile hydrocarbon oils, this method gives from 0.5 to 2 per cent. too high, depending on the character of the mineral oil and the amount of moisture present. The heating should be as brief as possible.

Where very exact work is required, Gillett (*J. Ind. & Eng. Chem.*, p 356, 1909), recommends Marcusson's xylol method: The grease is first tested with anhydrous copper sulphate if the grease is sufficiently light in color. If the copper sulphate turns blue showing the presence of water, or if the grease is dark, 10 grams of the grease are weighed into a 300 cc. Erlenmeyer flask and covered with xylol. (This xylol is prepared for use by distilling from water and separating out from the water after clearing in a separatory funnel.) The flask, connected with a dry condenser, is heated in a bath of cylinder oil, and the xylol and water slowly distilled off until the xylol comes over clear. The bulk of the water comes over with the first 10 cc. of distillate. The distillate may be caught in centrifuge tubes, or other suitable tubes, and the amount of water read off after centrifuging or on standing.

CHEMICAL TESTS.

The chief chemical determinations are: the amount and nature of the oils, the amount and nature of the soap, the amount of free acid or alkali, ash and filler.

The Oils.—The oils can be removed by extraction with ether or gasoline in a Soxhlet extractor. The oils are then recovered by driving off the solvent from the dissolved oil. If lime soaps are present some of the soap is also dissolved so the separation is not satisfactory. In this case the nature of the oil can be determined after extraction of the grease with cold ethyl acetate which seems to be about the only organic solvent which can be used at all successfully.

The proportion of fatty oil can be determined by saponification with alcoholic potash and benzol as given for the determination of fatty oils in cylinder oil (see Index). The fatty acids from this saponification can be recovered if desired and tested for further identification by the iodine number, melting point, etc. The per cent. of fatty oil in the mixed oils can be calculated from the saponification number by dividing by 190 and multiplying by 100. The average saponification of most fatty oils, except rape oil, rosin oil, etc., is about 190.

Rosin oil is tested for by means of the Liebermann-Storch reaction, and the amount of rosin acids can be determined by Twitchell's method if desired.

Soaps.—A satisfactory scheme for determining the amount of oils and soaps is as follows Stir 10 grams of the grease with ether until dissolved or disintegrated, place the whole in a separatory funnel and shake with about 10 cc. of 1 :1 hydrochloric acid to decompose the soaps. Remove the acid and shake the ether with another 10 cc. portion of the acid. Continue to wash the ether with successive small portions of water until all the acid has been removed. The ether now contains all the mineral oil, all the fatty oils, the original free fatty acids, and the fatty acids obtained from decomposing the soaps. The acid solutions and washings contain the bases in solution. The extraction can be made with naphtha, petroleum ether or very light gasoline instead of with ether.

The oils can be recovered by driving off the ether and weighing. The fatty acids are determined by the method given below for acidity, and the free fatty acids present in the original grease deducted; the remainder is the fatty acids from the decomposed soaps. The soaps may be calculated by multiplying the per cent. of such fatty acids by the following factors: Soda soaps 1.078, calcium or lime soaps 1.067, lead soaps 1.364, and aluminum soaps 1.032. If the grease contained more than one base, as in a mixture of soda and lime soap grease, the soap can be calculated to sufficient accuracy for ordinary purposes. The calculations are reasonably exact if rosin acids are absent.

The acid extract is evaporated, with or without washing with ether, the residue dissolved in water and analyzed for the bases present. These figures, if obtained, would serve as a check on the results calculated above.

Another method for determining the amount of soaps, where only alkali soaps are present, is by extracting the grease with ether or gasoline as given under "The Oils" just above, and then extracting the undissolved residue with hot water or hot alcohol. After filtering, the solution is evaporated to recover the soap which is weighed. The nature of the fatty acids can be determined by dissolving the soaps in water, liberating the acids by means of mineral acid, warming on a water bath until the acids separate clear on top of the water layer, and testing the acids for iodine number, melting point, etc.

The easiest method for determining the amount of soap is to ash several grams of the grease, dissolve the ash in standard (N/2) acid and titrate the excess of acid with standard alkali using methyl orange as indicator. Each cubic centimeter of N/2 acid is equivalent to 0.1535 gram of sodium stearate or 0.1520 gram of calcium stearate. This is sufficiently accurate unless rosin soaps are present in which case the result will be slightly low. The nature of the base in the soap can be found by inspecting or testing the ash, or by analyzing the acid solution for lime or aluminum.

Free Acid.—The amount of free acid can be determined by dissolving 2.82 grams of the grease in a neutral mixture of alcohol and ether, adding a few drops of phenolphthalein solution and titrating with N/10 alkali. Each cubic centimeter of the alkali is equal to 1 per cent. of oleic acid. The free acid should be below 2 per cent. as any free acid might corrode the bearings. Only fatty acids are present in the free state in soap-thickened greases. If the alcohol-ether solution turns pink upon adding the phenolphthalein, free alkali, usually lime, is present.

Ash.—The ash contains the alkalies (Na_2CO_3, CaO, etc.) and mineral impurities. The amount of the latter should be small or well under 1 per cent. By analysis of the ash the character and the amount of soaps can be determined, as lime, soda, potash, lead, zinc, magnesium, alumina, etc.

Filler.—If graphite is present the approximate amount can generally be determined by ashing the grease at a low temperature, weighing, then burning completely and re-weighing. This loss in weight can be reported as graphite, although graphite usually contains from 10 to 20 per cent. ash. Complete separation by extraction is not always practicable if graphite is present.

Mineral fillers can be determined by the ash after deducting the alkalies found, or by actually weighing the ash not dissolved by acid. These methods are suitable for determining the amount of mica, talc or soapstone, but not for determining the amount of lime filler as this would be dissolved by the acid.

For soda greases the amount of filler can be determined by extracting the grease with ether, then with alcohol, the final residue being the filler provided the extraction was complete and the filtrates clear.

See also "Analysis of Grease Mixtures", by T. L. Woodruff, Chem. Analyst, 20, 8-11, 1917; and "Tests of Lubricating Oils" including "Tests of Greases and Soluble Oils," Bureau of Steam Engineering, Navy Dept., Mch. 1, 1920.

CHAPTER XVII.

ANIMAL AND VEGETABLE OILS.

Oils and fats are found ready formed in all animals and in the seeds of plants. A fat is simply an oil which is solid at ordinary temperatures. Animal and vegetable oils are called fatty oils, fixed oils, or saponifiable oils.

Chemically, fatty oils are made up almost entirely of heavy fatty acids in combination with glycerine. Sperm oil which is a liquid wax rather than an oil has the fatty acids combined with other alcohols instead of with glycerine. However, most oils yield about 10 per cent. of glycerine when acted on by caustic potash.

The formula for glycerine is $C_3H_5(OH)_3$.

The three most widely distributed fatty acids are

Stearic acid, $HC_{18}H_{35}O_2$,
Palmitic acid, $HC_{16}H_{31}O_2$, and
Oleic acid, $HC_{18}H_{33}O_2$.

There are many other fatty acids, some of which are important. They usually have smaller molecules than stearic acid (like butyric acid, $HC_4H_9O_2$, found in butter), or they have less hydrogen than oleic acid (like linolenic acid, $HC_{18}H_{20}O_2$, found in linseed oil).

The fatty acids are not present in the oil in the free state to any great extent, but are combined with the glycerine. The glyceride of stearic acid, which is the compound actually existing in many fats, is called stearin which has the composition

$$C_3H_5(C_{18}H_{35}O_2)_3.$$

In general, glycerine holds in combination 3 molecules of stearic or other fatty acids. Stearin, palmitin, $C_3H_5(C_{16}H_{31}O_2)_3$, olein, $C_3H_5(C_{18}H_{33}O_2)_3$, and similar compounds make up practically all of the animal and vegetable oils and fats.

All *fats* contain a large percentage of stearin or palmitin as well as some olein. All oils contain considerable amounts of olein, or similar compounds with relatively less hydrogen than is present in stearin.

When any fatty oil is treated with caustic soda or caustic potash the oil is broken up by the caustic into glycerine and *soap*. Soap is the compound formed between the soda or potash and the fatty acids. This breaking up of the oil into glycerine and soap is called *saponification*. Thus palmitin is acted on as follows:

$$\underset{\text{Palmitin}}{C_3H_5(C_{16}H_{31}O_2)_3} + \underset{\text{Caustic Soda}}{3NaOH} = \underset{\text{Glycerine}}{C_3H_5(OH)_3} + \underset{\text{Soap}}{3NaC_{16}H_{31}O_2}.$$

All fatty oils are saponified by caustic alkalies while mineral oils cannot be saponified. During the saponification of an oil a definite amount of caustic is used up.

Another striking characteristic of oils is the amount of iodine each oil can absorb or combine with directly. Oils like linseed oil, which are known as drying oils on account of their power of thickening upon absorbing oxygen, have high iodine absorbing power. Other oils, which dry only slowly and incompletely, like cottonseed oil, are called semi-drying oils. These have somewhat lower iodine values. Finally, the non-drying oils have still lower iodine values. The non-drying oils show very little tendency to gum or thicken when exposed to the air.

The drying or non-drying character of an oil is determined by the relative amount of hydrogen present in the fatty acids making up the oil. The less hydrogen the oil contains, the more readily it dries and the more iodine it will absorb. Fatty acids, like stearic and palmitic acids, which have the general formula $C_n H_{2n} O_2$, do not combine directly with iodine and so are called *saturated* fatty acids. Consequently the corresponding compounds, stearin and palmitin, do not have the power of combining with iodine.

Unsaturated fatty acids combine with a definite amount of iodine. Oleic acid and other acids with the formula $C_n H_{2n-2}O_2$, can combine with 2 atoms of iodine. Linolic acid, found in cottonseed oil, and other acids with the formula $C_n H_{2n-4}O_2$, can combine with 4 atoms of iodine. Linolenic acid in linseed oil has the formula $C_n H_{2n-6}O_2$ and so can combine with 6 atoms of iodine.

Usually semi-drying oils have a large percentage of combined fatty acids capable of absorbing 4 atoms of iodine, while drying oils have much fatty acids which can absorb 6 atoms of iodine.

A large proportion of saturated fatty acids, with a fairly low iodine value, is characteristic of *fats*, while the *oils* contain a greater proportion of unsaturated acids with a higher iodine value. Vegetable oils are usually, though not always, more highly unsaturated than terrestial animal oils.

Within the last few years a process, known as "hydrogenation" or hardening of oils, has been devised to change unsaturated oils into saturated oils or fats on a commercial scale. This process which makes a fat out of an oil depends on the use of nickel which acts "catalytically" to cause hydrogen gas to combine with the heated oil. Thus olein can be converted into stearin. *Solid edible fats* can be made in this way from cottonseed oil, from fish oils and many other oils.

Many oils when first extracted are brown in color and have undesirable odors. The oil can be refined by treatment with sulphuric acid and caustic soda, or by filtration through fuller's earth, or by agitation with steam and air, so that the resulting oil is only slightly colored. The caustic soda treatment removes the small amount of free fatty acids which is often present in crude or rancid oils. Refining also improves the odor and keeping qualities of the oil.

VEGETABLE OILS.

Many of the vegetable oils are semi-drying or drying oils. Only the non-drying oils are satisfactory for lubricants as the other oils tend to gum or thicken. The chief vegetable oils used in lubrication are rape oil, castor oil and olive oil.

Castor Oil.—This pale green oil is extracted from the seed of the castor oil plant. It has a higher viscosity and holds its viscosity better under heat than any other fatty oil. It has the highest specific gravity of any of the usual fatty oils, but blown oils and rosin oils may have as high specific gravity. It consists largely of the glyceride of ricinoleic acid which differs from most fatty acids in having an extra oxygen atom. Castor oil unites readily with sulphuric acid to form soluble castor oil or Turkey red oil. The saponification number is low. The poorer grades have a nauseous odor and taste. Commercial castor oil contains from 1 to 14 per cent. of free fatty acids. Not over 3 per cent. should be present. The oil is insoluble in gasoline.

Castor oil is the only important oil readily soluble in cold alcohol. The presence of less than 10 per cent. of other oils in castor oil can be detected by shaking one volume of oil with five volumes of ordinary 95 per cent. alcohol at room temperature, failure to form a clear solution shows the presence of other oils.

Castor oil has been widelv used for lubricating heavy, quick-moving machinery, but the high price of this oil and the introduction of suitable heavy mineral oils has largely supplanted its use for this purpose. Castor oil is often used for compounding with mineral oils, but trouble often results from failure of the castor oil to remain in solution in the mineral oil. Separation of the castor oil from the mineral oil can be prevented by using some other fixed oil along with the castor oil. (See Index.)

Corn Oil (Maize Oil).—This is an important semi-drying oil which may at times find its way into lubricants, particularly by addition to lard oil and other oils. Such addition is undesirable.

Cottonseed Oil.—This is an important semi-drying oil. It is not much used for lubrication on account of its gumming tendency but it has been unwisely recommended for use in compounding cylinder oils. It is often used to adulterate other oils. Its presence can be detected by the Halphen test or by the Bechi test. (See Index.)

Linseed Oil.—This is the most important of the drying oils. It is not used in lubrication, but finds its chief uses in paints, varnishes and soaps. Its drying properties are increased by boiling the oil with lead or manganese oxides previous to use in paints and varnishes. This "boiled oil" has a higher specific gravity and a lower iodine number than the raw oil. The raw oil has a higher specific gravity and a higher iodine number than any oil that is likely to be used to adulterate it. The chief adulterants are cottonseed oil, corn oil, soy-bean oil, fish oils and rosin oils.

Olive Oil.—This non-drying oil is pressed from the pulp of the olive fruit. The poorer qualities only are used for lubrication as the better grades are too expensive. The oil is greenish in color and may have from 2 per cent. to 25 per cent. of free fatty acids. Olive oil for lubrication should have less than 4 per cent. of free fatty acids and should be clear showing absence of water and mucilaginous matter. It should be fluid at 40° F. and above. Owing to its high price the oil is very liable to adulteration with peanut oil and cottonseed oil.

The presence of olive oil can be shown by the Elaidin test which is carried out as follows: Dissolve a very little mercury in a little cold concentrated nitric acid. Ten drops of this solution are added to 15 cc. of the oil in a test tube and stirred. After standing one hour a hard, impenetrable yellow mass indicates olive oil. Lard oil shows a fairly hard mass by this test, other oils show softer, buttery masses.

Palm Oil.—This oil is a yellow or orange colored solid at ordinary temperatures. For lubrication, the oil must be tested for free acid as free fatty acids form easily, over 50 per cent. being present at times. In crude samples several per cent. of dirt, trash and water may be present. These can be removed by melting and straining. While palm oil is used considerably abroad, notably in England for railway carriage greases, its use as a lubricant has never been so great in the United States. For grease making, a fairly high percentage of free fatty acids is not undesirable provided the grease is made by converting the fatty acids into a soap.

Peanut Oil (Arachis Oil).—This is classed as a non-drying oil and is sometimes substituted for olive oil. While it has been used very little as a lubricant, it does not gum so much as does rape oil, and so owing to its increased production in the United States it may find some application as a lubricant.

Rape Oil (Rapeseed Oil, Colza Oil).—This is a pale yellow oil with a characteristic odor and taste. It is a semi-drying oil and so has some tendency to gum when used as a lubricant. The free fatty acids usually run from 1 to 6 per cent. Sulphuric acid may be present in the refined oil. Rape oil is rather difficult to saponify. Rape oil has never had the vogue in the United States it enjoyed abroad, except possibly for blending with heavy mineral oils for use in marine engines. It has a fairly high viscosity and so is used to some extent for compounding cylinder oils. This is particularly true of blown rape oil which has an exceedingly high viscosity and a high specific gravity in which respects it resembles castor oil.

Rosin Oils.—Many grades of these oils are obtained by the distillation of rosin, the usual standard grades being first, second, third and fourth run rosin oils. The first run oil is thicker, of a lighter color, and contains more rosin acids than the later runs. The early runs are therefore more valuable for grease making, *e. g.*, for axle grease. Besides the rosin acids the oils consist largely of hydrocarbon oils. The iodine number varies from around sixty for the first run oil to about twenty for the last runs. The saponification number, which shows the amount of free acid and saponifiable matter present, gives a satisfactory basis for the valuation of the oil for grease making, the oils with high saponification numbers being more valuable for this purpose. First run rosin oils are also known as "Hard Rosin Oils," the other grades being known as medium and soft rosin oils.

When heated, rosin oils have the odor of rosin. They flash around 320° F. and contain from 3 per cent. to 40 per cent. of free acids. The specific gravity varies from 0.96 to 1.02. Crude rosin oils have a fluorescence or "bloom" somewhat like mineral oils. The late runs of rosin oil may be refined by sulphuric acid to yield a lighter colored oil. In this case most of the rosin acids are removed which makes the oil more suitable for lubricating purposes. With the increased price of rosin, and consequently of rosin oils, the chief reason for the use of rosin oil for lubricating oil has been removed. The refined oils have been used widely as lubricating oils, either alone or mixed with mineral oils, but this practice is not advisable as mineral oils fully answer the same purpose.

The presence of rosin oil in fatty oils can be detected by a decrease in the saponification number and in the flash point, and by an increase in the specific gravity and in the acid number. Its presence in mineral oils is shown by high acid, iodine and Maumené numbers and by the refractive index. Rosin oils are dextro-rotatory and so can be detected by the polariscope. The most satisfactory method for the detection of rosin or rosin oil in any other oil is by the Liebermann-Storch reaction. (See Index.)

Soy-bean Oil.—This oil is now being largely imported into the United States from Manchuria. It is a semi-drying oil and is chiefly used to adulterate linseed oil, for paints and for making soap. It has no use in good lubricating practice owing to its gumming character. Several grades of "blown soy-bean oil" are now on the market. The production of soy-bean oil in the United States is increasing.

BLOWN OILS.

These oils are prepared from rape oil and cottonseed oil by forcing a stream of warm air through the oil heated to over 200° F. A partial oxidation results yielding a product resembling castor oil in viscosity and gravity. The blowing is stopped when the desired viscosity and gravity are obtained. High temperatures give a dark oil, but the blowing is accomplished more quickly. The gravity may be 0.960 to 0.970 or even higher and the viscosity several times higher than castor oil. Since blown rape oil is used chiefly for compounding with mineral oils to make marine engine oils and other engine and cylinder oils it is necessary to limit the blowing as the higher viscosity oils are more difficultly soluble in mineral oils. However, blown oils can be distinguished from castor oil by the fact that they are soluble in light mineral oils. Blown oils have a nauseous odor, a lowered flash point, a lowered iodine number and an increased Maumené number as compared with the corresponding raw oil.

Commercial blown oils are also made from soy-bean oil, corn oil, castor oil, fish oils, and even from the non-drying sperm and tallow oils, although the latter oils are very difficult to oxidize by this process.

DEGRAS OILS.

These oils are usually by-products in treating leather as in the chamoising process, or recovered wool grease from the scouring of wool. In treating leather, various fish oils are generally used, and the leather is exposed to the air. The oils as recovered from the wash solutions by acid treatment contain oxidized fatty acids or fats, much free fatty acid, much unsaponifiable matter and a high water content. Degras is used in making greases for lubrication, and the degras oil when neutral may be used for compounding cylinder oils.

On account of the varying character of true degras and degras oils, they are open to much adulteration and so should never be used except after thorough test of each lot. The writer has in mind an "acidless degras oil" for compounding cylinder oil, this degras oil being a pure mineral or spindle oil with a degras odor.

ANIMAL OILS.

The oils and fats from land animals contitute the most valuable of the fixed oils for lubricating purposes.

Bone Fat and Bone Oil.—Bone fat usually contains about 1 per cent. of ash and a large percentage of free fatty acids. Its general properties are somewhat similar to tallow. Bone oil, from bone fat, is somewhat like neatsfoot oil. It has a low cold test and is a good lubricant if the fatty acids are removed.

Horse Oil.—This oil is used to mix with or adulterate other oils used in lubrication and for manufacturing lubricating greases and soaps.

Lard.—This is the solid, rendered fat from pigs. It is chiefly used for edible purposes and for preparing lard oil.

Lard Oil.—This oil is prepared from lard somewhat as tallow oil is prepared from tallow. It is used for general lubrication, and is often seriously adulterated with light petroleum oils before it reaches the ultimate consumer. There are several grades of lard oil, depending on the grade of lard used and the temperature of pressing. The cold test varies considerably. The best grades have very little odor. Only the better grades should be used for compounding.

TABLE SHOWING PROPERTIES OF ANIMAL AND VEGETABLE OILS.
(Compiled from various standard sources.)

	Specific gravity at 60°F.	Average saponification No. (m.g. KOH)	Iodine No. (Hanus)	Average Maumené No. (°C.)	Average solidification point (°C.)	Average solidification point of fatty acids (°C.)
Permissible variation	0.003	3	—	5	5	5
Bone fat	0.915	192	48 to 55	35	16	28
Castor oil	0.964	182	82 " 88	47	—14	3
Corn (Maize) oil	0.923	190	113 " 125	83	16	15
Cottonseed oil	0.924	194	105 " 112	76	— 2	33
Horse oil	0.919	196	74 " 86	50	35	37
Lard	0.935	196	52 " 63	26	29	38
Lard oil	0.916	195	66 " 77	42	3	35
Linseed oil (raw)	0.934	190	171 " 192	124	—20	17
Menhaden oil	0 930	191	145 " 165	125	— 6	—
Neatsfoot oil	0 915	196	65 " 75	46	— 5	26
Olive oil	0.917	190	80 " 87	43	0	21
Palm oil	0.924	197	50 " 56	—	35	41
Peanut (Arachis) oil	0.919	193	85 " 98	58	0	27
Rape (Colza) oil	0.915	174	96 " 103	59	— 5	14
Rosin oils	(0.985)	20-34	(40 " 50)	30	(— 5)	—
Seal oil	0.921	192	130 " 150	92	— 2	18
Soy-bean oil	0.925	191	122 " 135	60	— 5	23
Sperm oil	0.880	130	81 " 88	47	0	14
Tallow	0.946	195	35 " 46	41	35	41
Tallow oil	0.916	196	55 " 57	41	54	—
Whale oil	0.922	190	120 " 135	91	— 4	23

Menhaden Oil.—This is a fish oil with drying properties. It is used in paints and soaps, but is not generally suitable for lubrication.

Neatsfoot Oil.—This oil consists largely of olein and does not become rancid easily. It is rendered from the feet of cattle. It is used as a lubricant, either alone or in mixtures with mineral oils similar to the use of tallow oil. It is a valuable oil for lubrication.

Porpoise Oil.—There are two varieties, the body oil and the jaw oil, which differ considerably in character. They are used for lubricating watches and other delicate machinery. The two varieties of dolphin or black fish oil find a similar use.

Seal Oil.—This oil is prepared from the blubber of the seal. It is not much used for lubrication as it has drying properties.

Sperm Oil.—This is not a true oil, but a liquid wax. It has the lowest specific gravity of the fixed oils and a low saponification number. It contains no glycerine. While its viscosity is not so high as that of some other oils, it keeps its viscosity unusually well at elevated temperatures. It is excellent for light running machinery, does not corrode, or turn rancid or gum.

Tallows.—Beef tallow is rendered from the fat of cattle, mutton tallow from the fat of sheep and goats. Tallow varies considerably in melting point and other properties, depending on the animal from which it comes, the temperature of rendering, etc. Soft tallows may melt as low as 36° C. while hard tallows may melt as high as 50° C. The free fatty acids usually range from almost none up to 6 per cent. Tallow consists chiefly of olein and stearin. Tallows are valued by the melting or solidification point, the high-melting point tallows being the more valuable. Tallow is used directly as a lubricant in tallow greases, or for soap-making, or for making tallow-soap greases.

Many garbage greases, yellow greases, etc., are sold for purposes similar to tallow. These are valued by their melting point and the amount of saponifiable matter they contain. They usually contain fairly large amounts of unsaponifiable matter.

Tallow Oil.—When tallow is melted and then allowed to remain for some time at approximately 85° F., part of the stearin crystallizes out and can be removed from the oil by filter pressing. The stearin is used for candle and soap making, while the "tallow oil" is used for lubrication and other purposes. The relatively cheaper mineral oils have largely displaced tallow oil as a lubricating oil, except that up to 20 per cent. of tallow oil is still added to mineral oils for steam cylinder lubrication. For this purpose the tallow oil should be "acidless" by actual test.

Whale Oil.—There are a number of varieties of this oil from the blubber of the whale. Only the best grades are suitable for lubrication. In common with most marine animal oils, the odor may be undesirable.

CHAPTER XVIII.

METHODS OF TESTING FATTY OILS.

A. PHYSICAL METHODS.

The **Specific Gravity** of fixed oils is characteristic for each oil and varies only within narrow limits. Any marked variation from the usual specific gravity is an indication of adulteration. The gravity can be taken with a hydrometer, but as considerable accuracy is necessary it is better to use a pycnometer or a Westphal balance, as explained under mineral oils. If the temperature is not at 60° F. a correction of 0.00038 is made for each degree Fahrenheit the temperature is found to differ from 60° F. (For each degree Centigrade the correction is 0.00068.) The correction is to be added if the observed temperature is above 60° F. (15.56° C.)

The **Solidification Point** of fixed oils is very important if the oil is used for lubricating purposes. It is made in the same manner as the cold test or pour test for mineral oils. This is sufficiently accurate for practical purposes. The melting point is usually several degrees higher than the solidification point, which varies considerably for the same oil. Thus tallows vary owing to a variation in the amount of stearin present. The oil does not freeze as a whole, but is solidified by the crystallizing out of some constituent of the oil, usually stearin or palmitin.

The **Solidification Point of the Fatty Acids** can be determined in the same way as for the oils. A very simple method for making the melting point determination is to put some of the melted acids in a capillary tube closed at one end, letting cool for several hours, fastening the tube with the closed end opposite the bulb of a thermometer, immersing in a water bath which is slowly heated, and noting the temperature at which the fatty acids become clear.

The fatty acids for the above test can be prepared by saponifying 50 grams of the oil with about 50 cc. of 30 per cent. caustic soda solution to which about 50 cc. of alcohol has been added. The mixture is evaporated to dryness over a very low flame so as to prevent scorching. The soap is then dissolved in some 600 cc. of water, and boiled for some time after the soap is completely dissolved to insure the removal of the alcohol. If the solution is not clear, or great accuracy is desired, the solution is cooled and the unsaponifiable matter removed by shaking out with ether. Finally about 100 cc. of 20 per cent. sulphuric acid is added to the hot soap solution to set the fatty acids free. Boil until the fatty acids collect on top of the water, remove the fatty acids and wash free of sulphuric acid by means of hot water. Heat the acids in a dish on the water bath until clear and free from water.

A determination of the **Refractive Index** of oils by means of the Abbé Refractometer or the Zeiss Butyro-Refractometer gives valuable data for determining the purity and character of an oil. This determination is easily and quickly made, and so is especially valuable in the routine examination of a large number of oils. The refractive index for any fixed oil varies only between narrow limits.

The **Flash Point** of natural fixed oils is usually above 500° F. with the open cup. Only blown oils, rosin oils, and sometimes neatsfoot oil have lower flash tests.

The **Viscosity** determination is of value in certain cases, as with blown oils, rape oil ,castor oil and sperm oil.

The approximate Saybolt viscosities of some fatty oils are as follows:

	100°F.	210°F.
Refined rape oil	225	59
Castor oil	1,250	97
Lard oil	190	—
Neatsfoot oil	195	55
Olive oil	195	52
Sperm oil	105	45
Tallow (hard, beef)	—	56

B. CHEMICAL METHODS.

The chief chemical tests for these oils are the determination of the saponification number, the iodine number, the Maumené number, the amount of free fatty acid, and a few other special determinations.

The **Saponification Number** (or Koettstorfer value) is the number of milligrams of caustic potash required to saponify 1 gram of the oil or fat. The number for most oils varies around 190 to 195; that is, most oils require from 19.0 to 19.5 per cent. of caustic potash to saponify them completely. Some oils, like castor oil, rape oil and sperm oil, have much lower numbers.

The saponification number is determined as follows: Weigh 2 grams of the oil or filtered fat in to a clear 200 cc. Erlenmeyer flask. Measure into the flask exactly 25 cc. of clear alcoholic potash (containing about 40 grams of KOH in a liter of 95 per cent. alcohol). A second flask is prepared at the same time and in the same way except that no oil is added. Connect the flask with a reflux condenser and boil on a water bath for 30 minutes or until saponification is complete. Cool and titrate with half-normal acid (HCl) using phenolphthalein as indicator. To calculate the saponification number, subtract the number of cubic centimeters of half-normal acid used in the titration from the number of cubic centimeters of half-normal acid used to titrate the "blank," multiply the result by 28.05 and divide by the number of grams of oil used.

A simple qualitative saponification can be carried out by putting a little of the oil in a flask, adding a short stick of caustic potash and a small amount of alcohol. Heat on a water bath for a half hour using a glass tube as a reflux condenser. Pour the mixture at once in a large beaker of water; a clear solution indicates freedom from mineral oils, a turbid solution indicates the presence of mineral oil or rosin oil.

Iodine Number.—This is the most important single determination for detecting the character of an oil. The Hanus method for determining the iodine number is as follows: Weigh out accurately from 0.12 to 0.25 gram of the oil, using the smaller amount for drying oils. For fats or mineral oils from 0.50 to 1.00 gram may be used. The amount of oil should be small enough so that not over 40 per cent. of the iodine solution will be used up. The oil can be weighed best by difference. Dissolve the weighed oil in a 250 cc. glass-stoppered flask by means of 10 cc. of chloroform. Now add 25 cc. of the Hanus iodine solution. Prepare a "blank" in the same way with exactly the same amount of iodine solution, draining the pipette carefully in each case. Let stand with occasional shaking for 30 minutes without exposing to strong light. At the end of just 30 minutes add 10 cc. of 15 per cent. potassium iodide solution, mix, add about 100 cc. of water and titrate with N/10 sodium thiosulphate solution. As the color fades add a little fresh starch solution and titrate slowly until the blue color disappears. The flask should be well shaken just before the end of the titration.

Calculate the iodine number as follows: Subtract the number of cubic centimeters of the thiosulphate solution required for the titration from the number of cubic centimeters of thiosulphate solution used to titrate the blank, multiply the result by 1.27 and divide by the amount of oil used.

The Hübl and the Wijs methods for determining the iodine number give approximately the same results as the Hanus method. Mineral oils have a very low iodine number, usually 8 to 16, or even higher for cracked oils, while fatty oils show a range from about 35 up to 200. The iodine number shows the degree of saturation of the oil, particularly the degree of saturation of the fatty acids. Oils with an iodine number much over 100 are not usually suitable for lubricating oils on account of their drying character which causes the oil to gum.

The **Maumené Number** is quickly and easily determined and often gives valuable information. Fifty grams of the oil are weighed into a tall beaker, the exact temperature of the oil noted, and 10 cc. of concentrated sulphuric acid at the same temperature are run in gradually with stirring. The beaker is protected as much as possible against loss of heat. The stirring is continued and the highest temperature noted, being careful to wait sufficiently long to be certain of the highest temperature. The rise in temperature expressed in degrees Centigrade is the Maumené number. It is usually roughly in proportion to the iodine number. It is very important that strong sulphuric acid, at least 96 per cent. be used. Such an acid will show a Maumené number of about 44 when tested with water instead of with oil.

Mineral oils usually give Maumené numbers from three to six. Higher values indicate the addition of rosin or fatty oils. Rosin oils usually give numbers around 30. Cylinder oil stocks have a Maumené number of four or five, while compounded cylinder oils have a Maumené number from seven to twelve.

When the temperature is found to rise much above 60° C. the test should be repeated using a mixture of equal parts of pure light mineral oil and the unknown oil. Subtract two from the rise of temperature and multiply by two to get the Maumené number.

Free Fatty Acids are usually present in varying amounts in fatty oils and may cause serious corrosion of machinery especially in the presence of water or at elevated temperatures, as in steam cylinder lubrication. From 2 to 3 per cent. of free fatty acids calculated as oleic acid should be about the maximum for fatty oils for lubricating purposes.

To determine the per cent. of free fatty acids, weigh out 10 grams of the oil into a flask, add about 60 cc. of alcohol, connect the flask with a dry reflux condenser and warm on a water-bath for a few minutes. Shake well, cool and titrate with N/5 caustic potash using phenolphthalein as indicator. The end-point is a permanent pink color after shaking the flask vigorously. A blank should be run in the same way and the proper correction made if the alcohol does not prove to have been neutral. To calculate the per cent. of "free oleic acid" multiply the number of cubic centimeters of N/5 caustic solution by 5.64 and divide by the number of grams of oil used.

Sometimes the fatty acids are reported as "acid number" which is the number of milligrams of KOH required to neutralize the free acids in 1 gram of the oil. This "acid number" can be calculated by multiplying the "free oleic acid" by 2. (For other methods for determining free fatty acids, see Index.)

The **Reichert-Meissl Number** is important for testing certain oils which contain notable percentages of volatile fatty acids soluble in water. Such oils as cocoanut oil, palmnut oil, porpoise oil, dolphin jaw oil, lard oil, blown oils, croton oil and butter show characteristically large amounts of such fatty acids by this test. The Reichert-Meissl number for these oils is over six while for most other oils the number is one or less. The Reichert-Meissl number is the number of cubic centimeters of N/10 caustic potash required to neutralize the volatile, water-soluble fatty acids obtained by a standard procedure from 5 grams of oil. See other texts for method of making the test which is not often necessary in testing lubricants.

Color Tests.—A large number of color tests for special oil have been devised, but most of these tests are unreliable. Only the best of these are given.

The **Liebermann-Storch Reaction** is reliable for detecting rosin or rosin oils, especially in mineral oils. About 2 cc. of the oil are gently heated in a test tube with 4 cc. of acetic anhydride. Cool, filter so as to remove the oil and add to the clear filtrate 1 drop of sulphuric acid made by mixing equal volumes of concentrated sulphuric acid and water. If rosin is present a fine fugitive violet color is produced at once. Some animal oils, particularly fish oils, and a few vegetable oils may give a similar test. The quantitative estimation of rosin or rosin oils is best made by Twitchell's method, but this method will not be described as the qualitative detection is usually sufficient.

The **Halphen Test** for cottonseed oil is a reliable color test except that cottonseed oil which has been heated to 250° C. and blown cottonseed oil do not give the test. Two cc. each of the oil, amyl alcohol, and a 1 per cent. solution of carbon disulphide are heated in a test tube in a boiling water bath for 20 to 30 minutes. As much as 5 per cent. of cottonseed oil gives a characteristic deep red color. Fat from cattle which have been fed on cottonseed meal may give the test.

The **Bechi or Silver Nitrate Test** is another characteristic reaction for cottonseed oil, although it has the same limitations as the Halphen test and is not quite so reliable. It is a very delicate test showing as little as 5 per cent. of cottonseed oil. Make a 1 per cent. solution of silver nitrate in 95 per cent. alcohol free from aldehyde and add about half as much ether as alcohol. Add 1 drop of nitric acid to a 100 cc. of this solution. Upon heating 10 cc. of the oil with about 5 cc. of the above reagent, using a test tube immersed in boiling water for about 20 minutes, a darkening will be observed in the presence of cottonseed oil owing to the reduction of the silver nitrate. The darkening is proportional to the amount of cottonseed oil present. Rancid oils or animal oils rendered at too high a temperature may also give the reaction. The test is more reliable if carried out on the separated fatty acids instead of on the oil.

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CHAPTER XIX.

SPECIFICATIONS FOR FATTY OILS.

Castor Oil (Navy Dept., June 2, 1919).*—The material supplied under these specifications shall be pure castor oil, free from resins, other oils, suspended matter, grit, water, or any other adulterant. Castor oil shall have at ordinary temperatures a thick, sluggish viscous consistency, and shall give off at first a faint, mild odor, which may afterwards become slightly acrid and offensive. Oil shall be furnished in accordance with the requirements for "Grade A" or "Grade B" as specified.

"Grade A" oil is intended to be used for lubricating purposes. "Grade B" oil is intended to be used for softening and preserving leather packing.

"Grade A" and "Grade B" castor oil shall conform to the following requirements:

(*a*) *Specific Gravity* at 15.5° C. (60° F.) shall be from 0.952 to 0.972.

(*b*) *Saponification* number shall be between 179 and 184.

(*c*) *Solubility.*—(1) The oil shall be completely soluble in all proportions in absolute alcohol and glacial acetic acid, and one volume of oil shall be completely soluble, at 20° C., in not more than 4 volumes of 90 per cent. ethyl alcohol (specific gravity 0.834). (2) When 90 cc. of 59° Baumé gasoline are added to 10 cc. of castor oil in a graduated, ground glass stoppered cylinder, thoroughly shaken, and allowed to settle, the castor oil shall dissolve from 3.25 to 4.25 cc. of the gasoline; the temperature of the gasoline, castor oil, and of the mixture of both shall be maintained between 18.3° and 24° C. [65° and 75° F.].

(*d*) *Acidity.*—(1) "Grade A": Not over three (3) milligrams of potassium hydroxide (KOH) shall be required to neutralize the organic acidity in one gram of the oil. (2) "Grade B": Not over ten (10) milligrams of potassium

*All Navy Department specifications are from the Bureau of Supplies and Accounts.

hydroxide (KOH) shall be required to neutralize the organic acidity in one gram of the oil.

(*e*) *Color.*—(1) "Grade A" oil shall have a pale yellowish or almost colorless transparent appearance. (2) "Grade B" oil may be greenish yellow in color.

Note.—The oil supplied under the above requirements for "Grade A" shall be "cold-pressed" oil. Oil extracted by a naphtha process and conforming to the above specifications will be acceptable as "Grade B" oil. (Supplied in specified cans and cases.)

Castor Oil for Aircraft Engine Lubrication.—(War Dept., Fuel and Forage Div., Oil Branch, Quartermaster Corps, April 24, 1918, Spec. No. 3500-A).

General.

1. This specification is drawn to cover the requirements of the U. S. Army in all purchases of castor oil for rotary engine lubrication. The oil must be a high grade vegetable castor oil suitable for this purpose. Both cold pressed vegetable castor oil and hot pressed vegetable castor oil, which has been refined so that it will meet the requirements of this specification may be submitted for purchase.
2. The castor oil must be free from adulteration, other oils, suspended matter, grit and water.

Physical Properties and Tests.

3. The castor oil must meet the following requirements.
4. *Color.*—When observed in a 4-oz. sample bottle, the castor oil must be colorless or nearly so, transparent, and without fluorescence.
5. *Specific gravity.*—The castor oil must have a specific gravity of 0.959 to 0.968 at 60° F. (Baumé gravity must be from 16.05 to 14.70 at 60° F.).
6. *Solubility.*—The castor oil must be completely soluble in four (4) volumes of ninety (90) per cent. alcohol (specific gravity 0.834 at 60° F.). This test shall be made on a 2 cc. sample.

7. *Acid number.*—It must not require more than three (3) milligrams of potassium hydroxide (KOH) or 2.14 milligrams of sodium hydroxide (NaOH) to neutralize one (1) gram of oil. This is equivalent to 1.5 per cent. oleic acid.

8. The test for acidity shall be made on samples weighing five (5) to ten (10) grams. Samples shall be heated for one-half (½) hour with fifty (50) cc. of neutral alcohol and then titrated with fifth normal (N/5) sodium or potassium hydroxide, using phenolphthalein as an indicator.

9. *Iodine number.*—(Hanus method). The iodine number must be between 80 and 90. Samples used for this test shall weigh 0.2 to 0.25 grams and shall be treated for one (1) hour.

10. *Saponification number.*—The saponification number must be between 176 and 187.

11. This test shall be made on samples weighing two (2) to three (3) grams. Samples shall be saponified with half normal (N/2) alcoholic sodium or potassium hydroxide for one (1) hour and shaken at least five (5) times. Titrate with fifth normal (N/5) acid using phenolphthalein as an indicator.

12. *Unsaponifiable matter.*—The unsaponifiable matter must not exceed one (1) per cent. Samples used for this test shall weigh five (5) to ten (10) grams.

13. *Rosin.—(Lieberman-Storch test).* The castor oil must not give a reaction for either rosin or rosin oil.

14. *Cottonseed oil.*—(Halphen test). The castor oil must not give a reaction for cottonseed oil.

15. This test shall be made on samples measuring one (1) to three (3) cc. Dissolve the oil in an equal volume of amyl alcohol, and then add a volume of Halphen reagent (1 per cent. solution of sulphur in carbon bisulphide) equal to the volume of oil used.

16. *Viscosity.*—The castor oil when tested in a Saybolt Universal Viscosimeter must have a viscosity of not less than 450 seconds at 130° F. and 95 seconds at 212° F.
17. *Flash point.*—The flash point must not be less than 450° F. in a Cleveland open flash cup.
18. *Cold test.*—The castor oil, in a 4-oz. sample bottle one-quarter (1/4) full, must not congeal at a temperature of 0° F. The thermometer bulb shall be inserted in the oil during the test.

(Also provisions for sampling, analysis and inspection. Test samples shall not be less than 8 fluid ounces.)

Cottonseed Oil.—(Navy Department, May 1, 1916.) To be thoroughly refined winter-pressed cottonseed oil; to stand a 5-hour cold test. Must be sweet, neutral in flavor and odor, and free from rancidity. To have a refractive index at 25° C. of not less than 1.47 and not more than 1.4725, and an iodine number of not less than 104 and not to exceed 110. (Packed in specified 1-gallon cans, labelled, and packed eight cans per case.)

Each bid is submitted with the distinct understanding that the cottonseed oil is guaranteed to keep good in any climate for a period of one year after date of delivery at the navy yard.

Fish Oil.—(Navy Department, Aug. 1, 1914.) To be strictly pure winter-strained, bleached, air-blown menhaden fish oil, free from adulteration of any kind.

The oil should show upon examination:

	Maximum	Minimum
Specific gravity	0.935	0.930
Iodine number (Hanus)	165	145
Acid number	6	—

The oil when poured on a glass plate and allowed to drain and dry in a vertical position, guarded from dust and exposure to weather, shall be practically free from tack in less than 75 hours at a temperature of 70° F. When chilled, the oil shall flow at temperatures as low as 32° F.

To be purchased by the commercial gallon; to be inspected by weight and the number of gallons to be determined at the rate of 7½ pounds of oil per gallon. (Delivered in barrels.)

Lard Oil (For Pipe Cutting and Threading Purposes).—Navy Department, Oct. 1, 1915.) Shall be a clear, light yellow lard oil of good quality, free from rancidity or adulteration. It shall not contain more free fatty acid than 5 per cent. of oleic acid.

The specific gravity at 15° C. shall be not lower than 90 per cent. or higher than 92 per cent. It shall flow at 8° C. or below. Its viscosity at 38° C. shall not exceed 220 seconds in a Saybolt viscosimeter having a water rate of 30 seconds at 15° C. (Deliveries in 50-gallon casks.)

Lard Oil.—(War Department, Depot Quartermaster, New York City, Feb. 1, 1909.) Must be a pure lard oil of the best quality.

Must have a specific gravity between 0.910 and 0.916 at 60° F.

Must not solidify above 42° F.

When saponified with alcoholic caustic potash the resulting soap must be completely soluble in water showing no turbidity.

Must not show more acidity than the equivalent of 2 per cent. oleic acid.

Must not show an orange or reddish-brown color when 5 cc. of oil is shaken thoroughly with 5 cc. of nitric acid (sp. gr. 1.37) and allowed to stand 24 hours. (A check test should be made at the same time with an oil of known purity.)

Must be no color change when 5 cc. of oil is shaken thoroughly in a test tube with 5 cc. of an alcoholic solution of silver nitrate (made by dissolving 0.1 gram of silver nitrate in 10 cc. of pure 95 per cent. alcohol and adding 2 drops of nitric acid), and the mixture heated for five minutes in a water bath.

Quart samples must be submitted with bid.

Lard Oil (Gen. Supply Comm., Washington, D. C., for fiscal year 1920.) Must be of best quality, made from fresh lard; must not contain admixture of any other oil; must be free from dirt and cracklings, and show no more acidity than the equivalent of 2 per cent. of oleic acid; should show a cold test of not over 9° C. and have a specific gravity of not less than 0.91 nor more than 0.92 at 15.5° C.

Lard Oil.—(Norfolk & Western Railway, Motive Power Dept., Roanoke, Va., Feb. 27, 1912.) Two grades of lard oil, known in the market as extra (or prime), and extra No. 1 will be purchased.

When the shipment is received a sample will be taken from any barrel at random, and the oil accepted or rejected on this test. The right will be reserved, however, to inspect any and all barrels.

Extra lard oil will not be accepted which:

1. Contains mixtures of other oils.
2. Contains more than 2 per cent. of free acid.
3. Shows a discoloration with the silver nitrate test.
4. Has a cold test above 45° F. between Oct. 1 and April 1.

Extra No. 1 lard oil will not be accepted which:

1. Contains mixtures of other oils.
2. Contains more than 12 per cent. free acid.
3. Has a cold test above 45° F. between Oct. 1 and April 1.

The standard purity test will be Maumené test, or rise of temperature with sulphuric acid. Should any doubt arise, however, the right to use any test, such as specific gravity, refractive index, iodine absorption, or Halphen's test, is reserved. (Methods specified for free acid, for the silver nitrate test, and for the cold test.)

Lard Oil.—(Pennsylvania Railroad, Office Gen. Supt. of Motive Power, April 14, 1904.) Two grades of lard oil, known in market as "Extra" and "Extra No. 1," will be used, the former principally for burning and the latter as a lubricant.

The material desired under this specification is oil from the lard of corn fed hogs, unmixed with other oils, and containing the least possible amount of free acid. Also from Oct 1 to May 1 it should show a cold test not higher than 40° F. Oil from lard of "mast" or distillery fed hogs does not give good results in service, and should never be sent. Also care should be taken to have the oil made from fresh lard. Old lard gives an oil that does not burn well, and also gums badly as a lubricant. The use of the so-called neatsfoot stock, either alone or as an admixture in making the "Extra No. 1" grade, is not recommended. Neatsfoot oil is used by the railroad company when the price will admit, but it is preferred to have it unmixed.

Shipments must be made as soon as possible after the order is placed. Also shipments received at any shop after Oct. 1 will be subjected to the cold test and rejected if they fail, unless it can be shown that the shipment has been more than a week in transit.

Shipments of the "Extra" grade will not be accepted which:

1. Contain admixture of any other oils.
2. Contain more free acid than is neutralized by 4 cc. of alkali as described in the printed method. (See under tallow oil for P. R. R.)
3. Show a cold test above 45° F. from Oct. 1 to May 1.
4. Show coloration when tested with nitrate of silver as described below.

Shipments of "Extra No. 1" grade will not be accepted, which:

1. Contain admixtures of any other oils.
2. Contain more free acid than is neutralized by 20 cc. of alkali as described in the printed method.
3. Show a cold test above 45° F. from Oct. 1 to May 1.

The cold test and the amount of free acid must be determined in accordance with Pennsylvania Railroad standard methods.

The nitrate of silver test is as follows: Have ready a solution of nitrate of silver in alcohol and ether, made on the following formula:

Nitrate of silver	1 gram
Alcohol	200 grams
Ether	40 grams

After the ingredients are mixed and dissolved, allow the solution to stand in the sun or in diffused light until it has become perfectly clear; it is then ready for use and should be kept in a dimly lighted place and tightly corked.

Into a 50 cc. test tube, put 10 cc. of the oil to be tested (which should have been previously filtered through washed filter paper), and 5 cc. of the above solution, shake thoroughly and heat in a vessel of boiling water 15 minutes with occasional shaking. Satisfactory oil shows no change of color under this test.

Shippers must pay freight charges both ways on rejected material.

Lard Oil.—(Seaboard Air Line Railway, Motive Power Dept., July 7, 1915.) Lard oil will be obtained in two grades—No. 1 and No. 2.

No. 1. This grade will be used chiefly for burning.

It must be light yellow in color and contain no other oil mixture or sediment of any kind.

It must have gravity of between 23° and 24° Bé., at 60° F., and not show on titration more than 3 per cent. free fat acid.

No. 2. This grade will be used about shops on turret lathes, cutting threads, staybolt cutters, etc.

It may be reddish in appearance, but preference will be given to oils that are lighter in color.

It must contain no mixture with other oil than lard, or more than a trace of sediment. Gravity approximately as above defined for No. 1 grade.

On titration it must not show more than 15 per cent. free fat acid.

Such tests will be applied to either of above grades as will satisfy the inspector that no other oils than lard are contained in admixture with the samples submitted.

Shipments which do not conform to this specification will be rejected. In cases of rejection the materials will be held for two weeks from the date of test. If by the end of that period the manufacturers have not given shipping directions, it will be returned to them at their risk, they paying freight both ways.

Linseed Oil (Raw).—(Navy Dept., Feb. 1, 1918.) Raw Linseed oil shall be strictly pure, well-settled oil, perfectly clear and free from foots.

The oil shall have the following characteristics:

	Maximum Per cent.	Minimum Per cent.
Loss on heating one-half hour at 103 to 105°C.	0.2	—
Specific gravity at 15.5°C.	0 937	0.932
Iodine number (Hanus)	190.	174.
Saponification number	192.	189.
Acid number	6.	—
Refractive index at 25° C.	1.4805	1.479
Unsaponifiable matter	1.5	—

The oil when flowed on a glass plate, which is held in a position inclined 30° to the vertical, shall dry practically free from tackiness in 75 hours at a temperature of 60° to 80° F.

To be purchased by the commercial gallon and inspected by weight. The number of gallons to be determined at the rate of 7½ pounds of oil to the gallon. (Detailed specifications given for cans, packing and method of inspection.)

Linseed Oil (Raw).—(General Supply Committee, Washington, D. C., for the fiscal year ending 1920). The oil shall be bright, clear, and well settled; free from rosin in any form, and from excessive "foots," and suspended matter. When heated in a current of inert gas at 100° C.(212° F.) for one-half hour it shall not show a loss of more than 0.2 per cent. in weight. It shall comply with the specifications of the American Society for Testing Materials (as published in the latest edition of the American Society for Testing Materials Standards) for "Purity of Raw Linseed Oil from North American Seed." The only deviation from these specifications which will be allowed is, that in case the oil furnished is from South American seed, the iodine number (Hanus method) shall be not less than 170.

Linseed Oil.—(U. S. Inter. Dept., Comm. on Paint Specif. Stand., Bur. of Stand. Circ. No. 82, June, 1919.)

Linseed oil, raw, refined, or boiled, as specified in contract, shall be pure and shall conform to the following requirements:

Raw Linseed Oil.

	Maximum	Minimum
Loss on heating at 105 to 110° C. (per cent.)	0.2	..
Foots by volume (per cent.)	2.0	..
Specific gravity 15.5/15.5° C.	.936	0.932
Acid number	6.0	..
Saponification number	195.0	189.0
Unsaponifiable matter (per cent.)	1.5	..
Iodine number (Hanus)*	...	170.0

Color—Not darker than a freshly prepared solution of 1.0 g. potassium bichromate in 100 cc. pure strong (1.84 specific gravity) sulphuric acid.

* When raw linseed oil from North American seed is specified by the purchaser, the iodine number must be not less than 180 and the oil shall conform to all the other requirements as above.

Refined Linseed Oil.

Contract shall state whether acid refined or alkali refined is desired.

	Maximum	Minimum
Loss on heating at 105 to 110° C. (per cent.)	0.2	..
Foots by volume (per cent.)	.2	..
Specific gravity 15.5/15.5° C.	.936	0.932
Acid number (acid refined oil)	9.0	3.0
Acid number (alkali refined oil)	3.0	..
Saponification number	195.0	189.0
Unsaponifiable matter (per cent.)	1.5	..
Iodine number (Hanus)*	...	170.0

Color—Not darker than a freshly prepared solution of 1.0 g. potassium bichromate in 100 cc. pure strong (1.84 specific gravity) sulphuric acid.

* When refined linseed oil from North American seed is specified by the purchaser, the iodine number must be not less than 180 and the oil shall conform to all the other requirements as above.

Boiled Linseed Oil.

Boiled oil shall be pure, well-settled linseed oil that has been boiled with oxides of manganese and lead. It shall conform to the following requirements:

	Maximum	Minimum
Loss on heating at 105 to 110° C. (per cent.)	0.2	..
Specific gravity at 15.5/15.5° C.	.945	0.937
Acid number	8.0	..
Saponification number	195.0	189.0
Unsaponifiable matter (per cent.)	1.50	..
Iodine number (Hanus)*	...	168.0
Ash (per cent.)	.7	.2
Manganese (per cent.)	...	.03
Lead (per cent.)	...	.1
Time of drying on glass (hours)	20.0	..

* When boiled linseed oil from North American seed is specified by the purchaser, the iodine number must be not less than 178 and the oil shall conform to all the requirements as above.

Linseed Oil (Boiled).—(Gen. Supply Comm., Washington, D. C., for fiscal year 1920.) The oil shall be free from rosin in any form, and from an excessive amount of "foots," and suspended matter. When heated in a current of inert gas at 100° C. (212° F.) for one-half hour, it shall not show a loss of more than 0.2 per cent in weight. When flowed on a clean dry glass plate, held in a vertical position, it shall dry in not more than 18 hours at a temperature of 15° to 35° C. (60° to 95° F.). It shall comply with the specifications of the American Society for Testing Materials (as published in the latest edition of the American Society for Testing Materials Standards) for "Purity of Boiled Linseed Oil from North American Seed." The only deviation from these specifications which will be allowed is, that in case the oil furnished is, that in case the oil is from South American seed, the iodine number (Hanus method) shall be not less than 170.

Linseed Oil (Boiled).—(Navy Dept., April 1, 1918.) Boiled linseed oil shall be strictly pure boiled oil of high grade, made wholly by heating pure linseed oil to over 180° C. with oxides of lead and manganese for a sufficient length of time to secure a proper combination of the constituents and shall be properly clarified by settling or other suitable treatment. Evidence of the presence of any matter not resulting solely from the combination of the linseed oil with the oxides of lead and manganese will be considered grounds for rejection.

The oil shall upon examination show:

	Maximum	Minimum
Iodine number (Hanus)	—	178
Saponification number	198	185
Acid number	10	—
Specific gravity at 15.5° C.	.945	.937
Refractive index at 25° C.	1.488	1.479
Unsaponifiable matter, per cent.	1.5	—
Lead oxide (PbO), per cent.	—	.15
Manganese oxide (MnO), per ceut.	—	.03
Ash, per cent.	.8	—

The oil when flowed on a glass plate held in a position inclined 30° to the vertical, shall dry practically free from tackiness in 12 hours at a temperature of 60° to 80° F. (Method of packing and inspection by weight given in detail.)

Neatsfoot Oil.—(Navy Dept., Jan. 2, 1917.) Neatsfoot oil must be free from admixture of other oils, and must not contain more acidity than the equivalent of 2 per cent. of oleic acid.

It must have a cold test below 25° C., as determined in the following manner: A couple of ounces of the oil will be put in a 4-ounce sample bottle and a thermometer placed in it. The oil will then be frozen, using a freezing mixture of ice and salt if necessary. When the oil has become hard the bottle will be removed from the freezing mixture and the oil allowed to soften, being stirred and thoroughly mixed at the same time by means of the thermometer until the mass will run from one end of the bottle to the other. The reading of the thermometer at this moment will be taken as the cold test of the oil.

Before acceptance the oil will be inspected. Samples of each lot will be taken at random, the samples well mixed together in a clean vessel, and the sample for test taken from this mixture. Should the mixture be found to contain any impurities or adulterations, the whole delivery of oil it represents will be rejected, and it is to be removed by the contractor at his own expense.

Each delivery will be considered a lot by itself and each lot will be inspected and accepted or rejected as it passes or fails to pass the test required. No second test of any lot rejected will be permitted. (Delivery to be made in specified cans and cases. Part of cans will be weighed full and empty.)

Neatsfoot Oil.—(Gen. Supply Comm., Washington, D. C., for fiscal year 1920.)

Must be free from admixtures of other oils, be clear and free from dirt, water, etc.; it must not show more acidity than the equivalent of 2½ per cent of oleic acid; it must have a cold test below 12° C.

Sperm Oil.—(Gen. Supply Comm., Washington, D. C., for year ending 1920). Should be pure, winter-strained sperm oil, free from adulteration or admixture with any other oil; must be clear and free from dirt, water, etc., specific gravity to be 0.875 to 884 at 15.5° C., and flash point 482° F., viscosity (Saybolt) at 68° F. not less than 171, at 122° F. not less than 72, and at 194° F. not less than 39.3. (This oil is intended for the Bureau of Engraving and Printing). Flash-point by the Pensky-Martens closed cup.

Sperm Oil.—(Navy Dept., Oct. 2, 1916.) Must be pure winter strained bleached sperm oil, free from admixture or adulteration with animal, mineral, vegetable, or other fish oil, grease, lard, or tallow, or any other adulterant.

The specific gravity must be between 0.875 and 0.885. The flash test of the oil in open cup must not be under 440° F. The oil must show less acidity specifically than the equivalent of 0.25 per cent. of oleic acid. To be purchased and inspected by weight; the number of pounds per gallon to be determined by the specific gravity of the oil at 60° F. multiplied by 8.33 pounds, the weight of a gallon (231 cubic inches) of distilled water at the same temperature.

(Method of inspection, sampling, weighing and rejection substantially as given in the last two paragraphs under neatsfoot oil above. (Packed in white oak casks.)

Sperm Oil (Natural).—(War Dept., Office Depot Quartermaster, New York City, January, 1915.) Must be absolutely pure natural winter sperm oil of best quality and must conform to the following tests:

Specific gravity	0.875–0.884 at 60°F.
Saponification value	123 – 147.
Iodine value	82 – 85.
Maumené test	81°– 85°F.
Color	Light straw.
Odor	Slight and sweet.
Flash	Must not flash below 485°F.
Cold test	Must flow at a temperature of 38°F.

Quart samples must be submitted with bid.

Sperm Oil (Bleached.—(War Dept., Office Depot Quartermaster, New York City, January, 1915.) (Specifications as for sperm oil, natural, except that color is "pale yellow," odor "none," flash "not below 500° F.," and test for acidity "must show less than the equivalent of 0.25 per cent. of oleic acid.)

Tallow.—(Navy Dept., May 1, 1917.) To be a high-grade tallow, pure and refined, free from rancidity, dirt, cracklings, soap, or other substances not properly belonging to tallow.

To be free from more acidity than the equivalent of 2 per cent. of oleic acid, and the mixed fatty acids to titer not less than 42° C.

Payment will be based on net weight, and net weight only should be delivered. (To be delivered in specified soldered top tins, to be boxed and marked as specified.)

Tallow.—(Norfolk & Western Railway, Office Supt. of Motive Power, Roanoke, Va., April 15, 1912.) The material desired under this specification should be made from beef or sheep fat, free from cottonseed stearines and wool grease, and should be rendered within 12 hours after the animal is killed, at a temperature not in excess of 250° F. It should be as near white in color as is possible to obtain, firm, of good odor, and free from granulation.

When a shipment of this material is received, a sample will be taken in such a manner as will represent the average condition of the entire lot, and acceptance or rejection will be based upon the results of the examination of this sample.

Material will not be accepted which upon examination shows:

1. Dirt or crackings disseminated through it or in streaks, or which has a layer of dirt or cracklings at the bottom of the cake or cakes more than 1/8 inch thick.
2. An amount of free acid, determined in accordance with method outlined below, in excess of 1.5 per cent.
3. Soap or other substances not properly belonging to the material, or more than 0.5 per cent. of animal tissue.

The free acid is determined as follows: Take 2 ounces of neutral 95 per cent. alcohol, and add a few drops of phenolphthalein solution. Heat to 150° F., then add 10 grams of the material. Shake the contents of the flask until solution of the tallow is effected, cool, and titrate with decinormal sodium hydrate until the color of the solution remains a permanent pink. From the numbei of cubic centimeters of decinormal solution required (1 cc. N/10 NaOH equals 0.0282 gram oleic acid) the percentage of free acid is obtained.

All material failing to conform to the requirements of this specification will be rejected and returned to the shipper, he being required to pay all freight charges both ways.

Tallow.—(Pennsylvania Railroad, Office Gen. Supt. Motive Power, Altoona, Pa., April 29, 1913.) Tallow according to this specification will be ordered in amounts as the demands of the service indicate.

The material desired under this specification is a tallow containing the least possible amount of free acid, and also as free as possible from dirt, "cracklings" and fiber.

To persons furnishing tallow who may not have appliances for determining the amount of free acid in tallow, it may be said that if the fat is rendered within 12 hours from the time the animal is killed, using a temperature of not more than 225° to 250° F. during the rendering, it is believed that the free acid in the tallow will be less than the amount specified. In very warm weather it may be necessary to render the fat in less than 12 hours after the animal is killed.

A shipment being received at any point, a sample of not less than ½ pound must be sent to the chief chemist, Pennsylvania Railroad, Altoona, Pa., by railroad service, in a "sample for test" box, accompanied by a "sample for test" tag properly filled out, and the tallow must not be used until report of test is received. A sample must be sent for test from every shipment of 1,000 pounds or less, and if more than 2,000 pounds are in the shipment, three samples must be sent, and so on. These large shipments must be divided into parts corresponding to the number of samples, and a designating mark put on each part and the same mark on the tag of its sample.

Shipments of tallow will not be accepted which:

1. On inspection, are found to contain dirt or "cracklings" disseminated through the material in the bar-

rels, or in streaks, or which have a layer of dirt or "cracklings" in the bottom of the barrel more than 1/8 inch thick.

2. Contain more free acid than is neutralized by three (3) cc. of alkali as described below.
3. Contain soap or other substances not properly belonging to tallow.

The amount of free acid in tallow is determined as follows: Have ready (1) a quantity of 95 per cent. alcohol, to which a few grains of carbonate of soda has been added, thoroughly shake and allow to settle; (2) a small amount of turmeric solution; (3) caustic potash solution of such strength that 31½ cc. exactly neutralizes 5 cc. of a solution of sulphuric acid and water, containing 49 milligrams of H_2SO_4 per cubic centimeter. Now weigh or measure into any suitable closed vessel, a 4-ounce sample bottle for example, 8.9 grams of the melted tallow. Add about 2 ounces of the alcohol, warmed to about 150° F., add a few drops of the turmeric solution and shake thoroughly. The color becomes yellow. Then add from a burette graduated to cubic centimeters, the caustic potash solution, little at a time with frequent shaking, until the color changes to red, which red color must remain permanent after the last vigorous shaking. The number of cubic centimeters used, shows whether the tallow stands test or not.

Ten cc. of melted tallow at 100° F., weigh almost exactly 8.9 grams. In ordinary work, therefore, it will probably not be necessary to weigh the tallow. Measurement with a 10 cc. pipette will usually be sufficiently accurate, provided the pipette is warmed to about 250° F., and allowed to drain, the last drops being blown out. In case of dispute, however, the balance must be used.

Samples of rejected material are usually held at the laboratory one month from date of test report. Accordingly, in case of dissatisfaction with the results of test, the shippers must make claims for rehearing, should they desire to do so, within that time. Failure to raise a question for one month will be construed as evidence of satisfaction with the tests, the samples will be scrapped, and no claims for rehearing will be considered.

Tallow.—(Seaboard Air Line Railway, Motive Power Dept., July 7, 1915.) Tallow will be furnished in either of the two grades, No. 1 or No. 2, as ordered.

No. 1 Tallow. The material desired under this specification is clear white tallow, as free from acid, dirt or cracklings as possible. Material must meet the following requirements and will be condemned if:

1. Sample shows dirt or cracklings disseminated through it or in streaks, or if the barrel from which sample was taken has a layer of dirt or cracklings in the bottom more than 1/8 inch in thickness.
2. Sample contains more than 1.5 per cent. of free acid.
3. Sample contains soap, or any other substance not properly belonging to tallow.
4. Sample has a melting point below 120° F. or above 125° F.

No. 2 Tallow. This material will be obtained for common uses, such as skidding lumber, protecting iron surface from rust, moving heavy machinery, etc. It is not to be used for lubrication of machinery, compounding hot box grease, or for use in shipyard around copper bottoms. The material desired in this specification is a clear, nearly white tallow, as free from dirt and cracklings as possible. The material must meet the following requirements, and will be condemned if:

1. Sample shows dirt or cracklings disseminated through it or in streaks, or if the barrel from which samples are taken has a layer of dirt or cracklings in the bottom more than 1/4 inch thick.
2. Sample contains more than 10 per cent. free acid.
3. Sample contains soap or any substance not properly belonging to tallow.
4. Sample has a melting point below 110° F. or above 120° F.

Tallow will not be accepted that is rancid. It must be free from odor of decomposition.

Remarks: Tallow not meeting the requirements of the above specifications will be condemned. In case of rejection the materials will be held for two weeks from the date of test. If by the end of that period the manufacturers have not given shipping directions, it will be returned to them at their risk, they paying the freight both ways.

Whale Oil.—(Navy Dept., Mar. 1, 1917.) Whale oil shall be best grade of bleached winter-strained oil, free from adulteration with other oils, and each lot shall be accompanied by a written guaranty from the manufacturer that it is pure whale oil.

Before acceptance the oil will be inspected and tested. Samples of each lot will be taken at random, the samples well mixed together in a clean vessel, and the sample for test taken from this mixture. Should the mixture be found to contain any impurities or adulterations, the whole delivery of oil it represents will be rejected.

(*a*) Tested with litmus paper, the oil shall show no trace of acid.

(*b*) It shall begin to become torpid at from 35° to 42° F.; cease to flow at 17° to 18° F.; and shall flash at not less than 490° F.

(*c*) The specific gravity of the oil at 60° F. shall be from 0.921 to 0.927.

CHAPTER XX.

SPECIFICATIONS FOR STEAM CYLINDER OILS.*

Steam Cylinder Oils (Light, Medium and Heavy). (Board of Purchase, City of New York, Jan., 1920). (For general Specifications, see Index).

	Light	Medium	Heavy
Viscosity at 210° F.	105–120	120–135	150–175
Flash point, Cleveland open cup	450	450	500
Pour test: Shall flow at	60° F.	60° F.	60° F.
Free acid, max.	0.6%	0.6%	0.1%
Matter insoluble in 88° gasoline	0.5%	0.5%	0.1%
Tallow oil, or mixt. of tallow oil & degras	6.0%	8.0%	None

No. 2 Cylinder Oil.—(City of St. Louis, Water Div., April, 1919). Cylinder oil furnished under this contract shall be pure filtered mineral oil. It must be free from dirt, grit, lumps and specks; transparent amber in thin film; bright ruby through neck of four ounce bottle; translucent greenish by reflected light. It must satisfactorily pass the following tests:—

TESTS.

Specific Gravity.—26° to 28° Baumé at 60° F.

Flash Point.—Must not flash below 540° F.

Burning Point.—Must not burn below 600° F.

Viscosity.—Must not be less than 130 (Saybolt) at 212° F.

Cold Test.—Must flow readily at 50° F.

Water.—Must not froth or bump when heated in flash cup.

Tarry and Suspended Matter.—5 cc. of this oil shaken with 95 cc. of 88° petroleum ether in a glass stoppered graduate must show no precipitation of tarry and suspended matter.

Volatility.—Heated for two hours at a temperature of 400° F. this oil must not show a loss of more than 5 per cent. by weight.

Quality Test.—Heated slowly over an open flame until vapors appear above the oil surface. Maintained at this temperature for fifteen minutes. Oil must remain

* Also see Index or Chapter on Standard Government Specifications for Lubricants.

perfectly clear and free from sediment after standing for twenty-four hours.

A one quart sample in glass must be submitted with each bid and all deliveries must be in substantial accordance not only with the above specifications but also with this bid sample.

(To be delivered in 54-gal. iron drums; the first delivery within 15 days of receipt of order, later deliveries within 5 days after notification).

[A private communication from Mr. L. A. Day, Engr. in Charge, states that the straight mineral oil did not prove satisfactory in use and so 2% tallow oil will be added as formerly.]

Cylinder Oil (Steam).—(Gen. Supply Comm., Washington, D. C., for fiscal year 1920). Must contain not less than 4 per cent. fatty oil; minimum flash point, 460° F.; minimum fire point, 570° F.; must not require more than 0.25 milligram KOH to neutralize 1 gram; cold test not higher than 40° F.; must not contain over 0.3 per cent of asphaltic or tarry matter; to be delivered in steel barrels, which shall remain the property of the contractor.

(*aa*) Light; viscosity (Saybolt) not over 800 at 130° F.; 120-135 at 210° F.

(*bb*) Heavy; viscosity (Saybolt) not over 890 at 130° F.; 135-150 at 210° F.

The Oil must be free, as determined by chemical test, from mineral acids, and soap. Flash test by the Pensky-Martens closed-cup.

Mineral Cylinder Oil.—(War Dept., Quartermaster Corps, Specif. No. 3509, April 24, 1918. Approved and adopted by Ordnance Dept., Quartermaster Corps, Engineer Corps, Medical Corps and Signal Corps, U. S. A.)

General.

1. This specification covers the requirements of the U. S. Army for mineral cylinder oil known to the trade as "600 Steam Refined Cylinder Oil," to be used for steam engine lubrication where a mineral oil is re-

quired, also as a stock oil for compounding, and as a medium transmission lubricant for motor vehicles.

PHYSICAL PROPERTIES AND TESTS.

2. The oil must be a well refined, unfiltered oil, without compounding of any nature. It must be free from moisture, dirt and all foreign matter.
3. *Viscosity.*—The viscosity must be within the following limits when the lubricant is tested in a Saybolt Universal Viscosimeter at 212° F. 135 seconds to 165 seconds.
4. *Flash Point.*—The flash point of oil must be more than 475° F. in a Cleveland open cup.
5. *Pour test.*—One ounce of the oil, in a standard four-ounce sample bottle, must not congeal at 45° F.
6. All tests must be made in accordance with methods adopted by the American Society for Testing Materails.
7. The bidder must state in his proposal the characteristics of the oils which he proposes to furnish: [*e.g.,* gravity, viscosity, etc., etc.]

Compounded Cylinder Oil.—(War Dept., Quartermaster Corps, Specif. No. 3510, April 24, 1918. Approved and adopted by Signal Corps, Quartermaster Corps, and Engineer Corps, U. S. A.)

GENERAL.

1. This specification covers the requirements of the U. S. Army for compound cylinder oil to be used for the lubrication of steam cylinders of engines and pumps, where a compounded oil is required.

PHYSICAL PROPERTIES AND TESTS.

2. The oil must be a well refined, clean, mineral cylinder oil, known to the trade as "600 Steam Refined Cylinder Oil." It must be compounded with from 5 to 10 per cent. of tallow oil. The finished oil must be free from moisture, dirt and all foreign matter.

3. *Viscosity.*—The viscosity, when the oil is tested in a Saybolt Universal Viscosimeter, at 212° F., must be as follows: 135 seconds to 150 seconds.
4. *Flash point.*—The flash point of the oil must be over 475° F., in a Cleveland open cup.
5. *Pour test.*—One ounce of the oil must not congeal in a standard four-ounce sample bottle at 50° F.
6. All tests shall be made in accordance with methods adopted by the American Society for Testing Materials.
7. The bidder must state in his proposal the characteristics of the oils which he proposes to furnish: [*e.g.*, gravity, viscosity, etc.]

Cylinder Oil No. 3.—(Baltimore & Ohio Railroad, Motive Power Dept., Baltimore, Md., April 27, 1914.) This is for use in isolated water pumping plants and other places where low pressure saturated steam is used and a high grade cylinder oil is not required.

This material will be tested and inspected on its arrival at destination by the B. & O. Test Bureau, and the decision of the engineer of tests, as to its acceptance or rejection, shall be final.

(*a*) The oil must be a mixture of pure petroleum distillate and acidless animal oil (tallow oil preferred), unmixed with any other substance, and meet the requirements of the following detail specifications.

(*b*) This material will be purchased by weight. Barrels must be in good condition, and must have the name of contents and consignor's name and address on each barrel, and plainly marked with the gross and net weights. This applies to oil tank cars as well as barrels. Parties failing to mark both gross and tare weights on their packages must accept this Company's weights without question.

(*c*) When received, all shipments will be promptly weighed. If not practicable to empty all barrels, 5 per cent. will be emptied, and the losses of the whole shipment will be adjusted in accordance with the 5 per cent. taken. Should the net weight taken be less by 1 per cent. than the weight charged on bill, a reduction will be made for all over 1 per cent. This 1 per cent. covers leakage in transit, and the amount which adheres to the barrels in emptying; also possible slight difference in scales.

(*d*) Price should be given in cents and hundredths of a cent per pound.

(*e*) Shipments, one or more barrels of which are filled with oil containing dirt, water or other impurities, will be rejected.

When a shipment is received, a single sample will be taken at random from any barrel and subjected to test, and shipment will be accepted or rejected on this sample.

(*a*) It must show not less than 5 per cent. acidless animal oil.
(*b*) It must have a flash test of at least 450° F.
(*c*) It must have a fire test not below 500° F.
(*d*) It must have a cold test below 55° F.
(*e*) The gravity must be between 21° and 27° Bé. at 60° F.
(*f*) It must contain not more than 0.10 per cent. free fatty acid.
(*g*) It must be free from dirt, specks, lumps, grit, wax, water, soap or suspended matter of any kind, acid or alkali.
(*h*) Must not contain more than 3 per cent. volatile matter at 400° F. in two hours.
(*i*) The viscosity at 210° F. must not be less than 100 seconds when tested in a Universal Saybolt Viscosimeter.

The "Cleveland" open cup is used for determining the flash and burning point of this oil, heating the oil at the rate of about 15° per minute and applying the test flame every 10°, beginning at 430° F.

Samples representing rejected material will be retained in the test bureau not longer than two weeks from date of test. If at the end of that period the sellers have not given shipping directions, the material represented will be returned to them at their risk, they paying the freight both ways, in either case.

Cylinder Stock.—(Philadelphia & Reading Railway, Office First Vice-President, Philadelphia, Pa., Nov. 15, 1893.) This grade of oil shall have a flashing point not below 525° F., and a burning point not below 600° F. The test will be made in an open vessel by heating the oil not less than 20° per minute, and applying the test flame every 7° beginning at 504°.

The oil must flow readily at 60° F., and at 350° F. must show a viscosity not lower than that of a pure cane sugar solution containing 52 grams of sugar in 100 cc. of the syrup, the viscosity of the sugar solution being taken at 80° F.

This oil must be transparent, with a reddish brown or green color, free from lumps or specks.

No oil will be accepted which shows more than 5 per cent. of flocculent or tarry matter settled out, after 5 cc. of the oil have been mixed with 95 cc. of 88° gasoline, and allowed to stand for one hour.

Cold Test.—About 2 ounces of oil is put in a 4-ounce sample bottle, a thermometer inserted and the oil frozen with a mixture of ice and salt. When the oil is hard the bottle is taken from the freezing mixture and the frozen oil stirred thoroughly with the thermometer until it will flow. The reading of the thermometer is then taken, and this temperature is regarded as the cold test of the oil.

NOTE.—The viscosity tests will be made upon the Torsion viscosimeter.

Cylinder Oil.—(Philadelphia & Reading Railway, Nov. 15, 1893.) This oil shall consist of a high grade cylinder stock, compounded with not less than 20 per cent. by weight of acidless animal oil, tallow or tallow oil being preferred.

(The other tests specified for this "compounded oil" are exactly as given for cylinder stock just above.)

CHAPTER XXI.

SPECIFICATIONS FOR TURBINE OILS.*

Turbine Oil.—(War Dept., Specif. No. 3528, June 3, 1919, Raw Materials Div., Oil Branch).

General.

1. This specification covers the requirements of the United States Army for Turbine Oils.

2. The oils shall be in four grades: No. 1 Light, No. 2 Medium, No. 3 Heavy, and No. 4 Extra Heavy.

Physical Properties and Tests.

3. The oil must be a pure, well refined, straight mineral oil free from water, acid, sediment and mineral impurities.

4. The Flash point (Cleveland open cup) shall be—

No. 1 Light	390-410° F.
No. 2 Medium	400-420° F.
No. 3 Heavy	420-430° F.
No. 4 Extra Heavy	425-435° F.

5. The Fire point (Cleveland open cup) shall be—

No. 1 Light	Not less than 450° F.
No. 2 Medium	Not less than 465° F.
No. 3 Heavy	Not less than 480° F.
No. 4 Extra Heavy	Not less than 500° F.

6. The viscosity (Saybolt Universal Viscosimeter) shall be as follows—

No. 1 Light	140 to 150 @ 100° F.
No. 2 Medium	175 to 200 @ 100° F.
No. 3 Heavy	250 to 275 @ 100° F.
No. 4 Extra Heavy	350 to 400 @ 100° F.

7. The Pour Test (A. S. T. M.) for No. 1, 2 and 3 grades shall be from 25-35° F. No. 4 shall have a pour test from 50 to 55° F.

8. Carbon. The oil must not show a carbon residue (Conradson Carbon Test) greater than—

No. 1 Light	0.10%
No. 2 Medium	0.12%
No. 3 Heavy	0.30%
No. 4 Extra Heavy	0.35%

* Also see Index or Chapter on Standard Government Specifications for Lubricants.

9. Acidity. The acidity of the oil must not be more than 0.03% calculated to SO_3.

10. Emulsion Test. One ounce of the oil shall be placed in a standard 4 oz. sample bottle with one ounce of distilled water. The mixture shall be heated to 180° F. and then shaken vigorously for five minutes. After standing for one hour, the oil must be clear and of the same color as before the test. All the water must have settled and appear only slightly cloudy.

11. All Tests must be made in accordance with methods adopted by the American Society for Testing Materials.

12. The bidder must state in his proposal the following characteristics of the oils which he proposes to furnish, *e.g.,* Gravity, Viscosity, etc.

Engine Oil (high speed and steam turbine). (Gen. Supply Comm., Washington, D. C., for fiscal year 1920). Minimum flash point, 300° F.; minimum fire point, 350° F.; must not require more than 0.07 miligram KOH to neutralize 1 gram; demulsibility as determined by Herschel's method (Bureau of Standards Technologic Paper No. 86).

(1) Light; viscosity (Saybolt) not over 95 at 130° F., 38-42 at 210° F., demulsibility at least 300.

(2) Heavy; viscosity (Saybolt) not over 175 at 130° F., 46-51 at 210° F.; demulsibility at least 200.

The oil must be free, as determined by chemical test, from mineral acids, soap, and asphalt or tarry matter. Flash test by the Pensky-Martens closed cup.

Light Turbine Oil.—(City of St. Louis, Water Div., 1919.) Turbine oil furnished under this contract shall be the filtered product obtained from the refinement of pure mineral crude oil without the subsequent addition of any other substance foreign to the distillation. It must be clear, free from water, tarry or suspended matter, and shall be absolutely neutral in its reaction.

The oil shall possess the following characteristics:—

1. Its specific gravity shall not be less than 31° Baumé at 60° F.
2. It must not flash below 400° F. when tested in Pensky-Marten closed flash cup apparatus.

3. It must not burn below 450° F., in the open cup of the Pensky-Marten apparatus.
4. Its specific viscosity shall not be less than 65 or more than 140 Saybolt between the temperatures of 120° F. and 150° F.
5. When heated for seven hours at 150° F. it shall show a loss of not more than 0.1% by weight; and when heated for two hours at 350° F. it shall show a loss of not more than 2.5% by weight. There shall be no deposit of carbonaceous matter resulting from either of these tests.
6. 25 cc. of the oil shall be placed in a glass test tube surrounded by cold water. Live steam from a 3/16″ glass tube shall be bubbled through the oil steadily, but not violently, for two minutes, and after standing quietly for twenty minutes, the oil and water of condensation shall show a clear cut separation.
7. The oil shall flow readily at 50° F.

A one quart sample in glass shall be submitted with each bid and all deliveries shall be in substantial accordance not only with the above specifications but also with this bid sample. (To be delivered in iron drums).

Medium Turbine Oil.—(City of St. Louis, Water Div., 1919.) Turbine oil under this contract shall be the filtered product obtained from the refinement of pure mineral crude oil without the subsequent addition of any other substance foreign to the distillation. It must be clear, free from water, tarry or suspended matter, and shall be absolutely neutral in its reaction.

The oil shall possess the following characteristics:—

1. Its specific gravity shall be not less than 26 Baumé at 60° F.
2. It must not flash below 400° F. when tested in Pensky-Marten apparatus closed flash cup apparatus.
3. It must not burn below 450° F. in the open cup of the Pensky-Marten apparatus.

4. Its specific viscosity shall not be less than 85 or more than 175 Saybolt between the temperatures of 120° F. and 150° F.
5. When heated for seven hours at 150° F. it shall show a loss of not more than 0.1% by weight; and when heated for two hours at 350° F. it shall show a loss of not more than 2.5% by weight. There shall be no deposit of carbonaceous matter resulting from either of these tests.
6. 25 cc. of the oil shall be placed in a glass test tube surrounded by cold water. Live steam from a 3/16″ glass tube shall be bubbled through the oil steadily, but not violently, for two minutes, and after standing quietly for twenty minutes, the oil and water of condensation shall show a clear cut separation.
7. The oil shall flow readily at 50° F.

A one quart sample in glass shall be submitted with each bid and all deliveries shall be in substantial accordance not only with the above specifications but also with this bid sample. (To be delivered in iron drums).

[Mr. L. R. Day, Engr. in Charge, states that it was difficult to find a commercial oil that would fully satisfy the water separation test, though two oils, out of 15 tested, did show a clear cut separation. The Herschel test did not seem so satisfactory for this medium oil as did the test specified, though the Herschel test was run on the 15 oils.]

Lubricating Oils.* (Bureau of Steam Engineering, Navy Dept., March 1, 1920).

FORCE FEED AND MOTOR CYLINDER OILS.

	Saybolt @ 130° F.	
Light	100–115	Force feed, turbine and reciprocating.
Medium	125–145	
Heavy	180–200	
Extra heavy	240–260	
Ultra heavy	300–320	
Aviation oil, summer	90–100 @ 210° F.	
Aviation oil, winter	75– 85 @ 210° F.	

* Additional requirements are given, with methods of testing, but were received too late to be included here.

CHAPTER XXII.

SPECIFICATIONS FOR CYLINDER OILS FOR INTERNAL COMBUSTION ENGINES.*

Motor Oils for Gasoline Engines.—(War Dept. Specif. No. 3502-A. Prepared by Oil Branch, Raw Materials Div., Office of Director of Purchase, July 10, 1919).

GENERAL.

1. This Specification covers the requirements of the U. S. Army for motor oils to be used for the lubrication of internal combustion engines other than airplanes engines and motorcycle engines.*
2. The oil shall be supplied in three grades, light, medium, and heavy. The light oil shall be used where specially specified. The medium oil shall be for general use in winter and for use in new engines at all times. The heavy oil shall be for general use in summer and for use in old engines.

PHYSICAL PROPERTIES AND TESTS.

3. Only straight minerals oils without the admixture of fatty oils, rosins, soaps or any other compounds not derived from crude petroleum will be considered. The oil must be entirely soluble in standardized petroleum ether. A clean polished copper plate, 1 inch square must not be discolored when partly covered by the oil for 24 hours.
4. *Viscosity.*—The viscosity of the three grades of oil, when tested in a Saybolt Universal Viscosimeter must be within the following limits:

		Temperature 130°F.	212°F.
Light Oil	Not over	95	40-44
Medium	Not over	130	45-49
Heavy	Not over	175	50-55

5. *Flash or Fire.*—The flash and fire-points of the three grades as determined in the Cleveland open cup should not be lower than the following:

* Also see Index or Chapter on Standard Government Specifications for Lubricants.

	Flash deg. F.	Fire deg. F.
Light Oil	325	375
Medium Oil	340	390
Heavy Oil	350	400

6. *Oxidation Test.*—Maximum amount of petroleum ether insolubles for all three grades, .25 per cent. as determined by Waters' method. (Bureau of Standards, Scientific Paper No. 160, and Tech. Paper No. 73.)
7. *Carbon.*—The Carbon residue, determined by the Conradson method, must be as follows:

Light Oil	Not more than 0.2 per cent.
Medium Oil	Not more than 0.4 per cent.
Heavy Oil	Not more than 0.6 per cent.

8. *Pour Test.*—The pour test temperatures of the oils as determined by the A. S. T. M. method, shall be not higher than—

Light Oil	25° F.
Medium Oil	30° F.
Heavy Oil	40° F.

9. *Acidity.*—Not more than 0.05 milligram potassium hydroxide should be required to neutralize 1 gram of the oil.
10. *Emulsion.*—One ounce of oil and one ounce of water shall be placed in a standard four ounce bottle at room temperature (70° F.) and shaken in a shaking machine for one-half hour at 600 r.p.m. After standing for 24 hours the oil and water must be perfectly separated the oil must be clear and the water, at most, slightly cloudy. A loss of brilliancy in the oil due to absorption of moisture and a slight white interface between the oil and water is permissible.
11. All tests, unless specified otherwise, shall be made in accordance with methods adopted by the American Society for Testing Materials.
12. Every bidder must state in his proposal the characteristics of the oils which he proposes to furnish.

* For these engines use Liberty Aero Oil, Specification No. 3, 501.

Gasoline Engine or Gas Engine Oil.—(Gen. Supply Comm., Washington, D. C., for fiscal year 1920). Maximum carbonization 0.15 per cent., as determined by Waters's method (Bureau of Standards Scientific Paper No. 160); must not require more than 0.05 milligram KOH to neutralize 1 gram; cold test not higher than 32° F.

1. *Medium.*—Minimum flash point, 330° F.; minimum fire point, 380° F.; viscosity (Saybolt) not over 130 at 130° F., 42-46 at 210° F.
2. Heavy; minimum flash point, 330° F.; minimum fire point, 380° F.; viscosity (Saybolt) not over 175 at 130° F., 46-51 at 210° F.
3. Extra heavy, for motor cycles; minimum flash point, 385° F.; minimum fire point, 430° F.; viscosity (Saybolt) not over 800 at 130° F., 65-140 at 210° F.

The oil must be free, as determined by chemical test, from mineral acids, soap, and asphalt or tarry matter. Flash test by the Pensky-Martens closed-cup.

"**Gas Engine Cylinder Oils** (Light, Medium and Heavy.) (Board of Purchase, City of New York, Jan., 1920.)

"General Specifications for all kinds of lubricating oils for the City of New York:

"*Quality.*—Lubricating oils shall be properly refined and filtered mineral oils, free from alkali, water, animal, vegetable, suspended matter, and sediment; except that plain bearing oils need not be filtered. They may be red or pale in color and shall meet all other requirements. Also certain grades as hereinafter specified shall be properly compounded with animal and vegetable oils as specifically required. [Compounded Oils: Steam Cylinder Oils, Heavy Marine Engine Oil, and Cutting Oil.]

"*Kinds and Grades.*—It shall be either of the kinds and grades *as called for in the schedules* and each grade shall meet its respective test requirements, as specified in the table of requirements.

"*Methods of Tests.*—All tests shall be made in accordance with the Board of Estimate's Standard Methods of Tests.

"Delivery.—It shall be delivered in the size and kind of container as *called for in the schedules.* The name of the vendor, the quantity, kind and grade of oil shall be plainly marked on each container. All containers shall become the property of the City of New York, *unless otherwise stated in the schedules.*

"Payment.—Payment shall be made for the number of gallons net of oil accepted, at the price bid per gallon, delivered in the size and kind of container specified.

	Light	Medium	Heavy
Viscosity at 100° F.	180–230	270–340	———
Viscosity at 210° F.	———	———	70–110
Flash point, Cleveland open cup	310	325	390
Pour test: Shall flow at	20° F.	35° F.	50° F.
Free acid, max.	0.1%	0.1%	0.1%
Matter insoluble in 88° gasoline	None	None	None
Carbon residue, Conradson method	0.5%	0.5%	2.0%
Emulsification	Negative	Negative	Negative
Ash, max.	0.02%	0.02%	0.02%

Liberty Aero Oil.—(War Dept., Fuel and Forage Div., Oil Branch, Quartermaster Corps, U. S. A. Specif. No. 3, 501, April 24, 1918. Approved and adopted by Ordnance Dept., Quartermaster Corps, Engineer Corps, Medical Corps and Signal Corps, U. S. A.)

GENERAL.

1. This specification covers the requirements of the U. S. Army in all purchases of oil to be used for the lubrication of stationary cylinder aircraft engines.
2. It is intended to use the name "Liberty Aero Oil" for all oils approved for the lubrication of these engines. On account of differences in characteristics of the high and low specific gravity oils, this specification is drawn to cover both types of oil and to include products manufactured from crude petroleum oils from all fields. For the purposes of this specification, oils are classified as follows:

CLASSIFICATION.

3. *High specific gravity oils.*—This class includes all oils having a specific gravity above 0.9100 (or below 24°

Baumé conversion by the Tagliabue Manual, 9th Edition, or below 23.85° Baumé conversion by the Bureau of Standards' conversion table, Circular No. 57)—and having a pour test below 15° F. (Tested by the method of the American Society for Testing Materials.)

4. *Low specific gravity oils.*—This class includes all oils having a specific gravity below 0.9100 (or above 24° Baumé conversion by the Tagliabue Manual, 9th Edition, or above 23.85° Baumé conversion by the Bureau of Standards' conversion table, Circular No. 57)—and having a pour test above 15° F. (Tested by the method of the American Society for Testing Materials).

PHYSICAL PROPERTIES AND TESTS.

5. The oil must be made from pure, highly refined petroleum products, and must be suitable in every way for the entire lubrication of stationary cylinder aircraft engines operating under all conditions.

6. The oil must be neutral in action and must not show the presence of moisture, sulphonates, soap, resin or tarry constituents which would indicate adulteration or lack of proper refining.

7. *Viscosity.*—The viscosity of the oil, when tested in a Saybolt Universal Viscosimeter at 212° F., shall be as follows:

   High specific gravity oil.....70 seconds to 75 seconds
   Low specific gravity oil.....85 seconds to 90 seconds

8. *Pour test.*—The oil must pass the following pour test:

   High specific gravity oil............not over 15° F.
   Low specific gravity oil............not over 40° F.

9. *Flash point.*—The oil must have a flash point over 350° F., in a Cleveland open cup.

10. *Carbon.*—The oil must not show a carbon residue of over 1.5 per cent. by the Conradson method. The carbon shown must be loose and flaky and must break up easily in the crucible.

11. *Emulsion test.*—One ounce of oil shall be placed in a standard four-ounce sample bottle with one ounce of distilled water. The mixture shall be heated to a temperature of 180° F., and then shaken vigorously for five minutes. After standing for one hour, the oil must be clear and of the same color as before the test. All of the water must have settled and appear only slightly cloudy.

12. All tests must be made in accordance with methods adopted by the American Society for Testing Materials.

13. The bidder must state in his proposal the characteristics of the oils which he proposes to furnish.

Motorcycle Engine Oil.—(Bur. of Aircraft Prod., U. S. A., Specif. No. 3, 520, June 30, 1918.)

GENERAL.

1. This specification covers the requirements of the Bureau of Aircraft Production for motor oil to be used for the lubrication of motorcycle engines.

PHYSICAL PROPERTIES AND TESTS.

2. The oil shall be a highly refined and filtered mineral oil or a blend of such oils. It must be suitable in every way for the lubrication of motorcycle engines.

3. *Viscosity.*—The viscosity of the oil, must not be less than 110 seconds at 212° F., when tested in a Saybolt Universal Viscosimeter.

4. *Carbon.*—The carbon residue, as determined by the Conradson method described in Signal Corps Specification No. 3.525, must not exceed 1.7 per cent.

5. *Pour Test.*—One ounce of the oil must not congeal in a standard 4-oz. sample bottle when exposed to temperatures above 50° F.

6. *Emulsion Test.*—One ounce of the oil together with one ounce of distilled water shall be placed in a standard 4-oz. sample bottle and heated to a temperature of 180° F. and then shaken vigorously for five minutes. Let stand for one hour, after which the sep-

aration of oil and water must be complete, leaving the oil clear and of the same color as before test and the water only slightly cloudy.

7. All tests shall be made in accordance with methods adopted by the American Society for Testing Materials.

STATEMENT TO BE SUBMITTED BY BIDDERS.

8. Every bidder shall state in his proposal the following characteristics of the oils which he proposes to furnish:

Gravity.—Baumé and 60° F.

Flash.—Cleveland open cup.

Fire.—Cleveland open cup.

Viscosity.—Saybolt Universal Viscosimeter, at 70, 100, 130, and 212° F.

Pour Test.—American Society for Testing Materials' method.

Carbon.—Conradson method.

Motor Oils.—Specifications recommended by C. W. Stratford, in address before Soc. Automotive Engrs.; *Nat. Pet. News,* pp. 20-22, March 20, 1918 (for methods of testing see Index).

The nomenclature used for designating the specifications is as follows: Aircraft engine oils, A. E. O.; automobile and truck engine oils, A. T. O.; and Knight sleeve-valve engine oils, K. S. V. O. The air cooled motorcycle engine oils are not given a separate designation, since the oils specified for other duty can be used.

AIRCRAFT ENGINES.

A. E. O. No. 1 (High Altitude or Low Altitude Winter.)

1. Viscosity at 212° F., seconds, 58 to 70; desired 65.
2. Cold test, maximum 40° F.
3. Boiling-point range, maximum 4 per cent. under 300° C.
4. Oxidation, insolubles, maximum 0.20 per cent.; evaporated loss, maximum 40 per cent.
5. Emulsion, maximum trace.

A. E. O. No. 2 (Low Altitude Summer.)

1. Viscosity at 212° F., seconds, 80 to 90; desired 85.
2. Cold test, maximum 45° F.
3. Boiling-point range, maximum 4 per cent. under 300° C.
4. Oxidization, insolubles, maximum 0.20 per cent.; evaporation loss, maximum 40 per cent.
5. Emulsion, maximum trace.

Automobile and Truck Engines.

A. T. O. No. 1 (Summer.)

1. Viscosity at 212° F., seconds, 52 to 50; desired 55.
2. Cold test, maximum 35° F.
3. Boiling-point range, maximum 30 per cent. under 300° C.
4. Oxidation, insolubles, maximum 0.30 per cent.; evaporation loss, maximum 40 per cent.
5. Emulsion, maximum trace.

A. T. O. No. 2 (Winter.)

1. Viscosity at 212° F., seconds, 45 to 50; desired 48.
2. Cold test, maximum 30° F.
3. Boiling-point range, maximum 30 per cent. under 300° C.
4. Oxidation, insolubles, maximum 0.30 per cent.; evaporation loss, maximum 50 per cent.
5. Emulsion, maximum trace.

Knight Sleeve-Valve Oil.

K. S. V. O. (Summer.)

1. Viscosity at 212° F., seconds, 100 to 120; desired 115.
2. Cold test, maximum 52° F.
3. Boiling-point range, maximum 3 per cent. under 300° C.
4. Oxidation, insolubles, maximum 0.20 per cent.; evaporation loss, maximum 30 per cent.
5. Emulsion, maximum trace.

Winter use, A. E. O. No. 2.

Air-Cooled Motorcycle Engines.

Winter.—One and two-cylinder types, use A. E. O. No. 2. Four-cylinder type, use A. T. O. No. 1.

Summer.—One and two-cylinder types, use K. S. V. O. Four-cylinder types, use A. E. O. No. 2.

CHAPTER XXIII.

SPECIFICATIONS FOR TRANSMISSION OILS AND CRANK CASE OILS.*

Transmission Lubricant.—(War Dept. Specif. No. 3504, April 24, 1918. Approved and adopted by the Ordnance Dept., Quartermaster Corps, Engineer Corps, Medical Corps and Signal Corps, U. S. A.)

GENERAL.

1. This specification covers the requirements of the U. S. Army for a very adhesive mineral oil, which must be suitable in every way for the lubrication of transmission gears and bearings, differential gears, worm drives, winch drives, and roller and ball bearings used in connection with such parts of the equipment of motor vehicles.

CHARACTERISTICS.

2. The lubricant must be a petroleum product only, without the addition of vegetable or animal oils or products, or residues or fats of any kind. It must be entirely free from fillers such as talc. resin, tar and all materials of every nature not related to the original product.

PHYSICAL PROPERTIES.

3. *Viscosity.*—The viscosity must be within the following limits, when the lubricant is tested in a Saybolt Universal Viscosimeter, at 212° F.:
   195 seconds to 220 seconds.

4. *Adhesiveness.*—The adhesiveness of the lubricant is one of the most essential qualities. As there is no satisfactory laboratory method for its determination, the adhesiveness will be determined by applying the lubricant to a set of gears operating under practical conditions, and comparing the effect produced by the lubricant with the effect produced by a standard

* Also see Index or Chapter on Standard Government Specifications for Lubricants.

sample of Army specifications, No. 10 under the same conditions.

5. The bidder must state in his proposal the characteristics of the lubricant which he proposes to furnish.

Compound Transmission Lubricant.—(Tentative Specif. No. 3, 505-A, July 15, 1818, Quartermaster Corps, War Dept.)

GENERAL.

1. This specification covers the requirements for a mineral-oil compound or grease, which must be suitable in every way for the lubrication of transmission gears and bearings, differential gears, worm drives, winch drives, and roller and ball bearings used in connection with such parts of the equipment of motor vehicles.

PHYSICAL PROPERTIES AND TESTS.

2. The lubricant shall be a petroleum compound of calcium, soda or lead soap, and mineral oil, and shall be manufactured in accordance with the best commercial processes.

3. Manufacturers must at all times maintain a standard consistency in the lubricant conforming to consistency of approved sample.

4. *Mineral Oil Base.*—The mineral oils used in compounding the lubricant, when tested in a Saybolt universal viscosimeter, at 212° F. must show a viscosity of not less than 180″; or, when the character of the finished lubricant is such that the viscosity can be taken in a Saybolt universal viscosimeter, the viscosity of the finished lubricant must be from 70 to 120″ at 212° F.

5. *Soap Base.*—The lubricant shall have a lime, soda, or lead soap base, made from animal fats, vegetable or fish oil.

6. *Moisture.*—The finished lubricant shall contain not more than one and one-half (1½) per cent. of moisture.

7. *Acidity.*—The lubricant must not show more than two (2) per cent. of free fatty acid and must not attack a sheet of polished copper within a period of 48 hours.
8. *Cold Test.*—The lubricant must have a cold test of 10° F. This means that the lubricant must not set a firm or channel at a temperature above 10° F. in the transmission or differential gear case.
9. *Moisture Test.*—Fifty grams of the lubricant, with 2½ cc. of water added, shall be whipped together with an ordinary egg beater, at normal inside temperatures, for a period of 2 minutes. The whipping action shall then be continued and water slowly added until the water content amounts to 25 cc. Let the mixture stand for 24 hours, at the end of which period and at normal inside temperatures it must not have set or become granular and must not channel.

FILLERS.

10. The lubricant shall contain no fillers such as rosin, oils, soapstone, wax talc, powdered mica, graphite, lamp-black, sulphur, clay, asbestos, metallic salts, or volatile matter such as naphtha or benzine, or any other substance detrimental to machinery or metallic surfaces.

STATEMENT TO BE SUBMITTED BY BIDDERS.

11. The bidder shall state in his proposal the characteristics of the lubricant which he proposes to furnish.

Transmission Oil (for use in automobiles.)—(Gen. Supply Comm., Washington, D. C., for fiscal year 1920). Minimum flash point, 460° F.; minimum fire point, 570° F.; must not require more than 0.10 milligram KOH to neutralize 1 gram; viscosity (Saybolt) not over 890 at 130° F.; 135-150 at 210° F.

The oil must be free, as determined by chemical test, from mineral acids, soap, and asphalt or tarry matter. Flash test by the Pensky-Martens closed-cup.

Cylinder Oil (for crank cases of Westinghouse engines.)—(Gen. Supply Comm., Washington, D. C., for fiscal year 1920). Minimum flash point [by the Pensky-Martens closed-cup] 460° F.; minimum fire point, 570° F.; must not require more than 0.10

milligram KOH to neutralize 1 gram; demulsibility zero by Herschel's method (Bureau of Standards Technologic Paper No. 86); viscosity (Saybolt) not over 800 at 130° F.; 100-135 at 210° F.

Oil must be free, as determined by chemical test, from mineral acids, soap, and asphalt or tarry matter.

Crank Case Oil.—(City of St. Louis, Water Div., for various City Institutions, April, 1919). Crank case oil shall be the filtered product obtained from the refinement of pure mineral crude oil without the subsequent addition of any other substance foreign to this distillation. It must be absolutely clear, free from water, tarry or suspended matter and shall be absolutely neutral in its reaction.

The oil shall possess the following characteristics:—

1. Its specific gravity shall not be less than 27½ Baumé at 60° F.
2. It must not flash below 370° F. when tested in Pensky-Marten closed flash cup apparatus.
3. It must not burn below 440° F. in the open cup of the Pensky-Marten apparatus.
4. Its specific viscosity shall not be less than 410 or more than 465 Saybolt at 70° F.
5. When heated for seven hours at 150° F. it shall show a loss of not more than 1% by weight; and when heated for two hours at 350° F. it shall show a loss of not more than 7% by weight. There shall be no deposit of carbonaceous matter resulting from either of these tests.
6. "25 cc. of the oil shall be placed in a glass test tube 1" in diameter, surrounded by cold water and subjected to the following test. Live steam from a glass tube 3/16" internal diameter is bubbled steadily, but not violently, through the oil for two minutes, and, after standing quietly twenty minutes, the oil and condensed water shall show a clear cut separation."

A one quart sample in glass must be submitted with each bid and all deliveries must be in substantial accordance not only with the above specifications but also with this bid sample.

CHAPTER XXIV.

SPECIFICATIONS FOR COMPRESSOR OILS.*

Compressor Oil.—(War Dept., Specif. No. 3,527, June 2, 1919, Raw Materials Div., U. S. A.)

GENERAL.

1. This specification covers the requirements of the United States Army for compressor oils.
2. The oil shall be in four grades. No. 1 Light, No. 2 Medium, No. 3 Heavy, and No. 4 Extra Heavy. Nos. 2 and 3 being suitable for all ordinary types of air compressors.

PHYSICAL PROPERTIES AND TESTS.

3. The oil must be a pure, well refined, straight mineral oil, free from water, acid, sediment and mineral impurities.
4. *Color.* The color of the Nos. 1, 2 and 3 grades may vary from 2 to 3 (N. P. A. Scale) and the No. 4 grade from 3 to 4 (N. P. A. Scale.)
5. *The Flash point* (Cleveland open cup) shall be:

No. 1 Light	375-400° F.
No. 2 Medium	Not less than 400° F.
No. 3 Heavy	450-500° F.
No. 4 Extra Heavy	Not less than 500° F.

6. *The Fire Point* (Cleveland open cup) shall be:

No. 1 Light	425-450° F.
No. 2 Medium	Not less than 450° F.
No. 3 Heavy	Not less than 500° F.
No. 4 Extra Heavy	Not less than 550° F.

7. *The Viscosity* on the Saybolt Universal Viscosimeter shall be as follows:

No. 1 Light	180-200 @ 100° F.
No. 2 Medium	275-300 @ 100° F.
No. 3 Heavy	275-400 @ 100° F.
No. 4 Extra Heavy	475-500 @ 100° F.

* Also see Index or Chapter on Standard Government Specifications for Lubricants.

8. *The Pour Test* (A.S.T.M.) for Nos. 1, 2 and 3 grades shall be from 35 to 40° F. No. 4 grade shall have a pour test from 50-55° F.
9. *Carbon.* The oil must not show a carbon residue (Conradson Carbon Test) greater than:

No. 1 Light	1.5%
No. 2 Medium	1.5%
No. 3 Heavy	1.5%
No. 4 Extra Heavy	2.0%

10. *Emulsion Test.* One ounce of the oil shall be placed in a standard 4 oz. sample bottle with one ounce of distilled water. The mixture shall be heated to 180° F. and then shaken vigorously for five minutes. After standing for one hour, the oil must be clear and of the same color as before the test. All the water must have settled and appear only slightly cloudy.
11. *Acidity.* The acidity of the oil must not be more than 0.03% calculated to SO_3.
12. All tests must be made in accordance with methods adopted by the American Society for Testing Materials.
13. The bidder must state in his proposal the characteristics of the oils which he proposes to furnish.

"**Air Compressor Oils, Etc.** (Light and Heavy). (Board of Purchase, City of New York, Jan., 1920.)

"(For General Specifications, see Index).

	Light	Heavy
Viscosity at 100° F.	145–200	240–300
Flash point, Cleveland open cup	310	325
Pour test: Shall flow at	30° F.	35° F.
Free acid, max.	0.1%	0.1%
Matter insoluble in 88° gasoline	None	None
Carbon residue, Conradson method	1.0%	1.0%
Emulsification	———	Negative
Ash, max.	———	0.02%

Air Compressor Oil.—(Gen. Supply Comm., Washington, D. C., for fiscal year 1920). Minimum flash point, 400° F.; minimum fire point, 450° F.; must not require more than 0.07 milligram KOH to neutralize 1 gram; maximum carbonization 0.25 per cent., as determined by Waters's method (Bureau of Standards Scientific Paper No. 160); viscosity (Saybolt) not over 130 at 130° F., 42-46 at 210° F.; flash and fire points to be determined by the Pensky-Martens instrument (closed-cup method); must be free, as determined by chemical test, from mineral acids, soap, and asphalt or tarry matter.

Ammonia Compressor Oil.—(Gen. Supply Comm., Washington, D. C., for fiscal year 1920). Minimum flash point, 330° F.; minimum fire point, 380° F.; must not require more than 0.07 milligram KOH to neutralize 1 gram; viscosity (Saybolt) not over 87 at 130° F.; 36-40 at 210° F.; cold test not higher than 5° F.

(1) Crank case; demulsibility at least 300 by Herschel's method (Bureau of Standards Technologic Paper No. 86).

(2) Cylinder; maximum carbonization 0.50 per cent. by Waters's method (Bureau of Standards Scientific Paper No. 160).

Flash test by the Pensky-Martens closed-cup. Oil must be free, as determined by chemical test, from mineral acids, soap, and asphalt or tarry matter.

Ice Machine Oil. (Board of Purchase, City of New York, Jan., 1920.)

(For General Specifications see Index.)

Viscosity at 100° F.	95–125
Flash point, Cleveland open cup	300
Pour test: shall flow at	0.0° F.
Free acid, max.	0.1%
Matter insoluble in 88° gasoline	None
Lard or tallow oil	None

Cylinder Oil, "Ammo."—(War Dept., Depot Quartermaster, New York City, Jan. 2, 1908.) This oil is suitable for use in ammonia cylinders of ice and refrigerating machinery.

Must be a pure filtered mineral oil. Must be free from acid, alkali, suspended matter, and satisfactorily pass the following tests:

Specific Gravity.—Must not be less than 0.870 nor more than 0.875 at 60° F. [30° to 31° Bé.]

Flash.—Must not flash below 370° F.

Fire.—Must not burn below 420° F.

Viscosity.—Must not be less than 2.38 at 50° C. (Engler.) [Approximately 78 Saybolt at 122° F.]

Cold Test.—Must flow at a temperature of 5° F.

(Acid, alkali and water tests as described for war department light cylinder oil above. Must show no saponification.)

Hydraulic Press Oil.—(Gen. Supply Comm., Washington, D. C., for fiscal year 1920). Minimum flash point, 300° F.; minimum fire point, 350° F.; must not require more than 0.05 milligram KOH to neutralize 1 gram; viscosity (Saybolt) not over 61 at 130° F., 33-36 at 210° F.; demulsibility at least 400 by Herschel's method (Bureau of Standards Technologic Paper No. 86).

The oil must be free, as determined by chemical test, from mineral acids, soap, and asphalt or tarry matter. Flash test by the Pensky-Martens closed-cup.

CHAPTER XXV.

SPECIFICATIONS FOR ENGINE OILS, PARAFFIN OILS AND CAR OILS.*

Engine Oil.—(City of St. Louis, Water Div., for various City Institutions, April, 1919). Engine oil shall be the filtered product obtained from the refinement of pure mineral crude oil without the subsequent addition of any other substance foreign to this distillation. It must be absolutely clear, free from water, tarry or suspended matter and shall be absolutely neutral in its reaction.

The oil shall possess the following characteristics:

1. Its specific gravity shall not be less than 25 Baumé at 60° F.
2. It must not flash below 370° F. when tested in Pensky-Marten closed flash cup apparatus.
3. It must not burn below 440° F. in the open cup of the Pensky-Marten apparatus.
4. Its specific viscosity shall not be less than 430 or more than 505 Saybolt at 70° F.
5. When heated for seven hours at 150° F. it shall show a loss of not more than 1 per cent. by weight; and when heated for two hours at 350° F. it shall show a loss of not more than 7 per cent. by weight. There shall be no deposit of carbonaceous matter resulting from either of these tests.

A one quart sample in glass must be submitted with each bid and all deliveries must be in substantial accordance not only with the above specifications but also with this bid sample.

Red Engine Oil.—(War Dept. Specif. No. 3,523, May 27, 1919, Raw Materials Div., U. S. A.)

GENERAL.

1. This specification covers the requirements of the U. S. Army for an engine oil to be used for general engine lubrication and for other ordinary lubrication purposes such as lathes, milling machinery, drill presses

* Also see Index or Chapter on Standard Government Specifications for Lubricants.

and in general all other power driven machinery not requiring definite physical and chemical characteristics.

2. The oil shall be supplied in three grades. No. 1 Light; No. 2 Medium; and No. 3 Heavy. The Medium Oil being suitable for general lubrication of all ordinary types.

PHYSICAL PROPERTIES AND TESTS.

3. The oil must be a pure, well refined, straight Mineral Oil free from water, acid, sediment and mineral impurities.

4. It shall be pale or red in color. Black oil will not be accepted.

5. The gravity shall be as follows:

No. 1 Light	25° to 26° Baumé
No. 2 Medium	24.5° to 23.5° Baumé
No. 3 Heavy	22.5° to 23° Baumé

6. Pour Test (A. S. T. M.) shall not be greater than 36° F.

7. The Flash Point (Cleveland Open Cup) shall not be less than—

No. 1 Light	360° F.
No. 2 Medium	370° F.
No. 3 Heavy	380° F.

8. The Fire Point (Cleveland Open Cup) shall not be less than—

No. 1 Light	430° F.
No. 2 Medium	440° F.
No. 3 Heavy	450° F.

9. The Viscosity on the Saybolt Universal Viscosimeter shall be as follows:

No. 1 Light	165-175 @ 100° F.
No. 2 Medium	200-210 @ 100° F.
No. 3 Heavy	250 @ 100° F.

10. All tests shall be made in accordance with the methods adopted by the American Society for Testing Materials.

11. Every bidder must state in his proposal the characteristics of the oil which he proposes to furnish.

Marine Engine Oil.—(War Dept., Quartermaster Corps, Tentative Specif. No. 3,519, for 1919.)

GENERAL.

1. This specification covers the requirements of the Army for marine engine oil to be used for the lubrication of reciprocating steam engines in marine service where a compounded engine oil is required.

This oil must not be used on circulating or forced feed systems.

PHYSICAL PROPERTIES AND TESTS.

2. The oil shall be a compounded oil made from refined mineral oil and refined vegetable oil, so compounded that it will not separate or break down in any way either before or while in service; it shall form a creamy emulsion of uniform consistency when worked with either salt or distilled water; the compounded oil or the emulsion before or in the service shall not show a tendency to stratify, or to deposit any separated constituent matter that will be heavier in consistency than the compounded oil or the emulsion.

COMPOUNDING.

3. The oil shall be compounded from well refined mineral oil and 15 per cent. to 20 per cent. of blow refined rape seed oil or blown refined peanut oil.

VISCOSITY.

4. The viscosity of the compounded oil when tested in a Saybolt Universal Viscosimeter shall be:

70 to 74 seconds..........................at 212° F.
Not over 700 seconds.....................at 100° F.

ACIDITY.

5. Acidity test shall not show greater than 1.50 per cent. as oleic acid. The compounded oil or emulsion of same shall not attack a sheet of polished copper exposed to it for a period of 48 hours.

Pour Test.

6. One ounce of the oil must not congeal in a standard four ounce sample bottle at a temperature above 32° F.

7. All tests shall be made in accordance with methods adopted by the American Society for Testing Materials.

Statement to be Submitted by Bidders.

8. Each bidder must state in his proposal the characteristics of the oil which he proposes to furnish: [*e. g.*, gravity, viscosity, etc.]

"**Marine Engine Oils** (Light and Heavy). (Board of Purchase, City of New York, Jan., 1920.)

"(For General Specifications, see Index).

	Light	Heavy
Viscosity at 100° F.	275–325	550–650
Viscosity at 210° F.	———	65–75
Flash point, Cleveland open cup	325	325
Pour test: Shall flow at	30° F.	30° F.
Free acid, max.	0.1%	2.0%
Matter insoluble in 88° gasoline	0.1%	0.2%
Emulsification	Negative	———
Fixed oil, non-drying, min.	None	15%

"This heavy oil shall be subjected to a centrifugal test and show no sign of separation when subjected to 2,000 revolutions per minute for 30 minutes."

Plain Bearing Oils (Light and Heavy). (Board of Purchase. City of New York, Jan., 1920.)

(For General Specifications see Index.)

	Light	Heavy
Viscosity at 100° F.	145–200	240–300
Flash point, Cleveland open cup	310	325
Pour test: Shall flow at	30° F.	35° F.
Free acid, max.	0.1%	0.1%
Matter insoluble in 88° gasoline	None	None
Carbon residue, Conradson method	1.0%	1.0%
Emulsification	———	Negative
Ash, max.	———	0.02%

Paraffin Oil.—(Gen. Supply Comm., Washington, D. C., for fiscal year 1920.) Must be clear, reduced oil, free from acid, dirt, and water; specific gravity at 15.5° C., between 0.90 and 0.92; flash point, not below 365° F.

The oil must be free, as determined by chemical test, from mineral acids, soap, and asphalt or tarry matter. Flash test by the Pensky-Martens closed-cup.

PENNSYLVANIA RAILROAD SPECIFICATIONS.

(Motive Power Dept., Altoona, Pa., Mar. 30, 1915.) (General specifications omitted.)

Paraffin and Neutral Oils.—These grades of oil will not be accepted if the sample from shipment:

Is so dark in color that printing from long primer type cannot be read with ordinary daylight through a layer of the oil ½ inch thick.

Flashes below 298° F.

Has a gravity at 60° F., below 24° or above 35° Bé.

From Oct. 1 to May 1 has a cold test above 10° F., and from May 1 to October 1 has a cold test above 32° F.

The color test is made by having a layer of the oil of the prescribed thickness in a proper vessel, and then putting the printing on one side of the vessel and reading it through the layer of oil with the back of the observer toward the source of light.

Well Oil.—This grade of oil will not be accepted if the sample from shipment:

Flashes, from May 1 to Oct. 1 below 298° F., or from Oct. 1 to May 1, below 249° F.

Has a gravity at 60° F., below 28° or above 31° Bé.

From Oct. 1 to May 1, has a cold test above 10° F., and from May 1 to Oct. 1, has a cold test above 32° F.

Shows any precipitation when 5 cc. are mixed with 95 cc. of gasoline.

The precipitation test is to exclude tarry and suspended matter. It is made by putting 95 cc. of 88° Bé. gasoline, which must not be above 80° F. in temperature, into a 100 cc. graduate, then adding the prescribed amount of oil and shaking thoroughly. Allow to stand 10 minutes. With satisfactory oil no separated or precipitated material can be seen.

530° Flash Test Oil.—This grade of oil will not be accepted if the sample from shipment:

Flashes below 522° F.

Has a gravity at 60° F., below 25° Bé.

Shows precipitation with gasoline when tested as described for well oil.

Shippers must pay freight both ways on rejected material.

CHAPTER XXVI.

SPECIFICATIONS FOR PRINTING OILS AND LIGHT MACHINE OILS.*

Monotype Oil (for monotype casting machines.)—(Gen. Supply Comm., Washington, D. C., for fiscal year 1920). Minimum flash point, 330° F.; minimum fire point, 380° F.; must not require more than 0.05 milligram KOH to neutralize 1 gram; maximum carbonization 0.25 per cent. as determined by Waters's method (Bureau of Standards Scientific Paper No. 160); viscosity (Saybolt) not over 175 at 130° F., 42-51 at 210° F.

The oil must be free, as determined by chemical test, from mineral acids, soap, and asphalt or tarry matter. Flash test by the Pensky-Martens closed cup.

Power-plate Press Oil (for Bureau of Engraving and Printing.) (Gen. Supply Comm., Washington, D. C., for fiscal year 1920). Minimum flash point, 390° F.; minimum fire point, 460° F.; must not require more than 0.25 milligram KOH to neutralize 1 gram; viscosity (Saybolt) not over 210 at 130° F.; 55-60 at 210° F.

The oil must be free, as determined by chemical test, from mineral acids, soap, and asphalt or tarry matter. Flash test by the Pensky-Martens closed cup.

Machine Oil.—(Gen. Supply Comm., Washington, D. C., for fiscal year 1920). Minimum flash point, 300° F.; minimum fire point, 350° F.; must not require more than 0.10 milligram KOH to neutralize 1 gram; demulsibility at least 50 as determined by Herschel's method (Bureau of Standards Technologic Paper No. 86); viscosity (Saybolt) not over 130 at 130° F., 42-46 at 210° F.

The oil must be free, as determined by chemical test, from mineral acids, soap, and asphalt or tarry matter. Flash test by the Pensky-Martens closed cup.

Spindle Oil.—(Gen. Supply Comm., Washington, D. C., for fiscal year 1920). Minimum flash point, 300° F.; minimum fire

* Also see Index or Chapter on Standard Government Specifications for Lubricants.

point, 350° F.; must not require more than 0.07 milligram KOH to neutralize 1 gram; demulsibility at least 300 as determined by Herschel's method (Bureau of Standards Technologic Paper No. 86); viscosity (Saybolt) not over 72 at 130° F., 35-38 at 210° F.

The oil must be free, as determined by chemical test, from mineral acids, soap, and asphalt or tarry matter. Flash test by the Pensky-Martens closed cup.

Airplane Machine Gun Oil.—(War Dept. Specif. No. 3,503-B, Bureau of Aircraft Production, U. S. A., Oct. 25, 1918).

GENERAL.

1. This specification covers the requirements of the Bureau of Aircraft Production for gun oil for the lubrication of machine guns on airplanes, for the c.c. interrupter gears and for gun oil for cleaning and oiling machine guns and small arms.

PHYSICAL PROPERTIES AND TESTS.

2. The oil must be a highly refined, highly filtered, straight-run mineral oil suitable in every way for the uses specified in paragraph 1. It must be a pure petroleum product, without the addition of vegetable or animal oils or fats of any kind and must contain no moisture.
3. The oil must be free from acids and from any material which might gum or corrode metals under any conditions.
4. *Viscosity.*—The viscosity, when the oil is tested in a Saybolt Universal Viscosimeter at 100° F., shall be as follows: 70 seconds to 95 seconds.
5. *Acidity.*—The acidity of the oil must not be more than 0.03 per cent. calculated as SO_3.
6. *Carbon.*—The carbon residue must not be more than 0.03 per cent. when determined by the Conradson method.
7. *Pour test.*—One ounce of the oil must not congeal in a standard four-ounce bottle at 45° below zero F.

8. All tests must be made in accordance with methods adopted by the American Society for Testing Materials.

STATEMENT TO BE SUBMITTED BY BIDDERS.

9. The bidder must state in his proposal the following characteristics of the oils which he proposes to furnish:

Gravity.—Baumé at 60° F.

Flash.—Cleveland open cup.

Fire.—Cleveland open cup.

Viscosity.—Saybolt Universal Viscosimeter at 40, 70, 100, 130 and 212° F.

Pour test.—American Society for Testing Materials' method.

Carbon.—Conradson method.

Color.—Lovibund.

Gun Oil.—(War Dept. Specif. No. 3,507-A, March 15, 1918. Approved and adopted by Ordnance Dept. and Signal Corps, U. S. A., and by the U. S. Navy.)

GENERAL.

1. This specification covers the requirements of the Signal Corps for gun oil to be used for the following purposes and where Airplane Machine Gun Oil (Specification No. 3, 503) is not required:

For cleaning and oiling guns and and small arms.

For oil switches and oil circuit breakers.

For transformers up to 6,600 volts.

For lubrication of the compressor and expander cylinders of ice machines.

For lubrication of pneumatic tools.

For hydraulic systems.

PHYSICAL PROPERTIES AND TESTS.

2. The oil must be a straight-run, highly refined and highly filtered mineral oil, suitable in every way for the uses listed in paragraph 1.

3. The oil must be a petroleum product only, free from vegetable or animal oils or fats of any kind, and entirely free from moisture.
4. *Viscosity.*—The viscosity must be within the following limits when the oil is tested in a Saybolt Universal Viscosimeter at 100° F., 95 seconds to 105 seconds.
5. *Flash Point.*—The flash point of the oil must not be less than 300° F., in a Cleveland open cup.
6. *Pour test.*—One ounce of the oil must not congeal in a standard four-ounce sample bottle at 5° below zero F.
7. *Carbon.*—The carbon residue must not be more than 0.03 per cent. by the Conradson method.
8. *Acidity.*—The oil must not show an acid reaction of more than 0.03 per cent. calculated as SO_3, and must not gum or corrode metals under any conditions.
9. All tests must be made in accordance with methods adopted by the American Society for Testing Materials.
10. The bidder must state in his proposal the characteristics of the oils which he proposes to furnish.

"**Light Mineral Lubricating Oil for Torpedo Lubrication** (Navy Dept., June 24, 1918).

"*Composition.*—Oil to be a high-grade mineral lubricating oil, free from adulterations, acid, sediment, gumming, or emulsifying constituents, and shall contain no matter insoluble in 88° gasoline.

"*Characteristics.*—Specific gravity not more than 0.880 at 60° F. Viscosity not less than 150 at 100° F. (Saybolt).

"Flash point not below 400° F., open cup.

"Cold point below 32° F.

"*Containers.*—To be delivered in commercial 5-gallon cans, cased two cans to a case. To be labeled Light mineral lubricating oil for torpedoes.

"*Bids.*—Bids will be received for only the following brands of lubricating oils, which have been tested by the Bureau of Ordnance and found satisfactory.

" 'Acme' engine oil, manufactured by the Atlantic Refining Co.

" 'Monogram' light oil, manufactured by the New York Lubricating Oil Co.

" 'D. T. E.,' manufactured by the Vacuum Oil Co.

" 'Regal' oil, manufactured by the Texas Co.

"NOTE.—Bidders who desire to submit proposals on future purchases of lubricating oil for torpedo lubrication and whose samples have not been previously tested, must arrange with the Bureau of Ordnance, Navy Department, Washington, D. C., for tests of the oils they propose to furnish. Oils that pass satisfactory tests will be added to the list of acceptable oils.

"Oils furnished must be identical with those submitted for test. Any lot of oil delivered will be subject to sampling and test.

"No oils will be considered except those which have been tested or tried out in service in recent years and have proven acceptable to the bureau concerned.

"New tests can not be made before awarding contracts, as tests require from 8 to 10 months' time.

"The contractor shall guarantee that each delivery of oil, ashore and afloat, shall lubricate satisfactorily in every respect, and shall be entirely suitable for the special requirements of the naval service."

CHAPTER XXVII.

SPECIFICATIONS FOR TRANSFORMER OIL, PETROLEUM RESIDUES AND MISCELLANEOUS OILS.

Transformer Oil.—(War Dept. Specif. No. 3518, July 22, 1918 [Tentative]. Quartermaster Corps, U. S. A.)

GENERAL.

1. This specification covers the requirements for an oil to be used in oil switches, oil circuit breakers and for transformers up to 6,600 volts.

PHYSICAL PROPERTIES AND TESTS.

2. The oil shall be a straight-run, highly refined and highly filtered mineral oil, suitable in every way for the uses listed in paragraph 1.
3. The oil must be a petroleum product only, free from vegetable or animal oils or fats of any kind, and must have an insulating value of not less than 30,000 volts, when measured with a spark gap consisting of two one-half inch discs. faces vertical, spaced 0.2 inch apart.
4. *Viscosity.*—The viscosity of the oils when tested in a Saybolt Universal Viscosimeter at 100° F. must not be above 105 seconds.
5. *Flash Point.*—The flash point of the oil must not be less than 300° F. when tested in a Cleveland open cup.
6. *Pour test.*—One ounce of the oil must not congeal in a standard four ounce sample bottle at temperatures above 20° F.
7. *Acidity.*—The oil must not show an acid reaction of more than 0.03 per cent. calculated as SO3 and must not gum or corrode metals under any conditions.
8. All tests shall be made in accordance with methods adopted by the American Society for Testing Materials.

STATEMENT TO BE SUBMITTED BY BIDDERS.

9. The bidder shall state in his proposal the following characteristics of the oil which he proposes to furnish.

Gravity.—Baumé at 60° F.

Flash Test.—Cleveland open cup.

Fire Test.—Cleveland open cup.

Viscosity.—Saybolt Universal Viscosimeter at 40, 70, 100, 130, and 212° F.

Pour Test.—American Society for Testing Materials method.

Carbon.—Conradson method.

Color.—Lovibund.

Petrolatum.—(Navy Dept., June 1, 1917). Petrolatum shall be of good quality, clean and refined, and free from acidity or adulteration. White petrolatum will not be accepted.

Petrolatum shall possess a melting point not lower than 80° F. nor higher than 120° F. The flash point shall be not lower than 350° F. when tested in an open cup by Tagliabue's method. Loss on heating for one hour between 105° C. and 110° C. shall not exceed 2 per cent.

(To be delivered in specified friction-top cans).

Petroleum Residuum.—(Navy Dept., July 1, 1919). The material desired is a black waxlike residue of pure bitumen resulting from the distillation of an asphaltic base petroleum.

Petroleum residuum shall have the following properties:

(*a*) The specific gravity at 15.5° C. (60° F.) shall be between 1.002 and 1.02.

(*b*) The melting point (Barrett method) shall be between 93.3° and 96.1° C. (200° and 205° F.).

(*c*) Not less than 74 per cent. shall be soluble in 88° naphtha (petroleum ether).

(*d*) Upon ignition the ash (exclusive of traces of sand or dirt present in the original crude oil) shall not exceed 0.2 per cent.

Petroleum residuum shall be delivered in substantial wooden barrels or kegs, or in suitable sheet iron drums, containing about 300 or 500 pounds net weight as specified.

Gear, Chain and Wire Rope Lubricant.—(War Dept., Fuel and Forage Div., Oil Branch, Quartermaster Corps, April 24, 1918, Specif. No. 3, 508. Approved and adopted by Ordnance Dept., Quartermaster Corps, Engineer Corps, Medical Corps, and Signal Corps, U. S. A.)

GENERAL.

1. This specification covers the requirements of the U. S. Army for a very adhesive, heavy-bodied, straight mineral oil, which must be suitable in every way for the following uses:

   For the lubrication and protection of chains, wire ropes and gears of cranes, dredges, steam shovels and all other heavy equipment.

   For the lubrication and protection of the gears and ropes of balloon hoists.

   For swabbing the wires and cables of airplanes and seaplanes.

   For slushing and protecting the bright and exposed metal parts of guns, machines and automobiles during storage or overseas shipment. When used for this purpose the lubricant shall be mixed with an equal amount of kerosene so that it may be applied with a brush.

2. Kerosene may be used to remove this lubricant from the equipment.

PHYSICAL PROPERTIES AND TESTS.

3. The quality of the lubricant must be equal to or better than that of a standard sample of No. 1 wire rope lubricant sample of which will be furnished by the Quartermaster General, Fuel and Forage Division, Washington, D. C.
4. The lubricant must be a petroleum product only, free from vegetable or animal oils or products, or residues or fats of any kind. It must be entirely free from fillers such as talc, resin, tar and all materials of every nature not related to the original product.

5. *Viscosity.*—The Viscosity must be within the following limits when the lubricant is tested in a Saybolt Universal Viscosimeter, at 212° F., 900 seconds to 1,100 seconds.

6. *Adhesiveness.*—The adhesiveness of the lubricant is one of its most essential qualities. As there is no satisfactory laboratory method for the determination of this quality, the adhesiveness will be determined by applying the lubricant to a set of gears operating under practical conditions, and comparing the effect produced with that produced by a standard sample of No. 1 wire rope lubricant mentioned above under the same conditions.

7. *Corrosion test.*—When applied to a plate of polished steel, the lubricant must protect the steel for a period of thirty days from chemical vapors, from the action of salt or fresh water and from the action of water containing from 10 to 25 per cent. of sulphuric acid. For the purposes of these tests the water and solutions shall be held at a temperature of 60° F.

DRYING TEST.

8. When the lubricant is applied to a wire rope that has not been oiled with any other material, it must not crack, peel or chip after exposure to low atmospheric temperatures for sixty days.

PENETRATION TEST.

9. When applied hot to the outside of a one-inch wire rope that has not been oiled with any other material, the lubricant must penetrate to, and be absorbed by, the fibre core, and at the end of sixty days, when the rope is put under strain, the oil must be forced out of the core between the wires of the strand.

STATEMENT TO BE SUBMITTED BY BIDDERS.

10. The bidder must state in his proposal the characteristics of the lubricants which he proposes to furnish.

Light-Colored Mineral Oil (for Cordage Oils).—(Navy Dept., July 1, 1918).

The oil shall be a light-colored pure mineral oil, entirely free from sediment or acid. It shall contain no animal oil, vegetable oil, or thickeners of any kind. Oil of an asphaltic base will be acceptable providing it conforms to the specifications.

The oil shall have the following properties:

(*a*) The specific gravity at 15.5° C. (60° F.) shall be between 27° and 30° Baumé (0.8917 to 0.8750).

(*b*) It shall not flash below 121° C. (250° F.) (open tester).

(*c*) The viscosity shall be not less than 100 nor more than 200 (Tagliabue) at 21° C. (70° F.).

(*d*) The oil shall not cease to flow at a temperature higher than 20° F.

(To be delivered in specified white-oak casks of about 50-gallons capacity).

Floor Oil.—(War Dept. Specif. No. 3,526, May 29, 1919, Raw Materials Div., U..S. A.)

GENERAL.

1. This specification covers the requirements of the U. S. Army for a Floor Oil to be used for the polishing and preserving of wooden floors.

PHYSICAL PROPERTIES AND TESTS.

2. The oil must be a pure, well refined, straight mineral oil free from water, acid, sediment, or mineral impurities.
3. It shall be pale or red in color. Black oil will not be accepted.
4. Pour test (A.S.T.M.) shall not be greater than 30° F.
5. The Flash Point (Cleveland open cup) shall not be less than 300° F.
6. The viscosity on the Saybolt Universal Viscosimeter shall be from 70-100 at 100° F.
7. All tests shall be made in accordance with methods adopted by the American Society for Testing Materials.
8. Every bidder must state in his proposal the characteristics of the oil which he proposes to furnish.

CHAPTER XXVIII.

STANDARD GOVERNMENT SPECIFICATIONS FOR LUBRICANTS.

(From Report of Committee on Standardization of Petroleum Specifications, Bulletin No. 4, Bureau of Mines, Effective April 16, 1920.)

The Committee on Standardization of Petroleum Specifications, acting under authority conferred by the order by the President, has adopted the methods of testing and the specifications for lubricants contained in this chapter. These specifications are effective on and after April 16, 1920.

Heretofore specifications for lubricants have been drawn up by the various departments and agencies purchasing them. The Committee on Standardization of Petroleum Specifications has found it possible to co-ordinate and standardize these various specifications, to eliminate some tests of doubtful value, and to simplify and harmonize the wording of the specifications. It has been found possible to draw up specifications that will eliminate oils that would prove unsatisfactory in service, and at the same time to allow the refiners great latitude in their choice of crude oils.

It is recognized that our knowledge of lubricants is incomplete at the present time. Accordingly, the Committee is prepared to receive suggestions as to possible future changes in the methods of testing and in the specifications themselves. It is also recognized that in some cases the various departments will have to require additional tests for some lubricants. Specifications for other lubricants and petroleum products are to be taken up and will be published in a later bulletin.

While these specifications are intended to supercede previous Government specifications, the former Government specifications have been retained elsewhere in this volume for comparison, in order to show the trend in lubricating practice and in lubricating specifications.

The methods of testing as adopted by the Committee have been given in the Chapters on Testing.

SPECIFICATIONS FOR LUBRICATING OILS.

Class A.

GENERAL:

1. This specification covers the grades of petroleum oil used by the United States Government and its agencies for the general lubrication of engines and machinery where a highly refined oil is not required. This oil is not to be used for steam cylinder lubrication.
2. Only refined petroleum oils without the admixture of fatty oils, resins, soap, or other compounds not derived from crude petroleum, will be considered.
3. These oils shall be supplied in five grades, known as extra light, light, medium, heavy and extra heavy.

PROPERTIES AND TESTS:

4. *Flash and Fire Points.*—The flash and fire points of the five grades shall not be lower than the following:

	Flash Deg. F.	Fire Deg F.
Extra Light	315	355
Light	325	365
Medium	335	380
Heavy	345	390
Extra Heavy	355	400

5. *Viscosity.*—The viscosity of the five grades of oil at 100° F. must be within the following limits:

	Seconds
Extra Light	140–160
Light	175–210
Medium	275–310
Heavy	370–410
Extra Heavy	470–520

6. *Color.*—The color of the extra heavy grade shall not be darker than No. 6 National Petroleum Association Standard, or its equivalent. The color of the other grades shall not be darker than No. 5 National Petroleum Association Standard, or its equivalent.
7. *Pour Test.*—The pour test shall not be above the following temperatures:

	Degrees F.
Extra Light	35
Light	35
Medium	40
Heavy	40
Extra Heavy	50

8. *Acidity.*—Not more than 0.10 milligrams of potassium hydroxide shall be required to neutralize 1 gram of the oil.
9. *Corrosion.*—A clean copper plate must not be discolored when submerged in the oil for 24 hours at room temperature.
10. All tests shall be made according to the methods adopted by the Committee on Standardization of Petroleum Specifications.

SPECIFICATIONS FOR LUBRICATING OILS.

Class B.

GENERAL:

1. This specification covers the grades of petroleum oil used by the United States Government and its agencies for the lubrication of turbines, dynamos, high speed engines and other classes of machinery where an oil better than Class A is required. The oil must be satisfactory for use in circulating and forced feed systems.
2. Only refined petroleum oils without the admixture of fatty oils, resins, soaps, or other compounds not derived from crude petroleum will be considered.
3. These oils shall be supplied in five grades, known as extra light, light, medium, heavy and extra heavy.

PROPERTIES AND TESTS:

4. *Flash and Fire Points.*—The flash and fire points of the five grades, shall not be lower than the following:

	Flash Deg. F.	Fire Deg. F.
Extra Light	315	355
Light	325	365
Medium	335	380
Heavy	345	390
Extra Heavy	355	400

5. *Viscosity.*—The viscosity of the five grades at 100° F., must be within the following limits:

	Seconds
Extra Light	140–160
Light	175–210
Medium	275–310
Heavy	370–410
Extra Heavy	470–520

6. *Color.*—The color of the extra heavy grade shall not be darker than No. 6 National Petroleum Association Standard, or its equivalent. The color of the other grades shall not be darker than No. 5 National Petroleum Association Standard, or its equivalent.

7. *Pour Test.*—The pour test shall not be above the following temperatures:

	Degrees F.
Extra Light	35
Light	35
Medium	40
Heavy	45
Extra Heavy	50

8. *Acidity.*—Not more than 0.07 milligrams of potassium hydroxide shall be required to neutralize 1 gram of oil.

9. *Corrosion.*—A clean copper plate must not be discolored when submerged in the oil for 24 hours at room temperature.

10. *Emulsifying Properties.*—The oil shall separate completely in 30 minutes from an emulsion with:

    1. Distilled water. 2. 1% salt solution. 3. Normal caustic soda solution.

    The demulsibility shall not be less than 300.

11. All tests shall be made according to the methods adopted by the Committee on Standardization of Petroleum Specifications.

SPECIFICATIONS FOR LUBRICATING OILS.

Class C.

GENERAL:

1. This specification covers the grades of petroleum oil used by the United States Government and its agencies for lubrication of air compressors and internal combustion engines, except aircraft, motor cycle and Diesel engines; also for the lubrication of turbines and other machinery where an oil better than Class B is required. This oil must be satisfactory for use in circulating and forced feed systems.
2. Only refined petroleum oils without the admixture of fatty oils, resins, soaps, or other compounds not derived from crude petroleum, will be considered.
3. These oils shall be supplied in five grades, known as extra light, light, medium, heavy and extra heavy.

PROPERTIES AND TESTS:

4. *Flash and Fire Points.*—The flash and fire points of the five grades shall not be lower than the following:

	Flash Deg. F.	Fire Deg. F.
Extra Light	315	355
Light	325	365
Medium	335	380
Heavy	345	390
Extra Heavy	355	400

Oil for use in air compressors where the air leaving any stage or cylinder has a temperature above 212° F. shall have a flash point not lower than 400° F.

5. *Viscosity.*—The viscosity of the five grades at 100° F. must be within the following limits:

	Seconds
Extra Light	140–160
Light	175–210
Medium	275–310
Heavy	370–410
Extra Heavy	470–520

6. *Color.*—The color of the extra heavy grade shall not be darker than No. 6 National Petroleum Association Standard, or its equivalent. The color of the other grades shall not be darker than No. 5 National Petroleum Association Standard, or its equivalent.
7. *Pour Test.*—The pour test shall not be above the following temperatures:

	Degrees F.
Extra Light	35
Light	35
Medium	40
Heavy	45
Extra Heavy	50

8. *Acidity.*—Not more than 0.05 milligrams of potassium hydroxide shall be required to neutralize one gram of the oil.
9. *Corrosion.*—A clean copper plate must not be discolored when submerged in the oil for 24 hours at room temperature.
10. *Emulsifying Properties.*—The oil shall separate completely in 30 minutes from an emulsion with:
    1. Distilled water. 2. 1% salt solution. 3. Normal caustic soda solution.

    The demulsibility shall not be less than 300.
11. *Carbon Residue.*—The carbon residue shall not exceed the following:

	Per Cent.
Extra Light	0.10
Light	0.20
Medium	0.30
Heavy	0.40
Extra Heavy	0.60

12. Further tests on oils of Class C may be required at the option of the Department of the Government using the oils.
13. All tests shall be made according to the methods adopted by the Committee on Standardization of Petroleum Specifications.

LIBERTY AERO AND MOTORCYCLE OIL.

GENERAL:

1. This specification covers the grade of petroleum oil used by the United States Government and its agencies for the lubrication of stationary-cylinder aircraft engines and motorcycle engines.
2. The oil must be made from pure, highly refined petroleum products and must be suitable in every way for the entire lubrication of stationary-cylinder aircraft engines and motorcycle engines operating under all conditions. The oil must not contain moisture, sulphonates, soap, resin, or tarry constituents which would indicate adulteration or lack of proper refining.

PROPERTIES AND TESTS:

3. *Flash Point.*—The flash point shall not be lower than 400° F.
4. *Viscosity.*—The viscosity of the oil at 210° F. shall be within the following limits: 80 to 90 seconds.
5. *Pour Test.*—The pour test for Summer Oil shall not be above 45° F. For Winter Oil not above 20° F.
6. *Acidity.*—Not more than 0.10 milligrams of potassium hydroxide shall be required to neutralize 1 gram of the oil.
7. *Emulsifying Properties.*—The oil shall separate completely in one hour from an emulsion with:
   1. Distilled Water. 2. 1% Salt Solution.
   At a temperature of 180° F.
8. *Carbon Residue.*—The carbon residue shall not be over 1.5%.
9. All tests shall be made according to the methods adopted by the Committee on Standardization of Petroleum Specifications.

MARINE ENGINE OIL.

GENERAL:

1. This specification covers the grade of oil used by the United States Government and its agencies for the

lubrication of reciprocating steam engines in marine service where a compounded engine oil is required.

THIS OIL MUST NOT BE USED IN CIRCULATING OR FORCED FEED SYSTEMS.

PROPERTIES AND TESTS:

2. The oil shall be a compounded oil made from refined petroleum oil and 10% to 20% of blown refined rape seed oil or blown refined peanut oil; so compounded that it will not separate or break down in any way either before or while in service.

3. *Viscosity.*—The viscosity shall be:
   65 to 75 seconds at 210° F. Not over 700 seconds at 100° F.

4. *Pour Test.*—The pour test shall not be above 32° F.

5. *Acidity.*—The oil shall not contain more than 1.50% of acid calculated as oleic acid, (equivalent to 3.0 mg. KOH per gram of oil).

6. *Corrosion.*—A clean copper plate must not be discolored when submerged in the oil for 24 hours at room temperature.

7. *Emulsifying Properties.*—The oil shall remain completely emulsified for an hour from an emulsion with: 1. Distilled Water. 2. 1% Salt Solution.

8. *Wick Feed.*—The oil shall show a flow at the end of 14 days of at least 30 per cent. of its flow at the end of the first 24-hour period.

9. All tests shall be made according to the methods adopted by the Committee on Standardization of Petroleum Specifications.

MINERAL STEAM CYLINDER OIL FOR NON-CONDENSING ENGINES.

GENERAL:

1. This specification covers the grade of petroleum oil used by the United States Government and its agencies for non-condensing steam engine cylinder lubri-

cation where a mineral oil is required; also as a stock oil for compounding.

PROPERTIES AND TESTS:

2. The oil must be a well refined petroleum oil without compounding of any nature.
3. *Flash Point.*—The flash point must not be less than 475° F.
4. *Viscosity.*—The viscosity at 210° F. must be within the following limits:
   135 to 165 seconds.
5. *Cold Test.*—The cold test must not be above 45° F.
6. *Precipitation Test.*—When 5 cc. of the oil is mixed with 95 cc. of petroleum ether and allowed to stand 24 hours, it shall not show a precipitate or sediment of more than 0.25 cc. (5% by volume of the original oil).
7. All tests shall be made according to the methods adopted by the Committee on Standarization of Petroleum Specifications.

COMPOUND STEAM CYLINDER OIL. FOR NON-CONDENSING ENGINES.

GENERAL:

1. This specification covers the grade of petroleum oil used by the United States Government and its agencies for the lubrication of steam cylinders of non-condensing engines and pumps where a compounded oil is required.

PROPERTIES AND TESTS:

2. The oil must be a well refined petroleum oil, compounded with not less than 5 nor more than 7 per cent. of acidless tallow oil or lard oil.
3. *Flash Point.*—The flash point must not be less than 475° F.
4. *Viscosity.*—The viscosity at 210° F., must be within the following limits:
   120 to 150 seconds.

5. *Cold Test.*—The cold test must not be above 45° F.
6. *Precipitation Test.*—When 5 cc. of the oil is mixed with 95 cc. of petroleum ether and allowed to stand 24 hours, it shall not show a precipitate or sediment of more than 0.25 cc. (5% by volume of the original oil).
7. *Acidity.*—The oil must not contain more than 0.40% of acid calculated as oleic acid (equivalent to 0.80 mg. KOH. per gram of oil).
8. All tests shall be made according to the methods adopted by the Committee on Standardization of Petroleum Specifications.

CUP GREASE.

GENERAL:

1. This specification covers the grades of cup grease used by the United States Government and its agencies for the lubrication of such parts of motor equipment and other machinery as are lubricated by means of compression cups; No. ½ and No. 1 to be used in spindle cups or transmissions.
2. The grease must be well manufactured product, composed of a calcium soap and a highly refined mineral oil.

PROPERTIES AND TESTS:

3. The mineral oil used in reducing the soaps must be a straight well refined mineral oil with a viscosity at 100° F. of not less than 100 seconds.
4. *Soap Base.*—This base to be a whole fat such as pure tallow oil, neats-foot oil, lard oil, horse oil or other pure animal oils used singly or in combination.
   (*a*) No. ½ cup grease shall contain approximately 13% of a calcium soap made from an approved fat.
   (*b*) No. 1 cup grease shall contain approximately 14% of a calcium soap made from an approved fat.

(*c*) No. 3 cup grease shall contain approximately 18% of a calcium soap made from an approved fat.

(*d*) No. 5 cup grease shall contain approximately 24% of a calcium soap made from an approved fat.

5. *Consistency.*—These greases must be similar in consistency to the approved trade standards for No. ½, No. 1, No. 3, and No. 5 grease.

6. *Moisture.*—The grease must be a boiled grease, containing not less than one or more than three per cent. of water when finished.

7. *Corrosion.*—A clean copper plate must not be discolored when submerged in the grease for 24 hours at room temperature.

8. *Ash.*—No. ½ grease. The ash shall not be greater than 1.7%.

No. 1 grease. The ash shall not be greater than 1.8%.
No. 3 grease. The ash shall not be greater than 2.3%.
No. 5 grease. The ash shall not be greater than 3.5%.

9. *Fillers.*—The grease shall contain no fillers such as resin, resinous oils, soapstone, wax, talc, powdered mica or graphite, sulphur, clay, asbestos, or any other filler.

10. All tests shall be made according to the methods adopted by the Committee on Standardization of Petroleum Specifications.

TRANSMISSION LUBRICANT.

GENERAL:

1. This specification covers the grade of petroleum oil used by the United States Government and its agencies for the lubrication of transmission gears and bearings, differential gears, worm drives, winch drives, and roller and ball bearings used in connection with such parts of the equipment of motor vehicles.

2. The lubricant must be a refined petroleum product, without the addition of any vegetable or animal oils

or products derived from them, and be entirely free from fillers.

PROPERTIES AND TESTS:

3. *Flash Point.*—The flash point shall not be lower than 460° F.
4. *Viscosity.*—The viscosity at 210° F. must be within the following limits:
   175 to 220 seconds.
5. All tests shall be made according to the methods adopted by the Committee on Standardization of Petroleum Specifications.

GEAR CHAIN AND WIRE ROPE LUBRICANT.

GENERAL:

1. This specification covers the grade of petroleum oil used by the United States Government and its agencies for the lubrication and protection of chains, wire ropes and gears of cranes, dredges, steam shovels and all other heavy equipment, for the lubrication and protection of the gears and ropes of balloon hoists; and for swabbing the wires and cables of aircraft.
2. The oil must be a petroleum product only, free from vegetable or animal oils or products derived from them. It must be entirely free from fillers, such as talc, resin, and all materials of every nature not related to the original product.

PROPERTIES AND TESTS:

3. *Viscosity.*—The viscosity at 210° F. must be within the following limits:
   900 to 1100 seconds.
4. *Protection.*—When applied to a plate of polished steel the lubricant must protect the steel for a period of thirty days when immersed in a 10% salt solution.
5. All tests shall be made according to the methods adopted by the Committee on Standardization of Petroleum Specifications.

FLOOR OIL.

GENERAL:

1. This specification covers the grade of oil used by the United States Government and its agencies for polishing and preserving wooden floors.
2. The oil must be a well refined straight petroleum oil.

PROPERTIES AND TESTS:

3. *Flash Point.*—The flash point shall not be less than 300° F.
4. *Viscosity.*—The viscosity at 100° F. shall be within the following limits:
   60 to 100 seconds.
5. *Pour Test.*—The pour test shall not be greater than 35° F.
6. *Color.*—The oil shall be pale or red in color. Black oil will not be accepted.
7. All tests shall be made according to the methods adopted by the Committee on Standardization of Petroleum Specifications.

GUN AND ICE MACHINE OIL.

GENERAL:

1. This specification covers the grades of petroleum oil used by the United States Government and its agencies for cleaning and oiling guns and small arms where Aircraft Machine Gun Oil is not required; also for lubrication of the cylinders of Ice Machines; for lubrication of pneumatic tools and for Hydraulic Systems.
2. The oil must be a straight-run, highly refined petroleum oil, free from vegetable or animal oils or products derived from them; must be suitable in every way for the uses listed in Paragraph 1; and must not gum or corrode metals under any conditions.
3. These oils shall be supplied in two grades known as No. 100 and No. 125.

PROPERTIES AND TESTS:

4. *Flash Point.*—The flash point must not be less than 300° F.
5. *Viscosity.*—The viscosity at 100° F. must be within the following limits:
   No. 100 oil—95 to 110 seconds.
   No. 125 oil—120 to 135 seconds.
6. *Pour Test.*—The pour test shall not be higher than 5° above zero F.
7. *Acidity.*—Not more than 0.03 milligrams of potassium hydroxide shall be required to neutralize 1 gram of the oil.
8. *Emulsifying Properties.*—The oil shall separate completely in 30 minutes from an emulsion with:
   1. Distilled water.
   2. 1% salt solution.
   3. Normal caustic soda solution.

   The demulsibility shall not be less than 300.
9. All tests shall be made according to the methods adopted by the Committee on Standardization of Petroleum Specifications.

HYDROLINE OIL.

GENERAL:

1. This specification covers the grade of petroleum oil used by the United States Government and its agencies to fill the recoil cylinders of gun carriages.
2. The oil must be entirely neutral and free from acid or alkali, free from ash and saponifiable oil.

PROPERTIES AND TESTS:

3. *Viscosity.*—The viscosity shall be not greater than 145 seconds at 32° F. Not less than 43 seconds at 100° F.
4. *Pour Test.*—The pour test must be below 0° F.
5. *Evaporation Test.*—The oil must not lose more than 5 per cent. in weight when heated at 212° F. for two hours. Preference will be given to oil having the

lowest per cent. loss in weight, other things being equal.

6. All tests shall be made according to the methods adopted by the Committee on Standardization of Petroleum Specifications.

AIRCRAFT MACHINE GUN OIL.

GENERAL:

1. This specification covers the grade of petroleum oil used by the United States Government and its agencies for the lubrication of machine guns on aircraft, for cc. interrupter gears and for gun oil for cleaning and oiling machine guns and small arms.
2. The oil must be a highly refined, filtered, straight-run petroleum oil, suitable in every way for the uses specified in Paragraph 1. It must be a pure petroleum product, without the addition of vegetable or animal oils or fats of any kind. It shall not contain any material which might gum or corrode metals under any conditions.

PROPERTIES AND TESTS:

3. *Flash Point.*—The flash point shall not be less than 200° F.
4. *Viscosity.*—The viscosity at 100° F. shall be within the following limits:
   70 to 95 seconds.
5. *Pour Test.*—The pour test shall be 45 degrees or more below zero F.
6. *Acidity.*—Not more than 0.03 milligrams of potassium hydroxide shall be required to neutralize 1 gram of oil.
7. *Carbon Residue.*—The carbon residue must not be more than 0.03%.
8. All tests shall be made according to the methods adopted by the Committee on Standardization of Petroleum Specifications.

BUFFER OIL FOR RECOIL AND RECUPERATOR CYLINDERS OF ALL BRITISH TYPES OF HOWITZERS AND GUN CARRIAGES.

GENERAL:

1. This specification covers the grade of petroleum oil used by the United States Government and its agencies for filling the recoil and recuperator cylinders of all British type howitzers and gun carriages.
2. The oil is to be a pure refined petroleum oil.

PROPERTIES AND TESTS:

3. The flash point shall not be lower than 265° F.
4. *Viscosity.*—The viscosity at 100° F. shall be within the following limits:
   65 to 75 seconds.
5. *Pour Test.*—The pour test shall not be above 0° F.
6. *Acidity.*—Not more than 0.05 milligrams of potassium hydroxide shall be required to neutralize 1 gram of the oil.
7. All tests shall be made according to the methods adopted by the Committee on Standardization of Petroleum Specifications.

OIL AND GREASE USED IN RECOIL MECHANISM OF 75 AND 155 MM. GUN CARRIAGE. (FRENCH).

GENERAL:

1. This specification covers the grade of petroleum oil and grease used by the United States Government and its agencies for the recoil mechanism of 75 and 155 mm. French gun carriages.

Recuperator Oil:

2. This oil shall be a highly refined petroleum product, free from animal or vegetable oils.

PROPERTIES AND TESTS:

3. *Flash Point.*—The flash point shall not be lower than 345° F.
4. *Viscosity.*—The viscosity at 100° F. shall be within the following limits:

385 to 430 seconds.

5. *Pour Test.*—The pour test shall be 5 or more degrees below zero F.
6. *Acidity.*—Not more than 0.05 milligrams of potassium hydroxide shall be required to neutralize 1 gram of the oil.
7. *Corrosion.*—A clean copper plate must not be discolored when submerged in the oil for 24 hours at room temperature.

Recuperator Grease:

8. The grease must be a well manufactured product composed of a calcium soap and a highly refined mineral oil.

PROPERTIES AND TESTS:

9. The mineral oil used in reducing the soap must have a viscosity at 100° F. of not less than 180 seconds.
10. *Soap Base.*—The grease shall contain approximately 18% of a calcium soap made from a whole fat, such as pure tallow oil, neatsfoot oil, lard oil, horse oil, or other pure animal oils used singly or in combination.
11. *Consistency.*—This grease must be similar in consistency to the approved trade standard for No. 3 grease.
12. *Moisture.*—The grease must be a boiled grease containing not less than 1 nor more than 3% of water when finished.
13. *Corrosion.*—A clean copper plate must not be discolored when submerged in the grease for 24 hours at room temperature.
14. *Ash.*—The ash shall not be greater than 2.3%.
15. *Fillers.*—The grease shall contain no fillers, such as rosin, resinous oils, soapstone, wax, talc, powdered mica or graphite, sulphur, clay, asbestos, or any other filler.
16. All tests shall be made according to the methods adopted by the Committee on Standardization of Petroleum Specifications.

CHAPTER XXIX.

SPECIFICATIONS FOR CUTTING OILS.

Cutting Compound, Paste.—(Navy Dept., Bureau of Supplies and Accounts, Washington, D. C., Jan. 2, 1917.) To be used for machine cutting tool lubricant when mixed as directed.

To be a soluble paste compound consisting of an alkali soap, mineral oil and fixed saponifiable oils and water. To be free from disagreeable odors, mineral acids, or any ingredients injurious to persons handling the material.

To contain not more than 25 per cent. of water, not more than 20 per cent. of alkali soap, not less than 40 per cent. of mineral oil, and the remainder fixed saponifiable oil. It must form a stable emulsion when mixed with water.

The emulsion must sufficiently lubricate turret and automatic machines to prevent sticking, the solution used to be suitable for work being performed on the machine, and must show no tendency to leave a gummy residue.

Strips of polished steel are to show no appreciable corrosion after being partly immersed in mixture for a period of two weeks.

One pound of the paste will be put into emulsification with 3 gallons of water and the emulsion permitted to flow at the rate of 1 gallon per minute over a steel cylinder heated by an electric coil consuming 440 watts which maintains a constant temperature of 100° C. in air. After a period of 8 hours, the maximum rise of temperature of the emulsion shall not exceed 12° C. This physical test will be conducted at the New York Navy Yard on samples before approval on the standard apparatus shown in drawing No. 36367-A, which may be obtained from the Engineer Officer at the Navy Yard, New York.

To be purchased by the pound and delivered in heavy barrels of not more than 500 pounds capacity, suitable for foreign shipment, or in 25-pound friction-top cans packed in wood cases, two to a case. The quality of the containers to be such as to provide against leakage or deterioration in storage and in handling.

Contractors who propose to furnish cutting compound (paste) under these specifications may have a 5-pound sample tested at Navy Yard, New York, and if the test proves satisfactory this cutting compound (paste), will be placed on an acceptable list. The contractor will be required to submit a 5-pound sample of cutting compound (paste) to be supplied with each new bid, and state the approximate date of test.

Soluble Cutting Oils or Cutting Compounds (Liquid Form).—(Navy Dept., Nov. 1, 1918.) Soluble cutting oils or cutting compounds shall be used in emulsion with water for the lubrication of machine cutting tools.

Soluble cutting oils or cutting compounds shall be clean and homogeneous mixtures of soluble alkali soap in mineral and fixed saponifiable oils; shall be free from disagreeable odors, sediment, mineral acids, or ingredients injurious to persons handling; and shall contain not more than 10 per cent. of water and not more than 20 per cent. of alkali soap.

Soluble cutting oil or cutting compound shall meet the following requirements:

(*a*) *Emulsification.*—It shall be capable of readily mixing with water in all proportions, without the addition of sodium carbonate or any other material, to form a stable emulsion.

(*b*) *Lubrication.*—The emulsion formed shall so lubricate turret and automatic machine tools as to prevent sticking. The solution used shall be suitable for the work being performed on the machine, and shall show no tendency to leave a gummy residue.

(*c*) *Corrosion.*—Strips of polished steel or brass shall show no appreciable corrosion after being partly immersed in the emulsion for a period of two weeks.

Mineral Lard Oil.—(Navy Dept., Nov. 1, 1918.) Mineral lard oil shall be used for machine cutting tool lubricant, either unadulterated or compounded with mineral oil or soda and water.

Mineral lard oil shall be clean and homogeneous, free from disagreeable odors, rancidity, sediment, or ingredients injurious to persons handling the material, and shall be easily soluble and retain its oily consistency in kerosene or soda and cold-water mixtures.

Mineral lard oil shall contain:

(*a*) Not less than 25 per cent. and not more than 35 per cent. of fixed saponifiable oils.

(*b*) Not less than 60 per cent. and not more than 70 per cent. of mineral oil.

(*c*) Not more than 5 per cent. of free fatty acid (calculated as oleic acid).

Mineral lard oil shall have the following properties:

(*a*) The specific gravity at 15° C. shall be about 0.90.

(*b*) The flash point (open tester) shall be not less than 180° C.

(*c*) The viscosity shall be about 185 at 38° C. and 115 at 48° C. when measured in a Saybolt viscosimeter which has a water rate of 30 seconds at 15° C.

Mineral lard oil shall pass the following tests:

(*a*) *Gumming.*—A saucer, containing enough of the test oil to cover the bottom, shall be kept for a period of eight hours in an oven at a constant temperature of 120° C. There shall be no sign of a gummy residue after removing the saucer and permitting it to cool gradually.

(*b*) *Corrosion.*—Strips of polished steel shall show no appreciable corrosion in two weeks' time when partly immersed in samples of the oil, or in a mixture of the oil and kerosene, or in an emulsion of the oil, soda, and water.

Lard Oil.—For pipe cutting and threading purposes. (Navy Dept., Oct. 1, 1915.) See Index under Lard Oil.

Lard Oil.—(Seaboard Air Line Railway, July 7, 1915.) No. 2 for turret lathes, cutting threads, staybolt cutters, etc. See Index under Lard Oil.

Screw Cutting Oil.—(Philadelphia & Reading Railway, Nov. 15, 1893.) This oil shall consist of paraffin oil of about 27° Bé. gravity, compounded with not less than 25 per cent. by weight of fat oil, cottonseed preferred.

The compounded oil shall show a flashing point not below 300° F., and a burning point not above 425° F. The test will be made in an open vessel by heating the oil not less than 15° per minute, and applying the test flame once in 7°, beginning at 275°.

From Oct. 1 to Apr. 1 the oil must have a cold test not above 15° F.

"**Cutting Oil.**—(Board of Purchase, City of New York, Jan., 1920).

"(For General Specifications see Index.)

	Per cent.
Free Acid, max. (as a percentage of the lard oil present)	20.1
Tallow oil or mixture of Tallow and Degras	None
Lard oil, min.	15.0

CHAPTER XXX.

SPECIFICATIONS FOR GREASES AND GRAPHITE.*

Cup Greases.—War Dept., Raw Materials Div., U. S. A., Specif. No. 3,506-B, May 24, 1919.)

GENERAL.

1. Specification covers the requirements of the Army for Cup Greases to be used for the lubrication of such parts of motor equipment and other machinery as are lubricated by means of compression cups. (Numbers 1 and 2 to be used in spindle cups.)
2. The grease must be a well manufactured product, composed of a calcium soap and a highly refined mineral oil.

PHYSICAL PROPERTIES AND TESTS.

3. The mineral oil used in reducing the soaps must be a straight, well refined mineral oil with a viscosity of 100 to 170 when tested in a Saybolt Universal Viscosimeter at 100° F.
4. *Saponifiable fat base.*—This base to be a whole fat such as pure tallow oil, neatsfoot oil, lard oil, horse oil or other pure animal oils used singly or in combination of one or more of the above animal oils.

(a) No. 1 Cup Grease shall contain approximately 14% of a Calcium Soap made from an approved fat.

(b) No. 2. Cup Grease shall contain approximately 15% of a Calcium Soap made from an approved fat.

(c) No. 3. Cup Grease shall contain approximately 18% of a Calcium Soap made from an approved fat.

(d) No. 4. Cup Grease shall contain approximately 22% of a Calcium Soap made from an approved fat.

(e) No. 5. Cup Grease shall contain approximately 24% of a Calcium Soap made from an approved fat.

5. *Consistency.*—These greases must be similar in consistency to the approved trade standards for a No. 1, No. 2, No. 3, No. 4 and No. 5 grease.

* For Additional Grease Specifications see Chapter on Standard Government Specifications for Lubricants, or see Index.

6. *Moisture.*—The grease must be a boiled grease, containing not less than one or more than three per cent. of water when finished.

7. *Acidity.*—The grease must not attack a sheet of polished copper within a period of forty-eight hours.

8. *Ash.*—No. 1 Grease. The ash shall not be greater than 1.8%.
   No. 2 Grease. The ash shall not be greater than 2.0%.
   No. 3 Grease. The ash shall not be greater than 2.3%.
   No. 4 Grease. The ash shall not be greater than 3.0%.
   No. 5 Grease. The ash shall not be greater than 3.5%.

9. *Fillers.*—The grease shall contain no fillers such as rosin, resinous oils, soapstone, wax, talc, powdered mica or graphite, sulphur, clay, asbestos, or any other filler or artificial thickening.

Statement to be submitted by Bidders.

10. The bidder must state in his proposal the following characteristics of the grease he proposes to furnish:
   (*a*) Gravity, Baumé at 60° F. of the mineral oil used.
   (*b*) Viscosity, Saybolt Universal Viscosimeter at 100° F. of the mineral oil used.
   (*c*) Kind and percentage of fat base used.
   (*d*) Percentage of ash.

Graphite (lubricating).—(Gen. Supply Comm., Washington, D. C., for fiscal year 1920.) Samples taken from any lot must show upon analysis at least 90 per cent. of graphitic carbon; it must be free from grit, dirt, or any other deleterious substance and be put up in air-tight rectangular tin cans with screwed or friction tops, each containing 1 or 5 pounds, as may be required:

(*a*) Amorphous; must be ground fine enough to pass through a No. 20 bolting cloth (state brand).

(*b*) Flake; must be finely ground (state brand).

SPECIFICATIONS OF NAVY DEPARTMENT, BUREAU OF SUPPLIES AND ACCOUNTS, Washington, D. C.

Mineral Lubricating Grease.—(Aug. 1, 1919.) Mineral lubricating grease shall be furnished in the following grades, as specified:

(*a*) Hard.
(*b*) Medium.

Flow Point.—(*a*) Medium lubricating grease shall have a flow point not lower than 75° C., nor higher than 80° C.

(*b*) Hard lubricating grease shall have a flow point not lower than 100° C., nor higher than 105° C.

(*c*) The flow point shall be determined as follows: Spread about 10 grams of grease over the bottom of glass crystallizing dish, 2½ inches diameter and about 1½ inches high; place dish on shelf in air oven so that a thermometer inserted in the top of the oven will be just above and over the grease in the dish. The temperature of the oven, starting at about 40° C., shall be raised at a rate of 2° C. per minute and the flow tested at the end of each minute. The temperature at which the grease moves across the bottom when the dish is inclined shall be taken as the flow point.

Composition.—(*a*) Mineral lubricating grease shall be a homogeneous mixture, consisting of a pure mineral oil and a pure odorless lime soap made from pure animal fats or prime yellow cottonseed oil properly saponified with calcium oxide. The mineral oil content shall not be more than 80 per cent. for medium grease and not more than 70 per cent. for hard grease.

(*b*) Mineral lubricating grease, both medium and hard, shall be free from fillers, unsaponified fats or oils, uncombined lime, gritty substance, rosin oil, rosin or resinates, mineral or fatty acids, tarry or asphaltic matter, and alkalies or other undesirable or deleterious impurities.

(*c*) Medium mineral lubricating grease shall yield not more than 2.5 per cent. of ash and hard mineral grease not more than 3.5 per cent. of ash.

(*d*) Mineral lubricating grease, both medium and hard, shall not lose more than 2 per cent. of its weight when heated for one hour at 100° C. in a glass crystallizing dish in an air oven.

Lubricating Properties.—The grease shall possess lubricating properties, determined by practical test in a Riehle bearing testing machine as follows:

When fed at a rate not exceeding 2 grains (or 130 milligrams) per minute, through a grease cup on the friction surface of a brass shoe having 9 square inches bearing surface, sustaining a load of 1,926 pounds against a steel journal 6 inches in diameter, revolving at a surface velocity of 405 feet per minute, it shall maintain an even temperature of not more than 50° C. above the surrounding air (which shall be approximately 25° C.), and the coefficient of friction shall be constant during the last hour of the run and shall not exceed 0.03 for medium and 0.04 for hard grease. The run shall be continued until a constant temperature rise has been attained and maintained for one hour.

Mineral lubricating grease shall be delivered in friction top cans of 10 pounds capacity.

Mineral lubricating grease is intended for use in compression grease cups for bearings. For rapid-running machines in cool climates, medium grease should be ordered. For hot climates, or heavy-running machinery, hard grease should in general be ordered. (Method of packing and inspecting specified.)

Graphite Lubricating Grease.—(Aug. 1, 1919) Graphite lubricating grease shall be furnished in the following grades, as specified:

(*a*) Hard.

(*b*) Medium.

Flow Point.—(*a*) Medium graphite grease shall have a flow point not lower than 75° C., nor higher than 80° C.

(*b*) Hard graphite grease shall have a flow point not lower than 100° C., nor higher than 105° C.

(*c*) The flow point shall be determined as follows: Spread about 10 grams of grease over the bottom of a glass crystallizing dish, 2½ inches in diameter and about 1½ inches high. Place dish on shelf in an air oven so that a thermometer inserted in the top of the oven will be just above and over the grease in the dish. The temperature of the oven, starting at about 40° C., shall be raised at the rate of 2° C. per minute, and the flow tested at the end of each minute. The temperature at which the grease moves across the bottom when the dish is inclined shall be taken as the flow point.

Composition.—(*a*) Graphite lubricating grease shall be a homogeneous mixture, consisting of a pure mineral oil, flake graphite containing at least 82 per cent. of graphitic carbon, and a pure odorless soap made from clean animal fats or prime yellow cottonseed oil properly saponified with calcium oxide. The mineral oil content shall be not more than 80 per cent. for medium grade and not more than 70 per cent. for hard grade. The graphite content shall not be less than 2 nor more than 3 per cent. for each grade.

(*b*) Graphite lubricating grease, both medium and hard, shall be free from fillers, unsaponified fats or oils, uncombined lime, gritty substance, resin oil, resin or resinates, mineral or fatty acids, tarry or asphaltic matter, and alkalies or other undesirable or deleterious impurities.

(*c*) Medium graphite grease shall yield not more than 3 per cent. of ash and hard graphite grease not more than 4 per cent. of ash.

(*d*) Graphite grease, both medium and hard, shall not loose more than 2 per cent. of its weight when heated for one hour at 110° C. in a glass crystallizing dish in an air oven.

Lubricating Properties.—The grease shall possess lubricating properties determined by practical test in a Riehle bearing-testing machine. (Requirement test for Mineral Lubricating Grease, above.)

Graphite lubricating grease shall be delivered in friction-top cans of 10 pounds capacity. (Method of packing and inspecting specified.)

Graphite lubricating grease under these specifications is intended for use on gearing of heavy machinery and bearings exposed to weather and heat.

Grades.—Graphite lubricating grease shall be specified as hard or medium grease; hard grease shall be used only where high operating temperatures are found to exist.

Flake Lubricating Graphite.—(Navy Dept., Nov. 1, 1917.) Flake lubricating graphite shall be the best grade of foliated flake graphite reasonably free from amorphous graphite. Samples taken from any lot shall contain at least 88 per cent. of graphitic carbon. Flake lubricating graphite shall be free from grit, dirt, or any other deleterious substance.

Flake lubricating graphite shall be delivered in air-tight rectangular cans with screwed tops. Each can shall contain 25 pounds of the graphite. Each container shall be marked or labeled with the name of the material, the quantity, and the name of the manufacturer or the trade-mark.

Deliveries shall be marked with the name of the material, the quantity, the name of the contractor, and the contract or requisition number under which delivery is made.

Contract, requisition, or order shall state whether coarse, medium, or fine flake lubricating graphite is desired.

Graphite, Ground, Amorphous (Lubricating).—(Navy Dept., Jan. 2, 1917.) Samples taken from any lot must show upon analysis at lease 82 per cent. of graphitic carbon. It must be free from grit, dirt, or any other deleterious substance.

Amorphous graphite must be ground fine enough to pass a No. 20 bolting cloth.

To be put up in strong well-made 100-pound barrels, with marking on heads, or, if directed, in 5- and 25-pound commercial tins.

Each container must be marked with the name of the material, the trade-mark, if any, and the name of the manufacturer.

CHAPTER XXXI.

SPECIFICATIONS FOR BOILER COMPOUNDS AND COTTON WASTE.

Boiler Compound.—(Navy Dept., Jan. 2, 1919.) Boiler compound shall be powdered and composed of sodium carbonate, trisodium phosphate, starch, and cutch or dry extract of hemlock, oak, or chestnut bark.

These materials shall be intimately mixed and finely powdered. The product shall be readily soluble in water and uniform in composition.

The compound shall show on analysis at least 76 per cent. of anhydrous sodium carbonate (Na_2CO_3), 10 per cent. of trisodium phosphate ($Na_3PO_4 12H_2O$), 1 per cent. of starch, and sufficient cutch or dry extract of hemlock, oak, or chestnut bark to yield 2 per cent. of tannic acid. The remainder to consist of water and only such impurities as are common to the ingredients.

The sodium carbonate content shall be determined by the following method:

Incinerate 1 gram, dissolve in water and wash into a flask. Add an excess of standard acid, boil, and titrate back with standard alkali, using phenolphthalein as indicator. Calculate to Na_2CO_3, which result is the actual sodium carbonate plus the sodium carbonate equivalent of the alkalinity of the trisodium phosphate. Therefore deduct from this figure 14/100 of the percentage of fully hydrated trisodium phosphate found present, and the result is the percentage of sodium carbonate.

Boiler compound shall be packed in practically air-tight tins, of the soldered-top type, each tin to contain 25 pounds net.

Cotton Waste.—(Navy Dept., Jan. 2, 1919.) The material furnished under these specifications shall be all new fine white, bleached or unbleached, soft cotton threads. It shall contain about 10 per cent. slasher and the balance shall be cop and spooler, properly mixed, and machined into a homogeneous mass. The waste shall be practically free from threads less than 3 inches long, and shall not contain any colored threads, any coarse or unabsorbent threads, strings, sweepings, flyings, dirt, or material that has been soiled or washed.

The inspection shall be made at the mill during the process of manufacture and baling. All handling of material necessary for purposes of inspection shall be performed and all test specimens necessary for the determination of the qualities of the material shall be prepared and tested at the expense of the contractor.

The waste shall be supplied in bales properly covered with clean burlap. Net weight shall be 50 or 100 pounds, as specified, such bales having a volume of 3½ cubic feet and 7 cubic feet, respectively. The bales supplied shall average the weight that is ordered, a variation of 10 per cent. in the weight of single bales being allowed.

Gross weight shall be paid for, subject to the following provisions, *viz.:* Weight of wrappings, including hoops, shall not exceed 6 per cent. of gross weight, and moisture shall not exceed 3 per cent. Any excess of the foregoing elements up to 3 per cent. shall be deducted from contract price at the same price per pound that is paid for the waste. If the tare exceed 9 per cent. or moisture 6 per cent., the waste shall not be accepted.

Cotton Waste (Colored).—(Office of Gen. Purchasing Officer, The Panama Canal, Washington, D. C.) Waste to be manufactured of long, clean, new, colored and white cotton thread, all over 3 inches in length, 50 per cent. by weight of each. Waste not to contain any fiber other than cotton, and no chopped material, duck, slasher, soft yarn, shredded or reclaimed stock to be used. Must not contain sweepings, flyings, or dirt. Must not contain any material which is not new, or which gives evidence of having been soiled or having been once used and afterwards washed or cleaned. Not over 1 per cent. of moisture will be permitted. Settlement will be made on the basis of net weights. The Panama Canal inspector will witness laying, mixing, machining, and baling of waste, and contractor shall provide facilities for The Panama Canal inspector to witness these operations, as well as weighing of the waste and noting the average tare. Stock to be used in the manufacture of waste must be offered to The Panama Canal inspector in the original bales unopened.

In the past considerable trouble has been experienced in obtaining satisfactory waste, and under this request for quotations no consideration will be given to samples submitted with bids, and all quotations will be assumed to be on the basis of supplying material in accordance with the above specifications.

Bales to be approximately 600 pounds each; waste to be properly mixed and well machined.

Cotton Rags for Wiping Machinery.—(Navy Dept., Dec. 1, 1917.) Rags shall be soft, absorbent, light-weight cotton cloths of regular or irregular shape. Rags shall be opened flat and be free from near-silks, sateens, heatherblooms, and kindred lustrous materials, buttons, hooks, eyes, grit, and dirt, and shall be dry.

(*a*) *Colored wipers.*—The colors shall run from black up to and including all white rags. The presence of 5 per cent. of black rags shall be sufficient cause for rejection. At least 50 per cent. of the rags in each bale shall be white or near-white.

(*b*) *White wipers.*—This grade shall consist of white wipers including near-white and light knit.

The minimum size cloths shall have an area of at least 2 square feet.

The contractor shall furnish an affidavit that the rags delivered have been laundered and sterilized. Each bale of rags shall contain a certificate attesting to the washing, sterilizing, and purification of the wipers contained therein.

Rags shall be delivered in bales of about 100, 200, or 500 pounds each, as specified. Gross weight will be paid for, but an excessive amount of wrapping will be sufficient cause for rejection.

CHAPTER XXXII.

SPECIFICATIONS FOR FUEL OIL.

Test and Specifications for Navy Petroleum.

Below are given the methods of test and specifications covering United States Navy fuel oil, gas oil, and bunker oil for Atlantic and Gulf ports, as adopted October 2, 1918:

Specifications for United States Navy Fuel Oil, Gas Oil, and Bunker Oil, Atlantic and Gulf Ports.*

As adopted by the Committee on Standardization of Petroleum Specifications October 2, 1918.

Methods of test.—(*a*) Flash point will be taken as indicated in the specifications.

(*b*) Viscosity will be taken by the Engler viscosimeter. (See note under "Specifications.")

(*c*) Water and sediment will be taken by the distillation method. When oil in small lots is consigned to naval vessels or to navy yards the centrifuge test will be used in order to obviate delay. In this test 30 cc. of oil and an equal quantity of best commercial benzol, 50 per cent. white, will be used and the mixture heated to 100° F.

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 gauze 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 cubic inches 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.

*Revision of Government Fuel Oil Specification is being considered by the Committee on Standardization.

(*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 viscosimeter is not available, the Saybolt standard universal viscosimeter may be used. Equivalent viscosities:

8 Engler = 300 seconds Saybolt.
40 Engler = 1,500 seconds Saybolt.

Special specifications for gas oil for diesel engines.—1. Flash point not lower than 150° F. (Abel or Pennsky-Marten's closed cup).

2. Water and sediment, trace only.

3. Asphaltum none.

Bunker oil "A."—To comply strictly with the provisions for Navy specifications fuel oil, except that there shall be no limit on sulphur.

Bunker oil "B."—Specifications to be the same as for Navy fuel oil except:

(*c*) Omit and substitute "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)."

(*d*) Omit and substitute "To have a minimum gravity of 18 Bé."

(*f*) Omit.

Bunker oil "C."—Specifications to be the same as for bunker oil "B" except it is to have a gravity of approximately 16 Bé.

Navy standard fuel oil only will be supplied to battleships, destroyers, and other vessels subject to heavy forced draft conditions or required to run smokeless. It will also be supplied for cargo oil for all shipments abroad or to Navy storage.

Bunker oil "A" will be used by other types of vessels requiring a light oil and by shore stations fitted with separate storage for yard use. It will not be used where bunker oil "B" or "C" can be satisfactorily used.

Bunker oil "B" will be used by all transports and cargo vessels which can satisfactorily burn an oil not heavier than 18 Bé. gravity. It will not be used where bunker oil "C" can be satisfactorily used.

Bunker oil "C" will be used by all transports and cargo vessels which can satisfactorily burn an oil of approximately 16 Bé. gravity.

The commander, cruiser and transport force, or his representative, and the district supervisor, Naval Overseas Transportation Service, shall determine the grade of oil to be used by vessels operating under their direction.

Fuel Oil.—(Seaboard Air Line Railway, Motive Power Dept., Nov. 24, 1913.) This oil or "liquid fuel" is crude petroleum as received from the wells, or the product of crude petroleum, distilled or reduced. It must contain no sand or foreign matter in shape of sticks, waste, stones, etc., and must be sufficiently liquid to flow readily in 4-inch pipes at a temperature of 70° F.

It must contain as little water as possible, and oil containing more than 2 per cent. of water and other impurities will not be accepted.

Fuel oil will be paid for on a basis of volume at 60° F., also deducting all water contained, according to methods outlined as follows:

One sample will be taken from each carload or fraction thereof. The sampling of cars is to be made with car thief having valve at lower end. The thief with open valve will be lowered gradually into car and valve closed at instant of touching bottom. The thief thus filled will contain oil sample to be tested for water, sand and B. S. (Bottom Settlings).

Oil received in settling or storage tanks will be sampled with Robinson or other standard thief, a sufficient number of samples being taken to secure an average of its contents.

Fuel oil will not be accepted for general use whose flash point is less than 110° F. when tested by the open cup, Tagliabue method. The oil to be heated at a rate of 5° per minute, and test flame applied every 5°, beginning at 90°.

The above flash point being the danger point at which the oil begins to give off inflammable gas, the fire or burning point is not required.

The test for water, sand and B. S. will be made as follows: 100 cc. of the sample will be placed in a 250 cc. graduated glass cylinder provided with stoppers, and thoroughly shaken up with not less than 150 cc. of gasoline. The mixture will be heated to 120° F., for from 3 to 6 hours to facilitate the separation of impurities, the amount of which can then be read from the graduations of the cylinder. All proportion of water and other impurities contained in the sample will be deducted from the volume contained in the car and not paid for.

The temperature of shipment will be tested directly as sample is removed from sampling tube, or by immersion of thermometer in the receptacle itself for not less than 1 minute. A deduction in volume for expansion at temperature of over 60° F. will be made at the rate of $^1/_{25}$ of 1 per cent. for each degree. At 90°, the deduction would be 1⅕ per cent., etc. Kansas and Oklahoma fuel oil furnished from Sugar Creek, or Kansas City, Mo., at 90° should have a deduction of 1¼ per cent.

Gravity of fuel oil should range between 13° and 29° Bé. at 60° F.

If any portion of an accepted shipment is subsequently found to be damaged, or otherwise inferior to the original sample, that portion will be returned to the shipper at his expense.

Any sample failing to meet all the requirements of this specification will be condemned, and this shipment represented by it will be returned to the manufacturer.

In cases of rejection the materials wll be held for two weeks from the date of test. If by the end of that period the manufacturers have not given shipping directions, it will be returned to them at their risk, they paying the freight both ways.

Fuel Oil.—("Specifications for the Purchase of Fuel Oils for the Government with Directions for Sampling Oil and Natural Gas," Tech. Paper No. 3, Bureau of Mines, 1911.) General specifications for the purchase of fuel oil:

1. In determining the award of a contract, consideration will be given to the quality of the fuel offered by the bidders, as well as the price, and should it appear to be to the best interest of the Government to award a contract at a higher price than that named in the lowest bid or bids received, the contract will be so awarded.
2. Fuel oil should be either a natural homogeneous oil or a homogeneous residue from a natural oil; if the latter, all constituents having a low flash point should have been removed by distillation; it should not be composed of a light oil and a heavy residue mixed in such proportions as to give the density desired.
3. It should not have been distilled at a temperature high enough to burn it, nor at a temperature so high that flecks of carbonaceous matter began to separate.
4. It should not flash below 60° C. (140° F.) in a closed Abel-Pensky or Pensky-Martens tester.
5. Its specific gravity should range from 0.85 to 0.96 at 15° C. (59° F.); the oil should be rejected if its specific gravity is above 0.97 at that temperature.
6. It should be mobile, free from solid or semi-solid bodies, and should flow readily, at ordinary atmospheric temperatures and under a head of 1 foot of oil, through a 4-inch pipe 10 feet in length.
7. It should not congeal nor become too sluggish to flow at 0° C. (32° F.).
8. It should have a calorific value of not less than 10,000 calories per gram (18,000 British thermal units per pound): 10,250 calories to be the standard. A bonus is to be paid or a penalty deducted according to the method stated under

Section 21, as the fuel oil delivered is above or below this standard.

9. It should be rejected if it contains more than 2 per cent. water.
10. It should be rejected if it contains more than 1 per cent. sulphur.
11. It should not contain more than a trace of sand, clay, or dirt.
12. Each bidder must submit an accurate statement regarding the fuel oil he proposes to furnish. (Details also given as to this statement, and in regard to sampling, deliveries and rejection.)

See also Tech. Paper No. 37, Bureau of Mines, by I. C. Allen, on "Heavy Oil as Fuel for Internal Combustion Engines."

CHAPTER XXXIII.

SPECIFICATIONS FOR KEROSENES.

Kerosene.—(Gen. Supply Comm., Washington, D. C., for year ending 1920).

Kerosene; must be water white in color, free from dirt and water, and show a flash test of 100° F. in Pensky-Martens tester; litmus paper immersed in the oil for 5 hours must remain unchanged; the oil must burn steadily and clearly in a suitable lamp or lantern without smoking and with a minimum incrustation of the wick for a period of 24 hours.

Signal Oil.—(Bur. of Aircraft Prod., U. S. A., Specif. No. 3,516, June 27, 1918).

GENERAL.

1. This specification covers the requirements of the Bureau of Aircraft Production for an oil to be burned in such devices as are subject to sever jars which would extinguish a flame resulting from burning a pure mineral oil. Also for safety and to meet statutes that require a 300-degree fire test for oils used for illumination or passenger conveyances, including steamboats.

PHYSICAL PROPERTIES AND TESTS.

2. *Composition.*—The oil must be a compound of prime lard oil or refined peanut oil, with 300° fire-test burning oil commonly known as Mineral Seal.
3. *Percentage.*—The oil must contain not less than 32 per cent. by weight of the fatty oil.
4. *Burning test.*—The oil must burn freely in the regulation trainman's lantern, using flat wick, for twelve hours without adjustment after the first hour, without serious drop in flame and without leaving a hard crust on the wick. After the observation, the lantern must be allowed to burn itself out. An oil that will not burn entirely from the font with reasonable drop in

flame will be subject to rejection as having poor burning qualities.

5. *Acidity.*—The oil must be free from mineral acid, and not contain more free fatty acid than can be neutralized with 1.0 milligram of caustic potash for each 1.0 gram of oil.
6. *Pour test.*—One ounce of the oil must not congeal in a standard four-ounce sample bottle when exposed to a temperature of 25° F.
7. *Suspended matter.*—The oil must not be cloudy from the presence of suspended matter of any kind.
8. All tests shall be made in accordance with methods adopted by the American Society for Testing Materials.

REPORT OF COMMITTEE ON STANDARDIZATION OF PETROLEUM SPECIFICATIONS.

Bulletin No. 2, Dec., 1918. (Oil Division, U. S. Fuel Administration).*

INTRODUCTION.

The specifications for illuminating oils which have been heretofore used by the different departments of the Government, including the Railroad Administration, have been, at times, so drawn that they could be met only when the oil was manufactured from the crude oil from some particular section of the United States, notwithstanding the fact that oils from other districts could produce an illuminating oil equally as desirable.

The Committee on Standardization of Petroleum Specifications early in its activities, recognized that this resulted in increased cost, not only to the Government, but to the railroads, when they purchased oils in one part of the country and transported them to another part, when a perfectly satisfactory product could have been obtained much nearer to the point of consump-

* The following specifications are in practical accord with this committee report: Kerosene, Navy Dept., May 1, 1918 and Kerosene, War Dept., Quartermaster Corps, No. 3,517 (1918). This report is intended to cover the Railroad burning oils also. For old specifications of Railroads and the various Government Departments for burning oils, see First Edition of this volume.

tion. As a result of this condition, new specifications have been drawn so as to allow these products to be made from any satisfactory crude petroleum, thereby saving not only unnecessary rail transportation but making the oil available at point of consumption at less cost.

WATER-WHITE KEROSENE.

Methods of Test.

Flash.—To be taken on the Tag closed cup, A. S. T. M. standard; oil to be heated at the rate of 2° F. per minute; test flame to be applied every 2°, commencing at 105° F.

Color.—To be determined on the Saybolt colorimeter or its equivalent.

Sulphur.—Test to be made by burning at least 2 grams of the oil in a small flask and absorbing the gases of combustion in a standard solution of Sodium Carbonate and titrating the excess of Sodium Carbonate with the standard solution of Sulphuric Acid.

Floc.—Directions for making test: Take a hemispherical iron dish, and place a small layer of sand in the bottom. Take a 500 cc. Florence or Erlenmeyer flask and into it put 300 cc. of the oil (after filtering if it contains suspended matter). Suspend a thermometer in the oil by means of a cork slotted on the side. Place flask containing the oil in the sand bath, and heat bath so that the oil has reached a temperature of 240° F. at the end of one hour. Hold oil at temperature of not less than 240° F. nor more than 250° F. for six hours. The oil may become discolored but there should be no suspended matter formed in the oil. The flask should be given a slight rotary motion and if there is a trace of "floc" it can be seen to rise from the center of the bottom.

Distillation test.—The oil shall all distill below temperature of 600° F. The test is made as described by the Bureau of Mines, Technical Paper 166, using A. S. T. M. apparatus with wet bulb and total immersion thermometer.

Cloud test.—Directions for making test: Take a 4-ounce oil sample bottle and introduce therein 1½ ounces of the oil to be tested; insert cork with cold-test thermometer so that thermometer is suspended in the oil. Place bottle in a freezing mixture and cool to 0° F. Keep oil cooled to this temperature for 10 minutes. Bottle should be given a rotary motion occasionally so as not to supercool the sides. The oil should not be clouded from crystals of paraffin wax at the end of 10 minutes.

Reaction.—Two ounces of the oil should be shaken with one-half ounce of warm neutral distilled water and allowed to cool and separate. The water when separated shall react neutral to methyl-orange and phenol-phthalein.

Burning test.—The oil must burn freely and steadily in a lamp fitted with a No. 1 sun hinge burner. It must give a good flame for a period of 18 hours without smoking or forming "ears" or "toad-stools" on the wick. The chimney must be only slightly clouded or stained at the end of the test.

SUMMARY OF SPECIFICATIONS.

Water-White Kerosene.

Appearance.—Oil must be free from water, glue, and suspended matter.

Flash.—Not less than 115° F., Tag closed cup, A. S. T. M. standard.

Color.—To be 21 color on Saybolt colorimeter or its equivalent on a Lovibond tintometer, these being equal to color of a solution of Potassium Bichromate containing 0.0048 grams per liter.

Sulphur.—Not more than 0.06 per cent.

Floc.—Oil to be free from floc.

Distillation.—Oil to distill below temperature of 600° F.

Cloud test.—Oil should not show cloud at 0° F.

Reaction.—Must be neither acid nor alkaline.

Burning test.—As stated above.

Special Notes Covering Kerosene for the United States Navy.

Water-white kerosene for United States Navy use, when specifically required for special fuel, shall have a heating value of not less than 20,000 B. t. u. per pound.

When specifically provided for, a representative sample of the oil delivered will be tested photometrically after burning for one hour in a lamp fitted with a No. 1 sun hinge burner. Five hours later another photometric test will be made to determine any change in intensity of the light; the maximum allowable loss shall be 5 per cent. The flame shall show at least 6 candlepower when compared photometrically with an incandescent lamp which has been standardized by the Bureau of Standards.

Otherwise specifications enumerated above apply for United States Navy kerosene.

LONG-TIME BURNING OIL.

Method of Test.

Flash.—To be taken on the Tag closed cup, A. S. T. M. standard; oil to be heated at the rate of 2° F. per minute; test flame to be applied every 2° commencing at 105° F.

Color.—To be determined on the Saybolt colorimeter or its equivalent.

Floc.—Directions for making test: Take a hemispherical iron dish, and place a small layer of sand in the bottom. Take a 500 cc. Florence or Erlenmeyer flask and into it put 300 cc. of the oil (after filtering if it contains suspended matter). Suspend a thermometer in the oil by means of a cork slotted on the side. Place flask containing the oil in the sand bath, and heat bath so that the oil has reached a temperature of 240° F. at the end of one hour. Hold oil at temperature of not less than 240° F. nor more than 250° F. for six hours. The oil may become discolored, but there should be no suspended matter formed in the oil. The flask should be given a slight rotary motion, and if there is a trace of "floc," it can be seen to rise from the center of the bottom.

Cloud test.—Directions for making test: Take a 4-ounce oil sample bottle and introduce therein 1½ ounces of the oil to be tested; insert cork with cold test thermometer so that thermometer is suspended in the oil. Place bottle in a freezing mixture and cool to 0° F. Keep oil cooled to this temperature for 10 minutes. Bottle should be given a rotary motion occasionally so as not to supercool the sides. The oil should not be clouded from crystals of paraffin wax at the end of 10 minutes.

Reaction.—Two ounces of the oil should be shaken with one-half ounce of warm neutral distilled water, and allowed to cool and separate. The water when separated shall react neutral to methyl-orange and phenol-phthalein.

Burning test.—Burning test will be made by introducing 25 fluid ounces of oil into the pot of a standard railway signal association semaphore lamp, fitted with the purchaser's standard burner, chimney, and wick. The wick shall be new and previously washed with redistilled ether and dried at room temperature; the lamp to be protected from the direct rays of the sun, but may be burned either outdoors or in a well-ventilated room. During the first hour of the test the wick will be adjusted so as to produce a flame seven-eighths inch high, measured from the top of the wick. The lamp shall burn continuously without readjusting the wick for 120 hours, or until all of the oil is consumed.

The flame shall remain symmetrical and free from smoke throughout the test period.

The height of flame at any time during the test shall be not less than three-fourths of an inch. The oil shall not produce any appreciable hard incrustation on the wick.

SUMMARY OF SPECIFICATIONS—LONG-TIME BURNING OIL.

Appearance.—Oil must be free from water, glue, and suspended matter.

Flash.—Not less than 115° F. Tag. closed cup, A. S. T. M. standard.

Color—To be 21 color on Saybolt colorimeter or its equivalent on a Lovibond tintometer, these being equal to color of a solution of Potassium Bichromate containing 0.0048 per liter.

Floc.—Oil to be free from "floc."

Cloud test.—Oil should not show cloud at 0° F. See Note No. 1 below.

Reaction.—Must be neither acid nor alkaline.

Burning test.—As stated above.

NOTE NO. 1. *Relative to cloud test.*—Temperature of 0° F. can be varied either up or down to suit the climatic conditions in the territory in which the oil is to be used.

SPECIAL NOTES COVERING LONG-TIME BURNING OIL—BUREAU OF LIGHTHOUSES.

Oil for use by the Bureau of Lighthouses shall be as described by the Department of Commerce, which specifications, etc. at the present time are as follows:

1. The kerosene must have a flash point of not less than 140° F. and fire point of not less than 160° F. (Tagliabue closed tester).

2. The kerosene must contain no free acids or mineral salts. Litmus paper immersed in it for five hours must remain unchanged.

3. One hundred grams of kerosene shaken with 40 grams of sulphuric acid (Sp. Gr. 1.73) must show little or no coloration.

4. When distilled from a still so jacketed as not to allow of local heating at a rate of not over 10 per cent. in 10 minutes, the kerosene shall not distill below 350° F. and 98 per cent. shall distill under 515° F., the temperature taken being that of the condensing vapor.

5. When burned for 120 hours in a lens lantern supplied with a fifth-order oil lamp, the kerosene must burn steadily and clearly without smoking, with minimum incrustation of wick, slight discoloration of chimney, and less thann 10 per cent. loss of candlepower. A lamp of this description will be loaned to successful bidder.

300-DEGREE MINERAL SEAL OIL.

Methods of Test.

Flash.—To be taken on the Cleveland open cup; oil to be heated at the rate of 7° F. per minute; test flame to be applied every 5° commencing at 210° F.

Fire test.—After the flash point is obtained the oil shall be heated at the same rate (7° per minute), test flame to be applied every 5° after the flash point has been obtained.

Color.—To be determined on the Saybolt colorimeter or its equivalent.

Floc.—Directions for making test.—Take 500 cc. Florence or Erlenmeyer flask and into it put 300 cc. of oil (after filtering if it contains suspended matter). Oil to be heated at the rate of 10° F. per minute to a temperature of 450° F. and held at that temperature for 15 minutes. The oil shall show no floc or precipitate at that temperature or 1 hour after cooling.

Cloud test.—Directions for making test: Take a 4-ounce oil sample bottle. Introduce therein 1½ ounces of oil to be tested.

Insert cork with cold-test thermometer so that bulb is slightly below the surface of the oil. Place bottle in a freezing mixture and cool oil to a temperature of 32° F. Keep oil cooled to this temperature for 10 minutes. Bottle should be given a rotary motion occasionally so as not to supercool the sides. The oil should not become cloudy from crystals of paraffin wax at the end of 10 minutes.

Reaction.—Two ounces of the oil should be shaken with one-half ounce of warm neutral distilled water and allowed to cool and separate. Water when separated shall react neutral to methyl-orange and phenol-phthalein.

Burning test.—Burning test will be made by introducing 20 fluid ounces of oil into a lamp fitted with a dual burner No. 3, dual chimney, and duplex wicks. The lamp used shall be such that the distance from the top of the wick tube to the bottom of the inside of the font is not less than 6½ inches nor more than 7 inches. During the first hour of the test the wicks will be adjusted so as to produce a symmetrical flame approximately one inch high, measured from the top of the wicks. The lamp shall burn continuously without readjusting until all of the oil is consumed. The flame shall remain symmetrical and free from smoke throughout the test period. The oil shall not produce any appreciable hard incrustation on the wick.

SUMMARY OF SPECIFICATIONS—300-DEGREE MINERAL SEAL OIL.

Appearance.—The oil must be free from water, glue, and suspended matter.

Flash.—Not less than 250° F. Cleveland open cup.

Fire.—Not less than 300° F. Cleveland open cup.

Color.—To be not less than 16 color on Saybolt colorimeter or its equivalent on the Lovibond tintometer, these being equal to color of a solution of Potassium Bichromate containing 0.012 grams per liter.

Floc.—Oil to be free from "floc."

Cloud test.—Oil should not show cloud at 32° F.

Reaction.—Must be neither acid nor alkaline.

Burning test.—As stated above.

SIGNAL OIL.

METHOD OF TEST.

Flash.—To be taken on the Cleveland open cup. Oil to be heated at the rate of 7° F. per minute and test flame to be applied every 5° commencing at 210° Fahrenheit.

Fire test.—After the flash point is obtained the oil shall be heated at the same rate (7° per minute), test flame to be applied every 5° after flash point has been obtained.

Cloud test.—Directions for making test: Take a 4 ounce oil sample bottle and introduce therein 1½ ounces of oil to be tested. Insert cork with cold-test thermometer so that bulb is slightly below the surface of the oil. Place the oil in a freezing mixture and cool to 32° F. Keep oil cooled to this temperature for 10 minutes. Bottle should be given a rotary motion occasionally so as not to supercool the sides. The oil should not become cloudy at the end of 10 minutes from crystals of paraffin wax or solid fats from the lard oil or sperm oil.

Burning test.—This test is to be made in a standard railway signal hand lantern the burner of which is fitted with a 1 inch wick. The oil to be burned 24 hours without trimming or adjusting the wick, the pot of the lantern to be refilled if too small for a test of the duration named.

Oil must produce a satisfactory flame throughout the test period.

The oil must not produce an appreciable amount of hard incrustation on the wick.

The flame must stand all forms of railroad signaling in any kind of weather without being extinguished or smoking the globe.

SUMMARY OF SPECIFICATIONS—SIGNAL OIL.

Appearance.—The oil must be free from water, glue, and suspended matter.

Composition.—To be 300-degree mineral seal oil as adopted by the Committee on Standardization of Petroleum Specifications, compounded with pure prime winter strained lard oil or sperm oil, or compounded with a mixture of pure prime winter strained lard oil and sperm oil.

Flash.—Not less than 250° F. Cleveland open cup.

Fire.—Not less than 300° F. Cleveland open cup.

Cloud test.—Oil should not show cloud at 32° F.

Percentage of fatty oil.—"A" grade must contain not less than 30 per cent. of fatty oil by volume. "B" grade must contain not less than 22 per cent. of fatty oil by volume. The "A" grade shall always be furnished unless "B" grade is specifically ordered.

Free fatty acids.—"A" grade must contain not over 0.60 per cent. free fatty acid calculated as oleic acid. "B" grade must contain not over 0.45 per cent. free fatty acid calculated as oleic acid.

Burning test.—As stated above.

EXPLANATION OF TESTS

Gravity.—It will be noted that there are no gravity specifications for any of the products mentioned above. It has been known for a number of years that the gravity of an oil, by itself, has no relation to the quality. Two oils may have exactly the same gravity and one might be an excellent oil, while the other would be absolutely worthless. This difference in quality is due to the crude from which it has been made. Therefore, no gravity was specified and the quality was left to be determined by other specifications.

Flash.—The Tag closed cup, A. S. T. M. standard, was adopted because it has been accepted by several societies and its measurements have been standardized.

Color.—The Saybolt colorimeter was adopted because most of the kerosene manufactured in this country is tested by this machine. We have also shown the relation between the standard color for water white oil and the solution of Potassium Bichromate, as well as the relation between the standard color of 300-degree mineral seal and Potassium Bichromate. This will enable the manufacturer who has no color machine to make up a standard solution of Potassium Bichromate and use this solution for comparison.

Sulphur.—No standard limit was placed on long-time burning oil or 300° mineral seal, because these oils are generally burned out of doors or where there is a good circulation of air.

Gasoline, Benzine or Naphtha.—(Gen. Supply Com., Washington, D. C., for fiscal year 1920.)

CHAPTER XXXIV.

SPECIFICATIONS FOR GASOLINE.

Engine Distillate No. 1.—(War. Dept., Raw Materials Div., Oil Branch, U. S. A., Specif. No. 3,524, May 26, 1919.)

GENERAL.

1. Specification covers the requirements of the Army for No. 1 Engine Distillate.

PHYSICAL PROPERTIES AND TESTS.

2. *Color.*—The color shall not be darker than a light straw.
   Test for color.—Inspection of a column in a 4-oz. sample bottle.
3. *Foreign Matter.*—The distillate must be free from acid, undissolved water and suspended matter.
4. *Acid Test.*—Shake 10 cc. of distillate with 5 cc. of pure water and test the water with blue litmus paper.
5. *Water and suspended matter.*—None.
6. *Volatility and Distillation Range.*—The distillate should have an initial boiling point of 250° to 275° F.
   The end point should range from 400° to 500° F.

REPORT OF COMMITTEE ON STANDARIZATION OF PETROLEUM SPECIFICATIONS.

Bulletin No. 1. (Oil Div. U. S. Fuel Administration, Oct., 1918).*

SPECIFICATIONS FOR AVIATION GASOLINE.

EXPORT, FIGHTING AND DOMESTIC.

As adopted by the Committee on Standardization of Petroleum Specifications, October 2, 1918.

1. *Color.*—The color shall be water white.

* The following Specifications are substantially in accord with this Committee Report:

Bur. of Aircraft Production, U.S.A., Specif. Nos. 3,511-B, 3,512, and 3,513, June 27, 1918, for Aviation Gasoline (Domestic, Export and Fighting).

War Dept., Raw Materials Div., Oil Branch, U. S. A., Specif. No. 3, 529, July 17, 1919, for Motor Gasoline.

Navy Dept., Gasoline Specif., July 1, 1919.

For old Railroad Specifications, see First Edition of this volume.

SPECIFICATIONS.

Property	Requirement	Method of determination
Color	Water white	Inspection of vertical column made by contents of 4-ounce bottle.
Odor	Not rank or unpleasant, but not necessarily perfectly sweet.	Spreading in thin film on some convenient clean surface and noting odor.
Water and sediment content	Total absence	Main sample to be shaken thoroughly and 100 cc. poured immediately into a clean graduate or sample bottle. Examination to be made both before and after standing.
Acidity	Total absence	25 cc. of the gasoline shall be shaken thoroughly with 10 cc. of distilled water. The aqueous extract must not color blue litmus pink.

DISTILLATION.

Standard A. S. T. M. method modified for gasoline:

Not more than—	(*a*) For motor gasoline	For cleaning		For gas generators	
		(*b*) Plate	(*c*) Type	(*d*) Grade	(*e*) Grade
20 per cent. must not distill under	122° F.	210° F.	122° F.	122° F.	—
20 per cent. must distill under	221° F.	320° F.	221° F.	185° F.	115° F.
60 per cent. must distill under	284° F.	340° F.	284° F.	220° F.	140° F.
90 per cent. must distill under	350° F.	374° F.	350° F.	280° F.	180° F.
"Dry point," not above	410° F.	420° F.	410° F.	350° F.	230° F.

DISTILLATION METHOD.

The distillation shall be performed with the standard apparatus recommended by the American Society for Testing Materials for the examination of paint thinners other than turpentine. The apparatus involves the standard 100-cc. Englar flask and an ice-cooled metal condenser 22 inches in length, cooled for 15 inches of this length, set up at an angle of 75 degrees with the perpendicular, and the lower end downwards for a length of 3 to 4 inches.

Rate of distillation between 4 and 5 cc. per minute. Maximum permissible distillation loss determined by measuring total volume of distillate and residue in flask, 3 per cent.

Temperatures to be read at each 10 per cent. of the initial charge of 100 per cent. has distilled. Instead of the 100 per cent. mark is read the dry point or highest temperature the thermometer registers at the end of the distillation.

The barometric pressure should be read in case there is any possibility of dispute over the results of a distillation. Temperature readings are not to be corrected for the cooling of the emergent stem. The thermometer bulb should be covered with a thin film of absorbent cotton to prevent fluctuations during the experiment.

Test.—Inspection of a column in a standard 4-ounce oil-sample bottle.

2. *Foreign matter.*—The gasoline shall be free from acid, undissolved water and suspended matter.

Acid test.—The residue remaining in the flask after distillation is completed, is shaken thooroughly with 1 cc. of distilled water. The aqueous extract must not be colored red on addition of a few drops of methyl-orange solution. Water and suspended matter would be in evidence in the test for color.

3. *Doctor test.*—The gasoline shall yield a negative doctor test.

DIRECTIONS FOR MAKING DOCTOR TEST.

(A) *Preparation of reagents.*—Sodium plumbate or "doctor solution:" Dissolve approximately 125 grams of sodium hydroxide (NaOH) in a liter of distilled water. Add 60 to 70 grams of litharge (PbO) and shake vigorously for 15 to 30 minutes, or let stand with occasional shaking for at least a day. Allow to settle and decant or siphon off the clear liquid. Filtration through a mat of asbestos may be employed if the solution does not settle clear. The solution should be kept in a bottle tightly stoppered with a cork.

Sulphur: Obtain pure flowers of sulphur.

(B) *Making of test.*—Shake vigorously together two volumes of gasoline and one volume of the "doctor solution" (10 cc. of gasoline and 5 cc. of "doctor solution" in an ordinary test tube; or proportional quantities in a 4-ounce oil- sample bottle may conveniently be used). After shaking for about 15 seconds, a small pinch of flowers of sulphur should be added and the tube again shaken for fifteen seconds and allowed to settle. The quantity of sulphur used should be such that practically all of the sulphur floats on the surface separating the gasoline from the "doctor solution."

(C) *Interpretation of results.*—If the gasoline is discolored, or if the sulphur film is so dark that its yellow color is noticeably masked, the test shall be reported as positive and the gasoline condemned as "sour." If the liquid remains unchanged in color and if the sulphur film is bright yellow or only slightly discolored with gray or flecked with black the test shall be reported negative and the gasoline considered "sweet."

4. *Corrosion and gumming test.*—The gasoline when subjected to the corrosion test shall show no gray or black corrosion and no weighable amount of gum.

Directions for making test.—The apparatus used in this test consists of a freshly polished hemispherical dish of spun copper, approximately 3½ inches in diameter.

Fill this dish to within three-eights inch of the top with the gasoline to be examined and place the dish upon a steam bath. Leave the dish on the steam bath until all volatile portions have disappeared.

If the gasoline contains any dissolved elementary sulphur the bottom of the dish will be colored gray or black.

If the gasoline contains undesirable gum-forming constituents, there will be a weighable amount of gum deposited on the dish.

Acid residues will show as gum in this test.

Interpretation of results—Corrosion.—It is specified that no gray or black deposit shall be formed. This wording is intended to admit gasolines that have so small a quantity of sulphur that the deposit is peacock colored.

Gum.—It is specified that there shall be no weighable amount of gum. The intention is to refuse admittance to gasolines that show an amount that can be readily weighed in this style of dish.

The distillation method and apparatus shall conform to those outlined and described in Bureau of Mines Technical Paper No. 166, entitled "Motor Gasoline, Properties, Laboratory Methods of Testing and Practical Specifications."

Volatility and Distillation Range.

Export Grade.

When 5 per cent. of the sample has been recovered in the graduated receiver the thermometer shall not read more than 65° C. (149° F.); or less than 50° C. (122° F.).

When 50 per cent. has been recovered in the receiver the thermometer shall not read more than 95° C. (203° F.).

When 90 per cent. has been recovered in the receiver the thermometer shall not read more than 125° C. (257° F.).

When 96 per cent. has been recovered in the receiver the thermometer shall not read more than 150° C. (302° F.) and the end point shall not exceed this temperature by more than 15° C. (27° F.).

At least 96 per cent. must be recovered in the receiver from the distillation.

The distillation loss shall not exceed 2 per cent. when the residue in the flask is cooled and added to the distillate in the receiver.

Fighting Grade.

When 5 per cent. of the sample has been recovered in the graduated receiver the thermometer shall not read more than 70° C. (158° F.), or less than 60° C. (140° F.).

When 50 per cent. has been recovered in the receiver the thermometer shall not read more than 95° C. (203° F.).

When 90 per cent. has been recovered in the receiver the thermometer shall not read more than 113° C. (235° F.).

When 96 per cent. has been recovered in the receiver the thermometer shall not read more than 125° C. (257° F.), and the end point shall not exceed this temperature by more than 15° C. (27° F.).

At least 96 per cent. must be recovered in the receiver from the distillation.

The distillation loss shall not exceed 2 per cent. when the residue in the flask is cooled and added to the distillate in the receiver.

The United States War Department requires the fighting grade to be colored red after inspection and acceptance.

Domestic Grade.

When 5 per cent. of the sample has been recovered in the graduated receiver the thermometer shall not read more than 75° C. (167° F.), or less than 50° C. (122° F.).

When 50 per cent. has been recovered in the receiver the thermometer shall not read more than 105° C. (221° F.)

When 90 per cent. has been recovered in the receiver the thermometer shall not read more than 155° C. (311° F.)

When 96 per cent. has been recovered in the receiver the thermometer shall not read more than 175° C. (347° F.)

At least 96 per cent. must be recovered in the receiver from the distillation.

The distillation loss shall not exceed 2 per cent. when the residue in the flask is cooled and added to the distillate in the receiver.

Explanation of Tests.

It will be noted that there are no gravity limitations in the specifications for aviation gasoline, nor in the specifications for motor gasoline which are given later, for it has been found that gravity is of little or no value in determining the quality of gasoline, and the other tests provided insure the highest possible grade of material.

In the previous specifications the acid test was conducted by means of litmus paper, but it was found from various experiments that where gasoline was not steam distilled after treatment the litmus-paper test was not always sufficient to disclose the presence of acid, and the methyl-orange test was substituted as a positive and sure test for disclosing the presence of acid.

With reference to the corrosion and gumming test, it was pointed out that the previous specifications limited the color of the residue to black. However, from various tests made and as shown by the copper dishes in evidence, much of the residue was gray in color, so that the specifications were made to read that no gray or black deposit shall be formed. This wording is intended to admit gasolines that have so small a quantity of sulphur that the deposit is only peacock colored.

It will also be noted in the case of the export and fighting grades of aviation gasoline that an end point has been provided that shall not exceed the temperature of the 96 per cent. recovery point by more than 15° C. (27° F.).

In explanation of this it may be stated that the members of the Specifications Commission of the Inter-Allied Petroleum Conference, who were meeting in Washington at the time the American committees were considering the subject, gave special consideration to this feature, attaching great importance, in the case of the two grades of gasoline mentioned, to the character of the final 4 per cent.

While ordinarily the distillation range provided in both cases should in itself insure gasoline of a satisfactory nature for the purposes required, the importance of attaining that object without question led the committee to incorporate the end (or dry) point with its limiting temperature above the 96 per cent. recovery point.

STANDARDIZATION OF GASOLINE SPECIFICATIONS (1919).

"Early in 1919 the oil trade represented to the Committee on Standardization of Petroleum Specifications that the specifications of October, 1918, had become unnecessarily stringent and under existing conditions would, if universally adopted, unnecessarily restrict the total production of motor gasoline in this country.

"The specifications adopted by the Committee on Standardization of Petroleum Specifications, October, 1918, under the U. S. Fuel Administration, promulgated in Bulletin No. 1, were drafted to cover Federal purchases of motor gasoline for domestic and military uses, and represented a grade equivalent to the larger proportion of motor gasolines being marketed in this country in the calendar years 1917 and 1918. Although these specifications had been drafted solely for Government use they were, nevertheless, voluntarily adopted by several States and municipalities, as standards for the sale of motor gasoline. In recognition of the fact that whatever the intent or opinions of this Committee the specifications were likely to be prescribed as standards in laws enacted by various legislative bodies to govern the sale of gasoline to the public, the Committee deemed it advisable to propose only such specifications as would be reasonably satisfactory in use, and if adopted universally, would not too greatly restrict the total available supply and thus be detrimental to the public good.

"The Committee was faced with the problem of determining what was a practical specification for motor gasoline, having regard to the total available supply and to satisfactory use in the motor. Obviously, both these factors are changing and it was fully recognized that the system of devising specifications must be flexible and permit revision from time to time as changing conditions of supply and use warranted. The difficulties of determining what was a satisfactory gasoline were also recognized. There could be no absolute standard because of varying conditions of use, such as engine construction and conditions, lubrication, climatic conditions, the personality of the driver, and many other elements, but the specifications could cover what experience had proved to be generally satisfactory under conditions as they exist to-day.

"To obtain information on the subject, the Bureau of Mines made a survey of the gasoline marketed throughout the entire country, and collected through its agents a total of 836 samples, covering practically all the types of gasoline produced and sold. Samples were obtained in every State, and included the products of all refineries of sufficient size to be of importance in the aggregate supply. The data collected in this survey are believed to be the most comprehensive now available with regard to the grades and quality of motor fuel now on the market."

SPECIFICATIONS FOR MOTOR GASOLINE.

As adopted by the Committee on Standardization of Petroleum Specifications. Bull. No. 3, Bureau of Mines, Nov. 25, 1919.

Quality.—Gasoline to be high grade, refined, and free from water and all impurities, and shall have a vapor tension not greater than 10 pounds per square inch at 100° F. temperature, same to be determined in accordance with the current "Rules and regulations for the transportation of explosives and other dangerous articles by freight" as issued by the Interstate Commerce Commission.*

Inspection.—Before acceptance the gasoline will be inspected. Samples of each lot will be taken at random. These samples immediately after drawing will be retained in a clean, absolutely tight closed vessel and a sample for test taken from the mixture in this vessel directly into the test vessel.

Specifications.—(*a*) Boiling point must not be higher than 60° C. (140° F.)

(*b*) 20% of the sample must distill below 105° C. (221° F.)

(*c*) 50% must distill below 140° C. (284° F.)

(*d*) 90% must distill below 190° C. (374° F.)

(*e*) The end or dry point of distillation must not be higher than 225° C. (437° F.)

* Said regulations have been amended as follows by the Interstate Commerce Commission.

It is ordered, That the second and sixth sections of paragraph 1824 (K) of the said regulations be amended, effective December 15, 1919, to read as follows:—

. Then the liquid condensate alone or blended with other petroleum products has a vapor pressure not exceeding 10 pounds per square inch, it must be described and shipped as gasoline, or casinghead gasoline.

When the liquid condensate, alone or blended withe other petroleum products has a vapor pressure not exceedin6 10 pounds per square inch it must be described as gasoline or casinghead gasoline and must be shipped in metal drums or barrels complying with specification No. 5; or in ordinary tank cars, 60 pounds test class equipped with mechanical arrangement for closing of dome covers as specified in Master Car Builders' specifications of tank cars.

It is further ordered, That the note to paragraph 1825 (A) of the said regulations be amended, effective December 15, 1919, to read as follows;—

An outage of 2 per cent. is frequently insufficient for light petroleum products, owing to the fact that they expand more than heavier petroleum products when the temperature increases, and this rate of expansion varies with the specific gravity of the material. It is recommended that when tank cars are loaded with gasoline, or casinghead gasoline (see paragraph 1824k), the outage in tank shall not be less than the following:

	Minimum outage required when gravity is:—		
Temperature product when loaded	50-60° B. Per cent.	60-70° B. Per cent.	70-80° B. Per cent.
0- 60° F.	3.2	3.5	4.1
61- 70° F.	2.5	2.8	3.3
71- 80° F.	2.0	2.1	2.4
81-100° F.	2.0	2.0	2.0

(*f*) Not less than 95% of the liquid will be recovered in the receiver from the distillation.

"*Test.*—One hundred cubic centimeters will be taken as a test sample. The apparatus and method of conducting the distillation test shall be that adopted by Sub-Committee XI of Committee D-1 of the American Society for Testing Materials,* with the following modifications:

"First: the temperature shall be read against fixed percentage points, and; Second: the thermometer shall be as hereinafter described:

"*Flask.*—The flask used shall be the standard 100 cc. Engler Flask, described in the various test books on petroleum. Dimensions are as follows:

Dimensions	CM	Inches
Outside diameter of bulb................	6.5	2.56
Outside diameter of neck................	1.6	0.63
Length of neck	15.0	5.91
Length of vapor tube...................	10.0	3.94
Outside diameter of vapor tube...........	0.6	0.24

"Position of vapor tube, 9 cm. (3.55 inches) above the surface of the gasoline when the flask contains its charge of 100 cc. The tube is approximately in the middle of the neck. The observance of the prescribed dimensions is considered essential to the attainment of uniformity of results.

"The flask shall be supported on a ring of asbestos having a circular opening 1¼ inches in diameter; this means that only this limited portion of the flask is to be heated. The use of wire gauze is forbidden.

"*Condenser.*—The condenser shall consist of a thin walled tube of metal (brass or copper) ½" internal diameter and 22 inches long. It shall be set at an angle of 75° C. from the perpendicular and shall be surrounded with a cooling jacket of the trough type. The lower end of the condenser shall be cut off at an acute angle and shall be curved down for a length of 3 inches. The condenser jacket shall be 15 inches long.

"*Thermometer.*—The thermometer shall be made of selected enamel-backed tubing having a diameter between 5.5 and 7 mm.

* American Society for Testing Materials, Year Book for 1915, pp. 568-569; or pt. 1, Committee Reports, 1916, vol. 16, pp. 518-521. See also Bureau of Mines Technical Papers Nos. 166 and 214.

The bulb shall be of Jena normal or Corning normal glass, its diameter shall be less than that of the stem and its length between 10 and 15 mm. The total length of the thermometer shall be approximately 380 mm. The range shall cover 0° C. (32° F.) to 270° C., (518° F.) with the length of the graduated portion between the limits of 210 to 250 mm. The point marking a temperature of 35° C. (95° F.) shall not be less than 100 mm. nor more than 120 mm. from the top of the bulb. For commercial use the thermometer may be graduated in the Fahrenheit scale.

"The scale shall be graduated for total immersion. The accuracy must be within about 0.5° C. The space above the meniscus must be filled with an inert gas, such as nitrogen, and the stem and bulb must be thoroughly aged and annealed before being graduated.

"*Source of Heat in Gasoline Distillation.*—The source of heat in distilling gasoline may be a gas burner, an alcohol lamp, or an electric heater.

"*Procedure and Details of Manipulation in Conducting Distillations.*—1. If an electric heater is used it is started first to warm it.

"2. The condenser box is filled with water containing a liberal portion of cracked ice.

"3. The charge of gasoline is measured into the clean, dry Engler flask from a 100 cc. graduate. The graduate is used as a receiver for distillates without any drying. This procedure eliminates errors due to incorrect scaling of graduates and also avoids the creation of an apparent distillation loss due to the impossibility of draining the gasoline entirely from the graduate.

"4. The above mentioned graduate is placed under the lower end of the condenser tube so that the latter extends downward below the top of the graduate at least 1 inch. The condenser tube should be so shaped and bent that the tip can touch the wall of the graduate on the side adjacent to the condenser box. This detail permits distillates to run down the side of the graduate and avoids disturbance of the meniscus caused by the falling of drops. The graduate is moved occasionally to permit the operator to ascertain that the speed of distillation is right, as indicated by the rate at which drops fall. The proper rate is from 4 cc. to 5 cc. per minute, which is approximately two drops a second. The top of the graduate is covered, preferably by several thicknesses of filter paper, the condenser tube passing through a snugly fitting opening. This minimizes evaporation losses due to circulation of air through the graduate and also excludes any water that may drip down the outside of the condenser tube on account of condensation on the ice-cooled condenser box.

"5. A boiling stone (a bit of unglazed porcelain or other porous material) is dropped into the gasoline in the Engler flask. The thermometer is equipped with a well fitted cork and its bulb covered with a thin film of absorbent cotton (preferably the long-fibered variety sold for surgical dressing). The quantity of cotton used shall be not less than 0.005 nor more than 0.010 g. (5 to 10 milligrams). The thermometer is fitted into the flask with the bulb just below the lower level of the side neck opening. The flask is connected with the condenser tube.

"6. Heat must be so applied that the first drop of the gasoline falls from the end of the condenser tube in not less than five or more than ten minutes. The initial boiling point is the temperature shown by the thermometer when the first drop falls from the end of the condenser tube into the graduate. The operator should not allow himself to be deceived as sometimes (if the condenser tube is not dried from a previous run) a drop will be obtained and it will be sometime before a second one falls; in this case the first drop should be ignored. The amount of heat is then increased so that the distillation proceeds at a rate of from 4 cc. to 5 cc. per minute. The thermometer is read as each of the selected percentage marks is reached. The maximum boiling point or dry point is determined by continuing the heating after the flask bottom has boiled dry until the column of mercury reaches a maximum and then starts to recede consistently.

"7. Distillation loss is determined as follows: The condenser tube is allowed to drain for at least five minutes after heat is shut off, and a final reading taken of the quantity of distillate collected in the receiving graduate. The distillation flask is removed from the condenser and thoroughly cooled as soon as it can be handled. The condensed residue is poured into a small graduate or graduated test tube and its volume measured. The sum of its volume and the volume collected in the receiving graduate, subtracted from 100 cc. gives the figure for distillation loss."

CHAPTER XXXV.

GASOLINES.

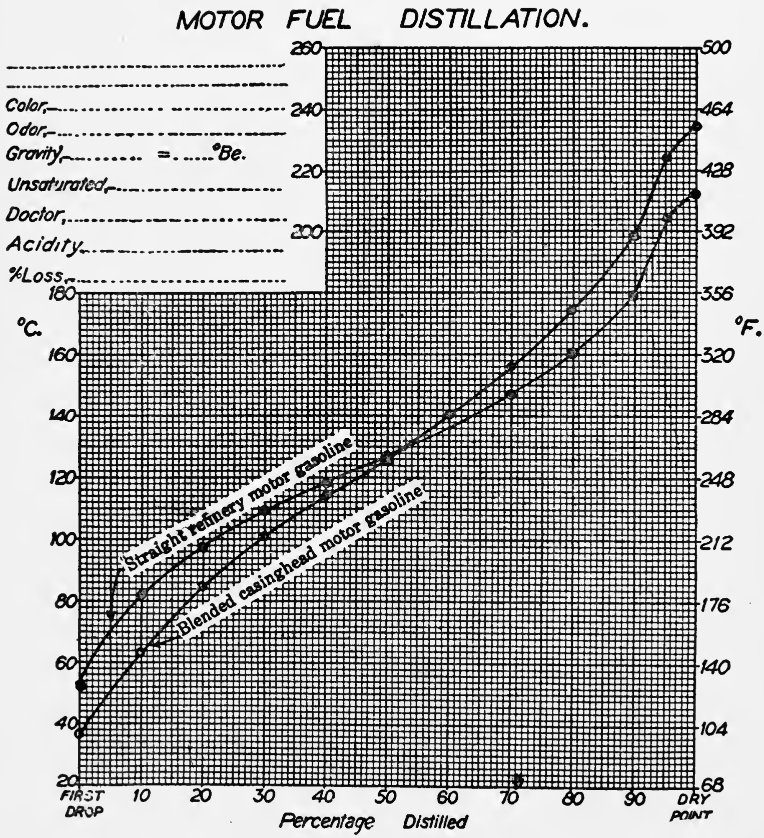
The producers' idea of gasoline is "anything that can be burned in a gasoline engine." The increased use of automobiles, and of internal combustion engines generally, has resulted in such a demand for light petroleum distillates that production has been severely taxed. Domestic consumption and exports have increased without any corresponding increase in oil production. The distillates lighter than kerosene have ceased to be a cheap by-product for which an outlet is sought and has become one of the chief products of petroleum refining. Instead of running as much of the light distillate as possible into the burning oil (kerosene) as formerly practiced, the producers now incorporate as much of the light kerosene distillate in their gasoline as the present stage of automobile engine design will permit.

When the gasoline engine first became a commercial success, gasoline was usually rated at 70° Bé. or higher. As the demand for light distillates increased, the gravity was necessarily lowered, first to 65° Bé., then to 60° Bé., and finally (?) to 55° Bé. This change has been rendered necessary as the amount of the old type of gasoline could not supply the trade demand. Fortunately, the automobile engine has developed so that it can use these heavier distillates successfully, but the end is not yet, either in lowering of the gravity for motor fuels or in improved automobile engine design. The real solution of the problem is as much in the hands of the motor designer as in the hands of the gasoline producer.

The total production of gasoline in 1918 was over 85,000,000 barrels, while the estimated production for 1919 was 92,700,000 barrels.

In order to increase the output of motor fuels to meet the demand, several new types of gasoline have been developed.

Straight refinery gasoline, the old type of gasoline, is made by distilling off the light oils already existing in certain crude petroleums, notably Pennsylvania crudes, the product being distilled several times to remove the heavy oils or "tailings." The output of this grade has been greatly increased by including more of the light kerosene distillate as explained above. Straight refinery gasolines are usually low in "unsaturated" hydrocarbons (olefins and poly-olefins) and aromatic hydrocarbons.



Graphic chart for recording results of gasoline analysis.
Tech. Paper 214, p. 29, Bur. of Mines.

"Cracked" gasoline, or synthetic gasoline, is made by a number of recently patented process (such as the Burton and the Rittman processes). The heavy petroleum oils are exposed to very high temperatures, either in the liquid or the gaseous condition and under more or less pressure, so that the heavy oils decompose into oils of lower boiling points. The light oils formed by this decomposition or "cracking" are distilled off for motor fuels, the product being similar to straight refinery gasoline so far as boiling point, or power production is concerned. The cracked gasolines are more likely to have undesirable odors than other gasolines. Over 20,000,000 barrels of gasoline have been made in five years by the Burton "cracking" process, where the cracking is done in the liquid phase in pressure stills. Future gasoline supplies must necessarily be largely "cracked" gasolines. In 1917, over 12 per cent. of the total gasoline in the United States, or 7,000,000 barrels out of a total of 65,000,000 barrels was cracked gasoline. In 1919, over 26 per cent. of the crude petroleum refined was converted into gasoline.

Casing-head gasoline is made by compression of natural gas with accompanying refrigeration or absorption in petroleum distillates. The straight casing-head gasoline is never used alone, on account of its high volatility and high cost, but is used to blend with distillates too heavy to use alone for motor fuels. About 10 per cent. of the present production of gasoline is blended casing-head gasoline. By blending a "blended casing-head gasoline" with other gasolines a suitable range of boiling points is secured. In 1918 282,535,550 gallons of unbleached natural gasoline was produced in the United States, of which 58 per cent. was produced in Oklahoma. Probably 30 per cent. of the total gasoline sold is blended with casinghead gasoline.

The difference in power possible from different gasolines is negligible provided the gasoline is burned completely in the motor, and the gasolines with a high percentage of volatile constituents and no "tailings" or heavy oil are easiest to burn completely. The low boiling-point constituents of the gasoline aid particularly in starting, but the evaporation loss is greater and the price of the gasoline is higher where excessive amounts of these light oils are present. The best gasolines have a large percentage of medium boiling constituents.

The following analyses of gasolines were made by the author in 1911. Ninety-seven per cent. was recovered in the distillation which was made from an Engler flask at the rate of 10 cc. per minute.

Sample No.	1	2	3	4	5	6	7	8	9	10
Gravity (°B.)	60.5	60.0	65.5	62.0	62.8	60.4	61.5	62.8	59.1	64.3
Boiling pt. (°C.)	85	80	90	91	86	80	60	68	78	82
Distillate to 100°C.	16	26	69	36	36	26	56	38	20	42
" " 120°C.	71	64	92	67	77	71	87	73	65	76
" " 140°C.	89	87	97	85	92	91	94	91	88	92

In connection with the tables on pages 307-308 (Bureau of Mines Tech. Paper No. 163) it may be noted that the uncracked gasolines gave iodine numbers from 0.6 to 6.5 and straight cracked gasolines gave iodine numbers of 20 to 60. Blended gasolines containing cracked gasolines gave iodine numbers above 8 or 10. The iodine number is a measure of the unsaturated hydrocarbons present, but the amount of unsaturated hydrocarbons can also be determined roughly by shaking 20 cc. of gasoline with 20 cc. of sulphuric acid (1.84 specific gravity, or 94 per cent.) and noting the amount of gasoline absorbed. Gasolines consisting largely of cracked distillates gave absorptions of 3 per cent. to 6 per cent.

Volatility is the most important property of a gasoline since vaporization in the motor is necessary. The test which gives the most information is distillation from an Engler flask of 100 cc. capacity, distillation being conducted at the rate of two drops per second (4 to 5 cc. per minute) using an ice-cooled condenser, and noting the temperatures at which each 10 per cent. is distilled, particularly the temperatures at which 20 per cent. and 90 per cent. are distilled, and the temperature at which the distillation is complete. The rate of heating is important to get the best results. The value of the distillation test lies in the fact that it gives a direct measure of the vaporizing power of the gasoline.

Recently W. H. Herschel (Bur. of Stand. Tech. Paper No. 125, May, 1919, "Viscosity of Gasoline") has suggested a probable relation between the viscosity or fluidity of gasoline, as shown by the Ubbelohde viscosimeter for illuminating oils, and the volatility or distillation range. He states that it seems probable that fluidity is more closely connected with the volatility than is the density. A viscosity determination therefore ought to give a quick method of determining the approximate volatility of a gasoline. It might be interesting in this connection to state that the author has used a similar routine method for viscosity in connection with the determination of heavy residues in kerosene (see Chapter on Kerosene).

SOME ANALYSES OF GASOLINES.

Sold During 1915

(Tables from Bureau of Mines Tech. Paper No. 163, pp. 17-18.)

Results of tests showing volatility ranges of typical "straight" refinery gasolines from Eastern, Mid-continent, and California fields.

EASTERN GASOLINE.

Sample No.	Commercial rating of gasoline (°B.)	Actual gravity as determined by test		Percentage distilled at temperatures of—					
		Specific gravity	°B.	Up to 50° C.	50° to 75° C.	75° to 100°C.	100° to 125° C.	125° to 150° C.	150° to 175° C.
12	(*a*)	0.736	60.2	1.2	4.4	20.0	59.0	87.3	99.3
13	68° to 70°.....	0.718	65.0	3.5	15 0	39.2	72.9	91.5	99.5
14	76°	0.699	70.3	7.2	33.0	69.7	91.2	—	—

MID-CONTINENT GASOLINE.

Sample No.	Commercial rating of gasoline (°B.)	Specific gravity	°B.	Up to 50° C.	50° to 75° C.	75° to 100°C.	100° to 125° C.	125° to 150° C.	150° to 175° C.
37	58° to 60°.....	0.745	57.9	1.7	7.4	21.2	50.9	79.4	93.6
38	60° to 62°.....	0.727	62.6	3.3	14.6	41.4	68.2	87.3	96.4
39	68° to 70°.....	0.703	69 2	8.6	34.4	70.4	91.2	—	—

CALIFORNIA GASOLINE.

Sample No.	Commercial rating of gasoline (°B.)	Specific gravity	°B.	Up to 50° C.	50° to 75° C.	75° to 100°C.	100° to 125° C.	125° to 150° C.	150° to 175° C.
49	....	0.749	56.9	3.0	12.6	51.1	81.9	94.3	—
50	....	0.733	61.0	3.8	16.1	45.5	71.8	94.1	—

(*a*) Rated as "motor" gasoline.

Results showing specific gravity and volatility ranges of blended casing-head and "straight" refinery gasolines from the eastern markets.

BLENDED CASING-HEAD GASOLINE.

Sample No.	Commercial rating (°B.)	Actual gravity as determined by test		Percentage distilled at temperatures of—					
		Specific gravity	°B.	Up to 50°C.	50° to 75° C.	75° to 100° C.	100° to 125° C.	125° to 150° C.	150° to 175° C.
15	60° to 65°.....	0.733	61.0	7.9	16.8	33.2	56.6	78.5	93.5
16	68° to 70°.....	0.706	68.3	16.7	32.1	53.0	75.1	88.2	—
17	76°	0.687	73.8	30.8	49.1	64.4	78.1	88.8	—

"STRAIGHT" REFINERY GASOLINE.

1	60° to 65°.....	0.724	63.4	0.0	2.2	33.8	75.5	94.4	—
2	68° to 70°.....	0.703	69.2	3.5	27.6	67.5	90.6	99.1	—
3	74° to 76°.....	0.684	74.7	14.5	46.2	78.3	95.1	—	—

Results showing calorific value, power developed in engine tests, specific gravity, and percentage of sulphur in various typical gasolines from Mid-continent and Eastern fields.

Sample No.	Field from which sample was obtained	Process of manufacture	Gravity		Calorific value of gasoline		Power developed, horse-power-hours per lb. of gasoline	Sulphur content
			Specific gravity	°B.	Calories per gram	B. t. u. per pound		Per cent.
22	Mid-continent .	Cracking plant	0.745	57.9	11,165	20,097	1.345	0.02
26	do	" Straight " refinery	0.742	58.7	11,174	20,113	1.403	0.01
43	do	do	0.733	61.0	11,180	20,124	1.350	0 05
13	Eastern	do	0.718	65.0	11,187	20,137	1.405	0.04
19	Mid-continent .	do	0.724	63.4	11,215	20,187	1.395	0.05
38	do	do	0.727	62.6	11,221	20,198	1.396	0.03
15	Eastern	Blended casing-head	0.733	61.0	11,230	20,214	1.376	0.03
1	do	" Straight " refinery	0.724	63.4	11,236	20,225	1.420	0.03
34	Mid-continent .	do	0.715	65.8	11,250	20,250	1.365	0.02
9	Eastern	do	0.687	73.8	11,315	20,367	1.487	0.02

The gravity test is the most widely used commercial test. It gives indications of value and is easily made.

Analyses of Gasolines 1919 and 1920.

The following table is compiled from Bureau of Mines Bulletin No. 191, Table 15, showing analyses of over 800 samples of gasoline sold throughout the United States in Aprl, 1919; Results for 81 samples of gasoline, sold in seven representative districts of the United States, in January, 1920, as reported by the Bureau of Mines:

District	Date	First drop	20%	50%	90%	Dry point	Avg. B. P.
New York	April, 1919	129	210	259	359	411	266
New York	Jan., 1920	121	204	256	354	418	261
	Difference	—8	—6	—3	—5	+9	+5
Washington	April, 1919	112	190	270	381	426	265
Washington	Jan., 1920	125	200	255	381	439	267
	Difference	+13	+10	—15	....	+13	+2
Pittsburgh	April, 1919	102	189	265	387	425	266
Pittsburgh	Jan., 1920	100	182	256	375	425	257
	Difference	—2	—7	—9	—12	....	—9
Chicago	April, 1919	123	192	253	369	423	261
Chicago	Jan., 1920	116	199	262	381	445	270
	Difference	—7	+7	+9	+12	+23	+9
New Orleans	April, 1919	131	210	269	373	435	274
New Orleans	Jan., 1920	128	206	258	354	424	254
	Difference	—3	—4	—8	—19	—9	—20
Salt Lake City	April, 1919	117	206	279	406	441	289
Salt Lake City	Jan., 1920	113	204	266	386	440	270
	Difference	—4	—2	—13	—20	—1	—14
San Francisco	April, 1919	134	202	240	328	374	247
San Francisco	Jan., 1920	130	212	258	347	406	262
	Difference	-4	+10	+18	+19	+32	+15
All districts	April, 1919	120	199	260	371	417	265
All districts	Jan., 1920	119	200	259	369	427	264
	Difference	—1	+1	—1	—2	+10	—1
Federal specifications	Nov. 25, 1919(°F.)	140	221	284	374	437	....

Proposed Specifications for Motor Gasoline.—(Bureau of Mines Tech. Paper, No. 214, p. 17.)

Color. Requirement.—Water white.
Method of Determination.—Inspection of column in 4-ounce sample bottle or 100 cc. graduate.

Acidity. Requirement.—Total absence of free or combined acid. Method of Determination.—The residue in the flask after completion of an analytical distillation shall be shaken thoroughly with 1 cc. of distilled water. The water extract shall be neutral in reaction. This may be determined by the use of any satisfactory indicator. Freedom from acidity is indicated by failure to color blue litmus paper pink, by failure to develop a reddish color when a few drops of methyl orange solution is added, or by the development of a red color on addition of a few drops of phenolphthalein solution and one drop of hundredth normal sodium hydroxide solution.

Volatility. Requirements.—The gasoline shall, when distilled by the method described hereafter, meet the following requirements:

(*a*) The temperature read on the thermometer when 20 per cent. has distilled shall not be below 70° C. (158° F.) nor above whatever limit is fixed after due consideration of conditions of use.

(*b*) The temperature read when 90 per cent. has distilled shall not be above another limit similarly chosen.

(*c*) The temperature read when 50 per cent. has distilled shall not be higher than a mark half way between the 20 per cent. and the 90 per cent. limit.

(*d*) The dry point shall not exceed the actual 90 per cent. reading by more than 40° C. (72° F.).

(The distillation method and apparatus are minutely described. The Engler flask is used with 100 cc. of gasoline and the heat applied so that 4 to 5 cc. distil per minute.)

Gasoline for Special Uses.—Gasoline, for use as a solvent where the gasoline is recovered, should be free from heavy boiling constituents, that is, have a low end point on distillation. Also gasoline for cleaning purposes should be volatile and free from "tailings" as shown by distillation.

For actual specifications of commercial gasoline, see Index.

Gasoline Substitutes.—The most promising are benzol and similar light coal tar oils and alcohol, in various blends with gasoline. The supply of benzol is greatly limited, while the quantity of alcohol can be indefinitely increased to meet demand.

Fuel Oils.—For specifications, see Index. For the calorific power of liquid fuels of different specific gravities see Sherman and Kropff, *J. Am. Chem. Soc.*, pp. 1626-1631 (1908). In connection with the use of powdered coal in fuel oil, see "Colloidal Fuel and Its Uses," by L. W. Bates, *Chem. Eng.*, Vol. 28, No. 3, p. 73, 1920; and *J. Ind. & Eng. Chem.*, p. 434, 1920.

ADDITIONAL REFERENCES.

"Determination of Unsaturated Hydrocarbons in Gasoline," by Dean and Hill, *Tech. Paper No. 181*, Bur. of Mines, 25 pp.

"The Pyrogenesis of Hydrocarbons," by Lomax, Dunstan and Thole, *J. Ind. & Eng. Chem.*, pp. 879-902, 1917; also *J. Inst. Pet. Tech.*, Vol. 3, No. 9, pp. 36-120, Dec., 1916; with complete bibliography and list of patents.

"Motor Gasoline, Properties, Laboratory Methods of Testing and Practical Specifications," by E. W. Dean *Tech. Paper No. 214*, Bureau of Mines, 1919. Also a similar earlier paper, No. 166.

"Motor Fuels," by E. W. Dean, *J. Frank. Inst.*, 189, pp. 269-302, 1920.

Distillation Apparatus and Procedure: Sub-Comm. XI of Comm. D-1 of Am. Soc. for Test. Mat., Year Book for 1915, pp. 568-569; or Pt. 1, Comm. Reports, 1916, Vol. 16, pp. 518-521.

Standard Method for Vapor Pressure of Gasoline: Report of Chief Inspector of Bur. of Explosives, Feb., 1916, pp. 27-30; also *Tech. Paper 214*, Bur. of Mines, pp. 26-27.

"Fuel for Automotive Apparatus," by E. W. Dean, *J. Soc. Automotive Eng.*, Vol. 2, Jan., 1918 pp. 47-53.

"Gasoline and How to Use It" (book), 281 pp., by G. A. Burrell.

"Liquid Fuels for Internal Combustion Engines," (book), 200 pp., by H. Moore.

CHAPTER XXXVI.

KEROSENE.

The importance of kerosene as a commercial product is indicated by the fact that 95 per cent. of domestic illumination is with kerosene.

Kerosene usually distils between 150° and 300° C. (302° to 572° F.) under atmospheric pressure, and has a gravity of 42° to 47° Bé. For general illuminating purposes, kerosene should be free from very light oils as shown by the flash test, free from heavy oils as shown by the distillation test, and free from sulphur and other encrusting substances as shown by a prolonged burning test.

The flash test is usually taken with the Tagliabue open cup, the best grade of oil being called "150° fire test" "water white" oil. The oil is sold largely by fire test, Baumé gravity and color.

Many States have inspection laws, usually for safety only, and specify the flash test in the open or closed cup. The flash test at 100° F. in the Elliott closed cup (so-called New York State Board of Health tester) is specified in a number of states, with or without a gravity requirement. The flash point in the Elliott closed cup is, for kerosene, some 21° F. lower than the Tagliabue flash test (open cup), and 41° F. lower than the Tagliabue fire test.

The author takes this opportunity to put in more accessible form some results of analyses made by him (Supp. Bull. of the N. C. Dept. of Agri., Sept., 1910; Sept., 1911; and June, 1912). The following is from the *Bulletin* for 1910:

"A comparison of 58 oils was made after classifying on the basis of 6 per cent. residue after distillation by the continuous Engler method:

Residue at 570°F.	Less than 6%	More than 6%
Number of oils tested	20	38
Candle-power (after ½ hour)	7.91	7.62
Candle-power (after 7½ hours)	7.10	6.23
Drop in candle-power (%)	10.2	18.6
Viscosity at 68°F. (Engler)	1.11	1.17

"Of the low-residue oils only one gave as much as 15 per cent. drop in candle-power. Of the 38 high-residue oils 58 per cent. gave more than 15 per cent. drop in the 7 hours.

"The photometric method was similar to that recommended by the International Committee. Glass lamps were used. The reservoirs were cylindrical with flat bottoms and held about 325 cc. The initial oil level was 6 cm. below the top of the wick tube and the drop in oil level was usually 40 mm. (1.6 in.) during the total burning period of 7½ hours. A No. 1 "Model" burner and Macbeth chimney No. 502 were used. New American wicks, recently dried for 1 hour at 110° C. were used each time. The lamps were allowed to stand over night after filling and trimming.

"The illuminating power was determined after burning ½ hour and again 7 hours later. During the first ¼ hour after lighting the flames were turned up to the highest safe limit and were not again disturbed. The oil was kept at a constant temperature of 80° to 85° F. by immersing in running water. Usually about 40 cc. of oil remained in the lamp at the last measurement. The measurements were made with a Reichsanstalt photometer using a standardized Hefner lamp. The Hefner unit was taken as equal to 0.90 candle-power and never varied more than 0.5 per cent. on account of humidity. Each reading was made five times. Many of the photometric tests were made in duplicate.

"The oils analyzed were chosen on account of some special feature, such as marked color, high or low viscosity, high specific gravity, etc., or, as in a number of cases, simply to get a sample of as many brands as possible.

"Only 17 per cent. of the 134 samples passing the flash test gave any distillate below 150° C. Seven oils gave less than 15 per cent. distillate below 200° C. Six others gave from 15 to 19 per cent. distillate below 200° C. Eight oils gave more than 40 per cent. distillate below 200° C." (The flash test requirement was 100° F. flash, or over, in the Elliott closed cup.)

As a result of the above tests, a residue requirement was adopted by the State of "not more than 6 per cent. by weight of residue remaining undistilled at 570° F. * * * except that oils of not less than 47° Bé. at 60° F. shall not contain more than 10 per cent. of residue by weight."

It is interesting to note that subsequent tests (reported Sept., 1911) of 41 different samples, representing over 30 different brands of kerosene, only four showed as much as 15 per cent. drop in candle-power in 12 hours' burning, the maximum drop being 24.8 per cent. in 12 hours, against 65.1 per cent. maximum drop for the 7 hours in the first series. Also two of these four bad oils had 6 per cent. and 8.9 per cent. residue undistilled at 570° F. The method of making the burning test in this case was as follows: "The candle-power was measured at the end of the first and twelfth hours after lighting, using as a comparison light a standard electric bulb at 4 watts per candle-power. The lamp had a glass reservoir of 600 cc. capacity and was fitted with a No. 1 sun-hinge burner and a No. 27 Macbeth chimney. No. 1 American wicks recently dried were allowed to soak in the oil over night. The oil level dropped 30 millimeters during the burning period. Over 150 cc. of oil remained at the end of each test. Duplicate tests were made on most of the samples. The Marcy patent burner was found unsuited for this work unless a much longer burning period were adopted."

"With the exception of one sample, the distillation began at 150° to 160° C. and the distillate below 200° C. varied from 26 per cent. to 45 per cent." After the adoption of the 6 per cent. residue test, the minimum amount of oil distilling below 250° C. increased from 39 per cent. to 68 per cent., the maximum being 85 per cent.

Five of the 41 oils gave more than 0.050 per cent. of sulphur. The amount of sulphur varied from 0.001 per cent. to 0.086 per cent., the sulphur being determined gravimetrically after burning the oil and wick completely.

Cracked oils may be shown by the iodine number. The Hanus iodine number for a 1-gram sample was from 7.2 to 25.2.

The viscosity can be used as a quick means for locating oils which would have high residues at 570° F. The Ubbelohde viscosimeter for illuminating oils was found more suitable for this work than the regular Engler apparatus. Before adoption of the 6 per cent. residue requirement, viscosities ran as high as 1.26 Engler; afterwards the range was from 1.07 to 1.13, the average being slightly below 1.09. (1.07 to 1.13 Engler is equivalent to 1.39 to 1.63 Ubbelohde viscosity.) Low viscosity oils never show high residues on distillation.

Suggestions for Specifications.—(*a*) *Safety.*—Take the flash point with the Elliott closed cup or with the Abel-Pensky apparatus. Sufficient safety will be attained by 95° to 100° F. flash in these cups, or 140° to 150° F. fire test in the open cup. There is no advantage in specifying both flash test and fire test, nor should a minimum boiling point, or a maximum distillate to a given temperature, ordinarily be specified.

(*b*) *Degree of Refining.*—The oil should be well-refined and water white. A well-refined oil will not usually have as much as 0.04 per cent. sulphur and will not show a marked color when shaken for two minutes with sulphuric acid of 1.73 specific gravity. As the burning test for a long period will show the practical degree of refining, by the amount of encrustation on the wick, no extended tests for refining are usually necessary.

(*c*) *Inherent Character of the Oil.*—The oil will be distilled from an Engler flask at the rate of two drops per second, attention being paid to the quantity distilling below 200° and 250° C. (The best oils give over 30 per cent. distillate at 200° and over 75 per cent. distillate at 250° C. when distilled at the rate of two drops per second.) The residue must not exceed 5 per cent. by weight at 300° C., except that oils of over 46.5° Bé. may show up to 8 per cent. of such residue. Large amounts of the lighter oils improve the candle-power and the burning qualities. "Cracked" oils are not desired, so the Hanus iodine number should be below 15 on a 1-gram sample. The gravity must not be below 42° Bé.

(*d*) *Burning Quality.*—The oil must not show more than a specified drop in candle-power (12 per cent.), or drop in flame height (¼ inch), under specified conditions of burning for a period of 24 to 72 hours. The condition of the flame as well as its size will be noted at the end of the burning test and no hard ash, crust, gum or cinders shall have formed on the wick. A long burning period with the burner too be used in service gives the most information. Ordinarily a photometric test will not be necessary as a drop of 10 to 15 per cent. in candle-power is readily apparent to the eye. The distillation test and the burning test will be given special weight.

For specifications of kerosene and other burning oils, see Index.

Kerosene for kerosene engines, such as tractor engines, etc., is usually burned by preheating the fuel charge before admission into the cylinder. Sometimes steam is introduced with the charge so as to facilitate combustion and to keep the cylinder clean. By preheating the charge of kerosene, vaporization is more nearly complete, though part of the kerosene remains as a finely atomized liquid and is burned rather than exploded. The explosion range for kerosene vapor mixed with air is much lower than with gasoline vapor and air, consequently the carburetor must be more carefully adjusted in order to give the proper explosive mixture.

Gasoline-Kerosene Mixtures.—In connection with the possible danger of such mixtures, it has been found that while ordinary kerosene will extinguish a burning match, the addition of 1 per cent. of gasoline to kerosene may give a flash; 3 to 5 per cent. may give violent flashing, and 7½ per cent. may inflame at once. Any of these mixtures would be explosive in the presence of flame, if confined. ("Flash and Burning Point of Gasoline-Kerosene Mixtures," by J. T. Robson and J. R. Withrow, Oil Paint & Drug Rep., p. 30, July 28, 1919, and p. 17, Aug. 4, 1919; also to appear in Trans. Am. Inst. Chem. Engrs; do., with Bibliography, J. Met. & Chem. Eng., XXI, pp. 244-252, 1919.)

CHAPTER XXXVII.

TABLES.

1. Viscosity Tables, Showing Relation of Saybolt Time to Engler Number.

2. Viscosity of Castor Oil.

3. Tables for Converting Baumé Gravity to Specific Gravity, Etc.

4. Table Showing Baumé Gravity Corrections for Temperatures Above 60° F.

5. Table of Centigrade and Fahrenheit Degrees.

6. Wholesale Prices of Oils and Heavy Chemicals.

7. Petroleum Statistics.

8. Analyses of American Oils for Internal Combustion Engines.

Conversion Table for Viscosimeters.

Tech. Paper No. 112, Bureau of Standards [Engler No. 2,204 U. and Standard Saybolt Universal].

Time, Engler	Time, Saybolt	Time, ratio	Engler degrees= time, Engler 51.3[1]	Kinematic viscosity	Time, Engler	Time, Saybolt	Time, ratio	Engler degrees= time, Engler 51.3[1]	Kinematic viscosity
Sec.	Sec.				Sec.	Sec.			Poises g/cm³
56	32.4	1.73	1.09	0.0155	130	83.6	1.56	2.54	0.1624
58	33.7	1.72	1.13	.0208	140	90.6	1.55	2.73	.1793
60	35.1	1.71	1.17	.0259	150	97.4	1.54	2.93	.1956
62	36.5	1.70	1.21	.0308	160	104.4	1.53	3.12	.2121
64	37.8	1.69	1.25	.0356	180	117.7	1.53	3.51	.2437
66	39.2	1.68	1.29	.0403	200	131.5	1.52	3.90	.2753
68	40.6	1.68	1.33	.0448	225	148.3	1.52	4.39	.3140
70	42.0	1.67	1.36	.0495	250	165.3	1.51	4.88	.3523
75	45.5	1.65	1.46	.0603	275	182.0	1.51	5.36	.3904
80	49.0	1.63	1.56	.0709	300	199.0	1.51	5.85	.4282
85	52.4	1.62	1.66	.0810	325	215.6	1.51	6.34	.4660
90	55.8	1.61	1.76	.0905	350	232.9	1.50	6.82	.5038
95	59.4	1.60	1.85	.1003	375	249.2	1.50	7.31	.5413
100	62.8	1.59	1.95	.1095	400	266.1	1.50	7.80	.5784
110	69.8	1.58	2.15	.1278	500	333.0	1.50	9.75	.7271
120	76.8	1.56	2.34	.1453	600	400.0	[2]1.50	11.70	.8753

[1] See Tech. Paper 100, p. 23.
[2] This value holds good for all higher viscosities.

Conversion Table for Redwood, Saybolt, and Engler Viscosimeters

Time, Engler	Time, ratio			Time, Redwood	Time, Engler	Time, ratio			Time, Redwood
	Engler-Saybolt	Engler-Redwood	Saybolt-Redwood[1]			Engler-Saybolt	Engler Redwood	Saybolt Redwood[1]	
Sec.				Sec.	Sec				Sec.
56	1.73	2.61	1.51	21.5	140	1.55	1.81	1.17	77 5
58	1.72	1.93	1.12	30.0	150	1.54	1.80	1.17	83.2
60	1.71	1.93	1.13	31.2	160	1.53	1.80	1.17	89.1
62	1.70	1.92	1.13	32.2	180	1.53	1.80	1.17	100.3
64	1.69	1.91	1.13	33.4	200	1.52	1.79	1.18	111.9
66	1.68	1.91	1.13	34.6	225	1.52	1.79	1.18	126.0
68	1.68	1.90	1.14	35.8	250	1.51	1.78	1.18	140.3
70	1.67	1.90	1.14	36.9	275	1.51	1.78	1.18	154.4
75	1.65	1.88	1.14	39.8	300	1 51	1.78	1.18	168.5
80	1.63	1.87	1.15	42.7	325	1.51	1.78	1.18	183.0
85	1.62	1.86	1.15	45.7	350	1.50	1.78	1.18	197.0
90	1.61	1.86	1.15	48.5	375	1.50	1.77	1.18	211.3
95	1.60	1.85	1.16	51.4	400	1.50	1.77	1.18	225.5
100	1.59	1.84	1.16	54.3	500	1.50	1.77	1.18	282.0
110	1.58	1.83	1.16	60.1	600	1.50	1.77	1.18	339.0
120	1.56	1.82	1.16	66.0					
130	1.56	1.81	1.17	71.7					

[1] These values were calculated directly from the times of discharge and differ in some cases by 0.01 from values calculated from the two previous columns.

Viscosity of Castor Oil.

(Tables from Bureau of Standards, *Tech. Paper No. 112,* pp. 24-25.)

Density and Viscosity of Castor Oil According to Kahlbaum and Räber

Temperature in degrees centigrade	Density in grams per cubic centimeter	Viscosity in poises	Kinematic viscosity	Temperature in degrees centigrade	Density in grams per cubic centimeter	Viscosity in poises	Kinematic viscosity
5	0.9707	37.60	38.74	23	0.9583	7.67	8.00
6	0.9700	34.475	35.54	24	0.9576	7.06	7.37
7	0.9693	31.56	32.56	25	0.9569	6.51	6.80
8	0.9686	28.90	29.84	26	0.9562	6.04	6.32
9	0.9679	26.45	27.33	27	0.9555	5.61	5.87
10	0.9672	24.18	25.00	28	0.9548	5.21	5.46
11	0.9665	22.075	22.84	29	0.9541	4.85	5.08
12	0.9659	20.075	20.78	30	0.9534	4.51	4.73
13	0.9652	18.25	18.91	31	0.9527	4.21	4.42
14	0.9645	16.61	17.22	32	0.9520	3.94	4.14
15	0.9638	15.14	15.71	33	0.9513	3.65	3.84
16	0.9631	13.805	14.33	34	0.9506	3.40	3.58
17	0.9624	12.65	13.14	35	0.9499	3.16	3.33
18	0.9617	11.625	12.09	36	0.9492	2.94	3.10
19	0.9610	10.71	11.15	37	0.9485	2.74	2.89
20	0.9603	9.86	10.27	38	0.9478	2.58	2.72
21	0.9596	9.06	9.44	39	0.9471	2.44	2.58
22	0.9589	8.34	8.70	40	0.9464	2.31	2.44

W. A. Kahlbaum and S. Räber, Abd. der Kaiserl. Leop.-Carol. Deutschen Akademie der Naturforscher **84**, p. 201; 1905.

Density and Viscosity of Castor Oil According to Archbutt and Deeley.

Temperature		Viscosity in poises	Density in grams per cubic centimeter	Kinematic viscosity
Degrees Fahrenheit	Degrees centigrade			
100	37.8	2.729	0.9473	2.881
150	65.6	0.605	0.9284	0.6517
212	100.00	0.169	0.9050	0.1867

L. Archbutt and R. M. Deeley, *Lubrication and Lubricants,* pp. 186–188; 1912.

DENSITY AND VISCOSITY OF CASTOR OIL ACCORDING TO DEERING AND REDWOOD

(This table, which is for 23 Indian oils, is chiefly valuable in showing the extent of variation in viscosity with different samples.)

Specific gravity at 60° F. (15.6° C)	Density at 60° F.	Time of discharge, in seconds, Redwood viscosimeter, at 100°F (37.8°C)	Kinematic viscosity at 100° F
0.9637 minimum	0.9628	1190 maximum	3.093
0.9639	0.9630	1160 minimum	3.015
0.9642 maximum	0.9638	1174	3.051

W. H. Deering and Boverton Redwood, *Jour. Soc. for Chem. Industry* 13, p. 959; 1894.

(From "The Manufacture of Castor Oil," by J. H. Schrader, *Chem. Age*, p. 108, Aug. 10, 1919; also *Trans. Am. Inst. Chem. Engrs.*):

	Hydraulic Cage Pressed No. 1 Oil	
		Average
Specific gravity (15.6 C.)	0.961— 0.965	0.9626
Acidity (per cent.)	0.45 — 1.6	1.22
Iodine number	83.0 — 87.5	85.6
Saponification matter	176.3 —188.0	182.5
Unsaponifiable number	0.21 — 0.78	0.33
Flash point	513°—570° F.	535° F.
Viscosity	93—112	97.1

	Expeller Refined No. 1 Oil	Expeller Extracted and Refined No. 3
		Average
Specific gravity (15.6 C.)	0.9643	0.960
Acidity (per cent.)	——	——
Iodine number	87.0	——
Saponification number	180.9	——
Unsaponifiable matter	——	——
Flash point	550° F.	550° F.
Viscosity	100—101	100

TABLE FOR CONVERTING BAUME' GRAVITY TO SPECIFIC GRAVITY, ETC. (Calculated from Bureau of Standards Circular No. 57; based on the formula:

$$\text{Sp. gr at } 60^\circ \text{ F} = \frac{140}{130 + \text{deg. Bé.}}).$$

Degrees Baumé (Modulus 140).	Specific gravity 60°/60° F.	Pounds per gallon	Gallons per pound	Degrees Baumé (Modulus 140).	Specific gravity 60/60° F.	Pounds per gallon	Gallons per pound
10.0	1.0000	8.328	0.1201	50.0	0.7778	6.476	0.1544
11.0	0.9929	8.269	0.1209	51.0	0.7735	6.440	0.1533
12.0	0.9859	8.211	0.1218	52.0	0.7692	6.404	0.1562
13.0	0.9790	8.153	0.1227	53.0	0.7650	6.369	0.1570
14.0	0.9722	8.096	0.1235	54.0	0.7609	6.334	0.1579
15.0	0.9655	8.041	0.1244	55.0	0.7568	6.300	0.1587
16.0	0.9589	7.986	0.1252	56.0	0.7527	6.266	0.1596
17.0	0.9524	7.931	0.1261	57.0	0.7487	6.233	0.1604
18.0	0.9459	7.877	0.1270	58.0	0.7447	6.199	0.1613
19.0	0.9396	7.825	0.1278	59.0	0.7407	6.166	0.1622
20.0	0.9333	7.772	0.1287	60.0	0.7368	6.134	0.1630
21.0	0.9272	7.721	0.1295	61.0	0.7330	6.102	0.1639
22.0	0.9211	7.670	0.1304	62.0	0 7292	6.070	0.1647
23.0	0.9150	7.620	0.1313	63.0	0.7254	6.038	0.1656
24.0	0.9091	7.570	0.1321	64.0	0.7216	6.007	0.1665
25.0	0.9032	7.522	0.1330	65.0	0.7179	5.976	0.1673
26.0	0.8974	7.473	0.1338	66.0	0.7143	5.946	0.1682
27.0	0.8917	7.425	0.1347	67.0	0.7107	5.916	0.1690
28.0	0.8861	7.378	0.1355	68.0	0.7071	5.886	0.1699
29.0	0.8805	7.332	0.1364	69.0	0.7035	5.856	0.1708
30.0	0.8750	7.286	0.1373	70.0	0.7000	5.827	0.1716
31.0	0.8696	7.241	0.1381	71.0	0.6965	5.798	0.1725
32.0	0.8642	7.196	0.1390	72.0	0.6931	5.769	0.1733
33.0	0.8589	7.152	0.1398	73.0	0.6897	5.741	0.1742
34.0	0.8537	7.108	0.1407	74.0	0.6863	5.712	0.1751
35.0	0.8485	7.065	0.1415	75.0	0.6829	5.685	0.1759
36.0	0.8434	7.022	0.1424	76.0	0.6796	5.657	0.1768
37.0	0.8383	6.980	0.1432	77.0	0.6763	5.629	0.1776
38.0	0.8333	6.939	0.1441	78.0	0.6731	5.602	0.1785
39.0	0.8284	6.898	0.1450	79.0	0.6699	5.576	0.1793
40.0	0.8235	6.857	0.1459	80.0	0.6667	5.549	0.1802
41.0	0.8187	6.817	0.1467	81.0	0.6635	5.522	0.1811
42.0	0.8140	6.777	0.1476	82.0	0.6604	5.497	0.1819
43.0	0.8092	6.738	0.1484	83.0	0.6573	5.471	0.1828
44.0	0.8046	6.699	0.1493	84.0	0.6542	5.445	0.1837
45.0	0.8000	6.661	0.1501	85.0	0.6512	5.420	0.1845
46.0	0.7955	6.623	0.1510	86.0	0.6482	5.395	0.1854
47.0	0.7910	6.586	0.1518	87.0	0.6452	5.370	0.1862
48.0	0.7865	6.548	0.1527	88.0	0.6422	5.345	0.1871
49.0	0.7821	6.511	0.1536	89.0	0.6393	5.320	0. 880

NOTE:—Another hydrometer widely used in the oil trade is based on a different formula: $\text{Sp. gr. at } 60^\circ\text{F.} = \frac{141.5}{131.5 + \text{deg. Bé.}}$. Such readings are too high by 0.1° to 0.2° Bé. for lubricating oils, 0.3° to 0.4° Be. for kerosene and 0.5° to 0.7° Bé. for gasolines.

Table Showing Baumé Gravity Corrections for Temperature Above 60° F. (Compiled from Bureau of Standards Circular No. 57.)

This table gives the corrections to be subtracted from the observed degrees Baumé of lubricating oils, etc., to obtain the true degrees Baumé at 60° F. (modulus 140).

Observed temperature	Observed Degrees Baumé — Subtract from observed degrees Baumé to give true degrees Baumé at 60° F.										
	16	18	20	22	24	26	28	30	32	34	36
60	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
62	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1
64	0.2	0.2	0.2	0.2	0.2	0.3	0.3	0.3	0.3	0.3	0.3
66	0.3	0.3	0.3	0.3	0.3	0.4	0.4	0.4	0.4	0.4	0.4
68	0.4	0.4	0.5	0.5	0.5	0.5	0.5	0.6	0.6	0.6	0.6
70	0.5	0.5	0.6	0.6	0.6	0.6	0.6	0.7	0.7	0.8	0.8
72	0.6	0.6	0.7	0.7	0.7	0.7	0.7	0.8	0.8	0.9	0.9
74	0.7	0.7	0.8	0.8	0.8	0.9	0.9	0.9	0.9	1.0	1.1
76	0.8	0.8	0.9	0.9	0.9	1.0	1.0	1.1	1.1	1.2	1.2
78	0.9	0.9	1.0	1.1	1.1	1.1	1.2	1.2	1.2	1.3	1.4
80	1.0	1.1	1.1	1.2	1.2	1.2	1.3	1.3	1.3	1.4	1.5
82	1.1	1.2	1.2	1.3	1.3	1.3	1.4	1.4	1.5	1.5	1.6
84	1.3	1.3	1.3	1.4	1.4	1.5	1.5	1.5	1.6	1.7	1.8
86	1.4	1.4	1.4	1.5	1.5	1.6	1.6	1.7	1.8	1.8	1.9
88	1.5	1.5	1.6	1.6	1.7	1.7	1.8	1.8	1.9	2.0	2.0
90	1.6	1.6	1.7	1.7	1.8	1.8	1.9	2.0	2.0	2.1	2.1
92	1.7	1.7	1.8	1.8	1.9	1.9	2.0	2.1	2.1	2.2	2.3
94	1.8	1.8	1.9	1.9	2.0	2.0	2.1	2.2	2.2	2.3	2.4
96	1.9	1.9	2.0	2.0	2.1	2.2	2.3	2.3	2.4	2.5	2.5
98	2.0	2.0	2.1	2.2	2.2	2.3	2.4	2.4	2.5	2.6	2.7
100	2.1	2.2	2.2	2.3	2.3	2.4	2.5	2.6	2.7	2.7	2.8
105	2.4	2.4	2.5	2.6	2.6	2.7	2.8	2.9	3.0	3.1	3.2
110	2.6	2.7	2.8	2.8	2.9	3.0	3.1	3.2	3.3	3.4	3.5
115	2.9	2.9	3.0	3.1	3.2	3.3	3.4	3.5	3.6	3.8	3.9
120	3.1	3.2	3.3	3.4	3.5	3.6	3.7	3.8	3.9	4.0	4.2

Note:—The corrections for temperatures *below* 60° F. are in the same proportion for lubricating oils as shown for temperatures *above* 60° F., but in this case the correction is to be added.

TABLE OF CENTIGRADE AND FAHRENHEIT DEGREES.

$$\text{Temp. Fahr.} = \frac{9}{5} \times \text{temp. C.} + 32°.$$

$$\text{Temp. C.} = \frac{5}{9} (\text{temp. F.} - 32°).$$

°C.	°F.	°C.	°F.	°C.	°F.
—40	—40	100	212	250	482
—35	—31	105	221	255	491
—30	—22	110	230	260	500
—25	—13	115	239	265	509
—20	— 4	120	248	270	518
—15	+ 5	125	257	275	527
—10	14	130	266	280	536
— 5	23	135	275	285	545
0	32	140	284	290	554
+ 5	41	145	293	295	563
10	50	150	302	300	572
15	59	155	311	305	581
20	68	160	320	310	590
25	77	165	329	315	599
30	86	170	338	320	608
35	95	175	347	325	617
40	104	180	356	330	626
45	113	185	365	335	635
50	122	190	374	340	644
55	131	195	383	345	653
60	140	200	392	350	662
65	149	205	401	355	671
70	158	210	410	360	680
75	167	215	419	365	689
80	176	220	428	370	698
85	185	225	437	375	707
90	194	230	446	380	716
95	203	235	455	385	725
		240	464	390	734
		245	473	395	743
				400	752

By noting that 5° C. are exactly equal to 9° F., and that the above figures are all even numbers (not rounded off) the exact temperature can be readily read for either thermometer.

WHOLESALE PRICES OF OILS AND HEAVY CHEMICALS.

Compiled from New York market quotations as given in the *Oil, Paint & Drug Reporter.* On account of the high prices prevailing, prices are also given for normal conditions.

(For a special comparison of prices see "Prices of Petroleum and its Products," Price Bulletin No. 36 of the War Industries Board, 1919, 55 pp.; also other price bulletins issued by the War Industries Board.)

	May 31, 1920	August 1, 1914
Mineral Lubricating Oils:		
Black, reduced, 29°B., 25-30° cold test, gal.	33 –35	13½–14
" " 29°B., 15° C. T.	35 –38	14 –14½
" " summer	30 –	13 –13½
Cylinder, light filtered	90 –95	21½–33
" dark filtered	80 –85	18 –26
" extra cold test	95 –100	27 –34
" dark steam refined	65 –90	14½–25
Neutral. West Virginia, 29 gravity	27⅛*–	23 –23½
Paraffin, 300 viscosity at 100°F.	55 –60	27 –28
" 903 sp. gr.	45 –	15 –15½
" 885 sp. gr.	35 –	12½–13
" Red	38 –45	15 –16
Spindle, No. 200	45 –55	18 –19
" No. 180	43 –	
" No. 150	42 –	
Animals Oils:		
Degras, foreign and domestic, lb.	7 –14	3 – 3½
Horse	15¼–	6 – 7
Lard, prime winter, gal.	1.80–1.95	92 –93
" extra No. 1	1.40–	62 –63
" No. 2	1.30–	51 –52
Neatsfoot, 20 deg.	2.05–	96 –98
" prime	1.65–	64 –65
Red, saponified, lb.	16¼–17	6¾– 7
Stearic acid, single press	25 –	8¾–10½
Tallow, acidless, gal.	1.40–	64 –65
Fish Oils:		
Cod, domestic, gal.	1.22–	32 –34
Menhadin, light, strained	1.15–1.19	37 –38
Sperm, bleached, winter, 38° C. T.	1.93–1.96	70 –
Porpoise, body	Nominal	40 –45
Whale, natural, winter	1.30–	48 –
Vegetable Oils:		
Castor, No. 3., lb.	19 –20	8 – 8½
Cocoanut, Cochin	19 –	10½–11½
Corn, crude, in barrels, 100-lbs.	17.56–17.81	6.35–6.40
Cottonseed, crude, f. o. b. mills, lb.	16 –	5.3 –5.5
" prime summer yellow, 100-lbs.	18 –	6.50–6.75
Linseed, raw, car-lots, gal.	1.67–1.72	59 –
" boiled, car-lots	1.69–1.74	60 –
Olive, denatured	Nominal	78 –82

* Natural.

	May 31, 1920	August 1, 1914
Vegetable Oils: (*Continued.*)		
Olive, foots, lb.	18½–	7 –7½
Palm, Lagos, spot	12 –	7 –7¼
Peanut, crude, f.o.b. mill, gal.	Nominal	62 –68
Rapeseed, refined	1.70–	59 –
" blown	1.75–	63 –
Rosin oil, first rectified	89 –	— –27
" " fourth rectified	1.14–	— –60
Soya bean, Manchuria, spot, barrels (lb.)	19¾–20½	6¼–
Grease, Naval Stores, Etc.		
Grease, white	12 –13	10½–
" brown	10 –11	5½–6½
Lard, Middle West	21. –21.12	10 –37
Tallow, special, loose	12. –	— –6⅛
Rosin. common to good strained, 280-lbs.	19.50	4 –4.10
Spirits of turpentine, gal.	2.08	47½–48
Chemicals, Heavy:		
Acid, sulphuric, 66°, 100-lbs.	1.2 –1.25	1. –1.10
Soda ash, light 58%, in bags	3.40–3.50	0.57½–0.62½
Soda, caustic, 76-78% in drums	6.25–6.35	1.42½–1.47½
Potash, caustic, 88-92%, lb.	30 –33	4½

PETROLEUM STATISTICS.

(From the United States Geological Survey Reports.)

Rank of Petroleum-Producing States based on quantity of oil marketed (1917). (Barrel = 42 gallons.)

State	Quantity			Value		
	Rank	Output (barrels)	Percentage	Rank	Value	Percentage
Oklahoma	1	107,507,471	32.06	1	$181,646,981	34.26
California	2	93,877,549	28.00	2	86,161,764	16.49
Texas	4	32,413,287	9.67	4	42,891,555	8.21
Illinois	5	15,776,860	4.70	5	31,358,069	6.00
Louisiana	6	11,392,201	3.40	9	17,224,602	3.30
Kansas	3	36,536,125	10.90	3	67,120,573	12.84
West Virginia	8	8,379,285	2.50	6	27,246,960	5.21
Ohio	9	7,750,540	2.31	8	21,104,483	4.04
Pennsylvania	10	7,733,200	2.30	7	25,154,290	4.81
Wyoming	7	8,978,680	2.68	10	11,047,876	2.11
Kentucky	11	3,088,160	0.92	11	7,033,714	1.35
New York	12	879,685	0.26	12	2,850,378	0.54
Indiana	13	759,432	0.23	13	1,470,548	0.28
Colorado	14	121,231	0.04	15	128,100	0.02
Montana	15	99,399	0.02	14	146,272	0.03
Alaska	17			17		
Missouri		10,300			20,600	0.01
Michigan	18		0.01	18		
Tennessee	16	12,196		16	28,448	
	—	335,315,601	100.00	—	522,635,213	100.00

PETROLEUM STATISTICS. (*Continued.*)

PRODUCTION BY FIELDS—1918–1919

Field	1918			1919 (est.)
	Quantity barrels	Value	Average price per barrel	Quantity barrels
Appalachian field	25,401,466	93,917,171	3.697	29,232,000
Lima-Indiana	3,220,722	7,450,932	2.313	3,444,000
Illinois field	13,365,974	31,230,000	2.337	12,436,000
Mid-Continent field:				
Oklahoma-Kansas	148,798,087			115,897,000
Central & N. Texas	17,280,612	393,031,158	2.191	67,419,000
N. Louisiana	13,304 399			13,575'000
Gulf field	24,207,620	41,053,846	1.696	20,568,000
Rocky Mountain field	12,808,896	18,474,078	1.442	13,584,000
California field	97,531,997	118,770,790	1.218	101,564,000
Other	†7.943	†15,986	2.013	—
Totals	355,927,716	$703,943,961	$1.978	377,719,000

‡ Includes Alaska and Michigan.

World Production of Crude Petroleum.

Country	Production, 1918		Total production, 1857–1918	
	Barrels of 42 gallons	Per cent. of total	Barrels of 42 gallons	Per cent. of total
United States	335,927,716	69.15	4,608,571,719	61.42
Mexico	63,828,327	12.40	285,182,489	3.80
Russia	40,456,182	7.86	1,873,039,199	24.96
*Dutch East Indies	13,284,936	2.58	188,388,513	2.51
Roumania	8,730,235	1.70	151,408,411	2.02
India	8,000,000	1.55	106,162,365	1.41
Persia	7,200,000	1.40	14,056,063	0.19
Galicia	5,591,620	1.09	154,051,273	2.05
Peru	‡2,536,102	0.49	24,414,387	0.33
Japan and Formosa	2,499,069	0.48	38,498,247	0.51
Trinidad	2,082,068	0.40	7,432,391	0.10
Egypt	2,079,750	0.40	4,848,436	0.07
Argentina	1,321,315	0.26	4,296,093	0.06
Germany	711,260	0.14	16,664,121	0.22
Canada	304,741	0.06	24,425,770	0.33
Venezuela	190,080		317,823	
Italy	35.953	0.04	973,671	0.02
Cuba	....	....	19,167	
Other countries	....	....	397,000	
	514,729,354	100.00	7,503,147,138	100.00

* Includes British Borneo. ‡ Estimated in part.

PETROLEUM STATISTICS. (*Continued.*)

AVAILABLE OIL REMAINING IN GROUND, AS ESTIMATED BY THE UNITED STATES GEOGRAPHICAL SURVEY, JANUARY, 1919.

(Barrels of 42 Gallons.)

Oil fields	Total marketed production to end of 1918	Available oil left in ground, January, 1919
Appalachian	1,221,737,000	550,000,000
Lima, Indiana	448,404,000	40,000,000
Illinois	298,159,000	175,000,000
Mid-Continent	990,573,000	1,725,000,000
North Texas	78,971,000	400,000,000
North Louisiana	90,902,000	100,000,000
Gulf	303,954,000	750,000,000
Wyoming	39,793,000	400,000,000
California	1,114,000,000	2,250,000,000
Alaska, Colorado, Michigan, Montana, etc.	10,651,000	350,000,000
Totals	4,598,144,000	6,740,000,000

The total oil reserves of the world are estimated at sixty billion barrels.

MINERAL OILS EXPORTED FROM THE UNITED STATES IN 1918 AND 1919.

Kind	1918		1919	
	Quantity	Value	Quantity	Value
	Gallons		*Gallons*	
Crude	205,829,030	$12,084,250	248,874,663	$14,825,202
Gasoline	351,967,164	85,225,574	259,783,919	61,757,864
Other Naphtha, etc	207,401,691	54,368,166	112,349,798	30,291,972
Illuminating oil	491,109,815	50,354,414	976,305,545	118,796,775
Lubricating (total)	257,317,253	75,603,055	277,591,158	85,451,399
Fuel and Gas oil(a)	1,200,750,319	66,615,743	584,849,605	30,818,877
Residuum	244,474	14,298	32,999,709	1,834,296
	2,714,619,746	$344,265,500	2,492,754,397	$343,776,385

(*a*) Does not include fuel or bunker oil laden on vessels engaged in the foreign trade, which aggregated in 1918, 6,603,043 barrels, valued at $11,676,053 and in 1919, 14,031,356 barrels, valued at $29,383,438.

NOTE:—For 1919, the excess of imports over exports was estimated at 46,854,959 barrels, due to the large imports amounting to a total of 65,000,000 barrels of crude petroleum, practically all of which came from Mexico, less than 100,000 barrels of crude petroleum coming from other countries. Mexico exported to all countries 79,927,340 barrels of crude petroleum in 1919.

OUTPUT OF REFINERIES FOR THE YEAR 1918. (Bureau of Mines)

	Crude run (Bbl.)	Oil purch, & re-run (Bbl.)	Gasoline (Gal)	Kerosene (Gal.)	Gas & Fuel (Gal)
East coast ..	64,119,528	7,330,083	718,720,111	485,559,229	1,118,998.731
Penna	18,804.510	1.992,336	241,639,462	136,951.334	201,775,157
Ind. & Ill...	22,184,148	7,987,413	460,795.843	187,070,255	344 497,236
Okla. & Kan.	60,805,183	9,378.896	865,799 574	415,222.396	1,344.145,229
Tex. & La. .	81,733,167	5.579,957	636,856,670	435.281.246	1,934,441,119
Colo. & Wyo.	11,913,125	4,627,512	212,108,809	62,695.223	243.755,929
California ..	66,464,969	13,669,007	434,392.494	102,580,454	2,133,784,156
Total 1918 ..	326,024,630	50,565,204	3,570.312,963	1,825,369,137	7,321,397.557

OUTPUT OF REFINERIES FOR THE YEAR 1918. (Bureau of Mines)

	Lubricating (Gal)	Wax (Lb.)	Coke (Ton)	Asphalt (Ton)	Miscellaneous (Gal.)	Losses (Bbl.)
East coast ..	257,412,655	215,791,443	222,644	270,172	78,617,550	6,631,988
Penna	182,864,252	86,432,928	19,758	2,900	36,308,371	1,187,926
Ind. & Ill...	97.460,092	78,020,865	137,759	71,942	43.476,748	1,890,377
Okla. & Kan.	109.876,505	48,726,352	56,659	10,434	68,125.325	2,525,447
Tex. & La. .	123,258.451	73,145,391	107,931	145,887	352,028,239	3,019,166
Colo. & Wyo.	3,653,559	2,259.346	14,912	40	136,475,995	732,931
California ..	66,940.253	768,032	—	106,593	571,678.155	1,568,790
Total 1918 ..	841,465,767	505,144,357	559,663	607,968	1.286,710,383	14.556,625

PROPERTIES OF REPRESENTATIVE AMERICAN LUBRICATING OILS FOR USE IN INTERNAL COMBUSTION ENGINES
(C. W. Stratford, *Nat. Pet. News*, p. 23, Mch. 20, 1918; for methods of testing see Index).

Kind of Oil	Physical Properties Fresh Sample								Lovibond Color		Vacuum Distillation	Oxidation Oven		
	Baumé Grav.	Flash, Deg. F.		Deg. F. Burn	Deg. F. Chill	Viscosity, Seconds			Fresh	After Heat Test	% Dist. Under 300° C.	% Evap. Loss	% Insol.	% Varnish
		Open Cup	Closed Cup			100° F.	150° F.	212° F.						
Aerial Oil	29.1	425–	410	490	50	593	176	71	550–2	670–2	13	18.98	0.0240	0.1875
Amalie Special	31.0	420	425	490	40	209	80	43	430–6	500–2	4	31.71	0.0220	0.3300
Atlas Aerul Heavy	27.6	460	460	540	47	868	228	85	400–½	600–½	328° I.B.P.	17.84	0.0120	0.1081
Cadillac Detroit Lt.	28.2	405	—	470	11	190	69	—	300–6	—	44	—	—	—
Duplex No. 350	30.7	425	435	495	27	194	77	46	240–6	250–2	1	21.49	0.0596	0.1760
Havoline														
Light	25.9	370	380	430	33	173	66	42	540–6	300–½	22	62.93	0.5500	0.6300
Medium	25.0	385	395	450	34	237	80	46	570–2	500–½	6	57.74	0.8600	0.3400
Heavy	25.6	395	410	455	46	361	111	54	480–2	300–½	18	40.49	0.1500	0.2800
Mobiloil														
Zeta Light	28.0	375	380	430	31	141	62	42	360–6	200–½	28	51.75	0.3010	0.3816
Zeta Medium	24.2	400	410	470	43	255	84	47	460–2	300–½	29	35.06	0.2599	0.2776
Zeta Heavy	25.6	420	425	480	42	470	137	62	500–½	650–½	301° I.B.P.	27.64	0.0404	0.2339
"E" Light	26.1	370	380	420	0 @ 0	167	66	44	430–6	400–2	21	76.44	0.1962	0.1580
"A" Medium	21.8	360	360	420–	24	330	97	49	660–2	320–½	21	57.66	0.6381	0.1612
"B" Heavy	26.3	500	470	580	41	1640	397	122	800–½	950–½	3	25.26	0.1766	0.1500
Artic Lt. Med.	23.3	370	380	425	6	221	74	45	280–6	400–2	28	71.52	0.3993	0.4759
Artic Medium	21.1	370	385	430	8	300	87	46	550–6	210–½	19	49.06	0.4160	0.5065
"BB" Med. Hvy.	25.8	460	—	540	46	926	243	86	670–½	800–½	344° I.B.P.	18.67	0.0290	0.0560
Monogram														
Light	27.6	360	360	410	20	140	60	41	200–6	260–2	14	67.12	0.4600	0.6700
Medium	26.0	375	370	430	23	289	95	50	600–6	250–½	16	46.19	0.1600	0.2600
Heavy	28.9	430	445	505	34	340	108	55	600–6	580–2	306° I.B.P.	25.75	0.0700	0.3600
Ex. Hvy.	24.7	465	425	555	58	1583	356	110	330–½	470–½	3	12.10	0.0440	0.2056
Oilzum														
Heavy	29.1	430	440	500	30	261	91	50	460–6	420–2	310° I.B.P.	15.86	0.1167	0.1357
Crystal G. E. Oil	17.0	505	490	590	2	1080	244	83	100–6	140–2	—	17.54	—	—

PROPERTIES OF REPRESENTATIVE AMERICAN LUBRICATING OILS FOR USE IN INTERNAL COMBUSTION ENGINES—(Continued)

Perfection														
"A" Light . . .	29.1	400	410	470	26	181	71	45	420–6	430–2	314° I.B.P.	49.36	0.1378	0.2293
"B" Medium	24.9	390	400	450	32	243	81	47	440–2	480–½	2	52.33	0.3704	0.2687
"C" Heavy . . .	29.3	420	430	495	40	316	103	54	480–2	300–½	2	27.53	0.0088	0.2292
Polarine, New Jersey	24.6	395	—	470	6	221	77	42	150–6	850–2	57	48.73	0.6200	0.4300
Quaker State Medium	28.8	440	450	520	21	301	102	48	600–6	700–2	29	22.42	0.0640	0.1700
Service Auto Oil . .	24.3	390–	—	460	33	195	72	44	500–2	440–½	7	28.91	0.9600	0.4100
Socony														
Zero	24.3	395	410	470	Sl. @ 0	219	77	46	140–6	250–2	3	42.85	0.1531	0.2167
Polarine Hvy. . . .	25.4	385	380	450	35	300	103	51	380–2	420–½	7	38.61	0.1353	0.2128
Supreme														
Light	22.3	325	315	360	Sl. @ 0	137	57	39	420–6	250–2	73	60.21	0.7689	0.3531
Medium	19.8	330	330–	380	Sl. @ 0	217	73	43	530–6	220–½	49	56.57	0.7041	0.3243
Heavy	19.4	330	330	370	0 @ 0	242	73	44	560–6	200–½	42	54.37	0.4509	0.3063
Texaco														
Light	21.3	335	340–	380	Sl. @ 0	205	69	42	190–6	260–2	44	56.13	0.1395	0.2371
Medium	20.9	350	350	400	Sl. @ 0	301	85	46	190–6	350–2	31	51.40	0.1009	0.2163
Heavy	19.3	355	360	420	10	495	119	51	330–6	450–2	19	42.87	0.0874	0.2097
Ursa	19.7	390	365	455	Sl. @ 0	735	152	58	240–6	360–2	—	37.63	0.2757	0.3562
Valvoline Medium . .	30.7	385	390	440	30	257	93	51	480–2	300–½	29	38.85	0.0250	0..714
Veedol														
Aero No. 1	26.2	455	450	535	39	795	212	78	580–2	300–½	3	34.96	0.3956	0.1504
Aero No. 2	27.1	450	445	530	38	814	222	80	580–2	310–½	3	36.58	0.1614	0.1900
Aero No. 3	26.3	435	435	520	38	517	149	63	470–2	260–½	310° I.B.P.	37.98	0.0358	0.1738
Aero No. 4	27.6	440	430	515	34	513	151	64	500–2	250–½	3	38.11	0.0416	0.2130
Aero No. 5	24.7	440	450	520	28	413	135	55	470–6	580–2	336° I.B.P.	38.83	0.0741	0.4151
Aero No. 6	24.7	460	460	540	27	474	134	58	480–6	550–2	310° I.B.P.	18.91	0.0732	0.2284
Zero Light	26.1	390	—	460	14	199	75	44	380–6	370–2	57	39.56	0.4548	0.2717
Medium	26.3	405	—	475	30	250	88	48	530–6	520–2	23	49.54	0.0201	0.2348
Heavy	26.2	410	—	480	33	329	107	52	700–6	650–2	28	30.80	0.0650	0.1719
Extra Heavy	26.1	465	—	550	44	—	355	111	210–½	450–½	3	90.2	0.0464	0.1155
Waverly	31.0	400–	405	460	24	160	09	40	300–6	570–2	37	44.76	0.1400	0.2900
White Star Motor Oil	25.8	360	370	415	18	170	66	43	500–6	800–2	17	59.65	0.4500	0.7500
Wolf's Head														
Light	31.2	390	—	445	34	142	62	40	130–6	210–2	1	58.70	0.1750	0.4800
Medium	28.8	410	—	470	26	223	82	46	410–6	350–½	310° I.B.P.	45.05	0.3800	0.2700
Heavy	28.6	415	—	475	32	334	108	52	480–6	750–2	304° I.B.P.	35.50	0.2100	0.2000
No. 8	27.6	465	460	550	46	1196	300	100	680–6	380–½	3	38.83	0.0470	0.2960

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