THE JOURNAL OF INDUSTRIAL AND ENGINEERING CHEMISTRY

VOL. II.

MAY, 1910.

No. 5

THE JOURNAL OF INDUSTRIAL AND ENGINEERING CHEMISTRY

PUBLISHED BY

THE AMERICAN CHEMICAL SOCIETY.

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Published monthly. Subscription price to non-members of the American Chemical Society \$6.00 yearly.

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ORIGINAL PAPERS.

LABORATORY TESTS OF LUBRICANTS—INTERPRETATION OF ANALYSES.

By P. H. CONRADSON.¹

Received March 14, 1910.

To make complete tests of lubricants, oils and greases requires a great deal of expert knowledge and experience to enable the chemist or engineer to interpret correctly the results obtained. This point will be clearer perhaps, if one considers the various classes of machinery to be lubricated, from the light spindles in cotton mills to the heavy rolls in the iron and steel mills; the fast running shaft or journals in a dynamo, to the slow heavy shaft in an ocean steamer or war ship, and the numerous classes of machinery in shops, the electric motors on street cars, the steam locomotives, the railroad cars, the steam turbine, automobiles, air compressors, steam cylinders, and so on, too long a list to enumerate, and if we consider that these machines are to be lubricated under all kinds of conditions as to weather changes, high and low temperatures, and service requirements, we readily will appreciate the wide scope "Lubricants and Lubrication" involves.

The method or methods of applying the oil to the parts to be lubricated plays a very important part

in connection with the proper interpretation of lubricating oil analyses; the conditions of the bearing surface, composition of the journal and bearings, etc.

An oil that would give satisfaction when applied direct to the journal by means of soaked waste, might fail altogether if the wick method of feeding the oil was used, likewise a sight-feed cup with wide enough orifice might give satisfaction, while a gravity feed through a long small bored pipe, might give very unsatisfactory results; or in other words the chemist or oil expert to interpret the results from laboratory tests of lubricating oils must be familiar with the particular kind of machines to be lubricated, the service conditions and requirements, and method of applying the oil, before he can give a qualified opinion as to the real adaptability of the lubricant, or comparative merits of two oils intended for the same service.

The value of physical and chemical tests of iron and steel used in construction work of all kinds and how to interpret the results obtained in laboratories is well known, likewise we must consider the laboratory tests of lubricants from a technical and practical point of view somewhat in the same light.

In making a complete investigation of the real or comparative value of a lubricating oil with another oil, we have then to consider the kind of machine to be lubricated, the service requirements and conditions, and the methods of applying the lubricant to the machine, and make the chemical and physical laboratory tests accordingly.

Generally speaking, the chemical tests, as made, are very inadequate, as are also the physical tests, especially frictional tests on oil-testing machines, unless the machines are constructed in such a way that the actual conditions can be approximately reproduced. For instance, in testing a spindle oil, the testing machine should be run practically at the same load and speed as the spindles are in actual service. In testing railway car and coach oils, the machine should have approximately the same size journal and bearing as would be found in actual railway car journals. The same is also true as regards speed, load and the application of the lubricant.

While many valuable conclusions may be drawn from properly conducted laboratory tests, those of the greatest practical value come from a close observation of the lubricant in actual service, and we can base our laboratory investigations on the results obtained, especially in comparing different oils intended for the same work. To bring out the point more

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clearly, let us consider an air compressor, such as is used on street cars and electric locomotives. As is well known, these compressors are not water-cooled or even air-cooled. It is not difficult to get an oil that will lubricate the compressor cylinder, but it is difficult to find an oil that will not carbonize at the high temperature, often 450 to 460° F. in the street-car compressor, and 550° to 560° F. in the electric locomotive air compressor.

of a suitable oil for such service, and to make a proper laboratory investigation and test of an air-compressor oil, it would be necessary to have an air compressor and test the oil as near as possible under actual service conditions.

Again, we may consider a steam turbine and suitable oils for its lubrication. Ordinary laboratory tests, both chemical and physical, such as are generally used in this country, do not bring out the essential

Fig. 1.

The difficulty lies in the fact that as the compressed air passes through the outlet ports and check valves in the compressor heads, there is a very rapid increase in the temperature. The small amount of oil that goes with the compressed air, if not of the best or suitable quality, will then begin to carbonize and cause trouble by forming heavy carbonaceous deposits on the check valves. Now, an ordinary oil-testing machine cannot bring out the essential requirements

qualities of a suitable turbine oil, because the service requirements and conditions are so entirely different from the general run of machinery, that special tests must be made. Therefore, from a practical point of view, to develop the essential qualities of turbine oils, it is necessary that the service conditions and requirements should be studied first, laboratory tests then being made in accordance therewith as far as practicable.

To illustrate, we consider a steam turbine of the Curtis type, where the oil is forced under high pressure to the step-bearing and then returned to the oil tank. At first this might to be a very small matter, but in actual practice and experience it is not, for the following reasons: In the first place, leakage of steam occurs in most of these steam turbines as now constructed; this steam condenses, becomes mixed or churned in with the oil, and if the oil is not of the proper kind, it becomes emulsified. The emulsified oil gradually becomes thicker, and as the same circulating system is used for the rest of the machine, the emulsified oil often causes considerable trouble. Then again, we often find that the amount of oil used in the oil-circulating system is entirely too small in quantity, so the oil has to pass through the turbine many times during the hour, in the twenty-four hours, and from week to week. This imposes a severe service requirement on the oil, which gradually becomes polymerized and oxidized, developing petroleum acids. If sulphur compounds are present to any extent, they become gradually oxidized and besides causing corrosion may also cause a great deal of trouble from formation of asphaltic and tarry matter, which would clog the filters and orifices through which the oil has to pass. From a practical point of view, therefore, the laboratory tests of turbine oils should be considered along these lines. The same may be said of all lubricating oils intended for use in oil-circulating systems, which are now so largely used in stationary power plants, shops, and mills, war vessels, steamships, etc.

It is a generally accepted idea that if the oil is adapted to the load and speed, the lower the viscosity the better lubricant it will be. This, to my mind, holds good only where the service conditions are uniform, and where the method of applying the oil to the bearing and journal is a positive one, such as in gravity or pressure-pump systems. Where the climatic changes are great, as on railroads, this will not hold good.

The load and speed of the railroad trains are the same during the summer and winter, and as is well known, the practice in this country is to convey the oil to the journals by means of oil-soaked waste. A satisfactory thin winter oil with a low cold test and low viscosity, containing sufficient lubricating capacity to keep the journal and bearing apart, would not be suitable during the hot season, not because it has not the adequate sustaining power, but because of the method of applying it to the surfaces to be lubricated, making it necessary to use a much thicker oil than is theoretically required.

Therefore, to make laboratory tests of the relative lubricating values of oils considered from a practical standpoint and to draw correct conclusions from the results obtained, we must consider the kind of machine or machines to be lubricated; the speed and the load;

the composition of the metal bearing; whether the journals are iron or hard steel; the method of applying the lubricant, either with wick feed, soaked waste, sight-feed cups, flooded bearing or continuous oil-circulating system; the actual service requirements and climatic conditions. We must make complete chemical and physical tests as near as possible in accordance with these conditions. I might with propriety state that one oil cannot be considered a better lubricant than another oil unless the service conditions and requirements are specified and fully understood and the laboratory tests made in accordance therewith.

I have spoken of the importance of adequate chemical tests in connection with physical and frictional tests. The following tests are therefore useful. While in some cases it is not necessary to subject the oil to all these tests, they are of great importance in connection with special or unusual service requirements and conditions.

CHEMICAL TESTS.

Flash point.	Evaporating tests, a given time
Burning point.	at 200° to 300° F. to study per-
Gravity.	centage of volatile and behavior
Color.	of residues in 88° gasoline tests
Odor.	and acidity.
Purity.	Heat tests, in air bath blowing
Gasolene tests, before and after flash.	air over the oil at 425° F. and
Cloud test.	540° F. Examination of residue.
Cold test.	Emulsifying tests, to determine
Viscosity.	adaptability of the oil, say in
Microscopic test for carbonaceous	turbine service.
matter in suspension.	Tar and coke-forming substances
Saponifiable fats.	present before and after heat test.
Free fatty acids.	Oxidation or gumming tests.
Petroleum acids.	Superheated steam tests.
Sulphuric acids.	Carbonizing test in connection
Chemicals from imperfect refining.	with air compressor (not water-
Sulphur-lamp tests and in wick.	cooled) automobile gas-engine
Maumené test.	lubrication.
Iodine test.	Capillarity or wick tests.

I will now consider the various tests and their importance.

First and Second, Flash Point and Burning Point.—This test indicates the temperature at which the more volatile elements present in the oil begin to go off to such an extent as to give a flash when a small flame is moved over and near the surface of the heated oil; the so-called open-cup method is generally used, and in connection with this test, the heat is continued till the oil begins to burn, when the flame test is made.

A too low flash and fire test may be objectionable on account of danger from fire; besides, too large a loss from evaporation, under given service conditions, in connection with the viscosity, congealing point or cold test and gravity, the flash and fire test also enables the analyst to form an idea of the source of the petroleum.

Third, Specific Gravity.—The gravity enables the analyst in many cases to form an idea whether the oil is a Pennsylvania, Virginia or western oil, the latter generally having a much higher gravity.

Fourth, Color.—While not of much importance, other things being equal, an oil with a lighter color

or pleasing appearance is oftentimes preferred to a very dark or black colored oil.

Fifth, Odor.—At times aids in detecting the kind and quality of fat oils in compounded oils.

Sixth, Purity.—Freedom from water, matters in suspension, whether clear or turbid, etc.

Seventh, Gasoline Tests.—This test tells you if water or other foreign matters are present, tar and asphaltic matter, and if the oil gives a clear solution with 88° gasoline before it is heated to take the burning point, but gives a precipitate with 88° gasoline after said test, this indicates petroleum compounds which are readily acted upon by heat, and such an oil in comparison with another oil, other things being equal, would not have the same lubricating value.

Eighth, Cloud Test of a lubricating oil is sometimes of value in determining the amount of paraffines present and the behavior of the oil in chilling down to a temperature above congealing point.

Ninth, Cold Test (Congealing point, Melting point).—This test together with the viscosity of the oil in comparative tests is of much importance in connection with the service utility of the oil and should be given careful consideration.

The method used in determining the cold test and melting point, as well as getting at the comparative fluidity or sluggishness at temperatures lower than 70° F., is generally not considered as it should be. To illustrate: A valve or cylinder oil, if the cold test was taken by the so-called P. R. R. method (that is, the oil was frozen direct in ice mixture, and then stirred by the thermometer till it began to flow when the bottle is inverted), might show a cold test of 40° F., and if no further observation was taken one would have no idea of the fluidity of 60° to 70° F.; that is, the cold test in the report would give 40° F., but in reality the oil at 60° F. would be so sluggish that it would hardly feed through the narrow-bore feed-pipe to the steam chest and cylinders, and unless the analyst knows for a fact that the engineer has his pipe covered or warmed in some way, trouble may arise, the oil be condemned, and still the oil might be of the best and purest quality.

Again if the congealing point is taken by the S. O. Co's. method (that is, the oil in the bottle with its thermometer inserted is put into a cooling box, gradually cooled till the oil just ceases to flow when the bottle is inverted, or still better, lifting up the thermometer stem from time to time and noting when the oil hardly flows from the stem), but without further observations this method like the P. R. R. does not tell all.

The rate of cooling or chilling, the time the oil remains in the chilling or cold test box, plays an important part in proper interpretation of the comparative value of the oil in actual service. Much more

could be said on this point, but the above allusion may be sufficient.

Tenth, Viscosity.—This test is the bugbear of the oil tester: it may mean so much and it may mean so little. Certainly in my line of work in connection with the cold test and flash point, we might have a good idea of the quality and adaptability of the oil with the aid of a good viscosimeter.

As an adjunct to other tests, and a careful study and knowledge of the service requirements, I have found the viscosity tests of the utmost value; in fact, from my knowledge of all the analytical data, with the aid of the viscosimeter, I can pretty near foretell the comparative friction under given conditions between two oils.

Eleventh, Microscopic Tests.—In testing dark-colored oils, heavy machine oils, and cylinder oils, it is well to put a few drops on a slide and examine under the microscope—one may find carbonaceous matter in suspension; and paraffine crystals if present at ordinary temperatures will disappear on warming the oil, and other foreign matters held in suspension will be brought out.

Certainly an oil, other things being equal, that is free or practically so from carbonaceous specks or flakes is superior to an oil containing these in some quantity.

Twelfth, Saponifiable Fats.—I will not enter into a discussion of the methods to determine these, but merely point out that two cylinder oils, one containing 30 per cent. of fat oil and the other only say 5 to 10 per cent. of fat oil, other things being equal, while not of the same intrinsic commercial value, may have equally good and economical practical lubricating value.

Again a cylinder oil containing 25 to 30 per cent. of good fat oil might give excellent and economical results in a steam engine of 100 to 150 pounds pressure per sq. in. and where the exhaust steam is not condensed or used over again in the boiler, and be very objectionable in connection with superheated steam and where surface condensers are used. The reason, of course, is obvious.

Thirteenth, Fourteenth, Fifteenth and Sixteenth.—Other things being equal, the less free fatty acids present the better.

The presence of petroleum acids, sulphuric acid, sulphonates and chemicals from imperfectly refined petroleum oils should always be carefully investigated, as the presence of these foreign materials in a lubricating oil, at least for certain important services, might lead to serious trouble and complications. A first-class lubricating oil should be free from, or at least only contain traces of, these impurities.

Seventeenth, Sulphur.—In general very little attention is paid to the sulphur and organic sulphur compounds that may be present in a lubricating oil.

In the future the sulphur in lubricating oils will have to be reckoned with when these oils are intended for turbine service, or in services where the oil is used over and over again as in a continued oil-circulating system, where the oil, due to continuous exposure to heat, air, moisture, metal wearings, gradually becomes oxidized and polymerized, forming acid petroleum products, changing it both chemically and physically. The sulphur compounds present in the oil largely augment the corrosive or pitting action on the bearings and journals under these conditions.

In the examination of lubricating oils for sulphur content, it is important to make a distinction of how the same occurs in the oil. I have often found that in making sulphur tests by burning a given amount of oil in lamps and taking up the products of combustion in carbonate of soda solution, it is necessary to consume all the oil in the test lamps, and to make a determination of the sulphur compounds left in the wick; in some poorly chemically refined lubricating oils, the sulphur compounds found in the wick oftentimes amount to from 20 to 40 per cent. of the sulphur present.

Eighteenth, Maumené Test.—The sulphuric acid thermal test is of value in connection with tests of compounded lubricating oils.

Nineteenth, Iodine Test.—Omitted. Refer to standard text-books.

Twentieth, Evaporating Tests.—At temperatures of 212 to 300° F., by exposing the oil in shallow flat-bottomed dishes in an air bath at 212 to 300° F. for six hours, noting the percentage of loss and condition of residue and its behavior when mixed with 88° gasoline, we obtain valuable information as to the amount of volatile matter at low temperatures.

Twenty-First, Heat Tests.—For certain service, such as for air compressors not water-cooled, turbines, etc., valuable data may be obtained by exposing the oils in shallow flat-bottomed dishes in a covered air bath through which air is blown for six hours at temperatures of 425 to 540° F.; and study the residue in the dish by dissolving the same in 88° gasoline, noting whether the gasoline solution is clear or turbid and the amount of precipitate, if any, on standing.

Twenty-Second, Emulsifying Tests.—To determine the adaptability of an oil for lubrication in turbines of the Curtis type (step-bearing) it is of the utmost importance to ascertain the behavior of the oil when coming in contact with steam through the step-bearing, whether it forms a thick, creamy emulsion or separates from the steam and condensed water.

FRICTIONAL TESTS.

To make frictional tests of oils and greases of practical value requires, as indicated, testing machines so constructed that various loads, speeds, size of journal and bearings, and methods of applying the

lubricant, comparable to those in actual service as well as devices to keep journal and bearing at any desired constant temperature during the tests.

The constant temperature tests are of importance not only for the purpose of standardizing the machine for each test so as to get all conditions, bearing, journal, and feed, etc., properly regulated before the actual tests begin, but equally so in making comparative frictional tests of two oils, which have practically the same viscosity.

The two oils may show practically the same friction at a given temperature, but to keep the journal and bearing at such temperature, one oil may require a great deal more water or steam to pass through the journal and bearing; again the two oils may give practically the same friction at a temperature of say 150° or at 125° F., but great difference at 90° or at 70° F.; therefore, the constant temperature frictional tests are of great value in conducting comparative tests.

As a rule the reports of frictional tests are very incomplete; the report should give all the constants and data taken during the frictional tests, such as area of contact, projected area, total pressure on journal in pounds, pressure by square inch in pounds, total, maximum, minimum and average friction in pounds, and coefficient of friction, temperature of journal and bearing number of revolutions and feet traveled by rubbing surface per minute, duration of tests, constant or freely increasing temperature, method and amount of lubricant fed besides complete chemical, analytical data.

If two oils or greases are submitted for comparative tests where the service conditions are uniform or fairly constant, such as in mills or power-houses, the comparative viscosity and congealing or fluidity points and friction, other things being equal, would establish the most economical or suitable oil or grease for the service. But in making comparative tests, chemical, physical and frictional, of lubricants where the service conditions vary much, especially as to climatic conditions, it should be borne in mind that while the two oils submitted may show considerable difference in viscosity, congealing or fluidity point and friction, one oil may be equally good for the service requirements as the other; that is, supposing a consumer requests two oil manufacturers to submit samples for comparative tests. They may submit one sample intended to do the service for the whole year, or they may submit samples for the different seasons which latter would be the proper thing, then the samples for each season could properly be submitted to comparative frictional and other tests, otherwise not.

GALENA OIL TESTING MACHINE.

This machine was specially constructed and built for the Galena-Signal Oil Company, by Tinius Olsen &

SKETCHES of DIFFERENT VISCOMETERS.

Fig. 3.

Co., Philadelphia, and is the largest and most complete ever made in this country, having a capacity up to 20,000 pounds load on the test-bearing.

It is constructed in such a way that full-size M. C. B. car journal boxes and bearings can be inserted;

Fig. 4.—Dr. Chas. B. Dudley viscosity pipette.

the test journals to the machine are $4\frac{1}{4} \times 8$ in. and 5×9 in.; by means of a leverage, screw and spring balance system, varying loads up to 20,000 pounds can be applied on the test journal while the machine is running in either direction, at any desired speed up to its maximum.

The machine is provided with a very complete and ingenious leverage and balancing system for automatic measuring and weighing of the load indicated on a dial and the friction in pounds on the periphery of the journal recorded on the scale beam in front of the machine.

It is provided with temperature indicator, revolution counter and tachometer, besides an autographic arrangement which shows the friction corresponding to the number of turns the machine makes.

The test journals and bearings are provided with a device for passing either water or steam through during the tests.

Arrangements for any desired method of applying the lubricant during the test are also provided.

The motive power is an electric motor of special construction so that the machine can be run in either direction at any desired speed, from the slowest to the fastest or *vice versa* during the test, without having to stop the same.

VISCOSIMETERS.

The cuts show two viscosimeters, the Redwood and Dudley pipette; the Redwood viscosimeter as shown in the cut is so well known that no further description is necessary.

The Dudley pipette as seen is a 100 cc. pipette with a mark on the stem both above and below the bulb; the viscosimeter is placed in a closed box provided with a glass door, and the temperature in the box kept during the test at the same temperature as the oil; this is of the greatest importance, taking the viscosity with an instrument of this kind.

In connection with the foregoing the following tables are of interest.

Table 1.—Nos. 1, 2, 3, 4 and 5 are the same oil fractionated by means of Florida fuller's earth. While the flash and fire test and gravity remain practically

Fig. 5.—Redwood viscosimeter.

the same, with changes in color and some in viscosity, the congealing or fluidity point has as seen during the successive stages materially changed from the original No. 1. Nos. 6 and 7 represent an oil before and after being in continuous service in an oil-circulating system about ten months. Here again the flash, fire and gravity tests remain practically the same, but the congealing point and body or viscosity have greatly

congealing points or degrees of fluidity at different temperatures.

Table 4 gives results of frictional tests on the Carpenter frictional machine at Cornell University of a Galena railway summer oil, with increasing load on the journal from 135 pounds to 878 pounds per square inch—a sort of endurance test to determine the load capacity of the oil. From the results obtained

TABLE 1.—LUBRICATING OILS.

	1.	2.	3.	4.	5.	6.	7.
Flash point.....	365° F.	370° F.	370° F.	370° F.	370° F.	410° F.	415° F.
Burning point.....	440° F.	440° F.	440° F.	440° F.	440° F.	470° F.	480° F.
Grav. at 60° F.....	30° B.	30.7° B.	30.5° B.	30.3° B.	30.2° B.	23.0° B.	22.8° B.
Color.....	Very dark	Yellowish	Orange	Red	Deep red	Red	Dark red
Cold test.....	Zero	+18° F.	+25° F.	+25° F.	+25° F.	+5° F.	+20° F.
Viscosity (P. R. R.) pipette:							
At 125° F.....	98	92	94	94	93	85	162
" 100°.....	160	149	148	153	151	143	309
" 90°.....	205	184	192	195	195	188	410
" 80°.....	271	238	249	254	254	253	Drops

changed during continuous service. Petroleum acids and polymerized products have formed to a considerable extent; the adaptability or durability of an oil like this is seriously questioned for the service in which it is used. Have we any laboratory test (frictional, physical, or chemical) that would reveal the unstableness of this oil? This is a practical question that practical men want to know, and to make laboratory tests of real practical value, problems of this nature must be satisfactorily worked out and answered.

some interesting curves as to friction and temperatures could be plotted. The main point, however, is to show that the oil after the pressure on the journal gets above 400 pounds per square inch, and to the maximum load used in the test, the coefficient of friction remains practically stationary, and would give a nearly horizontal curve. From a practical standpoint this information is of great value.

Table 5.—We find first three series of tests at constant but different temperatures; second, two

TABLE 2.—GALENA CAR. COACH AND ENGINE OILS, SHOWING WIDE RANGE OF VISCOSITY AND COLD TEST.

Dudley viscosity pipette, 100 cc. water at 60° F. (15.5° C.) 32 sec.
Redwood viscosimeter, 50 cc. rape-seed oil at 60° F. (15.5° C.) 535 sec.

Viscosity taken at 100° F. (37.7° C.).

	1.	2.	3.	4.	5.	6.	7.	8.	9.	10.	11.	12.	13.	14.	15.
	Time in seconds.														
Dudley.....	104	125	140	162	177	195	220	252	276	300	320	348	375	401	426
Redwood.....	151	183	204	240	260	283	335	378	392	444	480	510	556	595	650

Viscosity taken with Dr. Dudley viscosimeter, 100 cc. water at 60° F. (15.5° C.) 32 sec.

Instrument kept in air bath at same temp. of the oils.

Time in seconds.

125° F. (51.6° C.).....	67	71	86	109	125	138	150	171	197
100° F. (37.7° C.).....	96	99	132	185	214	247	277	318	370
90° F. (32.2° C.).....	115	124	170	243	291	321	362	422	509
80° F. (26.6° C.).....	141	156	216	318	380	439	501	...	...

	Flash point open cup.	Burning point.	Grav. at 60° F. Baumé.	Cold test.
Summer:				
Car.....	350-380° F.	425-450° F.	26.1-27.7°	+20- +40° F.
Engine.....	350-380° F.	425-450° F.	25.4-26.4°	+20- +40° F.
Coach.....	350-380° F.	425-450° F.	24.3-24.6°	+20- +40° F.
Winter:				
Car.....	210-300° F.	260-380° F.	27.4-29.0°	-5- +10° F.
Engine.....	210-300° F.	260-380° F.	26.6-27.9°	-5- +10° F.
Coach.....	210-300° F.	260-380° F.	25.5-26.4°	-5- +10° F.

Table 2 gives comparison between two viscosimeters, and illustrates the wide variation in congealing points or cold tests and viscosities possessed by first-class railroad car lubricating oils; a close study of this table is of great assistance to the practical user of lubricants.

Table 3 is of great interest in connection with viscosity and cold test or fluidity of cylinder oils both compounded and straight petroleum oils, indicating the necessity of additional data in taking the

series of great difference in speed (300 and 600 r. p. m.), all other things being the same; third, comparative tests of a purely vegetable oil (rape-seed) with a compounded petroleum oil (Galena lead-oxide process) with viscosities not far apart, as measured with the pipette viscosimeter; fourth, the difference in friction of the two oils at the slower speed (300 r. p. m.) is very small, while the difference at the greater speed (600 r. p. m.) is considerable, the Galena oil having a much lower friction. This is very instructive when

we consider the nature of these two oils, as well as the great load and speed.

Table 6 gives an interesting comparison between a winter and summer Galena car oil. Both have sufficient body to carry the heaviest load and speed in railroad service, but owing to the present method of conveying the oil to the car journals, a thick and sluggish oil with an unnecessary high viscosity is or has to be used during the warm or hot weather, naturally increasing the total train journal resistance, which, of course, means excessive coal consumption. Note the great difference in the fric-

Second, the necessary requisites or qualities that a first-class lubricating oil should possess in a high degree may be enumerated as follows: Necessary body to withstand the severest pressure in the service for which the oil is intended, so as to keep the rubbing surfaces apart, forming a continuous film between the same, filling up the inequalities in the surfaces; the quality of spreading itself rapidly over the rubbing surfaces, with the requisite degree of adhesive power to remain between the rubbing surfaces without creating undue friction and heating; requisite mobility or fluidity at all seasons of the year, and all climates

TABLE 3.—CYLINDER OILS.

	1.	2.	3.	4.	5.	6.	7.	8.
Flashing point.....	560° F.	595° F.	525° F.	525° F.	520° F.	515° F.	545° F.	550° F.
Burning point.....	....	....	600° F.	....	....	....	....	600° F.
Color.....	Very dark	Very dark	Light filter	Light filter	Light filter	Light filter	Reddish	Dark
Viscosity (Saybolt) at 212° F.....	196	212	126	146	112	83	136	145
Cold test.....	+30° F.	+48° F.	+55° F.	+60° F.	+50° F.	+55° F.	+40° F.	+32° F.
Barely flows from thermometer at.....	+30° F.	+50° F.	55° F.	+60° F.	+50° F.	+55° F.	....	+32° F.
Fair at.....	+40° F.	+60° F.	+60° F.	+65° F.	+60° F.	+60° F.	....	+40° F.
Fair to good at.....	+50° F.	+70° F.	+70° F.	+70° F.	+70° F.	+70° F.	....	+45-50° F.
Quite thick at.....	+60-65° F.	+70-80° F.	+70-75° F.	+70-80° F.	+70-80° F.	+70-80° F.	....	+60° F.
Saponifiable fat.....					10%	33%		

tional resistance between these oils. Practical railroaders should ponder a little more on these facts and utilize such knowledge.

In conclusion, what function should a lubricant perform? What are the necessary requisites or qualities that should be inherent in a first-class lubricating oil? These are trite questions, and will be answered briefly:

First, the function of a lubricant is to keep the rubbing surfaces (journal and bearing) apart to prevent undue abrasion, friction and heating.

from the coldest to the hottest, without impairment of the necessary intrinsic lubricating body for the required service; durability, freedom from mineral and organic impurities, tarry and asphaltic matter, unaffected by atmospheric conditions, non-drying, non-gumming; these are the essential qualities that a first-class lubricating oil should and must possess in a high degree.

Yet no matter how excellent and suitable a material or machine may be if it is not properly applied or used, the best and most economical results are not obtained.

TABLE 4.—FRICTIONAL TESTS OF GALENA SUMMER OIL, CARPENTER MACHINE.

Bearing metal, brass; journal, steel; bearing surface; length, 3.9 in.; diameter, 3.75 in.; width, 1.9 in.; area, 7.4 in.

Number of test.	1.	2.	3.	4.	5.	6.	7.	8.	9.
Pres. on jour., lbs. total.....	1000	2000	3000	3500	4000	5000	5500	6000	6500
Pres. on jour., lbs. per sq. in.....	135	270	405	475	540	675	743	810	878
Method of lubrication.....				Flooding bearing.					
Min. coef of friction.....	0.020	0.019	0.0163	0.016	0.0156	0.0158	0.0153	0.0152	0.0151
Max. temp. of journal F.....	109	114	115	118	122	134	136	140	144
Temperature of room F.....	68	68	68	69	68	70	71	71	71
Elev. temp. jour. ab. room.....	41	46	47	49	54	64	65	69	73
Rev. of journal per min.....	215	220	220	220	223	220	220	220	185
Ft. trav. by rubbing surf per min...	211	216	216	216	219	216	216	216	182

Time.	Rev. per min.	Temp. jour- nal, F.	Tot. fric., lbs.	Coef. fric.	Time.	Rev. per min.	Temp. jour- nal, F.	Total fric., lbs.	Coef. fric.
1: 8.40	210	106	20	0.020	6: 10.50	220	133	79.1	0.0458
45	218	107	20	0.020	55	220	134	79.1	0.0158
50	216	109	20	0.020	11.00	220	134	79.1	0.0158
2: 9.00	220	112	38	0.019	7: 11.10	220	135	84.0	0.0153
05	222	114	38	0.019	15	219	136	84.0	0.0153
10	218	114	38	0.019	20	221	136	84.0	0.0153
3: 9.20	220	114	49	0.0163	8: 11.30	220	138	92.0	0.0153
25	220	114	49	0.0163	35	218	140	92.0	0.0153
30	220	117	49	0.0163	40	221	140	92.0	0.0153
4: 9.40	220	117	56	0.016	9: 11.50	214	142	104.0	0.0160
45	220	117	56	0.016	55	180	144	104.0	0.0160
50	220	118	56	0.016	58	160	145	104.0	0.0160
5: 10.00	216	120	63	0.0157	10:1				
05	218	121	63	0.0157					
10	234	122	63	0.0157					

¹ Journal stopped at 11.58; pressure 6500 lbs.

This has brought about the idea of oil manufacturers employing practical and experienced men educated in actual service to follow up and watch the proper application and economic use of the various lubricating oils and greases. These men have demonstrated, not only to their employers, but also to the consumer, the practical and economic value of their educational work.

TABLE 5.—CONSTANT-TEMPERATURE TESTS, GALENA OIL TESTING MACHINE.

Comparative frictional tests between pure rape-seed oil and winter Galena railroad car oil (zero cold test oil).

Steel journal, size 5" X 9"; bearing, genuine babbitt; total load on bearing, 10,000 lbs.; projected area, 15.5 sq. in.

Area of contact, 16.40 sq. in.

Pressure per sq. in. projected area, 645 lbs.

Manner of lubrication, oil-bath.

300 revolutions per min. = 392.5 ft. surface speed, average friction of four tests for each temperature.

Rape-seed oil.		Winter Galena car oil.	
Total fric. in lbs.	Coef. of friction.	Total fric. in lbs.	Coef. of friction.
50° F.....21.06	0.00211	50° F....20.37	0.00205
70° F.....15.375	0.00154	70° F....14.54	0.00146
90° F.....13.875	0.00139	90° F....12.75	0.00128

600 revolutions per min. = 785 ft. surface speed, average friction of four tests for each temperature.

Rape-seed oil.		Winter Galena car oil.	
Total fric. in lbs.	Coef. of friction.	Total fric. in lbs.	Coef. of friction.
56° F.....26.25	0.00263	60° F....19.94	0.00199
70° F.....25.375	0.00254	70° F....18.31	0.00183
90° F.....19.75	0.00198	90° F....15.31	0.00153

Viscosity (P. R. R.):

Rape-seed oil.	Winter Galena car oil.
At 125° F.....80 units	72 units
100° F.....125 "	104 "
90° F.....141 "	125 "
80° F.....186 "	160 "
Cold test .....+15° F.	—5° F.

By constant temperature is meant that the oil-bath and bearing is kept at uniform constant temperature during the whole time of test, which lasts not less than one hour after the desired constant temperature of oil and bearing is reached.

The importance of this "following up" is far-reaching. It has gradually brought about much more systematic and uniform method or methods in lubrication, it has brought about greater economy in the consumption of lubricating oils, and at the same time demonstrated better lubrication; in fact, in many instances brought down the consumption of oil from 50 to 100 per cent., without impairment of the best and most economic lubrication. This, of course, means a saving of large sums of money by the consumers, and satisfaction to the company in the knowledge of giving its patrons the best possible service.

From these remarks, you will readily appreciate that to make laboratory tests of lubricants of real practical value, not only to the consumer but also to the manufacturer, involves considerable technical and practical knowledge and experience, besides full and complete laboratory equipment, and the chemist or engineer who is called upon to give a qualified opinion as to the relative, comparative lubricating values of two oils or greases for a given service, considered from

a practical and economical service standpoint, has indeed a difficult and oftentimes thankless task to perform.

TABLE 6.—CONSTANT-TEMPERATURE TESTS, GALENA OIL TESTING MACHINE.

Steel journal, 5" X 9"; bronze bearing; 7800 lbs. total load on bearing; 300 lbs. pressure per sq. in.; 27.7 sq. in. area of contact; 363 rev. per min. = 475 feet surface speed; manner of lubrication, oil-bath; average friction of four tests for each temperature.

	Galena winter car oil, lbs.		Galena summer car oil, lbs.	
Temp. 65° F.				
Friction, right.....	18.50	18.50	41.00	41.00
Friction, left.....	18.50	18.50	41.50	41.50
Friction, average.....	18.50		41.25	
Coef. of fric.....	0.00237		0.00529	
Mean resistance per sq. in. of surface.....	0.665 lb.		1.489 lbs.	
Temp. 80° F.				
Friction, right.....	15.50	15.00	29.50	28.50
Friction, left.....	15.00	15.00	30.25	29.50
Friction, average.....	15.125		29.44	
Coef. of fric.....	0.00196		0.00377	
Mean resistance per sq. in. of surface.....	0.546 lb.		1.063 lbs.	
Temp. 100° F.				
Friction, right.....	11.25	11.00	20.00	20.00
Friction, left.....	10.00	10.00	20.00	20.00
Friction, average.....	10.563		20.063	
Coef. of fric.....	0.00135		0.00257	
Mean resistance per sq. in. of surface.....	0.382 lb.		0.724 lb.	
The mean resistance per square inch of surface obtained by dividing the average total friction by the number of square inches (27.7) area of contact.				
	Galena winter car.		Galena summer car.	
Flashing point.....	315° F.		395° F.	
Burning point.....	370° F.		455° F.	
Gravity at 60° F.....	27.3° Bé.		24.3° Bé.	
Cold test.....	+2° F.		+36° F.	
Viscosity (P. R. R.):				
Pipette, at 125° F.	83 units		189 units	
100° F.	124 "		343 "	
90° F.	156 "		473 "	
80° F.	201 "		"	

METHODS OF ASPHALT EXAMINATION.

By ALBERT SOMMER.

Received March 16, 1910.

The present chemical knowledge of bituminous substances is undoubtedly most limited, and their practical chemistry is confined to the most rudimentary tests, basing on "rule of thumb" methods rather than on an exact system of chemical analysis. The lack of such scientific analytical methods has always been felt more or less keenly, but never more than at present.

The commercial importance of bituminous products has been vastly increased by the application of those materials to country roads, and the following discourse deals largely with asphaltic materials applicable for that purpose.

Bitumen available to-day for this purpose originates largely from the following sources: