A HANDBOOK

OF

Petroleum, Asphalt and Natural Gas

Methods of Analysis, Specifications, Properties, Refining Processes, Statistics, Tables and Bibliography

BY

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Published as

BULLETIN NO. 15

By

KANSAS CITY TESTING LABORATORY

1013 Grand Avenue, Kansas City, Mo.

1919

PREFACE

The purpose of this publication is to set forth in concise form for the petroleum producer, seller, refiner and technologist, scientific information and statistics on the production, properties, handling, refining and methods of valuation of petroleum and related products.

All matter formerly published in Bulletin No. 14 has been revised and included in this publication. In addition there has been added, fifty-five new illustrations, complete temperature-Baumé correction tables, extensive tank gauging tables, refinery engineering formulae, complete specifications for petroleum products, much additional data on oil cracking, geology, lubricants and asphalt, a complete set of methods of analysis of petroleum, asphalt and natural gas and a fairly complete bibliography.

The sources of original information have been from the research, commercial and engineering departments of the Kansas City Testing Laboratory and from the bibliography published at the end of the book.

November 1, 1919.
Kansas City, Missouri.

Publications of Kansas City Testing Laboratory on Petroleum and Related Products.

Bulletin No. 4. Asphalt and Asphalt Pavements. (Out of print.)

Bulletin No. 9. Petroleum and its Products. (Out of print.)

Bulletin No. 14. Petroleum, Asphalt and Natural Gas. 200 page book of Tables, Data and Statistics. $2.00 per copy, postpaid.

Bulletin No. 15. Handbook of Petroleum, Asphalt and Natural Gas. $5.00 per copy, postpaid.

CONTENTS.

(General outline only—see index for detailed subject matter.)

Value of Petroleum as a Mineral Product

On page 32 is a statement showing the value and amount of production of the most important marketed mineral products of the United States in 1918. An examination of this table, as well as other tables on this page, shows that petroleum in the United States in 1918 exceeded in value any of the metals except iron which it equalled in value and was greater than the combined value of gold, silver, copper, lead and zinc. Coal was the only mined product exceeding it in value.

The chief change in the demand for petroleum products has been its relative limitation as fuel for steam or stationary power plant purposes and its increase in use for lubrication and for automobile engines. However, nearly one-half of the consumption of petroleum is still due to its use as fuel. More than 100 million barrels of petroleum could, should and probably will eventually be replaced by coal. The U. S. Navy normally may be expected to consume at least six million barrels of fuel oil per year and there are some industries which require the flexibility of fuel oil and its low sulphur content with absence of ash. The price of coal must, in the long run, very largely govern the price of petroleum products as the demand for gasoline increases and gasoline must remain at the present or higher price. The governing factor in this situation has been the gasoline automobile. It is quite apparent that the point of saturation for automobiles has not been reached as is indicated by the following table showing the demand for gasoline.

Year	Automobiles	Gasoline	Per Cent from Crude Oil
1905	85,000	7,900,000	5.91
1910	400,000	14,750,000	7.04
1914	1,253,000	34,900,000	13.14
1916	2,225,000	49,020,000	19.85
1917	3,250,000	64,290,000	21.15
1918	4,500,000	86,561,150	26.07

The increase in automobiles must diminish or the increase in the percentage of gasoline obtainable from crude oil must continue.

During 1918 practically the entire increase in gasoline production was due to an additional production of cracked or artificial gasoline almost entirely from the Standard Oil Company. It is probable that the limit has been reached for the quality of gasoline as there has been no change in the past year. It does not seem probable that a satisfactory automobile engine will be worked out soon which will be capable of handling distillate mixed with gasoline as it seems that the increased efficiency by reason of cracking the heavy oil in the cracking plant or refinery easily offsets the lower price of distillate that might be used by cracking it in the automobile cylinder.

Wax and lubricants are the most valuable products of the refining of petroleum, both of which have shown very great increases in amount produced during the past year. For this purpose, however, the highest grades of petroleum are necessary and very elaborate and expensive refinery equipments are required for their production. It seems that Mexican and other high sulphur oils must, to a large extent, in the very near future be the source of fuel oils. When, however, natural petroleum has passed as a fuel a very abundant potential source of synthetic petroleum exists in the oil shales and cannel coal. The destructive distillation of oil shales yields fuel oil, lubricating oil, wax and illuminating oil. The very substantial yield of wax and lubricants particularly may stimulate an earlier development of the oil shale industry than might otherwise be expected.

The following outlines some of the uses of petroleum products:

Gasoline and Naphtha—Gas lighting, laboratory solvents, cleansing, gasoline stoves, automobiles, extraction of seed oils, metal polishes, gasoline engines, paint vehicles, asphalt paint and road binder solvent.

Kerosene and Illuminating Oils—Lamps, distillate engines, signal lights, gas washing and absorbents, portable stoves.

Gas Oil—Pintsch gas, Blaugas, town gas, straw oil, heating, cracking, anti-corrosives.

Heavy Distillates—Lubricants, spindle oil, auto oil, machine oil, engine oil, cylinder oil, greases, vaseline, wax, medicinal oil, waterproofing for fabrics, candles, soap filler, paints, polishes.

Liquid Residua—Steam production, heating, concrete waterproofing, road and macadam oils, dust prevention, cracking.

Semi-Solid Residua—Asphalt pavement, waterproofing, brick filler, roofing, rubber filler or substitute.

Crude Oils—Diesel engines, dust prevention, waterproofing.

Geological Occurrence of Petroleum and Natural Gas

The following summarizes the geological conditions under which petroleum and natural gas occur:

1. They occur in sedimentary rocks of all geologic ages from Silurian upward. The most productive areas are the Paleozoic in North America and the Miocene in Russia.

2. There is no relation of the occurrence of petroleum to volcanic or igneous action. There seems to be some relation particularly in the carboniferous and the Mississippian to the deposits of coal.

3. The most productive areas for oil in great quantity are where the strata are comparatively undisturbed. Oil frequently occurs where the strata are highly contorted and disturbed but in less abundance, and gas is usually absent.

4. In comparatively undisturbed as well as in disturbed areas a folded or dome structure often favors the accumulation of oil and gas in the domes or anticlines.

5. Important requisites for a productive oil or gas field are an impervious cap rock or cover and a porous reservoir.

6. Salt water almost universally accompanies oil and gas in the same sand.

In the United States, oil is found most abundantly in the Tertiary rocks in California and the Gulf Coast, in upper cretaceous in Wyoming, in carboniferous locally known as the Cherokee Shales in the Mid-Continent field, in the sub-carboniferous or Mississippian and the Upper Devonian in the Appalachian field and in Illinois, and in the Ordovician in Ohio and Indiana. The oils from the Tertiary are heavy and of low grade, those from the cretaceous, carboniferous and sub-carboniferous are light, high grade oils. The Mississippian in the Mid-Continent field is not supposed to carry any oil and very little is known of it or deeper strata in this territory. It is assumed that the deeper strata have vanished west of the Ozark uplift.

The accumulation of petroleum occurs in a pervious reservoir which usually consists of a loose sand though it may be a coarse gravel or a disrupted shale or limestone. It is merely necessary that the rock should contain a considerable amount of voids. The ordinary sand will have from 15 per cent to 35 per cent of voids and the amount of oil contained and the ease with which it is discharged into a well vary greatly. As a general rule, one gallon of oil may be obtained from one cubic foot of oil sand. It is probable that never over 75 per cent of the oil surrounding a well is discharged into it even with the lighter oils, and the per cent abstracted is much lower with the heavier and more viscous oils. Porous sand and gravel and heavy gas pressure are conducive to rapid expulsion of oil. Fine sand and low pressure give steadily producing wells of great longevity. The ultimate production of a well would be determined by the depth and extent of the sand, the physical character of the sand, the physical character of the oil and the pressure. Water is a very important element in the actual production of a well. It frequently causes very extensive subterranean oil movements destroying one productive structure and making new productive structures.

In nearly every oil sand there occur together, gas, oil and salt water. The gas invariably occupies the uppermost portion of the sand, the salt water, the bottom with the oil intermediate. The sand usually lies at the same angle or dip as the stratum in which it is contained, so that this fact forms the basis, to a great extent, of the geologist's work. It is to be noted that the surface topography has no relation to the probable location of oil or the dip or "strike" of the formation beneath the surface. Asphalt exposures are not good indications of oil in the immediate vicinity but indicate that oil may be found of good quality where this same geological structure is capped by an impervious cover. Anticlines bear no definite relation to surface topography, though the anticline is more likely to be found corresponding in a general way to the bottom of an old river or stream bed than corresponding to the divide between two streams.

Oil of good quality is usually found at sufficient depth that the lighter fractions have not evaporated, though some good wells are found at depths as shallow as 250 feet. The best wells of the Mid-Continent field vary from 1,000 to 3,500 feet in depth. The deepest well in the United States is the Lake Well in Harrison County, West Virginia, and is 7579 feet deep. Wells at Ranger, Texas, are about 3,400 feet deep. A well in Banner County, Nebraska, is 5,600 feet deep. Named in order of depth, the four deepest wells in the world are the Lake; the Goff, West Virginia, 7,386 feet, and a well at Czuchow, Germany, 7,348. In comparison with these great depths, other depths reached by wells or mines sunk in the crust of the earth are rather insignificant. The deepest mine in the world is Shaft No. 3 of the Tamarack mine, in Houghton County, Michigan, which has reached a depth of 5,200 feet.

The preponderance of evidence points to the theory that the greater part of petroleum has been produced from organic matter of any kind undergoing decomposition, followed by its segregation by the action of water and accumulation in pervious rocks of the oil produced. Other theories are that oil originated from animal matter and also that it came from the reaction of metallic carbides at high pressure with water.

A demonstration as to the origin of petroleum hydrocarbons is very readily made by the use of the cracking test described on page 319. By heating corn oil, cottonseed oil or other vegetable or animal oil a product is made which is identical in boiling point range with that of ordinary crude oil though it contains a rather large amount of volatile fatty acids. An almost exact duplication of crude petroleum oil can be produced with this apparatus by placing lime in the receptacle with the vegetable oil. In this case the light distillate is almost entirely composed of paraffin hydrocarbons.

TEMPERATURE IN WELLS (WEST VIRGINIA)

100 feet	55.6°
1,000 feet	65.3°
2,000 feet	74.9°
3,000 feet	87.6°
5,000 feet	114.2°
6,000 feet	132.1°
7,000 feet	153.2°
7,310 feet	158.3°

The rate of temperature increase varies continuously from 1 degree Fahr. in 97.5 feet at the surface to 1 degree Fahr. in 46.5 feet over the interval 6,000 to 7,000 feet. In the Texas and Oklahoma oil fields temperatures at a given depth differ widely from those found in Pennsylvania and West Virginia. The temperature of the oil in two wells near Mannington, W. Va., is 83.2 degrees Fahr. at a depth of about 2,900 feet. In the Ranger field, Texas, the temperature of the oil at 3,400 feet is estimated, from measurements at higher levels, to be about 135 degrees. The average rate of temperature increase at the surface for thirteen wells in Texas and Oklahoma is about 1 degree Fahr. in 51 feet, as compared with 1 degree in 91.5 feet for twelve wells in Pennsylvania and West Virginia.

SUMMARIZED TABLE OF OIL OCCURRENCES IN THE UNITED STATES

Field	Structure	Geologic Age	Kind of Rock	Kind of Petroleum
Appalachian or Eastern	Geo-Syncline with subordinate anticlines	Ordovician to Carboniferous	Sandstone	Paraffin base
Ohio-Indiana	Anticlines	Ordovician	Mostly limestone	Paraffin base
Illinois	Low anticlines	Carboniferous	Sandstone	Paraffin and semi-paraffin base
Mid-Continent	Anticlines	Carboniferous	Sandstone	Paraffin semi-paraffin base
Wyoming	Folds	Carboniferous to Tertiary	Mostly sandstone	Paraffin and asphalt base
Gulf Coast	Domes	Tertiary and Cretaceous	Dolomite and sandstone	Asphalt base
California	Folds and Faults	Tertiary	Sandstone, shales and conglomerates	Asphalt base
Mexico	....	Tertiary	....	Asphalt base

TYPICAL COMPOSITION OF "MISSISSIPPI LIME" AT TOP

(From Wilson County, Kansas)

Carbon dioxide	32.0%
Silica + Insoluble	20.5%
Iron and Alumina (R_2O_3)	3.3%
Lime (CaO)	23.4%
Magnesia (MgO)	11.8%

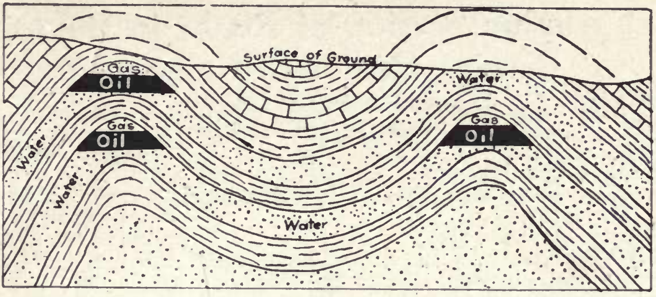


Diagram representing the accumulation of oil and gas in anticlines.

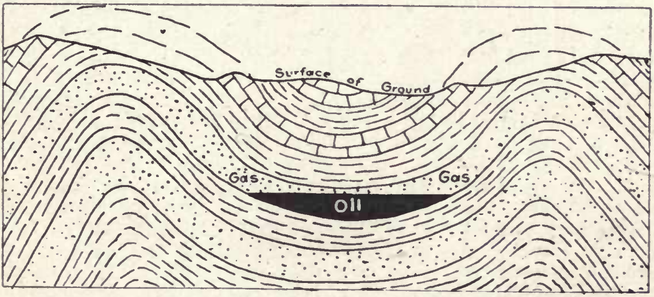
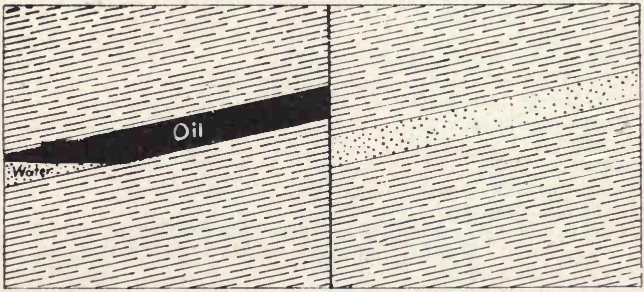


Diagram showing the accumulation of oil in a syncline in the absence of water



Ideal section showing an oil sand faulted in such a manner that an accumulation of oil will result

Stratigraphic Section of Rocks in the Oil-Bearing Region of Kansas

(Kansas Geological Survey)

PERMIAN SERIES

	Thickness
Wellington Formation—	
Sandstone, limestone, shale, salt and gypsum	400-600
Marion Formation—	
Abilene Conglomerate	25-50
Pearl Shale	55-75
Herington Limestone	12-15
Enterprise Shale	30-50
Luta Limestone	20-40
Chase Formation—	
Winfield Limestone	20-25
Doyle Shale	50-70
Fort Riley Limestone	40-45
Florence Flint	15-25
Matfield Shale	60-70
Wreford Limestone	35-50
Council Grove Formation—	
Garrison Limestone and Shale	135-150
Cottonwood Limestone	5-7

PENNSYLVANIAN SERIES

Wabaunsee Formation—	
Eskridge Shale	30-40
Neva Limestone	3-5
Elmdale Shale	120-140
Americus Limestone	6-10
Admire Shale, possibly contains shallow oil sand at Eldorado	275-325
Emporia Limestone	5-10
Willard Shale	45-55
Burlingame Limestone	7-12
Shawnee Formation—	
Scranton Shale	160-200
Howard Limestone	3-7
Severy Shale	40-60
Topeka Limestone	20-25
Calhoun Shale	0-50
Deer Creek Limestone	20-30
Tecumseh Shale	40-70
Lecompton Limestone	15-30
Kanawha Shale	50-100
Douglas Formation—	
Oread Limestone	50-70
Lawrence Shale, including Chautauqua Sandstone member, probably 1,500 feet sand at Augusta and Eldorado	150-300
Iatan Limestone	3-15
Weston Shale	60-100

PENNSYLVANIAN SERIES—Continued

	Thickness
Lansing Formation—	
Stanton Limestone	20-40
Vilas Shale	5-125
Plattsburg Limestone	5-80
Lane Shale	50-150
Kansas City Formation—	
Iola Limestone	2-40
Chanute Shale	25-100
Drum Limestone	0-30
Cherryvale Shale—possibly horizon of oil sand at 2,400 feet at Augusta and Eldorado	25-125
Winterset Limestone	30-40
Galesburg Shale	10-60
Bethany Falls Limestone	4-25
Ladore Shale	3-50
Hertha Limestone	10-20
Marmaton Formation—	
Pleasanton Shale	100-150
Coffeyville Limestone	8-10
Walnut Shale	60-80
Altamont Limestone	3-10
Bandera Shale	60-120
Pawnee Limestone (Big Lime)	40-50
Labette Shale (Horizon Peru Oil Sand)	0-60
Fort Scott (Oswego) Limestone	20-40
Cherokee Formation—	
Cherokee Shale—includes the main oil sands outside Augusta and Eldorado and Peru—contains Bartlesville and Burgess sands	400-500
Mississippian Limestone—	
Limestone, calcareous shale and chert shown in Neosho well—Boone Formation	320
Probably Older than Mississippian—	
1—Dolomitic limestone, sandstone and chert shown in Neosho well	77
2—Conglomerate and shale in Neosho well	23
3—Sandstone, conglomerate with pebbles up to three-quarters inch diameter; shown in Neosho well	1823

Stratigraphic Section in Main Oil and Gas District of Northern Oklahoma

(Oklahoma Geological Survey and Other Sources)

PERMIAN SERIES

	Thickness Feet
1—Red and gray sandstone, clay-iron conglomerates, red and vari-colored shale, thin beds of concretionary limestone near base, beds of gypsum and salt in the upper portion. Quartermaster, Greer, Woodward, Blaine and upper portions of Enid formations.	1200-2000
2—Beds of thin limestone, sandstone and shale. Contains near base the shallow gas sands at Blackwell, Billings and Garber.	500-600

PENNSYLVANIAN SERIES

Ralston Group—	
Consists of red and gray sandstone, red shale and beds of thin limestone. Contains the Hoy oil sand at Garber.	
1—Upper division down to Pawhuska limestone, inclusive	650
2—Lower division down to Elgin sandstone.	140
Sapulpa Group—	
1—Elgin Sandstone. Probable horizon of shallow oil sand in the Newkirk field and at Ponca City.	20-150
2—Oread Limestone.	0-20
3—Buxton Sandstone and Shale. Horizon of main oil sand at Ponca City and gas at Myers.	700-1000
4—Avant Limestone.	0-10
5—Ramona formation. Sandstone, shale and thin limestone beds. Includes Lost City limestone and the Musselman oil sands of the Cushing-Cleveland areas.	300-400
6—Dewey Limestone.	15-25
7—Skiatook formation. Sandstone, shale and thin limestone beds. Includes Hogshooter limestone and Layton oil sand.	350-400
8—Lenapah Limestone.	10-20
Tulsa Group—	
1—Nowata Shale—includes the Wayside oil sand and its correlations (local coal bed, Dawson coal).	75-150
2—Oolagah Limestone or "Big Lime" of the drillers.	20-50
3—Labette Shale. Sandstone, shale and beds of thin limestone. Includes the Cleveland and Peru oil sands.	250-300
4—Oswego Limestone (Fort Scott)	25-100

	Thickness Feet
Muskogee Group—	
Beds of shale, sandstone and thin limestone correlating with the Cherokee shale (Boggy and Winslow formations at Muskogee). Includes the main oil sands of Oklahoma, the Red Fork, Bartlesville, (Glenn), Tucker, Taneha, Booch, Morris and Muskogee sands, the latter lying at the unconformable base of the Pennsylvania series.................	450-1500
(Unconformity)	

MISSISSIPPIAN SERIES

1—Morrow Limestone.	100-200
(Unconformity)	
2—Pitkin Limestone.	40-60
3—Fayetteville formation. Sandstone, shale and limestone contains the Mounds oil sand and a deep sand near Sapulpa.	20-200
(Unconformity)	
4—Boone formation. Massive white limestone and massive beds of chert.	200-400

DEVONIAN SYSTEM

1—Chattanooga formation. Black fissile shale.........	30-50
2—Sylamore sandstone, clear quartz sandstone........	0-25
(Unconformity)	

ORDIVICIAN SYSTEM

1—Turner formation. Thin sandstone and limestone in shale.	60-100
2—Burgen (St. Peter) sandstone, massive quartz sandstone.	5-100

CAMBRIAN SYSTEM

Massive limestone beds shown in Harrington well at Joplin, Mo.	1165

World's Production of Petroleum

Country	Total Production 1857 to 1917		Production 1916		Production 1917		Production 1918	
	Barrels	Per Cent	Barrels	Per Cent	Barrels	Per Cent	Barrels	Per Cent
United States	4,252,644,003	60.89	300,767,158	65.29	335,315,601	66.98	345,500,000	66.94
Russia	1,832,583,017	26.24	72,801,110	15.81	69,000,000	13.78	65,000,000	12.59
Mexico	222,082,472	3.18	39,817,402	8.64	55,292,770	11.04	64,605,422	12.52
Dutch East Indies	175,103,267	2.51	13,174,399	2.86	12,928,955	2.58	13,000,000	2.52
Roumania	142,992,465	2.05	10,298,208	2.24	2,681,870	.54	2,900,000	0.56
India	98,583,522	2.41	8,228,571	1.79	8,500,000	1.70	8,500,000	1.65
Galicia	148,459,653	2.13	6,461,706	1.40	5,965,447	1.19	6,000,000	1.16
Japan and Formosa	36,065,454	.52	2,997,178	0.65	2,898,654	.58	2,750,000	0.53
Peru	21,878,285	.31	2,550,645	0.55	2,533,417	.51	2,500,000	0.48
Trinidad	5,418,885	.08	1,000,000	0.22	1,599,455	.32	1,600,000	0.31
Germany	15,952,861	2.30	995,764	0.22	995,764	.20	1,000,000	0.19
Argentina	3,047,858	0.04	870,000	0.19	1,144,737	.23	1,000,000	0.19
Egypt	2,768,686	.04	411,000	0.09	1,008,750	.20	1,000,000	0.19
Canada	24,112,529	3.50	198,123	0.04	205,332	.04	300,000	0.06
Italy	947,289	.01	43,143	0.01	50,334	.01	50,000	0.01
Other countries	927,000	.01	25,000	0.01	530,000	.10	500,000	0.10
	6,983,567,246	100.00	460,639,407	100.00	500,651,086	100.00	516,205,422	100.00

PETROLEUM PRODUCTION BY STATES.

State	1915	1916	1917	1918
Oklahoma.	97,915,243	111,000,000	97,600,000	84,950,300
California.	86,591,535	92,000,000	97,000,000	101,493,000
Texas.	17,467,598	26,000,000	30,000,000	42,000,000
Illinois.	19,041,695	16,500,000	11,000,000	11,000,000
Louisiana.	18,191,539	17,000,000	15,000,000	15,900,000
West Virginia.	9,264,798	8,500,000	8,000,000	8,000,000
Pennsylvania.	7,838,705	8,000,000	8,000,000	8,000,000
Ohio.	7,825,325	7,400,000	7,000,000	8,000,000
Kansas.	2,823,487	11,500,000	38,000,000	43,253,470
Wyoming-Montana.	4,245,525	6,300,000	10,000,000	13,815,000
Kentucky.	437,274	1,200,000	4,000,000	7,000,000
Indiana.	875,758	1,000,000	1,000,000	1,000,000
New York.	887,778	900,000	900,000	900,000
Colorado.	208,475	190,000	200,000	200,000
Other States.	14,262	10,000	10,000	10,000
	281,104,104	307,500,000	327,610,000	345,521,770

PRODUCTION OF PETROLEUM BY DISTRICTS

Field	1917	1918
Appalachian.	24,932,205	25,300,000
Lima-Indiana.	3,670,293	3,100,000
Illinois.	15,776,360	13,300,000
Oklahoma-Kansas.	155,043,596	139,600,000
Central and Northern Texas.	10,900,646	15,600,000
North Louisiana.	8,561,963	13,000,000
Gulf Coast.	26,087,587	21,700,000
Rocky Mountain.	9,199,310	12,600,000
California.	93,877,549	101,300,000
Alaska and Michigan.	10,300	. . . .
Totals.	335,315,601	345,500,000

SOURCES OF CRUDE OIL IN THE UNITED STATES IN 1918

	Barrels
Produced in the United States.	339,400,000
Drawn from stocks.	27,000,000
Imported (Mexico).	37,735,000
Total.	404,135,000

DISPOSITION OF CRUDE OIL IN U. S. IN 1918

	Barrels
Total amount refined.	326,024,630
Exported.	4,900,000
Unrefined sold as fuel and road oil.	73,210,370
	404,135,000

PETROLEUM MARKETED IN THE UNITED

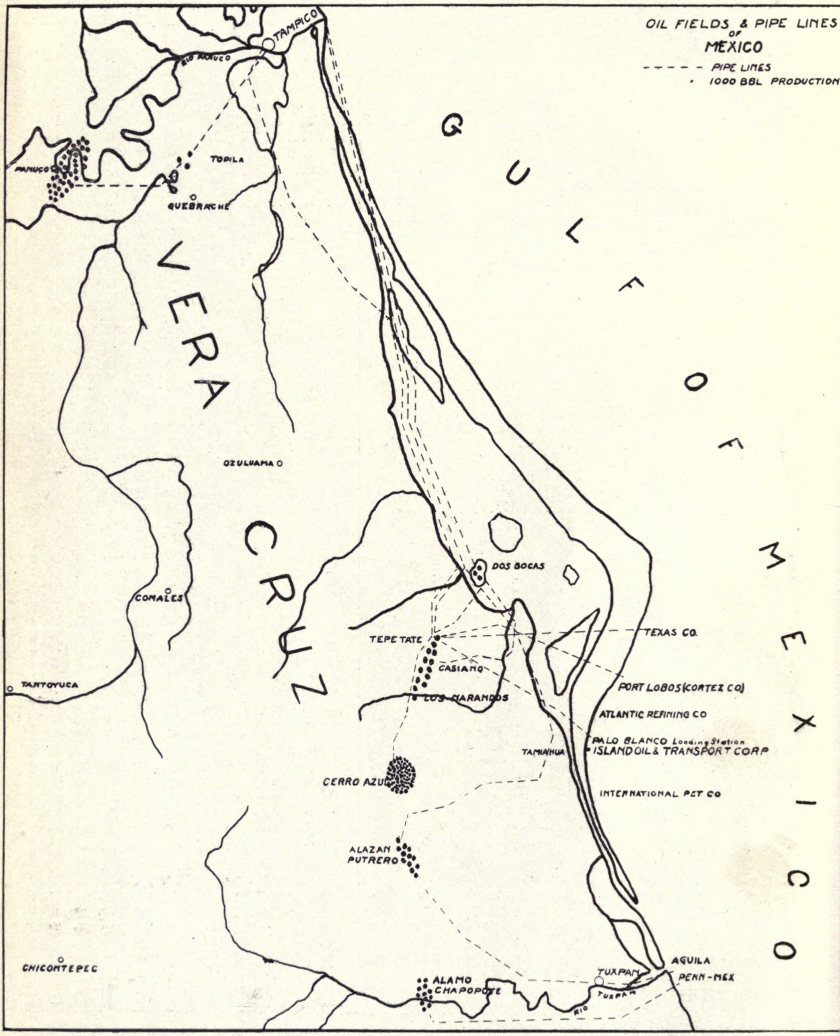
Year	Pennsylvania and New York	Ohio	West Virginia	California	Kentucky and Tennessee	Colorado	Indiana	Illinois
	Barrels	Barrels	Barrels	Barrels	Barrels	Barrels	Barrels	Barrels
1859	2,000	....	....	....	....	....	....	....
1860	500,000	....	....	....	....	....	....	....
1861	2,113,609	....	....	....	....	....	....	....
1862	3,056,690	....	....	....	....	....	....	....
1863	2,611.309	....	....	....	....	....	....	....
1864	2,116,109	....	....	....	....	....	....	....
1865	2,497.700	....	....	....	....	....	....	....
1866	3,597,700	....	....	....	....	....	....	....
1867	3,347,300	....	....	....	....	....	....	....
1868	3,646,117	....	....	....	....	....	....	....
1869	4,215,000	....	....	....	....	....	....	....
1870	5,260,745	....	....	....	....	....	....	....
1871	5.205,234	....	....	....	....	....	....	....
1872	6,293.194	....	....	....	....	....	....	....
1873	9.893,786	....	....	....	....	....	....	....
1874	10,926,945	....	....	....	....	....	....	....
1875	8,787,514	....	....	....	....	....	....	....
1876	8.968.906	31,763	120,000	12,000	....	....	....	....
1877	13,135,475	29,888	172,000	13,000	....	....	....	....
1878	15,163.462	38,179	180,000	15,227	....	....	....	....
1879	19,685,176	29,112	180,000	19,858	....	....	....	....
1880	26,027,631	38,940	179,000	40,552	....	....	....	....
1881	27.376,509	33,867	151,000	99,862	....	....	....	....
1882	30,053,500	39,761	128,000	128,636	....	....	....	....
1883	23,128,389	47,632	126,000	142,857	4,755	....	....	....
1884	23,772,209	90,081	90,000	262.000	4.148	....	....	....
1885	20,776,401	661,580	91,000	325,000	5,164	....	....	....
1886	25,798,000	1,782,970	102,000	377,145	4.726	....	....	....
1887	22,356,193	5,022,632	145,000	678,572	4.791	76,295	....	....
1888	16,488,668	10,010.868	119,448	690,333	5 096	297,612	....	....
1889	21,487,435	12,471,466	544,113	303,220	5,400	316,476	33,375	1,
1890	28,458,208	16,124,656	492,578	307,360	6,000	368,842	63,496	[illegible]
1891	33.009,236	17,740,301	2,406,218	323,600	9,000	665,482	136,634	6..
1892	28,422,377	16,362,921	3,810,086	385,049	6,500	824,000	698 068	521
1893	20.314,513	16,249,769	8,445.412	470,179	3,000	594,390	2,335,293	400
1894	19,019,990	16,792,154	8,577,624	705,969	1,500	515,746	3,688,666	300
1895	19,144,390	19,545,233	8,120,125	1,208,482	1,500	438,232	4,386,132	200
1896	20,584,421	23,941,169	10,019,770	1,252,777	1,680	361,450	4,680,732	250
1897	19,262,066	21,560,515	13,090,045	1,903,411	322	384,934	4,122,356	500
1898	15,948,464	18,738,708	13,615,101	2,257,207	5,568	444,383	3,730,907	360
1899	14,374,512	21,142,108	13,910,630	2,642,095	18,280	390,278	3,848,182	360
1900	14,559,127	22,362,730	16,195,675	4,324,484	62,259	317,385	4,874.392	200
1901	13,831,996	21,648,083	14,177,126	8,786,330	137,259	460,520	5,757,086	250
1902	13,183,610	21,014,231	13,513,345	13,984,268	185,331	396,901	7,480,896	200
1903	12,518,134	20,480,286	12,899,395	24,382,472	554,286	483,925	9,186,411	....
1904	12,239,026	18,876,631	12,644,686	29,649,434	998,284	501,763	11,339,124	....
1905	11,554,777	16,346,600	11,578,110	33,427,473	1,217,337	376,238	10,964,247	181,084
1906	11,500,410	14,787,763	10,120,935	33,098,598	1,213,548	327,582	7,673,477	4,397,050
1907	11,211,606	12,207,448	9,095,296	39,748,375	820,844	331,851	5.128,037	24,281,973
1908	10.584,453	10,858,797	9,523,176	44,854,737	f727,767	379,653	3,283,629	33,686,238
1909	10,434,300	10,632,793	10,745.092	55,471,601	f639,016	310,861	2,296,086	30,898,339
1910	9,848,500	9,916,370	11,753,071	73,010,560	f468,774	239,794	2,159,725	33,143,362
1911	9,200,673	8,817,112	9,795,464	81,134,391	f472,458	226,926	1,695,289	31,317,038
1912	8,712,076	a8,969,007	12,128,962	g87,272,593	f484,368	206,052	970,009	28,601,308
1913	8,865,493	8,781,468	11,567,299	97,788,525	f524,568	188,799	956,095	23.893,899
1914	9,109,309	8,536,352	9,680,033	99,775,327	502,441	222,773	1,335,456	21,919,749
1915	8,726,483	7,825,326	9,264,798	86,591,535	f437,274	208,475	875,758	19,041,695
	762,906,696	440,587,330	269,497,613	827,865,091	9,533.214	10,857,618	103,699,558	251,368,311

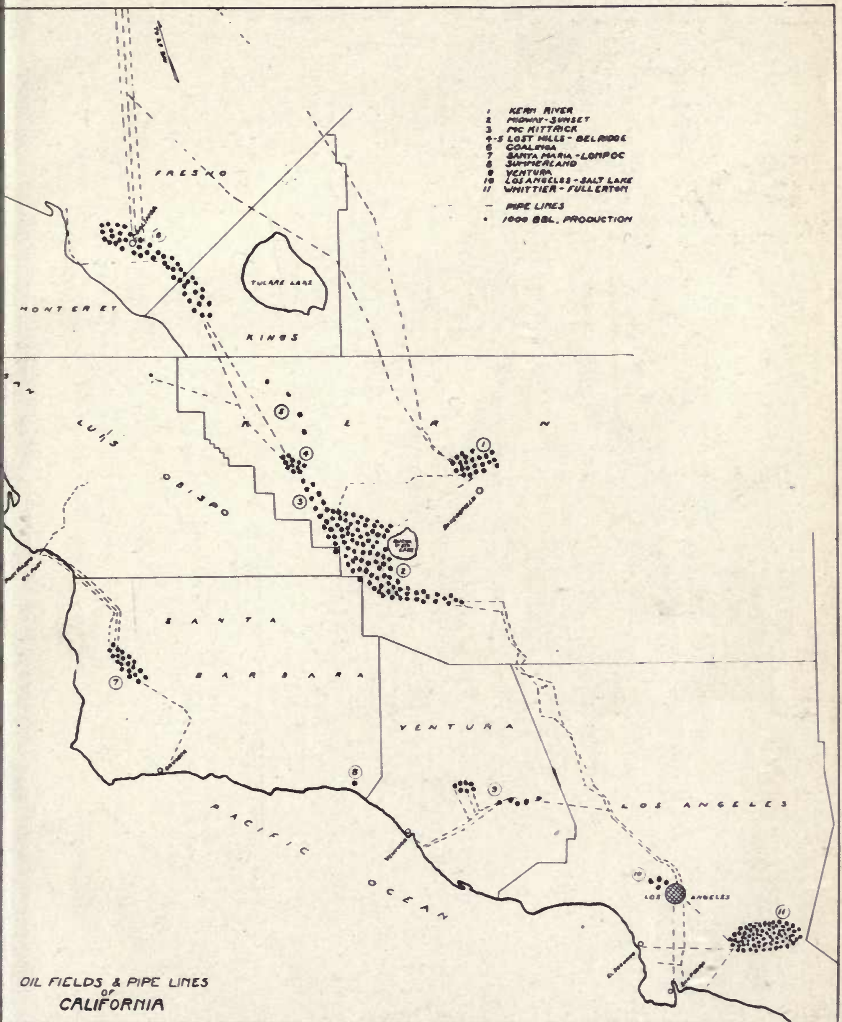
a Includes the production of Michigan.
b Includes the production of Oklahoma.
c Included with Kansas.
d Estimated.
e Includes production of Utah.

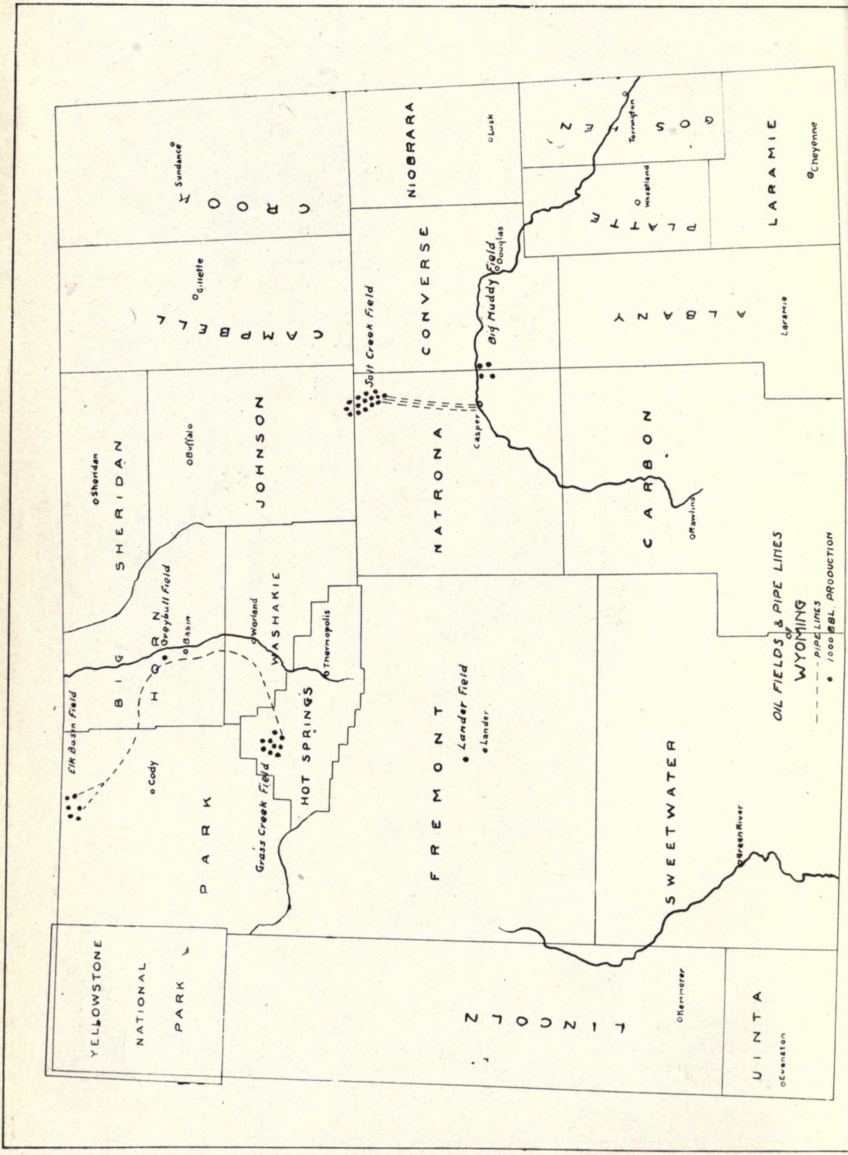
STATES, 1859-1915 (in 42-Gal. Bbls.)

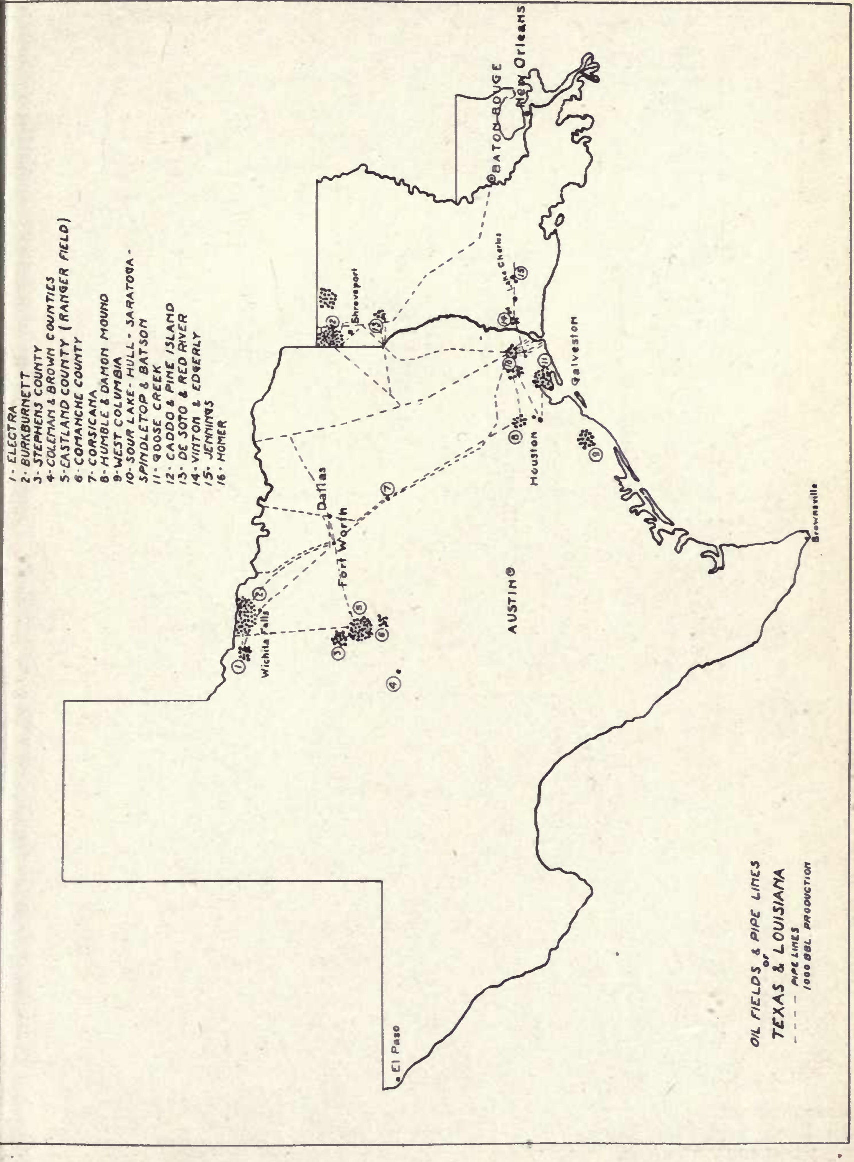
Kansas	Texas	Missouri	Oklahoma	Wyoming	Louisiana	United States	Total Value	Year
Barrels	Barrels	Barrels	Barrels	Barrels	Barrels	Barrels		
....	....	....	....	....	....	2,000	$32,000	1859
....	....	....	....	....	....	500,000	4,800,000	1860
....	....	....	....	....	....	2,113,609	1,035,668	1861
....	....	....	....	....	....	3,056,690	3,209,525	1862
....	....	....	....	....	....	2,611,309	8,225,663	1863
....	....	....	....	....	....	2,116,109	20,896,576	1864
....	....	....	....	....	....	2,497,700	16,459,853	1865
....	....	....	....	....	....	3,597,700	13,455,398	1866
....	....	....	....	....	....	3,347,300	8,066,993	1867
....	....	....	....	....	....	3,646,117	13,217,174	1868
....	....	....	....	....	....	4,215,000	23,730,450	1869
....	....	....	....	....	....	5,260,745	20,503,754	1870
....	....	....	....	....	....	5,205.234	22,591,180	1871
....	....	....	....	....	....	6,293,194	21,440,503	1872
....	....	....	....	....	....	9,893,786	18,100,464	1873
....	....	....	....	....	....	10,926,945	12,647,527	1874
....	....	....	....	....	....	8,787,514	7,368,133	1875
....	....	....	....	....	....	9,132,669	22,982,822	1876
....	....	....	....	....	....	13,350,363	31,788.566	1877
....	....	....	....	....	....	15.396,868	18,044,520	1878
....	....	....	....	....	....	19,914.146	17,210,708	1879
....	....	....	....	....	....	26,286,123	24,600,638	1880
....	....	....	....	....	....	27.661,238	25,448,339	1881
....	....	....	....	....	....	30,349,897	23,631,165	1882
....	....	....	....	....	....	23.449,633	25.790,252	1883
....	....	....	....	....	....	24,218,438	20,595,966	1884
....	....	....	....	....	....	21,858,785	19,198,243	1885
....	....	....	....	....	....	28.064,841	19,996,313	1886
....	....	....	....	....	....	28,283.483	18,877,094	1887
....	....	....	....	....	....	27,612,025	17,947,620	1888
500	48	20	....	....	....	35.163,513	26,963,340	1889
1,200	54	278	....	....	....	45,823,572	35,365,105	1890
1,400	54	25	30	....	....	54,292,655	30 526,553	1891
5,000	45	10	80	....	....	50,514,657	25,906,463	1892
18,000	50	50	10	....	....	48,431,066	28,950,326	1893
40,000	60	8	130	2,369	....	49,344,516	35,522,095	1894
44.430	50	10	37	3,455	....	52,892,276	57,632,296	1895
113,571	1,450	43	170	2.878	....	60,960,361	58,518,709	1896
81,098	65,975	19	625	3,650	....	60,475,516	40,874,072	1897
71 980	546,070	10	....	5,475	....	55,364,233	44,193.359	1898
69,700	669.013	132	....	5.560	....	57,070,850	64 603,904	1899
74,714	836,039	a1,602	6,472	5.450	....	63,620,529	75,989,313	1900
179,151	4,393,658	a2,335	10,000	5,400	....	69,389,194	66,417.335	1901
331,749	18.083,658	a757	37,100	6,253	548.617	88,766,916	71,178,910	1902
932,214	17,955,572	a3,000	138,911	8,960	917.771	100,461,337	94,694,050	1903
4,250,779	22,241,413	a2,572	1,366,748	11,542	2,958,958	117,080,960	101,175,455	1904
b12 013,495	28,136,189	a3,100	(c)	8,454	8,910,416	134,717,580	84,157,399	1905
b21.718.648	12,567,897	a3,500	(c)	d7,000	9.077,528	126,493 936	92,444,735	1906
2,409,521	12,332,696	a4,000	43,524,128	e9,339	5 000.221	166,095,335	120,106,749	1907
1,801 781	11,206,464	a15,246	45,798.765	e17.775	5,788 874	178,527,355	129,079,184	1908
1,263,764	9,534,467	a5,750	47,859,218	e20.056	3 059,531	183,170,874	128,328,487	1909
1,128,669	8,899,266	a3,615	52,028,718	e115,430	6,841,395	209,557,248	127,899,688	1910
1,278,819	9,526,474	a7,995	56,069,637	e186,695	10,720,420	220.449,391	134,044.752	1911
1,592.796	11,735,057	(h)	51,427,071	1,572,306	9,263.439	222,935 044	164,213,247	1912
2,375,029	15,009,478	i10,843	63,579,384	2,406,522	12.498 828	248,446,230	237,121,388	1913
3,103,585	20,068,184	j7,792	73,631,724	3,560,375	14 309,435	265,762,535	214,125,215	1914
2,823,487	24,942,701	j14,265	97,915,243	4,245,525	18,191,539	281,104,104	179,462,890	1915
57,725 079	228,742,082	86,977	533,394,201	12,210,469	108,086,972	3616561,244	2971388,126	

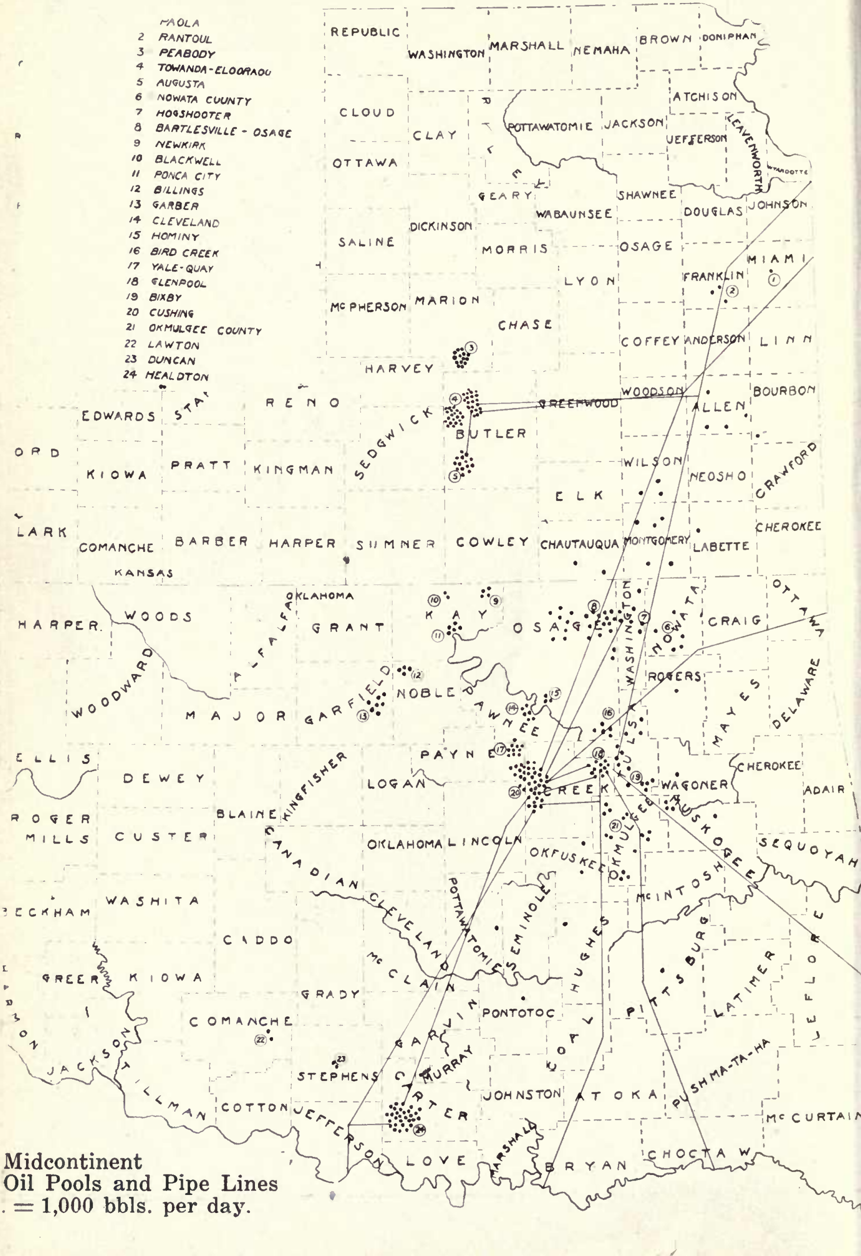
f No production in Tennessee recorded.
g Includes small production of Alaska.
h No production in Missouri; Michigan included in Ohio.
i Includes production of Alaska, Michigan and New Mexico.
j Includes production of Alaska and Michigan.


OIL FIELDS & PIPE LINES OF MEXICO
PIPE LINES
1000 BBL PRODUCTION
GULF OF MEXICO
VERA CRUZ
TAMPICO
RIO PANUCO
PANUCO
TOPILA
QUEBRACHE
OZULUAMA
CONALES
TANTOYUCA
CHICONTEPEC
DOS BOCAS
TEPETATE
CASIANO
LOS NARANJOS
CERRO AZUL
ALAZAN
PUTRERO
ALAMO
CHAPOPOTE
TAMIAHUA
TEXAS CO.
PORT LOBOS (CORTEZ CO)
ATLANTIC REFINING CO
PALO BLANCO Loading Station
ISLAND OIL & TRANSPORT CORP
INTERNATIONAL PET CO
TUXPAN
RIO TUXPAN
AGUILA
PENN-MEX

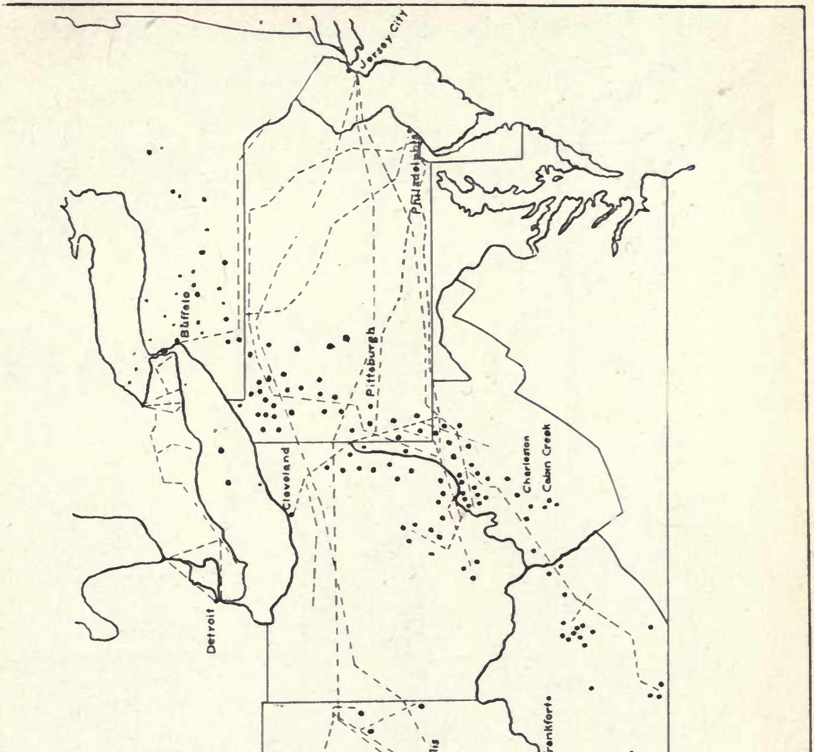

1 KERN RIVER
2 MIDWAY-SUNSET
3 MC KITTRICK
4-5 LOST HILLS - BELRIDGE
6 COALINGA
7 SANTA MARIA - LOMPOC
8 SUMMERLAND
9 VENTURA
10 LOS ANGELES - SALT LAKE
11 WHITTIER - FULLERTON
— PIPE LINES
• 1000 BBL. PRODUCTION
FRESNO
TULARE LAKE
MONTEREY
KINGS
SAN LUIS OBISPO
KERN
SANTA BARBARA
VENTURA
LOS ANGELES
PACIFIC OCEAN
OIL FIELDS & PIPE LINES OF CALIFORNIA


OIL FIELDS & PIPE LINES OF WYOMING
- - - PIPE LINES
• 1000 BBL. PRODUCTION
YELLOWSTONE NATIONAL PARK
PARK
BIG HORN
SHERIDAN
JOHNSON
CAMPBELL
CROOK
WASHAKIE
HOT SPRINGS
FREMONT
NATRONA
CONVERSE
NIOBRARA
GOSHEN
PLATTE
LARAMIE
ALBANY
CARBON
SWEETWATER
LINCOLN
UINTA
Elk Basin Field
Greybull Field
Grass Creek Field
Lander Field
Salt Creek Field
Big Muddy Field
Cody
Basin
Worland
Thermopolis
Sheridan
Buffalo
Gillette
Sundance
Lander
Casper
Douglas
Lusk
Torrington
Wheatland
Cheyenne
Laramie
Rawlins
Green River
Kemmerer
Evanston


OIL FIELDS & PIPE LINES OF TEXAS & LOUISIANA
PIPE LINES
1000 BBL PRODUCTION
1 - ELECTRA
2 - BURKBURNETT
3 - STEPHENS COUNTY
4 - COLEMAN & BROWN COUNTIES
5 - EASTLAND COUNTY (RANGER FIELD)
6 - COMANCHE COUNTY
7 - CORSICANA
8 - HUMBLE & DAMON MOUND
9 - WEST COLUMBIA
10 - SOUR LAKE - HULL - SARATOGA - SPINDLETOP & BATSON
11 - GOOSE CREEK
12 - CADDO & PINE ISLAND
13 - DE SOTO & RED RIVER
14 - VINTON & EDGERLY
15 - JENNINGS
16 - HOMER
Wichita Falls
Fort Worth
Dallas
Shreveport
AUSTIN
Houston
Galveston
Lake Charles
BATON ROUGE
New Orleans
Brownsville
El Paso



Midcontinent
Oil Pools and Pipe Lines
. = 1,000 bbls. per day.


Jersey City
Philadelphia
Pittsburgh
Buffalo
Cleveland
Detroit
Charleston
Cabin Creek
Frankfort
Indianapolis
Chicago
St. Louis
OIL FIELDS & PIPE LINES OF THE EASTERN STATES
PIPE LINES
1000 BBL. PRODUCTION

IMPORTANT PETROLEUM FIELDS
Eastern or Appalachian
Ohio-Indiana
Kentucky
Illinois
N. La Caddo
Texas Pan-Handle
Gulf Coastal
Mid-Continent Field
Wyoming Field
California Field

Production of Natural Gas-Gasoline in 1917

By Compression and by Vacuum Pumps

State	No.	Gasoline Produced, Quantity, Gallons	Gas Used, Estimated Volume M Cu. Ft.	Avg. Yield of Gasoline per M Cu. Ft. Gallons
Oklahoma	207	108,728,213	36,399,280	2.987
California	40	23,478,521	27,477,443	0.854
West Virginia	159	12,276,784	4,845,648	2.534
Pennsylvania	234	9,011,199	3,572,356	2.522
Louisiana	18	4,459,920	1,468,346	3.037
Illinois	54	4,268,158	2,020,044	2.113
Texas	9	3,997,337	2,685,316	1.489
Ohio	54	2,331,498	836,639	2.788
New York	5	....	....	.....
Kansas	1	....	....	.....
Kentucky	3	369,925	150,784	2.453
Colorado	1	....	....	.....
Totals	785	168,921,555	79,455,856	2.126

By Absorption

State	No.	Gasoline Produced, Quantity, Gallons	Gas Used, Estimated Volume M Cu. Ft.	Avg. Yield of Gasoline per M Cu. Ft. Gallons
West Virginia	29	20,391,863	163,925,703	0.125
Oklahoma	27	6,395,211	48,320,661	0.132
California	9	5,339,083	17,873,804	0.299
Pennsylvania	17	4,815,051	45,914,700	0.105
Kentucky	2	3,725,893	24,871,590	0.150
Ohio	7	3,108,062	29,225,502	0.106
Texas	3	2,978,068	10,010,233	0.298
Kansas	5	1,071,633	9,274,289	0.116
Illinois	1	665,851	665,851	1.000
Louisiana	2	519,834	675,165	0.770
New York	..	7,000	2,776	.....
Colorado	..	....	....	.....
Totals	102	49,017,549	349,760,274	0.140

TOTAL GASOLINE FROM NATURAL GAS MARKETED IN THE UNITED STATES IN 1917

State	No. Plants	Daily Capacity Gallons	Quantity Gallons	Price per Gallon Cents	Average Yield of Gasoline M Cu. Ft. Gas Gals.
Oklahoma	234	492,436	115,123,424	18.71	1.359
West Virginia	188	135,663	32,668,647	19.93	0.195
California	49	99,761	28,817,604	15.40	0.635
Pennsylvania	251	59,164	13,826,250	20.01	0.279
Texas	11	32,550	6,920,405	16.61	0.546
Ohio	61	25,137	5,489,560	19.38	0.181
Louisiana	20	20,118	4,979,754	16.36	2.323
Illinois	55	17,302	4,934,009	17.55	1.837
Kentucky	5	13,400	3,818,209	19.99	0.153
Kansas	6	4,642	1,174,980	20.53	0.126
New York	...	......	....	.....	.....
Colorado	6	2,122	181,262	18.27	2.659
Totals	886	902,385	217,884,104	18.45	0.508

CASINGHEAD GASOLINE INDUSTRY

The growth of the casinghead gasoline industry since 1911 is shown by the following table:

	Plants	Production
1911	8	338,058
1912	13	1,575,644
1913	40	6,462,968
1914	58	17,277,555
1915	63	31,665,991
1916	116	48,359,602

Daily Production of Crude Oil—Various Fields

			Barrels
California Daily Production, January, 1919			275,596
	Wells Producing	Production per Day	
Kern River	1,996	20,460	
McKittrick	333	7,806	
Midway-Sunset	2,208	87,871	
Lost Hills-Belridge	535	13,374	
Coalinga	1,140	43,805	
Santa Maria-Lompoc	343	17,520	
Ventura County-Newhall	456	4,503	
Los Angeles-Salt Lake	664	3,979	
Whittier-Fullerton	784	76,056	
Summerland	142	147	
Watsonville	5	75	
Totals	8,606	275,596	
Average value per barrel, $1.23			

Kentucky Daily Production, January, 1919			21,020
Big Sinking		12,000	
Pilot		2,060	
Ross Creek		1,900	
Ravenna		1,530	
Fitchburg		1,420	
Zachariah		1,000	
Fallsburg		250	
Steubenville		150	
Ragland		150	
Parmleyville		150	
Cooper		150	
Busseyville, Beaver Creek, Campton, Denney, Cannel City, Stillwater, Wagersville		300	
Louisiana Daily Production, January, 1919			53,200
North Louisiana		46,200	
Caddo and Pine Island	40,000		
De Soto and Red River	6,200		
South Louisiana		7,000	
Vinton	4,000		
Edgerly	1,800		
Jennings	1,200		
Wyoming Daily Production, 1918			35,500
Salt Creek Field		15,000	
Grass Creek		9,000	
Elk Basin		6,000	
Big Muddy		4,000	
Lander		1,000	
Greybull and Basin		500	

Texas Daily Production, 1919			310,265
High Gravity Crude Oil (North Texas) (Oct. 1)		242,890	
Burkburnett	86,000		
Eastland (Ranger)	66,100		
Electra	11,000		
Stephens County	44,800		
Comanche County and Miscellaneous	31,350		
Petrolia	750		
Holliday	175		
Thrall	90		
Strawn	500		
Moran	150		
Coleman and Brown Counties	1,000		
Northeast Texas	400		
Somerset and Bexar Counties	300		
Piedras Pintas	100		
Iowa Park	100		
Cameron County	75		
Low Gravity Crude Oil (South Texas) (Oct. 1)		67,375	
Goose Creek	22,000		
West Columbia	15,000		
Humble	10,000		
Sour Lake	8,000		
Hull	5,000		
Saratoga	2,100		
Spindletop	1,500		
Batson	1,450		
Damon Mound	1,200		
Corsicana	900		
Markham	150		
Dayton	25		
Miscellaneous	50		
Mexico Daily Production (Average for 1918)			177,000
South Fields		135,800	
Panuco		35,000	
Ebano		3,960	
Topila		2,240	
Oklahoma-Kansas (Mid-Continent) Average Daily Production, January, 1919			295,693
Washington County—			
Bartlesville	4,283		
Hogshooter	1,627		
Copan-Wann	481	6,391	
Nowata-Rogers Counties—			
Nowata	3,487		
Delaware	1,300		
Chelsea	1,200		
Inola	297	6,284	
Osage County	31,888	31,888	

Tulsa County—		
Bird Creek	6,807	
Lost City and Red Fork	752	
Broken Arrow and Jenks	2,151	
Bixby and Leonard	3,872	13,582
Okmulgee County—		
Mounds, Beggs and Youngstown	2,569	
Hamilton Switch	3,541	
Bald Hill	5,393	
Morris	2,481	
Tiger Flats	2,805	
Schulter	198	
Henryetta	191	17,178
Muskogee and Wagoner Counties—		
Coweta	1,280	
Haskell and Stone Bluff	1,528	
Boynton-Cole	1,986	
Muskogee	500	5,294
Pawnee County—		
Cleveland	6,948	6,948
Creek County—		
Cushing-Shamrock	41,807	
Glenn, Sapulpa and Kiefer	16,801	
Kellyville-Bristow	1,183	
Mannford and Olive	832	60,623
Payne County—		
Yale, Quay, etc	11,800	11,800
Kay County—		
Blackwell	4,980	
Newkirk and Mervine	4,328	
Ponca City	581	9,889
Garfield and Noble Counties—		
Billings	4,029	
Garber	6,400	10,429
Carter County—		
Healdton and Fox	38,803	38,803
Miscellaneous		2,105
Total Oklahoma		221,214
Kansas—		
El Dorado	46,281	
Augusta	13,400	
Outside	14,798	74,479

PRODUCTION AND DECLINE OF INDIVIDUAL OIL WELLS

Mid-Continent Field, 1916

Total number of wells drilled during year	11,240
Total number of dry holes (including gas)	1,970
Total number with gas	475
Total producing at end of year	9,270
Per cent producing at end of year	92.5%
Average production of this year's producing wells drilled during the year	26 Bbls.
Average production of all this year's producing wells, including dry holes	21.5 Bbls.
Total number of wells drilled up to end of this year	81,150
Total number of wells drilled and producing at end of this year	43,420
Per cent of wells drilled now productive	53.2%
Average production of all producing wells in field per day, including this year	8 Bbls.
Average production of all producing wells drilled excluding this year	3 Bbls.

OIL WELLS DRILLED IN UNITED STATES IN 1917-1918

District	Completed 1917	Completed 1918	Dry 1917	Dry 1918
Pennsylvania	5,435	4,400	985	738
Lima-Indiana	800	793	140	140
Central Ohio	582	605	139	159
Kentucky-Tennessee	1,651	2,191	411	360
Illinois	647	396	151	108
Kansas	3,469	4,671	547	925
Oklahoma-Arkansas	6,717	8,381	1,334	2,116
Texas Panhandle	1,020	1,140	262	625
North Louisiana	472	534	110	105
Gulf Coast	1,562	1,597	639	625
Total	22,355	24,708	4,718	5,901

Wells drilled during 1917 producing oil at end of year.............70.11%
Wells drilled during 1918 producing oil at end of year.............76.12%

OIL WELLS IN MEXICO, 1919

The total number of wells is 1,056, as follows:

Wells located	131
Wells being driven	114
Wells in production	298
Wells not profitable	27
Wells exhausted	64
Wells not producing	422
Total	1,056

The largest number of productive wells belong to the following companies:

Aguila Company (Lord Cowdray)	55
Mexican Petroleum Company of California	33
The Corona Company	10
Union Petroleum Company Hispano-Americana	17
The Texas Company of Mexico	10
Mexican Gulf Oil Company	8
Chicholes Oil Company, Ltd	7
Mexican Combustible Company	9
Penn. Mex. Fuel Oil Company	7
Freeport and Mexican Fuel Oil Company	7
Transcontinental Petroleum Company	12
Oil Fields of Mexico	12

RELATIVE ACTIVITY OF OIL FIELDS IN 1918

The rigs and drilling wells, at the close of December, in these fields were as follows:

Field	Rigs	Drillings	Total
Pennsylvania	69	143	212
West Virginia	94	187	281
Southeastern Ohio	33	104	137
Central Ohio	31	104	135
Northwestern Ohio	11	49	50
Indiana	2	56	58
Illinois	3	51	54
Kentucky	2	494	496
Tennessee	....	16	16
Arkansas	1	3	4
Kansas	132	481	613
Oklahoma	381	1,408	1,782
Wyoming	106	165	271
Panhandle-Texas	346	1,097	1,443
Gulf Coast	109	275	384
Louisiana	146	278	424
Totals	1,456	4,904	6,360

These data show that the chief decline in the amount of oil produced occurs in the first year of the life of the oil well. This decline occurs suddenly after the first gushing due to the sudden local relief of pressure. After this, there is a decline due to the gradual exhaustion of the sand. Every reservoir of oil is limited in capacity by the depth of the sand and the degree of impregnation with oil.

As a general rule, 500 barrels of oil is all that may be expected from each acre for each one foot depth of oil-hearing sand though this varies with the porosity and degree of saturation of the sand.

While the chief general cause for decline of oil wells is exhaustion of the sand, there are many causes that account for a decline in individual wells or localities.

Oil Gushers

The largest oil well in the world is one which came in near Tampico, Mexico, February 10, 1916. It was known as Cero Azul No. 4 and was drilled by the Pan-American Petroleum and Transport Company. The first twenty-four hours of oil flow yielded 260,000 barrels. In two years it is said to have produced approximately 60 million barrels of oil or about one-half of the total production of oil from Mexico. Its initial pressure was 1,035 pounds per square inch and the gravity of the oil is 21° Baume′ and without sediment or water. This well continued to produce at its usual rate during 1918.

It was in September, 1910, that the Mexican Petroleum Company brought in a well in the Juan Casiano field. It showed on a test that it was capable of giving a daily yield of something more than 100,000 barrels of oil. Pipeline connection was made, however, but not until more than 1,500,000 barrels of the inflammable product had been burned in order to prevent it from flowing into Lake Tamaihua, thus endangering boats and other property. It was throttled down to a flow of 20,000 barrels a day and for more than eight years it has been giving this yield. It has yielded, up to this time, more than 65,000,000 barrels of crude petroleum. Accompanying the oil is a gas pressure of 265 pounds per square inch. This natural gas is piped to the top of a hill a mile and a half distant from the well and is there burned in twelve great flares day and night, lighting up the country for a long way around.

On account of the lack of transportation facilities, it has not been allowed to flow at its maximum, being restrained to one million barrels per month at this time.

A number of wells in the Saboontchy-Romany oil fields of Russia have given daily yields of from 75,000 to 120,000 barrels per day for weeks and as much as 7,500,000 barrels in a year.

Another Mexican well at Dos Bocas, south of Tampico, yielded approximately five million barrels within two months.

A well in the Jennings pool in Louisiana in 1904 is reputed to be the largest gusher in the United States and gave 1,275,000 barrels of oil in four months.

Wells in Texas, California and Roumania have yielded 60,000 to 75,000 barrels of oil per day on the initial production.

The largest wells in the Mid-Continent field were in Butler County, Kansas, where, in the Towanda pool, gushers as large as 25,000 barrels per day, initial production, were struck in 1917.

TABLE SHOWING PRICE PER FOOT FOR DRILLING OIL AND GAS WELLS IN VARIOUS FIELDS

(Oklahoma Geological Survey)

	Feb. 22, 1916	June 23, 1917	July 27, 1917
To shallow sand in Bartlesville, Nowata and Tulsa districts	$0.80 to $1.00	$1.00 to $1.25	$1.25
To Layton sand in Cushing field	$1.35	$1.50	2.50
To Bartlesville sand in Cushing field, northwest	1.50	2.00	3.50
To Bartlesville sand in Cushing field, southeast	2.00	2.25	3.50 to $4.00
To shallow sand in Newkirk, Ponca City and Garber fields	1.50	1.50	1.50
To deeper sands in Newkirk and Ponca City fields (over 2,500 ft.)	2.50	3.50	3.50 to 4.00
Healdton field	1.40 to 1.50	1.75	1.75
Electra and Burkburnett to 1,200 ft. depth	2.00		
Electra and Burkburnett to 2,100 ft. depth	8.50		
Electra and Burkburnett to more than 2,500 ft. depth	5.00		

Note.—Price for rotary drilling to 2,000 feet is $3.00.

The regular charge for work by the day, February 22, 1917, was $50 for a double shift. This held good throughout the above fields. All wildcat propositions some distance (50 miles or more) from any of the above mentioned fields demanded $3.00 per foot. Contracts were let in 1918-1919, in Pine Island, La., at $11,000-$15,000 per well.

Refinery Operations on Crude Oil

	1916 Quantity	%	1917 Quantity	%	1918 Quantity	%
Crude Oil treated, bbls.	246,922,015	100.00	315,131,681	100.00	326,024,630	100.00
Gasoline bbls.	49,020,000	19.85	67,990,000	21.58	85,000,000	26.07
Kerosene, bbls.	34,655,000	14.03	41,120,000	13.05	43,450,000	13.33
Gas and Fuel Oil and Loss, bbls.	134,290,000	54,37	148,900,000	47.25	138,600.000	42.51
Lubricating Oil, bbls.	14,870,000	6.02	17,945,000	5.69	20,038,000	6.15
Wax, bbls.	386,180,898	0.55	481,200,081	0.48	505,144,357	0.49
Coke, tons.	405,319	1.04	539,366	1.05	559,663	1.05
Asphalt, tons.	716,490	1.83	739,425	1.44	607,968	1.14
Miscellaneous, bbls.	5,696,000	2.31	16,720,000	5.31	15,640,000	4.80

Miscellaneous includes binder, flux oil, medicinal oil, petroleum, road oil, roofing wax, tar, acid oil, foots oil, motor spirits, pitch, residuum, slops, tar oil, wax oil, wax tailings, straw oil.

REFINERY OPERATIONS BY DISTRICTS FOR FIRST SIX MONTHS OF 1917

District	Crude Handled Barrels	Per Cent Gasoline	Per Ce Kerose
Atlantic Coast	23,454,900	22.20	22.1
Pennsylvania	8,659,200	24.69	21.4
Illinois	13,830,300	35,92	14.5
Mid-Continent	29,260,260	26.95	14.4
Gulf Coast	27,543,470	12.65	11.3
Wyoming	4,035,800	37.43	17.0
California	36,403,400	11.14	4.2
January-July, 1917	143,189,374	20.35	13.04

INCREASE IN PRODUCTION OF CRACKED GASOLINE
(Estimated from Still Capacity)

Year	Barrels
1913	1,000,000
1914	3,000,000
1915	4,000,000
1916	6,000,000
1917	9,000,000
1918	18,000,000

KINDS OF GASOLINE AND AMOUNT PRODUCED IN 1917

Natural or Straight Run	54,000,000 bbls.
Artificial or Cracked	9,000,000 bbls.
From Natural and Casinghead Gas—	
By Compression	4,024,000 bbls.
By Absorption	1,167,000 bbls.
Total	68,191,000 bbls.

MARKETED MINERAL PRODUCTS IN THE UNITED STATES IN 1918

	Quantity		Value	% of World
Refined Petroleum	366,400,000	bbls.	1,300,000,000	65
Pig Iron ($33.50 per long ton)	38,820,000	tons	1,304,000,000	30
Copper (24.628c per pound)	1,869,949,686	lbs.	460,500,000	60
Zinc (8.159c per pound)	525,122	tons	85,710,000	30
Lead (6.777c per pound)	550,729	tons	74,640,000	35
Silver (.97875c per ounce)	67,879,206	oz.	66,430,000	50
Gold ($20.67 per ounce)	3,314,000	oz.	68,493,500	20
Coal	651,402,374	tons	....	..

PRICES OF CRUDE OIL AT THE WELLS.

Eastern Fields

	January 1 1918	January 1 1919
Pennsylvania	$3.75	$4.00
Cabell	2.72	2.77
Wooster	2.38	2.58
Corning	2.80	2.85
North Lima	2.08	2.38
South Lima	2.08	3.38
Indiana	1.98	2.28
Princeton	2.12	2.60
Somerset	2.55	2.42
Ragland	1.20	2.32
Illinois	2.12	2.42
Plymouth	2.03	2.33
Canada, Petrolia	2.48	2.78

Wyoming Field

	1918	1919
Elk Basin	1.85	1.85
Grass Creek	1.75	1.85
Big Muddy	1.40	1.50
Salt Creek	1.40	1.50

North Texas Field

	1918	1919
Electra	2.00	2.25
Henrietta	2.00	2.25
Corsicana, light	2.00	2.25
Corsicana, heavy	1.05	1.30
Strawn	2.00	2.25
Ranger	2.00	2.25

Mid-Continent Field

	January 1 1918	January 1 1919
Kansas-Oklahoma	$2.00	$2.25
Healdton, 32°	1.20	1.45
Cushing	2.50	2.75
Garber	3.50	3.75
Gulf Coast Field	1.05	1.80
Spindletop	1.00	1.80
Goose Creek	1.00	1.80
Sour Lake	1.00	1.80
Humble	1.00	1.80
Batson	1.00	1.80
Saratoga	1.00	1.80

Louisiana Field

	1918	1919
Caddo, above 38°	2.00	2.25
De Soto, above 38°	1.90	2.15
Caddo, 35°	1.90	2.15
Caddo, 32°	1.85	2.10
Caddo, below 32°	1.00	1.55
Crichton	1.50	1.75
Mexico at Gulf Points	1.60	.85

California Field

	1918	1919
Kern River, etc.		
14-17.9°	.98	1.23
18-18.9°	.99	1.24
Ventura County		
25-25.9°	1.07	1.32
Fullerton-Whittier		
16-17.9°	.98	1.23
18-18.9°	.99	1.24
25-25.9°	1.07	1.32
37-37.9°	1.32	1.57

REFINERY PRODUCTS (1919)

	Gasoline Gallon	Kerosene Gallon	Fuel Oil Barrel
At Refinery—Oklahoma	17.2c	8.0c	$0.75
Kansas City	22.3c	10.8c	1.05
Tulsa	23.5c	12.0c	1.00
Topeka	22.7c	11.2c	1.05
New York City	24.5c	14.5c	4.00
Boston	25.5c	10.7c	4.00
Chicago	23.0c	12.0c	1.60
San Francisco and Los Angeles	20.5c	10.5c	1.60
Seattle	21.5c	11.5c	1.62
New Orleans	23.0c	12.0c	2.00

	Melting point	Price
Paraffin Wax	103°F	7½c lb.
	120	8½c lb.
	125	9c lb.
	128	11c lb.
	133	13c lb.
	140	17c lb.

Lubricating Oil—	
Natural	20c per gallon
Black	20c per gallon
Cylinder, Pale	40c per gallon
Cylinder (low cold test)	60c per gallon
Paraffin High Viscosity	40c per gallon
Asphalt (at market)—	
50 per cent Asphalt Roal Oil, 7c per gallon	$17.50 per ton
70 per cent Asphalt Road Oil, 8c per gallon	20.00 per ton
Texaco Asphalt (Dallas)	30.00 per ton
California (San Francisco)	13.50 per ton
Mexican (Houston)	20.00 per ton
Trinidad (Kansas City)	32.50 per ton
Stanolind (Kansas City)	20.00 per ton
Stanolind (New York)	20.00 per ton
Natural Gas	6c-60c

HIGHEST AND LOWEST PRICES OF CRUDE PETROLEUM OF PENNSYLVANIA GRADE, 1859-1918, PER BARREL

	Highest		Lowest	
Year	Month	Price	Month	Price
1859	September	$20.00	December	$20.00
1860	January	20.00	December	2.00
1861	January	1.75	December	.10
1862	December	2.50	January	.10
1863	December	4.00	January	2.00
1864	July	14.00	February	3.75
1865	January	10.00	August	4.00
1866	January	5.50	December	1.35
1867	October	4.00	June	1.50
1868	July	5.75	January	1.70
1869	January	7.00	December	4.25
1870	January	4.90	August	2.75
1871	June	5.25	January	3.25
1872	October	4.55	December	2.67½
1873	January	2.75	November	.82½
1874	February	2.25	November	.62½
1875	February	1.82½	January	.75
1876	December	4.23¾	January	1.47½
1877	January	3.69⅜	June	1.53¾
1878	February	1.87½	September	.78¾
1879	December	1.28¾	June	.62⅛
1880	June	1.24⅜	April	.71¼
1881	September	1.01¼	July	.72½
1882	November	1.37	July	.49¼
1883	June	1.24¾	January	.83¼
1884	January	1.15⅝	June	.51¼
1885	October	1.12⅝	January	.68
1886	January	.92¼	August	.59¾
1887	December	.90	July	.54
1888	March	1.00	June	.71⅜
1889	November	1.12½	April	.79½
1890	January	1.07⅝	December	.60¾
1891	February	.81⅜	August	.50
1892	January	.64⅛	October	.50
1893	December	.80	January	52⅞
1894	December	.95¾	January	.78½
1895	April	2.60	January	.95¼
1896	January	1.50	December	.90
1897	March	.96	October	.65
1898	December	1.19	January	.65
1899	December	1.66	February	1.13
1900	January	1.68	November	1.05
1901	January, Sept.	1.45	May	.80
1902	December	1.54	Jan., Feb., March	1.15
1903	December	1.90	Jan., Feb., March, April, May, June, July	1.50
1904	January	1.85	July, December	1.50
1905	October	1.61	May	1.27
1906	April, May, June, July	1.64	Jan., Feb., March, April, Aug., Sept., Oct., Nov., Dec.	1.58
1907	March to Dec., incl.	1.78	January	1.58
1908	No change	1.78	No change	1.78
1909	Jan., Feb., March	1.78	December	1.43
1910	January	1.43	June to Dec., incl.	1.30
1911	December	1.35	January to December	1.30
1912	December	2.00	January	1.35
1913	March to Dec., incl.	2.50	January	2.00
1914	January to March, incl	2.50	September to Dec., incl.	1.45
1915	December	2.25	April to August, incl.	1.35
1916	December	2.85	January	2.25
1917	August 22 to Dec. 30	3.75	January 2 to 5, incl.	2.85
1918	Feb. 8 to Dec. 31, incl.	4.00	Jan. 1 to Feb. 8, incl.	3.75

PRICE SCHEDULE FOR CALIFORNIA CRUDE OIL—1919

Gravity	Price	Gravity	Price
14 to 17.9	$1.23	35 to 35.9	$1.57
18 to 18.9	1.24	36 to 36.9	1.59
19 to 19.9	1.25	37 to 37.9	1.62
20 to 20.9	1.27	38 to 38.9	1.65
21 to 21.9	1.29	39 to 39.9	1.68
22 to 22.9	1.31	40 to 40.9	1.71
23 to 23.9	1.33	41 to 41.9	1.74
24 to 24.9	1.35	42 to 42.9	1.77
25 to 25.9	1.37	43 to 43.9	1.80
26 to 26.9	1.39	44 to 44.9	1.83
27 to 27.9	1.41	45 to 45.9	1.86
28 to 28.9	1.43	46 to 46.9	1.89
29 to 29.9	1.45	47 to 47.9	1.92
30 to 30.9	1.47	48 to 48.9	1.95
31 to 31.9	1.49	49 to 49.9	1.98
32 to 32.9	1.51	50 to 50.9	2.01
33 to 33.9	1.53	51 to 51.9	2.04
34 to 34.9	1.55	52 to 52.9	2.07

PRICE CHANGES OF CRUDE OIL, MID-CONTINENT FIELD, SINCE 1905

1906	$0.44
1907	.40
1908	.39
1909	.36
1910	.38
1911—	
January 1	.44
April	.46
June	.48
September	.50
1912—	
January 2	.53
January 15	.55
January 25	.57
February 5	.60
April 10	.62
April 16	.64
May 7	.66
May 17	.68
July 16	.70
November 3	.73
November 27	.76
December 11	.78
December 16	.80
December 24	.83
1913—	
January 27	.86
January 29	.88
July 7	.93
July 21	.98
August 19	1.03
1914—	
February 2	1.05
April 8	1.00
April 10	.95
April 13	.90
April 15	.85
April 27	.80
April 29	.75
September 22	.65
October 1	.55
1915—	
February 8	.45
February 15	.40
August 2	.50
August 4	.55
August 11	.60
August 19	.65
August 21	.75
September 11	.80
November 13	.90
November 15	1.00
December 13	1.10
December 14	1.20
1916—	
January 20	1.25
January 26	1.30
March 4	1.40
March 11	1.45
March 14	1.55
July 24	1.45
July 29	1.35
August 1	1.25
August 7	1.15
August 12	1.05
August 15	.95
August 26	.90
November 29	1.00
December 12	1.10
December 18	1.20
December 23	1.30
December 28	1.40

PRICE CHANGES OF CRUDE OIL, MID-CONTINENT FIELD, SINCE 1905—Concluded

1917—	
January 3	1.50
January 6	1.60
January 12	1.70
August 3	1.85
August 16	1.90
August 18	2.00
1918—	
March 18	2.25
1919	2.25

ACTUAL PRODUCTION BY COMPANIES IN MEXICO

Companies	1918 Barrels	1917 Barrels
Cia. Pet. La Victoria	....	1,574
Topila Petroleum Company	....	2,000
Cia. Mex. Pet. del Golfo	....	29,993
National Oil Company	....	753,589
Panuco Petro. Maat. (Royal Dutch)	2,748	....
Cia. Exp. de Pet. La Universal	3,075	....
Hispano Mexicana (Tex. Mex. Fuel)	4,226	873
Mexico y Espana	5,459	29,625
Mexican Oil Company	3,490	288,770
Cia. Pet. Monterrey	25,021	24,958
Chijoles Oil Ltd. (R. Dutch)	25,266	1,515
Oil Fields of Mexico	29,906	34,689
Veracruz Mexico (S. O. N. J.)	51,716	360,258
La Petrolera Poblana	91,311	32,871
Cia. Mex. de Combustible (Pierce Oil)	300,064	60,852
La Corona (Royal Dutch)	337,603	740,576
Transcontinental de Petroleo (Standard Oil N. J.)	382,029	119,315
Panuco Bost. Oil (Atlan. Ref.)	531,511	828,067
Tampascas Oil Company	578,478	174,924
Internat. Pet. (J. H. Hamm'd)	609,733	619,828
Cia. Pet. Tal Vez. (So. O. & T.)	1,152,063	989,561
Tex. Co. of Mex. (Texas Co.)	1,279,746	2,315,433
Cia. Mex. de Petroleo (Mex. Pet. of Calif.)	1,445,976	1,125,702
Cia. Mex. de Pet. La Libertad (Island O. & T.)	1,550,869	....
Mex. Gulf Oil (Gulf Oil Co.)	1,728,190	1,160,794
Cortez Oil Corp. (Port Lobos Pet. Corp.)	2,161,775	....
East Coast Oil (So. Pac. Co.)	3,457,235	3,143,220
Freeport & Mex. F. O. Corp. (Sinclair Gulf)	4,119,654	4,076,982
Penn Mex. Fuel Co. (South Penn Oil)	6,854,080	4,129,296
Cia. Mex. de Pet. El Aguila (Mexican Eagle Oil)	16,910,646	16,922,322
Huasteca Pet. Co. (Mex. Pet. of Delaware)	20,186,459	17,325,171
Totals	63,828,326	55,292,770

Record of All Mexican Operations to Date—1919

Prepared by Mexican Petroleum Department, Secretary of Industry
1 Cubic Meter = 6.29 Barrels

Drilled by	Locations	Drilling Feb. 28 1919	Producing	Potential Daily Prod. in Cub. Met.	Abandoned	Total No. of Wells
La Universal	..	1	1	511.00	..	2
México y Espana	..	..	1	626.00	..	1
La Libertad	..	..	1	8,000.00	..	1
Cántabros en Pánuco	..	1	..	......	1	2
La Nacional	..	1	..	......	..	1
Pánuco Tamesí	1	..	..	......	..	1
Alamo de Pánuco	1	..	..	......	1	2
Tux. Ozuluama	..	2	..	......	..	2
Pet. Maritima	..	..	..	......	1	1
Freeport & Mex	1	4	7	5,794.90	2	14
Esfuerzo Tampiqueno	..	..	..	......	1	1
El Caimán	..	..	..	......	1	1
Pánuco Valley	2	..	1	66.77	..	3
Southern Co	..	..	1	800.00	..	1
Expl. Topila	..	..	1	160.00	..	1
La Trasatlántica	1	..	..	......	..	1
Pánuco Mahuaves	..	..	..	......	1	1
Lluvia de Oro	..	1	..	......	..	1
Esfuerza Nacional	1	..	..	......	1	2
Vado Oil Fields	..	..	..	......	1	1
La Victoria	..	..	1	6.00	..	1
Transcontinental	3	3	12	15,804.04	7	24
R. A. Mestres	3	..	..	......	..	3
English Oil Co	..	2	4	1,444.00	4	10
El Espino	..	1	..	......	..	1
Pedro Irisari	..	..	1	8.00	..	1
Tampascas Oil	..	1	5	713.00	1	7
National Pet	..	1	..	......	..	1
Gulf Coast Corp	1	..	4	22.69	1	6
Los Perforadores	..	..	2	319.00	..	2
Hispano Mexicana	..	..	1	1,600.00	2	3
Tal Vez, S. A	1	..	2	1,155.00	..	3
Monterrey, S. A	..	..	1	16.00	..	1
International Pet	2	4	3	6,661.22	8	17
Orbananos et al	1	..	..	......	..	1
Márgenes del Pám	..	1	..	......	..	1
Pánuco Topila	..	..	1	80.00	..	1
El Fénix, S. A	..	..	..	......	1	1
Las Dos Estrellas	1	..	..	......	..	1
Productora de Pet	..	1	1	238.50	1	3
National Oil Co	1	..	4	598.90	1	6
Mex. National Oil	1	..	..	......	2	3
Zaleta Mar Oil Co	..	..	..	......	1	1

RECORD OF ALL MEXICAN OPERATIONS TO DATE, 1919—Continued

Drilled by	Locations	Drilling Feb. 28 1919	Producing	Potential Daily Prod. in Cub. Met.	Abandoned	Total No. of Wells
La Herradura	..	..	..	......	1	1
Continental Mex.	..	..	1	1,500.00	1	2
El Indio	..	1	..	......	..	1
Lá Oaxaquena	..	..	..	......	1	1
Oil Fields of Méx	1	1	12	60.37	23	37
New England Fuel	..	..	4	3,900.02	..	4
La Oriental Méx	1	..	..	......	..	1
La Esperanza	..	1	..	......	..	1
Abastecedora	1	1	..	......	1	3
Pánuco Excelsior	..	..	1	190.00	..	1
Adrian Petroleum	1	2	1	5,000.00	..	4
Cortez Oil Corp	2	..	2	804.38	1	5
Inglesa Explot	..	1	..	......	1	2
Tantoyuca y Anexas	..	2	..	......	..	2
A. P. Wiechers	5	..	..	......	..	5
Mex. Pet. del Golfo	..	..	1	95.40	1	2
La Corona, S. A	..	4	10	8,095.42	12	26
Byrd, et al	..	2	..	......	..	2
Oro Mexicano	..	..	..	......	1	1
La Bonanza	..	..	1	16.00	..	1
Am. Fuel Oil	..	..	2	802.95	..	2
Topila Petroleum	..	..	1	63.60	..	1
Mexican Gulf	2	2	8	22,370.50	8	20
Tampico Pánuco	3	2	..	......	3	8
Chijoles Oil	..	..	7	154.33	..	7
American Inter	..	..	1	4.77	7	8
Hispano Amer	1	..	..	......	..	1
East Coast Oil	..	1	17	4,561.06	9	27
Soria y Socios	..	1	..	......	..	1
Texas Co. of Méx	2	3	10	17,072.19	2	17
Mexican Oil Co	1	..	3	639.98	..	4
Smith's Oil Co	..	..	..	......	1	1
Pan American Oil	..	1	2	875.00	..	3
Orillas de Pánuco	..	1	..	......	..	1
Nuevo León	..	1	1	15.90	..	2
Mex. de Combust	1	..	9	5,051.62	6	16
Hispano Cubana	..	..	1	397.00	..	1
M. C. Anderson	..	..	2	22.25	..	2
Piedras Devel. Co	..	..	..	......	1	1
Lot Seventeen Co	1	..	2	6.40	..	3
Punta Arena y Anex	..	..	..	......	1	1
Comercio de Puebla	..	..	..	......	1	1
La Argentina	1	..	..	......	1	2
México Fuel Oil	1	1	5	367.13	2	9
Hidalgo Oil Co	..	1	..	......	..	1
El Nayarit	..	..	1	2,000.00	..	1
Financiera de Pet	1	..	..	......	..	1
Mex. Development	..	..	..	......	1	1
El Azadón, S. A	..	1	..	......	1	2

RECORD OF ALL MEXICAN OPERATIONS TO DATE, 1919—Continued

Drilled by	Locations	Drilling Feb. 28 1919	Producing	Potential Daily Prod. in Cub. Met.	Abandoned	Total No. of Wells
La Concordia	..	..	1	......	..	1
Nueva Bonanza	..	..	..	......	1	1
El Aguila, S. A	32	18	55	20,590.18	284	389
Tamiahua Pet	2	1	..	......	4	7
Mex. Pet. Co. Cal	21	1	33	2,497.65	36	91
Huasteca Pet. Co	3	11	4	48,553.70	19	36
Tuxpam Pet. Co	..	1	..	......	..	1
Mundacádiz, S. A	..	1	..	......	..	1
Juan Casiano Tux	1	..	..	......	..	1
Harry Hummel	..	..	..	......	2	2
La Tolteca	1	..	..	......	..	1
Tampico Oil Ltd	1	..	4	47.00	4	9
Tampico Oil Co	..	..	..	......	1	1
Penn Mex. Fuel	4	22	7	13,969.35	13	26
La Equidad	..	1	..	......	..	1
Espana, S. A	1	..	..	......	..	1
Pet. de Tepetate	6	..	2	21,462.86	1	9
Consolidada de Pet	..	1	..	......	..	1
Eugenio F. Ruiz	..	1	..	......	..	1
Seguranza, S. A	..	2	..	......	1	3
La Giralda	..	..	2	160.05	..	2
La Meridional	1	..	1	494.52	..	2
Tampiquena-San Javier	..	1	..	......	..	1
Tex. Mex. Fuel Oil	..	..	1	400.00	..	1
Nacional de Petr	..	1	..	......	..	1
Mexican Premier	..	1	..	......	..	1
Eureka	1	..	1	1,072.00	..	2
Pánuco Tuxpam	..	..	1	223.00	..	1
Sun Oil Co	1	..	1	127.20	..	2
Petrolera Poblana	..	..	1	2,400.00	..	1
La Comercial	2	..	1	5.00	..	3
Pánuco Boston	..	..	2	1,113.00	..	2
Regiones Pet. Mex	..	..	4	3,465.10	..	4
Puebla en Pánuco	1	2	..	......	1	4
Allison W. Smith	1	..	..	......	..	1
Rodolfo H. Rader	1	..	..	......	..	1
Capuchinas Oil	..	1	..	......	1	2
Fomento de Chapala	1	..	..	......	..	1
Mexican Sinclair	1	5	4	2,951.00	1	11
Pet. Agríc. Mex. San José	1	1	..	......	..	2
Scottish Mex. Oil	..	..	..	......	5	5
Los Brujos	..	..	..	......	2	2
Catopico Oil Co	1	..	..	......	..	1
Dos Banderas Oil	..	1	..	......	..	1
Clipton & Smith	1	..	..	......	..	1
Freggs Oil Co	..	..	..	......	1	1
Hidalgo Pet. Co	..	1	..	......	..	1
W. H. Miliken	..	..	1	3.18	..	1
Ohio Mex. Oil	..	..	1	795.00	..	1

RECORD OF ALL MEXICAN OPERATIONS TO DATE, 1919—Concluded

Drilled by	Locations	Drilling Feb. 28 1919	Producing	Potential Daily Prod. in Cub. Met.	Abandoned	Total No. of Wells
Producers Oil Co.	1	1	2	1,224.30	..	4
Río Vista.	..	..	..	......	1	1
Sims & Bowser.	..	..	1	79.50	1	2
Spanish Mex. Oil.	..	1	..	......	..	1
J. W. Sloan.	..	1	..	......	..	1
J. R. Sharp.	..	..	1	39.75	..	1
Tampico Banking.	..	..	2	2.24	..	2
Tampico Fuel Oil.	..	..	1	127.20	..	1
Boston Mex. Leasing.	..	..	1	12,720.00	..	1
H. McKeever.	..	1	..	......	..	1
Mex. Tex. Pet.	..	..	..	......	1	1
Tamesí Pet. & Asph.	..	..	..	......	2	2
Gobiorno de la Fed.	..	..	4	3.86	5	9
Fom. del Sureste.	..	1	..	......	..	..
Totals.	131	114	299	253,217.93	512	1056

LARGE PRODUCERS OF KANSAS—WITH PRODUCTION

Daily Production in 1918

Name	Augusta Barrels	Eldorado Barrels	Outside Barrels	Total Barrels
Carter Oil Company.	154	6,799	.....	6,953
Carter and S. W. Oil Co.	.....	9,445	.....	9,445
Magnolia Petroleum Company.	3,126	.....	.....	3,126
Mid-Kansas Oil Company.	2,108	.....	.....	2.108
Prairie Oil & Gas Co.	747	47	.....	794
Tidal Oil Company.	.....	1,073	.....	1,073
Cosden Oil & Gas Co.	1,562	.....	.....	1,562
Empire Gas & Fuel Co.	12,041	31,376	.....	43,417
Gypsy Oil Company.	.....	18,812	.....	18,812
Monitor Oil & Gas Co.	1,539	.....	.....	1,539
Oklahoma Prod. & Ref. Co.	220	31	.....	251
Producers' Oil Company.	83	.....	.....	83
C. B. Shaffer.	.....	1,502	.....	1,502
Sinclair Oil & Gas Co.	.....	1,940	.....	1,940
Totals.	21,580	71,025	.....	92,605
All other companies.	1,613	14,643	13,000	29,256
	23,193	85,668	13,000	121,861

PRODUCTION IN MEXICO TO 1919

Year	Barrels	Year	Barrels
1901	10,345	1910	3,634,080
1902	40,200	1911	12,552,798
1903	75,375	1912	16,558,215
1904	125,625	1913	25,696,291
1905	251,250	1914	26,235,403
1906	502,500	1915	32,910,508
1907	1,005,000	1916	40,545,712
1908	3,932,900	1917	55,292,770
1909	2,713,500	1918	63,828,327

LARGE PRODUCERS IN CALIFORNIA

Operator	Per Cent of Total Oil	Proved Land Acres	Number Wells
Associated Oil Company.	9.1	7,347	1,048
Doheny (various companies).	7.3	4,286	379
General Petroleum Corporation.	4.3	2,584	400
Honolulu Consolidated Oil Company.	1.3	2,701	35
A. T. & S. F. Ry. (oil subsidiaries).	4.0	3,097	412
Shell Company of California.	6.8	2,442	236

LARGE PRODUCERS IN CALIFORNIA—Concluded.

Operator	Per Cent of Total Oil	Proved Land Acres	Number Wells
So. Pacific Co. (fuel oil department)	8.5	18,267	681
Standard Oil Company	22.6	8,187	771
Union Oil Company of California	8.1	8,198	427
All others	28.0	30,171	3,381
Total	100.0	87,280	7,770

IMPORTANT OIL COMPANIES OPERATING IN OKLAHOMA, CALIFORNIA, WYOMING, KANSAS AND TEXAS

Company	Affiliations
Amalgamated Oil Co.	The Amalgamated Oil Co., the Arcturus Oil Co. and the Salt Lake Oil Co. are affiliated and controlled by the Associated Oil Co. which in turn is controlled by the Kern Trading & Oil Co., the producing company of the Southern Pacific Railroad.
Associated Oil Co.	Controlled by the Kern Trading & Oil Co.
Carter Oil Co.	Owned by Standard Oil Co. of New Jersey.
Cosden Oil & Gas Co.	Presumably independent. Some of its affiliated companies are Cosden & Co., Cosden Pipeline Co., Glenn Pool Pipeline Co., Union Petroleum Co., Pen-Mar Oil Co.
Empire Gas & Fuel Co.	Affiliated with the Empire Refineries, Inc. Is an independent concern.
General Petroleum Corp.	An independent company.
Gulf Production Co.	Owned by the Gulf Oil Corporation which is considered an independent.
Gypsy Oil Co.	Held by Gulf Oil Corporation, an independent.
Humble Oil & Ref. Co.	An independent organization.
Invincible Oil Co.	This is an independent, so far as known.
Kern Trading & Oil Co.	A producing company of the Southern Pacific R. R.
McMan Oil Co.	Sold a controlling interest to the Magnolia Petroleum Co. several months ago.
Magnolia Petroleum Co.	Commonly known as a Standard Oil Co.
Monitor Oil & Gas Co.	An independent company so far as generally known.
Ohio Cities Gas Co.	An independent organization. Has a number of subsidiaries, some of which are the Ardmore Refining Co., International Refining Co., Pure Oil Co., Cornplanter Refining Co. and Quaker Oil & Gas Co.
Ohio Oil Co.	One of the Standard Oil group.
Pan-American Petroleum & Transport Co.	One of the Doheny interest, presumably with no Standard Oil relations.
Prairie Oil & Gas Co.	One of the Standard Oil group and was a subsidiary of Standard Oil of New Jersey until it was separated therefrom by dissolution decree of the U. S. Supreme Court in 1911.
Producers Oil Co.	Controlled by the Texas Co., 20 per cent of the stock of which the Federal Trade Commission states is owned by the stockholders of different Standard Oil Co.
Quaker Oil & Gas Co.	Originally controlled by Pure Oil Co. Now controlled by Ohio Cities Gas Co.
Republic Production Co.	A newly organized company in Texas and is believed to be independent.
Roxana Petroleum Co.	A subsidiary of the Royal Dutch Shell group.
Shell Co. of California	A subsidiary of the Royal Dutch Shell group.
Silurian Oil Co.	An independent organization so far as known.
Sinclair Oil & Gas Co.	An independent company which has acquired a large number of smaller producers. The Sinclair Oil and Sinclair Gulf are co-interests.
Standard Oil Co. (Cal.)	One of the Standard Oil group.
Sun Co.	A close corporation and its connection to other companies is not generally known.
Tidal Oil Co.	Principally owned by Tidewater Oil Co., some of the stock of which is held by stockholders in the Standard Oil Co., though presumably independent.
Wyoming Oil Fields Co.	Supposedly independent.

Petroleum Refineries of North America

Company	Location	Year Built	Approximate Investment	Ap. Barrels Crude Daily
ALABAMA				
Alabama Oil & Development Co...	Mobile	(Bldg.)		
ARKANSAS				
Ozark Oil & Refining Co..........	Fort Smith	1914	125,000	300
CALIFORNIA				
Beckett Refining Co..............	Arroyo Grande	....	......	.....
Associated Oil Co................	Avon	1912	1,500,000	22,000
Union Oil Co. of Calif...........	Avilla	1895	9,250,000*	17,000
		(*All Union Oil Plants)		
Phoenix Refining Co..............	Bakersfield	1902	300,000	1,200
Richfield Oil Co.................	Bakersfield	....	200,000	3,500
Slager Refining Co...............	Bakersfield	....	200,000	1,200
Standard Oil Co. of Calif........	Bakersfield	1914	......	20,000
Union Oil Co. of Calif...........	Bakersfield	1895	......	.....
Vulcan Oil Co....................	Bakersfield	1901	......	400
Capital Refining Co..............	Berkeley	1900	......	600
Monarch Oil Refining Co..........	Berkeley	1910	......	Idle
Pinal Dome Refining Co...........	Betteravis	1911	560,000	1,950
Union Oil Co. of Calif...........	Brea	1895	......	10,000
Columbian Oil, Asphalt & Ref. Co.	Carpanteria	1891	100,000	.....
O'Neal Refining Co...............	Casmalia	....	......	.....
Puente Oil Co....................	Chino	1892	200,000	1,000
American Petroleum Co............	Coalinga	1912	1,250,000	10,000
Shell Co. of Calif...............	Coalinga	....	225,000	2,000
Standard Oil Co. of Calif........	El Segundo	1913	......	40,000
Paraffin Paint Co................	Emeryville	1895	100,000	300
Wilshire Refining Co.............	Fellows	1912	150,000	10,000
Ventura Refining Co. (L).........	Fillmore	1915	650,000	6,000
California-Fresno Oil Co.........	Fresno	1901	50,000	500
Pacific States Refining Co.......	Fruitvale	1904	50,000	.....
Anaheim Union Water Co...........	Fullerton	....	......	500
St. Helens Petroleum Co..........	Fullerton	....	......	600
Associated Oil Co................	Gaviota	1899	530,570	10,000
Moore Refining Co................	Goleta	....	......	.....
California Liquid Asphalt Co.....	Hadley	1909	25,000	.....
Ensign Baker Refining Co.........	Hadley	1910	43,000	1,000
Hanford Oil Refining Co..........	Hanford	1913	45,000	250
King Refining Co.................	Kern River	1901	175,000	250
Producers Oil Refining Co........	Kern River	1904	65,000	Idle
Standard Oil Co..................	Kern River	1914	98,750,000*	65,000
		(*All S. O. Plants in Calif.)		
Buckeye Refining Co..............	Kern River	1901	......	.....
Warren Bros.	Kern River	1914	100,000	1,500
General Petroleum Co.............	Kerto	1913	10,000	100
Amalgamated Oil Co...............	Los Angeles	1905	200,000	10,000
Asphaltum & Oil Refining Co......	Los Angeles	....	......	.....
Atlas Refining Co................	Los Angeles	1892	75,000	600
California Oil & Asphalt Co......	Los Angeles	1900	15,000	450
Continental Oil Co...............	Los Angeles	1911	100,000	1,000
Densmore-Stabler Refining Co.....	Los Angeles	1907	......	600
Golden State Oil Co..............	Los Angeles	1902	75,000	650
Fairchild Gilmore Wilton Oil Co...	Los Angeles	1912	40,000	700
Guaranty Oil Co..................	Los Angeles	1900	......	700
Huasteca Petroleum Co............	Los Angeles	....	......	1,000
Jordan Oil Co....................	Los Angeles	....	......	.....
Pioneer Roll Paper Co............	Los Angeles	1904	80,000	500
Richfield Oil Co.................	Los Angeles	1898	200,000	900
Service Oil & Asphalt Co.........	Los Angeles	1892	100,000	800

L = Lubricating or Wax Plants.

PETROLEUM REFINERIES OF NORTH AMERICA—Continued

Company	Location	Year Built	Approximate Investment	Ap. Barrels Crude Daily
CALIFORNIA—Concluded.				
Shell Co. (Trumbull Process)	Los Angeles	....	......	5,000
Southern Refining Co	Los Angeles	1900	......	700
Turner Oil Co	Los Angeles	1914	175,000	1,150
Union Oil Co. of Calif	Los Angeles	1895	......	.....
Western Oil Co	Los Angeles	....	81,000	.....
Wilshire Oil Co. (old Atlas)	Los Angeles	1912	150,000	1,000
Vernon Oil Co	Los Angeles	....	21,000	15,000
Yosemite Oil Refining Co	Los Angeles	1898	30,000	600
Union Oil Co. of Calif	Maltha	....	......	3,000
Adeline Con. Road Oil Co	Maricopa	1913	52,000	250
Sunset Monarch Oil Co	Maricopa	1907	......	1,000
American Oriental Co. (Shell) (L)	Martinez	1901	265,000	6,000
Dutch Shell Co. of Calif	Martinez	1915	2,500,000	22,500
General Petroleum Co	Mojave	1914	......	8,000
Union Oil Co. of Calif	Oleum	....	......	22,000
Richfield Oil Co	Olinda	....	......	800
Union Oil Co. of Calif	Orcutt	1895	......	.....
Sunset Oil & Refining Co	Ostend	1903	......	2,000
Producers & Refiners Oil Co	Oil Port	1906	......	5,000
Standard Oil Co	Point Richmond	1902	......	60,000
Milriff Refining Co	Rodeo	....	......	500
Warren Bros.	Rodeo	1903	80,000	800
San Diego A-1 Refining Co	San Diego	1911	30,000	300
Pacific Roofing & Ref. Co	San Francisco	....	......	300
Prutzman Refining Co	San Francisco	....	......	.....
West Coast Refining Co	San Francisco	....	......	.....
Western Union Oil Co	Santa Maria	....	......	1,000
Union Oil Co. of Calif	San Pedro	1885	......	800
Capital Crude Oil Co	Santa Paula	....	......	160
El Merito Refining Co	Santa Paula	....	......	Idle
Marchus Bros.	Santa Paula	....	......	200
A. F. Gilmore	Sherman	....	150,000	1,000
Tulara Refining Co	Tulara	....	......	.....
Amalgamated Oil Co	Vernon	....	75,000	3,500
Asphaltum Oil & Ref. Co	Vernon	1896	50,000	500
British-California Oil Co	Vernon	....	......	6,000
California Oil & Asphalt Co	Vernon	1911	125,000	885
Crescent Refining Co	Vernon	....	......	500
General Petroleum Co	Vernon	1913	1,500,000	20,000
Hercules Oil Refining Co	Vernon	1900	250,000	1,000
Jordan Oil Co	Vernon	1907	175,000	700
Martin-Holloran Ref. Co	Vernon	....	......	.....
Pioneer Paper Co	Vernon	....	......	400
Richfield Oil Co	Vernon	1907	175,000	2,000
Turner Oil Co	Vernon	....	......	.....
National Oil Refining Co	Watts	1906	85,000	150
G. F. Gilmore Co	Roadamite	....	......	1,000
COLORADO				
Apex Refining & Drilling Co	Boulder	1918	100,000	1,000
The Inland Refinery	Boulder	1906	125,000	1,500
Florence Oil Co. (L)	Florence	1889	350,000	1,000
United Oil Co. (Standard)	Florence	1887	1,000,000	3,000
Urado Oil Co	Unitah Basin	1917	10,000	100
FLORIDA				
Jackson E. R. & Co	Jacksonville	(Bldg.)	150,000	1,500
GEORGIA				
Atlantic Refining Co	Brunswick	1919	8,000,000	10,000
IDAHO				
Idaho Oil & Refining Co	Pocatello	(Bldg.)	50,000	.....

L = Lubricating or Wax Plants.

PETROLEUM REFINERIES OF NORTH AMERICA—Continued

Company	Location	Year Built	Approximate Investment	Ap. Barrels Crude Daily
ILLINOIS				
Midland Oil & Ref. Co.	Allendale	1917	......	.....
Barnett Oil & Gas Co.	Blue Island	1913	225,000	2,400
Erie Oil & Gas Co.	Bridgeport	1912	35,000	500
Leader Refining Co.	Casey	....	250,000	500
Oil Jobbers Prod. & Ref. Co.	Chicago	1917	......	.....
Johnson Oil & Ref. Co.	Chicago Heights	1916	175,000	1,000
Republic Oil & Ref. Co.	East Moline	1917	500,000	2,500
Anderson & Gustafson	East St. Louis	1916	5,000	200
Consol. Oil Ref. Co.	East St. Louis	1915	35,000	300
Indiahoma Refining Co.	East St. Louis	1907	1,000,000	4,500
St. Clair Gas & Electr. Co.	East St. Louis	1914	40,000	Idle
Lubrite Refining Co.	East St. Louis	1918	50,000	300
Great Northern Ref. Co. (Great Lakes Refineries, Inc.)	Joliet	1917	300,000	1,500
Central Refining Co.	Lawrenceville	1908–9	3,000,000	3,000
Indian Refining Co.	Lawrenceville	1910	1,320,000	11,000
The Texas Company	Lockport	1911	1,225,000	4,000
Inter Ocean Ref. Co.	McCook	1918	250,000	2,000
Wabash Refining Co. No. 1 and 2.	Robinson	1907	250,000	800
Smith Oil & Refining Co.	Rockford	1909	75,000	300
Roxana Petroleum Corp.	Wood River	1917	11,500,000	6,000
Standard Oil Co.	Wood River	1912	5,000,000	25,000
INDIANA				
Sinclair Oil & Ref. Co.	Whiting	(Bldg.)	10,000,000	6,500
Standard Oil Co. of Ind.	Whiting	....	25,750,000	60,000
IOWA				
Washington Refining Co.	Cedar Rapids	(Bldg.)	90,000	.....
KANSAS				
Sinclair Refining Co.	Argentine	1917	......	4,500
Kanotex Refining Co.	Arkansas City	1906	700,000	3,000
Lesh Refining Co. (National)	Arkansas City	1914	300,000	2,000
Milliken Refining Co. (L)	Arkansas City	1917	1,150,000	6,000
Augusta Refining Co.	Augusta	1917	200,000	3,000
Bliss Oil & Ref. Corp.	Augusta	1917	175,000	1,200
Walnut River Ref. Co.	Augusta	1916	125,000	1,500
White Eagle Refining Co.	Augusta	1917	2,000,000	5,000
Good Eagle Refining Co.	Baxter Springs	1917	50,000	600
Chanute Refining Co.	Chanute	1907	......	1,600
Kansas Cooperative Ref. Co. (L)	Chanute	1906	250,000	1,000
Sinclair Refining Co.	Chanute	1907	......	2,200
Uncle Sam Oil Co. (L)	Cherryvale	1906	350,000	1,200
Wright Prod. & Ref. Co.	Cherryvale	1917	100,000	1,000
Kansas Oil Refining Co. (L)	Coffeyville	1906	1,500,000	1,800
National Refining Co. (L)	Coffeyville	1907	1,550,000	4,600
Sinclair Ref. Co. (Cudahy) (L)	Coffeyville	1909	......	4,500
El Dorado Refining Co.	El Dorado	1916	250,000	2,000
Fidelity Refining Co.	El Dorado	1918	30,000	2,500
Midland Refining Co.	El Dorado	1917	250,000	4,000
Railroad Men's Refining Co.	El Dorado	1918	100,000	1,500
Great Western Pet. Corp. (L)	Erie	1905	750,000	1,000
Miller Petroleum Refining Co.	Humboldt	1906	73,626	1,000
Hutchinson Refining Co.	Hutchinson	1915	125,000	1,500
Standard Asph. & Ref. Co.	Independence	1909	2,750,000	3,000
General Refining Co.	Kansas City	1909	100,000	800
Kansas City Refining Co.	Kansas City	1906	300,000	2,700
Sinclair Refining Co.	Kansas City	1917	500,000	5,000
Commonwealth Oil & Ref. Co.	Moran	1905	350,000	800
Standard Oil Co. of Kansas	Neodesha	1892	7,250,000	9,000
O. K. Refining Co. (L)	Niotaze	1906	400,000	1,200
H. & H. Refinery Co.	Osawatomie	1919	150,000	1,000

L = Lubricating or Wax Plants.

PETROLEUM REFINERIES OF NORTH AMERICA—Continued

Company	Location	Year Built	Approximate Investment	Ap. Barrels Crude Daily
KANSAS—Concluded				
Red Ball Oil & Ref Co.	Ottawa	1917	75,000	.....
North American Ref. Co. (operated by Smiley Petrol. Co.)	Rosedale	1915	75,000	1,000
Cumberland Refining Co. (Quaker Oil Co.)	Wichita	1919	400,000	1,000
Golden Rule Refining Co.	Wichita	1917	35,000	1,000
Sterling Oil & Refining Co.	Wichita	1917	500,000	5,000
Western Refining Co.	Wichita	1917	35,000	1,200
Wichita Indep. Oil & Ref. Co.	Wichita	1914	200,000	4,000
KENTUCKY				
Standard Oil Co.	Barbourville	1916	2,500,000	10,000
Neha Refining Co.	Compton Jct.	1917	90,000	500
Indian Refining Co.	Georgetown	....	......	Idle
Kentucky Prod. & Ref. Co.	Irvine	1917	1,500,000	30,000
Southern Oil Ref. Co.	Lexington	1917	......	.....
Melick Refining Co.	Lexington	1917	100,000	1,500
Aetna Refining Co.	Louisville	1917	1,100,000	3,000
Security Prod. & Ref. Co.	Louisville	1917	1,000,000	3,500
Standard Oil Co. of Kentucky	Louisville	(Bldg.)	......	.....
Victor Refining Co.	Louisville	1917	......	6,000
Oleum Refining Co.	Pryse	1917	125,000	1,000
Pioneer Refining Co.	Rodemer	1918	100,000	1,000
McCombs Prod. & Ref. Co.	Torrent	1918	100,000	1,000
LOUISIANA				
Federal Oil & Ref. Co.	Alexandria	1915	150,000	1,000
Standard Oil Co.	Baton Rouge	1910	6,000,000	40,000
Pelican Oil & Ref. Co.	Chalmette	1915	225,000	1,200
Red River Refining Co.	Crichton	1916	200,000	1,000
Freeport-Mexican Petroleum Corp.	Destrahan	1916	2,000,000	2,000
Tar Island Oil & Ref. Co.	Mooringsport	1918	60,000	300
Roxana Petroleum Co.	New Orleans	1918	1,500,000	5,000
Freeport & Mexican Fuel Oil Corp.	Meraux	1917	1,500,000	10,000
Corona Oil Co. (Dutch Shell Co.)	New Orleans	1916	2,000,000	10,000
Freeport & Tampico Fuel Oil Corp.	New Orleans	Prop.	......	.....
Liberty Oil Co., Ltd.	New Orleans	1915	40,000	700
New Orleans Ref. Co. (Dutch Shell)	New Orleans	1917	......	.....
Union Refining Co.	Oil City	1918	50,000	300
Southern Oil Co., Inc.	Plaquemine	1917	20,000	500
Louisiana Oil Refining Co.	Shreveport	1912	1,350,000	2,500
Superior Oil Works	Malvern (Lewis)	1919	100,000	1,000
Great Southern Prod. & Ref. Co.	Shreveport	1919	150,000	1,500
Pine Island Refining Co.	Shreveport	1916	50,000	300
Caddo Oil Refinery	Shreveport	1913	500,000	2,000
Marine Oil & Ref. Co.	Shreveport	1918	300,000	1,000
Shreveport Oil Ref. Co.	Shreveport	1911	50,000	1,300
Rio Bravo Oil Co.	Welsh	1907	50,000	200
MARYLAND				
Prudential Oil Corp. (L)	Baltimore	1915	3,750,000	10,000
Standard Oil Co. of N. J.	Baltimore	....	3,750,000	10,000
Gasoline Corporation	Curtis Bay	1917	100,000	Idle
Inter-Ocean Oil Co. (L)	E. Brooklyn	1913	250,000	1,500
U. S. Asphalt Ref. Co.	E. Brooklyn	1911	1,000,000	5,000
Red "C" Oil Mfg. Co. (L)	Highland Town	....	350,000	725
MASSACHUSETTS				
Galena-Signal Oil Co.	Boston	....	......	300
MICHIGAN				
White Star Oil Co.	Detroit	1917	175,000	400

L = Lubricating or Wax Plants.

PETROLEUM REFINERIES OF NORTH AMERICA—Continued

Company	Location	Year Built	Approximate Investment	Ap. Barrels Crude Daily
	MINNESOTA			
Pure Oil Co	Minneapolis	1917	60,000	400
	MISSOURI			
Wilhoit Refining Co	Joplin	1914	150,000	1,000
Evans-Thwing Refining Co	Kansas City	1917	500,000	4,000
North American Ref. Co	Kansas City	1917	150,000	4,000
St. Jos. Viscosity Oil & Ref. Co.	St. Joseph	1915	25,000	500
Standard Oil Co. of Indiana	Sugar Creek	1917	3,000,000	15,000
	MONTANA			
Dillon Oil Co	Butte	....	50,000	250
	NEBRASKA			
Omaha Oil Refining Co	Omaha	....	150,000	1,000
	NEW JERSEY			
Columbia Oil Co. of N. Y.	Bayonne	....	600,000	1,000
Standard Oil Co. of N. J. (L)	Bayonne	1873	37,000,000	78,000
Tidewater Oil Co. (L)	Bayonne	1879	33,000,000	13,000
Standard Oil Co. of N. J	Bayway	1914	15,000,000	40,000
Vacuum Oil Co., Paving	Bramwell's Pt.	1917	200,000	2,000
Warner-Quinlan Asphalt Co	Carteret	1916	25,000	1,000
Valvoline Oil Co. (L)	Edgewater	1901	500,000	1,000
Galena-Signal Oil Co. (L)	Elizabeth	1916	500,000	1,500
Columbia Refining Co	Jersey City	.....	50,000	100
Standard Oil Co. of N. J. (L)	Jersey City	1871	10,000,000	15,000
Barber Asphalt Co	Maurer	....	......	.....
Warner-Quinlan Co.	Maurer	1916	25,000	1,000
Vacuum Oil Co. (L)	Paulsboro	1916	3,000,000	10,000
	NEW YORK			
Standard Oil Co. of N. Y. (L)	Buffalo	....	1,250,000	3,500
Mexican Petroleum Co	Mariners' Harber	1915	350,000	3,000
Standard Oil Co. of N. Y. (L)	New York City	1882	55,000,000	23,000
Vacuum Oil Co. (L)	Olean	1882	5,000,000	12,00
Vacuum Oil Co. (L)	Rochester	....	750,000	.....
Wellsville Refining Co. (L)	Wellsville	1901	664,000	1,000
	OHIO			
Canfield Oil Co	Cleveland	1907	150,000	300
Clarke, Fred G., Co	Cleveland	....	200,000	1,500
Great Western Oil Co	Cleveland	....	100,000	400
Industrial Oil & Ref. Co	Cleveland	....	......	.....
Lake Carriers Oil Co	Cleveland	....	75,000	500
Standard Oil Co. of Ohio	Cleveland	1870	3,500,000	8,400
Middle West Refining Co	Columbus	1918	125,000	1,000
National Refining Co	Findlay	....	250,000	1,200
Craig Oil Co	Ironville	1891	250,000	1,200
Solar Refining Co	Lima	1886	2,575,000	10,000
National Refining Co	Marietta	....	150,000	500
Sterling Oil Works	Marietta	....	......	400
Ohio Cities Gas Co. (Heath Refineries).	Newark	1919	300,000	3,000
Rajah Oil & Ref. Co	New Middletown	....	......	80
Paragon Refining Co	Toledo	1888	4,500,000	3,000
Sun Oil Co	Toledo	....	350,000	4,000
Oil Refining & Devel. Co	Urbana	1917	......	.....
Ohio Valley Ref. Co	St. Mary's	1913	450,000	1,000

L = Lubricating or Wax Plants.

PETROLEUM REFINERIES OF NORTH AMERICA—Continued

Company	Location	Year Built	Approximate Investment	Ap. Barrels Crude Daily
	OKLAHOMA			
Crystal White Ref. Co	Allen	1915	25,000	1,000
Ardmore Ref. Co. (Ohio Cities)	Ardmore	1914	1,000,000	6,000
Cameron Refining Co	Ardmore	1917	250,000	2,000
Chickasha Refining Co	Ardmore	1917	250,000	3,000
Imperial Refining Co	Ardmore	1917	250,000	2,600
Bigheart Petroleum Ref. Co	Bigheart	1908	100,000	1,200
Bixby Oil & Ref. Co	Bixby	1917	200,000	2,000
Economy Oil & Ref. Co	Blackwell	1916	120,000	1,500
Globe Oil & Ref. Co	Blackwell	1917	175,000	1,500
Modern Refining Co	Blackwell	1918	250,000	2,000
Producers & Refiners Corp	Blackwell	1916	850,000	1,850
Boynton Refining Co	Boynton	1916	250,000	2,500
Continental Refining Co	Bristow	1914	275,000	2,000
Oklamade Ref. Co	Chelsea	1918	50,000	300
Great Central Ref. Co	Claremore	1917	500,000	500
American Oil & Tank Line Co	Cleveland	1913	750,000	1,200
Consolidated Ref. Co	Cleveland	1913	85,000	650
Webster Refining Co	Coalton	1911	......	.....
Superior Oil Ref. Co	Covington	1917	150,000	1,000
Anderson & Gustafson (Hillman Ref. Co.)	Cushing	1914	27,000	600
Chenning Refining Co	Cushing	1917	20,000	450
Consumers Refining Co. (L)	Cushing	1913	1,250,000	5,000
Cosden & Co	Cushing	1911	......	2,000
Cushing Acid Works	Cushing	....	......	.....
Cushing Petroleum Prod. Co	Cushing	1917	30,000	450
Dean Oil Co	Cushing	1916	25,000	Idle
Empire Refineries (Cushing)	Cushing	1912	......	4,000
Federal Refining Co	Cushing	1917	85,000	2,000
Illinois Oil Co	Cushing	1914	175,000	2,000
Indian Chief Ref	Cushing	1918	25,000	.....
Inland Refining Co	Cushing	1917	350,000	3,000
International Ref. Co. (Ohio Cities Gas Co.)	Cushing	1915	300,000	5,000
Occident Oil & Ref. Co	Cushing	1916	50,000	1,000
Peerless Ref. Co. (Empire)	Cushing	1914	651,000	3,000
Sinclair Oil & Ref. Co	Cushing	1914	......	6,000
Kay County Refining Co	Dilworth	1917	95,000	700
Central Refining Co	Drumright	1917	15,000	300
Interstate Oil Refining Co	Drumright	1917	25,000	.....
Bu-Co Oil & Refining Co	Enid	1917	10,000	.....
Champlin Refining Co	Enid	1917	75,000	1,500
Globe Oil & Ref. Co	Enid	1917	500,000	5,000
Oil State Refining Co	Enid	1918	250,000	1,200
Southwestern Oil Corp	Enid	1917	85,000	1,500
Garber Refinery	Garber	1918	100,000	600
Gotebo Refining Co	Gotebo	1917	10,000	100
Carbo Oil Refining Co	Guthrie	1918	100,000	1,500
Forty-Sixth Star Ref. Co	Healdton	1917	150,000	2,000
Terminal Refining Co	Healdton	1917	400,000	2,000
Henryetta Refining Co	Henryetta	1917	10,000	.....
Osage Refining Co	Hominy	1917	30,000	1,000
Wabash Refining Co	Hominy	1917	100,000	1,500
Southern Refining Co	Haskell	1919	100,000	1,000
Great American Refining Co	Jennings	1917	600,000	3,000
Acme Ref. & Pipe Line Co	Jennings	1917	250,000	2,500
Odessa Oil & Refining Co	Jennings	1917	100,000	.....
Republic Refining Co	Jennings	1918	85,000	.....
Comanche Oil & Ref. Co	Lawton	1917	125,000	500
Lawton Refining Co	Lawton	1916	365,000	1,550
North Iowa Oil & Ref. Co	Lawton	1917	50,000	.....
Birmingham Oil & Gas Co	Muskogee	1917	1,000,000	.....
Haskell Refining Co	Muskogee	1917	150,000	.....
Muskogee Refining Co. (L)	Muskogee	1905	1,350,000	2,100
Nupro Refining Co	Muskogee	1917	50,000	800
Oklahoma Prod. & Ref. Corp	Muskogee	1916	2,000,000	2,000

L = Lubricating or Wax Plants.

PETROLEUM REFINERIES OF NORTH AMERICA—Continued

Company	Location	Year Built	Approximate Investment	Ap. Barrels Crude Daily
	OKLAHOMA—Continued			
Sinclair Oil & Ref. Co. (Cudahy)	Muskogee	1905	......	800
Crescent Refining Co.	Newkirk	1917	200,000	3,000
Dilworth Oil & Refining Co.	Newkirk	1917	......	.....
Ardmore Producing & Refining Co.	New Wilson	1917	350,000	2,500
Triangle Oil Refining Co.	New Wilson	1917	35,000	.....
Carter Oil Co.	Norfolk	1916	3,500,000	18,000
Oilton Refining Co.	Oilton	1917	15,000	500
Riverside Refining Co.	Oilton	1918	300,000	800
Atwood Refining Co.	Oklahoma City	1915	350,000	1,250
Capital Refining Co. of Okla.	Oklahoma City	1915	20,000	300
Empire Refineries (Okla. Ref. Co.)	Oklahoma City	1906	250,000	2,200
Golden Belt Refining Co.	Oklahoma City	1918	200,000	.....
Home Petroleum Co. (L)	Oklahoma City	1918	1,500,000	2,500
Naphth-oil Mfg. Co.	Oklahoma City	1918	80,000	300
Sterling Refining Co.	Oklahoma City	1918	200,000	1,000
Allied Refining Co.	Okmulgee	1917	250,000	1,000
Empire Ref. (American Ref.) (L)	Okmulgee	1907	......	4,000
Indiahoma Refining Co.	Okmulgee	1910	1,258,000	3,750
Lake Park Refining Co.	Okmulgee	1915	750,000	2,000
Okmulgee Prod. & Ref. Co.	Okmulgee	1916	2,125,000	2,500
Oneta Refining Co.	Oneta	1917	40,000	1,300
Limbocker Oil & Ref. Co.	Paul's Valley	Prop.	150,000	1,000
Osage Mutual Refining Co.	Pawhuska	1917	30,000	.....
North American Refining Co.	Pemeta	1915	200,000	2,500
Empire Ref. (Ponca Ref. Co.) (L)	Ponca City	1912	......	3,50
Lake Park Refining Co.	Ponca City	1917	150,000	2,0
Marrland Refining Co.	Ponca City	1918	2,500,000	2,0
Bison Refining Co.	Quay	1918	125,000	1,
Peoples Refining Co.	Ringling	1917	100,000	
Mohawk Refining Co.	Sand Springs	1917	......	..
Phoenix Refining Co.	Sand Springs	1913	350,000	5,0
Pierce Oil Corporation (L)	Sand Springs	1913	2,750,000	9,5
Wabash Refining Co.	Sand Springs	1917	250,000	5,0
Golden Glow Refining Co. (Duluth Refining Co.)	Sapulpa	1917	175,000	3,00
Sapulpa Refining Co.	Sapulpa	1908	2,000,000	7,500
Victor Refining Co.	Sapulpa	1917	100,000	1,000
Shawnee Refining Co.	Shawnee	1917	100,000	.....
Mayfield Oil & Ref. Co.	Terlton	1918	25,000	1,500
Bliss Oil & Refining Co.	Tulsa	1917	3,000,000	.....
Brazilian Oil & Refining Co.	Tulsa	1917	100,000	.....
Constantin Refining Co.	West Tulsa	1911	1,350,000	8,000
Consumers Oil & Refining Co.	West Tulsa	1917	340,000	1,200
Cosden & Co. (L)	West Tulsa	1913	47,000,000	15,000
Federal Refining Co.	Tulsa	1917	50,000	.....
Jayhawker Refining Co.	Tulsa	1917	100,000	.....
Mid-Continent Gasoline Co.	West Tulsa	1916	250,000	4,000
Phoenix Refining Co.	Tulsa	....	300,000	.....
Pan-American Refining Co.	West Tulsa	1916	2,000,000	6,500
The Texas Company	West Tulsa	1910	2,350,000	8,500
Uncle Sam Oil Co. (Valley)	West Tulsa	1906	150,000	600
Valley Refining Co.	West Tulsa	1906	150,000	1,000
Western Products & Ref. Co.	Tulsa	1917	1,000	.....
White Star Refining Co.	West Tula	1917	100,000	1,500
Milliken Ref. Co. (Sinclair) (L)	Vinita	1910	......	10,000
Wilson Refining Co.	Wilson	1917	20,000	1,000
Canfield Refining Co.	Yale	1917	250,000	1,000
Home Oil Refining Co.	Yale	1916	40,000	2,000
Liberty Refining Co.	Yale	1917	30,000	2,000
Pawnee Bill Oil & Ref. Co.	Yale	1916	125,000	1,000
Southern Oil Corporation	Yale	1915	1,000,000	5,000
Star Refining Co.	Yale	1916	16,000	600
Sun Company	Yale	1915	600,000	3,000
Superior Refining Co.	Yale	1916	21,000	190

L - Lubricating or Wax Plants.

PETROLEUM REFINERIES OF NORTH AMERICA—Continued

Company	Location	Year Built	Approximate Investment	Ap. Barrels Crude Daily
	OKLAHOMA—Concluded			
Victor Refining Co.	Yale	1916–17	100,000	1,000
Webster Oil & Gasoline Co.	Yale	1915	80,000	800
Worth Oil & Refining Co.	Yale	1918	125,000	250
Yale Oil Refining Co.	Yale	1916	30,000	1,000
	PENNSYLVANIA			
Donecker-Hiller Oil Ref. Co. (L)	Allentown	1917	50,000	150
Emery Mfg. Co. (L)	Bradford	1888	610,500	1,200
Kendall Refining Co. (L)	Bradford	1882	425,000	500
Chippewa Refining Co.	W. Bridgewater	1919	(Bldg.)	
Butler County Oil Ref. Co. (L)	Bruin	1911	600,000	800
Valvoline Oil Co.	Butler	....	......	1,000
East Welbourne Oil Co. (L)	Butler	1896	500,000	1,000
Inter-Ocean Oil Co.	Chester	....	......	.....
Manufacturer's Paraffin Co.	Chester	....	......	.....
Clarendon Refining Co. (L)	Clarendon	1885	220,000	1,300
Levi Smith, Ltd.	Clarendon	1890	150,000	1,050
Tiona Refining Co. (L)	Clarendon	1886	326,000	400
Amber Oil & Realty Co.	Clarendon	1915	50,000	150
Canfield Oil Co. (L)	Coraopolis	1897	180,000	370
Glenshaw Development Co.	Coraopolis	....	......	600
Pittsburgh Oil Refining Co. (L)	Coraopolis	1892	225,000	1,000
Robinson Oil Corporation	Coraopolis	....	22,037,000	.....
Vulcan Oil Refining Co. (L)	Coraopolis	1900	200,000	850
[illegible]ennsylvania Oil Prod. Ref. Co. (L)	Eldred	1913	227,000	500
[illegible]mlenton Refining Co. (L)	Emlenton	1891	500,000	500
[illegible]verson Oil Works	Erie	....	......	.....
[illegible]ted Oil Manufacturing Co.	Erie	....	......	.....
[illegible]ntic Ref. Co. (Eclipse) (L)	Franklin	1872	......	8,000
[illegible] Oil Co. (L)	Franklin	1917	175,000	200
[illegible]klin Quality Ref. Co. (L)	Franklin	1918	100,000	100
[illegible]ena-Signal Oil Co. (L)	Franklin	1869	4,500,000	2,000
[illegible]nklin Oil Works (L)	Franklin	1877	20,000	300
[illegible]edom Oil Refining Co. (L)	Freedom	1889	300,000	1,500
[illegible] Refining Co.	Gibson's Point	....	......	5,000
[illegible]nnsylvania Refining Co. (L)	Karnes City	1901	90,000	100
[illegible]tarlight Refining Co.	Karnes City	1893	60,000	100
Pure Oil Co. (Ohio Cities Gas Co.) (L)	Marcus Hook	1890	2,500,000	4,500
Sun Oil Co (L)	Marcus Hook	....	3,500,000	6,000
Island Petroleum Co. (L)	Neville Island	1912	150,000	1,000
Advance Oil Co.	Oil City	1917	75,000	300
Jas. Berry's Sons (L)	Oil City	....	550,000	2,200
Continental Refining Co. (L)	Oil City	1885	275,000	750
Crystal Oil Works	Oil City	1886	250,000	800
Independent Refining Co. (L)	Oil City	1882	350,000	1,000
Penn-American Oil Co. (L)	Oil City	1892	2,000,000	2,500
Sunrise Oil Co.	Oil City	1917	100,000	.....
Crew Levick Co.	Petty's Island	....	......	.....
W. H. Daugherty & Son Ref. Co.	Petrolia	1880	125,000	200
Petrolia Refining Co.	Petrolia	1890	20,000	50
Crew Levick Co. Seaboard (Doherty) (L)	Philadelphia	....	500,000	800
Sunlight Oil & Gasoline Wks.	Philadelphia	....	......	130
Atlantic Refining Co. (L)	Pittsburgh	1862	57,000,000	3,500
Chippena Refining Co.	Pittsburgh	1917	......	.....
A. D. Millers' Sons Co. (L)	Pittsburgh	1862	1,125,000	1,000
Waverly Oil Works (L)	Pittsburgh	1880	650,000	650
Atlantic Refining Co. (L)	Point Breeze	1866	......	42,000
Coldwater Refining Co.	Raymilton	....	......	.....
Empire Oil Works (L)	Reno	1886	350,000	650
Crystal Oil Works (L)	Rouseville	1886	250,000	800
Pan-American Refining Co.	Rouseville	1892	2,000,000	3,000
Mutual Sales Co. (L)	Russell	1918	75,000	200
Amber Oil & Realty Co.	Stoneham	....	......	.....

L = Lubricating or Wax Plants.

PETROLEUM REFINERIES OF NORTH AMERICA—Continued

Company	Location	Year Built	Approximate Investment	Ap. Barrels Crude Daily
PENNSYLVANIA—Concluded				
Valvoline Oil Co.	Struthers	....	......	.....
Natural Gasoline Co.	Tidioute	1919	(Bldg.)	
Interior Oil & Gas Corporation	Tiona	1917	50,000	250
American Oil Works (L)	Titusville	1888	350,000	800
Crew Levick (Messimer plant)	Titusville	1912	300,000	780
Crew Levick (Pa. Par. Wks.) (L)	Titusville	1905	400,000	800
Muir Oil Works	Titusville	....	......	.....
Titusville Oil Works	Titusville	1876	210,000	1,000
Fred G. Clarke Co.	Warren	....	500,000	.....
Conewango Refining Co.	Warren	1895	400,000	450
Cornplanter Refining Co. (Ohio Cities Gas Co.)	Warren	1888	1,150,000	2,000
Mutual Refining Co. (L)	Warren	1909	166,800	500
Ohio Cities Gas Co.	Warren	....	......	1,500
Seneca Oil Works (L)	Warren	1893	350,000	560
Crew Levick Co. (Glade Oil Wks.) (L)	Warren	1885	350,000	680
United Oil Refining Co. (L)	Warren	1902	425,000	500
Superior Oil Works (L)	Warren	1901	275,000	400
Warren Refining Co. (L)	Warren	1890	......	1,700
Wilburine Oil Works (L)	Warren	1897	1,000,000	500
Beaver Refining Co. (L)	Washington	1890	115,000	200
RHODE ISLAND				
Standard Oil Co. of N. Y.	Providence	1919	(Bldg.)	
TENNESSEE				
Lookout Oil & Refining Co.	Chattanooga	1917	100,000	1,500
Dixie Refining Co.	Memphis	1917	10,000	200
General Ref. & Producing Co.	Nashville	1915	30,000	400
Dix et al.		1917	75,000	300
TEXAS				
Magnolia Petroleum Co. (L)	Beaumont	1902	6,800,000	55,000
United Oil & Ref. Co.	Beaumont	1903	200,000	2,000
Brown Ard Refining Co.	Brownwood	1918	......	600
Brownwood Refining Co.	Brownwood	1918	40,000	600
Carson Oil & Refining Co.	Brownwood	1918	25,000	600
Gotebo Oil & Refining Co.	Brownwood	1918	50,000	Idle
Hall-Mountain Refining Co.	Brownwood	1918	75,000	1,000
Burkburnett Refining Co.	Burkburnett	1918	300,000	2,000
Dilman & Wright	Burkburnett	1918	......	1,500
Federal Oil & Refining Co.	Burkburnett	1918	......	2,000
Burkburnett-Victor Ref. Co.	Burkburnett	1918	......	2,500
Beaver Valley Oil & Ref. Co.	Cisco	1918	100,000	1,000
Liberty Refining Co.	Cisco	1918	50,000	1,350
Lone Star Oil & Ref. Co.	Coleman	1918	50,000	500
Central Oil Co.	Corsicana	1903	75,000	Idle
Magnolia Petroleum Co. (1)	Corsicana	1898	600,000	5,000
Hercules Petroleum Co.	West Dallas	1918	215,000	3,600
Oriental Oil Co. (1) (L)	Dallas	1912	500,000	3,500
State Refining Co.	Dallas	1919	150,000	.....
The Texas Co.	Dallas	1908	......	16,000
Dallas Refining Co.	DeLeon	1918	300,000	3,500
Eastland Oil & Refining Co.	Eastland	1918	......	600
Great Southern Oil & Ref. Co.	Eastland	1918	......	1,200
Beaver-Electra Refining Co.	Electra	1918	250,000	2,000
Electra Refining Co.	Electra	1918	100,000	2,000
Hercules Refining Co.	Electra	1918	125,000	2,000
Robert Lignon	El Paso	1917	25,000	200
Baltic Refining Co. (Inland Refining Co.)	Fort Worth	1918	......	5,000

L = Lubricating or Wax Plants.

PETROLEUM REFINERIES OF NORTH AMERICA—Continued

Company	Location	Year Built	Approximate Investment	Ap. Barrels Crude Daily
	TEXAS—Concluded			
El Dorado Refining Co	Fort Worth	(s)	......	5,000
Evans-Thwing Refining Co	Fort Worth	1918	......	5,000
Federal Refining Co	Fort Worth	1918	(Prop.)	2,000
Gulf Refining Co	Fort Worth	1911	1,500,000	6,000
Home Oil & Refining Co	Fort Worth	1919	......	5,000
Magnolia Petroleum Co	Fort Worth	1914	1,000,000	15,000
Panther City Oil & Ref. Co	Fort Worth	(s)	......	1,000
Pierce Oil Corporation	Fort Worth	1912	5,600,000	15,000
Southern Oil & Refining Assn. (L)	Fort Worth	1918	100,000	500
Texas Producing & Ref. Co	Fort Worth	....	......	4,000
Star Refining Co	Fort Worth	1919	......	1,000
Producers Refining Co. (Empire)	Gainesville	1915	1,500,000	13,000
Inland Refining Co	Gorham	....	......	3,000
Empire Refineries	Houston	....	......	2,000
Hoffman Oil & Ref. Co. (L)	Houston	1916	150,000	1,000
Petroleum Refining Co. (L)	Houston	1916	1,000,000	1,000
Sinclair-Gulf Corp. (L)	Houston	1918	2,500,000	40,000
Trans-Atlantic Pet. Co. (L)	Houston	1918	150,000	Idle
Globe Refining Co	Humble	1916	10,000	150
Humble Oil & Refining Co	Humble	1916	15,000	600
Mary Owens Oil Co	Humble	1917	15,000	Idle
Wichita Valley Refining Co	Iowa Park	1914	125,000	2,500
Avis Refining Co	Jacksboro	1915	150,000	300
Eureka Refining Co. (tar)	La Porte	1917	10,000	100
Oriental Oil Co	Oriental	....	......	600
Seaboard Oil & Refining Co. (L)	Orange	1917	150,000	.....
Gulf Refining Co	Port Arthur	1901	25,000,000	60,000
The Texas Co. (L)	Port Arthur	1902	50,000,000	32,000
The Texas Co. (L)	Port Neches	1906	......	13,000
Odessa Refining Co. (L)	Ranger	1918	100,000	3,600
Ranger Oil & Refining Co	Ranger	....	......	1,000
Ranger Refining Co	Ranger	1919	350,000	1,000
Dixie Oil & Refining Co	San Antonio	1913	240,000	700
Eggleston & Todd	San Antonio	1918	......	1,200
Humble Oil & Ref. Co. (L)	San Antonio	1913	350,000	1,800
Slump Oil Co	Somerset	1915	25,000	300
Pierce Oil Corp. (L)	Texas City	1911	2,000,000	5,000
Black Diamond Oil Co	Thrall	1916	500,000	600
Riverside Oil & Refining Co	Waco	....	......	1,500
South Bosque Refining Co	Waco	....	......	.....
American Refining Co	Wichita Falls	1919	......	3,000
Banker Petroleum & Ref. Co	Wichita Falls	1918	......	1,500
Gilliland & Fisher (L)	Wichita Falls	1918	100,000	1,200
Lone Star Refining Co	Wichita Falls	1918	250,000	2,500
Panhandle Refining Co	Wichita Falls	1915	1,500,000	5,000
Power Oil & Refining Co	Wichita Falls	1918	125,000	1,000
Ranger Wichita Oil & Ref. Co	Wichita Falls	1918	......	2,500
Red River Refining Co	Wichita Falls	....	......	500
Sunshine State Oil & Ref. Co	Wichita Falls	1918	335,000	1,250
Texas Gulf Ref. & Pipeline Co	Wichita Falls	....	......	.....
Victory Refining Co	Wichita Falls	(s)	......	2,700
	UTAH			
Basin Oil Refining Co	Basin	1917	......	.....
Utah Refining Co	Salt Lake City	1907	250,000	800
Utah Oil & Refining Co	Salt Lake City	1916	1,200,000	1,500
White Rock Oil & Ref. Co	Salt Lake City	....	......	.....
Urado Oil Co	Uintah Basin	....	......	.....
Dixie Oil Refining Co	Virginia City	1918	10,000	100
	VIRGINIA			
Gulf Refining Co	Norfolk	1917	......	.....
Mexican Petroleum Corp	Norfolk	1917	......	.....
Louisiana Oil Refining Co	Richmond	1917	......	.....

L = Lubricating or Wax Plants.

PETROLEUM REFINERIES OF NORTH AMERICA—Continued

Company	Location	Year Built	Approximate Investment	Ap. Barrels Crude Daily
WEST VIRGINIA				
Warner-Quinlan Co.	Cairo	....	......	400
Ohio Cities Gas Co.	Cabin Creek Jct.	1917	1,500,000	4,000
Elk Refining Co.	Falling Rock	1913	100,000	800
Petroleum Products Co.	Jacksonburg	....	......	200
Galena-Signal Oil Co. (L)	Parkersburg	1896	650,000	2,000
Standard Oil Co. of N. J.	Parkersburg	1893	1,500,000	2,500
Ohio Valley Ref. Co. (L)	St. Mary's	1913	900,000	1,000
Indiana Refining Co.	Staunton	1916	......	.....
WYOMING				
Mid-West Refining Co.	Casper	1912	25,250,000	35,000
Natrona Pipeline & Ref. Co.	Casper	....	687,767	.....
Northwestern Refining Co.	Casper	(Bldg.)	......	.....
Standard Oil Co. of Indiana	Casper	1914	3,750,000	40,000
Utah-Wyoming Oil Ref. Co.	Casper	....	......	.....
Kinney Oil & Refining Co.	Cheyenne	(Bldg.)	......	.....
Northwestern Oil Ref. Co.	Cowley	1909	750,000	20,000
Wyatt Oil & Refining Co.	Douglas	1918	175,000	500
Colorado-Wyoming Ref. Co.	Douglas	....	......	.....
Idaho-Wyoming Oil Co.	Fossil	....	......	.....
Consumers Oil & Refining Co.	Greybull	1918	30,000	3,000
Greybull Refining Co.	Greybull	1915	1,500,000	12,000
Standard Oil Co.	Greybull	1916	1,500,000	5,000
Mid-West Refining Co.	Greybull	1915	25,000,000	10,000
Glenrock Refining Co.	Glenrock	(Bldg.)	......	2,000
Mutual Producing & Ref. Co.	Glenrock	1918	500,000	800
Wyoming Refining Co.	Greybull	....	800,000	.....
Western Exploration Co.	Lander	....	......	.....
Wind River Refining Co.	Lander	1918	350,000	1,000
Mid-West Refining Co.	Laramie	1919	......	5,000
Standard Reserve Oil Co.	Le Roy	....	2,221,629	.....
Riverton-Wyoming Ref. Co.	Riverton	1918	150,000	1,000
Wyoming Refining Co.	Thermopolis	....	......	.....
Southwest Oil Co.	Thornton	1918	25,000	100
CANADA				
Imperial Oil Co. (L)	Dartmouth, N.S.	1918	2,500,000	3,000
Imperial Oil Co. (L)	Ioco, B.C.	1914	4,000,000	3,500
Imperial Oil Co. (L)	Montreal, Que.	1917	2,000,000	2,500
Calgary Petroleum Products, Ltd.	Okotoks, Alt.	1915	45,000	30
Canada Southern Oil & Ref. Co.	Okotoks, Alt.	1917	35,000	25
Southern Alberta Ref., Ltd.	Okotoks, Alt.	1916	45,000	30
Canadian Oil Companies, Ltd. (L)	Petrolia	1909	1,500,000	800
Canadian Oil Prod. & Ref. Co. (L)	Petrolia	1919	200,000	150
British Columbia Ref. Co.	Moody, B. C.	1902	1,000,000	500
Continental Oil Co.	Regina, Sask.	....	1,000,000	.....
Imperial Oil Co. (L)	Regina, Sask.	1916	2,000,000	2,500
Imperial Oil Co. (L)	Sarnia	1898	25,000,000	20,000
British-American Oil Co. (L)	Toronto	1906	1,500,000	800
Great Lakes Oil & Ref. Co. (L)	Wallaceburg	1910	200,000	250
MEXICO				
Atlantic Refining Co. (Cia. Refinadores y Productori de Petroleo La Atlantica)	Port Lobos	....	......	10,000
Texas Co.	Port Lobos	....	......	.....
Mexican Eagle Co., Ltd.	Puerto Minatitlan (Isthmus of Tehauntepec)	1908	......	15,000
La Corona Petroleum Co.	Tampico (plans)	....	......	6,000
Mexican Eagle Oil Co., Ltd.	Tampico (W)	1914	......	12,500
Pierce Oil Corporation	Tampico (W-L)	1896	......	10,000
Huasteca Petroleum Co.	Tampico	1915	......	60,000
Standard Oil Co. (N. J.)	Tampico	1914	......	6,000
Texas Co.	Tampico	1918	......	6,000
Mexican Eagle Oil Co., Ltd.	Tuxpan	....	......	5,000
Pierce Oil Corporation	Vera Cruz	....	......	2,500

L = Lubricating or Wax Plants.

Texas Oil Companies With Production in April, May and June, 1919

Company and Address.	Production, barrels.
Abner Davis, Wichita Falls	2,350.78
American Reclaim Oil Co., South Houston	2,796.74
Arlington Oil Company, Arlington	595.04
Anderson Oil Co., Lawton, Okla.	3,080.58
A No. 1 Oil Co., Lawton, Okla.	1,528.49
Adams, Brown & McAlister, Wichita Falls	37,783.83
Abilene-Brownwood Oil Co., Abilene	251.04
Anna Zip Oil Association, Brownwood	1,994.59
Allday Oil Co., Wichita Falls	1,761.72
Art Oil Co., Wichita Falls	1,383.13
Arcade Oil Co., Beaumont	763.46
Aikin, L. H., San Antonio	1,533.22
Adams Oil Co., Wichita Falls	12,868.68
Amalgamated Oil Co., Wichita Falls	3,856.28
Ada Bell Oil Co., Independence, Kan.	20,154.65
Acorn Oil Co., Beaumont	6,823.58
Annox Oil Co., Beaumont	14.18
Apple, Dunlap & Sykes, Ardmore, Okla.	7,805.83
Abernathy Oil & Gas Co., Wichita Falls	1,833.15
Burk-Star Oil Co., Wichita Falls	4,773.30
Bartles & Jones, Ranger	520.00
Butler-Harper Oil Association, Lawton, Okla.	1,402.76
Block Six Oil Co., Frederick, Okla.	19,103.80
Big Pool Oil Co., Wichita Falls	11,823.49
Block Twenty Oil Co., Wichita Falls	5,627.21
Brundage - Hancock Oil Co. No. 2, Wichita Falls	7,614.30
Bradley Bros. Oil Co., Houston	5,560.00
Burkburnett - O'Nail Oil Co., Wichita Falls	1,540.15
Bowers & Witherspoon, Palestine	987.40
Brown & Jones, Wichita Falls	160,987.50
Burk-Vernon Oil Co., Wichita Falls	2,614.61
Burkdell Oil Co., Odell	971.88
Bernstein, Eli, Dallas	24.64
Broome Bros., Brownwood	191.25
Broome Oil Co., Brownwood	2,077.29
Bullington, Orville, Wichita Falls	40,886.02
Bishop Evans Oil Co., Wichita Falls	11,244.43
Brock-Lunday Oil Co., Bowie	736.00
Big Four Oil Co., Sour Lake	21,933.91
B. O. O. G. Oil Co., Iowa Park	861.07
Brazos River Oil Corp., Fort Worth	92,263.55
Buchanan, S. R., Batson	20,455.99
Barkley, T. G., Sour Lake	1,536.29
Big Flow Oil Co., Wichita Falls	3,334.50
Big Burk Oil & Gas Co., Wichita Falls	4,841.47
Bradley, E. L., Beaumont	1,613.00
Burkburnett - Van Cleve Oil Co., Wichita Falls	1,622.19
Burnett Petroleum Co., Wichita Falls	12,104.35
B. C. Oil Co., Wichita Falls	246.12
Big Seven Oil Company, Wichita Falls	6,622.08
Big Three Oil Company, Wichita Falls	2,286.18
Brown Oil Co. No. 1, Wichita Falls	4,150.65
Bowman, S. M., Brownwood	258.81
Bowman & Williams, Brownwood	41.76
Burkburnett Oil & Gas Co., Custer City, Okla.	150.23
Baker Oil Co., Houston	2,404.00
Burnett-Mann Oil Co. No. 2, Wichita Falls	192.50
Block Thirty-Six Oil Co., Wichita Falls	3,411.98
Burgess, Burgess & Chrestman, Dallas	2,368.25
Burkburnett Production Co., Dallas	25,679.20
Biggs Oil & Gas Co., McKinney	1,115.36
B. M. C. Oil Co., Electra	151.72
Burkburnett Southern Oil Co., Wichita Falls	2,378.41
Bi-State Oil and Gas Co., Granfield, Okla.	381.83
Big Burk Oil and Gas Co. No. 1, Wichita Falls	10,424.73
Big Jahn Oil Co., Beaumont	106.45
Burk-Electra Petroleum Co., Dallas	3,769.72
Central Producing Co., Chickasha, Okla.	5,531.31

TEXAS OIL COMPANIES WITH PRODUCTION IN APRIL, MAY AND JUNE, 1919—Continued

Company and Address.	Production, barrels.
Chenault, N. B., Wichita Falls	8,660.59
Connor & Kinnard, Wichita Falls	22,965.00
Colony School Well Co., Eastland	66,777.50
Cotton Oil Co., Saratoga	2,980.18
Cullinan Oil Association, Ardmore, Okla.	1,366.52
Cochran-Collis Oil Co., Wichita Falls	448.71
Crosbie, J. E., Tulsa	9,762.92
Caldwell Oil Co., Oklahoma City	1,579.74
Curtis, J. S., Davidson, Okla.	3,649.23
Conner, W. E., Wichita Falls	10,379.57
Crown Oil & Ref. Co., Houston	302,065.71
Cain-Marvin Oil Co., Dallas	1,889.05
Church Oil Co., Corsicana	1,929.11
Capital Oil & Gas Company, Hereford	134.56
Canada Oil Co., Wichita Falls	5,297.03
Cozy Oil Corporation, Wichita Falls	2,622.86
Cline, W. D. & Co., Wichita Falls	1,334.61
C. Y. T. Oil Co., Beaumont	2,198.27
Crowell & Gant, Dallas	19,972.72
Coalson Bros. & Affleck, Brownwood	139.44
Castell Oil Co., Houston	5,708.15
Cass Oil Co. Wichita Falls	2,778.08
Centerfield Oil Company, Wichita Falls	1,611.70
Crescent Oil Co., Wichita Falls	1,815.19
Clay, J. D., Houston	4,477.36
Couch Winfrey Oil Company, Wichita Falls	3,334.00
Cadillac Oil & Gas Co., Denton	406.50
Castles Oil Co., Corsicana	2,023.92
Crowell, L. R., Dallas	27,126.73
Castro, M., Brownwood	10.00
Dale-Knott Oil Co., Wichita Falls	240.00
Diplomat Oil Co., Waco	4,528.27
Diebel Oil Co., Thrall	265.00
E. Z. Mark Oil Co., Electra	351.38
Eclipse Oil Co., Ft. Worth	5,749.02
Excelsior Oil Co., Wichita Falls	1,634.99
Davis, L. R., Tulsa	4,118.32
Davis-Coggins Oil Co., Wichita Falls	1,020.55
Duggan Oil Co., Dallas	480.69
Developers Oil & Gas Co., Wichita Falls	800.49
Drillers Oil & Gas Co., Wichita Falls	5,842.66
Double Standard Oil Co., Wichita Falls	111.50
East Batson Oil Co., Batson	18,843.45
Electra-Burk Oil Co., Electra	3,910.75
Engel, Hendrickson & Haron, Wichita Falls	420.00
Eastland Oil & Ref. Co., Dallas	21,252.56
Eddy Oil Co., Guffey	738.32
Ellett Oil Co., Wichita Falls	1,180.62
Elm Hill Oil Co. Corsicana	662.00
Farabee Oil Co., Wichita Falls	3,249.68
Findley-Leach Oil Association, Wichita Falls	1,442.89
Freedman, Alex, Corsicana	187.04
Fisher-Parker Oil Co., Wichita Falls	1,740.14
Frederick Oil Co., Frederick, Okla.	2,467.31
Four and Four Oil Co., Dallas	1,269.17
Farish & Ireland, Houston	22,130.26
Farqueharson, C. B., Wichita Falls	6,198.93
Federal Oil Co. of Texas, Cleveland, Ohio	1,637.00
Findley-Leach, Wichita Falls	1,442.89
Fisher, Gates & Co., Wichita Falls	185.75
Fisher & Gilliland, Wichita Falls	7,618.68
Fowler Farm Oil Co., Wichita Falls	30,922.52
Findley-Minnick Oil and Gas Co., Benjamine	6,458.00
Foster-Sander Oil Co., Electra	1,005.16
Floydada Oil Co., Wichita Falls	4,872.50
Forest Oil Co., Wichita Falls	5,338.73
Floyd Oil Co., Electra	520.00
Fowler, M., Wichita Falls	961.91
Fritz, D. L., Wichita Falls	1,498.73
Fritz, L. W., Wichita Falls	462.35
Gates, F. M., Wichita Falls	6,432.56
Gusher Oil Co., Wichita Falls	345.88
Gladstone Oil and Ref. Co., Oklahoma City	31,274.14
Gulf Coast Oil Corporation, Houston	110,734.97
Ginsite Oil Co., Frederick, Okla.	17,577.54
Gatlin, Mrs. M. W., San Antonio	54.12
Gilbert Co., Beaumont	7,672.58

TEXAS OIL COMPANIES WITH PRODUCTION IN APRIL, MAY AND JUNE, 1919—Continued

Company and Address.	Production, barrels.
Guaranty Oil Co., Electra	851.08
Granite Oil & Gas Co., Electra	589.34
Gulf Production Co., Houston	1,999,294.73
Great Dome Oil Co., Wichita Falls	3,290.50
Grayburg Oil Co., San Antonio	8,840.01
Gholson, Moorman & Dorsey & Co., Ranger	450,980.14
Galconda Oil Co., Wichita Falls	47,231.00
Goodloe-Kennedy Oil Co., Wichita Falls	560.00
Gem Oil & Gas Co., Iola, Kans.	573.91
Harvester Oil Co., Wichita Falls	20,630.33
Healdton Oil and Gas Co., Wichita Falls	11,511.32
Hoffman Oil & Ref. Co., Houston	26,469.44
Houston's Texas Petroleum Co., Houston	794.64
Hartzell Oil Co., Corsicana	357.89
Harvey, R. O., lease, Wichita Falls	26,925.43
Hiawatha Oil Co., Hopkins, Minn.	117.50
Hereford Oil Co., Hereford	2,276.35
Houston Oil Co. of Texas, Houston	11,535.12
Hunt, J. C., Wichita Falls	1,273.34
Humble Oil and Ref. Co., Houston	1,490,503.96
Heydrick, J. C., Wichita Falls	74.53
Herne Oil Co., Wichita Falls	6,328.75
Hearn Oil Co., Wichita Falls	7,713.90
Hicks, E. P., Wichita Falls	12,325.06
Helen-Elizabeth Oil Co., Wichita Falls	7,446.40
Harvey Oil Co., Wichita Falls	4,383.62
Hodge Oil Co., Burkburnett	482.53
Hardin, Willis, Fowler & Staley, Burkburnett	194.68
Holiday & Gaffall, Beaumont	2,775.49
Haile Oil Co., Wichita Falls	336.82
High Land Oil & Gas Co., Electra	908.34
Hollingsworth, W. E., Brownwood	302.00
Hall Bros. Oil Co., Brownwood	1,051.00
Imperial Petroleum Co., Wichita Falls	27,493.18
Ilsong-Worth Oil Co., Wichita Falls	13,471.39
Itex Oil Co.. Wichita Falls	6,105.71
Invincible Oil Co., Houston	60,005.81
Independent Oil Co., Thrall	58.64
Jones, Cham, Waurika, Okla.	379.00
Julia Oil Co., Sour Lake	4,296.67
Jones, Roy B., Trustee, Wichita Falls	4,195.68
Junior Oil and Pipeline Co., Corsicana	432.47
Jackson, J. S., Trustee, Sour Lake	1,980.81
Janellen Oil Co. Tulsa, Okla.	2,634.06
John and Jeff Oil Co., Wichita Falls	5,245.38
Jones-Light Petroleum Co., Pilot Point	1,399.90
Jacks, A. L. & Co., Benavides	824.00
Kirby Oil Association, Ellis	6,063.52
Keever & Gordon Oil Co., Beaumont	387.00
Kribs Oil Co., Wichita Falls	4,512.23
Knotts, F. F., Wichita Falls	449.82
Kemp, E. R., Tulsa, Okla.	12,358.31
K. A. P. Oil Co., Wichita Falls	1,673.66
Keim, F. D., Wichita Falls	1,388.00
Knauth Oil Co., Wichita Falls	1,610.24
Kurz Oil Co., Von Ormy.	2,190.00
Kerr, T. P., Corsicana	343.66
Kemp & Farris, Chillicothe	2,682.40
Lone Star Oil Co., Burkburnett	8,788.22
Lawton Oil Co., Burkburnett	59,030.00
Long, R. A., Association, Wichita Falls	1,213.53
Ligon, Blair & Rowe, Alvarado	4,516.05
Lake View Oil Co., Sour Lake	6,042.00
Leon Oil Co., Wichita Falls	7,302.28
Lone Star Gas Co., Dallas	8,856.28
Lyle Oil Co., Mineral Wells	966.00
Lake Oil Co., Beaumont.	33,147.16
Logan Oil Co., Humble	1,305.90
Lucky Seven Oil Co., Wichita Falls	3,764.97
Liberty Oil Association, Wichita Falls	3,908.16
Lord, C. A. & Co., Beaumont	1,688.75
Lee-Graham Oil Co., Sour Lake	5,612.72
Lone Acre Oil Co., Beaumont	214.83

TEXAS OIL COMPANIES WITH PRODUCTION IN APRIL, MAY AND JUNE, 1919—Continued

Company and Address.	Production, barrels.
Lucky Six Oil Co., Bangs.	782.52
L. N. Lockridge, Wichita Falls	122.00
Leon Valley Oil Co., De Leon	3,398.00
Liberty Oil & Gas Co., Tulsa, Okla.	37,278.96
Minta Oil Co., Saratoga.	979.80
Munger-Verchoyle Oil Co., Dallas	9,363.40
McElroy Oil Association, Wichita Falls	3,029.83
Merrimac Oil Co., Beaumont	868.41
Lary Lou Gile Oil Co., Wichita Falls	677.91
McMann Oil Co., Wichita Falls	10,583.60
Mackeckney Oil Co., Wichita Falls	1,660.08
Minneapolis Oil and Development Co., Minneapolis, Minn.	154.43
Magnolia Petroleum Co., Dallas	1,793,296.28
George A. Martin, Humble	464.00
Levely-Maxwell Oil Co., Wichita Falls	322.00
Morris & White, Carbon.	1,712.64
Mills & Garrity, Corsicana	2,901.55
Morrisey, Shaw & Heydrick, Wichita Falls	1,419.86
Morrisey, Shaw & Heydrick, Wichita Falls	553.44
Martin Oil Co., Beaumont	3,307.85
Minor Oil Co., Beaumont.	10,373.31
McGoldrick, E. W., Batson	3,460.63
Mann-Isleng Oil Co., Wichita Falls	262.70
Maer, W. Newton, Wichita Falls	1,278.61
Marnet Oil Co., Corsicana	6,748.12
Morris Oil Co., Wichita Falls	2,792.74
Minchew Oil Co., Wichita Falls	5,138.09
Minchew and Street, Wichita Falls	6,288.56
McNamara Oil Co., Beaumont	4,220.41
McMann Oil & Gas Co., Tulsa, Okla.	852,894.41
McLain, Thad, Oil Co., Columbus, Ohio	2,396.35
Majestic Petroleum Co., Denver, Colo.	401.04
Michael Murphy Estate, Thrall	4,871.41
Mid-Kansas Oil and Gas Co., Mineral Wells	368,035.55
Mennis & Horn, Beaumont	1,010.19
Mann-Power Oil Co., Wichita Falls	6,008.67
Mann Oil Co., Wichita Falls	3,870.68
Mann-Hood Oil Co., Wichita Falls	1,006.55
Mayfield Adams & Co., Fort Worth	212.15
Mitchel Petroleum Co., Fort Worth	579.50
Mid-Texas Oil Co., Wichita Falls	123.09
Matador Oil and Gas Co., Quanah	982.00
Minn-Texas Oil Co., Electra	214.73
Mann-Naber Oil Co., Wichita Falls	3,114.02
Mann-McPhall Oil & Gas Co., Wichita Falls	3,421.82
Memphis Petroleum Co., Memphis	518.48
Mauprine Oil Co., Sour Lake	86.50
Mayflower Oil Co., Ardmore, Okla.	1,366.52
Nacona-Burk Oil Co., Burkburnett	12,306.00
Northern Oil and Gas Co., Humble	1,542.00
Nutt, Horace, Wichita Falls	2,330.30
1919 Oil and Gas Co., Wichita Falls	3,001.14
National Oil Co., Chickasha, Okla.	5,767.22
National Oil and Gas Co., Wichita Falls	3,655.58
Nineteen Oil Co., Beaumont	886.70
Norton, Lester L., Indianapolis, Ind.	1,000.00
Ozark Trail Oil Co., Electra	4,566.61
O'Neil, John, Wichita Falls	537.00
Odell Oil Co., Wichita Falls	4,570.00
Oktaha Oil Co., Tulsa, Okla.	2,792.51
Ohio Fuel Co., Pittsburgh, Pa.	5,510.08
Osage Oil and Gas Co., Oklahoma City, Okla.	210.00
Old Dominion Oil Co., Wichita Falls	88.00
Oriental Oil Co., Dallas	3,537.83
Old Colony Oil Co., Dayton	721.99
P. & M. Oil Co., Houston	201.87
Patterson Oil Co., Brownwood	1,504.87
Prairie Oil and Gas Co., Independence, Kans.	1,058,181.41
Palo Pinto Oil Co., Strawn	40,783.24
Purcell Oil Co., Wichita Falls	4,783.91
Plainview Oil and Gas Co., Wichita Falls	6,215.34

TEXAS OIL COMPANIES WITH PRODUCTION IN APRIL, MAY AND JUNE, 1919—Continued

Company and Address.	Production, barrels.
Peerless Oil Co., Saratoga	2,934.13
Petroleum Ref. Co., Houston	103,426.65
Pippin Oil Co., Brownwood	6,888.52
Possum Hill Oil Co., San Antonio	800.00
Perkins, J. J., Wichita Falls	8,492.69
Panhandle Oil Co., Wichita Falls	2,580.85
Prime Oil Co., St. Jo	1,282.34
Plains Oil and Gas Co., Ardmore, Okla.	36,675.00
Paraffine Oil Co., Beaumont	11,104.66
Paggi Bros. Oil Co., Beaumont	17,216.43
Palmer Oil Co., Henrietta	602.00
Peerless Oil Co., Dallas.	5,666.79
Prather, Ad. "Special," Houston	7,117.31
Parker-Ezzell Oil Co., Wichita Falls	1,941.12
Primrose Oil Co., Houston	5,749.31
Pilot Point Oil and Gas Co., Pilot Point	438.88
Powhatan Oil Co., Houston	1,028.05
Phillip Bros. Oil Co., Guffey	3,893.22
Panther Oil Co., Wichita Falls	12,577.79
Pinto Oil Co., Wichita Falls	1,275.79
Powell, J. L., Wichita Falls	719.71
Plainview-Littlefield Oil Co., Littlefield	8,685.93
Pivote, M. V., Sour Lake	4,191.67
Pilant Lake Oil and Gas Co., Houston	1,045.31
Quanah Oil Co., Quanah.	5,325.85
Red River Oil and Gas Co., Bowie	303.96
Richardson Oil Co., Brownwood	1,535.76
Robertson, N. A., Lawton, Okla.	2,097.62
Robertson Petroleum Co., Lawton, Okla.	39,605.22
Regna Oil Co., Saratoga.	12,408.32
Robertson & Knotts, Wichita Falls	562.88
Rogers-Martin Oil Co., Brownwood	608.57
Rowe, M. D., Wichita Falls	8,754.79
Russell-Sanderson Oil Co., Wichita Falls	4,536.55
Ream Oil Co., Wichita Falls	341.88
Roberts & Hill, Wichita Falls	739.30
Ruyle Farm Oil Co., Wichita Falls	39,010.25
Reliance Oil Co., Beaumont	11,846.99
Reynolds Oil Co., Wichita Falls	421.44
Russell-Mann-Frank Oil Co., Wichita Falls	4,377.43
Rio Bravo Oil Co., Houston	60,426.41
Red River Oil Co., Wichita Falls	18,124.50
Republic Production Co., Houston	244,015.27
Ryan Petroleum Co., Wichita Falls	59,187.78
Silurian Oil Co., St. Louis, Mo.	12,924.49
Slaughter & Hutchinson, Bowie	100.20
Sinclair Gulf Oil Co., Tulsa, Okla.	22,786.53
Sinclair Gulf Oil Co. No. 2, Tulsa, Okla.	43,736.95
Sinclair Gulf Oil Co. No. 3, Tulsa, Okla.	73,275.77
Skelly, W. G., Tulsa, Okla.	17,079.72
Sheegog & Co., Chickasha, Okla.	417.55
Southwestern Petroleum Co., Tulsa, Okla.	2,632.12
Shelby Oil and Gas Co. (J. E. Crosbie), Tulsa, Okla.	2,532.41
Swastika Oil Co., Beaumont	1,418.04
Stratton Oil Co., Wichita Falls	7,327.93
Sheldon & Woodruff, Electra	318.20
Shallow Oil Co., Wichita Falls	186.60
Sextette Oil Co., Lawton, Okla.	4,671.05
6666 Oil Co., Wichita Falls	10,985.70
States Oil Corporation, Eastland	1,094.73
Spencer Oil Co., Wichita Falls	7,664.50
South Bosque Petroleum Co., Waco	852.04
Sixty-Six Oil Co., Wichita Falls	1,201.90
Sinks, Joel Co., Corsicana	254.00
Skaggs Oil Co., Wichita Falls	2,433.40
Sheperd-Conrey Oil Co., Wichita Falls	1,222.66
Sun Co. (North Texas Division), Dallas	354,295.06
Somerset Oil Co., San Antonio	2,380.87
School Block Oil Co., Burkburnett	7,744.89
Simms, E. F. & Co., Houston	260,364.10
Superior Oil Co., Superior, Wis.	854.98

TEXAS OIL COMPANIES WITH PRODUCTION IN APRIL, MAY AND JUNE, 1919—Continued

Company and Address.	Production, barrels.
Shamrock Oil Co., Wichita Falls	21,284.28
Sun Co., Beaumont	127,997.27
Schlicher Oil Co., Sour Lake	1,434.05
Staley Mashburn Oil Co., Wichita Falls	4,211.88
Sam Oil Co., Wichita Falls	2,354.36
Snider, C. W., Wichita Falls	7,884.89
Speed, C. D., Corsicana	156.00
Stella Oil Co., Beaumont	7,928.98
Stephens Oil Co., Sour Lake	816.92
Sykes, C. E., Ardmore, Okla.	402.68
Sanders-Taylor Oil Co., Wichita Falls	8,495.28
Sammies Oil Corporation, Ranger	313.00
Surenuff Oil Co., Wichita Falls	4,063.95
Sinclair Gulf Oil Co. (Damon Mound), Houston	67,142.79
Swensondale Oil Co., Valley Mills	146,002.95
Sunshine Surety Oil Co., Wichita Falls	475.00
Silver Lake Oil Co., Abilene	495.60
Schultz-Britain Oil Co., Seymour	257.52
Sutherland, W. C., Wichita Falls	893.58
Southern Petroleum Co., Houston	23,393.69
San Diego Oil and Gas Co., Alice	932.00
Stine-Cameron Oil Co., Henrietta	471.29
Steelsmith, C. A., Electra	703.88
San Bernard Oil Co., Beaumont	4,304.49
Saxon Oil Co., Sour Lake	3,631.37
Snowden, Geo. M., Humble	542.00
Sutherland Oil Co., Houston	4,583.96
Thirty-Nine Oil Co., Wichita Falls	2,620.00
Turner & Sheegog, Wichita Falls	1,189.50
Thompson Oil Co., Electra	3,910.75
Thrity-One Oil Co., Lawton, Okla.	386.54
Trojan Oil Co., Wichita Falls	6,952.62
Town Line Oil Co., Wichita Falls	8,367.00
Thirty-Two Oil Association, Wichita Falls	1,344.15
Tarver Drilling Co., Dallas	557.69
Thaxton, W. H., Austin	433.46
Tex-Penn Oil Co., Pittsburgh, Pa.	149,051.36
Texas-Eastern Oil Co., Buffalo, N. Y.	153.48
Texas Company Producing Department, Houston	2,356,166.73
Texas Pacific Coal & Oil Co., Thrall	1,521,379.67
Tip Top Oil and Mineral Co., San Antonio	80.20
Tatum & Cunningham, Corsicana	93.12
Taylor Oil & Gas Co., Taylor	8,081.88
Texas Dividend Co., Wichita Falls	203.71
Texas-Electra Co., Dallas	269.88
Tex-Homa Oil and Refining Co., Wichita Falls	79,886.18
Triangle Oil Co., Wichita Falls	3,461.08
T. H. Y. Oil Co., Sour Lake	1,278.95
Tri-Mutual Oil Co., Rapid City, S. D.	1,886.94
Theis Oil Co., Sour Lake	13,534.81
United Petroleum Co., Houston	2,201.37
United Producers Co., Wichita Falls	15,292.01
United Oil and Fuel Co., Philadelphia, Pa.	3,294.02
Unity Oil Co., Beaumont	18,208.79
United Petroleum Co., Denver, Colo.	1,445.84
Valley Oil Co., Petrolia	157.76
Vat Oil Co., Byers	873.33
Victor Oil Co., Fredericks, Okla.	7,318.82
Vindicator Oil Co., Wichita Falls	7,461.68
Van Cleve Oil Co., Fort Worth	57,641.36
Vertate Oil Co., Dallas	1,141.15
Virginia Oil Association, Houston	3,158.48
Victory Petroleum Co., Wichita Falls	5,605.02
Vernon Oil Co., Wichita Falls	2,509.26
Valley View Oil Co., Wichita Falls	2,407.17
Willis Oil Co., Wichita Falls	1,214.50
Wichita Burk Oil Co., Wichita Falls	5,423.77
Wichita Southern Oil Co., Wichita Falls	5,230.06
West Production Co., Houston	10,403.78
Woods, G. C., Wichita Falls	17,407.26
Wichita Valley Oil and Gas Co., Wichita Falls	120.00

TEXAS OIL COMPANIES WITH PRODUCTION IN APRIL, MAY AND JUNE, 1919—Concluded

Company and Address.	Production, barrels.
Wilson-Broach Oil Co., Beaumont	21,943.43
Weowna Oil Co., Wichita Falls	28,415.61
Wichita Falls Gas Co., Wichita Falls	71.56
Walker-Caldwell Producing Co., Dallas	6,095.69
Witherspoon Oil Co., San Antonio	3,746.58
Walker-Smith Oil Co., Brownwood	39.14
West Texas Oil Co., Wichita Falls	5,435.75
Woodrow-Lee Oil Co., Wichita Falls	26,073.22
Wichita-Clay Oil Co., Wichita Falls	780.48
Weiss-Martin Oil Co., Dallas	677.41
Williams, J. L., Brownwood	622.00
Welden Oil Co., Saratoga	13,400.00
Willis, W. T., Wichita Falls	3,251.67
Wichita Oil Trust Estate, McKinney	179.00
Westheimer Realty and Mineral Co., Dallas	34,192.49
Wood-Dale Oil Co., Henrietta	4,913.32
Watson-Lee Oil Co., Brownwood	1,307.49
Worth Oil Co., Tulsa, Okla.	1,475.92
Webber, A., Oil Co., Freeport	2,028.14
Wichita Oil and Gas Co., Wichita Falls	2,160.00
Wichita Falls Petroleum Co., Wichita Falls	11,093.06
Waggoner, J. J., Hamlin	766.69
Woods Oil Co., Beaumont	4,014.79
Webb Oil Co., Humble	4,092.52
Whale Oil Co., Durant, Okla.	2,512.95
Yount-Lee Oil Co., Sour Lake	56,114.67
Ramming, R. W., Wichita Falls	3,880.00
Ramming, Staley & Co., Wichita Falls	760.00
South Side Oil Co., Wichita Falls	2,460.00
Staley, Langford & Co., Wichita Falls	98,377.59
Staley, J. I. & Co., Wichita Falls	92,111.00
Staley, J. A., Wichita Falls	8,841.19

STANDARD OIL GROUP

Refiners and Marketers

Company	Capitalization	Mkt. Price	Mkt. Value
Anglo-American	$15,000,000	25	$ 75,000,000
Atlantic Refining	5,000,000	1350	67,500,000
Borne-Scrymser	200,000	500	1,000,000
Chesebrough Mfg.	1,500,000	310	4,650,000
Continental Can	3,000,000	655	19,650,000
Galena Signal, 2d pfd	6,000,000	107	6,420,000
Galena Signal Oil, 1st pfd	2,000,000	125	2,500,000
Galena Signal, common	16,000,000	138	22.080,000
International Pet	6,265,000	31	38,844,000
Solar Refining	2,000,000	370	7,400,000
S. O. of California	99,373,310	282	280,232,706
S. O. of Indiana	30,000,000	800	240,000,000
S. O. of Kansas	2,000,000	600	12,000,000
S. O. of Kentucky	6,000,000	400	24,000,000
S. O. of Nebraska	1,000,000	550	5,500,000
S. O. of New Jersey	98,338,300	710	698,201,930
S. O. of New York	75,000,000	382	286,500,000
S. O. of Ohio	7,000,000	525	36,750,000
Swan & Finch	1,450,000	100	1,450,000
Vacuum Oil	15,000,000	440	66,000,000

Producing Companies

Company	Capitalization	Mkt. Price	Mkt. Value
Ohio Oil Company	15,000,000	386	231,000,000
Prairie Oil & Gas Company	18,000,000	750	135,000,000
South West Penn	20,000,000	313	62,600,000
Washington Oil	100,000	40	400,000
Carter Oil Co	25,000,000	...	....

STANDARD OIL GROUP—Concluded

Pipe Lines and Carriers

Buckeye Pipe Line	10,000,000	100	20,000,000
Crescent Pipe Line	3,000,000	36	2,160,000
Cumberland Pipe Line	1,488,851	200	2,977,600
Eureka Pipe Line	5,000,000	167	8,320,000
Illinois Pipe Line	20,000,000	184	36,800,000
Indiana Pipe Line	5,000,000	105	10,500,000
National Transit	6,362,500	22	11,198,000
New York Transit Company	5,000,000	185	9,250,000
Northern Pipe Line	4,000,000	112	4,480,000
Prairie Pipe Line	27,000,000	300	81,000,000
Southern Pipe Line	10,000,000	165	16,500,000
South West Penn	3,500,000	100	3,500,000
Union Tank Line	12,000,000	130	15,600,000

Total market values, all companies	$2,486,214,236
Market value refining and marketing companies	1,834,928,636
Market value producing companies	429,000,000
Market value pipe line and carrying companies	222,285,600

PRINCIPAL AMERICAN AFFILIATIONS OF ROYAL DUTCH-SHELL PETROLEUM COMBINE

Shell Transport & Trading Co., Ltd.—London	$111,880,000
Royal Dutch	60,750,000
Roxana Petroleum Co.—N. J.	60,000,000
Roxana Petroleum Co.—Okla.	8,000,000
Puora Oil Co.—Okla	....
Turner Oil Co.—Cal.	500,000
New Orleans Refining Co	400,000
Shell Co. of California	45,000,000
Simplex Refining Co.—Cal.	3,000,000
Valley Pipeline Co.—Cal	10,000,000
General Asphalt Co.	31,000,000
Caribbean Petrol. Syndicate—Venezuela	
Petrol. Development Co.—Trinidad	
Trinidad Lake Petroleum Co.—Trinidad	
Bermudez Co., Ltd.—Venezuela	
Anglo Saxon Petroleum Co. Ltd.—London	38,880,000
Mexican Eagle Oil Co., Ltd.—Mexico	90,000,000
Eagle Oil & Transp. Co.	
Anglo Mexican Petrol. Co., Ltd.	
Oil Fields of Mexico, Ltd.	
Alliance Co. of Mexico.	
La Corona Petroleum Co.—Mexico (Tampico-Panuco Oil Flds., Ltd.)	
Tampico-Panuco Petrol. Co.—(Holland), Mexico (Tampico-Panuco Val. Ry. Co.)	
British-American Oil Co.—Canada (Chjoles Oil Co.)	
Shell Co. of Canada	
United British and West Indies Petrol. Synd., Ltd.	

Casinghead Gasoline Plants (1917)

Company	Location	Capacity, Gallons
CALIFORNIA		
Fellows Gasoline Co	Fellows, Calif.	
ILLINOIS		
Vacuum Gasoline Co	Bridgeport, Ill.	
Central Refining Co	Lawrenceville, Ill.	
Warner-Caldwell Oil Co	Robinson, Ill.	
Roxana Petroleum Co. of Oklahoma	Wood River, Ill.	
KANSAS		
Paul F. Dahlgren	Elgin, Kan.	
Rhode Island Oil Co	Independence Kan.	
S. C. Redd	Iola, Kan.	
Hygrade Petroleum & Gasoline Co	Sedan, Kan.	
Sedan Gasoline Co	Sedan, Kan.	
LOUISIANA		
De Soto Gasoline Co	Goss, La.	
Bayou Gasoline Co	Oil City, La.	
Standard Oil Co	Trees City, La.	
Central Oil & Gasoline Co., Inc	Vivian, La.	
OHIO		
Kinkade Oil & Gas Co	Bremen, Ohio	
Marietta Oil Co	Marietta, Ohio	
Jefferson County Oil Co	Rayland, Ohio	
Jefferson Gasoline Co	Rayland, Ohio	
Summerfield Gas Co	Summerfield, Ohio	
Dinsmore & Co	Washington, Ohio	
John Mildren Sons & Co	Winton, Ohio	
OKLAHOMA		
Mid-Co. Gasoline Co	Adair Okla.	
T. B. Gasoline Co	Alluwe, Okla.	4,000
Hygrade Petroleum & Gasoline Co	Avant, Okla.	1,200
Brighton Gasoline Co	Bald Hill, Okla.	1,000
Crystal Gasoline Co	Bald Hill, Okla.	1,500
Mileage Gasoline Co	Bald Hill, Okla.	
Producers Oil Co	Bald Hill, Okla.	
Sinclair Oil & Gasoline Co	Bald Hill, Okla.	
Twin Hill Gasoline Co	Bald Hill, Okla.	600
Akin Gasoline Co	Bartlesville, Okla.	
Mid-Co. Petroleum & Gasoline Co	Bartlesville, Okla.	
Moon Gasoline Co	Bartlesville, Okla.	
Frank Phillips	Bartlesville, Okla.	2,500
Wolverine Oil Co	Bartlesville, Okla.	5,000
Corlis Oil Co	Bartlesville, Okla.	
Mileage Gasoline Co	Bartlett, Okla.	
Smith & Swan Gasoline Co	Bartlett, Okla.	600
Chestnut & Smith	Beggs, Okla.	
H. F. Wilcox	Beggs, Okla.	
Paul F. Dahlgren	Big Heart, Okla.	
Whitehall, Donavan, Hayden & Whitehall	Bird Creek, Okla.	
Aiken Gasoline Co	Bixby, Okla.	
Livingston Oil Corporation	Bixby, Okla.	
Okla. Petroleum & Gasoline Co	Bixby, Okla.	
The Three Gasoline Co	Bixby, Okla.	
S. C. Redd	Bixby, Okla.	
H. F. Wilcox	Bixby, Okla.	
Boynton Gasoline Co	Boynton, Okla.	4,000
Carter Oil Co	Boynton, Okla.	3,000

CASINGHEAD GASOLINE PLANTS—Continued

OKLAHOMA—Continued

Company	Location	Capacity, Gallons
Hays Gasoline Co	Boynton, Okla.	1,100
Sterling Gasoline Co	Boynton, Okla.	
Arrow Gasoline Co	Broken Arrow, Okla.	500
Consumers Oil & Refining Co	Broken Arrow, Okla.	
Misener Gasoline Co	Broken Arrow, Okla.	500
Okla. Petroleum & Gasoline Co	Broken Arrow, Okla.	
Piedmont Petroleum & Gasoline Co	Broken Arrow, Okla.	1,100
Altena Oil Co	Chelsea, Okla.	2,500
Cinco Oil Co	Chelsea, Okla.	500
Liquefield Petroleum Co	Chelsea, Okla.	5,000
Okla. Petroleum & Gasoline Co	Chelsea, Okla.	
Una Gasoline Co	Chelsea, Okla.	1,200
Henderson Gasoline Co	Childers, Okla.	16,000
Whitehall, Donavan, Hayden & Whitehall	Childers, Okla.	
Gypsy Oil Co	Cleveland, Okla.	
National Products Co	Cleveland, Okla.	
Okla. Petroleum & Gasoline Co	Cleveland, Okla.	
Sinclair Oil & Gasoline Co	Cleveland, Okla.	
B. T. Curley	Coalton, Okla.	200
Tidal Gasoline Co	Coalton, Okla.	
Chestnut & Smith	Cushing, Okla.	
Hillman Refining Co	Cushing, Okla.	500
Magnolia Petroleum Co	Cushing, Okla.	
S. C. Redd	Cushing, Okla.	
C. B. Shafer	Cushing, Okla.	600
Standard Oil Co. of Indiana	Cushing, Okla.	
Roxana Petroleum Co. of Okla	Cushing, Okla.	
Diamond Gasoline Co	Delaware, Okla.	8,000
Aikin Gasoline Co	Dewey, Okla.	2,000
Paul F. Dahlgren	Dewey, Okla.	
Dewey Portland Cement Co	Dewey, Okla.	600
Mid-Co. Gasoline Co	Dewey, Okla.	
Barmont Oil Co	Drumright, Okla.	250
Chestnut & Smith	Drumright, Okla.	
Consumers Refining Co	Drumright, Okla.	
Gypsy Oil Co	Drumright, Okla.	
Hesco Gasoline Co	Drumright, Okla.	
Imperial Gasoline Co	Drumright, Okla.	2,000
McMan Gasoline Co	Drumright, Okla.	600
Mid-Co. Petroleum & Gasoline Co	Drumright, Okla.	
Ohio Cities Gasoline Co	Drumright, Okla.	3,000
Producers Oil Co	Drumright, Okla.	
Sinclair Oil & Gasoline Co	Drumright, Okla.	
Standard Oil Co. of Indiana	Drumright, Okla.	
Tidal Gasoline Co	Drumright, Okla.	
Okla. Petroleum & Gasoline Co	Glenn Pool, Okla.	
Producers Oil Co	Glenn Pool, Okla.	
Sun Gasoline Co	Glenn Pool, Okla.	
Tulsa Gasoline Co	Glenn Pool, Okla.	600
Victor Gasoline Co	Glenn Pool, Okla.	
Watkins Oil Co	Glenn Pool, Okla.	
Gates Oil Co	Healdton, Okla.	
Magnolia Petroleum Co	Healdton, Okla.	3,000
Superior Oil & Gas Co	Healdton, Okla.	
Mileage Gasoline Co	Haskell, Okla.	
Okla. Petroleum & Gasoline Co	Haywood Spur, Okla.	
Gypsy Oil Co	Jenks Okla.	
Oil State Gasoline Co	Jenks, Okla.	2,500
Okla. Petroleum & Gasoline Co	Jenks, Okla.	
Totem Gasoline Co	Jenks, Okla.	
Atlas Petroleum Co	Jennings, Okla.	
Crosby & Gillespie	Kiefer, Okla.	9,000
Chestnut & Smith	Kiefer, Okla.	
D. W. Franchot & Co	Kiefer, Okla.	1,000
Glenn Gas Co	Kiefer, Okla.	1,100
Gypsy Oil Co	Kiefer, Okla.	
Victor Gasoline Co	Kelleyville, Okla.	
Heva Gasoline Co	Kelleyville, Okla.	
Lawton Refining Co	Lawton, Okla.	
Continental Gas Compressing Co	Lenapah, Okla.	1,000

CASINGHEAD GASOLINE PLANTS—Continued

OKLAHOMA—Concluded

		Gallons Capacity,
Mileage Gasoline Co	Lost City, Okla.	
Marland Refining Co	Mervin Field, Okla.	3,000
Okla. Petroleum & Gasoline Co	Mohawk, Okla.	
National Products Co	Mounds, Okla.	
Nine Oil & Gas Co	Maud, Okla.	
Chestnut & Smith	Morris, Okla.	
Bradstreet & Co	Muskogee, Okla.	250
De Soto Gasoline Co	Muskogee, Okla.	
Goodwell Oil Co	Muskogee, Okla.	250
Motor Gasoline Co	Muskogee, Okla.	1,100
Persian Oil Co	Muskogee, Okla.	250
Red Demon Gasoline Co	Muskogee, Okla.	800
Sun Gasoline Co	Muskogee, Okla.	
Victor Gasoline Co	Muskogee, Okla.	
Whitfield Sears Oil Co	Muskogee, Okla.	250
Childers Gasoline Co	Nowata, Okla.	500
Tidal Gasoline Co	Nowata, Okla.	
Osage Gasoline Co	Ochelata, Okla.	2,750
Tidal Gasoline Co	Ochelata, Okla.	
A. C. F. Gasoline Co	Oilton, Okla.	2,000
Chieftain Gasoline Co	Oilton, Okla.	
B. B. Jones	Oilton, Okla.	500
Mid-Co. Gasoline Co	Oilton, Okla.	
Mid-Co. Petroleum & Gasoline Co	Oilton, Okla.	
National Products Co	Oilton, Okla.	
Southland Gas Co	Oilton, Okla.	600
Standard Oil Co. of Indiana	Oilton, Okla.	
Kingwood Oil Co	Okmulgee, Okla.	
Magnolia Petroleum Co	Okmulgee, Okla.	
O. K. Refining Co	Okmulgee, Okla.	
Pine Pool Gasoline Co	Okmulgee, Okla.	600
Southern Gas Co	Okmulgee, Okla.	
Tibbins Gasoline Co	Okmulgee, Okla.	1,000
Mac Betty Gasoline Co	Osage City, Okla.	
H. V. Foster	Osage Junction, Okla.	
Victor Gasoline Co	Peru, Okla.	
Victor Gasoline Co	Preston, Okla.	
Marland Chemical Co	Ponca City, Okla.	
Marland Gasoline Co	Ponca City, Okla.	
Whitehall, Donavan, Hayden & Whitehall	Pumpkin Center, Okla.	
Mileage Gasoline Co	Red Fork, Okla.	
Arthur Oil Co	Sapulpa, Okla.	500
Bluff Gasoline Co	Sapulpa, Okla.	200
Commerce Gasoline Co	Sapulpa, Okla.	1,000
Max Rhea Gasoline Co	Sapulpa, Okla.	600
Richards Gasoline Co	Sapulpa, Okla.	600
Sapulpa Refining Co	Sapulpa, Okla.	
W. G. Skelly	Sapulpa, Okla.	
Cosden Oil & Gas Co	Shamrock, Okla.	8,000
Magnolia Gasoline Co	Shamrock, Okla.	
Sinclair Oil & Gasoline Co	Shamrock, Okla.	
Union Skiatook Gasoline Co	Skiatook, Okla.	
Rotary Gasoline Co	Sperry, Okla.	
Black Hawk Petroleum Co	Stone Bluff, Okla.	
Hygrade Petroleum & Gas Co	Stone Bluff, Okla.	1,200
Sinclair Oil & Refining Co	Stone Bluff, Okla.	
Okla. Petroleum & Gasoline Co	Standard Spur, Okla.	
O. G. Bantley	Tamaha, Okla.	
The Dallas Co	Tulsa, Okla.	
Pulaski Refining Co	Turkey Mountain, Okla.	700
Silver Gasoline Co	Vega, Okla.	
De Soto Gasoline Co	Wann Okla.	3,000
Mid-Co. Gasoline Co	Wann, Okla.	
Okla. Petroleum & Gasoline Co	Wateva, Okla.	
Chestnut & Fitzgerald	Watkins, Okla.	600
Eagle Gasoline Co	Watkins, Okla.	1,100
Monarch Gasoline Co	Watkins, Okla.	1,100

CASINGHEAD GASOLINE PLANTS—Concluded

PENNSYLVANIA

Bradford Oil & Gasoline Co	Bell's Camp, Pa.
Pennsylvania Gasoline Co	Bradford Pa.
B. B. Stroud Co	Bradford Pa.
W. H. Miller	Chicora, Pa.
Clarendon Gasoline Co	Clarendon, Pa.
Clarendon Refining Co	Clarendon, Pa.
D. and C. P. McKee	Clintonville, Pa.
Jane Oil Co	Emlenton, Pa.
Gilmore Gasoline Co	Gilmore, Pa.
Kane Gasoline Co	Kane, Pa.
C. J. Ritzert Co	St. Joe, Pa.
Henry Farm Oil Co	Warren, Pa.
Gilmore Gasoline Co	Wafferty Hollow, Pa.
Wayne Naptha Co	Waynesburg, Pa.

TEXAS

Humble Oil & Refining Co	Burkburnett, Tex.
Schulz Gasoline Co	Burkburnett, Tex.
Forest Oil Co	Electra, Tex.
Forest Oil Co	Iowa Park, Tex.

WEST VIRGINIA

Imperial Oil & Gas Products Co	Hannahdale W. Va.
Jas. B. Berry's Sons Co	Sisterville, W. Va.
Consumers Refining Co	Waverly, W. Va.
Laughner & Fleming	Wellsburgh, W. Va.

American Gas Syndicates and Their Holdings (Gas Record 1919)

Company	City	State
SOUTHERN CALIFORNIA GAS CO....... Operating at Los Angeles, Glendale, San Bernardino, Gardena, Riverside, Colton, Arlington, Rialto, Beverley Hills, Van Nuys, Tropico, Lankersheim, San Fernando, Eagle Rock and Burbank.	Los Angeles 805 Garland Bldg.	California
SOUTHERN COUNTIES GAS CO. of Calif... A consolidation of Southern Counties Gas Co., Long Beach (Calif.) Gas Co., and gas properties of the Southern Calif. Edison Co. Serves natural gas to 42 cities of Los Angeles, Orange and San Bernardino counties.	Los Angeles 724 S. Spring St.	California
W. F. BOARDMAN CO................... Operates Oregon Gas & Electric Co. at Grant's Pass, Medford, Ashland and Roseburg; Ukiah Gas Co., Ukiah, Calif.; Guadalajara Gas Co., Guadalajara, Jalisco, Mexico.	San Francisco 718 Mission St.	California
CALIFORNIA LIGHT & FUEL CO......... Engineers: Palo Alto (Calif.) Gas Co.; Nevada Gas Co., Tonopah, Nev.	San Francisco 626 Pacific Bldg.	California
COAST COUNTIES GAS & ELECTRIC CO... Operates at Santa Cruz, Watsonville, Hollister and the Gilroy (Calif.) Gas Works, Contra Costa Gas Co., at Martinez, Pittsburgh, Antioch, Concord, Crockett, Calif.	San Francisco 454 California St.	California
COAST VALLEYS GAS & ELECTRIC CO... Operates at Monterey, Pacific Grove, Carmel-by-the-Sea, Salinas, King City, Soledad, Gonzales, Chular.	San Francisco 58 Sutter St.	California
NORTHERN CALIFORNIA POWER CO.... Operates Northern Calif. Power Co., Keswick Electric Power Co., Battle Creek Power Co., Redding Water Co. and Sacramento Valley Power Co. Owns and operates gas plants at Redding, Red Bluff and Willows.	San Francisco 995 Market St.	California
PACIFIC GAS & ELECTRIC CO........... Supplies gas to over 50 California towns and cities.	San Francisco 445 Sutter St.	California
NORTHERN COLORADO POWER CO.... Operates: Cheyenne (Wyo.) Light, Fuel & Power Co., Boulder (Colo.) Elec. Lt. & Pr. Co., Western Lt. & Pr. Co., Lafayette, Colo.	Boulder	Colorado
SOUTHERN UTILITIES CO..............	Jacksonville	Florida
COPLEY GAS & ELEC. SYNDICATE..... Owns: Western United Gas & Elec. Co., operating gas plants at Aurora, Elgin and Joliet; Murpheysboro (Ill.) Water Wks. & Elec. & Gas Light Co.; Southern Ill. Gas Co., Marion, Ill.	Aurora	Illinois

AMERICAN GAS SYNDICATES AND THEIR HOLDINGS —Continued

Company	City	State
ILLINOIS TRACTION SYSTEM (McKINLEY SYND.). Operates: Danville St. Ry. & Light Co., Urbana & Champaign Ry., Gas & Elec. Co., Decatur Ry. & Light Co.; Jacksonville Ry. & Lt. Co.; Jefferson City (Mo.) Lt., Heat & Pr. Co.; Atchison (Kans.) Ry. Lt. & Pr. Co.; Galesburg (Ill.) Gas & Elec. Co.; Citizens Lighting Co., LaSalle, Ill.; Cairo (Ill.) Gas Co.; Clinton (Ill.) G. & E. Co.; Madison County Lt. & Pr. Co., Carlinville, Ill.; Oskalooa (Ia.) Lt. & Fuel Co.	Champaign	Illinois
AMERICAN COAL & BY-PRODUCT COKE CO. Operate by-product plants for Dover By-Products Coke Co., Canal Dover, O., Union By-Products Coke Co., Buffalo, N. Y., Geo. W. Niedringhaus and associates, Granite City, Ill.	Chicago 608 S. Dearborn St.	Illinois
K. L. AMES SYNDICATE. Owns and operates Jacksonville (Fla.) Gas Co.	Chicago Woman's Temple Bldg.	Illinois
GAS & ELECTRIC IMPROVEMENT CO. Operates Austin (Tex.) Gas Lt. Co., Benton Harbor & St. Joseph (Mich.) Gas & Fuel Co.; Ft. Madison (Ia.) Gas Light Co.; Palestine (Tex.) Lt., Ht. & Pr. Co.	Chicago 39 S. LaSalle St.	Illinois
H. M. BYLLESBY & CO. Operates: Muskogee Gas & Elec. Co., Muskogee & Ft. Gibson, Okla.; Mobile (Ala.) Electric Co.; Ft. Smith Lt. & Traction Co., Ft. Smith & Van Buren, Ark., NORTHERN STATES POWER CO., Div. Hqrs.—Minneapolis, Faribault, Stillwater, Mankato, Cannon Falls, Northfield, St. Paul and South St. Paul, Minn., Hudson, Wis. (St. Croix Gas Co.), and Platteville, Wis., Fargo, Grand Forks, Minot, N. D., Galena, Ill., Sioux Falls, S. D.; MOUNTAIN STATES PR. CO. at Kalispell, Mont. and Sandpoint, Idaho, and Newport, Wash.; Tacoma (Wash.) Gas Co.; OKLA. GAS & ELEC. CO., Enid, El Reno and Okla. City; The Ottumka (Ia.) Ry. & Lt. Co.; San Diego (Cal.) Con. Gas & Elec. Co.; Puget Sound Gas Co., Everett, Wash.; OREGON POWER CO., Marshfield, Eugene, Albany, Corvallis, Dallas, Independence, Monmouth, Oregon; the Southwestern General Gas Co., Fort Smith, Ark.; Olympia (Wash.) Gas Co.; WESTERN STATES GAS & ELEC. CO., Stockton, Richmond and Eureka, Calif.; ARKANSAS VALLEY RY. LT. & PR. CO., Pueblo, Victor, Cripple Creek, Rocky Ford, La Junta and Canon City; LOUISVILLE GAS & ELECTRIC CO.	Chicago Cont. & Com'l Bk. Bldg.	Illinois
METROPOLITAN GAS & ELECTRIC CO. Owns and operates: Southwestern Gas & Elec. Co., Shreveport, La., and Texarkana, Tex.; Mobile (Ala.) Gas Co.; Central Indiana Gas Co. of Muncie (hdqrs.), Anderson, Marion; Alexandria, Elwood, Fairmount and Hartford City, Ind.; Jackson Co. Lt., Ht. & Pr. Co. of Independence, Mo.; Beaumont (Tex.) Gas Lt. Co.; Seattle	Chicago Harris Trust Bldg.	Illinois

AMERICAN GAS SYNDICATES AND THEIR HOLDINGS —Continued

Company	City	State
(Wash.) Lighting Co.; Mt. Clemens (Mich.) Gas Light Co.; Gainesville (Tex.) Gas & Elec. Co.		
L. E. MYERS CO. Owns Ashland (Wis.) Lt., Pr. & St. Ry. Co.	Chicago Monadnock Blk.	Illinois
UNION UTILITIES CO. Control The Indiana Gas Light Co., operating plants at Noblesville and Tipton, Ind. Also, Lewanee County Gas & Electric Co., Vicksburg, Miss. & St. Charles Lighting Co., St. Charles, Mo.; Dubuque (Ia.) Elec. Co.; Northern Ia. Gas & Elec. Co., Hdqrs., Humboldt, Ia., serving 20 towns in Northern Iowa; gas at Eagle Grove.	Chicago 39 S. LaSalle St.	Illinois
MIDDLE WEST UTILITIES CO. Controls and operates following gas properties:	Chicago 72 W. Adams St.	Illinois
—Illinois Northern Utilities Co. Belvidere, DeKalb, Dixon, Geneseo, Mendota, Morrison, Rock Falls, Sterling and Sycamore, Ill.	Dixon	Illinois
—Central Illinois Public Service Co. Beardstown, Charleston, Macomb, Mattoon, Pana, Paris and Taylorville, Ill.	Mattoon	Illinois
—Hoopeston (Ill.) Gas & Elec. Co.		
—Interstate Public Service Co. Bedford, Greenfield, New Castle, Seymour and Shelbyville, Ind.; Franklin (Ind.) Water, Light & Power Co.; Central Indiana Lighting Co., Bloomington, Ind.	Indianapolis	Indiana
—Central Indiana Lighting Co.	Indianapolis	Indiana
—Franklin (Ind.) Water, Lt. & Pr. Co.		
—United Gas & Electric Co. Jeffersonville and New Albany, Ind.	New Albany	Indiana
—Twin State Gas & Electric Co. Bennington, Va.; Brattleboro, Va.	Dover	New Hampshire
—Michigan Gas & Electric Co. Ishpeming, Negaunee, Houghton and Hancock, Mich.		
—Missouri Gas & Electric Service Co. Lexington, Marshall, Mo.		
—Kentucky Utilities Co. Shelbyville, Ky.		
—Chickasha Gas & Electric Co.	Chickasha	Oklahoma
—Michigan Gas & Electric Co.	Three Rivers	Michigan
—Nebraska City (Neb.) Utilities Co.		
—Citizens Gas Light Co.	Jackson	Tennessee
PUBLIC SERVICE CO. OF NORTHERN ILLINOIS. Gas plants: Evanston, Blue Island, Weber, Morris, Ottawa, Strator, Pontiac and Kankakee.	Chicago 72 W. Adams St.	Illinois
NORTH AMERICAN LIGHT & POWER CO. Hold and operate: Adair County Lt., Pr. & Ice Co. and Mo. Ht., Lt. & Pr. Co., of Kirksville, Mo.; Moberly (Mo.) Lt. & Pr. Co.; Huntsville (Mo.) Lt. & Pr. Co.; Boonville (Mo.) Lt., Ht. & Pr Co.; Ardmore (Okla.) City Gas Co.; Durant (Okla.) Consumers Lt. & Pr. Co.; Washington C. H. (O.) G. & E. Co.; Pocatello (Ida.) Gas & Pr. Co.; Waurika (Okla.) Consumers Lt. & Pr.	Chicago 2013 Peoples Gas Bldg.	Illinois

AMERICAN GAS SYNDICATES AND THEIR HOLDINGS —Continued

Company	City	State
Co.; Southern Okla. Pipe Line Co., Ardmore, Okla.; Citizens Elec. Co., Higbee, Mo.; La Plata (Mo.) Lt. & Pr. Co.		
UNITED LT. & RYS. CO. (FINANCIAL OFFICE)	Chicago	Illinois
UTILITIES DEVELOPMENT CO.	Chicago 327 S. LaSalle St.	Illinois
WISCONSIN PR. & LT. & HT. CO. Owns Baraboo, Beaver Dam, Berlin.	Chicago 72 W. Adams St.	Illinois
E. A. POTTER Controls Madison, Ind., Creston, Ia., Junction City, Abilene, Great Bend, and Manhattan, Kansas.	Chicago Rector Bldg.	Illinois
J. J. FREY SYNDICATE Owns Southern Illinois Lt. & Pr. Co. and Citizens Gas, Elec. & Htg. Co. Gas plants at Mt. Vernon, Litchfield, and Hillsboro.	Hillsboro	Illinois
NORTHERN INDIANA GAS & ELECTRIC CO. Northern Division operates Hammond, Michigan City and South Bend; also, Southern Division operates LaFayette, Lebanon, Logansport, Fort Wayne, Bluffton, Decatur, Frankfort, Crawfordsville, and Wabash; Ohio Division operates Lima, St. Marys, Wapakoneta, Celina, Recovery, Cridersville, and Coldwater.	Hammond	Indiana
INTERSTATE PUBLIC SERVICE CO. (Listed above.)	Indianapolis	Indiana
W. A. MARTIN GAS SYNDICATE Operates Greencastle (Ind.) Gas & Elec. Co., Rochester Gas & Fuel Co.	Laporte	Indiana
CONSOLIDATED GAS & OIL CO. Owns plants at Ridgeville, Red Key and Dunkirk, Ind.	Ridgeville	Indiana
IOWA ELECTRIC CO. Operates gas plants at Fairfield, Iowa Falls and Perry; also various electric and railway plants. Under name of Iowa Ry. & Lt. Co. also operates Marshalltown Ia.	Cedar Rapids	Iowa
R. K. RUNNER Interested in Austin, Minn.; Charles City, Ia., and Cherokee, Ia.	Charles City	Iowa
IOWA GAS & ELEC. CO. Owns gas plants at Mt. Pleasant and Washington, Ia.	Iowa City	Iowa
AMERICAN GAS CONSTRUCTION CO. Interested in Ia. Pub. Serv. Co., Ames, Ia.; Citizens Gas Co., Carroll, Ia.; Belle Plaine (Ia.) Gas Co.	Newton	Iowa
AMERICAN CITIES CO. Controls: N. O. Ry. & Lt. Co., Birmingham (Ala.) Ry., Lt. & Pr. Co., Houston (Tex.) Ltg. & Pr. Co.; Little Rock Ry. & Elec. Co., Memphis St. Ry. Co., Knoxville Ry. & Lt. Co.	New Orleans 201 Baronne St.	Louisiana
GENERAL UTILITIES & OPERATING CO. Controls Americus (Ga.) Ltg. Co. and several electric properties.	Baltimore Munsey Bldg.	Maryland

AMERICAN GAS SYNDICATES AND THEIR HOLDINGS —Continued

Company	City	State
COMMONWEALTH GAS & ELECTRIC COS. Owns: Marlboro-Hudson Gas Co., Marlboro, Mass., and Athol (Mass.) Gas & Elec. Co.	Boston 78 Devonshire	Massachusetts
MASSACHUSETTS GAS COS. Controls Boston Con. Gas Co., E. Boston Gas Co., Citizens' Gas Lt. Co., of Quincy, Mass.; Newton & Watertown Gas Lt. Co., of Newton, Mass.; New England Coal & Coke Co., of Boston; New Eng. Fuel & Trans. Co.	Boston 111 Devonshire	Massachusetts
MASSACHUSETTS LIGHTING COS. Operating companies— Adams Gas Light Co., Arlington Gas Light Co., Clinton Gas Light Co., Gloucester Light Co., Leominster Gas Light Co., Lexington Gas Co., Milford Gas Light Co., Northampton Gas Light Co., North Adams Gas Light Co., Spencer Gas Co., Williamstown Gas Co., Worcester County Gas Co. Gas & Electric Improvement Co., Boston; The Light, Heat & Power Corporation, Boston; Daytona (Fla.) Public Service Co. and New Smyrna (Fla.) Public Service Co.	Boston 77 Franklin St.	Massachusetts
STONE & WEBSTER (Branches New York and Chicago) Operates: Blackstone Valley Gas & Elec. Co., Fall River (Mass.) Gas Works, Haverhill (Mass.) Gas Lt. Co., Paducah (Ky.) Light & Pr. Co., Puget Sound Traction, Lt. & Pr. Co. of Bellingham, Wash.; Keokuk (Ia.) Electric Co., Conn. Power Co., New London, Conn., Baton Rouge (La.) Electric Co.; Carson City (Nev.) Coal Gas Co.; Columbus (Ga.) Gas Light Co.; Pawtucket (R. I.) Gas Co.; Reno (Nev.) Pr., Lt. & Wtr. Co.	Boston 147 Milk St.	Massachusetts
CHARLES H. TENNEY & CO. Represents: Suburban Gas & Elec. Co., Revere, Mass.; Peoples Gas & Elec. Co., Oswego, N. Y.; Springfield (Mass.) Gas Lt. Co., Nyack, N. Y.; Malden & Melrose (Mass.) Gas Lt. Co.; Fitchburg (Mass.) Gas & Elec. Lt. Co.; No. Boston Lighting Properties; Bristol & Plainville Tramway Co., Bristol, Conn., Montpelier & Barre Lt. & Pr. Co., Montpelier, Vt.	Boston 201 Devonshire	Massachusetts
W. E. MOSS & CO. Operates: Coldwater (Mich.) Gas, Lt. & Fuel Co.; Columbus (Ind.) Gas Lt. Co.; Fulton (N. Y.) Fuel & Lt. Co.; Grand Haven (Mich.) Gas Co.; Citizens Gas Co. of Hannibal, Mo.; Winston-Salem (N. C.) Gas Co.; Monroe (Mich.) Gas, Light & Fuel Co.; Hillsdale (Mich.) Gas Light Co.	Detroit 710 Union Trust Bldg.	Michigan
AMERICAN PUBLIC UTILITIES CO. (Kelsey-Brewer interests.) Holland (Mich.) City Gas Co., Albion (Mich.) Gas Light Co., Valparaiso (Ind.) Lighting Co., Elkhart (Ind.) Gas & Fuel Co., Jackson (Miss.) Light & Traction Co., Utah Gas & Coke Co.,	Grand Rapids G. Rapids Savgs. Bldg.	Michigan

AMERICAN GAS SYNDICATES AND THEIR HOLDINGS —Continued

Company	City	State
Salt Lake; Wisconsin-Minnesota Light & Power Co., serving Eau Claire, La-Crosse, Chippewa Falls, and Menominee, Wis., Red Wing and Winona, Minn.; Eastern Wis. Elec. Co., Fond du Lac, and upwards of 20 smaller communities in immediate vicinity. All operated by Kelsey-Brewer & Co., and all except Fond du Lac (which belongs to Kelsey-Brewer Co.) owned by Amer. Pub. Util. Co.		
HOWE, SNOW, CORRIGAN & BERTLES.. Control Emporia (Kans.) Gas Co., McAlester (Okla.) Gas & Coke Co.; Choctaw Natural Gas Co., Okla.	Grand Rapids	Michigan
UNITED LIGHT AND RAILWAYS CO..... (Financial offices: 72 W. Adams, Chi. Operating hdqrs.: Grand Rapids and Davenport, Iowa.) Operates: Chattanooga (Tenn.) Gas Co.; Cedar Rapids (Ia.) Gas Co.; Muscatine (Ia.) Ltg. Co.; Ft. Dodge (Ia.) Gas & Elec. Co.; Iowa City (Ia.) Lt. & Pr. Co.; Peoples Gas & Elec. Co., Mason City, Ia.; La Porte (Ind.) Gas & E. Co.; Cadillac (Mich.) Gas Lt. Co., Ottumwa (Ia.) Gas Co.; also The Peoples Power Co. of Moline and Rock Island, Ill., The Peoples Lt. Co. of Davenport, Ia., and the Davenport (Ia.) Gas & Elec. Co.	Grand Rapids Michigan Trust Bldg.	Michigan
MICHIGAN LIGHT CO.................... Owns gas and electric plants at Jackson, Flint, Bay City, Kalamazoo, Saginaw, Pontiac and Manistee.	Jackson	Michigan
APPLEBY & WAGNER.................... Own: Consumers' Gas Co., Waycross, Ga., Gratiot County Gas Co., Alma, Mich., Washington County Gas Co., Johnson City, Tenn.	Saginaw Forester Temple	Michigan
UTILITIES OPERATING CO............. Own gas plants at Allegan, Otsego, Plainwell, Sturgis and South Haven, Mich.; Auburn, Brazil, Garrett, Avilla and Kendallville, Ind.; Rochester, Minn.; Manitowoc, Wis.	Minneapolis 348 Security Bldg.	Minnesota
PUBLIC IMPROVEMENT CO............ Controls: Bemidji, Minn.; Montevideo, Minn., and Thief River Falls, Minn.	Kalamazoo 310 Peck Bldg.	Michigan
UNION PUBLIC SERVICE CO............ Operates: Baldwin (Kans.) Gas Co.; Beggs (Okla.) Gas Co.; Johnson Co. Gas Co., Merriam, Kans.; Miami Co. Gas Co., Osawatomie and Paola, Kans.; Wier (Kans.) Gas Co.; Parsons (Kans.) Gas Co.; Nowata Co., Nowata Okla.; Tri-City Gas Co., Altoona and Cherryvale, Kans. and Chelsea, Okla.; Gardner (Kans.) Gas Co.; Wellsville (Kans.) Gas Co.; Anderson Co. Lt. & Ht. Co., Colony, Kans.; Richmond (Kans.) and Princeton Gas Co.; Weston (Mo.) Gas & Lt. Co.	Kansas City 1116 Commerce Bldg.	Missouri
THE LIGHT & DEVELOPMENT CO. OF ST. L. .... Operates: Cape Girardeau (Mo.) Public	St. Louis 750 Ry. Ex. Bldg.	Missouri

AMERICAN GAS SYNDICATES AND THEIR HOLDINGS —Continued

Company	City	State
Utilities Co.; Paris (Ky.) Gas and Elec. Co.; Ft. Scott (Kas.) Gas & Elec. Co.; Mitchell (S. D.) Power Co.′ Oberlin (O.) Gas & Elec. Co.; Monmouth (Ill.) Pub. Serv. Co.		
THE WATTS ENGINEERING CO. Owns Columbia (Mo.) Gas Co.	St. Louis	Missouri
GAS CONSTRUCTION CO. Operate: Broken Bow (Neb.) Gas Co.	Omaha, 48th & Leavenworth Sts.	Nebraska
UNION POWER & LIGHT CO. Operates North Platte (Nebr.) Lt. & Pr. Co. and Southern Ia. Elec. Co., Osceola, Ia.	Omaha, 424 First Natl. Bk. Bldg.	Nebraska
SIERRA-PACIFIC ELECTRIC CO. (Stone & Webster management) Controls: Carson City (Nev.) Coal Gas Co. and Reno Pr., Lt. & Water Co.	Reno	Nevada
CUMBERLAND COUNTY GAS CO. Operates: Millville Gas Lt. Co.; Citizens Gas Co. of Landis Tp., N. J.; Pittsgrove (N. J.) Gas Co.; Fairfield (N. J.) Gas Co.; Citizens Gas Co., Vineland, N. J.; Maurice River (N. J.) Gas Co.; The Commercial Gas Co., Port Norris, N. J.; Downe Township Gas Co., Newport, N. J., and Lawrence (Tp.) Gas Co., Cedarville, N. J., and Deerfield Gas Co., Rosenhayn, N. J.	Millville	New Jersey
PUBLIC SERVICE GAS CO. Operates: (Essex Division) Essex & Hudson Gas Co.; East Newark (N. J.) Gas Lt. Co.; Morristown (N. J.) Gas Lt. Co.; (Hudson Division Hudson Co. Gas Co.; (Passaic Division) Patterson & Passaic Gas & Elec. Co.; (Southern Division) South Jersey Gas, Elec. & Trac. Co.; Princeton Lt., Ht. & Pr. Co.; (Central Division) Somerset, Union & Middlesex Ltg. Co.; New Brunswick (N. J.) Gas Lt. Co.; Shore Ltg. Co.; (Bergen Division) Gas & Elec. Co. of Bergen Co.; Ridgewood (N. J.) Gas Co.	Newark, 80 Park Place	New Jersey
FLORIDA UTILITIES CO. Moon Clay & Kaolin Co. Owns gas companies at Palm Beach, W. Palm Beach and Ocala, Fla.	Trenton, 715 Broad St. Bk. Bldg.	New Jersey
BROOKLYN UNION GAS CO. Owns and operates: Flatbush Gas Co., 29th ward, Brooklyn; Newton Gas Co., 2d ward, Queens′ Jamaica (Long Island) Gas Co.; Woodhaven (L. I.) Gas Co.; Richmond Hill & Queens County Gas Lt. Co., 4th ward, Queens.	Brooklyn, 176 Remsen St.	New York
EASTERN OIL CO. Operates: W. Va. Central Gas Co., Elkins, W. Va.; W. Va. & Md. Gas Co., Davis, W. Va., and Cumberland, Md.; Northern Natural Gas Co., Oakland and other Maryland towns, and Terra Alta, W. Va.; West Union (W. Va.) Gas Co.; Salem (W. Va.) Natural Gas Co.; Glenville (W. Va.) Nat. Gas Co.	Buffalo	New York
SOUTH SHORE NATURAL GAS & FUEL Co. Owns: Dunkirk, N. Y., and other points.	Buffalo, 842 Marine Bk. Bldg.	New York

AMERICAN GAS SYNDICATES AND THEIR HOLDINGS —Continued

Company	City	State
EMPIRE COKE CO. Furnishes gas for Empire Gas & Elec. Co., which does all the gas and electric business in Auburn, Weedsport, Cayuga, Seneca Falls, Waterloo, Geneva, Phelps, Palmyra, Newark, Lyons and Clyde.	Geneva 103 Castle St.	New York
AMERICAN LIGHT & TRACTION CO. Own practically all the capital stock of Binghamton (N. Y.) Gas Works; Consolidated Gas Co., of Long Branch, N. J., Detroit (Mich.) City Gas Co.; Grand Rapids (Mich.) Gas Light Co.; Madison (Wis.) Gas & Elec. Co.; Milwaukee (Wis.) Gas Lt. Co.; Muskegon (Mich.) Traction & Ltg. Co.; St. Joseph (Mo.) Gas Co.; St. Paul (Minn.) Gas Light Co.; San Antonio (Tex.) Pub. Serv. Co.; So. St. Paul (Minn.) G. & E. Co.; West Allis (Wis.) Gas Co.; Wuawatosa (Wis.) Gas Co.	New York 120 Broadway	New York
AMERICAN POWER & LIGHT CO.	New York 71 Broadway	New York
CONSOLIDATED GAS CO. Owns directly or indirectly a majority of the capital stock of Astoria (L. I.) Lt., Ht. & Pr. Co.; Central Union Gas Co., the Bronx, N. Y. City; N. Y. & Queens Gas Co., Flushing, N. Y.; N. Y. Mutual Gas Lt. Co., N. Y. City; Northern Union Gas Co., the Bronx, N. Y. City; Northern Westchester Lighting Co., Ossining, N. Y.; Peekskill (N. Y.) Ltg. & R. R. Co.; Standard Gas Lt. Co., N. Y. City; Westchester Ltg. Co., Mt. Vernon, N. Y.; New Amsterdam Gas Co., N. Y. City.	New York 124-130 E. 15th St.	New York
ASSOCIATED GAS & ELEC. CO. Controls: Homer and Cortland (N. Y.) Gas Light Co.; Norwich (N. Y.) Gas & Electric Co.; Ithaca (N. Y.) Gas & Elec. Co.; Oneonta (N. Y.) Lt. & Pr. Co.; Greenville (O.) Gas Lt. Co.; Van Wert (Ohio) Gas Light Co. and Ky. Service Co., with plants at Bowling Green, Owensboro, Frankfort, Hopkinsville, Ky., and Clarksville, Tenn.	New York 43 Exchange Place	New York
BROOKS & CO., P. W. As Eastern States Pub. Service Co. operates N. J. Gas & Elec. Co., Dover, N. J.; Newton (N. J.) Gas & Elec. Co.; Lambertville (N. J.) Pub. Service Co. Also owns: Port Arthur (Tex.) Gas & Pr. Co. and Utah Valley Gas & Coke Co., Provo, Utah.	New York 115 Broadway	New York
HENRY L. DOHERTY & CO. (Cities Service Co.) Operates: Alliance (O.) Gas & Pr. Co.; Bartlesville (Okla.) Gas & Oil Co., Beaver Oil & Gas Co., Kingsville, Ont. Can.; Brantford (Ont.) Gas Co.; Bristol (Tenn.) Gas & Elec. Co.; Buckeye State Gas & Fuel Co., and Coshocton Gas Co. of Coshocton, O.; Carthage (Mo.) Gas Co.; City Light & Traction Co., Sedalia, Mo.; Danbury & Bethel (Conn.) Gas & Elec. Lt. Co.; Denver (Colo.) Gas & Elec. Lt. Co.; Dominion	New York 60 Wall St.	New York

AMERICAN GAS SYNDICATES AND THEIR HOLDINGS —Continued

Company	City	State
Natural Gas Co. of Hamilton, Ont., Can.; Fremont (Neb.) Gas, Elec. Lt. & Pr. Co.; Knoxville (Tenn.) Gas Co.; Lebanon (Pa.) Gas & Fuel Co.; Lincoln (Neb.) Gas & Elec. Lt. Co.; Meridian (Miss.) Lt. & Ry. Co.; Montgomery (Ala.) Lt. & Water Pr. Co.; Pueblo (Colo.) Gas & Fuel Co.; Spokane (Wash.) Gas & Fuel Co.; Trumbull Public Service Co., Warren & Niles, O.; Toledo (O.) Ry. & Lt. Co.; Webb City & Carterville Gas Co.., Webb City, Mo.; Woodstock (Can.) Gas Lt. Co.; Empire Gas & Fuel Co. of Kansas, Missouri and Oklahoma; Hattiesburg (Miss.) Traction Co.; Arkansas Valley Gas Co.; Glenwood Nat. Gas Co., Ltd. (Can.); Manufacturers Nat. Gas Co., Ltd. (Can.); Quapaw (Okla.) Gas Co.; So. Ontario (Can.) Nat. Gas Co., Ltd.; S. W. Oklahoma Gas & Fuel Co.; Washita (Okla.) Gas & Fuel Co.; Western Oklahoma Gas & Fuel Co., Duncan, Lawton and Marlow, Okla.; Niagara (N. Y.) Lt., Ht. & Pr. Co.; Wichita Natural Gas Co.; Wichita Pipeline Co.; Columbus (O.) Nat. Gas Co.; Medina (O.) Gas & Fuel Co.; Mansfield (O.) Gas Lt. Co.; Ingersoll (Can.) Gas Lt. Co.; Thorold (Can.) Nat. Gas Co.; United Gas Co. (Can.); Salina (Kans.) Lt., Pr. & Gas Co.; Western Distributing Co. (Okla.); Reserve Gas Co. (Okla.); Toledo (O.) Rys. & Lt. Co.; Venture Gas Co., Morral, O.; Frost Gas Co.. owning Brocton (N. Y.) Gas & Fuel Co.; Silver Creek (N. Y.) Gas & Impvt. Co., and So. Shore Nat. Gas & Fuel Co., Westfield, N. Y.		
ELECTRIC BOND & SHARE CO......... Fiscal Agents: Carolina Power & Lt. Co.; Raleigh & Durham, N. C., operating Asheville (N. C.) Pr. & Lt. Co.; Yadkin River Pr. Co.; Utah Securities Co., controlling Utah Pr. & Lt. Co., which controls Utah Lt. & Tr. Co. at Ogden, Salt Lake City, etc., Utah; American Pwr. & Lt. Co., operating Portland (Ore.) Gas & Coke Co.; Kansas Gas & Elec. Co. of Wichita, Kans., Nebr. Pr. Co., Omaha; Pacific Pr. & Lt. Co. of Vancouver, Yakima and Walla Walla, Wash.; Pendleton and Astoria, Ore., and Lewiston, Idaho; Texas Pr. & Lt. Co. of Brownwood, Denison, Cleburne, Paris and Waco, Texas; Galveston (Tex.) Gas Co.; El Paso (Tex.) Gas Co.; Hutchinson (Kans.) Gas & Fuel Co.; Newton (Kans.) Gas & Fuel Co.; National Securities Corp., controlling Idaho Pr. Co.	New York 71 Broadway	New York
FEDERAL LIGHT & TRACTION CO...... Operates. Albuquerque (N. M.) Gas & Electric Co.; Consumers' Gas Co., Hot Springs, Ark.; Tucson (Ariz.) Gas. Elec. Lt. & Pr. Co.; Springfield (Mo.) Gas & Elec. Co.; Trinidad (Colo.) Elec.	New York 60 Broadway	New York

AMERICAN GAS SYNDICATES AND THEIR HOLDINGS —Continued

Company	City	State
Trans. Ry. & Gas Co.; Gray's Harbor Ry. & Light Co., of Aberdeen, Wash.; and various electric and railway companies.		
GENERAL GAS & ELECTRIC CO........ Controls: Rutland (Vt.) Ry., Lt. & Pr. Co.; Sandusky (O.) Gas & Elec. Co.; Interurban Gas Co., Easton, Penn.	New York 50 Pine St.	New York
COMMONWEALTH PR. RY. & LT. CO.... Controls: Michigan Light Co. in Bay City, Flint, Jackson, Kalamazoo, Manistee, Pontiac and Saginaw, Mich.: Springfield, Ill., Gas & Elec. Co.; Evansville (Ind.) Public Utilities Co.; Central Illinois Light Co., Peoria and Pekin, Ill.	New York 14 Wall St.	New York
GENERAL ENGINEERING & MANAGEMENT CORP........................ Controls: Peoples Gas & Electric Co., Chillicothe, Mo.; Trenton (Mo.) Gas & Elec. Co.	New York 141 Broadway	New York
NASSAU & SUFFOLK LIGHTING CO.... Operates: Nassau & Suffolk Lighting Co.'s plants at Garden City, Hempstead, Freeport, Merrick, Mineola, Roosevelt and other Long Island points.	New York 149 Broadway	New York
NATIONAL FUEL GAS CO............. Controls: United Natural Gas Co., Oil City, Pa.; Iroquois Natural Gas Co., Buffalo, N. Y.; Provincial Natural Gas Co. of Ontario, Niagara Falls, Ont., Can.; Pennsylvania Gas Co., Warren, Pa.; Clarion Gas Co., Oil City, Pa.	New York 26 Broadway	New York
NATIONAL LIGHT, HEAT & POWER CO. .... Operates: Twin State Gas & Elec. Co. of Dover, N. H., Bennington and Brattleboro, Vt.	New York 111 Broadway	New York
NATIONAL UTILITIES CO............. Operates: Ft. Scott & Nevada (Mo.) Lt., Ht., Wtr. & Pr. Co.; N. J. Gas & Elec. Co., Dover, N. J.; Port Arthur (Tex.) Gas & Pr. Co.; Hillsboro (O.) Lt. & Fuel Co.	New York 61 Broadway	New York
THE NORTH AMERICAN CO........... Operates: St. Louis Co. Gas Co., Webster Groves, Mo.; Wisconsin Edison Co., operating Wisconsin Gas Electric Co. of Racine, Kenosha, Watertown and Burlington, Wis.; North Milwaukee Lt. & Pr. Co.; Wells Pr. Co.; Mil. Elec. Ry. & Lt. Co.; Mil. Lt., Ht. & Tr. Co......	New York 30 Broad St.	New York
PEARSON ENGINEERING CORP'N....... Operates gas plant at Rio de Janeiro, Brazil.	New York 115 Broadway	New York
THE UNITED GAS & ELECTRIC ENGINEERING CORPORATION......... Controls: Altoona (Pa.) Gas Light & Fuel Co.; Citizens Gas & Fuel Co., Terre Haute, Ind.; Colorado Springs (Colo.) Lt., Ht. & Pr. Co.; Consumers Electric Light & Pr. Co., New Orleans; Elmira (N. Y.) Water, Lt. & Rd. Co.; Harrisburg (Pa.) Lt. & Pr. Co.; Houston (Tex.) Gas & Fuel Co.; Lockport (N. Y.) Lt., Ht. & Pr. Co.; Richmond (Ind.) Lt., Ht. & Pr. Co.; Union Gas &	New York 61 Broadway	New York

AMERICAN GAS SYNDICATES AND THEIR HOLDINGS —Continued

Company	City	State
Electric Co., Bloomington, Ill.; Wilkes Barre (Pa.) Co.; Birmingham (Ala.) Ry., Lt. & Pr. Co.; Houston (Tex.) Lt. & Pr. Co.; New Orleans (La.) Gas Light Co.; Lancaster (Pa.) Gas Lt. & Fuel Co.; Columbia Gas Co., Lancaster, Pa.; Leavenworth (Kans.) Lt., Ht. & Pr. Co.		
H. D. WALBRIDGE & CO. Controls: Dallas (Tex.) Gas Co.; County Gas Co., Dallas, Tex.; Johnstown (Pa.) Fuel Supply Co., Penn. Pub. Serv. Co., Clearfield, Pa.	New York 14 Wall St.	New York
THE J. G. WHITE MANAGEMENT CORP'N. Operates the Associated Gas & Electric Co., controlling Greenville (O.) Gas Lt. Co.; Homer & Cortland Gas Lt. Co., Cortland, N. Y.; Ithaca (N. Y.) G. & E. Co.; Norwich (N. Y.) Gas & Elec. Co.; Oneonta (N. Y.) Lt. & Pr. Co.; Van Wert (O.) Gas Lt. Co.; also operates the Kentucky Public Service Co., operating in Bowling Green, Frankfort, Hopkinsville and Owensboro, Ky., and Clarksville, Tenn.; Eastern Pa. Lt., Ht. & Pr. Co., Pottsville, Pa.; Helena (Mont.) Lt. & Ry. Co., Thornapple Gas & Elec. Co., Hastings, Mich.; Palatka (Fla.) Pub. Serv. Co.; Sanford (Fla.) Public Service Co.	New York 43 Exchange Place	New York
ALLEN & PECK. Control Newport News and Hampton (Va.) Ry., Gas & Elec. Co.	Syracuse Vinney Bldg.	New York
UTICA GAS & ELEC. O. Operates the Utica plant; Central N. Y. Pr. Co., Canastota; Utica G. & E. Co., Little Falls; Utica G. & E. Co., Herkimer; Utica G. & E. Co., Ilion, N. Y.; Glens Falls (N. C.) Gas & Elec. Co.; Whitehall (N. Y.) Con. Lt. & Pr. Co.; Sandy Hill & Ft. Edward (N. Y.) United Gas, Elec. Lt., Ht. & Fuel Co.	Utica	New York
NORTH CAROLINA PUBLIC SERVICE CO. Operates: No. Car. Pub. Ser. Co., Greensboro, Concord, High Point, Salisbury and Spencer.	Greensboro	North Carolina
CAROLINA POWER & LIGHT CO. Owns Carolina Pr. & Lt. Co., Durham, N. C., and Raleigh, N. C.	Raleigh	North Carolina
CONTINENTAL GAS AND ELECTRIC CORP'N. Operates: Gage Co. Gas. Lt. & Pr. Co., Beatrice, Neb.; Peoples Gas Co., Shenandoah, Ia.; Nebraska Ltg. Co., Plattsmouth, Neb.; Red Oak (Ia.) Gas Co.; York (Neb.) Gas Co.; Brandon (Man., Can.) Gas & Pr. Co.; Nebraska Gas & Elec. Co. and Iowa Gas & Elec. Co., both of Omaha.	Cleveland Cuyahoga Bldg.	Ohio
CONSOLIDATED GAS, ELEC. & WATER CO. Operates: Menominie (Wis.) Gas. Co., Hurley (Wis.) Gas Co., Ironwood (Mich.) Gas Co., Iron Mountain (Mich.) Gas Co.	Cleveland 1123 Illuminating Bldg.	Ohio

AMERICAN GAS SYNDICATES AND THEIR HOLDINGS —Continued

Company	City	State
OHIO CITIES CO. Owns Columbus (O.) Gas & Fuel Co.; Dayton (O.) Gas Co. and Springfield (O.) Gas Co.	Columbus	Ohio
OHIO FUEL SUPPLY CO. (See Pittsburgh).	Columbus	Ohio
OHIO GAS LIGHT & COKE CO. Operates. Plants at Napoleon, Wauseon, Bryan, Stryker, Archbold, Montpelier and Delta, Ohio; Central States Gas Co., Vincennes, Ind. (operates at Vincennes and supplies Lawrenceville, Bridgeport, Sumner and Olney); Illinois Gas Co., Lawrenceville, Ill. (operates at Lawrenceville, Bridgeport, Sumner and Olney; Wabash Gas Co., Robinson, Ill. (operates at Robinson).	Napoleon	Ohio
EMPIRE GAS & FUEL CO. Owns, either directly or through ownership of securities, leases in Kansas and Oklahoma.	Bartlesville	Oklahoma
PACIFIC POWER & LIGHT CO. (See Elec. Bond & Share Co., N. Y.) Gas plants at Walla Walla, Yakima and Vancouver, Wash.; Astoria and Pendleton, Ore., and Lewiston, Idaho.	Portland Gasco Bldg.	Oregon
THE AMERICAN GAS CO. Owns: Bangor (Me.) Gas Lt. Co.; Burlington (Ct.) Lt. & Pr. Co.; Consolidated Lt. & Pr. Co. of Kewanee, Edwardsville, Sheffield and Galva, Ill.; Kingston (N. Y.) Gas & Elec. Co.; Luzerne Co. Gas & Elec. Co. of Kingston, Nanticoke, Hazelton, Plymouth and Fort, Pa.; Phila. Suburban Gas & Elec. Co. of Chester, Coatesville, Pottstown, Wyncote, West Chester, Phoenixville, Royersford, Spring City and other Pa. points; Petersburg (Va.) Gas Co.; Portage (Wis.) American Gas Co.; Rockford (Ill.) Gas Lt. & Coke Co.; St. Clair Co. Gas & Elec. Co. of Bellville (also operating E. St. Louis (Ill.); Waukesha (Wis.) Gas & Elec. Co.; Waterloo (Ia.) Citizens Gas & Elec. Co.	Philadelphia W. Washington Sq.	Pennsylvania
EASTERN LIGHT & FUEL CO. Operates: New Jersey Gas Co., Glassboro, N. J.; Schuylkill Haven (Pa.) Gas & Water Co.; Wildwood (N. J.) Gas Co.; Pottsville (Pa.) Gas Co.	Philadelphia Real Estate Trust Bldg.	Pennsylvania
DAY & ZIMMERMANN. Operate gas plants of the Penn. Central Light & Power Co. at Huntingdon, Lewistown; Eastern Shore Gas & Elec. Co., controlling the Cambridge (Md.) Gas, Elec. Lt. & Pr. Co.	Philadelphia	Pennsylvania
THE C. H. GEIST CO. Operates: Freeport (Ill.) Gas Co.; Roanoke (Va.) Gas Lt. Co.; Atlantic City (N. J.) Gas Co.; Lansing (Mich.) Fuel & Gas Co., East Chicago (Ind.) & Indiana Harbor Water Co.; Northern Alabama Gas Co., of Florence, Ala.; Wilmington (Del.) Gas Co.; Indianapolis (Ind.) Water Co.	Philadelphia Land Title Bldg.	Pennsylvania

AMERICAN GAS SYNDICATES AND THEIR HOLDINGS —Continued

Company	City	State
GIRARDVILLE GAS CO. Operate: Girardville, Lansford and Frackville.	Philadelphia 4014 Chestnut St.	Pennsylvania
GRIBBEL SYNDICATE CO. Operates: Athens (Ga.) Gas Lt. & Fuel Co.; Helena (Ark.) Gas & Elec. Co.; Tampa (Fla.) Gas Co.	Philadelphia 1513 Race St.	Pennsylvania
INTERNATIONAL GAS & ELECTRIC CO. Operates: Concord (N. C.) Gas Co. and the Georgetown (S. C.) Gas & Elec. Co.; Syracuse (N. Y.) Suburban Gas Co.; Gaston Co. Gas Co., Gastonia, N. C.; Chester City Gas Co., Chester, S. C.	Philadelphia Widener Bldg.	Pennsylvania
NATIONAL GAS, ELEC. LT. & PR. CO. Operates: Cape May (N. J.) Lt. & Pr. Co.; Carbondale (Pa.) Gas Co.; Goshen (Ind.) Gas Co.; Joplin (Mo.) Gas Co.; Niles (Mich.) Gas Lt. Co.; Port Huron (Mich.) G. & E. Co.; Portsmouth (O.) Gas Co.; Quincy (Ill.) Gas, Elec. Lt. & Pr. Co.; Warsaw (Ind.) Gas Co.	Philadelphia Witherspoon Bldg.	Pennsylvania
INTERURBAN GAS IMPROVEMENT CO.	Philadelphia Real Estate Trust Bldg.	Pennsylvania
PUBLIC SERVICE CO. Operates: Bucks Co. Public Service Co., Newtown, Pa.; Doylestown (Pa.) Gas Co.; Southern Gas Improvement Co. of Elizabeth City, Henderson and Oxford, N. C.; Rock Hill (S. C.) Gas Co.	Philadelphia Real Estate Trust Bldg.	Pennsylvania
PHILADELPHIA SUBURBAN GAS & ELEC. CO. A consolidation of: Suburban Gas Co. of Philadelphia; Peoples Gas Co. of Pottstown; Coatesville Gas Co., Jenkintown and Cheltenham Gas Co.; Huntingdon Valley Light & Power Co., and Pottstown Light, Heat & Power Co., and others.	Philadelphia S. W. Corner 7th and Locust Sts.	Pennsylvania
J. C. REED & CO. Control: Key West (Fla.) Gas Co.; Colon (Republic of Panama) Gas Co.; Panama (Republic of Panama) Gas Co.	Philadelphia Morris Bldg.	Pennsylvania
UNION RAILWAY SUPPLY CO. Operates: Lewisburg (Pa.) Gas Co.; Ocean Co. Gas Co., Toms River, N. J.; Standard Gas Co. of Atlantic Highlands, Keansburg and Keyport, N. J.; Tuckerton (N. J.) Gas Co.; Equitable Lt., Ht. & Pr. Co., Monmouth Shore Gas Co.	Philadelphia Real Estate Trust Bldg.	Pennsylvania
UNITED GAS IMPROVEMENT CO. Philadelphia Gas Works. Interested in Allentown-Bethlehem (Pa.) Gas Co.; Burlington (Ia.) Gas Lt. Co.; Charleston (S. C.) Con. Ry. & Ltg. Co.; Chester Co. Gas Co., W. Chester, Pa.; Concord (N. H.) Lt. & Pr. Co.; Consumers Gas Co., Reading, Pa.; Counties Gas & Elec. Co., Philadelphia (operating at Ardmore, Conshohocken, Norristown); Des Moines (Ia.) Gas Co.; Fulton Co. Gas & Elec. Co., Gloversville, N. Y.; Harrisburg (Pa.) Gas Co.; Kansas City (Mo.) Gas Co.; Nashville (Tenn.) Gas & Heating Co.; New Gas	Philadelphia Broad & Arch Sts.	Pennsylvania

AMERICAN GAS SYNDICATES AND THEIR HOLDINGS —Continued

Company	City	State
Lt. Co., Janesville, Wis.; Northern Indiana Gas & Elec. Co.; Hammond, Ind.; (also operates Michigan City, South Bend and Ft. Wayne, Ind.; Northern Liberties Gas Co., Philadelphia; Omaha (Neb.) Gas Co.; Pensacola (Fla.) Gas Co.; Peoples Gas Lt. Co.; Manchester, N. H.; St. Augustine (Fla.) Gas & Elec. Lt. Co.; Savannah (Ga.) Gas Co.; Sioux City (Ia.) Gas & Elec. Co.; Sioux Falls (S. D.) Gas Co.; Syracuse (N. Y.) Ltg. Co.; Vicksburg (Miss.) Gas Wks.; Wyandotte Co. Gas Co., Kansas City, Kan.; Northern Indiana Gas & Elec. Co., Hammond (see above).		
ARKANSAS NATURAL GAS CO.......... Pipes natural gas to Little Rock and many towns and cities in Arkansas.	Pittsburgh 223 Fourth Ave.	Pennsylvania
MANUFACTURERS LIGHT & HEAT CO.. Owns and controls: New Cumberland Water & Gas Co.; Venture Oil Co. and Sewickley Gas Co.	Pittsburgh 248 Fourth Ave.	Pennsylvania
OHIO FUEL SUPPLY CO................ Owns Northwestern Ohio Natural Gas Co., Toledo, Ohio; Point Pleasant (W. Va.) Natural Gas Co.; Miami Valley Gas & Fuel Co. Serves: Piqua, Troy, Sidney, Covington, Tippecanoe City, Mt. Sterling, South Charleston, Tarlton, Williamsport, Urbana, Rockbridge, Bloomingburg, Sedalia, Fremont City, North Hampton, New Carlisle, Lawrenceville, Beatty Town, Five Points, Lancaster, Middletown, Mt. Vernon, Xenia, Zanesville and 118 other Ohio towns.	Pittsburgh	Pennsylvania
THE PHILADELPHIA CO................ Controls Chartiers Valley Gas Co.; Mansfield & Chartiers Gas Co.; Penna. Nat. Gas Co., Philadelphia Co. of W. Va.; Union Gas Co. of McKeesport; Allegheny Heating Co., Pittsburgh; Equitable Gas Co., Pittsburgh; Pittsburg & W. Va. Gas Co.	Pittsburgh 435 Sixth Ave.	Pennsylvania
UNION NATURAL GAS CORP'N......... Controls. Logan Natural Gas & Fuel Co. of Lancaster, O.; Newark (O.) Natural Gas & Fuel Co.; Athens (O.) Gas Lt. & Elec. Co.; Buckeye Gas Co., of Circleville, O.; Bellevue (O.) Gas Co.; Marion (O.) Gas Co.; Fremont (O.) Gas, Elec. Lt. & Pr. Co.; Citizens Gas Lt. & Coke Co., Findlay, O.; Citizens Gas & Elec. Co. of Elyria and Lorain; Manufacturers Gas Co., Bradford, Pa.; Warren & Chautauqua Gas Co., of Warren, Pa.	Pittsburgh Union Bank Bldg.	Pennsylvania
WABASH GAS CO...................... Serves: Marshall, Martinsville, Annapolis, Hutsonville and Porterville, Ill.	Pittsburgh Benedum-Trees Bldg.	Pennsylvania
UNITED SERVICE CO.................. Operates: Ohio Service Co., Coshocton, Cambridge, Dennison, New Philadelphia; Warren (Pa.) Lt. & Pr. Co., Punxsutawney, Pa.; Wabash (Ind.) Water & Light Co.; E. Penna. Gas & Elec. Co., Bristol, Pa.; Hanover (Pa.)	Scranton 700 Scranton Life Bldg.	Pennsylvania

AMERICAN GAS SYNDICATES AND THEIR HOLDINGS —Concluded

Company	City	State
Lt., Ht. & Pr. Co.; Susquehanna (Pa.) Lt. & Pr. Co.		
NORTHERN CENTRAL GAS CO. Controls: Hagerstown (Md.) Lt. & Ht. Co.; Northern Central Gas Co. of Milton, Watsontown, Dewart, Montgomery and Williamsport, Pa.	Williamsport	Pennsylvania
BLACKSTONE VALLEY GAS & ELEC. CO. Controls: Pawtucket (R. I.) Elec. Co.; Pawtucket (R. I.) Gas Co.; Woonsocket (R. I.) Gas Co.	Pawtucket	Rhode Island
TEXAS POWER & LIGHT CO. Operates gas plants at Brownwood, Clebourne, Paris, Denison and Waco, the two latter natural gas.	Dallas 1322 Commerce St. (N. Y. Office, 71 Broadway	Texas
TWIN STATE GAS & ELEC. CO. Operates: Bennington Gas Lt. Co.; Brattleboro Gas Lt. Co.; Hoosick Falls Illuminating Co.; Dover Gas Light Co.; United Gas & Elec. Co.	Brattleboro	Vermont
SOUTHERN GAS & ELECTRIC CORP'N. Operates: Suffolk (Va.) Gas-Elec. Co.; Bluefield (W. Va.) Gas & Pr. Co.; Sumter (S. C.) Gas & Pr. Co., Henrico Co. Gas Co., Richmond, Va.; Gas Light Co. of Augusta, Ga.	Richmond	Virginia
VIRGINIA RY. & PR. CO. Owns City Gas Co., Norfolk, Va.	Richmond	Virginia
NORTH PACIFIC PUBLIC SERVICE CO. Operates: Gray's Harbor Gas Co., Aberdeen, Wash.; Centralia and Chehalis Gas Co., Centralia, Wash.; Bremerton-Charleston Lt. & Fuel Co.	Tacoma 323 Tacoma Bldg.	Washington
BOYD E. HORNER SYNDICATE	Clarksburg	West Virginia
COLUMBIA GAS & ELECTRIC CO. Controls: Union Gas & Elec. Co., Cincinnati; Union Lt., Ht. & Pr. Co., Covington, Ky.	Huntington	West Virginia
WISCONSIN SECURITIES CO. Controls: Wis. Pub. Service Co. of Green Bay, De Pere and Two Rivers; Sheboygan Gas Light Co.; Wis. Ry., Lt. & Pr., La Crosse and Winona; Manitowoc & Northern Traction Co.; West Side Pr. Co. Manitowoc; Calumet Service Co., Chilton.	Milwaukee First Nat. Bank Bldg.	Wisconsin
COLUMBUS GAS CONSTRUCTION CO. Owns or controls: Little Falls-Darling Gas Co., Little Falls, Minn.; Taylor (Tex.) Gas Co.; Victoria (Tex.) Gas Co.; Oconomowoc (Wis.) Gas Co.	Milwaukee Majestic Bldg.	Wisconsin
DOMINION GAS CO. Owns: Dominion Natural Gas Co., Ltd., of Ontario, Canada; Brantford Gas Co.; Woodstock Gas Light Co., Ltd.; Beaver Oil & Gas Co.; Ingersoll Gas Co.; Thorold Nat. Gas Co.; United Gas Co. Supplies: Natural gas from its own wells to Dunnville, Brantford, Galt, Tillsonburg, Simcoe, Paris, St. George, Dundas, Bartonville, Jarvis, Cayuga and several other smaller towns.	Hamilton	Ontario, Canada
QUEBEC RY., LT., HT. & PR. CO. Operates: Quebec Ry., Lt. & Pr. Co.; Quebec Gas Co.; Frontenac Gas Co.	Quebec	Canada

By-Product Coke Plants in United States

Owner or Operator	Location	No. of Ovens
Calhoun Gas Co	Battle Creek, Mich	18
Ford Motor Co	Detroit, Mich	120
Semet-Solvay Co	Detroit, Mich	215
Michigan Light Co	Flint, Mich	48
Michigan Light Co	Kalamazoo, Mich.	
Michigan Alkali Co	Wyandotte, Mich	30
Minnesota Steel Co	Duluth, Minn	90
Zenith Furnace Co	Duluth, Minn	65
Minn. By-Products Coke	St. Paul, Minn	65
Laclede Gas Light Co	St. Louis Mo	56
Camden Coke Co	Camden N. J	150
Seaboard By-Prod. Coke Co	Jersey City N. J	55
Seaboard By-Prod. Coke Co	Jersey City, N. J	110
Semet-Solvay Co	Buffalo, N. Y	60
Empire Coke Co	Geneva, N. Y	46
Solvay Process Co	Syracuse, N. Y	40
Dominion Iron & Steel Co	Sydney, N. S	120
Dominion Iron & Steel Co	Sydney, N. S	520
Nova Scotia Steel & Coal Co	Sydney Mines	[illegible]
Dover By-Prod. Coke Co	Canal Dover, Ohio	[illegible]
United Furnace Co	Canton, Ohio	4
Cleveland Furnace Co	Cleveland, Ohio	
River Furnace Co	Cleveland, Ohio	
American Steel & Wire Co	Cleveland, Ohio	[illegible]
Hamilton Otto Coke Co	Hamilton, Ohio	[illegible]
Ironton Solvay Coke Co	Ironton, Ohio	[illegible]
National Tube Co	Lorain, Ohio	
Portsmouth Solvay Coke Co	Portsmouth, Ohio	[illegible]
Toledo Furnace Co	Toledo, Ohio	
Brier Hill Steel Co	Youngstown, Ohio	
Republic Iron & Steel Co	Youngstown, Ohio	145
Youngstown Sheet & Tube Co	Youngstown, Ohio	[illegible]
Youngstown Sheet & Tube Co	Youngstown, Ohio	102
Steel Co. of Canada	Hamilton, Ont	60
Algoma Steel Co	Sault Ste. Marie, Ont	50
Algoma Steel Co	Sault Ste. Marie, Ont	110
Phil. Suburb. Gas & Elec Co	Chester, Pa	40
Carnegie Steel Co	Clairton, Pa	640
Carnegie Steel Co	Clairton, Pa	128
Semet-Solvay Co.	Dunbar, Pa	110
Carnegie Steel	Farrell, Pa	212
Alleghany By-Prod. Coke Co	Glassport, Pa.	210
Jones & Laughlin Steel Co	Hazelwood, Pa	300
Cambria Steel Co	Johnstown, Pa	147
Cambria Steel Co	Johnstown, Pa	462
Bethlehem Steel Co	Lebanon, Pa	318
Bethlehem Steel Co	Steelton, Pa.	60
Bethlehem Steel Co	Steelton, Pa.	120
Lehigh Coke Co	So. Bethlehem, Pa	424
Providence Gas Co	Providence, R. I	40
Memphis Gas & Electr. Co	Memphis, Tenn	27
Seattle Lighting Co	Seattle, Wash	20
Fairmount By-Prod. Co	Fairmount, W. Va	110
LaBelle Iron Works	Follansbee, W. Va	94
National Tube Co	Benwood, W. Va	120
Northwestern Iron Co	Mayville, Wis.	72
Milwaukee Coke & Gas Co	Milwaukee, Wis.	160
Northwestern Iron Co	Mayville, Wis	36
Chattanooga Coke & Gas Co	Chattanooga, Tenn	24

and Canada (Naphtha Producers)

Kind of oven	Coal	Coke	Ammonia as NH3
Gas Machinery, inclined chambers	36,000	25,300	90
Semet-Solvay	864,000	622,000	2,160
Semet-Solvay	1,343,300	1,009,000	3,696
Park Gas Machinery, inclined chambers	96,400	67,500	240
Parker-Russell, Horiz.	43,800	30,700	131
Otto	94,000	65,800	235
Koppers	600,000	450,000	1,500
Otto	200,000	144,000	500
Koppers	380,000	273,600	1,140
Koppers	320,000	240,000	880
Otto	360,000	252,000	990
Koppers	340,500	255,350	937
Koppers	681,000	510,700	1,874
Semet-Solvay	386,000	289,500	965
Semet-Solvay	146,000	102,200	401
Semet-Solvay	65,000	45,500	195
Koppers	720,000	518,400	2,160
Otto	1,664,000	1,198,080	4,576
30 Bauer, 160 Bernard	159,000	110,000	....
Roberts	120,000	87,600	300
Koppers	280,000	204,400	770
Semet-Solvay	450,000	337,500	1,125
Koppers	1,300,000	949,000	3,575
Koppers	1,150,000	839,500	3,162
Otto	240,000	168,000	720
Semet-Solvay	432,000	270,000	1,031
Koppers	1,320,000	963,600	3,630
Semet-Solvay	770,000	559,900	1,944
Koppers	560,000	408,800	1,540
Koppers	520,000	397,600	1,438
Koppers	1,020,000	744,600	2,805
Koppers	1,300,000	949,000	3,575
Koppers	650,000	474,500	1,788
Wilputte	342,000	260,400	779
Wilputte	285,000	217,000	650
Koppers	681,000	510,700	1,874
Semet-Solvay	125,000	87,500	313
Koppers	4,000,000	2,800,000	12,000
Koppers	800,000	560,000	2,400
Semet-Solvay	248,000	173,600	682
Otto	830,000	581,000	2,283
Otto	260,000	195,000	650
Koppers	2,000,000	1,300,000	5,000
Otto	529,200	338,888	1,293
343 Otto, 92 Koppers, 27 Gas Mach.	1,529,500	1,223,700	3,440
228 Otto, 90 Semet-Solvay	887,000	638,000	2,267
Koppers	375,000	270,000	1,031
Semet-Solvay	516,000	371,500	1,354
Koppers	2,400,000	1,920,000	5,400
Koppers	240,000	172,800	720
Gas Mach., including slots	59,000	41,300	148
National Chamber Oven	48,600	29,200	90
Koppers	......	....	....
Koppers	610,000	445,300	1,677
Semet-Solvay	270,000	189,000	743
Otto	320,000	230,400	800
Semet-Solvay	732,000	549,000	2,104
Otto	197,000	147,000	....
Semet-Solvay	173,000	124,000	432

The Flow of Oil in Pipes

The quantity of oil of the same viscosity as water discharged through a pipe is in accordance with the following formula:

$Q = a\,v$ in which Q is the quantity discharged in cubic feet per second
a is the pipe area in square feet
v is the velocity in feet per second

To find the velocity discharged from the pipe line, knowing the head, length and inside diameter use the following formula:

$$v = m\sqrt{\frac{hD}{L + 54\,D}}$$

in which v = approximate mean velocity in feet per second
m = coefficient from table below
D = diameter of pipe in feet
h = total head in feet
L = total length of line in feet

Value of Coefficient "m"

Diameter of Pipe Feet	Inches	m	Diameter of Pipe Feet	Inches	m
0.1	1.2	23	1.5	18	53
0.2	2.4	30	2.0	24	57
0.3	3.6	34	2.5	30	60
0.4	4.8	37	3.0	36	62
0.5	6.0	39	3.5	42	64
0.6	7.2	42	4.0	48	66
0.7	8.4	44	5.0	60	68
0.8	9.6	46	6.0	72	70
0.9	10.8	47	7.0	84	72
1.0	12.0	48	10.0	120	77

The above coefficients are averages deduced from a large number of experiments. In most cases of pipes carefully laid and in fair condition they should give results within 5 to 10% of the truth.

Example: Given the head, h = 50 feet, the length, L = 5280 feet, and the diameter D = 2 feet; to find the velocity and quantity of discharge.

The value of the coefficient m from the table when D = 2 feet is m = 57.

Substituting these values in the formula, we get:

$$v = 57\left(\frac{50 \times 2}{5280 + 108}\right) = 57\left(\frac{100}{5388}\right) = 57 \times 0.136 = 7.52 \text{ ft. per second.}$$

To find the discharge in cubic feet per second, multiply this velocity by the area of cross section of the pipe in square feet.

Thus, 3.1416 x (1) 2 x 7.752 = 24.35 cubic feet per second.

Since there are 7.48 gallons in a cubic foot, the discharge in gallons per second = 24.35 x 7.48 = 182.1.

The above formula is only an approximation, since the flow is modified by bends, joints, incrustations, etc. Wrought pipes are smoother than cast iron ones, thereby presenting less friction and less encouragement for deposits; and being in longer lengths, the number of joints is reduced, thus lessening the undesirable effects of eddy currents.

Principal Pipelines

Pipeline	Mileage		Capacity, barrels
Alluwe Pipeline Co. (Kas. Oil Ref. Co.)	40	From Alluwe Dist., Okla., to Coffeyville, Kans.	2,500
Amalgamated Petroleum Co.	70	From Salt Lake Dist., Cal., to Los Angeles, Cal.	9,000
American Petroleum Co.	20	From Humble to E. Houston, Tex.	....
Associated Oil Co.	105	From Coalinga Dist., Cal., to Monterey, Cal.	15,000
Associated Oil Co.	60	From Santa Barbara Co., Cal. to Gaviota, Cal.	23,000
Arkansas City Pipeline Co.	..	From Blackwell to Arkansas City, Kans.	....
Associated Pipeline Co.	281	From Kern River Dist., Cal., to Port Costa, Cal.	13,000
Associated Pipeline Co.	278	From Kern River Dist., Cal., to Port Costa, Cal.	26,000
Bessemer Pipeline	..	From Titusville, Pa., to W. Pa.	....
Buckeye Pipeline Co., Lima Division	700	From Ohio-Ind. state boundary to Ohio-Penn. state boundary	75,000
Buckeye Pipeline Co., Macksburg Division	350	From Eastern Ohio to Ohio-Penn. and Ohio-W. Va. boundary	10,000
Colive Oil Co.	...	From Healdton to Ardmore...	....
Cosden & Co.	...	From adjacent wells to Bigheart, Okla.	500
Cosden Pipeline Co.	...	From various Okla. oil dist. to West Tulsa, Okla.	30,000
Crescent Pipeline Co.	315	From Greggs, Pa., to Marcus Hook, Pa.	5,600
Crown Pipeline Co.	58	From Okmulgee, Okla., to Muskogee, Okla.	....
Cumberland Pipeline Co.	475	From Southeastern Kentucky to Kentucky-W. Va. bound.	10,000
Emery Pipeline Co.	480	From adjacent oil dist. to Bradford, Pa.	1,000
Empire Pipeline Co.	85	From Eldorado and Augusta, Kans., to Ponca City, Okla	....
Empire Pipeline Co.	67	From Ponca City, Okla., to Norfolk, Okla.	....
Empire Pipeline Co.	70	From northern Oklahoma to Independence, Kans.	....
Empire Pipeline Co.	55	From Healdton, Okla., to Gainesville, Tex. (Total)...	35,000
Empire Pipeline Co.	17	From Gainesville, Tex., to Red River, Tex.	8 inch
Eureka Pipeline Co.	4,300	From Kentucky-W. Va. boundary and Ohio-W. Va. boundary to W. Va.-Pa. boundary	65,000
Franklin Pipe Co.	...	From adjacent fields to Franklin, Pa.	150
General Pipeline Co.	156	From Midway Dist., Cal., to Los Angeles and San Pedro	25,000
General Pipeline Co.	52	From Liebere, Cal., to Mojave, Cal.	5,000
Gulf Pipeline Co.	458	From Tex.-Okla. State Line to Port Arthur, Tex.	28,000
Gulf Pipeline Co.	76	From Batson, Tex., to Sour Lake and Houston	14,000
Gulf Pipeline Co.	117	From La.-Tex. State Line to Lufkin Station, Tex.	9,600
Gulf Pipeline Co.	124	From Saltillo Station, Tex., to Fort Worth, Tex.	7,000
Gulf Pipeline Co. of Okla.	275	From Bartlesville, Okla., to Okla.-Tex. boundary	25,000

PRINCIPAL PIPELINES—Continued

Pipeline	Mileage		Capacity, barrels
Gulf Refining Co. of La	21	From Mansfield, La., to La.-Texas boundary	10,000
Gulf Pipeline Co	305	From Olean, Tex., to Red River, Tex.	8 inch
Gulf Pipeline Co	124	From Fort Worth, Tex., to Saltillo, Tex.	6 inch
Gulf Pipeline Co	98	From Caddo, Tex., to Lufkin, Tex.	6 inch
Gulf Pipeline Co	86	From Ranger, Tex., to Fort Worth, Tex.	8 inch
Gulf Pipeline Co	63	From Houston to Sour Lake, Tex.	6 inch
Hale Petroleum Co	20	From Eldorado, Kan., to Wichita, Kan.	7,500
Illinois Pipeline Co	1,300	From Alton, Ill., to Centerbridge, Pa.	60,000
Illinois Pipeline Co.	25	From Grass Creek, Wyo., to Chatham, Wyo.	....
Illinois Pipeline Co	20	From Elk Basin, Wyo., to Frannie, Wyo.	....
Illinois Pipeline Co	20	From Big Muddy, Wyo., to Casper, Wyo.	20,000
Imperial Pipeline Co., Ltd	155	From Sarnia, Ont., to Cygnet, Ohio	8 inch
Indiana Pipeline Co	800	From Griffith, Ind., to Indiana-Ohio boundary	110,000
Magnolia Petroleum Co	569	From Electra, Tex., to Sabine, Tex.	60,000
Magnolia Petroleum Co	137	From Healdton, Okla., to Fort Worth, Tex.	60,000
Magnolia Petroleum Co	150	From Cushing Dist., Okla., to Addington, Okla.	50,000
Magnolia Petroleum Co. (Double Line)	800	From Red River, Tex., to Beaumont, Tex.	8 inch
Magnolia Petroleum Co	76	From Electra, Tex., to Bowie, Tex.	8 inch
Maryland Pipeline Co.	..	From Kay County, Okla., to Ponca City, Okla.	....
Midwest Refining Co	90	From Salt Creek Dist., Wyo., to Caspar, Wyo.	13,000
National Pipeline Co.	60	From oil fields in Wood Co., Ohio, to Findlay, Ohio	1,000
National Pipeline Co	110	From oil fields in southeastern Ohio to Marietta, Ohio	500
National Transit Co	205	From Nedska, Pa., to New York-Pa. boundary	....
National Transit Co	175	From Colegrave, Pa., to Milway, Pa.	....
National Transit Co	35	From Milway, Pa. to Fawn Grove Pa.	75,000
National Transit Co	70	From Milway, Pa., to Point Breeze, Pa.	....
National Transit Co	70	From Milway, Pa., to Centerbridge, Pa.	....
Natrona Pipeline Co	90	From Salt Creek, Wyo., to Casper, Wyo.	6 inch
New York Transit Co	130	From Pa.-New York boundary to Buffalo, N. Y.	55,000
New York Transit Co	1,100	From Olean, N. Y., to Bayonne, N. J., and Long Island, N. Y.	....
Northern Pipe Co	525	From Pa.-Ohio boundary to Pa.-N. Y. boundary	60,000
Oklahoma Pipeline Co	229	From Creek County, Okla., to McCurtain, Okla.	35,000
Paragon Refining Co	237	From Sandusky County Ohio, to Toledo, Ohio	4,000
Pierce Pipeline Co	135	From Healdton, Okla., to Fort Worth, Tex.	....

PRINCIPAL PIPELINES—Continued

Pipeline	Mileage		Capacity, barrels
Prairie Pipeline Co.	...	From Drumright, Okla., to Ranger, Tex.	8 inch
Prairie Pipeline Co. (Double (Line)	260	From Ranger, Tex., to Red River, Tex.	8 inch
Prairie Pipeline Co.	701	From Cushing Dist., Okla., to Humboldt, Kan.	100,000
Prairie Pipeline Co.	1,820	From Humboldt, Kan., to Sugar Creek, Mo., and Wood River, Ill.	94,000
Prairie Pipeline Co.	90	From McCurtain, Okla., to Ida, La.	31,000
Prairie Pipeline Co.	85	From Eldorado-Augusta Kan., to Neodesha, Kan.	....
Producers' & Refiners' Pipe Line Co.	210	From Watertown, Ohio, to Titusville, Pa.	9,000
Producers' Transportation Co.	41	From Coalinga Dist., Cal., to Junction, Cal.	15,000
Producers' Transportation Co.	50	From Sunset Dist., Cal., to Junction Cal.	20,000
Producers' Transportation Co.	39	From Kern River Dist., Cal., to McKittrick, Cal.	....
Producers' Transportation Co.	13	From Lost Hills Dist., Cal., to Trunk Line, Cal.	....
Producers' Transportation Co.	3	From Belridge Dist., Cal., to Trunk Line, Cal.	....
Producers' Transportation Co.	74	From Junction, Cal., to Port San Luis, Cal.	30,000
Pure Oil Pipeline Co.	250	From Morgantown, W. Va., to Marcus Hook, Pa.	10,000
Rio Brava Oil Co.	13	From Saratoga, Tex., to Sour Lake, Tex.	1,500
Pierce Pipeline Co.	76	From Fort Worth, Tex., to Red River, Tex.	8 inch
Sinclair-Cudahy Pipeline Co.	750	From Cushing Dist., Okla., to Kansas City and Chicago.	....
Sinclair-Cudahy Pipeline Co.	70	From Cushing Dist., Okla., to Coffeyville, Kan.	....
Sinclair-Cudahy Pipeline Co.	340	From branches and lateral in Okla. and Kansas	50,000
Sinclair-Cudahy Pipeline Co.	...	From Cushing field, Okla., to Whiting, Ind.	8 inch
Sinclair-Cudahy Pipeline Co.	...	From Cushing field to Healdton, Okla.	8 inch
Southern Pipeline Co.	1,130	From Pa.-W. Va. boundary to Philadelphia, Pa.	51,000
Southwestern Penn. Pipelines	1,650	Operates exclusively in southwestern Pennsylvania	45,000
Standard Oil Co., Cal.	281	From Kern River Dist., Cal., to Richmond, Cal.	65,000
Standard Oil Co., Cal.	32	From Midway Dist., Cal., to Bakersfield, Cal.	65,000
Standard Oil Co., Cal.	29	From Coalinga Dist., Cal., to Mendota, Cal.	28,000
Standard Oil Co., Cal.	21	From Lost Hills Dist., Cal., to Pond, Cal.	20,000
Standard Oil Co., Cal.	24	From Northan Dist., Cal., to El Segundo. Cal.	27,000
Standard Oil Co., Cal.	45	From Newhall Dist., Cal., to Ventura, Cal.	1,400
Standard Oil Co., Cal.	32	From Santa Mina Dist., Cal., to Port Hartford, Cal.	20,000
Standard Oil Co. of La.	522	From Ida, La., to Baton Rouge, La.	35,000
Sun Co.	250	From Seneca and Wood Co., O., to Toledo, O.	1,000
Sun Pipeline Co.	100	From Humble, Tex. (also Yale, Okla.) to Sabine Pass, Tex.	21,000
Sun Pipeline Co.	53	From Humble, Tex., to Sour Lake, Tex.	6 inch

PRINCIPAL PIPELINES—Concluded

Pipeline	Mileage		Capacity, barrels
Sun Pipeline Co.	25	From Spindle Top, Tex., to Sabine Pass, Tex.	8 inch
Sun Pipeline Co.	23	From Sour Lake, Tex., to Spindle Top, Tex.	8 inch
Sun Pipeline Co.	16	From Batson, Tex., to Sour Lake, Tex.	8 inch
Sun Pipeline Co.	4	From Spindletop, Tex., to Sun Station, Tex.	6 inch
Texas Co. (main lines)	742	From Bartlesville, Okla., to Port Arthur, Tex.	20,000
Texas Co. (main lines)	160	From Electra, Tex., to West Dallas, Tex.	17,000
Texas Co. (main lines)	253	From Vivian, La., to Port Arthur, Tex.	20,000
Texas Co. (main lines)	96	From Evangaline, Tex., to Garrison, Tex.	9,600
Texas Co. (main lines)	60	From Healdton, Okla., to Sherman, Tex.	12,000
Texas Co. (laterals)	222	From in Oklahoma and Texas to.	.....
Texas Co.	400	From Dennison, Tex., to Port Arthur.	6 inch
Texas Co.	155	From Logansport, Tex., to Port Arthur, Tex.	8 inch
Texas Co.	85	From Ranger, Tex., to Fort Worth, Tex.	8 inch
Texas Co. (two lines)	60	From Dallas, Tex., to Fort Worth, Tex.	8 inch
Texas Co.	25	From Dayton, Tex., to Goose Creek.	8 inch
Texas Co.	130	From Electra, Tex., to Fort Worth, Tex.	6 inch
Texas Co.	15	From Humble, Tex., to Houston, Tex.	6 inch
Texas Co.	...	From Healdton, Okla., to Gates Station, Tex.	8 inch
Tidewater Pipe Co. (main line)	830	From Stoy, Ill., to Bayonne, N. J.	11,000
Tidewater Pipe Co. (laterals)	1,929	In Pennsylvania, N. Y., Ill., and Ind.	.....
Union Oil Co.	65	From Orcutt, Cal., to Port San Luis, Cal.	.....
Union Oil Co.	43	Local lines in Ventura County, Cal.	.....
Union Oil Co.	51	Local lines in Los Angeles, Orange County, Fields, Cal.	.....
Valley Pipeline Co.	170	From Coalinga Dist., Cal., to San Francisco Bay	25,000
War Pipeline Co.	...	From Cushing Field, Okla., to Humboldt, Kans.	8 inch
Wilburine Pipeline Co.	125	From Shannopin, Pa., to Warren, Pa.	5,000
Yarhola Pipeline Co.	135	From Healdton, Okla., to Cushing, Okla.	9,000
Yarhola Pipeline Co.	400	From Cushing, Okla., to St. Louis, Mo., and Wood River, Ill.	36,000

Losses in the Storage of Crude Petroleum

The principal losses in the storage of crude petroleum are due to evaporation, to fire and to seepage.

Oils having the greatest loss are the crude oils containing the most gasoline, since they are the most volatile, most readily form explosive and inflammable mixtures and due to their low viscosity most readily flow through walls of loose texture.

The loss from evaporation is greater the larger the amount of gasoline. The loss also depends upon the temperatures of storage, upon the amount of surface exposed to the atmospheric circulation. If the tank or container is perfectly tight, then there will be no loss by evaporation.

There are three general types of storage now in use in the Mid-Continent fields, the earthen reservoir, the steel tank with wooden roof and the steel tank with a steel gas tight roof.

The 55,000 and 35,000 barrel steel tanks are the usual sizes. Altogether there are more than 3,000 of these large steel tanks in use in the Mid-Continent field.

The earthen storage is extremely wasteful from both seepage and evaporation. Petroleum standing in this type of reservoir has been known to shrink 40% in volume in two or three weeks. The shrinkage in value is of course much greater as the portion lost by evaporation is the best of the gasoline.

The following losses by evaporation took place in steel tanks with no seepage, with wooden roof covered with paper and tarred and apparently tight. The oil was of 40°Be′ gravity and the tanks were of a diameter of 114½ feet.

Capacity	Loss in Gauge	Actual Loss	Period	Per Cent Loss
55,000 bbls.	1 ft. 1¾ in.	2101 bbls.	5 mos.	4.2
55,000 bbls.	1 ft. 2⅝ in.	2235 bbls.	4½ mos.	4.6
55,000 bbls.	11⅛ in.	1700 bbls.	3½ mos.	3.4
55,000 bbls.	1 ft. ½ in.	1910 bbls.	3¼ mos.	3.8

The above figures indicate that there might be a loss of 1% per month of storage in wood roof steel tanks and this might amount to as much as 6,000 barrels per year per tank.

It has been claimed that oil stored in white tanks is subjected to 1 to 1½% less evaporation than in red tanks and 2½% less evaporation than in black tanks.

Various types of insulation have been used with success.

A typical storage temperature for the Mid-Continent field for oil stored above ground would be 80°F. A typical temperature of the ground for a submerged tank would be 60°F which would more nearly approach the storage temperature of the air for the whole year.

If tanks could be successfully and cheaply built in the ground, they would have the advantage of almost perfect insulation from outheat, and the oil would be stored at practically the temperature at which it comes from the ground. For this submerged type of tank, concrete construction would be proper if capable of perfect construction. It should be monolithic, well reinforced and lined with a coating impervious to water and gasoline.

Next in quantity after the evaporation losses in the storage of crude oil is the loss due to fire. Petroleum fires destroyed 12,850,000 barrels of oil in the United States in 1918. From Jan. 1, 1908, to Jan. 1, 1918, approximately 12,850,000 barrels of oil and 5,024,506,000 cubic feet of gas were destroyed by fire in the United States entailing a total estimated property loss of $25,254,000. During this period 503 fires were reported. Of these fires 310 were caused by lightning and 193 by other causes. The losses from the fires caused by lightning were estimated to be $11,148,000 and from those due to other causes, $14,106,200. Directly and indirectly the fires resulted in the deaths of nearly 150 persons and were responsible for almost as many more being permanently disabled.

Loss from fire in the oil field storage in the year 1916 amounted to about $4,000,000.

The causes of fires are electrical discharges or open flames in the presence of an inflammable or explosive mixture of gasoline and air. The amount of gasoline vapor in air necessary for an explosive mixture is within the limits of 1½% and 5% by weight. Less than the lower limit or more than the upper limit will not inflame. In an open tank if the amount at the surface of the oil exceeds 1½% there is at some point an explosive mixture and an igniting temperature of 900°F. or over will cause it to take fire. In a perfectly tight tank with gasoline vapor in excess of the upper limit for an explosive mixture, there will be no fire unless the roof of the tank is open at some point.

The ingress of a flame through an opening may be prevented in the same way that the flame in the Davy miner's lamp is prevented from passing outward. This operates by having some metal screen or other material cool the flame and prevent it being propagated into the tank. This will not prevent ignition from an electrostatic discharge in the vapor space of the tank.

Methods for prevention of fires of oil in storage are as follows:

1st. Means of preventing the passage of the spark in a portion of the unfilled face of the tank.

2d. The maintenance of a mixture in the unfilled portion of the tank which is not an explosive mixture.

3d. A tank so placed and constructed that the cooling effect of the walls will tend to smother the flames and the ingress of air will be so arranged that the fire is not readily fed.

4th. A means for quickly eradicating the fire after it is ignited.

Several more or less successful methods for extinction of oil tank fires have been in use. The best involves the use of mixtures of sodium bicarbonate and sulphuric acid which produce sufficient carbon dioxide to smother the flame. If some sort of saponifying agent is used the carbon dioxide will make a froth which will float on the surface of the oil and is very effective in extinguishing the flame.

The application of steam is very effective but in the storage of a very large amount of oil the steam is not always available when needed and at the point where needed.

For small oil fires dust or other finely divided mineral matter is effective in extinguishing the fire.

Fuel Oil Storage Tanks Regulations Drafted by Fire Protection Association

The Committee on Inflammable Liquids of the National Fire Protection Association has submitted the following tentative regulations covering the construction of concrete tanks for fuel oil storage.

Setting of Tanks.—(a) Tanks, if underground, shall be buried so that the top of the tank will be not less than three feet below the level of the surface of the ground and below the level of any piping to which the tanks may be connected.

(b) Tanks shall be set on a firm foundation.

(c) All tanks shall be provided with a concrete or other non-combustible roof.

Material and Construction of Tanks.—(a) **Reinforcement.**—Sufficient steel reinforcement shall be used to resist the oil pressure, and the horizontal and vertical reinforcement shall be proportioned properly and located to reduce the shrinkage cracks, so that they will be too minute to permit leakage. The fiber stress in the steel shall not exceed 10,000 pounds per square inch. (Note. A fiber stress of 10,000 pounds per sq. in. should prevent shrinkage cracks although a number of tanks have been designed with a fiber stress of 6,000 to 8,000 pounds.)

(b) **Concrete.**—The concrete for floor and walls shall be at least 8 inches thick, mixed in the proportion of 1:2:3 or better 1:1½:3 and having the coarse aggregate of clean, dense, crushed rock or gravel ranging in size from one inch down. The concrete shall be thoroughly mixed, carefully placed and worked around the reinforcement. The forms should not be held together by wire as is frequently done in building construction because leakage is likely to take place along the wire. The concrete shall preferably be poured in a continuous operation so as to form a monolithic construction. (Note.—Where this cannot be done, the bottom shall be poured without joints and the walls as a second continuous operation. One method of making a tight joint between the bottom of the tank and the walls is by means of a strip of galvanized iron six inches wide with joints riveted and soldered, so as to form a continuous band. This strip should be vertically embedded three inches in the floor slab and on the center line of the wall. The floor slab under the walls should be thoroughly cleaned, and before pouring the walls a mixture of 1:1 mortar should be placed in the bottom of the forms and around the galvanized strip to make a tight joint.)

(c) **Finish.**—As soon as the wall and sides have been poured the floor shall be floated and troweled smooth. The wall forms shall be removed as soon as the concrete has hardened sufficiently to be self-sustaining and all projections and irregularities shall be removed from the surface and all cavities filled with a 1:1 mortar thoroughly rubbed in and troweled smooth. No plastering shall be applied.

(d) **Aging.**—The concrete shall be allowed to harden at least 30 days and longer if possible. (Note.—To assist in the setting of the concrete before it becomes oil soaked it is advantageous to use several priming coats of a 1:4 solution of 40° Baume' sodium silicate, followed by a finish coat of a 1:2 solution. This forms a glazed surface on the concrete, which although it is not permanent, gives the concrete an opportunity to harden until the protection from the silicate of soda is not longer necessary.)

Location of Pipe Connections.—All pipe connections to the tank shall be made through the top.

Venting of Tanks.—(a) Tanks shall be provided with a permanently open vent, or with a combined fill and vent fitting so arranged that the fill pipe cannot be opened without opening the vent pipe.

(b) Vent openings shall be screened (30x30 brass mesh or equivalent) and shall provide sufficient area for allowing proper flow of liquid during the filling operation. Permanently open vent pipes shall be provided with weatherproof hoods and terminate at a point at least twelve feet above the top of the fill pipe and never within less than three feet, measured horizontally and vertically, from any window or other building opening. Where a battery of tanks is installed vent pipes may be run into a main header. Individual vent pipes should, however, be screened between tank and header and connection to the header should be not less than one foot above the level of the top of the highest reservoir from which the tanks may be filled.

(c) Fill pipes shall be screened and when installed in the vicinity of a building, shall not be located within five feet of any door or other opening and shall terminate in a metal box or casting provided with means for locking.

Rules Governing the Shipment of Oil Samples by Express

Oils having a flash point of 20°F or below must not be shipped in quantities greater than one gallon.

This includes benzine, benzol, casinghead gasoline, casinghead naphtha, coal tar light oils, coal tar naphthas, distillates, petroleum ether, gas drips, gasoline, liquefied petroleum gas, naphthas, naphtha distillates, gas oil, pentane and toluol.

Not more than one gallon shall be in one outside container and the package containing the fluid must not be entirely filled.

The vacant space must be not less than 2% of the contents. If in tightly closed metal cans, the package must be packed in wooden boxes. The package shall be labeled with a red label.

Crude oils, crude petroleums or petroleum naphthas or liquids having a flash point above 20°F and below 80°F may be shipped in quantities less than six gallons in one package. The package, if a metal can, must be covered with wood or packed in wooden boxes.

Gasoline or naphtha with a flash point of 20°F or lower when shipped in glass must be in capacity of one pint or less and cushioned in fiber board or corrugated straw board containers and with not more than eight quarts in one package.

Lubricating oils, motor oils, coal oil, fuel oil, illuminating oil, kerosene and other petroleum oils with a flash point higher than 80°F are not subject to special rules governing the transportation of dangerous articles by express and do not require special labels. The red label is required on all inflammable liquids, including light crude oils and light distillates having a flash point below 80°F.

Ownership of Tank Cars

TANK CARS OWNED BY RAILROADS.

Name and Location.	Tank Cars.
Colorado & Southern	14
Delaware River & Union R. R.	211
Denver & Rio Grande	44
East Jersey R. R.	120
El Paso & Western	98
Kansas City Southern Ry. Co.	193
Los Angeles & Salt Lake R. R. Co.	214
Midland Valley R. R. Co.	97
Missouri, Kansas & Texas Ry.	677
Morenci Southern Ry. Co.	2
New Orleans, Texas & Mexico R. R.	75
Northwestern Pacific R. R. Co.	34
Oregon-Washington R. R. & Nav. Co.	44
Pacific Electric Ry. Co.	29
Pennsylvania R. R. Co.	514
Philadelphia & Reading Ry. Co.	20
St. Louis & San Francisco R. R. Co.	629
St. Louis, Brownsville & Mexico Ry.	59
St. Louis, Southwestern Ry. Co.	29
San Antonio & Aransas Pass Ry. Co.	81
Santa Fe Ry. Co.	3,178
Santa Fe & Arizona Ry.	4
Southern Pacific Ry.	2,963
Texas & New Orleans R. R. Co.	459
Trinity & Brazos Valley R. R.	25
	9,813

TANK CARS OWNED BY OIL INDUSTRY.

Name and Location.	Tank Cars.
Akin Gasoline Co., Tulsa, Okla.	3
Ajax Gasoline Co., Kansas City	4
American Oil Products Corp., Erie	3
American Oil Works, Titusville, Penn.	57
American Refining Co., Tulsa	256
Anderson & Gustafson, Cushing, Okla.	59
Asphaltum Oil & Refining Co., Los Angeles	3
Associated Oil Co., California	337
Atlantic Refining Co., Philadelphia	4
Atwood Refining Co., Oklahoma City	23
Allied Refining Co., Okmulgee	63
Barkhausen Oil Co., Green Bay, Wis.	1
Beaver Refining Co., Washington, Pa.	13
J. B. Berry Sons Co., Oil City, Pa.	105
Bigheart Petroleum Refining Co., Bigheart, Okla.	25
F. W. Bird & Sons, E. Walpole, Mass.	3
Blake Oil Co., Liberal, Kansas	1
Bliss Refining Co., Augusta, Kansas	37
Boynton Gasoline Co., Tulsa	4
Brooks Oil Co., Cleveland, Ohio	2
Boynton Refining Co., Boynton, Okla.	61
British-American Oil Co, Toronto, Canada	200
E. A. Bush Co., Palmer, Mass.	3
Butler County Refining Co., Bruin, Pa.	85
Caddo Oil Refining Co., Shreveport, La.	120
Canfield Oil Refining Co., Coraopolis, Pa.	45
Canfield Tank Line, Cleveland, O.	78
Canfield Refining Co., Yale, Okla.	55
Cameron Refining Co., Ardmore, Okla.	50
Capital Refining Co., Buffalo, N. Y.	47
Carbo Refining Co., Guthrie, Okla.	30
Central Refining Co., Lawrenceville, Ill.	293
Champlin Oil & Refining Co., Enid, Okla.	38

OWNERSHIP OF TANK CARS—Continued

Name and Location.	Tank Cars.
Chestnut & Smith, Tulsa, Okla	12
Cincinnati Oil Works, Cincinnati	1
Clarendon Refining Co., Clarendon, Pa	75
Cleveland Petroleum Refining Co., Cleveland, O	21
Climax Refining Co., Corsicana, Texas	13
Columbia Oil Co., New York	39
Commonwealth Refining Co., Moran, Kansas	24
Conewango Refining Co., Warren, Pa	47
Canadian Oil Companies, Ltd., Petrolia, Canada	200
Constantin Refining Co., Tulsa	500
Consumers Mutual Tank Line, Chicago	88
Consumers Refining Co., Cushing, Okla	379
Continental Oil Co., Denver	8
Continental Refining Co., Oil City, Pa	50
Continental Refining Co., Bristow, Okla	50
Cosden & Co., Tulsa	2,163
Craig Oil Co., Toledo, Ohio	161
Crescent Refining Co., Newkirk, Okla	80
Crew Levick Co., Philadelphia	215
Crown Gasoline & Oil Co., Pittsburgh, Pa	2
Crystal White Refining Co., Allen, Okla	35
Crystal Oil Works, Rouseville, Pa	35
Dallas Oil & Refining Co., Dallas, Texas	20
W. H. Daugherty & Son, Petrolia, Pa	10
El Dorado Refining Co., El Dorado, Kansas	136
Economy Oil & Refining Co., Blackwell, Okla	68
Elk Refining Co., Charleston, W. Va	48
Emery Mfg. Co., Bradford, Pa	90
Emlenton Refining Co., Emlenton, Pa	74
Empire Refineries, Tulsa	2,100
Empire Oil Works, Oil City, Pa	980
Ensign Oil Co., Norristown, Pa	4
Evans-Thwing	250
Foco Oil Co., Franklin, Pa	25
D. W. Frauchot Co., Tulsa, Okla	12
Franklin Quality Refining Co., Franklin, Pa	10
Freeport-Mex. Fuel Oil Corp., New Orleans, La	350
Freedom Oil Works, Freedom, Pa	97
General Refining Co., Tulsa	70
Glenn Pool Tank Line, Kansas City	265
Golden Rule Refinery, Wichita, Kansas	30
Great American Refining Co., Jennings, Okla	116
Great Western Oil Co., Cleveland	21
Great Western Oil Refining Co., Erie, Kansas	86
Gulf Refining Co., Pittsburgh, Pa	1,411
Gasoline Corporation, New York	59
General Petroleum Co., Los Angeles, Calif	10
Home Oil Refining Co., Yale, Okla	195
Great Lakes Oil & Refining Co., Wallaceburg, Can	12
Hillman Refining Co., Cushing, Okla	49
High Grade Petroleum Products Co., St. Mary's, W. Va	50
Humble Oil & Refining Co. (Dixie O. & F. Co.), San Antonio, Texas	33
Humboldt Refining Co., Humboldt, Kansas	3
Hutchinson Refining Co., Hutchinson, Kansas	35
Illinois Oil Co., Cushing, Okla	75
Illinois Refining Co., Rock Island, Ill	61
Imperial Refining Co., Ardmore, Okla	26
Imperial Oil Co., of Canada	668
Independent Refining Co., Oil City, Pa	82
Indiahoma Refining Co., St. Louis	600
Indian Refining Co., Lawrenceville, Ill	1,032
Inland Refining Co., Tulsa	152
International Oil Works, Ltd., St. Louis	3
International Refining Co., Tulsa	418
Inter-Ocean Oil Co., E. Brooklyn, Md	15
Interstate Oil Co., Minneapolis, Minn	1
Island Petroleum Co., Pittsburgh	70
Kansas City Oil Co., Kansas City, Kansas	5

OWNERSHIP OF TANK CARS—Continued

Name and Location.	Tank Cars.
Kansas Oil Refining Co., Coffeyville, Kansas	94
Kansas City Refining Co., Kansas City, Kansas	181
Kansas Co-Operative Refining Co., Chanute, Kansas	193
Kendall Refining Co., Bradford, Pa	28
A. Knabb & Co., Marcus Hook, Pa	1
Lake Park Refining Co., Okmulgee, Okla	205
Lawton Refining Co., Lawton, Okla	32
Leader Oil Co., Casey, Ill	13
Lesh-National Refining Co., Arkansas City, Kansas	45
Liquified Petroleum Gas Co. Tulsa	8
Louisiana Oil Refining Co., Shreveport, La	60
Magnolia Petroleum Co., Dallas, Texas	590
Manufacturers Paraffine Co., Chester, Pa	1
Marland Refining Co., Ponca City, Okla	320
Marshall Oil Co., Marshalltown, Ia	7
Mexican Petroleum Co., Ltd., New York	170
Mid-Co Gasoline Co., Tulsa	166
Mid-Continent Oil Refining Co., East St. Louis, Ill	14
Mid-Continent Gasoline Co. Tulsa	166
Midland Refining Co., Eldorado, Kansas	148
Midwest Refining Co., Denver	22
Miller's Oil Refining Works, Allegheny, Pa	44
Miller Petroleum Refining Co., Chanute, Kansas	59
Milliken Refining Co., St. Louis	70
Motor Fuel Co., Sapulpa, Okla	24
Muskogee Refining Co., Muskogee, Okla	150
Mutual Oil Co., Kansas City, Mo	82
Mutual Refining Co., Ltd., Warren, Pa	39
National Oil Co., New York	24
New Haven Gas Light Co., New Haven, Conn	5
North American Refiners Co., Oklahoma City	415
Oconee Oil Refining Co., Athens, Ga	10
Ohio Valley Refining Co., St. Mary's, W. Va	50
Oil Products Corp., New York	20
O. K. Refining Co., Niotaze, Kansas	161
Oklahoma Petroleum & Gasoline Co., Tulsa	41
Oklahoma Refining Co., Oklahoma City	93
Okmulgee Products & Refining Co., Okmulgee, Okla	20
Oil State Refining Co, Enid, Okla	30
Oklahoma Products & Refining Co., Tulsa	22
Oneta Refining Co., Oneta, Okla	31
Oriental Oil Co., Dallas, Texas	39
Ozark Refining Co., Fort Smith, Ark	13
Ohio Cities Gas Co	900
National Refining Co., Cleveland	1,004
Pelican Oil Refining Co., New Orleans, La	15
Pennsylvania Refining Co., Oil City, Pa	6
Pennsylvania Refining Co., Karns City, Pa	4
Pan-American Refining Co., Tulsa	260
Panhandle Refining Co., Wichita Falls, Texas	35
Paragon Refining Co., Toledo, Ohio	173
Pawnee Refining Co., Oklahoma	48
Penn-American Refining Co., Oil City, Pa	174
Pennsylvania & Delaware Oil Co., New York	19
Pennsylvania Oil Products Oil Refining Co., Eldred, Pa	35
Petroleum Products Co., Pittsburgh	12
Phoenix Refining Co., Tulsa	164
Pierce-Fordyce Assn., Dallas, Texas	403
Pierce Oil Corp., St. Louis	643
Pinal Dome Refining Co., Santa Maria, Calif	1
Pittsburgh Oil Refining Co., Pittsburgh	100
Ponca Lub. Oil Co., Ponca City, Okla	30
Ponca Refining Co., Ponca City, Okla	140
Producers Refining Co., Oklahoma City	270
Prod. & Ref. Co., Blackwell, Okla	136
Frank Prox Co., Terre Haute, Ind	5
Prudential Oil Corp., Baltimore, Md	250
Puente Oil Co., Los Angeles	2

OWNERSHIP OF TANK CARS—Concluded

Name and Location.	Tank Cars.
Pure Oil Co., Minneapolis, Minn	74
Railroad Men's Refinery, Eldorado, Kansas	3
Record Oil Refining Co., New Orleans	35
Red "C" Oil Mfg. Co., Highland Town, Md	92
Richardson Lub. Co., Quincy, Ill	3
Richfield Oil Co., Los Angeles	10
Riverside Western Oil Co., Tulsa	225
Roxana Petroleum Corp., Tulsa	400
Robinson Oil Refining Co., Robinson, Ill	9
Rosedale Refining Co., Rosedale, Kansas	90
Rucker Bros., Everett, Washington	2
Sapulpa Refining Co., Sapulpa, Okla	441
Sarco Petroleum Products Co., Independence, Kansas	183
Seneca Oil Works, Warren, Pa	67
Sinclair Refining Co., Chicago	3,700
Levi Smith, Ltd., Clarendon, Pa	18
Shell Co. of California, San Francisco	84
Southern Oil Corp., Tulsa	250
Standard Oil Co (Union Tank)	21,600
Stannard, C. A., Emporia, Kansas	14
Starlight Refining Co., Karns City, Pa	5
Sterling Oil & Refining Co., Wichita, Kansas	36
St. Louis Oil & Refining Co., El Dorado, Kansas	25
Southern Alberta Refineries, Ltd., Okotoks, Alta	1
Southern Refining Co., Los Angeles	2
A. Speare's Sons Co., Boston	6
Superior Oil Works, Ltd., Warren, Pa	25
Superior Refining Co., Covington, Okla	18
Terminal Oil Refining Co., Healdton, Okla	18
The Texas Co., Houston, Texas	3,435
Tiona Refining Co. Clarendon, Pa	5
Titusville Oil Works, Titusville, Pa	50
Turner Oil Co., Los Angeles	9
Uncle Sam Oil Co., Cherryvale, Kansas	51
Union Oil Co. of California, Los Angeles	115
Union Petroleum Co., Philadelphia	105
Union Refining Co., East St. Louis, Ill	3
United O. & R. Co., Beaumont, Texas	5
United Oil Co., Denver	19
United Refining Co., Warren, Pa	40
U. S. Asphalt Co., E. Brooklyn, Md	300
Upson's Oil & Soap Co., Parkersburg, W. Va	7
Valley Refining Co., Tulsa	23
Valvoline Oil Works. Ltd., East Butler, Pa	89
Victor Refining Co., Yale, Okla	10
Vulcan Oil Refining Co., Cleveland, O	48
Wabash Refining Co., Robinson, Ill	88
Wadhams Oil Co., Milwaukee	5
Warren Oil Co., Warren, Pa	50
Warren Refining Co., Warren, Pa	106
Waverly Oil Co., Pittsburgh	50
Webster Oil & Gas Co., Yale, Okla	5
Webster Refining Co., Humboldt, Kansas	4
Western Refining Co., Wichita, Kansas	22
West Virginia Oil Co., Parkersburg, W. Va	1
Wichita Independent Oil & Refg. Co. (Sterling), Wichita, Kansas	115
Wilburine Oil Works, Ltd., Warren, Pa	61
Wilhoit Refining Co., Springfield, Mo	51
Wilshire Oil Co	50
White Eagle Petroleum Co., Augusta, Kansas	260
Wright Pro. & Refining Co., Cherryvale, Kansas	11
Yaryan Rosin & Turpentine Co., Brunswick, Ga	5
Car manufacturers	7,969
Total	65,500

RULES GOVERNING THE LOCATION OF LOADING RACKS AND UNLOADING POINTS FOR CASINGHEAD GASOLINE, REFINERY GASOLINE, NAPHTHA OR ANY INFLAMMABLE LIQUID WITH FLASH POINT BELOW 30 DEG. F. (Temporarily Suspended.)

The location of loading racks and unloading points for volatile inflammable liquids is considered of great importance to the safety of railroad property, and there is at present lack of uniformity in the enforcement of proper safeguards for the protection of life and property. The following rules shall govern all carriers under Federal control with respect to the location of loading racks or unloading points hereafter installed. As to present locations these rules shall be observed when practicable, and for locations not in accordance therewith carrier through its proper officer shall submit report with recommendation covering each such location to the director of the Division of Operation for instruction. Whenever practicable, throug co-operation with the owners of such loading or unloading faciliti efforts will be made to secure their removal to a safe distance, o such other remedy as the facts may justify will be applied.

Loading

1. Loading racks for refinery gasoline, benzine, naphtha or any liquid with flash point below 30°F, must not be located nearer th eighty feet to a track over which trains or engines are operat (This does not apply to the track serving the loading rack.) Loa racks for casinghead gasoline or casinghead blends must be loc not less than 160 feet distance from such tracks, whenever practicab and in no case should they be located at a less distance than 100 fe These rules apply to casinghead condensates or blends whether made by the compression or absorption process.

Unloading

2. a. The unloading of tank cars of casinghead gasoline, benzine, naphtha and similar petroleum products on railroad sidings must not be permitted, except where facilities exist for piping the contents from the tank cars to permanent storage tanks.

b. The part of any siding on which tank cars of gasoline, benzine, naphtha, or any liquid with flash point below 30°F are to be unloaded, must be located not less than 80 feet from a track over which trains or engines are operated. (This does not apply to the track serving the unloading point.) Where casinghead gasoline is to be unloaded the unloading point must be not less than 160 feet from such track, whenever practicable, but in no case should the distance be less than 100 feet.

c. If the unloading is done on a private siding into tank wagons, barrels or drums (not permanently located storage tanks) the distance at which this operation is permitted must not be less than 160 feet.

d. If tank cars of refinery gasoline, benzine, naphtha, or any liquid with flash point below 30°F are loaded or unloaded at a place within 80 feet from a track over which trains or engines are operated, such tank cars must be provided with a dome cover equipped with a vent line to liberate any escaping vapors. This vent line must be carried to a point at least 80 feet distant from such track. For casinghead gasoline 160 feet will be required whenever practicable, but in no case shall the distance be less than 100 feet from the center of track over which trains or engines are operated. The end of the vent line must be covered with a proper screen of not less than 20x20 mesh.

Storage

3. a. Gasoline, benzine, naphtha, or any liquid with flash point below 30°F, when stored in properly constructed tanks, is comparatively safe. The following regulations will apply for the construction and location of such storage tanks:

b. These regulations apply only to above ground tanks. Underground tanks should be considered separately as occasion may arise. All storage tanks will be considered above ground unless they are buried so that the top of the tank is covered with at least three feet of earth.

c. All tanks should be set upon a firm foundation and be electrically grounded.

d. Each tank over 1,000 gallons in capacity should have all manholes, hand holes, vent openings, and other openings which may contain inflammable vapor, provided with 20x20 mesh brass wire screen or its equivalent, so attached as to completely cover the openings and be protected against clogging; these screens may be made removable but should be kept, normally, firmly attached. Such a tank should also be vented or provided with a suitable safety valve set to operate at not more than five pounds per square inch for both interior pressure and vacuum; manhole covers kept closed by their weight only will be considered satisfactory.

e. Tanks used with a pressure system may have a safety valve set at not more than one-half the pressure to which the tank was originally tested.

f. Tanks containing over 500 gallons and not exceeding 48,000 gallons of gasoline, benzine, naphtha, or any liquid with flash point below 30°F, should be located not less than 80 feet from a track over which trains or engines are operated.

g. For capacities exceeding 48,000 gallons the following distances shall govern:

Capacity of Tanks. (In gallons.)	Distance from Railroad Tracks or Property, Feet.	Distance from Other Tanks, Feet.
48,001 to 75.000	85	3
75.001 to 100.000	100	15
100.001 to 150.000	150	25
150.001 to 250,000	250	35
250.001 to 500.000	300	50
500.001 to 1,000,000	350	75
Unlimited	400	200

h. The above distances should be doubled for tanks containing casinghead gasoline or casinghead blends.

i. Where practicable, tanks should be located on ground sloping away from railroad property, if this is impracticable, then the tanks should be surrounded by dikes of earth, or concrete, or other suitable material, of sufficient capacity to hold all the contents of the tanks, or of such nature and location that in case of breakage of the tanks the oil will be diverted to point such that railway property and passing trains will not be endangered.

General

4. a. In measuring distances from any railroad track the center line of the track should be considered as the starting point.

b. During the time that the tank car is connected by loading or unloading connections, there must be signs placed on the track or car so as to give necessary warning. Such signs must be at least 12x15 inches in size and bear the words "Stop—Tank Car Connected," the word "STOP" being in letters at least 4 inches high and the other words in letters at least two inches high. The printing must be in white letters on a blue background.

c. In laying pipelines on railroad property for the loading or unloading of tank cars, they should be laid at a depth of at least three feet, and at points where such pipelines pass under tracks they should be laid at least four feet below the bottom of the ties.

d. All connections between tank cars and storage tanks must be in good condition, and must not permit any leakage. They must be frequently examined and replaced when they have become worn in order to insure at all times absolutely tight connections. Rubber, leather, or fabric hose must not be used. Tank cars must not be left connected to pipelines except when loading or unloading is going on and while a competent man is present and in charge.

e. Goose-necks, when used for loading and unloading tank cars, must be so constructed that when not in use they will automatically assume a stable position that will provide a horizontal clearance of not less than eight (8) feet from center line of track and be locked in that position. Where this method of unloading is used the rack supporting standpipe and goose-neck shall be of non-combustible material.

f. The ends of pipelines for loading or unloading tank cars from their bottom opening should be placed in shallow pits with brick or concrete walls not closer than 8 feet from center line of track. These pits should be ventilated and be protected by substantial one-piece covers, level with the surface of the ground, which must be kept locked in place when the pits are not in use. These pits should not be drained into a sewer or running stream.

g. The loading or unloading of tank cars should not be permitted except during daylight, when artificial light is not required. The presence of nearby switch lights, lanterns, or other exposed lights or fires during the process of loading or unloading is prohibited.

The following table is used in the calculation of capacities of reservoirs and tanks and in quickly converting different measures of petroleum and water into each other.

MEASUREMENT OF WATER AND PETROLEUM AT 60° F

Multiply or divide, as required, the weight-measure values by the specific gravity of the petroleum. Specific gravity of average crude oil=0.850; fuel oil=0.900; gasoline=0.750; kerosene=0.820; gas oil=0.850.

	Cubic Foot	Cubic Inch	U. S. Gallon	Imperial Gallon	Liter	Petroleum Barrel	Pound	Kilo-gram	Metric Ton
Cubic foot.	1.000	1728.	7.48	6.23	28.317	0.1781	62.37	28.29	.02829
Cubic inch.	.0005787	1.000	.004329	.003605	.016387	$1.303.10^{-4}$	.03609	.01637	$1.637.10^{-5}$
U. S. Gallon........	.13367	231.	1.000	.8328	3.785	.02381	8.338	3.782	.003782
Imperial Gallon. . .	.1605	277.4	1.201	1.000	4.545	.02859	10.01	4.541	.004541
Liter.	.03532	61.03	.2642	.2200	1.000	.00629	2.203	.999034	.000999
Petroleum Barrel ..	5.615	9703.	42.00	34.98	159.3	1.000	350.2	158.85	.15885
Pound (Av.).	.01603	277.1	.1199	.0999	.4539	.002856	1.000	.45359	.0004536
Kilogram.	.03535	61.08	.2644	.2202	1.001	.006296	2.205	1.000	.001
Metric ton.	35.35	61080.	264.4	220.2	1001.	6.296	2205.	1000.	1.000
Pood (Russian). . .	.5791	1000.	4.331	3.607	16.40	0.1031	36.12	16.38	.01638

1 Koku (Jap) = 4.756 gal. 1 Piculi (Jap) = 133⅓ lbs. 1 Yen = 0.498 cts.

Horizontal Cylindrical Tanks

C = Liquid contents in gallons
L = Length of tank in inches
d = Diameter of tank in inches
x = Depth of liquid contents in inches

$$C = \frac{L}{231}\left(0.004363\ d^2\ \mathrm{Cos}^{-1}\ \frac{d-2x}{d} - \frac{d-2x}{2}\sqrt{x(d-x)}\right)$$

$\mathrm{Cos}^{-1}\ \frac{d-2x}{d}$ means the value of the angular degrees whose cosine is $\frac{d-2x}{d}$

The cosine of an angle is the ratio in its right angled triangle, of the side adjacent the angle to the hypothenuse of the triangle.

When L = 300 inches
d = 100 inches
x = 30 inches

$$\frac{d-2x}{d} = .4$$

$\mathrm{Cos}^{-1}\ .4 = 66.42°$ (From Trigonometric tables)

$$C = \frac{300}{231}\left(0.004363\ (10000)\ (66.42) - 20\sqrt{2100}\right)$$

$$= \frac{300}{231}\ (2897 - 882.)$$

$= 2617$ gallons.

Total capacity of horizontal cylindrical tank in gallons.
C = $.0034\ d^2L$
d = diameter in inches. L = length in inches.
c = capacity in U. S. Gallons.

Total capacity of horizontal cylindrical tanks in barrels.

C = $0.14\ d^2L$.
d = diameter in feet.
L = Length in feet.
c = capacity in barrels.

Horizontal Cylindrical Tank Capacity Table

Diameter		Capacity	Capacity		Diameter
1%	=	.17%	1%	=	3.3%
2%	=	.48%	2%	=	5.2%
3%	=	.87%	3%	=	7.0%
4%	=	1.34%	4%	=	8.2%
5%	=	1.87%	5%	=	9.7%
6%	=	2.45%	6%	=	11.0%
7%	=	3.08%	7%	=	12.2%
8%	=	3.75%	8%	=	13.4%
9%	=	4.46%	9%	=	14.5%
10%	=	5.20%	10%	=	15.6%
11%	=	5.98%	11%	=	16.7%
12%	=	6.79%	12%	=	17.8%
13%	=	7.64%	13%	=	18.8%
14%	=	8.51%	14%	=	19.8%
15%	=	9.41%	15%	=	20.8%
16%	=	10.33%	16%	=	21.7%
17%	=	11.27%	17%	=	22.6%
18%	=	12.24%	18%	=	23.6%
19%	=	13.23%	19%	=	24.5%
20%	=	14.24%	20%	=	25.4%
21%	=	15.27%	21%	=	26.3%
22%	=	16.31%	22%	=	27.2%
23%	=	17.37%	23%	=	21.8%
24%	=	18.45%	24%	=	29.0%
25%	=	19.55%	25%	=	29.8%
26%	=	20.66%	26%	=	30.6%
27%	=	21.78%	27%	=	31.5%
28%	=	22.92%	28%	=	32.4%
29%	=	24.07%	29%	=	33.2%
30%	=	25.23%	30%	=	34.0%
31%	=	26.40%	31%	=	34.8%
32%	=	27.58%	32%	=	35.7%
33%	=	28.78%	33%	=	36.5%
34%	=	29.98%	34%	=	37.3%
35%	=	31.19%	35%	=	38.1%
36%	=	32.41%	36%	=	38.9%
37%	=	33.63%	37%	=	39.7%
38%	=	34.87%	38%	=	40.5%
39%	=	36.11%	39%	=	41.3%
40%	=	37.35%	40%	=	42.1%
41%	=	38.60%	41%	=	42.9%
42%	=	39.86%	42%	=	43.7%
43%	=	41.12%	43%	=	44.5%
44%	=	42.38%	44%	=	45.3%
45%	=	43.64%	45%	=	46.1%
46%	=	44.91%	46%	=	46.9%
47%	=	46.18%	47%	=	47.7%
48%	=	47.45%	48%	=	48.5%
49%	=	48.73%	49%	=	49.2%
50%	=	50.00%	50%	=	50.0%

Tank Car Outage Table

Showing Capacity of an 8,000-Gallon Tank Car at Different Levels

Wet Reading		Contents U. S. Gal.	Wet Reading		Contents U. S. Gal.	Wet Reading		Contents U. S. Gal.
Ft.	In.		Ft.	In.		Ft.	In.	
..	1	20.4	3	4	4160.	6	7	8084.
..	2	63.7	3	5	4293.	6	8	8093.8
..	3	102.	3	6	4424.	6	9	8103.74
..	4	157.	3	7	4554.	6	10	8113.66
..	5	218.	3	8	4684.	6	11	8123.57
..	6	285.	3	9	4814.	7	0	8133.49
..	7	356.5	3	10	4945.	7	1	8143.4
..	8	434.6	3	11	5073.	7	2	8153.32
..	9	516.7	4	0	5201.	7	3	8163.23
..	10	602.	4	1	5330.	7	4	8173.14
..	11	692.2	4	2	5456.	7	5	8183.06
1	0	785.5	4	3	5582.	7	6	8192.97
1	1	881.3	4	4	5705.	7	7	8202.89
1	2	981.1	4	5	5829.	7	8	8213.05
1	3	1082.	4	6	5950.	7	9	8223.97
1	4	1187.	4	7	6071.	7	10	8234.88
1	5	1296.	4	8	6191.	7	11	8245.04
1	6	1456.	4	9	6308.	8	0	8254.96
1	7	1518.	4	10	6424.	8	1	8264.87
1	8	1630.	4	11	6536.	8	2	8274.79
1	9	1746.	5	0	6649.	8	3	8284.7
1	10	1863.	5	1	6758.	8	4	8294.62
1	11	1983.	5	2	6867.	8	5	8304.53
2	0	2104.	5	3	6972.	8	6	8314.45
2	1	2225.	5	4	7073.	8	7	8324.36
2	2	2349.	5	5	7173.	8	8	8334.28
2	3	2472.	5	6	7269.	8	9	8342.29
2	4	2598.	5	7	7362.	8	10	8346.98
2	5	2724.	5	8	7452.08	8	11	8349.48
2	6	2853.	5	9	7538.32	9	0	8351.98
2	7	2981.	5	10	7620.07	9	1	8354.48
2	8	3109.	5	11	7699.34	9	2	8356.98
2	9	3240.	6	0	7771.36	9	3	8359.49
2	10	3370.	6	1	7839.86	9	4	8361.49
2	11	3500.	6	2	7902.96	9	5	8362.70
3	0	3630.	6	3	7960.76	9	6	8363.31
3	1	3761.	6	4	8002.86	9	7	8363.93
3	2	3894.	6	5	8051.24	9	8	8364.54
3	3	4027.	6	6	8074.			

GAUGING TABLE FOR EACH ONE-QUARTER INCH IN DEPTH FOR TANK AS DETAILED ON PETROLEUM IRON WORKS COMPANY DRAWING No. 2050-A

8050-Gallon 78-Inch Diameter Tank With Steam Coils for Type "A" and "A-1" Cars

(Side labels: "Steam Coils, Con." beside Feet 1 to 2; "Steam Coils 46 Gallons Deducted" beside Depth 7 to 11¾; "DOME" beside Feet 9¾ to 10¼ of the 6-foot column.)

Depth	Bottom	Feet	Gallons	Feet	Gallons	Feet	Gallons	Feet	Gallons	Feet	Gallons	Feet	Gallons	Feet	Gallons
0	....	1	731	2	2037	3	3565	4	5142	5	6583	6	7695	7	8085
¼	....	¼	754	¼	2067	¼	3598	¼	5174	¼	6611	¼	7713	¼	8088
½	....	½	777	½	2097	½	3631	½	5206	½	6638	½	7731	½	8091
¾	....	¾	801	¾	2128	¾	3364	¾	5238	¾	6665	¾	7749	¾	8094
1	20	1	825	1	2159	1	3697	1	5269	1	6692	1	7766	1	8097
¼	28	¼	849	¼	2189	¼	3730	¼	5301	¼	6719	¼	7783	¼	8100
½	37	½	875	½	2220	½	3765	½	5332	½	6746	½	7800	½	8103
¾	46	¾	898	¾	2251	¾	3796	¾	5364	¾	6772	¾	7816	¾	8106
2	55	2	823	2	2282	2	3830	2	5395	2	6798	2	7832	2	8109
¼	65	¼	948	¼	2313	¼	3863	¼	5427	¼	6824	¼	7847	¼	8112
½	76	½	973	½	2344	½	3896	½	5458	½	6850	½	7862	½	8115
¾	88	¾	998	¾	2375	¾	3929	¾	5489	¾	6876	¾	7877	¾	8118
3	100	3	1024	3	2406	3	3963	3	5520	3	6901	3	7891	3	8120
¼	113	¼	1050	¼	2437	¼	3997	¼	5551	¼	6927	¼	7905	¼	8123
½	126	½	1076	½	2468	½	4030	½	5582	½	6952	½	7918	½	8126
¾	139	¾	1102	¾	2499	¾	4063	¾	5613	¾	6977	¾	7931	¾	8129
4	153	4	1128	4	2531	4	4096	4	5644	4	7002	4	7943	4	8132
¼	167	¼	1154	¼	2562	¼	4130	¼	5675	¼	7027	¼	7954	¼	8135
½	181	½	1180	½	2594	½	4163	½	5706	½	7052	½	7965	½	8138
¾	196	¾	1207	¾	2625	¾	4196	¾	5737	¾	7077	¾	7976	¾	8141
5	211	5	1234	5	2657	5	4229	5	5767	5	7101	5	7986	5	8144
¼	226	¼	1261	¼	2688	¼	4262	¼	5799	¼	7125	¼	7995	¼	8147
½	241	½	1288	½	2720	½	4295	½	5829	½	7149	½	8003	½	8150
¾	256	¾	1315	¾	2752	¾	4328	¾	5859	¾	7173	¾	8010	¾	8153
6	272	6	1343	6	2784	6	4361	6	5889	6	7197	6	8015	6	8155
¼	287	¼	1370	¼	2816	¼	4394	¼	5919	¼	7221	¼	8018	¼	....
½	305	½	1398	½	2848	½	4427	½	5949	½	7244	½	8021	½	....
¾	319	¾	1426	¾	2880	¾	4430	¾	5979	¾	7267	¾	8024	¾	....
7	335	7	1454	7	2912	7	4493	7	6009	7	7290	7	8027	7	....
¼	352	¼	1482	¼	2944	¼	4526	¼	6039	¼	7313	¼	8030	¼	....
½	369	½	1510	½	2976	½	4559	½	6069	½	7335	½	8033	½	....
¾	386	¾	1538	¾	3008	¾	4592	¾	6098	¾	7357	¾	8036	¾	....
8	403	8	1567	8	3041	8	4624	8	6127	8	7379	8	8039	8	....
¼	421	¼	1595	¼	3073	¼	4657	¼	6157	¼	7401	¼	8042	¾	....
½	439	½	1624	½	3106	½	4690	½	6186	½	7422	½	8045	½	....
¾	457	¾	1653	¾	3138	¾	4723	¾	6215	¾	7443	¾	8048	¾	....
9	476	9	1682	9	3171	9	4755	9	6244	9	7484	9	8050	9	....
¼	496	¼	1711	¼	3203	¼	4788	¼	6273	¼	7485	¼	8053	¼	....
½	516	½	1740	½	3236	½	4820	½	6302	½	7506	½	8056	½	....
¾	536	¾	1769	¾	3269	¾	4853	¾	6351	¾	7526	¾	8059	¾	....
10	556	10	1799	10	3302	10	4885	10	6359	10	7546	10	8062	10	....
¼	577	¼	1826	¼	3334	¼	4918	¼	6388	¼	7566	¼	8065	¼	....
½	598	½	1857	½	3367	½	4950	½	6416	½	7585	½	8068	½	....
¾	619	¾	1887	¾	3400	¾	4982	¾	6444	¾	7604	¾	8071	¾	....
11	640	11	1917	11	3433	11	5014	11	6472	11	7623	11	8074	11	....
¼	662	¼	1947	¼	3466	¼	5046	¼	6500	¼	7641	¼	8077	¼	....
½	684	½	1977	½	3499	½	5078	½	6528	½	7659	½	8080	½	....
¾	707	¾	2007	¾	3532	¾	5110	¾	6556	¾	7677	¾	8083	¾	....

DOME 244 gallons = 11.60 gallons to one inch.
Furnished by Pennsylvania Tank Car Company, Sharon, Pa.

Tank Car Outage Tables*

Calculated from 0.25 Inch to 5 Inches Out of Shell, at 60°F
Capacity of Car in Gallons at 60°F

Inches	4231 Gallons	6000 Gallons	6641 Gallons	7000 Gallons	8087 Gallons	8102 Gallons	8505 Gallons	10000 Gallons
0.25	3	4	4	4	5	5	5	6
0.5	6	8	8	8	10	10	10	12
0.75	9	13	13	13	16	16	17	19
1.	13	18	18	18	23	23	25	26
1.25	18	24	25	25	31	31	33	36
1.5	23	31	33	33	39	39	45	46
1.75	29	38	41	41	48	48	56	58
2.	35	46	49	50	58	58	67	71
2.25	41	54	58	59	69	69	79	84
2.5	48	63	68	69	80	80	92	98
2.75	55	72	78	79	90	91	105	111
3.	63	82	88	90	103	103	119	125
3.25	71	92	99	101	115	115	133	140
3.5	79	103	110	113	128	128	148	156
3.75	87	114	123	125	141	141	163	171
4.	96	125	134	137	154	154	178	186
4.25	105	136	146	150	167	167	194	203
4.5	114	148	159	163	181	181	211	220
4.75	123	160	172	176	195	195	288	237
5.	133	173	186	190	210	210	244	254

*Furnished by Phoenix Refining Co.

CONTENTS OF HORIZONTAL TANKS (GALLONS).
Multiply Capacity in Tables by Length of Tanks in Inches.

36 Inches in Diameter	37 Inches in Diameter	38 Inches in Diameter	Depth Inches	39 Inches in Diameter	40 Inches in Diameter	41 Inches in Diameter
....	....	....	20½	....	....	2.858
....	....	....	20	....	2.720	2.769
....	....	....	19½	2.586	....	....
....	....	2.445	19	2.501	2.547	2.591
....	2.327	....	18½	....	....	....
2.203	2.247	2.290	18	2.332	2.374	2.415
2.047	2.087	2.126	17	2.165	2.202	2.239
1.893	1.928	1.963	16	1.998	2.032	2.065
1.739	1.770	1.801	15	1.832	1.863	1.894
1.585	1.613	1.643	14	1.669	1.697	1.724
1.434	1.459	1.484	13	1.509	1.533	1.557
1.286	1.308	1.330	12	1.351	1.372	1.393
1.140	1.159	1.179	11	1.198	1.216	1.233
.999	1.015	1.032	10	1.047	1.063	1.079
.861	.875	.889	9	.903	.916	.929
.729	.740	.752	8	.763	.774	.785
.603	.612	.621	7	.631	.639	.648
.483	.490	.497	6	.505	.512	.518
.371	.376	.382	5	.387	.392	.398
.268	.271	.275	4	.280	.283	.287
.175	.178	.180	3	.183	.185	.188
.096	.098	.099	2	.100	.102	.103
.034	.035	.035	1	.036	.036	.037

CONTENTS OF HORIZONTAL TANKS—Continued.

42 Inches in Diameter	43 Inches in Diameter	44 Inches in Diameter	Depth Inches	45 Inches in Diameter	46 Inches in Diameter	47 Inches in Diameter
....	....	....	23½	....	....	3.755
....	....	....	23	....	3.597	3.653
....	....	....	22½	3.442	....	....
....	....	3.291	22	3.344	3.397	3.450
....	3.143	....	21½	....	....	....
2.998	3.050	3.100	21	3.149	3.199	3.248
2.817	2.864	2.908	20	2.955	3.002	3.047
2.636	2.679	2.721	19	2.763	2.805	2.846
2.455	2.495	2.533	18	2.572	2.609	2.647
2.276	2.313	2.347	17	2.381	2.416	2.450
2.098	2.132	2.163	16	2.193	2.225	2.256
1.922	1.952	1.981	15	2.009	2.037	2.064
1.750	1.776	1.802	14	1.827	1.852	1.876
1.580	1.603	1.626	13	1.648	1.672	1.693
1.414	1.434	1.454	12	1.473	1.494	1.513
1.252	1.269	1.287	11	1.304	1.321	1.338
1.094	1.110	1.125	10	1.139	1.154	1.168
.942	.955	.968	9	.980	.993	1.005
.797	.807	.817	8	.827	.838	.848
.657	.665	.675	7	.682	.691	.699
.526	.532	.540	6	.546	.552	.558
.403	.408	.414	5	.418	.424	.428
.291	.294	.297	4	.301	.304	.308
.190	.193	.194	3	.197	.199	.200
.104	.106	.107	2	.108	.110	.111
.037	.038	.038	1	.038	.039	.039

HORIZONTAL TANKS.

Multiply Capacity in Tables by Length of Tanks in Inches.

48 Inches in Diameter	49 Inches in Diameter	50 Inches in Diameter	Depth Inches	51 Inches in Diameter	52 Inches in Diameter	53 Inches in Diameter
....	....	....	26½	....	....	4.776
....	....	....	26	....	4.597	4.660
....	....	....	25½	4.422	....	....
....	....	4.250	25	4.309	4.371	4.431
....	4.082	....	24½	....	....	....
3.917	3.975	4.033	24	4.085	4.146	4.203
3.707	3.765	3.817	23	3.835	3.922	3.976
3.498	3.555	3.602	22	3.647	3.700	3.749
2.289	3.345	3.388	21	3.431	3.479	3.523
3.084	3.136	3.175	20	3.216	3.259	3.300
2.881	2.928	2.964	19	3.002	3.044	3.078
2.679	2.722	2.755	18	2.790	2.825	2.859
2.478	2.517	2.548	17	2.580	2.613	2.644
2.281	2.316	2.344	16	2.374	2.405	2.432
2.087	2.118	1.145	15	2.170	2.199	2.222
1.900	1.924	1.948	14	1.971	1.996	2.016
1.716	1.734	1.756	13	1.777	1.797	1.815
1.533	1.550	1.569	12	1.585	1.605	1.622
1.353	1.370	1.386	11	1.402	1.417	1.433
1.180	1.195	1.210	10	1.223	1.235	1.251
1.017	1.027	1.040	9	1.052	1.063	1.077
.859	.866	.878	8	.888	.897	.907
.708	.716	.723	7	.729	.737	.746
.565	.575	.578	6	.583	.587	.595
.432	.440	.442	5	.447	.451	.454
.310	.317	.319	4	.319	.326	.329
.201	.205	.208	3	.211	.214	.214
.113	.114	.114	2	.114	.117	.119
.040	.041	.041	1	.041	.041	.042

HORIZONTAL TANKS.

Multiply Capacity in Tables by Length of Tanks in Inches.

54 Inches in Diameter	55 Inches in Diameter	56 Inches in Diameter	Depth Inches	57 Inches in Diameter	58 Inches in Diameter	59 Inches in Diameter
....	....	....	29½	....	....	5.918
....	....	....	29	....	5.719	5.790
....	....	....	28½	5.523	....	....
....	....	5.331	28	5.399	5.467	5.535
....	5.143	....	27½	....	....	....
4.957	5.023	5.089	27	5.153	5.217	5.280
4.723	4.785	4.847	23	4.907	4.967	5.026
4.490	4.547	4.605	25	4.662	4.717	4.773
4.258	4.311	4.365	24	4.417	4.469	4.521
4.026	4.076	4.125	23	4.175	4.223	4.271
3.794	3.842	3.886	22	3.934	3.978	4.023
3.566	3.611	3.651	21	3.694	3.736	3.777
3.340	3.381	3.418	20	3.456	3.495	3.534
3.116	3.152	3.188	19	3.222	3.256	3.293
2.893	2.926	2.959	18	2.992	3.020	3.057
2.674	2.704	2.734	17	2.766	2.788	2.823
2.459	2.486	2.513	16	2.543	2.563	2.594
2.248	2.271	2.296	15	2.321	2.344	2.369
2.041	2.061	2.084	14	2.104	2.128	2.149
1.838	1.857	1.878	13	1.895	1.916	1.934
1.640	1.657	1.675	12	1.692	1.710	1.726
1.449	1.464	1.478	11	1.496	1.509	1.524
1.265	1.279	1.290	10	1.304	1.316	1.329
1.086	1.099	1.108	9	1.120	1.130	1.141
.915	.926	.936	8	.943	.953	.961
.755	.759	.769	7	.776	.784	.791
.602	.607	.614	6	.620	.626	.631
.461	.466	.470	5	.473	.479	.483
.331	.335	.337	4	.340	.344	.347
.217	.219	.220	3	.223	.225	.227
.119	.120	.121	2	.122	.123	.124
.042	.042	.043	1	.043	.044	.044

HORIZONTAL TANKS.
Multiply Capacity in Tables by Length of Tanks in Inches.

60 Inches in Diameter	61 Inches in Diameter	62 Inches in Diameter	Depth Inches	63 Inches in Diameter	64 Inches in Diameter	65 Inches in Diameter
....	....	....	32½	....	....	7.182
....	....	....	32	....	6.963	7.039
....	....	....	31½	6.747	....	....
....	....	6.535	31	6.610	6.686	6.755
....	6.326	....	30½	....	....	....
6.119	6.193	6.267	30	6.337	6.410	6.472
5.858	5.929	5.999	29	6.065	6.134	6.193
5.598	5.668	5.732	28	5.794	5.858	5.915
5.339	5.407	5.465	27	5.523	5.584	5.639
5.082	5.146	5.199	26	5.254	5.310	5.363
4.826	4.885	4.935	25	4.986	5.038	5.089
4.572	4.625	4.672	24	4.722	4.769	4.817
4.318	4.366	4.412	23	4.458	4.503	4.547
4.066	4.111	4.153	22	4.196	4.239	4.281
3.818	3.859	3.898	21	3.937	3.976	4.016
3.572	3.609	3.645	20	3.683	3.718	3.756
3.328	3.363	3.397	19	3.430	3.464	3.496
3.088	3.120	3.151	18	3.181	3.213	3.242
2.582	2.881	2.910	17	2.937	2.964	2.992
2.621	2.646	2.672	16	2.698	2.723	2.748
2.392	2.417	2.440	15	2.463	2.486	2.508
2.171	2.192	2.213	14	2.232	2.254	2.274
1.954	1.972	1.991	13	2.008	2.027	2.045
1.743	1.759	1.776	12	1.791	1.808	1.823
1.538	1.552	1.567	11	1.581	1.595	1.608
1.341	1.352	1.366	10	1.378	1.390	1.401
1.152	1.161	1.173	9	1.183	1.192	1.203
.971	.980	.988	8	.996	1.005	1.013
.799	.806	.812	7	.819	.827	.833
.634	.642	.648	6	.653	.659	.664
.487	.491	.496	5	.500	.504	.508
.349	.354	.357	4	.359	.362	.365
.229	.230	.233	3	.235	.238	.238
.125	.126	.128	2	.128	.129	.131
.045	.045	.045	1	.046	.046	.047

HORIZONTAL TANKS.

Multiply Capacity in Tables by Length of Tanks in Inches.

66 Inches in Diameter	67 Inches in Diameter	68 Inches in Diameter	Depth inches	60 Inches in Diameter	70 Inches in Diameter	71 Inches in Diameter
....	....	....	35½	....	....	8.570
....	....	....	35	....	8.330	8.413
....	....	....	34½	8.094	....	....
....	....	7.861	34	7.944	8.026	8.107
....	7.631	....	33½	....	....	....
7.406	7.485	7.567	33	7.640	7.723	7.801
7.120	7.194	7.273	32	7.348	7.421	7.495
6.834	6.904	6.979	31	7.051	7.120	7.190
6.549	6.617	6.687	30	6.755	6.819	6.886
6.264	6.327	6.395	29	6.459	6.519	6.583
5.981	6.041	6.104	28	6.164	6.222	6.283
5.699	5.756	5.814	27	5.870	5.927	5.983
5.419	5.473	5.528	26	5.580	5.634	5.686
5.141	5.191	5.244	25	5.292	5.343	5.391
4.865	4.913	4.961	24	5.006	5.052	5.098
4.592	4.637	4.681	23	4.724	4.764	4.809
4.322	4.363	4.403	22	4.444	4.481	4.524
4.054	4.092	4.128	21	4.167	4.204	4.241
3.789	3.824	3.859	20	3.893	3.929	3.962
3.529	3.561	3.593	19	3.625	3.657	3.688
3.273	3.302	3.331	18	3.360	3.388	3.418
3.020	3.046	3.074	17	3.101	3.125	3.152
2.772	2.797	2.821	16	2.846	2.868	2.894
2.530	2.553	2.575	15	2.595	2.617	2.640
2.294	2.314	2.333	14	2.352	2.372	2.391
2.064	2.080	2.099	13	2.116	2.135	2.150
1.839	1.855	1.871	12	1.886	1.901	1.916
1.622	1.635	1.650	11	1.663	1.674	1.693
1.413	1.426	1.439	10	1.449	1.459	1.476
1.213	1.223	1.235	9	1.242	1.254	1.264
1.022	1.030	1.041	8	1.047	1.060	1.063
.841	.847	.855	7	.859	.871	.874
.670	.675	.680	6	.687	.689	.697
.512	.516	.529	5	.524	.528	.531
.368	.371	.374	4	.377	.378	.382
.240	.243	.244	3	.246	249	.250
.131	.132	.133	2	.134	.135	.136
.047	.047	.047	1	.048	.048	.048

HORIZONTAL TANKS.
Multiply Capacity in Tables by Length of Tanks in Inches.

72 Inches in Diameter	73 Inches in Diameter	74 Inches in Diameter	Depth Inches	75 Inches in Diameter	76 Inches in Diameter	77 Inches in Diameter
....	....	....	38½	....	....	10.079
....	....	....	38	....	9.819	9.912
....	....	....	37½	9.562	....	....
....	....	9.309	37	9.400	9.489	9.579
....	9.059	....	36½	....	....	....
8.813	8.899	8.989	36	9.076	9.160	9.246
8.500	8.582	8.669	35	8.752	8.832	8.914
8.188	8.267	8.349	34	8.428	8.505	8.583
7.887	7.953	8.030	33	8.104	8.178	8.253
7.567	7.639	7.712	32	7.782	7.782	7.924
7.259	7.326	7.395	31	7.461	7.528	7.596
6.952	7.015	7.080	30	7.142	7.205	7.268
6.645	6.706	6.766	29	6.824	6.885	6.944
6.341	6.397	6.454	28	6.509	6.567	6.622
6.038	6.091	6.145	27	6.195	6.250	6.302
5.736	5.786	5.839	26	5.885	5.938	5.988
5.439	5.485	5.535	25	5.578	5.628	5.675
5.144	5.188	5.232	24	5.274	5.320	5.364
4.852	4.892	4.934	23	4.975	5.014	5.056
4.563	4.599	4.639	22	4.677	4.715	4.753
4.278	4.311	4.374	21	4.383	4.418	4.453
3.997	4.025	4.062	20	4.094	4.127	4.161
3.719	3.748	3.781	19	3.809	3.839	3.871
3.446	3.474	3.501	18	3.529	3.556	3.585
3.179	3.204	3.229	17	3.255	3.280	3.305
2.917	2.938	2.962	16	2.985	3.008	3.032
2.658	2.681	2.702	15	2.723	2.744	2.764
2.408	2.429	2.447	14	2.467	2.485	2.503
2.167	1.184	2.200	13	2.216	2.234	2.250
1.932	1.946	1.960	12	1.978	1.990	2.003
1.703	1.716	1.727	11	1.742	1.753	1.767
1.483	1.494	1.505	10	1.515	1.527	1.538
1.272	1.281	1.291	9	1.300	1.309	1.318
1.071	1.079	1.086	8	1.095	1.102	1.110
.880	.887	.893	7	.899	.906	.912
.701	.707	.712	6	.717	.722	.727
.536	.540	.544	5	.548	.551	.555
.386	.388	.391	4	.393	.396	.399
.252	.253	.254	3	.256	.259	.260
.138	.138	.139	2	.140	.141	.142
.048	.049	.049	1	.050	.050	.050

HORIZONTAL TANKS.
Multiply Capacity in Tables by Length of Tanks in Inches.

78 Inches in Diameter	79 Inches in Diameter	80 Inches in Diameter	Depth Inches	81 inches in Diameter	82 Inches in Diameter	83 Inches in Diameter
....	....	....	41½	....	....	11.711
....	....	....	41	....	11.431	11.531
....	....	....	40½	11.154	....	....
....	....	10.880	40	10.978	11.075	11.172
....	10.610	....	39½	....	....	....
10.343	10.439	10.533	39	10.627	10.720	10.814
10.000	10.097	10.187	38	10.277	10.365	10.456
9.666	9.756	9.841	37	9.927	10.012	10.098
9.329	9.416	9.496	36	9.578	9.659	9.741
8.994	9.076	9.151	35	9.231	9.307	9.385
8.659	8.737	8.809	24	5.532	5.574	5.615
8.325	8.398	8.468	33	8.538	8.608	8.679
7.992	8.060	8.128	32	8.194	8.260	8.328
7.660	7.724	7.789	31	7.854	7.916	7.980
7.330	7.391	7.454	30	7.514	7.575	7.633
7.001	7.059	7.120	29	7.176	7.234	7.286
6.676	6.734	6.788	28	6.842	6.893	6.947
6.354	6.407	6.458	27	6.508	6.557	6.610
6.035	6.085	6.132	26	6.181	6.228	6.274
5.719	5.764	5.809	25	5.583	5.899	5.943
5.406	5.449	5.490	24	5.532	5.574	5.615
5.096	5.138	5.175	23	5.212	5.252	5,291
4.791	4.829	4.864	22	4.900	4.933	4.970
4.487	4.523	4.557	21	4.592	4.624	4.657
4.189	4.224	4.254	20	4.286	4.316	4.436
3.897	3.928	3.956	19	3.987	4.013	4.043
3.610	3.637	3.665	18	3.691	3.717	3.742
3.329	3.355	3.377	17	3.403	3.426	3.450
3.053	3.076	3.098	16	3.120	3.141	3.164
2.784	2.804	2.825	15	2.846	2.863	2.883
2.522	2.540	2.558	14	2.576	2.592	2.612
2.267	2.282	2.299	13	2.315	2.329	2.345
2.019	2.033	2.047	12	2.062	2.074	2.089
1.779	1.791	1.804	11	1.816	1.827	1.840
1.548	1.560	1.570	10	1.582	1.591	1.606
1.328	1.336	1.345	9	1.355	1.365	1.372
1.118	1.126	1.132	8	1.141	1.148	1.156
.919	.925	.931	7	.937	.943	.950
.731	.736	.742	5	.569	.574	.576
.559	.563	.565	6	.746	.752	.757
.401	.404	.407	4	.409	.412	.415
.261	.264	.265	3	.267	.269	.269
.143	.143	.145	2	.146	.147	.148
.051	.051	.051	1	.052	.052	.053

HORIZONTAL TANKS.

Multiply Capacity in Tables by Length of Tanks in Inches.

84 inches in Diameter	85 inches in Diameter	86 inches in Diameter	Depth Inches	87 inches in Diameter	88 inches in Diameter	89 inches in Diameter
....	....	....	44½	....	....	13.466
....	....	....	44	....	13.165	....
....	....	....	43½	12.867	....	....
....	....	12.573	43	12.679	12.783	12.887
....	12.283	....	42½	....	....	....
11.995	12.099	12.201	42	12.303	12.401	12.501
11.632	11.731	11.829	41	11.927	12.019	12.116
11.269	11.363	11.457	40	11.552	11.638	11.734
10.906	10.997	11.086	39	11.177	11.261	11.352
10.544	10.632	10.716	38	10.802	10.884	10.970
10.183	10.267	10.347	37	10.430	10.508	10.589
9.822	9.903	9.979	36	10.058	10.132	10.209
9.462	9.540	9.611	35	9.687	9.759	9.832
9.104	9.177	9.245	34	9.318	9.387	9.458
8.747	8.816	8.883	33	8.951	9.018	9.085
8.392	8.459	8.523	32	8.587	8.651	8.713
8.040	8.105	8.164	31	8.226	8.287	8.345
7.690	7.751	7.807	30	7.865	7.925	7.978
7.344	7.401	7.454	29	7.509	7.566	7.617
7.000	7.054	7.104	28	7.156	7.210	7.258
6.658	6.710	6.756	27	6.805	6.856	6.901
6.320	6.369	6.413	26	6.458	6.504	6.549
5.983	6.030	6.074	25	6.118	6.158	6.201
5.656	5.699	5.738	24	5.773	5.816	5.858
5.330	5.368	5.404	23	5.445	5.482	5.516
5.007	5.043	5.078	22	5.114	5.150	5.182
4.690	4.724	4.756	21	4.790	4.821	4.855
4.378	4.410	4.440	20	4.469	4.499	4.528
4.071	4.098	4.126	19	4.155	4.181	4.211
3.770	3.796	3.821	18	3.847	3.872	3.896
3.475	3.497	3.522	17	3.544	3.576	3.590
3.186	3.206	3.227	16	3.249	3.269	3.291
2.904	2.924	2.941	15	2.961	2.980	2.999
2.629	2.646	2.663	14	2.679	2.699	2.714
2.362	2.378	2.393	13	2.406	2.421	2.439
2.104	2.116	2.129	12	2.142	2.154	2.169
1.853	1.865	1.876	11	1.888	1.900	1.200
1.613	1.621	1.633	10	1.641	1.656	1.663
1.383	1.391	1.400	9	1.407	1.416	1.425
1.162	1.169	1.176	8	1.185	1.190	1.200
.954	.962	.967	7	.973	.979	.983
.760	.765	.770	6	.776	.778	.784
.580	.585	.587	5	.592	.595	.598
.417	.420	.422	4	.429	.429	.430
.272	.274	.275	3	.278	.279	.280
.148	.149	.151	2	.151	.153	.154
.053	.053	.053	1	.054	.055	.055

HORIZONTAL TANKS.
Multiply Capacity in Tables by Length of Tanks in Inches.

90 Inches in Diameter	91 Inches in Diameter	92 Inches in Diameter	Depth Inches	93 Inches in Diameter	94 Inches in Diameter	95 Inches in Diameter
....	....	....	47½	....	....	15.342
....	....	....	47	....	15.021	15.136
....	....	....	46½	14.703	....	....
....	....	14.388	46	14.501	14.612	14.726
....	14.078	....	45½	....	....	....
13.770	13.880	13.988	45	14.098	14.207	14.316
13.378	13.487	13.590	44	13.693	13.802	13.905
12.987	13.094	13.194	43	13.296	13.397	13.495
12.597	12.701	12.798	42	12.896	12.993	13.086
12.209	12.308	12.403	41	12.497	12.590	12.679
11.822	11.915	12.008	40	12.098	12.187	12.273
11.436	11.525	11.613	39	11.699	11.785	11.867
11.051	11.137	11.218	38	11.301	11.384	11.463
10.667	10.750	10.826	37	10.906	10.983	11.061
10.284	10.363	10.438	36	10.513	10.587	10.662
9.903	9.977	10.050	35	10.123	10.193	10.265
9.524	9.596	9.665	34	9.733	9.800	9.870
9.184	9.216	9.281	33	9.344	9.410	9.476
8.773	8.837	8.900	32	8.962	9.024	9.084
8.403	8.463	8.523	31	8.580	8.639	8.697
8.035	8.093	8.149	30	8.200	8.257	8.313
7.670	7.724	7.777	29	7.827	7.880	7.932
7.308	7.358	7.409	28	7.456	7.506	7.553
6.948	6.996	7.046	27	7.089	7.138	7.182
6.593	6.638	6.687	26	6.727	6.771	6.812
6.242	6.283	6.331	25	6.367	6.407	6.450
5.894	5.934	5.976	24	6.013	6.052	6.090
5.552	5.588	5.626	23	5.662	5.700	5.734
5.215	5.248	5.284	22	5.320	5.352	5.386
4.883	4.916	4.948	21	4.979	5.010	5.042
4.656	4.587	4.617	20	4.647	4.673	4.701
4.235	4.264	4.292	19	4.317	4.343	4.368
3.921	3.946	3.972	18	3.996	4.021	4.045
3.611	3.635	3.657	17	3.681	3.703	3.727
3.309	3.331	3.353	16	3.375	3.393	3.414
3.014	3.035	3.056	15	3.073	3.091	3.109
2.729	2.747	2.763	14	2.781	2.796	2.814
2.452	2.468	2.480	13	2.497	2.510	2.524
2.183	2.196	2.210	12	2.222	2.232	2.248
1.922	1.934	1.946	11	1.957	1.966	1.981
1.673	1.682	1.696	10	1.703	1.714	1.723
1.433	1.443	1.455	9	1.459	1.469	1.474
1.204	1.214	1.216	8	1.226	1.232	1.240
.989	.995	1.000	7	1.007	1.010	1.019
.787	.793	.799	6	.803	.807	.812
.601	.605	.608	5	.613	.616	.618
.432	.435	.440	4	.440	.445	.445
.281	.284	.290	3	.290	.291	.292
.154	.155	.156	2	.157	.158	.160
.055	.055	.056	1	.056	.056	.056

HORIZONTAL TANKS.
Multiply Capacity in Tables by Length of Tanks in Inches.

96 Inches in Diameter	Depth Inches	97 Inches in Diameter	96 Inches in Diameter	Depth Inches	97 Inches in Diameter
....	48½	15.995	6.128	24	6.163
15.638	48	15.785	5.770	23	5.803
15.248	47	15.365	5.416	22	5.450
14.828	46	14.945	5.066	21	5.101
14.410	45	14.525	4.726	20	4.757
13.992	44	14.108	4.394	19	4.421
13.574	43	13.692	4.068	18	4.092
13.158	42	13.276	3.752	17	3.770
12.744	41	12.860	3.444	16	3.455
12.336	40	12.446	3.139	15	3.145
11.930	39	12.033	2.838	14	2.844
11.524	38	11.622	2.546	13	2.554
11.119	37	11.214	2.260	12	2.273
10.716	36	10.807	1.990	11	2.001
10.315	35	10.400	1.728	10	1.742
9.915	34	9.997	1.480	9	1.492
9.518	33	9.599	1.240	8	1.254
9.124	32	9.204	1.016	7	1.032
8.736	31	8.810	.804	6	.821
8.352	30	8.420	.620	5	.625
7.974	29	8.035	.447	4	.448
7.600	28	7.654	.292	3	.293
7.230	27	7.274	.160	2	.160
6.862	26	6.897	.057	1	.057
6.494	25	6.526			

HORIZONTAL TANKS.
Multiply Capacity in Tables by Length of Tanks in Inches.

98 Inches in Diameter	Depth Inches	99 Inches in Diameter	98 Inches in Diameter	Depth Inches	99 Inches in Diameter
......	49½	166.662	6.569	25	6.607
16.327	49	16.446	6.203	24	6.239
15.898	48	16.016	5.841	23	5.874
15.473	47	15.587	5.484	22	5.514
15.049	46	15.159	5.131	21	5.160
14.626	45	14.732	4.786	20	4.814
14.205	44	14.305	4.449	19	4.472
13.784	43	13.880	4.116	18	4.138
13.363	42	13.458	3.792	17	3.811
12.944	41	13.036	3.472	16	3.491
12.527	40	12.615	3.160	15	3.181
12.111	39	12.197	2.856	14	2.878
11.698	38	11.780	2.565	13	2.583
11.287	37	11.365	2.282	12	2.298
10.877	36	10.952	2.016	11	2.025
10.468	35	10.539	1.754	10	1.759
10 063	34	10.128	1.501	9	1.508
9.661	33	9.723	1.260	8	1.266
9.263	32	9.322	1.035	7	1.040
8.867	31	8.921	.823	6	.828
8.473	30	8.526	.628	5	.633
8.085	29	8.136	.453	4	.453
7.700	28	7.747	.295	3	.297
7.318	27	7.362	.162	2	.162
6.940	26	6.982	.058	1	.058

HORIZONTAL TANKS.

Multiply Capacity in Tables by Length of Tank in Inches.

100 Inches in Diameter	Depth Inches	101 Inches in Diameter	100 Inches in Diameter	Depth Inches	101 Inches in Diameter
....	50½	17.342	6.647	25	6.685
17.000	50	17.122	6.274	24	6.311
16.565	49	16.683	5.908	23	5.942
16.132	48	16.247	5.546	22	5.579
15.699	47	15.812	5.190	21	5.221
15.267	46	15.377	4.841	20	4.868
14.837	45	14.942	4.498	19	4.523
14.407	44	14.507	4.162	18	4.185
13.978	43	14.073	3.833	17	3.855
13.551	42	13.642	3.511	16	3.531
13.125	41	13.213	3.198	15	3.215
12.700	40	12.784	2.893	14	2.908
12.277	39	12.356	2.597	13	2.612
11.855	38	11.931	2.311	12	2.324
11.436	37	11.508	2.035	11	2.041
11.020	36	11.090	1.769	10	1.779
10.605	35	10.672	1.516	9	1.524
10.194	34	10.257	1.274	8	1.282
9.785	33	9.846	1.046	7	1.053
9.379	32	9.437	.833	6	.838
8.977	31	9.032	.636	5	.640
8.578	30	8.630	.456	4	.458
8.184	29	8.233	.297	3	.298
7.793	28	7.840	.162	2	.162
7.407	27	7.450	.058	1	.058
7.024	26	7.065			

HORIZONTAL TANKS.

Multiply Capacity in Tables by Length of Tank in Inches.

102 Inches in Diameter	Depth Inches	103 Inches in Diameter	102 Inches in Diameter	Depth Inches	103 Inches in Diameter
. ...	51½	18.033	7.108	26	7.148
17.687	51	17.811	6.722	25	6.764
17.246	50	17.364	6.340	24	6.387
16.805	49	16.918	5.972	23	6.010
16.364	48	16.473	5.608	22	5.644
15.924	47	16.030	5.251	21	5.281
15.485	46	15.587	4.895	20	4.924
15.047	45	15.144	4.549	19	4.576
14.609	44	14.701	4.208	18	4.230
14.172	43	14.259	3.877	17	3.896
13.738	42	13.819	3.554	16	3.568
13.304	41	13.384	3.235	15	3.250
12.871	40	12.950	2.916	14	2.938
12.440	39	12.516	2.622	13	2.639
12.011	38	12.083	2.333	12	2.348
11.587	37	11.655	2.056	11	2.069
11.163	36	11.229	1.787	10	1.798
10.743	35	10.805	1.531	9	1.542
10.325	34	10.386	1.278	8	1.295
9.911	33	9.968	1.057	7	1.064
9.498	32	9.556	.854	6	.844
9.087	31	9.147	.642	5	.646
8.680	30	8.738	.458	4	.462
8.282	29	8.331	.300	3	.301
7.884	28	7.930	.163	2	.164
7.497	27	7.537	.058	1	.059

HORIZONTAL TANKS.
Multiply Capacity in Tables by Length of Tank in Inches.

104 Inches in Diameter	Depth Inches	105 Inches in Diameter	104 Inches in Diameter	Depth Inches	105 Inches in Diameter
....	52½	18.742	7.190	26	7.229
18.387	52	18.513	6.804	25	6.841
17 936	51	18.057	6.423	24	6.457
17.485	50	17.603	6.046	23	6.075
17.035	49	17.150	5.671	22	5.704
16.587	48	16.697	5.308	21	5.336
16.140	47	16.245	4.950	20	4.978
15.693	46	15.794	4.599	19	4.626
15.247	45	15.343	4.255	18	4.277
14.802	44	14.893	3.920	17	3.938
14.357	43	14.447	3.588	16	3.608
13.912	42	14.002	3.267	15	3.285
13.470	41	13.558	2.955	14	2.971
13.032	40	13.116	2.653	13	2.667
12.597	39	12.675	2.361	12	2.373
12.164	38	12.237	2.080	11	2.090
11.732	37	11.802	1.809	10	1.814
11.297	36	11.371	1.548	9	1.556
10.872	35	10.940	1.300	8	1.308
10.450	34	10.511	1.068	7	1.074
10.029	33	10.088	.850	6	.853
9.610	32	9.666	.649	5	.652
9.198	31	9.249	.467	4	.469
8.789	30	8.837	.302	3	.304
8.382	29	8.430	.164	2	.165
7.978	28	8.025	.059	1	.059
7.582	27	7.623			

HORIZONTAL TANKS.
Multiply Capacity in Tables by Length of Tank in Inches.

106 Inches in Diameter	Depth Inches	107 Inches in Diameter	106 Inches in Diameter	Depth Inches	107 Inches in Diameter
....	53½	19.463	7.668	27	7.710
19.101	53	19.230	7.272	26	7.312
18.639	52	18.766	6.877	25	6.919
18.180	51	18.303	6.491	24	6.526
17.723	50	17.841	6.111	23	6.143
17.266	49	17.381	5.733	22	5.767
16.810	48	16.922	5.366	21	5.395
16.354	47	16.463	5.005	20	5.029
15.898	46	16.004	4.648	19	4.673
15.444	45	15.545	4.300	18	4.323
14.991	44	15.087	3.960	17	3.980
14.539	43	14.629	3.626	16	3.643
14.089	42	14.176	3.302	15	3.320
13.642	41	13.724	2.988	14	3.001
13.196	40	13.275	2.680	13	2.696
12.752	39	12.828	2.384	12	2.398
12.310	38	12.384	2.101	11	2.110
11.869	37	11.943	1.824	10	1.834
11.434	36	11.503	1.564	9	1.571
11.005	35	11.069	1.314	8	1.320
10.576	34	10.635	1.077	7	1.084
10.150	33	10.205	.858	6	.862
9.725	32	9.779	.655	5	.658
9.303	31	9.354	.470	4	.473
8.888	30	8.937	.306	3	.306
8.474	29	8.523	.166	2	.167
8.069	28	8.116	.059	1	.060

HORIZONTAL TANKS.

Multiply Capacity in Tables by Length of Tank in Inches.

108 Inches in Diameter	Depth Inches	109 Inches in Diameter	108 Inches in Diameter	Depth Inches	109 Inches in Diameter
....	54½	20.198	7.756	27	7.796
19.828	54	19.962	7.352	26	7.391
19.359	53	19.490	6.953	25	6.993
18.892	52	19.019	6.560	24	6.597
18.426	51	18.548	6.176	23	6.209
17.961	50	18.077	5.797	22	5.827
17.496	49	17.607	5.428	21	5.453
17.031	48	17.137	5.059	20	5.084
16.567	47	16.670	4.696	19	4.720
16.103	46	16.203	4.343	18	4.367
15.639	45	15.737	4.000	17	4.022
15.178	44	15.272	3.661	16	3.682
14.719	43	14.810	3.335	15	3.353
14.263	42	14.349	3.020	14	3.032
13.810	41	13.890	2.711	13	2.723
13.359	40	13.435	2.409	12	2.422
12.910	39	12.983	2.121	11	2.131
12.464	38	12.531	1.843	10	1.852
12.019	37	12.083	1.575	9	1.586
11.576	36	11.639	1.323	8	1.336
11.135	35	11.197	1.085	7	1.095
10.698	34	10.758	.868	6	.871
10.265	33	10.322	.662	5	.665
9.836	32	9.892	.476	4	.477
9.412	31	9.463	.309	3	.309
9.992	30	9.037	.169	2	.170
8.576	29	8.619	.060	1	.060
8.165	28	8.207			

HORIZONTAL TANKS.

Multiply Capacity in Tables by Length of Tank in Inches.

110 Inches in Diameter	Depth Inches	111 Inches in Diameter	110 Inches in Diameter	Depth Inches	111 Inches in Diameter
....	55½	20.946	8.244	28	8.290
20.570	55	20.703	7.833	27	7.878
20.093	54	20.219	7.428	26	7.468
19.616	53	19.738	7.026	25	7.063
19.140	52	19.259	6.628	24	6.665
18.664	51	18.781	6.238	23	6.274
18.188	50	18.305	5.856	22	5.888
17.715	49	17.829	5.481	21	5.509
17.244	48	17.353	5.116	20	5.136
16.774	47	16.877	4.754	19	4.771
16.304	46	16.403	4.396	18	4.413
15.836	45	15.932	4.046	17	4.059
15.368	44	15.461	3.704	16	3.718
14.905	43	14.992	3.366	15	3.385
14.444	42	14.523	3.036	14	3.062
13.983	41	14.064	2.724	13	2.748
13.524	40	13.589	2.428	12	2.445
13.066	39	13.130	2.140	11	1.153
12.608	38	12.676	1.864	10	1.870
12.155	37	12.223	1.599	9	1.600
11.704	36	11.772	1.347	8	1.347
11.258	35	11.323	1.102	7	1.106
10.816	34	10.879	.876	6	.880
10.378	33	10.437	.671	5	.671
9.944	32	10.002	.479	4	.480
9.514	31	9.570	.310	3	.312
9.087	30	9.141	.170	2	.170
8.664	29	8.714	.060	1	.061

HORIZONTAL TANKS.
Multiply Capacity in Tables by Length of Tank in Inches.

112 Inches in Diameter	Depth Inches	113 Inches in Diameter	112 Inches in Diameter	Depth Inches	113 Inches in Diameter
....	56½	21.707	8.338	28	8.383
21.325	56	21.461	7.919	27	7.962
20.837	55	20.971	7.507	26	7.548
20.349	54	20.481	7.101	25	7.139
19,863	53	19.991	6.703	24	6.736
19.379	52	19.504	6.307	23	6.339
18.897	51	19.017	5.916	22	5.948
18.415	50	18.530	5.536	21	5.560
17,936	49	18.044	5.163	20	5.188
17.457	48	17.559	4.795	19	4.817
16.980	47	17.074	4.434	18	4.457
16.503	46	16.590	4.081	17	4.101
16.028	45	16.112	3.738	16	3.755
15.554	44	15.638	3.402	15	3.419
15.080	43	15.165	3.077	14	3.091
14.610	42	14.692	2.764	13	2.772
14.141	41	14.221	2.457	12	2.468
13.672	40	13.751	2.162	11	2.171
13.210	39	13.283	1.881	10	1.887
12.751	38	12.821	1.610	9	1.615
12.292	37	12.361	1.350	8	1.357
11.838	36	11.904	1.111	7	1.113
11.388	35	11.449	.885	6	.886
10.942	34	10.999	.674	5	.675
10.497	33	10.552	.482	4	.486
10.055	32	10.108	.314	3	.317
9.620	31	9.669	.171	2	.171
9.188	30	9.235	.031	1	.062
8.761	29	8.805			

HORIZONTAL TANKS.
Multiply Capacity in Tables by Length of Tank in Inches.

114 Inches in Diameter	Depth Inches	115 Inches in Diameter	114 Inches in Diameter	Depth Inches	115 Inches in Diameter
....	57½	22.482	8.855	29	8.898
22.093	57	22.230	8.425	28	8.468
21.599	56	21.733	8.008	27	8.040
21.105	55	21.236	7.583	26	7.622
20.611	54	20.740	7.176	25	7.213
20.117	53	20.244	6.770	24	6.806
19.624	52	19.748	6 369	23	6.401
19.132	51	19.252	5.978	22	6.007
18.643	50	18.756	5.592	21	5.619
18.155	49	18.262	5.212	20	5.238
17.668	48	17.772	4.841	19	4.865
17.181	47	17.282	4.476	18	4.499
16.695	46	16.795	4.120	17	4.139
16.212	45	16.309	3.771	16	3.786
15.731	44	15.823	3.436	15	3.451
15.253	43	15.341	3.109	14	3.121
14.775	42	14.862	2.786	13	2.799
14.299	41	14.383	2.481	12	2.491
13.828	40	13.906	2.183	11	2.192
13.360	39	13.431	1.898	10	1.907
12.893	38	12.964	1.624	9	1.632
12.428	37	12.497	1.365	8	1.371
11.967	36	12.033	1.120	7	1.126
11.511	35	11.572	.890	6	.895
11.057	34	11.116	.681	5	.684
10.609	33	10.664	.488	4	.490
10.165	32	10.217	.317	3	.319
9.722	31	9.771	.172	2	.173
9.288	30	9.331	.062	1	.062

HORIZONTAL TANKS.

Multiply Capacity in Tables by Length of Tank in Inches.

116 Inches in Diameter	Depth Inches	117 Inches in Diameter	116 Inches in Diameter	Depth Inches	117 Inches in Diameter
....	58½	23.271	8.944	29	8.988
22.875	58	23.016	8.513	28	8.555
22.371	57	22.506	8.086	27	8.125
21.868	56	21.998	7.663	26	7.701
21.366	55	21.493	7.247	25	7.282
20.865	54	20.989	6.838	24	6.870
20.365	53	20.485	6.434	23	6.460
19.866	52	19.992	6.036	22	6.065
19.368	51	19.479	5.645	21	5.675
18.870	50	18.977	5.262	20	5.292
18.373	49	18.476	4.888	19	4.913
17.877	48	17.975	4.519	18	4.541
17.382	47	17.478	4.160	17	4.179
16.888	46	16.984	3.813	16	3.826
16.398	45	16.491	3.468	15	3.483
15.911	44	15.999	3.136	14	3.149
15.427	43	15.510	2.813	13	2.828
14.944	42	15.024	2.502	12	2.516
14.462	41	14.540	2.201	11	2.215
13.981	40	14.056	1.914	10	1.925
13.501	39	13.578	1.639	9	1.645
13.023	38	13.102	1.376	8	1.385
12.549	37	12.632	1.131	7	1.136
12.079	36	12.162	.899	6	.903
11.613	35	11.698	.686	5	.689
11.152	34	11.238	.492	4	.496
10.697	33	10.778	.320	3	.321
10.250	32	10.323	.175	2	.175
9.812	31	9.872	.062	1	.063
9.377	30	9.428			

HORIZONTAL TANKS.

Multiply Capacity in Tables by Length of Tank in Inches.

118 Inches in Diameter	Depth Inches	119 Inches in Diameter	118 Inches in Diameter	Depth Inches	119 Inches in Diameter
....	59½	24.074	9.476	30	9.524
23.671	59	23.816	9.031	29	9.082
23.160	58	23.301	8.595	28	8.643
22.649	57	22.787	8.165	27	8.207
22.138	56	22.273	7.739	26	7.779
21.627	55	21.760	7.319	25	7.357
21.117	54	21.247	6.905	24	6.940
20.609	53	20.734	6.496	23	6.529
20.102	52	20.221	6.094	22	6.127
19.597	51	19.710	5.702	21	5.730
19.092	50	19.203	5.317	20	5.342
18.587	49	18.697	4.937	19	4.959
18.083	48	18.191	4.562	18	4.587
17.582	47	17.685	4.197	17	4.220
17.082	46	17.182	3.845	16	3.867
16.584	45	16.681	3.501	15	3.520
16.088	44	16.180	3.163	14	3.180
15.595	43	15.682	2.841	13	2.853
15.105	42	15.188	2.526	12	2.535
14.620	41	14.697	2.223	11	2.232
14.137	40	14.209	1.932	10	1.938
13.654	39	13.725	1.655	9	1.659
13.174	38	13.245	1.390	8	1.396
12.698	37	12.767	1.141	7	1.146
12.225	36	12.291	.909	6	.910
11.758	35	11.818	.694	5	.696
11.292	34	11.350	.497	4	.498
10.832	33	10.888	.322	3	.325
10.377	32	10.429	.175	2	.178
9.924	31	9.975	.063	1	.063

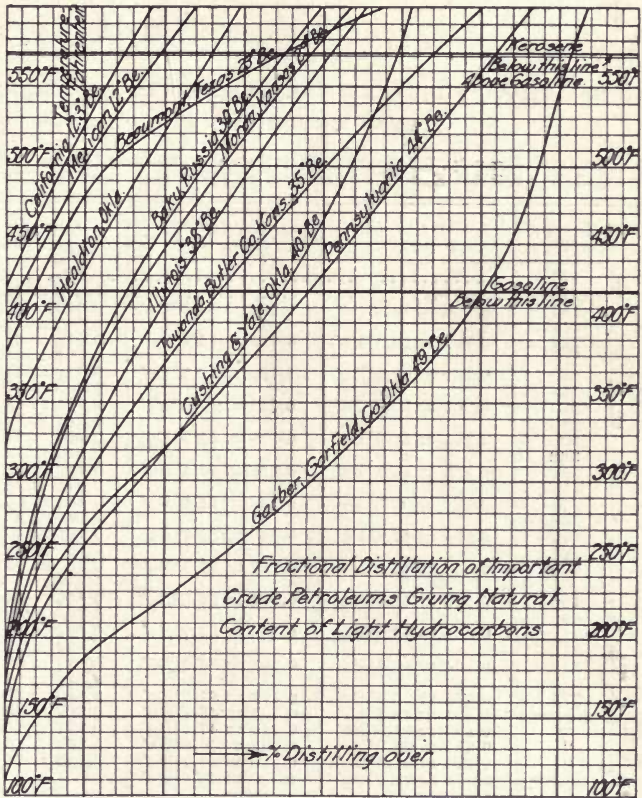
HORIZONTAL TANKS.
Multiply Capacity in Tables by Length of Tank in Inches.

120 Inches in Diameter	Depth Inches	120 Inches in Diameter	Depth Inches	120 Inches in Diameter	Depth Inches
24.479	60	14.287	40	5.363	20
23.954	59	13.797	39	4.981	19
23.434	58	13.314	38	4.608	18
22.914	57	12.833	37	4.240	17
22.395	56	12.354	36	3.882	16
21.877	55	11.881	35	3.538	15
21.359	54	11.411	34	3.198	14
20.842	53	10.944	33	2.866	13
20.328	52	10.483	32	2.537	12
19.815	51	10.024	31	2.239	11
19.305	50	9.567	30	1.949	10
18.795	49	9.124	29	1.668	9
18.287	48	8.683	28	1.396	8
17.780	47	8.244	27	1.151	7
17.273	46	7.816	26	.915	6
16.767	45	7.393	25	.699	5
16.265	44	6.976	24	.501	4
15.768	43	6.561	23	.326	3
15.273	42	6.153	22	.178	2
14.779	41	5.751	21	.063	1

Content of Crude Oils

(Typical Samples.)

Source	Specific Gravity	Natural Commercial Automobile Gasoline, % by Vol. to 410° F.	Kerosene, 410° F., 572° F., % by Vol.	Total Obtainable Gasoline, Natural and Artificial (KCTL Test), % by Vol.
Garber, Garfield Co., Oklahoma..	49.5° Be′ 0.780	60.0%	10.8%	91.0%
Pennsylvania (Light).............	44.5° Be′ 0.802	37.5%	12.7%	86.2%
Cushing, Oklahoma...............	40.1° Be′ 0.823	35.0%	15.0%	83.7%
Towanda, Butler Co., Kansas.......	34.7° Be′ 0.850	26.5%	27.5%	77.9%
Neodesha, Wilson Co., Kansas.......	33.3° Be′ 0.860	25.0%	17.0%	81.2%
Newkirk, Oklahoma................	40.3° Be′ 0.822	32.5%	24.0%	83.1%
Mexico (Panuco)...................	11.4° Be′ 0.990	2.0%	18.0%	44.5%
California..........................	12.3° Be′ 0.984	0.0%	12.3%	50.0%
Texas (Beaumont)..................	23.4° Be′ 0.912	4.0%	16.0%	61.0%
Russia..............................	30.2° Be′ 0.874	15.0%	20.0%	.....
Healdton, Oklahoma................	22.1° Be′ 0.920	8.5%	17.5%	64.0%
Moran, Kansas (Allen County)......	30.7° Be′ 0.871	15.0%	17.5%	74 5%
Kentucky (Wayne County)...........	37.7° Be′ 0 835	28.0%	21.0%	.....
Wyoming (Lander County)..........	24.0° Be′ 0.909	13.0%	13.0%	.....
Ranger, Texas......................	39.2° Be′ 0.829	30.0%	25.0%	84.0%
Burkburnett, Texas................	40.1° Be′ 0 8[illegible]4	41.0%	20.0%	83.5%
Pine Island, Louisiana..............	25.4° Be′ 0.902	0.0%	25.0%	57.0%
West Virginia, Cabin Creek.........	48 0° Be′	36.0%	24.0%	86.0%



Diagrammatic Proximate Composition of Crude Petroleum as to Gasoline and Kerosene.

FRACTIONAL GRAVITY DISTILLATION ANALYSIS OF BURKBURNETT, TEXAS, CRUDE OIL.

Specific Gravity, 0.821; °Be′ U. S., 40.5°; °Be′ Tag, 40.9°.
Summary: 59.7°Be′ Gasoline = 40.0%; 40.5°Be′ Kerosene = 25.0%.

%	Temp. °F	Gravity of Fraction	Gravity of Total Over	Gravity of Stream
0	121	....	....	....
	179	....	....	0.686 = 74.8°Be′
5	197	0.686 = 74.8°Be′	0.686 = 74.8°Be′	0.693 = 72.7°Be′
	211			0.701 = 70.4°Be′
10	227	0.701 = 70.4°Be′	0.693 = 72.7°Be′	0.710 = 67.8°Be′
	238			0.720 = 65.0°Be′
15	253	0.720 = 65.0°Be′	0.702 = 70.1°Be′	0.729 = 62.6°Be′
	268			0.738 = 60.2°Be′
20	283	0.738 = 60.2°Be′	0.711 = 67.5°Be′	0.744 = 58.7°Be′
	295			0.751 = 56.9°Be′
25	309	0.751 = 56.9°Be′	0.719 = 65.3°Be′	0.756 = 55.7°Be′
	322			0.762 = 54.2°Be′
30	342	0.762 = 54.2°Be′	0.726 = 63.4°Be′	0.769 = 52.5°Be′
	358			0.776 = 50.8°Be′
35	375	0.776 = 50.8°Be′	0.733 = 61.6°Be′	0.782 = 49.4°Be′
	394			0.789 = 47.8°Be′
40	410	0.789 = 47.8°Be′	0.740 = 59.7°Be′	0.795 = 46.5°Be′
	426			0.801 = 45.2°Be′
45	440	0.801 = 45.2°Be′	0.747 = 57.9°Be′	0.807 = 43.8°Be′
	470			0.813 = 42.5°Be′
50	485	0.813 = 42.5°Be′	0.754 = 56.2°Be′	0.819 = 41.3°Be′
	508			0.825 = 40.0°Be′
55	529	0.825 = 40.0°Be′	0.760 = 54.7°Be′	0.829 = 39.2°Be′
	547			0.834 = 38.2°Be′
60	562	0.834 = 38.2°Be′	0.766 = 53.2°Be′	0.838 = 37.4°Be′
	574			0.842 = 36.6°Be′
65	578	0.842 = 36.6°Be′	0.772 = 51.8°Be′	0.846 = 35.8°Be′
70	steam	0.854 = 34.2°Be′	0.785 = 48.7°Be′	0.861 = 32.8°Be′
75	"	0.868 = 31.5°Be′	0.791 = 47.3°Be′	0.877 = 29.8°Be′
80	"	0.887 = 28.0°Be′	0.797 = 46.0°Be′	0.898 = 26.0°Be′
85	"	0.910 = 24.0°Be′	0.803 = 44.7°Be′	0.913 = 23.4°Be′
90	residue	0.916 = 22.9°Be′	0.809 = 43.4°Be′	....

FRACTIONAL GRAVITY DISTILLATION ANALYSIS OF BIXBY, OKLA., CRUDE OIL.

Specific Gravity, 0.845; °Be′ U. S., 35.7°; °Be′ Tag, 36.0°.
Summary: 60.7°Be′ Gasoline = 25.0%; 41.0°Be′ Kerosene = 20.0%.

%	Temp. °F	Gravity of Fraction	Gravity of Total Over	Gravity of Stream
0	121	....	....	....
	173	....	....	0.695 = 72.1°Be′
5	213	0.695 = 72.1°Be′	0.695 = 72.1°Be′	0.712 = 67.2°Be′
	253			0.729 = 62.6°Be′
10	274	0.729 = 62.6°Be′	0.712 = 67.2°Be′	0.734 = 61.2°Be′
	293			0.752 = 56.6°Be′
15	309	0.752 = 56.6°Be′	0.725 = 63.6°Be′	0.761 = 54.4°Be′
	337			0.770 = 52.2°Be′
20	370	0.770 = 52.2°Be′	0.736 = 60.7°Be′	0.778 = 50.3°Be′
	391			0.787 = 48.3°Be′
25	40[illegible]	0.787 = 48.3°Be′	0.746 = 58.1°Be′	0.794 = 46.7°Be′
	437			0.802 = 44.7°Be′
30	447	0.802 = 44.9°Be′	0.755 = 55.9°Be′	0.807 = 43.8°Be′
	464			0.813 = 42.5°Be′
35	490	0.813 = 42.5°Be′	0.764 = 53.7°Be′	0.819 = 41.2°Be′
	512			0.826 = 39.8°Be′
40	534	0.826 = 39.8°Be′	0.771 = 52.0°Be′	0.830 = 38.9°Be′
	547			0.835 = 37.9°Be′
45	567	0.835 = 37.9°Be′	0.778 = 50.3°Be′	0.838 = 37.3°Be′
	580			0.842 = 36.5°Be′
50	600	0.842 = 36.5°Be′	0.785 = 48.7°Be′	0.848 = 35.3°Be′
	steam			0.855 = 34.0°Be′
55	"	0.855 = 34.0°Be′	0.791 = 47.3°Be′	0.860 = 33.0°Be′
	"			0.865 = 32.0°Be′
60	"	0.865 = 32.0°Be′	0.797 = 46.0°Be′	0.871 = 30.9°Be′
	"			0.878 = 29.6°Be′
65	"	0.878 = 29.6°Be′	0.803 = 44.7°Be′	0.884 = 28.5°Be′
	"			0.890 = 27.4°Be′
70	"	0.890 = 27.4°Be′	0.809 = 43.4°Be′	0.894 = 26.7°Be′
	"			0.899 = 25.9°Be′
75	"	0.899 = 25.9°Be′	0.815 = 42.1°Be′	0.903 = 25.2°Be′
	"			0.907 = 24.5°Be′
80	"	0.907 = 24.5°Be′	0.820 = 41.0°Be′	0.911 = 23.8°Be′
	"			0.915 = 23.1°Be′
85	"	0.915 = 23.1°Be′	0.827 = 39.6°Be′	0.919 = 22.5°Be′
	"			0.923 = 21.8°Be′
90	"	0.923 = 21.8°Be′	0.833 = 38.4°Be′	....
	"			
95-100	residue	0.953 = 17.0°Be′	....	....

FRACTIONAL GRAVITY DISTILLATION ANALYSIS OF CUSHING, OKLA., CRUDE OIL.

Specific Gravity, 0.824; °Be′ U. S., 39.9°; °Be′ Tag, 40.2°.
Summary: 60.2°Be′ Gasoline = 35.0%; 42.1°Be′ Kerosene = 25.0%.

%	Temp. °F	Gravity of Fraction	Gravity of Total over	Gravity of Stream
0	130	....	....	....
	163	....	....	0.685 = 75.0°Be′
5	179	0.685 = 75.0°Be′	0.685 = 75.0°Be′	0.695 = 72.1°Be′
	205			0.706 = 68.9°Be′
10	229	0.706 = 68.9°Be′	0.695 = 72.1°Be′	0.716 = 66.1°Be′
	250			0.727 = 63.1°Be′
15	270	0.727 = 63.1°Be′	0.706 = 68.9°Be′	0.736 = 60.7°Be′
	283			0.745 = 58.4°Be′
20	297	0.745 = 58.4°Be′	0.715 = 66.4°Be′	0.751 = 56.9°Be′
	316			0.757 = 55.4°Be′
25	327	0.757 = 55.4°Be′	0.724 = 63.9°Be′	0.762 = 54.2°Be′
	339			0.768 = 52.7°Be′
30	352	0.768 = 52.7°Be′	0.731 = 62.0°Be′	0.774 = 51.3°Be′
	372			0.780 = 49.9°Be′
35	394	0.780 = 49.9°Be′	0.738 = 60.2°Be′	0.786 = 48.5°Be′
	414			0.793 = 46.9°Be′
40	427	0.793 = 46.9°Be′	0.745 = 58.4°Be′	0.799 = 45.6°Be
	447			0.805 = 44.2°Be′
45	460	0.805 = 44.2°Be′	0.751 = 56.9°Be′	0.810 = 43.2°Be′
	481			0.816 = 41.9°Be′
50	507	0.816 = 41.9°Be′	0.758 = 55.1°Be′	0.822 = 40.5°Be′
	523			0.826 = 39.4°Be′
55	542	0.823 = 39.4°Be′	0.764 = 53.7°Be′	0.832 = 38.5°Be′
	559			0.837 = 37.4°Be′
60	588	0.837 = 37.4°Be′	0.770 = 52.2°Be′	0.842 = 36.5°Be′
	steam			0.847 = 35.5°Be′
65	"	8.847 = 35.5°Be′	0.779 = 50.1°Be′	0.857 = 33.6°Be′
	"			0.867 = 31.7°Be′
70	"	0.867 = 31.7°Be′	0.785 = 48.7°Be′	0.875 = 30.2°Be′
	"			0.884 = 28.5°Be′
75	"	0.884 = 28.5°Be′	0.792 = 47.1°Be′	0.890 = 27.4°Be′
	"			0.896 = 26.4°Be′
80	"	0.896 = 26.4°Be′	0.798 = 45.8°Be′	0.907 = 24.5°Be′
	"			0.909 = 24.1°Be′
85	"	0.909 = 24.1°Be′	0.805 = 44.2°Be′	0.916 = 22.9°Be′
	"			0.924 = 21.6°Be′
90	"	0.924 = 21.6°Be′	0.811 = 42.9°Be′	0.930 = 20.7°Be′
	"			....
95-100	residue	0.940 = 19.0°Be′	....	....

FRACTIONAL GRAVITY DISTILLATION ANALYSIS OF PINE ISLAND. NO. LOUISIANA, CRUDE OIL.

Specific Gravity, 0.902; °Be′ U. S., 25.2°; °Be′ Tag, 25.4°Be′.
Summary: Gasoline = none; 31.0° Kerosene = 25.0% (Naphthene base oil)

%	Temp. °F	Gravity of Fraction	Gravity of Total Over	Gravity of Stream	
0	365	....	....	....	....
5	471	0.839 = 37.2°Be′	0.839 = 37.2°Be′	0.849 = 35.1°Be′	....
10	500	0.860 = 33.0°Be′	0.849 = 35.1°Be′	0.864 = 32.2°Be′	....
15	530	0.869 = 31.3°Be′	0.856 = 33.8°Be′	0.872 = 30.7°Be′	....
20	549	0.876 = 30.0°Be′	0.861 = 32.8°Be′	0.878 = 29.6°Be′	....
25	564	0.880 = 29.3°Be′	0.865 = 32.0°Be′	0.881 = 29.1°Be′	....
30	589	0.883 = 28.8°Be′	0.867 = 31.7°Be′	0.886 = 28.2°Be′	....
35	steam	0.889 = 27.7°Be′	0.870 = 31.1°Be′	0.890 = 27.4°Be′	Viscosity
40	"	0.892 = 27.1°Be′	0.873 = 30.5°Be′	0.893 = 26.9°Be′	66
45	"	0.894 = 26.8°Be′	0.875 = 30.2°Be′	0.894 = 26.7°Be′	80
50	"	0.895 = 26.6°Be′	0.877 = 29.8°Be′	0.895 = 26.6°Be′	100
55	"	0.896 = 26.4°Be′	0.879 = 29.4°Be′	0.896 = 26.4°Be′	152
60	"	0.897 = 26.2°Be′	0.880 = 29.3°Be′	0.897 = 26.2°Be′	210
65	"	0.897 = 26.2°Be′	0.880 = 29.3°Be′	0.897 = 26.2°Be′	270
70	"	0.897 = 26.2°Be′	0.880 = 29.3°Be′	0.897 = 26.2°Be′	625
75	"	0.897 = 26.2°Be′	0.880 = 29.3°Be′	0.898 = 26.0°Be′	580
80	"	0.899 = 25.9°Be′	0.885 = 28.3°Be′	0.899 = 25.9°Be′	620
85	"	0.900 = 25.7°Be′	0.885 = 28.3°Be′	0.901 = 25.5°Be′	654
90	"	0.902 = 25.4°Be′	0.886 = 28.2°Be′	....	waxy
					waxy

FRACTIONAL GRAVITY DISTILLATION ANALYSIS OF BILLINGS, OKLA., CRUDE OIL.

Specific Gravity, 0.812; °Be′ U. S. 42.4°; °Be′ Tag 42.8°.
Summary: 60.5°Be′ Gasoline = 40.0%; 41.0°Be′ Kerosene = 25.0%.

%	Temp. °F	Gravity of Fraction	Gravity of Total Over	Gravity of Stream
0	116	....	....	....
	169	....	....	0.679 = 76.9°Be′
5	191	0.679 = 76.9°Be′	0.679 = 76.9°Be′	0.689 = 73.8°Be′
	207			0.700 = 70.6°Be′
10	223	0.700 = 70.6°Be′	0.689 = 73.8°Be′	0.710 = 67.8°Be′
	235			0.720 = 65.0°Be′
15	252	0.720 = 65.0°Be′	0.699 = 70.9°Be′	0.728 = 62.8°Be′
	264			0.736 = 60.7°Be′
20	277	0.736 = 60.7°Be′	0.708 = 68.3°Be′	0.742 = 59.2°Be′
	286			0.748 = 57.6°Be′
25	303	0.748 = 57.6°Be′	0.716 = 66.1°Be′	0.753 = 56.4°Be′
	317			0.761 = 54.4°Be′
30	337	0.761 = 54.4°Be′	0.724 = 63.9°Be′	0.767 = 52.9°Be′
	353			0.774 = 51.3°Be′
35	367	0.774 = 51.3°Be′	0.731 = 62.0°Be′	0.779 = 50.1°Be′
	381			0.785 = 48.7°Be′
40	396	0.785 = 48.7°Be′	0.737 = 60.5°Be′	0.790 = 47.6°Be′
	413			0.795 = 46.3°Be′
45	431	0.795 = 46.3°Be′	0.744 = 58.7°Be′	0.801 = 45.1°Be′
	456			0.808 = 43.6°Be′
50	482	0.808 = 43.6°Be′	0.750 = 57.1°Be′	0.814 = 42.3°Be′
	500			0.820 = 41.0°Be′
55	513	0.820 = 41.0°Be′	0.756 = 55.6°Be′	0.825 = 40.0°Be′
	530			0.830 = 38.9°Be′
60	550	0.830 = 38.9°Be′	0.763 = 53.9°Be′	0.835 = 37.9°Be′
	577			0.840 = 36.9°Be′
65	593	0.840 = 36.9°Be′	0.768 = 52.7°Be′	0.843 = 36.3°Be′
	steam			0.847 = 35.5°Be′
70	"	0.847 = 35.5°Be′	0.774 = 51.3°Be′	0.855 = 34.0°Be′
	"			0.864 = 32.3°Be′
75	"	0.864 = 32.3°Be′	0.780 = 49.9°Be′	0.870 = 31.1°Be′
	"			0.878 = 29.6°Be′
80	"	0.878 = 29.6°Be′	0.786 = 48.5°Be′	0.886 = 28.2°Be′
85	"	0.893 = 27.0°Be′	0.792 = 47.2°Be′	0.900 = 25.7°Be′
90	"	0.906 = 24.7°Be′	0.798 = 45.8°Be′	0.918 = 22.6°Be′
95-100	residue	0.930 = 20.7°Be′	....	....

FRACTIONAL GRAVITY DISTILLATION ANALYSIS OF GARBER, OKLA., CRUDE OIL.

Specific Gravity, 0.780; °Be' U. S. 49.5°; °Be' Tag 49.9°.
Sulphur = 0.05%.
Summary: 59.2°Be' Gasoline = 55.0%; 40.5°Be' Kerosene = 20.0%.

%	Temp. °F	Gravity of Fraction	Gravity of Total Over	Gravity of Stream	Olefins %
0	110	....	....	....	1.0
5		....	....	0.670 = 79.7°Be'	
10	188	0.675 = 78.1°Be'	0.675 = 78.1°Be'	0.694 = 72.4°Be'	1.0
15			0.684 = 75.3°Be'	0.712 = 67.2°Be'	
20	226	0.712 = 67.2°Be'	0.694 = 72.4°Be'	0.726 = 63.4°Be'	1.0
25			0.701 = 70.3°Be'	0.739 = 59.9°Be'	
30	264	0.739 = 59.9°Be'	0.709 = 68.0°Be'	0.748 = 57.6°Be'	1.2
35			0.715 = 66.4°Be'	0.757 = 55.4°Be'	
40	322	0.757 = 55.4°Be'	0.721 = 64.7°Be'	0.769 = 52.5°Be'	1.4
45	350		0.727 = 63.1°Be'	0.781 = 49.6°Be'	
50	380	0.781 = 49.6°Be'	0.733 = 61.5°Be'	0.793 = 46.9°Be'	1.5
55	400	0.793 = 47.0°Be'	0.742 = 59.2°Be'	0.806 = 44.0°Be'	
60	420	0.806 = 44.0°Be'	0.745 = 58.4°Be'	0.821 = 40.8°Be'	1.7
65	435	0.818 = 41.5°Be'	0.751 = 56.9°Be'	0.830 = 38.9°Be'	
70	550	0.830 = 38.9°Be'	0.757 = 55.4°Be'	0.850 = 34.9°Be'	1.8
75		0.840 = 37.0°Be'	0.763 = 53.9°Be'	0.855 = 34.0°Be'	
80		0.850 = 34.9°Be'	0.769 = 52.5°Be'	0.860 = 33.0°Be'	2.0
85		0.855 = 34.0°Be'	0.774 = 51.3°Be'	0.865 = 32.0°Be'	
90		0.860 = 33.0°Be'	0.779 = 50.1°Be'	0.870 = 31.1°Be'	3.0
95	4%	residue			

FRACTIONAL GRAVITY DISTILLATION ANALYSIS OF RANGER, TEX., CRUDE OIL.

Specific Gravity, 0.829; °Be', U. S. 38.9°; °Be' Tag 39.2°.
Summary: 57.4°Be' Gasoline = 30.0%; 41.1°Be'; Kerosene = 30.0%.

%	Temp. °F	Gravity of Fraction	Gravity of Total Over	Gravity of Stream
0	154	....	....	....
5	239	0.705 = 69.2°Be'	0.705 = 69.2°Be'	0.717 = 65.8°Be'
10	268	0.729 = 62.5°Be'	0.717 = 65.8°Be'	0.737 = 60.5°Be;
15	294	0.745 = 58.4°Be'	0.726 = 63.4°Be'	0.752 = 56.6°Be'
20	325	0.759 = 55.2°Be'	0.734 = 61.3°Be'	0.765 = 53.4°Be'
25	362	0.771 = 52.0°Be'	0.742 = 59.2°Be'	0.777 = 50.6°Be'
30	390	0.783 = 49.2°Be'	0.749 = 57.4°Be'	0.789 = 47.8°Be'
35	423	0.796 = 46.4°Be'	0.755 = 55.9°Be'	0.800 = 45.3°Be'
40	460	0.805 = 44.2°Be'	0.762 = 54.2°Be'	0.811 = 42.9°Be'
45	494	0.817 = 41.7°Be'	0.768 = 52.7°Be'	0.822 = 40.6°Be'
50	528	0.827 = 39.6°Be'	0.774 = 51.3°Be'	0.831 = 38.7°Be'
55	558	0.835 = 38.0°Be'	0.779 = 50.1°Be'	0.837 = 37.5°Be'
60	582	0.840 = 37.0°Be'	0.784 = 49.0°Be'	0.843 = 36.3°Be'
65	vacuum	0.851 = 34.8°Be'	0.789 = 47.8°Be'	0.858 = 33.4°Be'
70	"	0.865 = 32.1°Be'	0.795 = 46.4°Be'	0.870 = 31.1°Be'
75	"	0.875 = 30.2°Be'	0.800 = 45.3°Be'	0.880 = 29.3°Be'
80	"	0.885 = 28.4°Be'	0.805 = 44.2°Be'	0.890 = 27.4°Be'
85	"	0.895 = 26.6°Be'	0.810 = 43.2°Be'	0.897 = 26.2°Be'
90	"	0.900 = 25.7°Be'	0.815 = 42.1°Be'	0.923 = 21.8°Be'
95-100	residue	0.947 = 17.9°Be'	0.823 = 40.4°Be'	....

FRACTIONAL GRAVITY DISTILLATION ANALYSIS OF KENTUCKY CRUDE OIL.

Specific Gravity, 0.8415; °Be′ U. S. 36.7°; °Be′ Tag.
Summary: Gasoline = 27.5%; Kerosene = 22.5%.

%	Temp. °F	Gravity of Fraction	Gravity of Total Over	Gravity of Stream
0	186	....	....	....
5	259	0.720	0.720 = 65.0°Be′	0.728 = 63.8°Be′
10	285	0.737	0.728 = 63.8°Be′	0.742 = 59.2°Be′
15	310	0.748	0.735 = 61.0°Be′	0.755 = 55.9°Be′
20	342	0.762	0.741 = 59.4°Be′	0.769 = 52.5°Be′
25	387	0.776	0.748 = 57.6°Be′	0.784 = 48.9°Be′
30	422	0.793	0.756 = 55.6°Be′	0.796 = 46.2°Be′
35	458	0.800	0.762 = 54.2°Be′	0.805 = 44.2°Be′
40	502	0.811	0.768 = 52.7°Be′	0.816 = 41.9°Be′
45	542	0.822	0.774 = 51.3°Be′	0.827 = 39.6°Be′
50	582	0.833	0.780 = 49.9°Be′	0.839 = 37.1°Be′
55	600	0.845	0.786 = 48.5°Be′	0.849 = 35.1°Be′
60	600	0.853	0.791 = 47.3°Be′	0.857 = 33.6°Be′
65	600	0.862	0.797 = 46.0°Be′	0.871 = 30.9°Be′
70	600	0.880	0.803 = 44.7°Be′	0.887 = 28.0°Be′
75	600	0.895	0.809 = 43.4°Be′	0.919 = 22.4°Be′
80	residue	0.943	0.817 = 41.7°Be′	

FRACTIONAL GRAVITY DISTILLATION OF CRUDE OIL FROM EASTERN ALLEN COUNTY, MORAN, KAN.

Sp. Gr. = .8775
Be. Gr. = 29.7

Per Cent	Temp. °F	Gravity of Fraction	Gravity of Total Dist.	Gravity of Stream
0	...	...	....	....
5	342	.753	.753 = 56.4	.762 = 54.2
10	384	.771	.762 = 54.2	.778 = 50.3
15	422	.788	.770 = 52.2	.796 = 46.2
20	459	.804	.779 = 50.1	.810 = 43.2
25	490	.816	.786 = 48.5	.822 = 40.6
30	529	.829	.792 = 47.1	.835 = 37.9
35	562	.840	.800 = 45.3	.844 = 36.2
40	592	.849	.806 = 44.0	.853 = 34.3
45	600	.858	.812 = 42.7	.863 = 32.4
50	600	.868	.817 = 41.7	.874 = 30.4
55	600	.881	.823 = 40.4	.886 = 28.2
60	600	.891	.829 = 39.1	.896 = 26.4
65	600	.901	.834 = 38.1	.904 = 25.0
70	600	.907	.839 = 37.1	.912 = 23.6
75	620	.921	.845 = 35.9	.946 = 18.0
Residue	...	.972	.853 = 34.3	....

Chemical Constitution of Petroleum

Petroleum is composed of carbon and hydrogen in chemical combination known as hydrocarbons. In conjunction with the carbon and hydrogen there frequently is oxygen, nitrogen and sulphur in much smaller amounts.

In crude oils the amount of carbon varies from 80 to 89%, the hydrogen from 10 to 15%, oxygen from 0.0 to 5.0%, nitrogen from 0.0 to 1.8% and sulphur from .01 to 5.0%.

Typical ultimate analyses of petroleum products are as follows:

	Carbon	Hydrogen	Sulphur	Nitrogen	Oxygen
Pennsylvania Crude. . .	86.06%	13.88%	0.06%	0.00%	0.00%
Texas Crude.	85.05	12.30	1.75	0.70	0.00
California Crude.	84.00	12.70	0.75	1.70	1.20
Mexican Crude.	83.70	10.20	4.15	. . . .	. . . .
Oklahoma Crude.	85.70	13.11	0.40	0.30	. . . .
Kas. Crude (Towanda) .	84.15	13.00	1.90	0.45	. . . .
Kansas Residuum.	85.51	11.88	0.71	0.32	0.63
Healdton (Okla.) Crude.	85.00	12.90	0.76	. . . .	. . . .
Kansas Air Blown Residuum.	84.37	10.39	0.42	0.21	4.61
Byerlite Pitch.	87.61	9.97	0.55	0.29	1.58
Grahamite.	87.20	7.50	2.00	0.20	. . .
Trinidad Asphalt.	82.60	10.50	6.50	0.50	. . . .
Commercial Gasoline . .	84.27	15.73	0.00	0.00	0.00
Kerosene.	84.74	15.26	0.01	0.00	0.00
Lubricating Oil. . . . . (Paraffin)	85.13	14.87	0.01	. . . .	. . . .
Lubricating Oil. . . . . (Naphthene)	87.49	12.51	0.01	. . . .	. . . .
Benzol.	92.24	7.76	0.00	0.00	0.00

Paraffin (C_nH_{2n+2}) **hydrocarbons** largely compose the light or more volatile constituents of all petroleum. They are "saturated" hydrocarbons and have a very low ration of specific gravity to distilling temperature, are not acted upon by concentrated sulphuric acid or by fuming sulphuric acid (oleum), are not nitrated by nitric acid and are extremely resistant to all chemical reactions. The chief differences in petroleum are in the heavy constituents, the heavy hydrocarbons of the paraffin series being found chiefly in Pennsylvania and some Mid-Continent oils.

Naphthenes (C_nH_{2n}) ring or cyclic compounds are less common hydrocarbons in lighter portions of petroleum, but commonly found as heavy hydrocarbons of petroleum. They have a higher ratio of specific gravity to distilling temperature than the paraffin comopunds, are resistant to the action of sulphuric acid and some types may be distinguished by the "formolit" reaction. Oils containing light naphthenes are found in Russia and Louisiana. All heavy oils contain naphthenes.

C_nH_{2n} (NAPHTHENES) POLYMETHYLENE SERIES.

	Formula	Boiling Temperature	Gravity
Cyclopropane	C_3H_6	—35°C = —31°F	....
Cyclobutane	C_4H_8	+12°C = 54°F	.709 = 67.5°Be'
Cyclopentane	C_5H_{10}	49°C = 120°F	.769 = 52.1°Be'
Cyclohexane	C_6H_{12}	81°C = 178°F	.799 = 45.2°Be'
Cycloheptane	C_7H_{14}	117°C = 243°F	.089 = 43.1°Be'
Methyl Cyclopentane	C_6H_{12}	72°C = 162°F	.766 = 52.8°Be'
Dimethyl Cyclopentane	C_7H_{14}	91°C = 196°F	.778 = 50.0°Be'
Methyl Cyclohexane	C_7H_{14}	98°C = 208°F	.778 = 50.0°Be'
Dimethyl Cyclohexane	C_8H_{16}	118°C = 244°F	.781 = 49.3°Be'
Trimethyl Cylohexane	C_9H_{18}	198°C = 388°F	.787 = 47.9°Be'

Aromatic or Benzene Hydrocarbons (C_nH_{2n-6}) exist to some extent in certain California petroleums and have a very high ratio of specific gravity to distilling temperature. Gasoline made from the California petroleum is heavier than light gasoline with the same end point made from Mid-Continent petroleum. The aromatic compounds are acted upon by nitric acid forming nitro products. They are formed from paraffin and naphthene hydrocarbons by pyrogenic decomposition at temperatures above 1000°F. The production of aromatic compounds from petroleum has not been commercially satisfactory on account of incomplete conversion and difficulty of freeing from paraffin hydrocarbons.

Olefines or Ethylenes (C_nH_{2n}) are "unsaturated" hydrocarbons, rarely if ever existing naturally in crude oil but commonly resulting from its exposure to high temperatures. These compounds contain less hydrogen and more carbon than paraffin hydrocarbons and are capable of taking in more hydrogen. They are removed from aromatic compounds, paraffin compounds and naphthene compounds by the action of concentrated sulphuric acid in the usual process of refining gasoline. These hydrocarbons give gasoline, to a large extent, its disagreeable odor before refining. Their combination with sulphur gives a more intense odor. Each of these groups of hydrocarbons is supposed to exist in a complete series, represented by the general formula given. The paraffin or methane series of "saturated" hydrocarbons has been fairly well worked out and is given in the following table:

According to Hofer, the following olefines have been isolated from "North American" petroleum:

Ethylene	C_2H_4	Heptylene	C_7H_{14}	Dodecylene	$C_{12}H_{24}$
Propylene	C_3H_6	Octylene	C_8H_{16}	Decatrilene	$C_{18}H_{36}$
Butylene	C_4H_{10}	Nonylene	C_9H_{18}	Cetene	$C_{16}H_{32}$
Amylene	C_5H_{10}	Decylene	$C_{10}H_{20}$	Cerotene	$C_{27}H_{54}$
Hexylene	C_6H_{12}	Endecylene	$C_{11}H_{22}$	Melene	$C_{30}H_{60}$

If the residue contains much wax, the crude is known as paraffin base oil, but if napthenes or similar hydrocarbons predominate, it is an "asphalt" base oil. Practically the "asphalt" is determined by the solubility of the solid hydrocarbons in pentane and by the gravity and physical character of the residue.

Among the light hydrocarbons of petroleum, either existing naturally or pyrogenically produced, the relation of the specific gravity to the distilling temperature affords a simple and practical method of estimating the amount of olefin, paraffin and aromatic compounds. This relation is set forth in the curves on page 227.

The value of crude oil is not measured by its ultimate analysis or by its "base" so much as by the amount of volatile constituents which it contains. The amount of volatile constituents obtained from various crude oils is shown by the curves on page 121.

Paraffin Hydrocarbons in Petroleum

Name	Baume' Gravity	Sp. Gr. Liquid 15.5°C	Formula	Melting Point	Boiling Point	Molecular Weight
GASEOUS HYDROCARBONS (Natural Gas)						
Methane	...	.....	CH_4	—184.0°C	—165.0°C	16.03
Ethane	194	0.432	C_2H_6	—171.4	— 93.0	30.05
Propane	142	0.525	C_3H_8	—195.0	— 45.0	44.07
Butane	109	0.585	C_4H_{10}	—135.0	+ 1.0	58.08
"GASOLINE" HYDROCARBONS						
Pentane	92.2	0.630	C_5H_{12}	....	36.3	72.10
Hexane	78.9	0.670	C_6H_{14}	....	69.0	86.12
Heptane	70.9	0.697	C_7H_{16}	....	98.4	100.13
Octane	65.0	0.718	C_8H_{18}	....	125.5	114.15
Nonane	59.2	0.740	C_9H_{20}	— 51.0	150.0	128.16
Decane	56.7	0.750	$C_{10}H_{22}$	— 31.0	173.0	242.18
Undecane	54.2	0.760	$C_{11}H_{24}$	— 26.0	195.0	156.20
HEAVY LIQUID HYDROCARBONS (Kerosene)						
Duodecane	51.8	0.770	$C_{12}H_{26}$	— 12.0	214.0	170.22
Tridecane	46.8	0.792	$C_{13}H_{28}$	— 6.0	234.0	184.24
Tetradecane	45.0	0.800	$C_{14}H_{30}$	+ 5.0	252.0	198.25
Pentadecane	43.5	0.807	$C_{15}H_{32}$	10.0	270.0	212.26
Hexadecane	41.8	0.815	$C_{16}H_{34}$	28.0	287.0	226.27
Heptadecane	40.3	0.822	$C_{17}H_{36}$	22.0	295.0	240.28
Octadecane	38.6	0.830	$C_{18}H_{38}$	28.0	317.0	254.30
HEAVY SOLID HYDROCARBONS					(vacuo)	
Eicosane	37.2	0.837	$C_{20}H_{42}$	37.0	117.5	282.34
Tricosane	36.5	0.841	$C_{23}H_{48}$	48.0	138.0	325.38
Tetracosane	...	....	$C_{24}H_{50}$	51.0	145.5	338.39
Pentacosane	...	....	$C_{25}H_{52}$	54.0	152.5	352.41
Hexacosane	...	....	$C_{26}H_{54}$	56.0	160.0	366.43
Mericyl	...	....	$C_{27}H_{56}$	59.4	167.0	370.45
Octocosane	...	....	$C_{28}H_{58}$	60.0	173.5	384.47
Nonocosane	...	....	$C_{29}H_{60}$	63.0	179.0	398.48
Ceryl	...	....	$C_{30}H_{62}$	65.6	186.0	422.49
Pentriacontane	...	....	$C_{31}H_{64}$	68.0	193.5	436.52
Duotriacontane	...	....	$C_{32}H_{66}$	70.0	201.0	450.53
Tetratriacontane	...	....	$C_{34}H_{70}$	72.0	215.0	478.56
Pentatriacontane	35.4	0.846	$C_{35}H_{72}$	75.0	222.0	492.58

There is no natural petroleum composed exclusively of the paraffin series of hydrocarbons, even Pennsylvania and Garber, Oklahoma, crude oils having members of other series. The main body of the light petroleum is made up of paraffin hydrocarbons and the heavy residues are largely made up of napthenes.

Typical Refinery Practice

There is much variation in the practice of petroleum distillation in different refineries. This depends to a large extent upon the character of the crude oil used, the market to which the refiner sells and the ability of the refiner both as to knowledge and equipment.

The following outlines the progressive distillation and treatment of crude oil in a typical refinery:

1. **Crude Benzine** (Gasoline and Naphtha) includes all of the light distillate which vaporizes up to 410°F. In the ordinary Mid-Continent or Texas petroleum, 420°F indicates a gravity of the stream of distillate from the condenser in the receiving house of 46.5°Be' to 47.0°Be'. The gravity of the total distillate at this point varies with different types of crude. In some crudes this will be as high as 64.0° gravity, in others as low as 50.0°. For example, referring to pages 122 to 127, Burkburnett crude boiling at 410°F has a gravity of 59.7° of the total benzine and a stream gravity of 46.5°Be'; Bixby, Okla., crude benzine at 410°F has a gravity of 58.0°Be' and a stream gravity of 46.7°Be'; Cushing, Okla., crude benzine at 410°F has a gravity of 59.7°Be' and a stream gravity of 47.0°Be'; Billings, Okla., crude has a gravity of 60°Be' at 410°F and a stream gravity of 46.5°Be'; Ranger, Texas, crude oil has a benzine gravity of 410°F of 56.6°Be' and a stream gravity of 46.7°Be'. The gravity of crude benzine depends upon the initial boiling point of the crude, the relative proportion of the different paraffin constituents and the chemical series of hydrocarbons to which the crude belongs (see page 227.

The crude benzine is run off with direct fire under the still, though after a temperature of 212°F is reached some steam may be put in. The steam decidedly sweetens the product and brings over the benzine at a lower temperature. In the use of steam the distillation must be entirely governed by the gravity of the stream in the receiving house and not by temperatures. In cases where the crude is of good quality it is not necessary to treat the benzine as it may merely be redistilled with steam. In many cases the refiner puts a good dephlegmator over on his crude still and makes a marketable gasoline without either treating it with acid or redistilling it with steam.

When a high sulphur or low grade petroleum is treated the distillate is put into an agitator with sulphuric acid, the mixing being perfected by blowing air through the acid in the bottom of the agitator, thus contacting it with all portions of the benzine. The acid is drained out and the benzine washed with water. Caustic soda or "doctor" solution is added to neutralize the acid and the benzine is thoroughly washed to remove the last traces of caustic or sulfonates. The benzine is redistilled in a steam still to give a gasoline of 58 to 60 gravity and about 430 end point, this depending largely upon the perfection of the dephlegmator. The last portion of the distillate is naphtha if a gasoline of high Baume' is desired. High gravity crudes are blended with low gravity crudes to eliminate the naphtha fraction.

2. **Kerosene or Water White Distillate** comes over just after the crude benzine, with the gravity of the stream in the receiving house at about 37.0 and a vapor temperature of 572°F. This will give a kerosene ordinarily of a 41 gravity, but this again varies greatly with the type of the oil. For example, a certain Wyoming crude

oil under these conditions gives a 31.0° kerosene, whereas Cushing, Okla., and Bixby, Okla., crude oils give a 41.0° to 42.0° gravity kerosene. Pine Island cracked oil gives a 33-34°Be' kerosene. In distilling kerosene from the crude it is desirable to stop before there is discoloration from decomposition or cracking. Cracking may be very largely prevented and kerosene very greatly sweetened by using open steam throughout the entire distillation. The water white distillate or first run kerosene is now treated with acid and caustic in the agitator and exposed to heat, air and light in a shallow tank or bleacher in which all water is settled out. If the kerosene after treatment is not water white or has too high an end point it is redistilled with superheated open steam. The residue in the still may be mixed with the solar oil.

3. **Solar Oil or Distillate Oil** is taken out immediately following the kerosene, being a crude distillate not subjected to refining, and sold for use in explosion engines and as a high grade special fuel oil. The making of this product depends upon the market. It may be about a 36 gravity product or it may be combined with gas oil or straw oil.

4. **Gas Oil** is taken immediately following the distillate oil or kerosene and its distillation is continued until the residuum in the still has a gravity of 23 to 26°Be'. It is distinctly a destructive distillation and the yield depends largely upon the method and rate of firing. Gas oil is used in making gas and contains a considerable amount of olefins and cracked products, and is not refined except for special purposes. If a gas oil fraction low in olefins (straw oil) is desired it is necessary to distill using open steam and direct fire. Straight firing gives a more fluid residue on account of cracking.

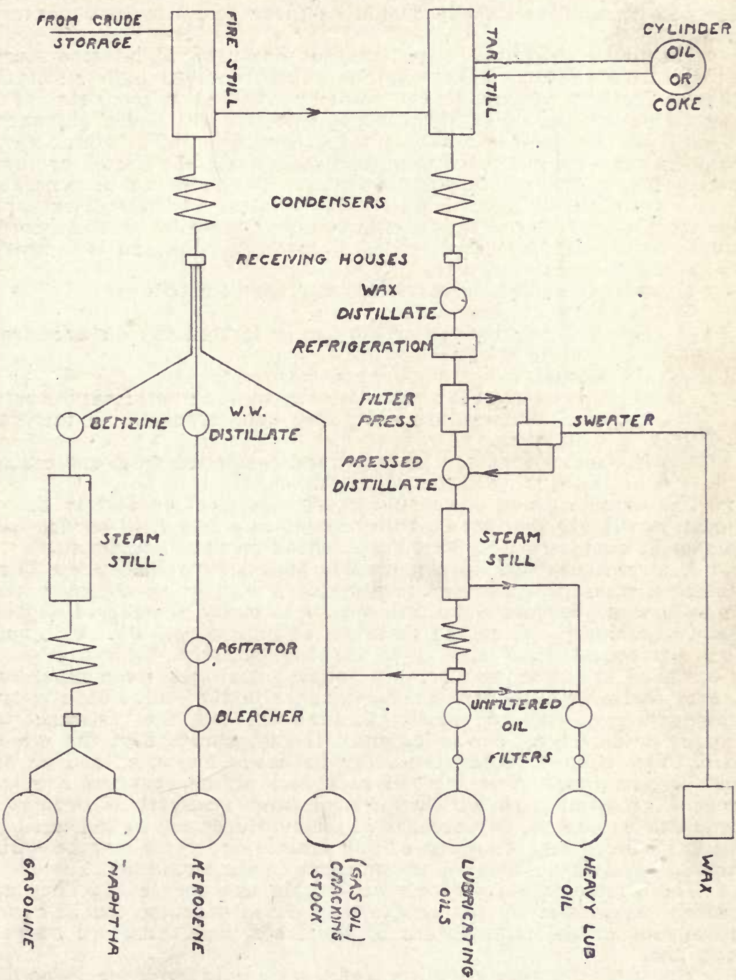
5. **Residuum or tar** is sold as **fuel oil** or it may be used to produce lubricating oil. In the latter case it may be put into tar stills and run down to **coke**. The distillate is treated, refrigerated and the **paraffin** is removed by the filter press. If the crude oil contains no wax then the lubricants may be made by vacuum, steam or gas distillation, and the distillate is only filtered through fullers earth for use.

6. The filtrate from the paraffin wax or **pressed distillate** may be redistilled with steam to produce lubricating oil of the desired gravity, viscosity and cold test. The heaviest residual oil is the steam cylinder stock. Steam cylinder stock is the residue from the steam distillation of light colored crude oils, such as Cabin Creek, W. Va., and Ranger, Tex. The most careful refining is required for the automobile cylinder oil in order to obtain low fixed carbon to prevent separation of free carbon in the cylinder.

7. When **asphalt** is desired the residue from the gasoline and kerosene may be distilled by blowing superheated steam through it until the desired consistency is reached. Asphalt base oils or cracked paraffin base oils are necessary to make first class asphalt. An outline of the methods used for producing asphalts and road oils is given on page 191. Frequently, particularly for road oils, the stock remaining after cracking heavy gas oil is run down to a semi-solid or solid consistency. This gives a specially valuable road oil on account of its high asphalt content, good hardening or drying properties, low viscosity and excellent penetration.

For refining by cracking see pages 209-232.

For illustration of a refinery operation see flow sheet on page 133.



TYPICAL FLOW SHEET OF COMPLETE REFINERY

PYROMETRY APPLIED TO PETROLEUM DISTILLATION.

C. Benton Kennedye, Pyrometric Engineer.

Refinery operation is largely dependent upon temperature. Considerable thought and study should be given to its correct measurement.

The most widely used instruments for measuring high temperatures are the Thermo-Electric Pyrometers. The improved high resistance Thermo-Electric Pyrometer for refinery application consists of a thermo-couple inserted eighteen inches into the still and a galvanometer. The thermo-couple is formed of two wires of different alloys welded at one end and when this junction is heated by the oil or vapor it generates a small current of electricity. The current thus generated operates a millivolt meter. As the temperature in the still or vapor line increases or decreases, the millivoltage generated by the thermo-couple is increased or decreased in direct proportion and is indicated on the instrument in degrees.

The advantages of Pyrometers over Thermometers are:

A. Ease of observation.
B. Adaptability—recorders can be located any distance from stills or cracking plant.
C. Robustness of apparatus, ease of repair.
D. Availability for automatically making permanent records of temperature extending over considerable intervals of time.
E. Indications can be noted and controlled from one central point by means of switch.

The pyrometers of one manufacturer are most popular in the oil industry owing to the fact that they maintain a free field service with competent engineers who periodically check up their equipment.

A recent practical development is known as a Resistance Thermometer, which will measure temperatures with great accuracy from three hundred degrees Fahr. below zero to eighteen hundred degrees Fahr. above zero. A coil of platinum or pure nickel wire with suitable protecting tube similar to diagram on the following page, is installed in the vapor line just before entering the condenser and another bulb installed in a similar manner in the still. With a constant source of current passing through the coil, the resistance increases or decreases, depending upon the temperature of the coil of wire. This change in resistance can be easily measured and an adjustable resistance balancing the resistance of the bulb and a galvanometer or deflector shows when the balance is reached. With suitable switching apparatus, any number of temperatures can be indicated by the one instrument. Gasoline of any desired end point may be easily secured by maintaining that temperature in the vapor line.

These instruments are accurate within one degree F. They are entirely unaffected by the length of leads connecting the bulb and instrument or the temperature of the leads, and there are no cold junctions.

The rapidly growing tendency of the trade to purchase oil on distillation tests as well as on gravity, makes it desirable for the refiner to make runs on oil and vapor temperatures rather than on tailhouse gravities alone.

In the cracking processes, the temperatures of the oil being treated must be maintained within very narrow ranges and for this purpose accurate pyrometers are absolutely necessary.

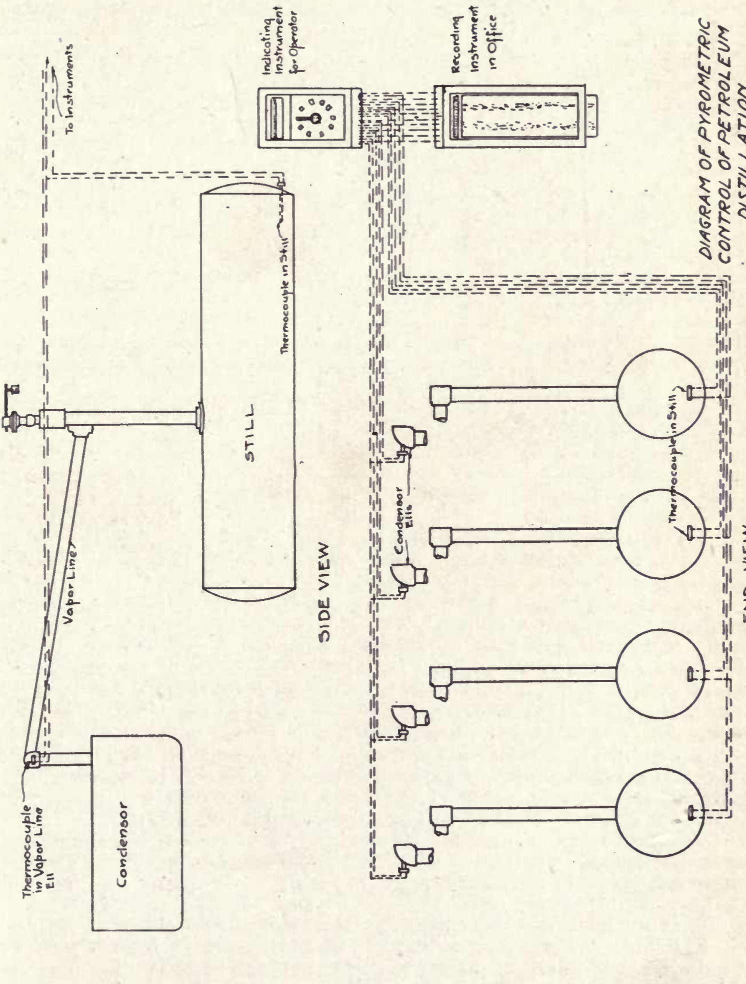


DIAGRAM OF PYROMETRIC CONTROL OF PETROLEUM DISTILLATION

Cause of Color and Odor in Refined Petroleum

Most distillates from petroleum contain sufficient foreign matter to give an undesirable odor or a yellowish to red color.

The odor in natural distillates is due ordinarily to sulphur compounds, characteristic of which is hydrogen sulphide. Gasoline or light hydrocarbons produced by cracking have a more or less offensive odor even though sulphur is not present in appreciable quantity. In a general way, color is present in proportion as the odor is more disagreeable. The color of petroleum products is thought to be largely due to nitrogen compounds. Light hydrocarbons produced by cracking have a higher color the larger the amount of nitrogen in the heavy oils cracked, as a general rule. Cracked products from paraffin hydrocarbons such as those from Oklahoma give a yellowish color in the distillate above 300°F, though they may be colorless below 300°F. California and Mexico cracked gasoline give a red color, which is not noticeable immediately upon distilling, but becomes more intense as the gasoline is exposed to the action of the acid. This coloring matter on standing largely settles out or is oxidized so that the redistilled gasoline may be free from color.

Kerosene, the first refined product of petroleum marketed on a large scale, was a yellow or dark red liquid. It was first produced from coal, and it was found in 1857 that "coal oil" could be deodorized and decolorized by treatment with sulphuric acid, and this is the process that is in general use at the present time. 66°Be' sulphuric acid is ordinarily used, as it reacts upon the unsaturated compounds, the sulphur compounds and the nitrogenous compounds in the oil by forming substances which dissolve largely in the sulphuric acid. The shrinkage of the oil treated may vary from almost nothing up to 10%, depending upon the character of the oil being refined. In ordinary natural distillates, one pound of acid per barrel is commonly sufficient, but with cracked oil as much as 10 pounds of acid are often required. Even then the treatment is often not sufficiently severe, and oleum or Nordhausen sulphuric acid, which contains an excess of sulphur trioxide, is necessary. This is the case with California and Towanda oil. After treatment with sulphuric acid, thorough washing and neutralization with caustic soda is always necessary. Other substances used for neutralizing the acid and acid sulfonates are soda ash, lime, silicate of soda and sodium plumbite.

Other chemicals may be quite successfully used in removing the odor of cracked gasoline, among these being sodium plumbite, copper oxide, manganese dioxide, potassium permanganate, sodium chromate, aluminum chloride and chlorine.

Dry hydrochloric acid gas (hydrogen chloride, HCl) is often highly effective in treating gasoline to remove the color.

The "bloom" or fluorescence of mineral oils is supposed to be due to the presence of asphalt-like or pitchy material in colloidal condition. This is overcome by the use of mono-nitro-napthalene ($C_{10}H_7NO_2$) in small amounts. The physical means of removing color and to some degree odor is by filtration through fuller's earth. This is common practice with lubricating oils.

THE EFFECT OF SULPHUR IN THE REFINING OF PETROLEUM.

Sulphur is present in all petroleums. (See page 128.) It exists in the elementary form dissolved in the oil or in a chemically combined form as the sulphides of hydrocarbon groups. When it is found in very large amount there is usually a considerable amount of free or elementary sulphur. The alkyl or organic sulphides give to petroleum its characteristic odor. High sulphur petroleum residues such as Trinidad asphalt have characteristic odors of complex sulphur compounds. Lighter gasoline-bearing oils such as the Ohio and the Butler County, Kansas, oils have characteristic odors varying from that of pure hydrogen sulphide to that of the complex organic sulphides such as exist in natural asphalt. A typical distillation of a heavy crude oil by means of steam shows the following results as to distribution of sulphur:

Fraction	Specific Gravity	Sulphur
0-10%	0.868 = 31.3° Be'	0.39%
10-20%	0.877 = 29.6° Be'	0.35%
20-30%	0.895 = 26.4° Be'	0.43%
30-40%	0.909 = 24.0° Be'	0.53%
40-50%	0.920 = 22.1° Be'	0.70%
50-60%	0.920 = 22.1° Be'	0.70%
60-70%	0.917 = 22.7° Be'	0.70%
70-80%	0.917 = 22.7° Be'	0.56%

This condition does not hold in the case of all oils, particularly the oils from Butler County, Kansas, which are characterized by the giving off of the rather large amount of hydrogen sulphide in the early part of the distillation.

Sulphur causes trouble in the refinery in the purification of the distilled products and in the corrosive effect of the oxidized sulphur, particularly on the condenser pipes.

At the time that the first sulphur oils were discovered in Ohio (.8% sulphur) they brought a price of only 14c per barrel, while at the same time the Pennsylvania oils (0.04% sulphur) sold at $2.25 per barrel. According to Frash it is a comparatively simple matter to free petroleum of elementary sulphur or hydrogen sulphide, but the sulphur compounds, which are the cause of the offensive odor, are very stable and cannot easily be broken up into hydrogen sulphide or other sulphur compounds which can be eliminated. It was because of the presence of these stable compounds that high sulphur oils for many years resisted all efforts to refine it. These complex sulphur compounds have the peculiarity of dissolving a number of metallic oxides. When the oil is saturated with all of the oxide which can be carried, the disagreeable odor disappears. It tends to reappear, however, when an attempt is made to separate the metal from the oil unless more oxide is used than is necessary to precipitate all of the sulphur, in which case complete desulphurization of the petroleum is effected. The Frash method, which has been successfully used for nearly thirty years by the Standard Oil Co., consists in the use of 1,000 pounds of the copper oxide to 2,000 barrels of distillate. The copper is recovered by filtering and roasting.

In distillation the chemical action of the sulphur may result from the direct combination of the sulphur with the iron or by the oxidation of the sulphur with formation of sulphonic acids, which pit the iron, particularly of the condensers.

The acid withdrawn from the agitator after treatment of oils to remove color and odor is a black viscous material. Much of this sulphuric acid may be recovered by digestion to decompose the complex organic compounds and oxidation usually with air to burn out the carbonaceous material and preserve as much of the sulphur as SO_3 instead of driving it off as SO_2.

Gasoline

Gasoline as now found on the market is a mixture of petroleum hydrocarbons, having an initial boiling point of from 80°F to 160°F, an end boiling point of from 368°F to 450°F, gravity of 56° to 61°Be'., a sweet to oily aroma and a water white color.

The particular hydrocarbons composing it belong to a general group known as the paraffins. Other types of hydrocarbons are occasionally present in a very small amount. These are known as olefins and as benzenes. The olefins are removed by a thorough treatment with sulphuric acid, but the benzenes remain if originally present.

Ordinary gasoline made by the natural distillation of Mid Continent crude oil will contain several or all of the following substances:

Name	Boiling point	Specific gravity	Baume'Gravity
1. Pentane	97°F	0.630	92.2°
2. Hexane	156°F	0.670	78.9°
3. Heptane	209°F	0.697	70.9°
4. Octane	258°F	0.718	65.0°
5. Nonane	302°F	0.740	59.2°
6. Decane	343°F	0.750	56.7°
7. Undecane	383°F	0.760	54.2°

The following aromatic compounds are produced by pyrogenic decomposition of heavy hydrocarbons and rarely exist naturally in crude petroleum.

They are produced by the cracking of oil in the vapor phase and at high temperatures and occur in artificial or what has been called "synthetic" gasoline.

Name	Boiling point	Specific gravity	Baume' gravity
Benzol (C_6H_6)	176°F	0.880	29.1°
Toluol ($C_6H_5CH_3$)	232°F	0.872	30.6°
Xylene ($C_6H_4(CH_3)_2$	291°F	0.882	28.7°

A small amount of these hydrocarbons in commercial gasoline very materially affects the gravity.

The character of gasoline is governed almost entirely by its use for automobiles. It is also used to some extent for stove gasoline and for cleaning purposes, in which case it has a lower end point and a higher Baume' gravity.

Gasoline is commonly blended and originates from one or more of the following sources:

1. The natural product distilled from crude oil. This constitutes about 73% of the total on the market (1917-18).

2. As a condensate from natural gas and known as casinghead gasoline. This constitutes about 7% of all gasoline and is always incorporated with heavy hydrocarbons such as naphtha or with gasoline distilled from a heavy crude or with gasoline made by cracking.

3. The light hydrocarbons produced by the pyrogenic decomposition of heavy petroleum residua. This constitutes about 20% of the market gasoline and tends to have a considerable amount of aromatic compounds.

The most desirable properties of gasoline are low end point and a low initial boiling point, the usual refiner's practice being to call everything gasoline which distills up to a temperature of 410°F. This practice in a light crude gives a 58°Be' product, although in the unusually light crudes a 61° product is obtained and in heavy crudes a gravity as low as 54° may be obtained. This heavy gasoline must be blended to make it satisfactory for ordinary market purposes.

Page 227 shows the relation of the boiling point to the specific gravity of ordinary market gasoline. Gasolines containing considerable olefins, aromatics or naphthenes have a higher relation of specific gravity to boiling point than do gasolines composed entirely of paraffin hydrocarbons.

Page 148 shows the relation of the boiling temperature to the percentage distilled over in ordinary commercial gasoline. These curves show that the gravity alone is not a good measure of the quality of a gasoline. For example, a 58° gravity gasoline in one case has an initial boiling point of less than 100°F and in another case has an initial boiling point of 190°F. A naphtha blended with casinghead will have a very high gravity test, but will show a very low initial boiling point and a very high end point.

The method of determining the quality of gasoline is described on page 307.

U. S. GASOLINE SPECIFICATIONS.

Specifications for standard tests of aviation gasoline, motor gasoline and fuel oil as announced in October, 1918, by the Inter-departmental Committee on Stardardization of Specifications for Petroleum Products.

AVIATION GASOLINE.

The specifications for aviation gasoline (export, fighting and domestic) as adopted are as follows:

1. Color.

The color shall be water white.

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 complete is shaken thoroughly 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 on gasoline:

(a) Preparation of Reagents: Sodium plumbite 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 flower of sulphur.

(b) Making a 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 may be conveniently used). After shaking for about fifteen seconds a small pinch of flowers of sulphur should be added and the tube again shaken for 15 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.

The gasoline, when subjected to the corrosion test, shall show no gray or black corrosion and no weighable amount of gum.

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 ⅜ 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 gasoline that shows 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% of the sample has been recovered in the graduated receiver the thermometer shall not read more than 65°C (149°F) or less than 95°C (203°F).

When 50% has been recovered in the receiver the thermometer shall not read more than 95°C (203°F).

When 90% has been recovered in the receiver the thermometer shall not read more than 150°C (302°F).

When 95% 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% must be recovered in the receiver from the distillation.

The distillation loss shall not exceed 2% when the residue in the flask is cooled and added to the distillate in the receiver.

Volatility and Distillation Range—Fighting Grade.

When 5% of the samples 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% has been recovered in the receiver the thermometer shall not read more than 95°C (203°F).

When 90% has been recovered in the receiver the thermometer shall not read more than 113°C (235°F).

When 96% has been recovered in the receiver the thermometer shall not read more than 113°C (235°F) and the end point shall not exceed this temperature by more than 15°C (27°F).

At least 96% must be recovered in the receiver from the distillation.

The distillation loss shall not exceed 2% when the residue in the flask is cooled and added to the distillate in the receiver.

The United States War Department requires fighting grade to be colored red after inspection and acceptance.

Volatility and Distillation Range—Domestic Range.

When 5% 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% has been recovered in the receiver the thermometer shall not read more than 105°C (221°F).

When 90% has been recovered in the receiver the thermometer shall not read more than 155°C (311°F).

When 96% has been recovered in the receiver the thermometer shall not read more than 175°C (347°F).

At least 96% must be recovered in the receiver from the distillation.

The distillation loss shall not exceed 2% when the residue in the flask is cooled and added to the distillate in the receiver.

MOTOR GASOLINE.

The specifications for motor gasoline are:

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"—paragraph 1824 (k) as issued by the Interstate Commerce Commission.

Inspection and Tests.

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.

Test—100 cc will be taken as a test sample. The apparatus and method of conducting the distillation test shall be that described in Bureau of Mines Technical Paper No. 166, Motor Gasoline:

(a) Boiling point must not be higher than 60°C (140°F).

(b) 20% of the sample must distill below 105°C (275°F).

(c) 45% must distill below 135°C (275°F).

(d) 90% must distill below 180°C (356°F).

(e) The end of dry point of distillation must not be higher than 220°C (428°F).

(f) Not less than 95% of the liquid will be recovered from the distillation.

MINERAL SPIRITS—1918.

1. General Specifications—General specifications for paint and painting materials, issued by the Railroad Administration, in effect at date of opening of bids, shall form part of these specifications.

2. The mineral spirits shall be a hydrocarbon distillate, water white, neutral, clear and free from suspended matter and water. It shall have no darkening effect when mixed with basic carbonate white lead.

3. Properties and Tests—When 100 cc are submitted to continuous distillation in an Engler flask with a condenser 22 inches long and at an angle of 30 degrees with the horizontal and cooled with water, the first drop shall issue from the condenser at a temperature of not less than 265°F and 97 per cent shall distill below 470°F.

4. When 10 cc of the distillate are placed in a glass crystallizing dish 2½ inches in diameter, in a steam bath maintained at a temperature of 212°F and evaporated not more than 0.2 per cent of residue shall remain after 2½ hours.

5. The flash point shall be not less than 85°F when determined by the closed Elliott tester method, the test being made in the usual official manner.

Summary of Gasoline Inspection Laws

(By Dr. G. W. Gray.)

Arkansas.—Gravity shall be taken at 60°F, and marked on tank, can, cask, barrel or other vessel containing said gasoline.

California.—No law. Los Angeles has adopted motor transport specification.

Colorado.—Gravity shall be taken, but no products shall be offered for sale which contain more than 5 per cent of solid matter.

Georgia.—Gravity shall be taken and no product known as gasoline, benzine or naphtha shall be offered for sale unless casks, barrels or packages containing such products are labeled with figures denoting gravity and the words "gasoline" "Benzine" or "naphtha", in large red letters.

Idaho.—The standard adopted by the Bureau of Mines shall be the standard for Idaho.

Indiana—Gravity shall not be less than 56°Be., and the correction for temperature shall be 1°Be. or 10°F.

Illinois.—There is no law except that gasoline must be branded "Condemned for illuminating purposes".

Iowa.—Gravity shall be between 80°Be. and 70° Be. Boiling point shall not be below 150°F. and not above 210°F. All other products shall be branded "Substitute for gasoline" and these substitutes shall be sold under label, which label shall be printed in large, legible type, etc., defined as follows:

(a) Per cent of boiling below 135°F.
(b) Per cent of boiling between 135°F and 210°F.
(c) Per cent of boiling between 201°F. and 302°F.
(d) Per cent boiling above 302°F.

Bills of lading and the labels of such substitutes shall call attention to the danger of such low boiling point.

Kansas—Gravity must not be heavier than 58°Be., initial boiling point shall not exceed 90°F., end boiling point not above 410°F. All products sold not meeting this test shall be known and sold as "Gasoline under test."

Michigan—No law. Grand Rapids, 20 per cent shall distill over at or below 320°F. Fifty per cent shall distill over at or below 300°F. End point not above 450°F. If product does not meet this test, it shall be known as a mixed gasoline-kerosene; Detroit, same law as Grand Rapids, but method of distillation is entirely different. Gasoline passing Grand Rapids specification by their method of distillation, might be rejected by Detroit.

Minnesota—Gravity shall be taken and containers shall be marked "Unsafe for illuminating purposes."

Missouri.—Gravity must not be less than 58°Be.

Montana.—Any gasoline used for heating, burning or power purposes in any automobile, engine or in any machinery which falls below 63°Be., shall be deemed below standard, but nothing in this act shall prevent the sale of a heavier product, when product is sold under its proper name and its specific gravity given.

Nebraska.—Gravity shall be taken and marked upon container.

New Mexico.—No gasoline for illuminating purposes can be sold which is less than 63° gravity, and it shall be conclusively presumed that all sales are for illuminating purposes, unless containers are marked "Not for illuminating purposes."

North Carolina.—The initial boiling point not higher than 158°F; 16 per cent off at 230°F; residue not more than 35 per cent at 302°F.; end point not higher than 437°F.

North Dakota.—Gravity shall be taken and all gasoline sold for household purposes shall show not less than 3 per cent off at 158°F. and not more than 6 per cent residue at 248°F.

Ohio.—Shall be branded according to its commercial name and with the word "Dangerous".

Oklahoma.—Gravity shall be taken. If gravity is greater than 74°F. it shall be deemed unsafe and sale is prohibited for use in vapor stoves or other domestic uses.

Oregon.—Gravity shall be not less than 56°Be.

South Dakota.—Gas machine gasoline, light gasoline, power gasoline, when made from Mid-continent crude shall be as follows: Gas machine gasoline, not less than 64°Be; residue not more than 4 per cent at 300°F; all off below 350°F. Light gasoline, gravity not less than 60°Be.; residue not over 10 per cent above 300°F. and not over 25 per cent above 350°F. Power gasoline gravity not less than 57° Be; residue not more than 25 per cent at 300°F and not more than 3 per cent at 400°F. Below is a table giving gravities depending upon what crude the products are made from:

	Gravity in degrees Be'	
	Mid-Continent Field.	Penn. Field
Gasoline for use in automobile engines and in other gasoline engines should have a gravity of not less than	57	62
Gasoline for household use in stoves, flatirons, gasoline lamps, dry cleaning, etc., should have a gravity of not less than	62	65
Gasoline for use in gas machines for the production of gasoline gas, should have a gravity of not less than	70	80
Naphtha for use in engines and for other purposes should have a gravity of not less than	55	

In describing kerosene or gasoline by its gravity it is necessary to indicate the State or Territory producing the crude petroleum from which the finished product was distilled, because crude petroleum differs in different regions and its products differ likewise. In stating the crude petroleum fields above, the Western is taken to include Texas, Oklahoma, Kansas, Wyoming, Illinois and other oil-producing States in the west-central portion of the United States. The Pennsylvania field includes Pennsylvania, West Virginia and neighboring States.

South Carolina.—Flash point not more than 32°F; distillation test not less than 25 per cent off at 230°F; not more than 16 per cent of residue at 302°F; dry point not more than 392°F. Any product not meeting this specification must be sold under the name of "naphtha."

Tennessee.—The container shall be branded "Gravity not less than °Be.; unsafe for illuminating purposes; for power purposes only."

Utah.—Standards adopted by the Bureau of Mines shall be standard for this State. No product sold shall contain more than 1 per cent of solid matter.

Washington.—Shall be inspected for its specific gravity and all containers shall be branded with the specific gravity.

Wisconsin.—Containers shall have gravity stamped on same.

Wyoming.—Gasoline for household use. Distillation test: Not less than 10 per cent off at 150°F; not less than 50 per cent off at 212°F; not less than 98 per cent off at 325°F. Gasoline for power purposes: Not less than 10 per cent off at 170°F; not less than 50 per cent off at 240°F; not less than 94 per cent off at 350°F.

Benzinum Purificatum (U. S. Pharmacopoeia)

Purified Petroleum Benzin.
Benzin. Purif.—*Petroleum Ether.*

A purified distillate from American petroleum consisting of hydrocarbons, chiefly of the marsh-gas series. Preserve it carefully in well-closed containers, in a cool place, remote from fire.

Purified Petroleum Benzin is a clear, colorless, non-fluorescent, volatile liquid, of an ethereal, or faint, petroleum-like odor, and having a neutral reaction. It is highly inflammable and its vapor, when mixed with air and ignited, explodes violently.

It is practically insoluble in water, freely soluble in alcohol, and miscible with ether, chloroform, benzene, volatile oils and fixed oils. with the exception of castor oil.

Specific gravity: 0.638 to 0.660 at 25°C.

It distils completely between 40°C and 80°C (104°F to 176°F).

Evaporate 10 mils of Purified Petroleum Benzin from a piece of clean filter paper: no greasy stain remains, and the odor is not disagreeable or notably sulphuretted. Not more than 0.0015 Gm. of residue remains on evaporating 50 mils of Purified Petroleum Benzin at a temperature not exceeding 40°C.

Boil 10 mils of Purified Petroleum Benzin for a few minutes with one-fourth its volume of an alcoholic solution of ammonia (1 in 10) and a few drops of silver nitrate T. S.; the liquid does not turn brown (pyrogenous products and sulphur compounds).

Add 5 drops of Purified Petroleum Benzin to a mixture of 40 drops of sulphuric acid and 10 drops of nitric acid in a test tube, warm the liquid for about ten minutes, set it aside for half an hour, and dilute it in a shallow dish with water; no odor of nitrobenzene is evolved.

NAVY SPECIFICATIONS FOR GASOLINE.

Regular Gasoline.

The navy specifications for gasoline are as follows:

Initial below	140
20% off at	200
45% off at	275
90% off at	356
End point below	428

Aero Gasoline.

The aero gasoline (for fighting planes) shall be:
(a) Not more than 5% shall distill below 60°C (140°F).
(b) Not less than 5% shall distill below 70°C (167°F).
(c) At least 50% shall distill below 95°C (202°F).
(d) At least 90% shall distill below 113°C (235°F).
(e) At least 96% shall distill below 125°C (257°F).

Export Gasoline.

Export gasoline (for use in bombing planes):
(a) Not more than 5% shall distill below 60°C (140°F).
(b) Not less than 5% shall distill below 75°C (167°F).
(c) At least 50% shall distill below 100°C (212°F).
(d) At least 90% shall distill below 125°C (257°F).
(e) At least 96% shall disitll below 150°C (302°F).

Domestic Gasoline.

Domestic gasoline (for use in training planes):
(a) Not more than 5% shall distill below 60°C (140°F).
(b) Not less than 5% shall distill below 75°C (167°F).
(c) At least 50% shall distill below 105°C (223°F).
(d) At least 90% shall distill below 155°C (311°F).
(e) At least 96% shall distill below 175°C (347°F).

Comparison of Gasoline and Benzol as Motor Fuel.

Heat of combustion:	Benzol.	Gasoline.
B. T. U. per gallon	132330	129060
B. T. U. per pound	18054	20750
Freezing temperature	41°F	50°F below Zero
Boiling temperature	170-180	130-400°F
Rate of evaporation	Slower	Faster
Mileage per gallon (comparative)	110.	100.
Ignition temperature	Higher	Low
Preignition from carbon	Less trouble	More trouble
Carbon formed	More	Less
Relative volume of air required per gallon	1.04	1.00
Relative volume of explosive gases produced per gallon	.92	1.00
Temperature of explosion	Higher	Lower
Rapidity of explosive force	Less sudden	More sudden

Benzol is most satisfactory if used mixed with gasoline or alcohol, preferably the latter.

Possible Savings in Gasoline

The Bureau of Mines estimates that the following savings can be effected daily:

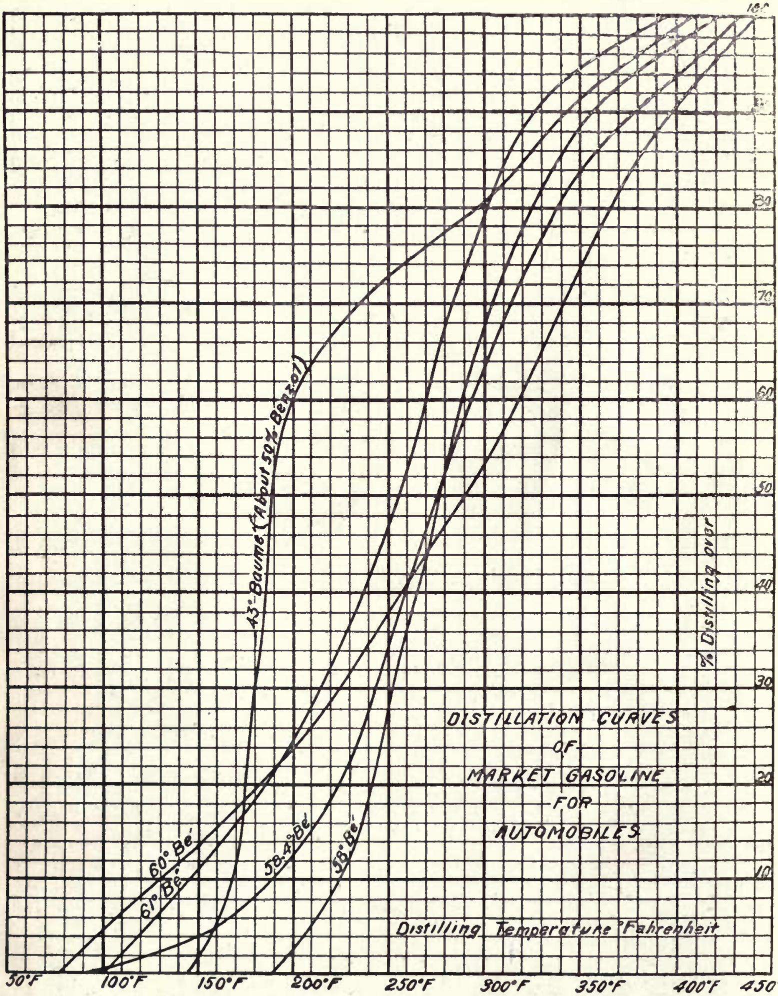
	Gallons
Tank wagon losses	7,200
Leaky carburetors, average 1/17th of a pint per car	31,400
Poorly adjusted carburetors, ½ pint per car	240,000
Motors running idle, ¼ pint per car	150,000
Wasted in garages, 10 pints per day	67,000
Saved by using kerosene in garages	108,000
Needless use of passenger cars, 1¾ pints per car	897,400

This makes a total of 1,500,000 gallons a day, or 561,000,000 gallons a year, whereas our war needs are 350,000,000 gallons a year, or less than two-thirds of what may be considered as wasted at the present time.

SUGGESTIONS TO GASOLINE USERS.

The following important suggestions for avoiding waste will not only save gasoline, but users of motor vehicles will be benefitted personally and individually through more efficient and more economical operation of cars:

1. Store gasoline in underground steel tanks. Use wheeled steel tanks with measuring pump and hose. They prevent loss by fire, evaporation and spilling.
2. Don't spill or expose gasoline to air—it evaporates rapidly and is dangerous.
3. Don't use gasoline for cleaning and washing—use kerosene or other materials to cut grease.
4. Stop all gasoline leakages. Form habit of shutting off gas at tank or feed pipe.
5. Adjust brake bands so they do not drag. See that all bearings run freely.
6. Don't let engine run when car is standing. It is good for starter battery to be used frequently.
7. Have carburetors adjusted at service stations of carburetor or automobile companies—they will make adjustments without charge.
8. Keep needle valve clean and adjust carburetor (while engine is hot) to use as lean mixture as possible. A rich mixture fouls the engine and is wasteful.
9. Pre-heat air entering carburetor and keep radiator covered in cold weather—this will insure better vaporization.
10. See that spark is timed correctly with engine and drive with spark full advanced—a late spark increases gas consumption.
11. Have a hot spark, keep plugs clean and spark points properly adjusted.
12. Avoid high speed. The average car is most economical at 15 to 25 miles an hour.
13. Don't accelerate and stop quickly—it wastes gas and wears out tires. Stop engine and coast long hills.
14. Cut down aimless and needless use of cars. Do a number of errands in one trip.
15. Know your mileage per gallon. Fill tank full and divide odometer mileage by gallons consumed.


DISTILLATION CURVES
OF
MARKET GASOLINE
FOR
AUTOMOBILES
43° Baume (About 50% Benzol)
60° Bé
61° Bé
58.4° Bé
58° Bé
% Distilling over
Distilling Temperature °Fahrenheit
50°F
100°F
150°F
200°F
250°F
300°F
350°F
400°F
450°F
10
20
30
40
50
60
70
80

Kerosene, Coal Oil, Illuminating Oils

Kerosene in a general way may be defined as that fraction of crude petroleum or oil made by the pyrogenic decomposition of shales or coal and it distills at a temperature of from 302°F to 572°F (150-300°C) and contains no gasoline or residuum. Its flash point is always greater than 100°F and usually greater than 120°F. Its color may be standard white, prime white, superfine white or water white. Its gravity ranges from 31 to 48° Baume'. Typical kerosene has a gravity of 41 to 42°Be'. Sulphur is usually almost completely absent from kerosene, being less than 0.03%. It consists chiefly of the paraffin series, particularly when the gravity is greater than 38. The principal constituents are nonane, decane, undecane, duodecane, tridecane, tetradecane, pentadecane, hexadecane and heptadecane. With lower gravities it contains naphthenes and aromatic compounds. This is particularly true of Louisiana oils and California oils.

The quality of good kerosene has been found to be within the following limits:

1. Specific gravity shall be between 0.760-0.860 (54.2-32.8°Be').
2. Flash point shall be over 100°F by closed tester.
3. Color shall be water white, with no turbidity.
4. Cold test shall be below 10°F.
5. End point shall be below 600°F.
6. Sulphur shall be below 0.03%.
7. Acid shall be absent.
8. It should not lose more than 1% on treatment with 66° sulphuric acid.

The U. S. Government specifications for various illuminating oils are as follows:

WATER WHITE KEROSENE.

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 degrees 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.—For making the 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 240F° nor more than 350°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.—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 ten minutes.

Reactions.—Two ounces of the oil should be shaken with ½ ounce of warm neutral distilled water and allowed to cool and separate. The water when separated shall react neutral to methyl-orange and phenolphthalein.

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 "toadstools" on the wick. The chimney must be only slightly clouded or stained at the end of the test.

Specification Summary.—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 gram per liter.

Sulphur.—Not more than 0.06%.

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.

KEROSENE FOR U. S. NAVY.

Water white kerosene for U. S. 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 1 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%. The flame shall show at least 6 candle power when compared photometrically with an incandescent lamp which has been standardized by the Bureau of Standards.

Otherwise specifications enumerated above apply for U. S. Navy kerosene.

LONG-TIME BURNING OIL.

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.—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 6 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.—For making cloud 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 zero degrees Fahr. 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 ½ ounce of warm neutral distilled water and allowed to cool and separate. The water when separated shall react neutral to methyl-orange and phenolphthalein.

Burning Test.—This 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 ⅞-inch high, measured from the top of the wick. The lamp shall burn continuously without re-adjusting 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 the flame at any time during the test shall be not less than three-quarters of an inch. The oil shall not produce any appreciable hard incrustation on the wick.

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.—Twenty-one color on Saybolt colorimeter or its equivalent on a Lovibond tintometer, these being equal to color of a solution of potassium bichromate containing .0048 gram per liter.

Floc.—Oil to be free from "floc."

Cloud Test.—Oil should not show cloud at 0°F. See Note 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.

LIGHT HOUSE OIL.

Oil for use by the Bureau of Light Houses 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 (Tag 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% in ten minutes the kerosene shall not distill below 350°F and 98% 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 than 10% loss of candle power. A lamp of this description will be loaned to successful bidder.

300 DEGREE MINERAL SEAL OIL.

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.—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 one hour after cooling.

Cloud Test.—For making this 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 ½ ounce of warm neutral distilled water and allowed to cool and separate. Water when separated shall react neutral to methyl-orange and phenolphthalein.

Burning Test.—This 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 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 1 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.

The oil must be free from water, flue 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.

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°F.

Fire Test.—After the flash point is obtained the oil shall be heated at the same rate (7° per minute) and test flame to be applied every 5° after flash point has been obtained.

Cloud Test.—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 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.

Appearance.—The oil must be free from water, glue and suspended matter.

Composition.—To be 300° 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% of fatty oil by volume.

"B" grade must contain not less than 22% 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% free fatty acid calculated as oleic acid.

"B" grade must contain not over 0.45% free fatty acid calculated as oleic acid.

Burning Test.—As stated above.

Gravity.—It will be noted that there are not 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.

GAS OIL.

Gas oil is that fraction of petroleum distillation coming off after the kerosene or other illuminating oil. It is usually a destructive distillation resulting in a distilled product carrying a considerable amount of olefins and a residue having a lower viscosity than would be the case without a partially destructive distillation. When it is desired to avoid a destructive distillation, steam may be used, giving an oil suitable for absorption purposes sometimes known as straw oil.

Gas oil is used for making gas and for carburetting coal gas or water gas. It is also used to make Blaugas, which is a prodnct liquified under a pressure of about 1,500 pounds. It is also used for Pintsche gas. A typical gas oil has the following properties:

Specific gravity	0.843 = 36.1°Be′
Flash point	90°C
Burning test	116°C
Distillation test	
0°C-150°C	0.0%
150°C-300°C	44.0%
300°C up	55.3%
Coke	0.7%

GAS OIL FOR DIESEL ENGINES (U. S. NAVY).

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 "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 15° Baume′."

(f) Omit.

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" 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 15° Baume′.

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.

STRAW OIL (U. S. BUREAU OF STANDARDS).

The characteristics of a straw oil for absorption of light oils from gas as recommended by some operators and which are concurred in by the committee of coal-tar products are substantially as follows:

1. Specific gravity not less than 0.860 (34°Be') at 15.5°C (60°F).
2. Flash point in open cup tester not less than 135°C (275°F).
3. Viscosity in Saybolt viscosimeter at 37.7°C (100°F) not more than 70 seconds.
4. The pour test shall not be over 1.1°C (30°F).
5. When 500 cc of the oil are distilled with steam at atmospheric pressure collecting 500 cc of condensed water, not over 5 cc of oil shall have distilled over.
6. The oil remaining after the steam distillation shall be poured into a 500 cc cylinder and shall show no permanent emulsion.
7. The oil shall not lose more than 10% by volume in washing with 2½ times its volume of 100% sulphuric acid when vigorously agitated with acid for five minutes and allowed to stand for two hours.

An additional set of specifications for wash oil which is used by one Government department is as follows:

Specific gravity shall not be greater than thirty-five and nine-tenths degrees (35.9°) Baume' at 60°F, equivalent to specific gravity 0.844.

Viscosity shall not be more than 56 seconds in a Saybolt viscosimeter at 100° Fahrenheit.

The oil shall not thicken or cloud at 25°F in the cold test.

At least 95% of the oil shall separate as a clear layer within 10 minutes after 100 cubic centimeters of oil and 100 cubic centimeters of water have been shaken together vigorously for 20 seconds at a temperature of 70°F.

There shall not be more than 14% of loss in volume of oil when 1 volume of oil and 2½ volumes of 100% sulphuric acid are vigorously agitated for 5 minutes and allowed to settle for 2 hours.

The oil shall not begin to distill below 240°C.

Quality of Absorption Oil for Extracting Gasoline from Natural Gas (Westcott "Casinghead Gasoline").

Gravity	35.6°
Initial boiling point	536°F
End point	698°F
Fire test	312.8°F
Saybolt viscosity @ 100°F	40.5

Distillation.

Initial	273 °C
5%	295 °C
10%	300 °C
20%	305 °C
30%	308.6°C
40%	311 °C
50%	316 °C
60%	322 °C
70%	329 °C
80%	336.5°C
90%	360 °C

Kerosene Regulations (March 1919)

(By Dr. G. W. Gray.)

State.	Tabulation of Essential Points in State Laws.				
	Cup	Flash	Fire	Gravity	Distillation
Alabama			120		No law
Arizona					
Arkansas	Open Tag		160		No law
California					
Colorado	Foster	90			
Connecticut	Open Tag	110	140		
Delaware	Open Tag		115		
Florida					No law
Georgia	Elliott	100			
Idaho	Open Tag		120		
Illinois	Open Tag		150		
Indiana	Indiana	120		50-46	
Iowa	Elliott	100			
Kansas	Foster	110			
Kentucky	Tag		130		
Louisiana	Tag	125			
Maine	Tag		120		
Maryland					No law
Massachusetts	Tag	100	110		
Michigan	Foster	120			
Minnesota	Tag		120		
Mississippi					No law
Missouri	Tag	120		40 min.	4% resid. at 570
Montana	Foster	110			No law
Nebraska	Foster	112		42 min.	7% resid. at 570
Nevada					No law
New Hampshire		100	120		
New Jersey	Tag	110			
New Mexico			120		
New York	Tag	110	110		
North Carolina	Elliott	100			6% resid. at 570*
North Dakota	Elliott	100	125		4% resid. at 570 6% max. at 310
Ohio	Foster	120			
Oklahoma	Tag	115		40-48	†
Oregon					No law
Pennsylvania	Tag		110		
Rhode Island	Tag		110		
South Carolina	Elliott	100			6% res. at 570
South Dakota	Elliott	105		47° Pa. crude 41° M-C crude	Not more than 10% at 300 Not more than 4% at 570
Tennessee	Tag	120			
Texas					No law
Utah	Foster	110			
Vermont	Tag		110		
Virginia					No law
Washington	Tag elec. cup		120		
West Virginia					No law
Wisconsin	Tag	105	120		
Wisconsin	Foster	110			5% resid. at 572

*North Carolina—If oils are lighter than 47 gravity, then residue must not be more than 10 per cent.

†Oklahoma—Oils 40-48 gravity must be branded Good. Oils less than 40 or more than 48 must be branded Inferior.

Specifications for Petroleum Products of the Kansas City Southern Railway Co.

Material.—The materials desired under this specification are the products of distillation and refining of petroleum, unmixed with any other substance, and conforming to the detailed specifications below.

Illuminating Oils.

General Requirements.—These oils must be water white in color, and free from sulphur in any form. "Cracked" oils are not desired. Products having an offensive odor or containing any admixture of other oils will not be accepted. All samples must show a neutral or slightly alkaline reaction.

Tests.—One sample shall be taken from each carload or fraction thereof, and subjected to the following tests:

Headlight or 150 Degree Oil.

Sample must not flash below a temperature of 130 degrees, or burn below a temperature of 150 degrees Fahrenheit, when heated at the rate of 2 degrees per minute. The test flame to be applied once every 5 degrees, beginning at 110. The above flash and fire tests will be made in the Tagliabue open cup tester.

Samples must remain clear and transparent when called to a temperature of 0 degrees and held there for ten minutes.

It must have a specific gravity of between 41 and 48 degrees Baume'.

Mineral Seal or 300 Degree Oil.

Sample must not flash below a temperature of 245 degrees or burn below a temperature of 300 degrees Fahrenheit, when heated at rate of 5 degrees per minute. The test flame to be applied once every 5 degrees, beginning at 180. The above flash and fire tests will be made in the Tagliabue open cup tester.

Sample must remain clear and transparent when called to a temperature of 32 degrees Fahrenheit, and held there for ten minutes.

It must have a specific gravity of between 38 and 43 degrees Baume'.

Gasoline.

General Requirements.—Gasoline shall be water white in color.

Tests.—A sample sufficiently large to provide for the following tests, taken at random, will represent the shipment:

1. Gasoline must not be heavier than specific gravity of 72 degrees Baume, but when specifically ordered stove gasoline may be furnished at specific gravity of 66 degrees Baume.
2. A portion of the sample must be entirely volatile at a temperature not exceeding 100 degrees Fahrenheit.
3. When blotting paper is moistened with a few drops of the sample it must evaporate entirely, leaving no greasy stain.

Conditions.—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 the shipment represented by it will be returned to the manufacturers, they paying freight both ways.

Pennsylvania Railroad Company

No. 20-A.

SPECIFICATIONS FOR PETROLEUM PRODUCTS.

1. Five different grades of Petroleum Products will be used. These will be purchased in amounts as the demands of the service indicate.

2. The materials desired under this specification are the products of the distillation and refining of petroleum unmixed with any other substances, and conforming to the detail specifications below. Products having a very offensive odor, or being mixed with other oils, will not be accepted.

3. Shipments must be made as soon as possible after the order is received. It will be observed that the detail specifications provide for a change of cold test and flashing point in some of the oils on May 1st and October 1st. Shipments reaching destination on or after these dates must conform to the specifications characteristic of these dates and will be rejected if they fail, unless it can be shown that they have been more than a week in transit. No preliminary examination of samples will be required, but a limited amount of special preliminary examinations will be made on the request of the Purchasing Agent for use of parties desiring the information. Definite printed methods for determining flashing and burning points, for making cold test and for taking gravity will be furnished if desired, and in case of dispute these methods must be used.

4. A shipment being received at any shops, one sample of not less than a pint must be taken from any barrel at random, for each shipment of a carload or less, and sent by R. R. S. to the Chemist, Altoona, Pa. This sample must be accompanied by a "Sample for Test" tag properly filled out, and must be sent in a proper can, enclosed in a "Sample for Test" box. In taking the sample, care must be exercised to prevent contaminating the sample with any other oil or any other substance, and a clean, dry can must always be used. This sample will represent the shipment. If it stands the tests, the shipment will be accepted, except as provided in Section 5. If the sample fails to stand the tests, the shipment will be rejected and returned to the shippers, who must pay return freight.

5. The examination of a shipment for oil that is cloudy from glue or suspended matter must be made by those by whom the oil is received. The examination applies especially to 150 degree and 399 degree Fire Test Oils. As this defect rarely characterizes all of the barrels of a shipment, it is obvious that the sample for test may fail to show it. Accordingly when any barrel or barrels in a shipment are found to be cloudy from glue or suspended matter, such barrels must be set aside and returned to the shipper, notwithstanding the Test Report has shown the shipment to be ready for use.

6. The following detail specifications will be enforced:

150° Fire Test Oil.

This grade of oil will not be accepted if sample from shipment:

1. Is not "water white" in color.
2. Flashes below 130° Fahrenheit.
3. Burns below 151° Fahrenheit.
4. Is cloudy or shipment has cloudy barrels when received, from the presence of glue or suspended matter.
5. Becomes opaque or shows cloud when the sample has been 10 minutes at a temperature of 0° Fahrenheit.

300° Fire Test Oil.

This grade of oil will not be accepted if sample from shipment:

1. Is not "water white" in color.
2. Flashes below 249° Fahrenheit.
3. Burns below 298° Fahrenheit.
4. Is cloudy or shipment has cloudy barrels when received, from the presence of glue or suspended matter.
5. Becomes opaque or shows cloud when the sample has been 10 minutes at a temperature of 32° Fahrenheit.
6. Shows precipitation when some of the sample is heated to 450° Fahrenheit.

The precipitation test is made by having about two fluid ounces of the oil in a six-ounce beaker, with a thermometer suspended in the oil, and then heating slowly until the thermometer shows the required temperature. The oil changes color but must show no precipitation.

Paraffine and Neutral Oils.

These grades of oil will not be accepted if the sample from shipment:

1. Is so dark in color that printing with long primer type cannot be read with ordinary daylight through a layer of the oil ½ inch thick.
2. Flashes below 298° Fahrenheit.
3. Has a gravity at 60° Fahrenheit below 24° or above 35° Baume'.
4. From October 1st to May 1st has a cold test above 10° Fahrenheit, and from May 1st to October 1st has a cold test above 32° Fahrenheit.

The color test is made by having a layer of the oil of the prescribed thickness in a proper glass 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:

1. Flashes, from May 1st to October 1st, below 298°F, or from October 1st to May 1st below 249°F.
2. Has a gravity at 60°F below 28° or above 31° Baume'.
3. From October 1st to May 1st has a cold test above 10°F, and from May 1st to October 1st has a cold test above 32°F.
4. Shows any precipitation when 5 cubic centimeters are mixed with 95 cubic centimeters of gasoline.

The precipitation test is to exclude tarry and suspended matter. It is made by putting 95 cc of 88 degree B. gasoline, which must not be above 80 degrees Fahrenheit 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.

500° Fire Test Oil.

This grade of oil will not be accepted if sample from shipment:

1. Flashes below 494° Fahrenheit.
2. Shows precipitation with gasoline when tested as described for well oil.

Lubricating Oil

The principal source of lubricating oil is petroleum, from which the lighter components (naphtha and kerosene) have been removed by distillation, the residue thus obtained being used directly as a lubricant or separated by distillation into various fractions. By removing some of the fractions, as well as by mixing others, a variety of products may be obtained with special properties (viscosity, flash point, cold test and specific gravity).

This is the principle on which the industry is based. The separate fractions are further refined to remove odor, resinous materials, etc., as well as to attain the desired lightness of color. This is accomplished by means of sulphuric acid, agitating with a stream of air, the acid being later removed by washing with alkali or water; the purification may also be brought about by filtration through fuller's earth (customary in the United States).

In Europe the oil is distilled with superheated steam, recently also with partial vacuum, direct firing being avoided to prevent decomposition. The temperature of the superheated steam is kept somewhat higher than that of the still. Commercially, the distillates are cooled and separated according to specific gravity, flash point and viscosity.

In the United States direct firing is much used in separating the crude oil fractions, thus increasing the yield of illuminating oils. The refining, however, is carried on with superheated steam.

ECONOMY OF LUBRICATION.

The economical transmission of power is largely dependent upon the maximum reduction of friction.

The purpose of lubrication is to overcome friction in so far as possible and to prevent wear and deterioration of adjacent moving parts.

It is claimed that from 40% to 80% of all power produced by machinery is lost in friction, and a very considerable part of this is lost in avoidable friction due to improper lubrication.

THEORY OF LUBRICATION.

A lubricant should prevent direct contact between the bearings and the moving parts of machinery, thus substituting for metallic friction and wear the much smaller internal friction of the lubricant. The more completely this result is attained under the conditions of temperature, speed and pressure, the more valuable the lubricant from a mechanical point of view. Whether the mechanically most efficient lubricant is the most economical depends somewhat on the ratio of efficiency, the amount used and the price of the material. Greases have a low mechanical efficiency compared with liquid oils, but from the point of economy and cleanliness they are far superior.

Only liquids with great tendency to adhere are suited for lubrication, since only these have the property to penetrate by capillarity where journal and bearings are the closest and where the danger of contact and wear is the greatest. The lubricating oils prevent direct contact of the metal surfaces because of their adhesion to these surfaces and because their viscosity keeps them from being squeezed out by the pressure on the bearing.

Experience has shown that the power to adhere to metals increases with the viscosity of the oil. Since the danger that an oil will be pressed out increases with the pressure on the bearings, it is advisable for high pressures to use oils of considerable viscosity.

With low pressure and high speed there should be used a very mobile oil, with higher pressure and great velocity more viscous oils. If, for example, a spindle rotating with practically no pressure but very rapidly were lubricated with a very viscous oil, it would mean a ıvish waste of power. But to lubricate a transmission gear with a mobile oil would be a waste of lubricant, while the use of a heavy rease would be entirely suitable. In fact, the use of a solid lubricant, raphite, with heavy oils as a vehicle, has proven most desirable in the case of very heavy bearings and transmission gears with enormous pressures.

The oil should not lose its power of reducing friction by evaporation, gumming or by acting chemically on the metal of the bearings or journal.

The oil or grease should not solidify or greatly change its viscosity under conditions of use.

PHYSICAL TESTS FOR LUBRICANTS.

1. Flash and burning points of lubricants are the respective tem-atures at which the vapors arise in sufficient amount to ignite and burn continuously. They should be high enough to prevent any ıger of fire in using the oil and to be assured that a light oil has been added to a heavy oil to regulate viscosity. With the same osity asphaltic base oils (Texas, California and Mexico) have a ver flash point and a higher specific gravity than paraffin base oils ennsylvania and West Virginia).

2. Specific gravity is the relation of the weight of a given volume of oil to the weight of the same volume of water. The oil trade usually uses the Baume' scale of gravity, which is entirely arbitrary (see ables). The paraffin oils with the same viscosity are lighter (have a higher gravity--Baume') than the asphaltic or semi-asphaltic oil. Gravity is not a measure of the quality of a lubricating oil.

3. Viscosity is the most important property for lubrication. The viscosity is expressed in the terms of the Saybolt Universal Viscosimeter in this country, the Engler in Germany and the Redwood in England (see conversion factors). Paraffin oils lose their viscosity most readily in use in an explosion cylinder by reason of the greater ease in decomposing to lighter products than do asphaltic oils (see also cracked lubricating oils). They tend to be more viscous at higher temperatures than naphthene base oils (note).

4. Carbon. The fixed carbon is a most harmful property in lubricants for explosion motors, such as automobiles. High fixed carbon is found in poorly refined and blended oils. It is higher in asphaltic than in Pennsylvania or Mid-Continent oils with the same refining. Less carbon is present in light oils.

5. Cold test determines the lowest temperature at which the oil will pour. A low cold test is desirable for ease in circulating and handling in cold weather. A low cold test for motor oils indicates the absence of heavy ends that produce excessive carbon in the cylinder.

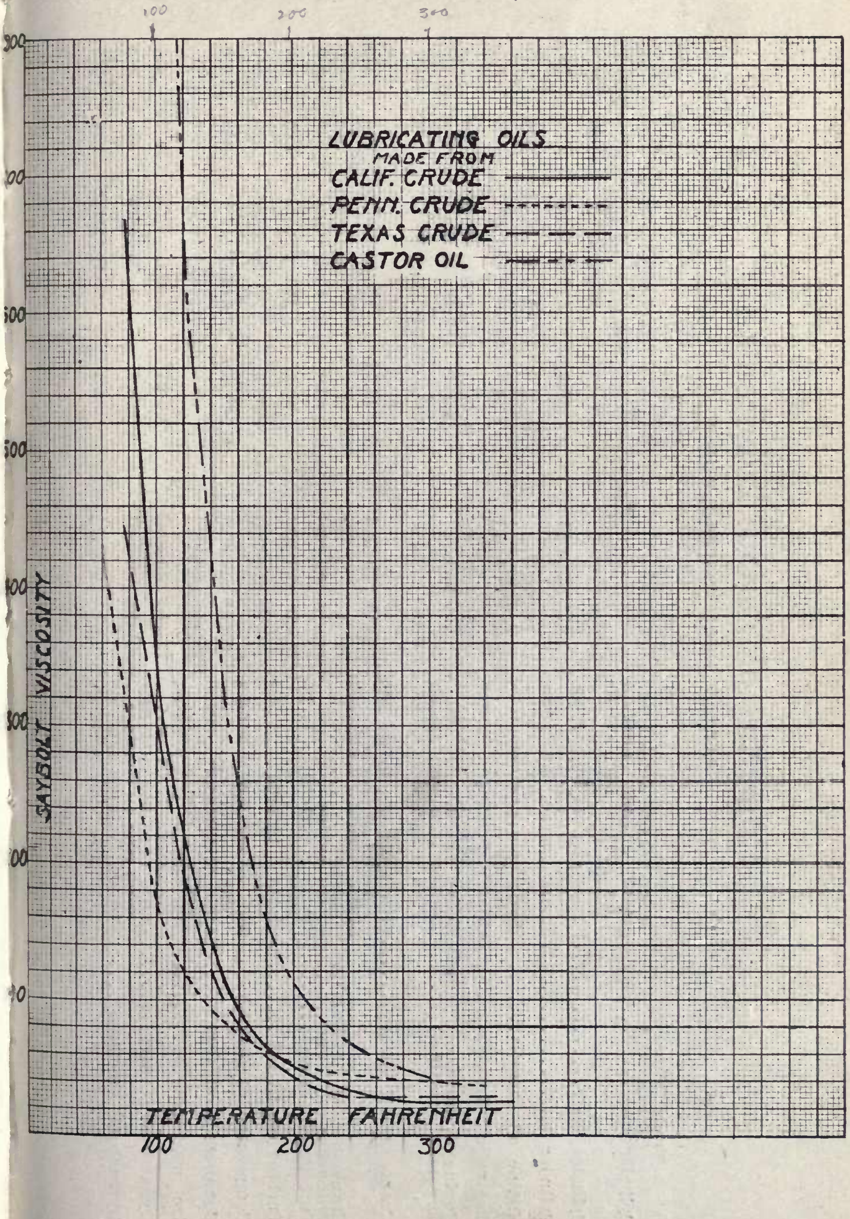
6. Color is not an index of the value of a lubricating oil. The lighter the color, other things being equal, the purer the oil.

7. Free acid should be, and usually is, absent. It is an indication of mineral acid that has not been neutralized and washed out in refining or of the presence of naphthenic acids.

The qualities of various lubricating oils are as follows:

Viscosity at	Spindle	Light M'ch'n'y	Heavy M'ch'n'y	Auto-mobile	Engine	Steam Cylinder	Large Cylinder
70°F.	75-500	375-750	750-1875	470-1100	300-400	......	2800-4000
100°F.	....	180-220	....	160-400	130-150	......	....
122°F.	75-90	.....	110-280	......	......	1100	300-560
210°F.	....	40-50	45-60	40-55	44-47	120-150	....
Flash point, °F Min.	140	160	390	350	430	525	450
Cold test, °F.	10	5	10-40	10	25	45	40
Gravity, Be'.	....	.....	......	19-32	23-30	24-30	....

Note.—See Lubricating Engineer's Handbook, by J. R. Battle.


LUBRICATING OILS
MADE FROM
CALIF. CRUDE
PENN. CRUDE
TEXAS CRUDE
CASTOR OIL
SAYBOLT VISCOSITY
TEMPERATURE FAHRENHEIT
100
200
300
100
200
300
400
500
600
700
800

Properties of Various Lubricants

PARTLY FROM "PETROLEUM."

Trade Name or Classification	Machines and Conditions	Compound Per Cent	Baume Gravity Degrees	Saybolt Viscosity	Flash Point, F°	Fire Test, F°	Cold Test, F°
Cylinder oil	Steam engine; medium pressure; no superheater	Five per cent	24.5-27	250 @ 212°F	620	690	44
Cylinder oil	Steam engine; high pressure; superheater	Straight mineral	24.5	375 @ 212°F	630	700	..
Cylinder oil	Steam engine; low pressure; no superheater	Five per cent	25-26.0	130-150 @ 212°F	550	600	..
Engine oil (heavy)	Heavy, hot bearings (extreme)	Straight mineral	24.0	300-325 @ 100°F	450	500	40
Engine oil (heavy)	Heavy bearings; lower duty than above	Straight mineral	24.5-25	250-280 @ 100°F	400	450	35
Engine oil (heavy compound)	Heavy bearings	5% compound	24-25	190-240 @ 100°F	400	450	34-36
Engine oil (medium)	Medium bearings; splash feed; pump circulation	Five per cent	28-30	190-210 @ 100°F	400	450	32
Crankcase oil (heavy)	Steam engine; crankcase splash	Straight mineral	26.5	150 @ 100°F	440	490	30
Crankcase oil (medium)	Steam engine; crankcase splash	Straight mineral	28.0	120 @ 100°F	400	450	28
Crankcase oil (light)	Steam engine	Straight mineral	32.0	75 @ 100°F	395	445	26
Turbine oil (heavy)	Steam turbine; large sizes	Straight mineral	30.5	200 @ 100°F	420	470	20
Turbine oil (light)	Steam turbine; small sizes	Straight mineral	32.0	150 @ 100°F	395	445	..
Compressor oil (heavy)	Air compressor; single stage	Straight mineral	26.5	115 @ 212°F	500	550	55
Compressor oil (light)	Air compressor; two-stage	Straight mineral	30.0	200-380 @ 100°F	420	470	20-25
Ice machine	Ammonia compressor; two-stage	Straight mineral	26-27	100 @ 70°F	350-360	420	0-4
Dynamo oil (heavy)	Large dynamos and motors; ring oil bearings	Straight mineral	30.5	200 @ 100°F	420	470	20
Dynamo oil (medium)	Medium dynamos and motors; ring oil bearings	Straight mineral	32.0	150 @ 100°F	395	445	..

Dynamo oil	Small motors, 1-32 to 5 HP; small ring oil bearings	Straight mineral	27.5	90 @ 100°F	345	400	18
Black machine	Rough, slow speed bearings, lineshafts, crushers, etc.; cheap work	Straight mineral	29.0	100 @ 70°F	325	380	5-15
General machine (heavy)	Hoists, elevators and general machinery, cool running	Straight mineral	24.0	300 @ 100°F	410	460	40
General machine (medium)	Machine tools, print presses, large lathes, etc.	Straight mineral	26.0	150 @ 100°F	380	430	30
Spindle oil	Light machines for spinning, automatics, etc.	Straight mineral	30-35	60-150 @ 70°F	340	390	..
Loom oil	Weaving machines; high speed medium weight machines	Straight mineral	28.0	203 @ 100°F	360	400	..
Gas engine oil	Gas engine cylinders and general splash and force feed lubrication of gasoline automobile and tractor engines	Straight mineral	24.0	300-400 @ 212°F	210-420	250-470	..
Motor (light)	Pa. Petroleum	0.0012% C. Carbon	30.5	185 @ 100°F	415	475	20°F
Motor (medium)	Pa. Petroleum	0.0031% C. Carbon	30.0	285 @ 100°F	435	500	25
Motor (heavy)	Pa. Petroleum	0.0060% C. Carbon	29.5	475 @ 100°F	440	500	35
Cylinder oil	Ranger, Texas	1.976 % C. Carbon	22.6	135 @ 212°F	485	550	50
Motor oil	Texaco	0.045 % C. Carbon	20.0	652 @ 100°F	380	450	10°F

EFFECT OF AIR-COOLED MOTOR (FRANKLIN) ON LUBRICATING OIL.

	No. 1	No. 2
Crude from which manufactured	South Texas	Pennsylvania
Gravity before using	.934 = 20.0°Be'	.875 = 30.2°Be'
Gravity after using	.920 = 22.3°Be'	.860 = 33.0°Be'
Viscosity at 100° before use	652	251
Viscosity at 100° after use	229	140
Free carbon before use	0.00	0.00
Free carbon after use	0.08%	0.90%
Conradson carbon before use	0.045%	0.050%
Miles car run in use	1000	600
Lubricating oil consumed	8%	40%

EFFECT OF CRACKING ON THE LUBRICATING QUALITIES OF OIL.

In the cracking of petroleum by heat the paraffin hydrocarbons are most readily decomposed into lighter hydrocarbons. The lubricating hydrocarbons remaining in cracked oil are therefore not paraffin but consist chiefly of naphthenes and aromatics. In other words, cracking reduces the viscosity of heavy hydrocarbon oils based on the same gravity. This fact is set forth in the patent to Burton (U. S. No. 1,167,884, Jan. 11, 1916) as follows:

Lubricating fractions made from Mid-Continent Crude Petroleum

Baume' Gravity	Viscosity at 100° (Saybolt Viscosimeter)
25.0	235
26.0	190
26.0	165
26.5	145
27.5	100

Lubricating fractions made from California Crude Petroleum

Baume' Gravity	Viscosity at 100°
18.8	449
20.4	235
20.6	339
21.6	146
21.8	167
22.5	139

Lubricating fractions made from Cracked Petroleum Residua

Baume' Gravity	Viscosity	Gravity	Viscosity
28.9	36	15.2	88
26.5	38	15.0	89
23.8	42	14.7	97
21.5	45	14.1	105
21.1	51	13.2	110
20.2	52	13.0	116
18.7	58	12.0	158
17.8	62	10.8	198
17.2	65		
16.7	66		
15.8	76		

NATURAL HYDROCARBONS—VACUUM DISTILLED.

Table showing the properties of vacuum distilled hydrocarbons and atmospheric pressure forced fire distilled hydrocarbons of a heavy residuum from Mid-Continent oil.

Fraction	Gravity	Viscosity	Sulphur
0—10%	0.868 31.3°Be′	46	0.39%
10—20%	0.877 29.6°Be′	60	0.35%
20—30%	0.895 26.4°Be′	143	0.43%
30—40%	0.909 24.0°Be′	293	0.53%
40—50%	0.920 22.1°Be′	740	0.76%
50—60%	0.920 22.1°Be′	745	0.68%
60—70%	0.920 22.1°Be′	1058	0.70%
70—80%	0.920 22.1°Be′	2600	0.56%

HYDROCARBONS FROM FORCED FIRE DISTILLATION OF SAME OIL.

Fraction	Gravity	Viscosity
0—10%	0.864 32.1°Be′	51
10—20%	0.877 29.6°Be′	69
20—30%	0.888 27.6°Be′	109
30—40%	0.893 26.7°Be′	141
40—50%	0.894 26.6°Be′	141
50—60%	0.887 27.0°Be′	106
60—70%	0.878 29.4°Be′	75
70—80%	0.877 29.6°Be′	69

EFFECT OF TEMPERATURE ON VISCOSITY OF NATURAL MID-CONTINENT HEAVY OILS.

		Av'ge Mid-Continent Fuel Oil 26.8°Be′	Heavy Kansas Crude 19.6°Be′
60°F	=	294.	.....
70°F	=	190.	3360.
100°F	=	94.	1250.
120°F	=	70.	680.
120°F	=	55.	328.
212°F	=	41.	105.

(Viscosity is expressed in terms of the Saybolt Universal)

U. S. GOVERNMENT SPECIFICATIONS FOR LUBRICATING OILS

LIBERTY AERO OIL.

SPECIFICATION NO. 3,501.

1. This specification covers the requirements of the 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 the 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 degrees Baume' conversion by the Tagliabue Manual, 9th edition, or below 25.85 degrees Baume' conversion by the Bureau of Standards' conversion table, Circular No. 57) and having a pour test below 15 degrees Fahrenheit. (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 degrees Baume' conversion by the Tagliabue Manual, 9th edition, or above 23.85 degrees Baume' conversion by the Bureau of Standards' conversion table, Circular No. 57) and having a pour test above 15 degrees Fahrenheit. (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 degrees Fahrenheit, 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 degrees Fahrenheit.

Low specific gravity oil—not over 40 degrees Fahrenheit.

9. Flash Point—The oil must have a flash point over 350 degrees Fahrenheit 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 degrees Fahrenheit, 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. Detailed descriptions of the Conradson carbon test and the pour test have been reprinted in Army Specification No. 3,525 which will be furnished on application.

MOTOR OIL FOR GASOLINE ENGINES.
SPECIFICATION NO. 3,502.

This specification has been approved and adopted by the Ordnance Department, the Quartermaster Corps, the Engineer Corps, the Medical Corps and the Signal Corps, United States Army.

GENERAL.

1. This specification covers the requirements of the Signal Corps for motor oil to be used for the lubrication of internal combustion engines other than airplant 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. The oil must be a refined and filtered mineral oil, or a mixture of such oils. It must be suitable in every way for the satisfactory lubrication of the internal combustion engines specified above.

4. Viscosity—The viscosity of the three grades of oil, when tested in a Saybolt viscosimeter at 100 degrees F., must be within the following limits:

Light oil—270 seconds to 230 seconds.
Medium oil—270 seconds to 330 seconds.
Heavy oil—470 seconds to 530 seconds.

5. 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.

6. Pour Test—One ounce of the oil must not congeal in a standard 4-ounce sample bottle when exposed to the following temperatures:

Light oil—25 degrees F.
Medium oil—30 degrees F.
Heavy oil—40 degrees F.

7. All tests shall be made in accordance with methods adopted by the American Society for Testing Materials. Detailed descriptions of the Conradson carbon test and the pour test have been reprinted in army specification No. 3,525, which will be furnished on application.

AIRPLANE MACHINE GUN OIL.
SPECIFICATION NO. 3,503.

GENERAL.

1. This specification covers the requirements of the Army for gun oil for the lubrication of machine guns on airplanes 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 degrees F., shall be as follows:

Seventy 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 0.003 per cent when determined by the Conradson method.

7. Pour Test—One ounce of the oil must not congeal in a standard 4-ounce bottle at 45 degrees below zero F.

8. All tests must be made in accordance with methods adopted by the American Society for Testing Materials. Detailed descriptions of the Conradson carbon test and the pour test have been reprinted in army specification No. 3,525, which will be furnished on application.

TRANSMISSION LUBRICANT.

SPECIFICATION NO. 3,504.

This specification has been approved and adopted by the Ordnance Department, the Quartermaster Corps, the Engineer Corps, the Medical Corps and the Signal Corps, United States Army.

GENERAL.

1. This specification covers the requirements of the Army for a very adhesive mineral oil, which must be suitable in every way for the lubrication of transmission gears and bearings, differential gears, warm 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 degrees 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 sample of army specifications No. 10 under the same conditions.

NON-FLUID TRANSMISSION LUBRICANT.

Specification No. 3,505.

This specification has been approved and adopted by the Ordnance Department, the Quartermaster Corps, the Engineer Corps, the Medical Corps and the Signal Corps, United States Army.

General.

1. This specification covers the requirements of the Army for purchases of non-fluid transmission lubricant to be used for the axles and transmissions of motor trucks.

Physical Properties and Tests.

2. The lubricant shall be composed of calcium soap and mineral oil manufactured in accordance with the best commercial process. It must have a consistency similar to that known to the trade as "No. 00 grease."

3. The lubricant must be a boiled grease containing not less than 1 nor more than 1½ per cent of moisture in the finished product.

4. Mineral Oil Base.—The mineral oil used in reducing the soaps, when tested in a Saybolt universal viscosimeter at 100 degrees F., must show a viscosity of not less than 180 seconds.

5. Saponifiable Fat Base.—Not more than 10 per cent of either pure tallow oil, neatsfoot oil, lard oil or horse oil, singly or in combination, shall be used as a fat base.

6. Acidity.—The lubricant must not attack a sheet of polished copper within a period of 48 hours.

7. Heat Test.—Two ounces of the grease shall be heated to 212 degrees F., or until the entire mass becomes liquid, and then allowed to cool. The soaps must not separate from the oils during this test, and the grease must return to its original consistency.

8. Fillers.—The grease shall contain no fillers, such as resin, resinous oils, soapstone, wax, talc, powdered mica, lamp black, sulphur, clay, asbestos or any other artificial thickening.

MEDIUM CUP GREASE.

Specification No. 3,506.

This specification has been approved and adopted by the Ordnance Department, the Quartermaster Corps, the Engineer Corps, the Medical Corps and the Signal Corps, United States Army.

General.

1. This specification covers the requirements of the Army for a medium cup grease to be used for the lubrication of such parts of motor equipment and other machinery as are lubricated by means of compression cups.

2. The grease must be a well manufactured product, composed of calcium soap and mineral oil.

Physical Properties and Tests.

3. Mineral Oil Base.—The mineral oil used in reducing the soaps must show a viscosity of at least 180 seconds when tested in Saybolt universal viscosimeter at 100 degrees F.

4. Saponifiable Fat Base.—The grease must have a fat base of 15 to 20 per cent of either pure tallow oil, neatsfoot oil, lard oil or horse oil, used singly or in combination.

5. Consistency.—The grease must be a medium cup grease similar in consistency to that known to the trade as "No. 3 cup grease."

6. Moisture.—The grease must be a boiled grease containing not less than 1 nor more than 3 per cent of moisture when finished.

7. Acidity.—The grease must not attack a sheet of polished copper within a period of 48 hours.

8. Ash.—The ash shall not be greater than 2 per cent.

9. Heat Test.—Two ounces of the grease shall be heated to 212 degrees F., or until the entire mass becomes liquid and then allowed

to cool. The soaps must not separate from the oils during this test, and the grease must return to its original consistency.

10. Fillers.—The grease must contain no fillers, such as resin, resinous oils, soapstone, wax, talc, powdered mica, lamp black, sulphur, clay, asbestos or any other filler or artificial thickening.

GUN OIL.

Specification No. 3,507.

This specification has been approved and adopted by the Ordnance Department, the Quartermaster Corps, the Engineer Corps, the Medical Corps and the Signal Corps, United States Army.

General.

1. This specification covers the requirements of the Army 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 small arms.
For filling recoil cylinders of artillery and naval guns.
For oil switches and oil current 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. Specific Gravity.—The oil must have a Baume' gravity of not more than 23 degrees at a temperature of 60 degrees F.

5. Viscosity.—The viscosity must be within the following limits when the oil is tested in a Saybolt universal viscosimeter at 100 degrees F.: 95 seconds to 105 seconds.

6. Flash Point.—The flash point of the oil must not be less than 300 degrees F. in a Cleveland open cup.

7. Pour Test.—One ounce of the oil must not congeal in a standard sample bottle at 5 degrees below zero F.

8. Carbon.—The carbon residue must not be more than 0.003 per cent by the Conradson method.

9. Acidity.—The oil must not show an acid reaction of more than 0.03 per cent, calculated at SO_3, and must not gum or corrode metals under any conditions.

10. All tests must be made in accordance with methods adopted by the American Society for Testing Materials. Detailed descriptions of the Conradson carbon test and the pour test have been reprinted in Army Specification No. 3,525, which will be furnished on application.

GEAR, CHAIN, WIRE ROPE LUBRICANT.

Specification No. 3,508.

This specification has been approved and adopted by the Ordnance Department, the Quartermaster Corps, the Engineer Corps, the Medical Corps and the Signal Corps, United States Army.

General.

1. This specification covers the requirements of the 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 degrees 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 degrees 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 1-inch wire rope that has not been oiled with any other material the lubricant must penetrate to and be absorbed by the fiber 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.

MINERAL CYLINDER OIL.
Specification No. 3,509.

This specification has been approved and adopted by the Ordnance Department, the Quartermaster Corps, the Engineer Corps, the Medical Corps and the Signal Corps, United States Army.

General.

1. This specification covers the requirements of the 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 required, also as a stock oil for compounding, and as a light 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 degrees F.: 135 seconds to 165 seconds.

4. Flash Point.—The flash point of oil must be more than 475 degrees Fahrenheit in a Cleveland open cup.

5. Pour Test.—One ounce of the oil, in a standard 4-ounce sample bottle, must not congeal at 45 degrees F.

6. All tests must be made in accordance with methods adopted by the American Society for Testing Materials. Detailed description of the pour test has been reprinted in Army Specification No. 3,525, which will be furnished on application.

COMPOUND CYLINDER OIL.
Specification No. 3,510.

This specification has been approved and adopted by the Signal Corps, Quartermaster Corps and the Engineer Corps, United States Army.

General.

1. This specification covers the requirements of the 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 degrees F. must be as follows: 135 seconds to 150 seconds.

4. Flash Point.—The flash point of the oil must be over 475 degrees F. in a Cleveland open cup.

5. Pour Test.—One ounce of the oil must not congeal in a standard 4-ounce sample bottle at 50 degrees F.

6. All tests shall be made in accordance with methods adopted by the American Society for Testing Materials. Detailed description of the pour test has been reprinted in Army Specification No. 3,525, which will be furnished on application.

Lubricating Refinery Terminology

Aeroplane Oil.—This is oil used for aeroplanes, typical of which is the Liberty aeroplane oil under Specification No. 3501, page 168. It is frequently a light colored, straight production, viscous neutral oil.

Automobile Oils are usually viscous neutral oils with a flash point above 400°F and a Saybolt viscosity over 145 at 70°F.

Axle Oil is a natural black lubricating oil, commonly summer black oil of a 500°F to 550°F fire test. It is used also as a tempering oil.

Bolt Oil is a viscous neutral oil with a gravity of about 30° Baume', viscosity of about 220, used for thread cutting.

Brick Oil is a light non-viscous neutral oil with a gravity about 34° Baume', a flash point of about 340°F, viscosity of about 80 at 70°F. It is also known in terms of **Paint Oil.**

Car Oil is the same as axle oil and summer black oil.

Castor Oil is oil from castor beans; has a specific gravity of .965 Baume', gravity of 15°, cold test of 5°F, viscosity on the Saybolt universal viscosimeter at 100°F of 1200

125°F	600
150°F	300
175°F	175
200°F	110
250°F	60
300°F	40

Claroline Oil has a viscosity of 4.4° Engler at 70°F. It is essentially the same as straw oil or absorption oil.

Condenser, Compounded and **Blown Oils** are mixtures of mineral lubricating oils with seed oil, the seed oil usually being blown to increase the viscosity.

Cylinder Oil or **Cylinder Stock** is the residue obtained from distilling special grades of light crude oils with a very large amount of steam, avoiding cracking as much as possible, and from which the wax distillate has been removed. Cylinder oil varies in gravity from 20° to 27°Be', flash point 475°F to 650°F, viscosity at 210 Saybolt, 100 to 350, cold test 30 to 60°F. They usually are not filtered, but may be refined by filtering through Fuller's earth or bone black.

Cove Oil is 36° gravity mineral oil compounded with seed oil.

Cream Separator Oils are non-viscous oils of about 30 to 34° gravity, 70 to 200 viscosity at 70°F.

Cup Greases are mixtures of petroleum oil and lime soap with or without rosin oil.

Dynamo Oil is a viscous neutral oil, gravity 30-32°Be', flash point 400-425°F, fire test 450-500°F, cold test 15-30°F, Saybolt viscosity 140-225.

Engine Oil is a variable quality of lubricating oil, a common type of which has a Saybolt viscosity of 180-300, cold test 20-30°F, flash point of 400°F, gravity of 29°Be'.

Floor Oil is a light non-viscous neutral oil.

Gear Case Oil is a steam refined cylinder oil with a gravity of about 25°Be', flash point 600°F, cold test of 30°F, Saybolt viscosity at 210°F of 240.

Hammer Oil is a steam cylinder oil with a viscosity of about 220.

Harness Oil is a compounded oil containing petrolatum, leather oil and wax and some fatty oils.

Knitting Machine Oil is a spindle oil of 70-200 viscosity at 70°F.

Leather Oil is a non-viscous neutral oil of low viscosity.

Machine Oil is made in various grades with viscosities of 290 to 800 Saybolt at 70°F. It is usually a red oil with a cold test of about 30°F.

Motor-Cycle Oil is a high viscosity lubricating oil similar to aeroplane oil.

Neutral Oils are oils obtained from pressed distillates.

Non-Viscous Neutral Oils are oils having a viscosity below 135 Saybolt at 100°F.

Viscous Neutral Oils are oils having a viscosity above 135 at 100°F.

Mineral Seal Oils are heavy burning oils obtained in the distillation for cylinder stock.

Oil Dag is a compound of deflocculated graphite suspended in petroleum lubricating oil covered by U. S. Patent No. 911,358 by Acheson.

Paraffin Oil is the wax-free oil obtained by pressing wax distillate.

Paraffin Scale is crude wax.

Sweated Wax is crude wax freed from oil.

Refined Wax is sweated wax which has been filtered and decolorized with Fuller's earth.

Pressed Distillate or **Pressed Oil** is the oil after the wax distill[illegible] has been refrigerated and the wax removed from it.

Petroleum Coke is the residue in coking or tar stills and usu[illegible] constitutes about 5% of the crude oil. Mid-Continent crude leave[illegible] residue ordinarily about 6 inches thick in the still, and Mexican cru[illegible] petroleum leaves a residue about 30 inches thick in the bottom of th[illegible] still.

Roll Oil for tin, copper and brass rolls has the same qualities a[illegible] engine oil.

Sewing Machine Oil is light neutral oil with a viscosity of 75 at 70°F, cold test 20°F or below, fire test 400°F, flash point 340°F, a gravity of 34.5°Be'.

Spindle Oils are the lighter lubricating oils usually of a gravity of 25-35°Be', flash point 300-450°F, viscosity 40-400 at 70°F, cold test 0°-40°F, a colorless to dark red.

Stitching Oil is a light non-viscous neutral oil used for stitching shoes.

Summer Black Oil is a black lubricating oil of about 500-600 fire test and is used for tempering and for concrete waterproofing.

Tar Stills or **Coking Stills** are large oil stills in which heavy portions of crude petroleum are distilled by intense firing until nothing but coke remains in the bottom of the still. This sort of distillation is desirable to produce a wax distillate from which the crystalline wax may be easily filtered.

Tower Stills are types of crude oil stills used to prevent the accumulation of coke in the still and does not subject the oil to as much cracking in the still as in the ordinary method.

Tempering Oil is a viscous neutral oil, frequently the same as hammer oil and summer black oil.

Thread Cutting Oil is viscous neutral oil of the quality of engine oil. It is sometimes compounded with 20-40% of lard oil.

Thickened Oils are mineral oils in which the viscosity is increased by the addition of unvulcanized rubber, aluminum soap or blown vegetable oil.

Transformer Oils are oils free from acid with flash point over 300°F and viscosity of about 100.

Transmission Oil is steam cylinder oil of a viscosity of 245 at 210°F.

Turbine Oil is a non-emulsifying oil of about 150 viscosity at 70°F and a flash point of about 420°F.

Vaseline is a semi-solid paraffin oil or wax composed of sufficient varieties of petroleum hydrocarbons to give an indistinct melting point.

Watch Oil is usually a non-petroleum oil and is ordinarily Dolphin oil.

Winter Oil is an engine oil having a cold test of —20°F.

Wax Distillate is the distillate coming from the coking stills and containing wax in crystalline form which immediately follows the gas oil.

Wool Oil is a sun bleached neutral oil sometimes compounded with lard oil and with a viscosity of 140-160 Saybolt, gravity of about 32°Be′ and flash point of 375°F.

PETROLATUM LIQUIDUM, U. S. P.

Liquid Petrolatum.

Petrolat. Liq.—Liquid Paraffin, Mineral Oil.

A mixture of liquid hydrocarbons obtained from petroleum. Preserve it in well closed containers, protected from light.

Heavy Liquid Petrolatum.—Heavy Liquid Petrolatum has a viscosity of not less than 3.1 when determined by the test given below.

Light Liquid Petrolatum.—Light Liquid Petrolatum has a viscosity of not more than 3 when determined by the test given below and vaporizes freely.

Each variety conforms to the following description and tests:

Specific gravity for Liquid Petrolatum, 0.828 to 0.905 at 25°C.

A colorless, transparent, oil liquid, free or nearly free from fluorescence, odorless and tasteless when cold and possessing not more than a faint petroleum odor when heated.

When cooled to 10°C Liquid Petrolatum does not become more than opalescent (solid paraffins).

Insoluble in water or alcohol; soluble in ether, chloroform, petroleum benzin or in fixed or volatile oils. Camphor, menthol, thymol and many similar substances are dissolved by Liquid Petrolatum.

Boil 10 mils. of Liquid Petrolatum with an equal volume of alcohol, the alcoholic liquid is not acid to litmus (acids).

Introduce into a glass-stoppered cylinder which has been previously rinsed with sulphuric acid 5 mils. of Liquid Petrolatum and 5 mils. of colorless sulphuric acid, heat in a water bath during 10 minutes, shaking well at intervals of 30 seconds; the oil remains unchanged in color and the acid does not become darker than pale amber (carbonized impurities).

Prepare a clear, colorless saturated solution of lead oxide in an aqueous solution of sodium hydroxide (1 in 5) and mix 2 drops of this solution with 4 mils. of Liquid Petrolatum and 2 mils. of dehydrated alcohol; the mixture does not darken after heating for 10 minutes at 70°C and cooling (sulphur compounds).

Viscosity.—Make a permanent mark about 2 cm. below the bulb of a 50 mil. pipet of the usual type and note the time in seconds required at 25°C for the level of distilled water to fall from the upper to the lower mark as the liquid flows from the pipet. The time should not be less than 25 seconds nor more than 30 seconds for the pipet selected.

Draw the Liquid Petrolatum to be tested into this pipet, which should be clean and dry, and note the time in seconds required at 25°C for its level to fall from the same upper to the lower mark as used for the water. Divide the number of seconds thus noted by the number of seconds required for water to fall from the upper to the lower mark as above determined. The quotient indicates the viscosity. Distilled water at 25°C is taken as 1.

Average Dose.—Metric, 15 mils.; apothecaries, 4 fluidrachms.

PETROLATUM, U. S. P.

Petrolat.—Petrolatum Ointment, Petroleum Jelly.

A purified mixture of semi-solid hydrocarbons obtained from petroleum.

Petrolatum is an unctuous mass, varying in color from yellowish to light amber, having not more than a slight fluorescence even after being melted. It is transparent in thin layers, completely amorphous, free or nearly free from odor or taste.

Petrolatum is insoluble in water, almost insoluble in cold or hot alcohol or in cold dehydrated alcohol, freely soluble in ether, chloroform, carbon bisulphide, oil of turpentine, petroleum benzin, benzene or in most fixed or volatile oils.

Specific gravity, 0.820 to 0.865 at 60°C.

It melts between 38° and 54°C.

Heat about 2 gms. of Petrolatum in an open porcelain or platinum dish over a Bunsen burner flame. It volatilizes without emitting an acrid odor and on incineration not more than 0.05% of ash remains.

Shake melted Petrolatum with an equal volume of hot distilled water; the latter remains neutral to litmus (acid or alkalies).

Digest 10 grams of Petrolatum at 100°C for half an hour with 10 gms. of sodium hydroxide and 50 mils. of distilled water, then separate the aqueous layer and supersaturate it with sulphuric acid; no oils or solid substance separates (fixed oils, fats or rosin).

PETROLATUM ALBUM. U. S. P.

White Petrolatum.

Petrolat. Alb.—White Petroleum Jelly.

Petrolatum wholly or nearly decolorized.

White Petrolatum is a white or faintly yellowish unctuous mass, transparent in thin layers even after cooling to 0°C, completely amorphous.

In other respects White Petrolatum has the characteristics of and responds to the tests for identity and purity under Petrolatum.

PARAFFINUM, U. S. P.
Paraffin.

A purified mixture of solid hydrocarbons usually obtained from petroleum.

Paraffin is a colorless or white more or less translucent mass, crystalline when separating from solution, without odor or taste and slightly greasy to the touch.

It is insoluble in water or alcohol, slightly soluble in dehydrated alcohol, freely soluble in ether, petroleum benzine, benzene, carbon disulphide, volatile oils or in most warm fixed oils.

Specific gravity, about 0.900 at 25°C.

It melts between 50° and 57°C.

When strongly heated it ignites, burns with a luminous flame and deposits carbon.

Heat about 0.5 gm. of paraffin in a dry test tube with an equal weight of sulphur; the mixture becomes black from separated carbon and hydrogen sulphide gas is evolved.

Paraffin is not acted upon or colored by concentrated sulphuric or nitric acid in the cold.

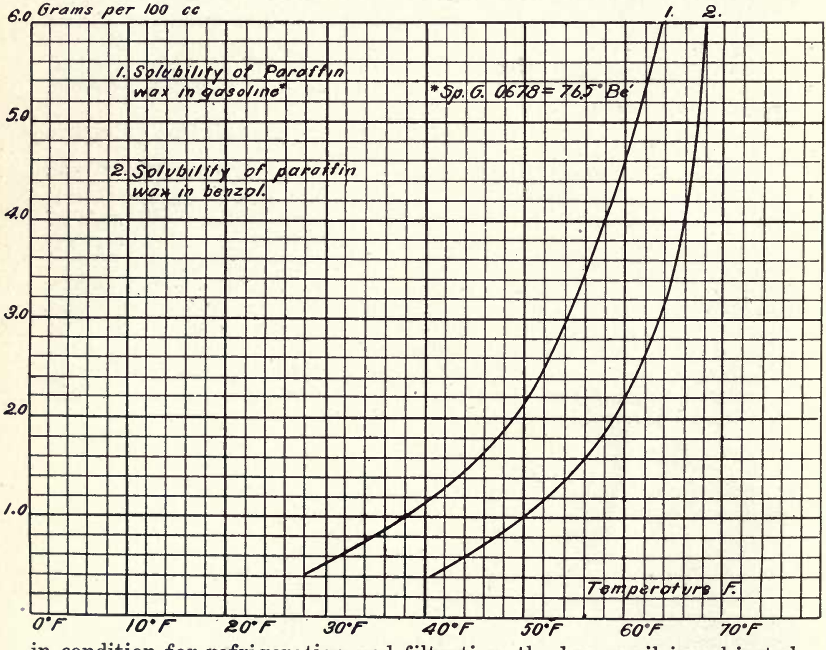
Shake melted paraffin with an equal volume of hot alcohol; the separated alcohol does not redden moistened blue litmus paper (acids).

Ichthyol is an artificial preparation obtained by the distillation of certain bituminous shales and subsequent sulphonation and neutralization with ammonia or soda. It comes on the market under the official name of Ammonii Icythyo-sulphonas or Ammonium Sulpho-ichthyolate. The specific gravity of the preparation is approximately 1.0, and it has a viscosity of 17.7 (Engler). A typical preparation contains 15% to 16% of sulphur, and it is to the sulphur that the value of the preparation is largely due. On account of the difficulty in duplicating exactly the original product and the scarcity of the original product, it has now attained a very high price.

Paraffin Wax

Paraffin wax is valued by the color, melting point and the specific gravity. The price of the crude wax having a melting point of from 103°F to 108°F is about 6c per pound, while the highly refined wax having a melting point of up to 140°F is worth about 17c per pound.

Paraffin wax is ordinarily obtained from petroleum; also from shale oil and ozocerite. Paraffin exists in crude petroleum in the form of protoparaffin, in which condition it does not crystallize out and cannot be expressed from oil at low temperatures. In order to obtain it



in condition for refrigeration and filtration, the heavy oil is subjected to a destructive distillation, thereby producing the crystalline pyroparaffin.

Pennsylvania petroleum furnishes from 1½% to 2% paraffin wax, some petroleum such as one in Roumania giving as much as 10%.

The wax distillate from which paraffin is obtained contains ordinarily about 10% of wax. This distillate has a gravity of from 33°Be' to 35°Be' and distills over at a temperature of 500°F to 700°F. The paraffin is freed from oil by the sweating process after filtration.

Fuel Oil

Petroleum as a fuel for use in steam plants has considerable variation, the only feature common to all oils coming under this class being that it is free from gasoline.

The gravity varies according to the character of the oil and the amount of light constituents that have been distilled out of it. The following table shows typical gravities of fuel oil from different sources.

Source	Gravity
Mexican fuel oil	12.6°Be′
Paraffin base fuel oil	27.5°Be′
California fuel oil	15.5°Be′
Towanda fuel oil	26.0°Be′
Mid-Continent heavy fuel oil	23.5°Be′
Typical Mid-Continent oil	26.5°Be′
Garber, Oklahoma, fuel oil	31.3°Be′

The chief property making fuel oil available for use is the ease with which it flows, or its viscosity. The viscosity is not proportional to the gravity, as is indicated by the following table:

Viscosity and Gravity of Fuel Oils (See Pages 187-8).

Source	Gravity	Viscosity at 70°F
California crude	16.9°Be′	5400
Residuum from same after cracking	15.5	414
Heavy Kansas crude	19.7	3360
Residuum from same after cracking	21.2	178
Heavy Mid-Continent fuel oil	23.5	810
Residuum from same after cracking	21.2	135
Garber, Oklahoma, fuel oil	31.3	183
Residuum from same after cracking	28.0	70
Mexican heavy flux oil	10.8	14500
Residuum from same after cracking	12.6	530
Average Mid-Continent fuel oil	27.5	272
Residuum from same after cracking	23.7	88

Fuel oil has a remarkably constant heating value based on British thermal units per pound of oil. Oil free from water has a higher B.T.U. per pound and a lower B.T.U. per gallon, the lighter the oil; and a lower B.T.U. per pound and a higher B. T. U. per gallon, the heavier the oil. This is set forth in the curves on page 189.

As compared with other sources of heat the theoretical amount of heat obtainable from petroleum or fuel oil as determined when the combustion is complete and the absorption of heat is complete is as follows:

1,000,000 B. T. U. of Petroleum @ $1.00 per bbl. costs	$0.165
1,000,000 B. T. U. of Cherokee slack coal @ $3.00 per ton	0.136
1,000,000 B. T. U. of natural gas @ $0.30 per 1,000 cu. ft. =	0.33
1,000,000 B. T. U. of coal gas @ $0.50 per 1,000 cu. ft. =	0.79
1,000,000 B. T. U. of electricity @ 1c per k.w.hour =	2.93

The above data is from the following: Fuel oil based on specific gravity 0.900 = 25.7°Be′, weight per gallon, 7.5 lbs., weight per barrel 315 lbs.

B. T. U. per lb. = 19,225, per ton = 38,450,000, per gallon = 144,200, cubic foot = 1,078,500, per barrel = 6,056,000.

Slack coal = 11,000 B. T. U. per pound.

Natural gas = 900 B. T. U. per cubic foot.

Equivalents.

1 ton of coal = 3.6 bbls. oil = 24,500 cu. ft. of natural gas.
1 gallon of oil = 13.1 lbs. coal = 160 cu. ft. of natural gas.
1 barrel oil = 0.278 ton coal = 680.6 cu. ft. of natural gas.
1 pound oil = 1.75 lbs. coal = 21.3 cu. ft. of natural gas.
1 pound coal = 0.763 gallon oil = 12.2 cu. ft. of natural gas.

As to the actual heating value of fuel oils from various sources the following is representative:

Heating Value of Fuel Oils.

	Mid Continent Av'ge 1255 Samples	Light Mid Continent	Heavy Mid Continent	To'da Fuel Oil	Gas Oil	Mexican
Specific gravity.....	0.892	.863	0.922	0.921	0.856	0.975
Baume' gravity......	26.9	32.2	21.8	22.0	33.5	12.6
Weight per gal. (lbs)	7.43	7.18	7.68	7.67	7.13	8.25
Heat value B. T. U. per pound.........	19376	19580	19170	19175	19635	18710
Heat value B. T. U. per gallon.......	143950	140580	157220	147600	139990	154360
Flash point........	125°F	110°F	132°F	180°F	170°F	100°F
Sediment	1.0 %	0.2 %	1.5 %	1.0 %	0.0 %	2.0 %
Sulphur	0.3 %	0.24%	0.65%	0.75%	0.05%	2.5 %

It is to be noted that purchasers obtain more heat from a heavy fuel oil as it is purchased on the basis of the gallon.

The chief impurities found in fuel oil are water or brine and asphaltic sediment. The asphaltic sediment has almost as great heating value as the oil itself but the brine or water very greatly diminish the heatin value as well as interfere with the mechanical use of the oil.

The price of coal is the most important factor governing the price of fuel oil. In a general way it is claimed that one unit of heat from oil will produce the same amount of steam as 1.4 units of heat from coal. This takes into consideration the higher efficiency in using the oil, the greater ease in handling, the absence of certain mechanical features attendant upon the use of coal but does not consider the flexibility of the oil where this is a necessary feature of the power plant. According to this one pound of oil would be equivalent to 2½ pounds of coal or one barrel of oil would be equivalent to .45 ton of coal. Oil at $2.00 per barrel would be equivalent to slack coal at $4.45 per ton. This assumes that the slack has a heating value of about 10,000 B. T. U. per pound.

Specifications for Fuel Oil of U. S. Navy.

The specifications for navy fuel oil, gas oil and bunker oil, Atlantic and Gulf ports, are:

1. 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 "2. 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 centrifugal 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% white will be used and the mixture heated to 100°F.

2. Specifications.

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

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

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

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

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

(f) Sulphur not over 1/5%.

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

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

FUEL OIL FOR DIESEL ENGINES.

Explosion Engine oils should have the following properties:

1. Specific gravity shall be below 0.920.
2. Water shall be below 1%.
3. Flash point shall be between 60°C—100°C.
4. Volatility shall be 80% or more at 350°C in Engler flask.
5. Cold test shall be below 32°F.
6. Coke shall be less than 3%.
7. Sulphur shall be below 0.75%.
8. Solubility in xylene shall be more than 99.5%.
9. Acids and alkalies shall be absent.

Some of the advantages claimed for liquid fuel under boilers are: (Poole—Calorific Power of Fuels.)

1. Diminished loss of heat up the stack owing to the clean condition in which the tubes can be kept, and to the smaller amount of air which has to pass through the combustion-chamber for a given fuel consumption.

2. A more equal distribution of heat in the combustion-chamber as the doors do not have to be opened and consequently a higher efficiency is obtained.

3. With oil there is no chance of getting dirty fires on a hard run as with coal.

4. A reduction in cost of handling fuel, since oil is handled

mechanically or by gravitation while with solid fuel, manual labor is required.

5. No firing tools or grate bars are used, consequently the furnace lining and brickwork floors, etc., suffer less damage.

6. No dust nor ashes to cover or fill the tubes and diminish the heating surface, nor to be handled or carted away.

7. Petroleum does not suffer while being stored, while the deterioration of coal under atmospheric influence is well known.

8. Ease with which fire can be regulated from a low to a most intense heat in a short time.

9. Absence of sulphur or other impurities and longer life of plates, etc.

10. Lessening of manual labor of fireman.

11. Great increase of steaming capacity.

For burning liquid fuel the best burner is that which atomizes or sprays the fuel. By thus forming a fine mist an approximation to the theoretical fuel, gas, is obtained. Several methods are in use for this purpose. By some the oils are vaporized by heat but this is applicable only to light oils which are not much used. The favorite method is by having the burner so constructed that the oil is forced out in a spray and at the same time mixed with the air necessary for its combustion.

To have the best results, the burner must be so regulated as to have a flame bordering on, but not quite, smoky. Thus sufficient and not too much air is obtained. The quantity of steam needed to atomize the oil is about 4% of the water evaporated.

MISCELLANEOUS FACTS CONCERNING HEATING BY OIL.

Good practice in the atomization of fuel oil requires an average of 0.3 pound of steam per pound of oil burned.

One pound of fuel oil requires 14 to 15 pounds or 200 cubic feet of air for complete combustion. 225 cubic feet is good practice.

The stack gases from an oil furnace for the highest efficiency should not contain less than 15% of carbon dioxide (over 13% is good).

The temperature of an oil flame with complete combustion and without an excess of air is about 3750°F. (Natural gas flame, 3250°F.)

One pound of oil will yield on combustion 16 to 17 pounds of gases of combustion or 400-500 cubic feet at a temperature of 400°F.

Oil is successfully used in melting iron and steel scrap. For this purpose it is much superior to coal on account of the absence of mineral matter and the very much smaller amount of sulphur.

One barrel of oil will melt one ton of steel in the reverberatory furnace, with the furnace walls already hot.

A typical malleable iron foundry by the changing of the furnaces from coal to oil fuel increased the strength of their castings 100% and increased the output 20%.

Diesel engines consume from .45 to .7 pound of heavy oil per brake H. P. per hour.

Oil requires 60% of stack area needed for coal firing.

Oil gives a fuel efficiency at least 10% greater than coal.

The advantages of oil fuel installations for locomotives and boats have been found to be as follows:

(a) Economy of space reserved for carrying fuel; 50% more fuel value per unit space.

(b) Ease in filling tanks.

(c) Rapidity of time in meeting a varying load on boiler. Fires may be instantly lighted.

(d) Ability to force boiler to extreme duty in case of emergency.

(e) Short height of stack.

(g) Superior personnel available for the operation of the burners.

(h) Ability to secure and maintain higher speed with oil fuel than with coal. No deterioration in storage.

In the distillation of crude oil in which 50% of the crude is distilled off as benzine and kerosene, in good practice, 2.8 barrels of fuel oil are used per 100 barrels of crude oil treated.

For all refining purposes in the production of gasoline, naphtha and kerosene only, from 6 to 7 barrels of fuel oil are required for each 100 barrels of crude treated, assuming that 50% of the lighter hydrocarbons are distilled from the crude.

One-fourth of a gallon of fuel oil is required to produce one gallon of 58° Baume' gasoline by cracking according to a pressure distillation process now extensively used.

The **specific heat** of petroleum is about 0.5 (.49-.53), the **heat of vaporization** averages about 130 B. T. U. per pound and the **heat of fusion** 63 B. T. U. per pound (Paraffin).

For Natural Dry Petroleum of Paraffin or Semi-Paraffin Base the following relation of gravity (Baume-U. S.) and heating value holds:

$$\text{B. T. U. per pound} = 18700 + 40\ (\text{Be}'-10).$$

SAMPLING OF FUEL OIL.

The accuracy of tests depends upon the care with which an average representative sample of the fuel oil delivery has been taken and the importance of obtaining such a sample cannot be overestimated. Top, middle and bottom samples should be taken with a standard "car thief" and these samples should be combined and thoroughly mixed to form one sample for car deliveries. Where oil is received in tanks or reservoirs the swing pipe should first be locked at a position well above the level of the water and sediment usually found in the bottom of such tanks. Tanks schould be sampled every foot for the first five feet above the bottom of the swing pipe, and at five-foot intervals from there to the surface of the oil. This sampling should be done with a standard tank thief, the samples "cut" individually, and deductions for impurities made on the separate volumes which these samples represent. If the tank is a large one, it should be sampled through at least two hatches. In receiving large deliveries of the more viscous oils it is necessary to take many samples in order to insure fair and average impurity (M. & B. S.) deductions. This is because water and sediment do not readily settle out of such oils.

Natural Gas Fuel and Producer Gas Costs

The following table of Producer Gas Costs includes fuel, power, repairs and maintenance, labor and supervision, interest and depreciation, in fact, every item of cost except the interest and taxes on the land occupied.

Producer Gas Costs per 1000 Cu. Ft. for Coal Costs Given			Costs at Which Other Fuels Must be Bought to Obtain the Same Number of B. T. U. as When Buying Producer Gas With Coal at the Price Given							
Cost of One Ton of Coal	Hot Raw Producer Gas at Offtake	Clean Cold Producer Gas	Natural Gas per 1000 Cu. Ft.		Fuel Oil per Gallon		Coal Gas or Carburetted Water Gas per 1000 Cu. Ft.		Blue Gas per 1000 Cu. Ft.	
			Hot Raw Gas	Clean Cold Gas	Hot Raw Gas	Clean Cold Gas	Hot Raw Gas	Clean Cold Gas	Hot Raw Gas	Clean Cold Gas
$2.00	3.13c	4.15c	23.7c	31.5c	2.91c	3.86c	12.6c	16.72c	6.45c	8.59c
2.50	3.55	4.57	26.9	34.67	3.3	4.25	14.3	18.40	7.34	9.45
3.00	3.96	4.98	30.1	37.84	3.69	4.64	16.6	20.09	8.20	10.32
3.50	4.38	5.40	33.3	41.01	4.08	5.03	17.65	21.77	9.07	11.18
4.00	4.79	5.82	36.3	44.18	4.46	5.42	19.3	23.45	9.92	12.05
4.50	5.21	6.24	39.5	47.35	4.85	5.81	21.	25.13	10.78	12.91
5.00	5.63	6.66	42.7	50.52	5.24	6.20	22.7	26.82	11.65	13.78
5.50	6.05	7.08	45.9	53.69	5.63	6.59	24.35	28.50	12.5	14.64
6.00	6.46	7.49	49.1	56.85	6.01	6.97	26.0	30.18	13.36	15.50

HEATING VALUES USED

Producer Gas	145 B. T. U. per cu. ft.
Natural Gas	1,100 B. T. U. per cu. ft.
Fuel Oil	135,000 B. T. U. per gallon
Coal Gas or Carburetted Water Gas	585 B. T. U. per cu. ft.
Blue Gas	300 B. T. U. per cu. ft.

Note: These costs are based on the plant operating with a 100% load factor, that is, operating at rated capacity 24 hours per day, 365 days per year. Comparatively few plants have a 100% load factor, therefore, it is necessary to take this very important point into consideration when estimating the cost of gas.

The cost of Producer Gas, with a reasonable degree of accuracy may be estimated for any load factor by applying the formula:

$$C = T + \left\{ \left(\frac{R \times 400}{A \times B} \right) - 2.38 \right\}$$

Where C = Cost of Producer Gas per 1000 cu. ft. under conditions specified.

A = Number of feet of gas used per day.

B = Days per week plant is in operation.

T = Cost figures shown in table at 100% load factor.

R = Rated hourly capacity of plant in cubic feet.

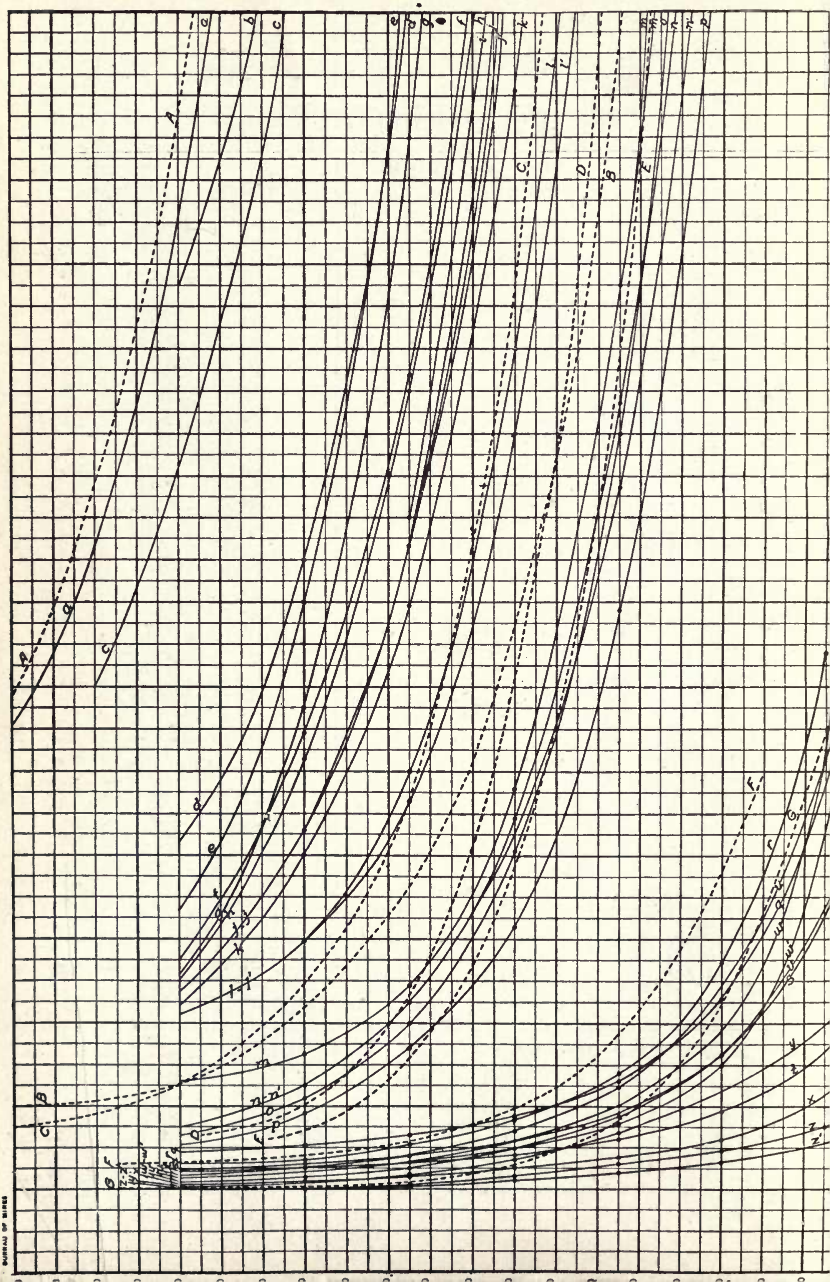
It also must be kept in mind that furnace efficiencies have a very great bearing on the cost of the finished product. Without regeneration or recuperation Producer Gas cannot be used as efficiently as the more concentrated fuels.

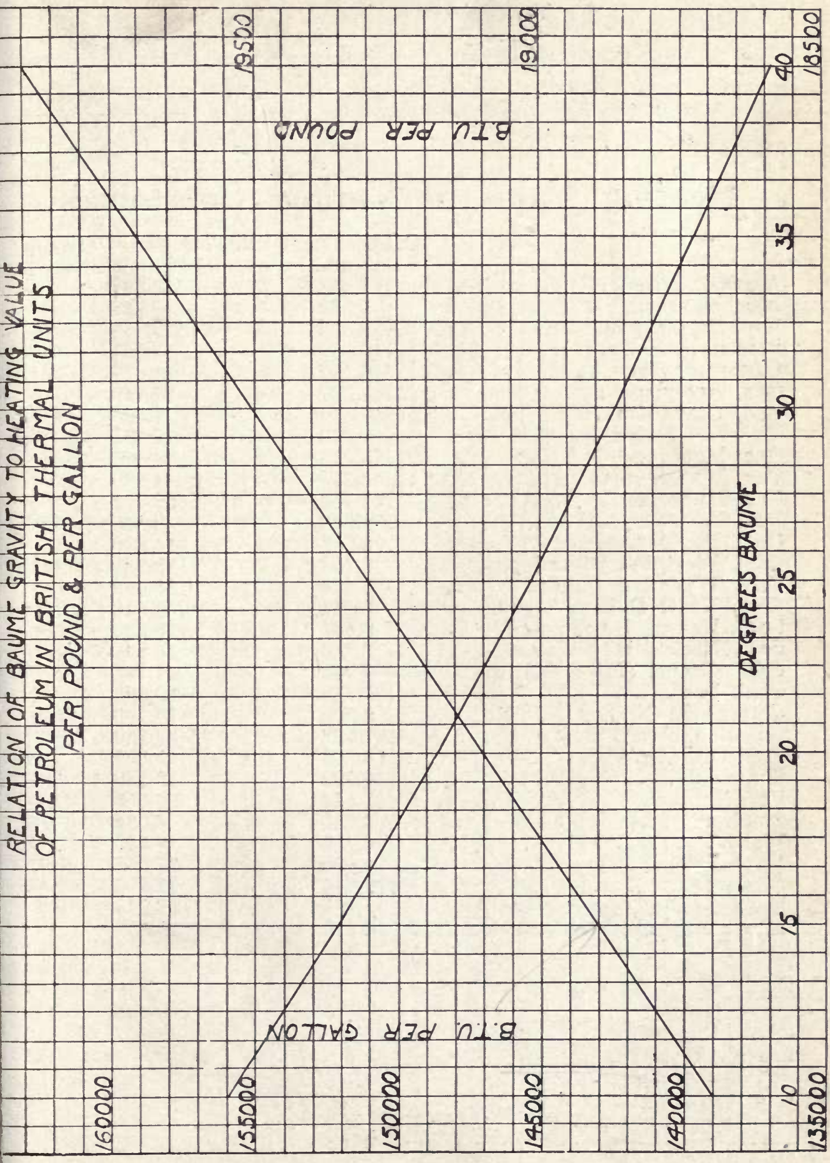
The expense of the distribution system and the furnaces also have an important bearing on the total cost of doing the work.

KEY TO PAGE 188.

Curve No.	TYPE OF OIL	Gravity		Flash point, °F
		Specific	°Bé	
	Solid curves			
a	Mexican residue	1.000	10.0	374
b	"Toltec fuel oil," Inter-Ocean Oil Co., N. Y.	.988	11.7	220
c	"Toltec or Panuco oil," Inter-Ocean Oil Co	.986	12.0	124
d	"No. 102," Union Oil Co., Bakersfield, Cal	.980	12.9	280
e	"No. 18," Union Oil Co., Bakersfield, Cal	.980	12.9	285
f	"Standard" Mexican crude (lot 2)	.964	13.4	202
g	"No. 25," Union Oil Co., Bakersfield, Cal	.978	13.2	262
h	Mexican crude, Texas Co	.952	17.3	126
i	Sample No. 3, Anglo-Mex. Pet. Products Co	.952	17.3	164
j	"Gaviota Refinery," Associated Oil Co., Cal	.953	17.1	230
j′	Mexican oil, Atlantic torpedo flotilla, March, 1914	.947	18.1	182
k	Standard Mexican crude (lot 1)	.954	17 0	145
l	Mexican oil, U. S. S. Arethusa	.950	17.6	182
l′	"Nos. 1, 2, 3," Anglo-Mexican Pet. Products Co.	.955	16.8	188
m	Producers Crude No. 1 fuel oil, Union Oil Co., California	.959	16.1	174
n	"Coalinga Field," Associated Oil Co., Monterey, Cal	.957	16.5	186
n′	"Avon Refinery," Asso'd Oil Co., Avon, Cal	.953	17.1	168
o	Richmond, California	.953	17.1	228
p	Sun Co., Louisiana	.936	19.8	275
q	"Standard," Illinois	.893	27.3	146
r	Gulf Refining Co., Navy standard oil, U. S. S. Perkins	.892	27.5	180
s	"Standard," Indiana	.880	29.6	144
t	"Standard Star," California	.912	23.9	180
u	"Standard," Illinois (lot 4)	.893	27.3	146
v	"Standard," Indiana (lot 4)	.880	29.6	144
w	Gulf Refining Co., Navy contract	.882	29.3	170
w′	"Standard," Lima, Ohio, crude	.876	30.4	149
x	Camden Chemical Co., by-product of coal tar.			
y	"Star," California	.912	23.9	180
z	Gulf Refining Co., Navy standard oil, U. S. S. Roe	.885	28.7	182
z′	Standard Mexican gas oil	.856	34.2	151
●	Indicates test results.			
	Dotted curves			
A	Panuca crude, Inter-Ocean Oil Co	.975	13.7	140
B	Mexican petroleum, Texas Co	.938	19.5	234
C	Associated Oil Co., California	.971	14.2	257
D	Bakersfield, Cal., pipe line to Port Costa	.970	14.4	260
E	California Standard Oil Co., steamer Santa Barbara	.962	15.7	282
F	Beaumont, Tex., Gulf Refining Co	.907	24.8	222
G	Navy standard oil, Texas Co	.911 to .900	24 to 26	195 to 220

From "Oil Fuel Handbook."




RELATION OF BAUME GRAVITY TO HEATING VALUE
OF PETROLEUM IN BRITISH THERMAL UNITS
PER POUND & PER GALLON
B.T.U PER POUND
19500
19000
18500
B.T.U. PER GALLON
160000
155000
150000
145000
140000
135000
DEGREES BAUME
10
15
20
25
30
35
40

Heating Value of Various Substances

	Calories per gram.	B. T. U. per lb. of Combustible Matter.
Alcohol, grain	7,054	12,697
Alcohol, wood	5,330	9,594
Asphalt, 60° pen.	9,532	17,159
Benzol	10,030	18,054
Carbon or Coke	8,137	14,647
Gas, Acetylene	11,527	20,749
Gas, Coal, Min	4,440	7,990
Max.	7,370	12,266
Gas, Methane	13,344	24,019
Gas, Water	2,350	4,230
Gas, Hydrogen	34,462	62,032
Iron	1,582	2,848
Coal, Pa. Anthracite	8,266	14,880
Coal, West Va. Bituminous	8,778	15,800
Coal, Wyoming Lignite	7,444	13,400
Coal, North Dakota Lignite	6,411	11,540
Coal, Kansas Bituminous	8,461	15,230
Coal, Illinois Bituminous	8,056	14,500
Coal, Cannel (Missouri)	8,980	16,165
Coal, Peat	5,940	10,692
Cottonseed Oil	9,500	17,100
Gasoline, avg.	11,528	20,750
Fuel Oil, avg.	10,833	19,500
Shale Oil	10,970	19,750
Paraffin wax	11,140	20,050
Sulphur	2,241	4,034
Wood	4,750	8,550
Naphthalene	9,690	17,442
Gilsonite	9,944	17,900
Hard Asphalt from petroleum	9,989	17,980
Blown Asphalt from petroleum	10,210	18,380

Refining of Oil for Road Building and Paving Purposes

The various methods of refining which yield residues adaptable or used for road building and paving purposes are as follows:

Sedimentation.
Dehydration.
Fractional distillation by direct fire.
Forced fire distillation with direct fire.
Steam distillation.
Inert gas distillation.
Air blowing.

In the types of oil which are ordinarily used for making asphalt or road binders, water is one of the most common impurities. The water is ordinarily salt water and may contain more or less other mineral matter than the salt. These impurities are insoluble in the bitumen proper, and, as they differ from the bitumen in specific gravity, they may be removed wholly or in part by the process of sedimentation or separation by gravity. In the more fluid petroleums sedimentation occurs during storage in the large tanks and the water is ordinarily automatically drawn off from the bottom of the tank by reason of the different pressure produced by the salt water and by the oil. However, a small amount of emulsified water nearly always remains in all petroleums, so that there will always be a small amount of sediment. If the petroleum is very heavy and viscous, approximately equal in gravity to water, then the water will remain emulsified and will not separate by gravity. This type of oil happens to be the most suitable in quality for producing asphalt, and special means of removing this water is necessary before the oil can be reduced to the desired consistency. The dehydration processes are designed primarily for removal of the water in the bituminous material which will not completely separate by sedimentation. It is desirable to do this before distillation because of the fact that the presence of the water will cause foaming when the mixture is heated to the temperature of boiling water. Dehydrating plants vary considerably in design, but those more commonly used for petroleum in California are spoken of as topping plants. In this sort of plant the oil is pumped with or without pressure through a length of pipe containing many bends and turns, so that the oil is considerably stirred. The pipe coils are set in furnaces, so that they may be suitably heated to a temperature above that of boiling water. This pipe discharges the foam into a large expansion chamber, where the water and more volatile constituents separate in the form of vapor, which is condensed in an ordinary condenser for the recovery of the light products. This sort of plant is commonly spoken of as a pipe still. From the pipe still the oil passes through another line, direct to a large batch still, where it is subjected to the ordinary fractional distillation.

The essential principle in the distillation of an oil for road purposes is that it shall distill at a temperature sufficiently low to prevent the decomposition of the hydrocarbons. Since asphalt hydrocarbons begin to decompose at a temperature of 600°F or slightly below, it is desirable that the fire distillation be carried only to that temperature. After this temperature has been reached, the usual method is to blow superheated steam, which mechanically carries over the more volatile hydrocarbons at a temperature much below th actual boiling point.

This distillation has a special action in removing the paraffin compounds which are particularly undesirable in that they have very little ductility and cementition value. The distillate will contain any light oils such as are used as spindle oils and for general lubrication, as well as any paraffin wax. It is particularly desirable in this distillation to prevent the formation of free carbon or coke. The distillation with steam may be carried down until the residue shows a penetration of about 10 millimeters.

A method of distillation which gives very great yields of solid or semisolid asphalt even from semiparaffin base oils is that of blowing the oil at moderately high temperature with air. This in many Mid-Continent oils gives much more asphalt than naturally exists in the oil. The action of the air is to produce a more viscous product which is very much less susceptible to temperature changes than the natural asphalt. It is strictly a chemical transformation process formed from the hydrocarbons in the oil which are ordinarily not useful for asphalt making purposes. It has been found from practical experience that this type of asphalt is not sufficiently cementitious and ductile to be used for ordinary paving purposes in producing first-class asphalt pavement. It can, however, be successfully used and is in great demand for waterproofing purposes, for filler in brick and wood block pavement and for roofing purposes and for fluxing ductile asphalt.

The best types of petroleum for asphalt paving purposes are those from California, Mexico, Trinidad and Texas.

Asphalt production in 1917 from domestic petroleum was 701,8 short tons valued at $7,734,690. This includes 327,142 tons of semi-solid and 374,677 tons of semi-fluid asphalt. The total manufactur asphalt from Mexican petroleum was 645,613 tons. The import native asphalt and asphalt rock in 1917 was 187,886 tons.

ASPHALT PAVEMENT

Asphalt is a black non-oxidized bituminous hydrocarbon, semi fluid to hard in consistency, the heavy residuum from petroleum or occurring naturally. The residua from petroleum are known as oil asphalts and come most largely from California, Mexican, Texas and Mid-Continent petroleums. The most commonly used natural asphalts are Trinidad, Bermudez, Cuban and Gilsonite.

The term asphalt is commonly applied to bituminous pavements, being mixtures usually of oil asphalt with dust, sand, gravel or rock in varying proportions from 6% to 20%. The terms "bitumen" or "asphaltic cement" are commonly applied to the pure asphalt material.

The types of asphalt construction now commonly used are:

1. Asphaltic concrete. This mixture is very common in localities where Joplin chats are available. It is known also as "Topeka Specification Pavement" and "Bituminous Concrete," but it might be called bituminous gravel. The stone it carries is of ½″ and ¼″ size.

2. Sheet asphalt is the original type of asphalt pavement laid in two courses, the bottom one with coarse stone, the top with sand mixed with the bitumen.

3. Bituminous concrete (Warren) is laid with coarse stone in the wearing surface.

4. Bituminous earth is laid without an appreciable amount of sand or rock.

There are two different basic principles involved in proportioning the mineral matter of an asphalt pavement. One is to so grade the coarse mineral particles that they support each other and interlock. The other is to produce a mastic of bitumen and finely divided earthy material that is rigid and self-supporting because of surface tension action. This mastic fills the voids in the coarse material and has a much higher melting point than the pure bitumen and does not so readily allow softening or movement of the pavement.

COMPOSITION OF NATURAL ASPHALT

	Natural Trinidad	Bermudez	Gilsonite	Grahamite	Cuban
Bitumen	56.0%	94.0%	99.4%	94.1%	75.1%
Mineral Matter	36.8%	2.0%	0.5%	5.7%	21.4%
Specific Gravity	1.400	1.085	1.045	1.171	1.305
Fixed Carbon	11.0%	13.5%	13.0%	53.3%	25.0%
Melting Point, °F	190	180	300	Cokes	240
Penetration	0.5	2.5	0	0	0
Free Carbon	6.0%	4.0%	0.1%	0.2%	3.5%
Sulphur (ash free basis)	6.5%	5.6%	1.3%	2.0%	8.3%
Petroleum ether soluble	65.0%	70.0%	30.0%	0.4%	41.1%
Total Carbon (ash free)	82.6%	82.5%		87.2%	
Hydrogen (ash free)	10.5%	10.3%		7.5%	
Nitrogen (ash free)	0.5%	0.7%		0.2%	

COMPOSITION OF OIL ASPHALTS

	Mexican	Mid-Continent Air Blown	California	Stanolind (cracked-pressure tar residue)
Bitumen	99.5%	99.2%	99.5%	99.8%
Mineral Matter	0.3%	0.7%	0.3%	0.3%
Specific Gravity	1.040	0.990	1.045	1.060
Fixed carbon	17.5%	12.0%	15.0%	17.5
Melting Point °F	140	180	140	135
Penetration	55	40	60	50
Free Carbon	0.0	0.0	0.0	0.0
Sulphur (ash free basis)	4.50%	0.60%	1.65%	0.35
Petroleum Ether Soluble	70.0%	72.0%	67.0%	70.0%
Cementing Properties	good	poor	good	good
Ductility	45 cm	'2 cm	70 cm	100+
Loss at 32°F. 5 hrs	0.2%	0.1%	0.2%	0.1%
Heat test	adherent	smooth	adherent	scaly

Composition of Rock Asphalt

ASPHALTIC LIMESTONES

	Ragusa Sicily	Seyssel France	Mons France	Cass Co. Missouri	Buckhorn Oklahoma
Bitumen	9.9%	5.9%	8.9%	6.9%	5.9%
Passing 200 mesh	37.1	44.1	53.1	20.0	9.0
80 "	23.0	15.0	13.0	21.0	8.4
50 "	14.0	9.0	7.0	17.0	9.0
40 "	4.0	7.0	5.0	6.0	9.9
30 "	2.0	7.0	3.0	6.5	15.0
20 "	5.0	6.0	5.0	5.1	8.8
10 "	5.0	6.0	5.0	7.5	8.0
4 "	0.0	0.0	0.0	10.0	26.0
Calcium carbonate	89.0	91.3	90.0	92.9	96.0

ASPHALTIC SANDSTONES

	Breckenridge County, Ky.	Buckhorn District Oklahoma	Higginsville, Missouri
Bitumen	9.2%	9.2%	7.9%
Passing 200 mesh	5.2	1.5	25.7
80 "	45.5	56.5	71.3
40 "	36.3	30.4	3.0
10 "	3.8	2.4	0.0
Calcium carbonate	0.0	0.0	0.0

Composition of Asphalt Pavements

The following table gives a comparison of a typical composition and properties of good mixtures representing the various types of asphalt wearing surface pavements:

	Bituminous Concrete (Topeka Spec.)	Bituminous Concrete (Warren)	Sheet Asphalt	Bituminous Earth "National"
Asphaltic cement	8.0%	6.0%	10.0%	20.0%
Dust passing 200 mesh screen	12.0	5.5	12.0	62.0
Dust passing 80 mesh screen	12.0	2.8	16.0	15.0
Dust passing 40 mesh screen	20.0	6.7	38.0	3.0
Dust passing 10 mesh screen	20.0	24.5	24.0	0.0
Dust passing 4 mesh screen	18.0	15.3	0.0	0.0
Dust passing 2 mesh screen	10.0	13.3	0.0	0.0
Dust passing 1 mesh screen	0.0	25.0	0.0	0.0
	100.0	100.0	100.0	100.0
Weight per sq. yd. 2 in. surface	215 lbs.	225 lbs.	205 lbs.	185 lbs.

SHEET ASPHALT PAVEMENT

Sheet asphalt is the standard asphalt pavement. Specifications call for two courses of the following composition and properties:

BINDER OR BOTTOM COURSE

	Limits	Standard
Bitumen	5½%— 8%	6.0%
Mineral passing 200 mesh	7 —12	8.0
Mineral passing 80 mesh	10 —20	12.0
Mineral passing 40 mesh	10 —20	15.0
Mineral passing 10 mesh	7 —20	13.0
Mineral passing 4 mesh	10 —20	17.0
Mineral passing 2 mesh	10 —20	16.0
Mineral passing 1 mesh	10 —20	13.0
		100.0
Thickness		1½ in.
Density		over 2.30

TOP COURSE

	Limits	Standard
Bitumen	9.75%—11.0%	10.0%
Mineral passing 200 mesh	12 —18	13.0
Mineral passing 80 mesh	20 —34	23.0
Mineral passing 40 mesh	20 —40	27.5
Mineral passing 10 mesh	12 —35	26.5
Mineral passing 4 mesh	0	0.0
Mineral passing 2 mesh	0	0.0
Mineral passing 1 mesh	0	0.0
		100.0
Thickness		1½ in.
Density		over 2.17

MATERIALS REQUIRED FOR 1000 YARDS OF ASPHALTIC CONCRETE PAVEMENT ARE AS FOLLOWS (Typical):

For wearing surface		For concrete base (6 inches of 1:3:6 mix)	
"Chats" or Gravel	= 32 tons	Cement	= 732 sacks=183 barrels
Sand (Coarse)	= 32 tons	Sand	= 77 cubic yards
Sand (Fine)	= 32 tons	Rock	= 155 cubic yards
Dust	= 7 tons	Water	= 7,000 gallons
Asphaltic cement	= 8½ tons		

RELATION OF THE DEFECTS OF AN ASPHALT PAVEMENT TO ITS PHYSICAL PROPERTIES

Cracking is caused by asphaltic cement without sufficient ductility, with too low penetration, insufficient in quantity or that has been over-heated; Imperfections in the base, such as a cracking in the base or the lack of a rigid base or lateral support; Insufficient compression when laid; Lack of traffic.

Disintegration and Hole Formation are caused by asphaltic cement with poor ductility and cementing value, or insufficient to coat mineral aggregate and fill voids; Dirty sand; Non-uniform thickness of surface mixture; Weak foundations in spots; Water from beneath.

Scaling of the Surface Mixture is caused by asphaltic cement lacking in cementing power, insufficient in quantity or subject to decomposition by the weather; Improper grading of mineral, particularly insufficient dust; Dirt conglomerates in sand; Insufficient density.

Waviness and Displacement are caused by asphaltic cement without cementing power, too soft or in too large quantity; Irregularity of surface thickness, or of composition of asphaltic surface mixture; Insufficient dust or filler; Non-rigid base or expansion of the base; Street with heavy grade.

Marking is caused by asphaltic cement that is too soft or in too large quantity; and that is too uniform; Insufficient dust or filler; Insufficient density.

FUNCTIONS OF VARIOUS CONSTITUENTS OF ASPHALTIC SURFACE MIXTURE.

Gravel and Coarse Sand in proper relation diminish voids, insure greater stability and increase density, allow the use of less asphaltic cement, decrease tendency to displacement, waviness and marking, increase susceptibility to damage by erosion and abrasion.

Sand in proper relation increases stability by filling voids in stone, increases capacity to resist abrasion, diminishes tendency to raveling.

Filler or Very Fine Dust in proper relation increases density and stability by filling voids in sand, increases capacity to resist abrasion, allows wider range in penetration of A.C., diminishes or overcomes tendency to marking, displacement and waviness, increases cementition of mixture, increases capacity for A.C., increases the need for much compression and softer A.C. in laying mixture, eliminates lakes of A.C., decreases brittleness of pavement.

A.C. in proper quantity and relation cements mineral particles together, keeps out water, imparts pliability, resiliency and noiselessness, prevents erosion and disintegration of coarse mineral of pavement.

Specifications for Asphaltic Cement for Asphalt Surface Mixture

Impurities.

The asphaltic cement shall contain no water, decomposition products, granular particles or other impurities, and it shall be homogeneous.

Ash passing the 200-mesh screen shall not be considered an impurity, but if greater than 1% corrections in gross weights shall be made to allow for the proper percentage of bitumen.

Specific Gravity.

The specific gravity of the asphaltic cement shall not be less than 1.000 at 77°F.

Fixed Carbon.

The fixed carbon shall not be greater than 18%.

Solubility in Carbon Bisulphide.

The asphaltic cement shall be soluble to the extent of at least 99% in chemically pure carbon bisulphide at air temperature and based upon ash free material.

Solubility in Carbon Tetrachloride.

The asphaltic cement shall be soluble to the extent of at least 98.5% in chemically pure carbon tetrachloride at air temperature and based upon the ash free material.

Melting Point.

The melting point shall be greater than 128°F and less than 160°F (General Electric method).

Flash Point.

The flash point shall be not less than 400°F by a closed test.

Penetration.

The asphaltic cement shall be of such consistency that at a temperature of 77°F a No. 2 needle weighted with 100 grams in five seconds shall not penetrate more than 9.0 nor less than 5.0 millimeters. For asphaltic cement containing ash 0.2 millimeter may be added for each 1.0% of ash to give the true penetration.

Loss by Volatilization.

The loss by volatilization shall not exceed 2%, and the penetration after such loss shall be more than 50% of the original penetration. The ductility after heating as above shall have been reduced not more than 20%, the value of the ductility in each case being the number of centimeters of elongation at the temperature at which the asphaltic cement has a penetration of 5.0 millimeters. The volatilization test shall be carried out essentially as follows:

Fifty grams of the asphaltic cement in a cylindrical vessel 55 millimeters in diameter and 35 millimeters high shall be placed in an electrically heated oven at a temperature of 325°F and so maintained for a period of 5 hours. The oven shall have one vent in the top 1 centimeter in diameter, and the bulb of the thermometer shall be placed adjacent the vessel containing the asphaltic cement.

Ductility.

When pulled vertically or horizontally by a motor at a uniform rate of 5 centimeters per minute in a bath of water, a cylinder of asphaltic cement 1 centimeter in diameter at a temperature at which its penetration is 5 millimeters shall be elongated to the extent of not less than 10 centimeters before breaking.

EPITOME OF THE PURPOSES OF CERTAIN SPECIFICATIONS FOR ASPHALTIC CEMENT.

Impurities are a measure of the care with which the asphaltic cement has been refined and handled. Usually the presence of impurities in large quantities indicates a poor grade of asphalt. Water as an impurity would act as a diluent and would cause foaming in the kettle. Ash or mineral matter is not considered an impurity if it is a natural constituent of the asphaltic cement, but the mix and cementing value must be figured on the bitumen alone.

Specific Gravity of the asphaltic cement should be over 1.000. The advantage of a specific gravity more than 1.000 is that there will be less tendency for water to float out the asphaltic cement. The specific gravity is raised by the presence of mineral matter. Asphaltic oils of a penetration satisfactory for paving purposes always have a specific gravity greater than 1.000. Paraffin base oil and air-blown products usually have a specific gravity less than 1.000.

Fixed Carbon is a measure of the chemical constitution of an asphalt to some extent. Certain types of asphalt such as Mexican have naturally a constitution that yields a large amount of fixed carbon. Fixed carbon is largely used for determining the source and uniformity of an asphalt. Fixed carbon is not free carbon, but includes free carbon, which is practically absent in asphaltic cements.

Solubility in Carbon Bisulphide is a measure of the purity of an asphaltic cement. The cementing value, other things being equal, is proportional to the carbon bisulphide solubility. Any carbonaceous material such as coal tar or pitch is detected by the carbon bisulphide solubility test.

Solubility in Carbon Tetrachloride is very nearly the same as the solubility in carbon bisulphide. It is claimed that an asphalt having more than 1½% difference in the solubility in carbon bisulphide and carbon tetrachloride has been subjected to excessive heat in refining.

Melting Point is the temperature at which the asphaltic cement will flow readily. The melting point desired is dependent upon the mixture. If the amount of fine dust in the mineral aggregate is low, the asphalt should have a melting point higher than the highest temperature to which the pavement is subjected.

Flash Point is a measure of the amount of volatile hydrocarbons that are present in the asphalt and its readiness to decompose by heat.

Penetration is a measure of the consistency of the asphaltic cement. It is merely a quick, convenient test for checking up numerous individual samples. The penetration is expressed in degrees and in accordance with the method of the American Society for Testing Materials, each degree representing 1/10 of a millimeter or 1/250 of an inch. The penetration, then, is the number of degrees that a No. 2 sewing needle when weighted with 100 grams will pass vertically into the A. C. at a temperature of 77°F (25°C) in 5 seconds. The penetration to be desired will depend upon the climate, the nature of the traffic, the grading of the mineral particles, the amount of voids, the amount of compression attainable, the ductility and cementing strength of the A. C. and the amount of dust filler.

Loss by Volatilization is a measure of the amount of light hydrocarbons that are present in asphalt and is also a measure of the tendency of an asphalt to oxidize and to lose its ductility and penetration. Asphaltic cement which has no ductility after this volatilization test will not be satisfactory for paving purposes.

Ductility is the measure of the ability of an asphaltic cement to expand and contract without breaking or cracking. The same asphalt at a higher penetration should have a higher ductility, so all ductility tests should be based on a certain definite penetration regardless of the temperature, or should be based upon a temperature of 32°F. Ductility is also a measure of the cementing strength.

Viscosity is a measure of ability of the asphaltic cement to impart plasticity and malleability.

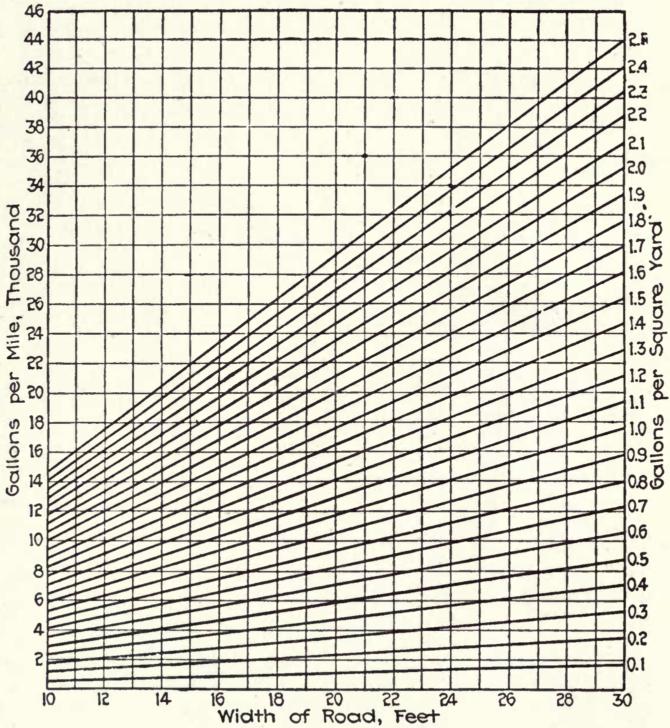
EFFECT OF MINERAL MATTER ON THE PENETRATION OF ASPHALTIC CEMENT (Typical Case).

% Dust	Penetration	Melting Point
0	200	100
35	128	110
55	92	120
70	34	150

In a general way, 1% of dust in asphaltic cement decreases the penetration 2 points with A. C. of ordinary penetration. This will vary somewhat according to the character of the asphaltic cement. A pavement having a relation of 2 parts dust and 1 part bitumen cannot soften or flow in hot weather.

FLUXING OF HARD ASPHALT.

As a general rule, 30% of 10-12°Be' asphaltic flux is required to bring Trinidad asphalt to a penetration of 50. Less of paraffin flux is required. For each 1% of asphaltic flux added to about 50° asphalt the penetration is raised 3 points. For exact results a test should be made with the actual materials in question.



GALLONS OF ROAD OIL REQUIRED PER MILE OF ROAD AT GIVEN WIDTH AND RATE

Table for Calculating Voids in Sand and Hard Limestone

Weight in Pounds per Cubic Foot	% Voids	Weight in Pounds per Cubic Foot	% Voids
60	63.9		
61	63.3	96	42.2
62	62.6	97	41.6
63	62.1	98	41.0
64	61.5	99	40.4
65	60.9	100	39.8
66	60.3	101	39.2
67	59.6	102	38.6
68	59.1	103	38.0
69	58.5	104	37.4
70	57.9	105	36.7
71	57.3	106	36.2
72	56.7	107	35.6
73	56.0	108	35.0
74	55.4	109	34.4
75	54.8	110	33.8
76	54.2	111	33.2
77	53.6	112	32.5
78	53.0	113	32.0
79	52.4	114	31.4
80	51.8	115	30.7
81	51.2	116	30.2
82	50.6	117	29.6
83	50.0	118	28.9
84	49.4	119	28.3
85	48.8	120	27.8
86	48.2	121	27.2
87	47.6	122	26.6
88	47.0	123	26.0
89	46.4	124	25.4
90	45.8	125	24.7
91	45.2	126	24.1
92	44.6	127	23.5
93	44.0	128	22.9
94	43.4	129	22.3
95	42.8	130	21.7

Grams per 100 cc $\times$ .6243 $=$ pounds per cubic foot.
% voids $= 100 - (0.376 \times$ grams per 100 cc).

Typical Specifications for Wearing Surface of Asphaltic Concrete

The wearing surface shall be composed of a properly prepared mixture of bitumen, dust, sand and chats, gravel or trap rock.

The amount of asphaltic cement, dust, sand and chats shall be so regulated that the average mixture shall be within the following limits by weight:

	Size of Opening, In. Square	Lower Limit	Upper Limit	Average Typical
Bitumen..................		7.0%	10.0%	8.0%
Dust passing 200 mesh.....	0.0029	8.0	18.0	12.0
Sand passing 80 mesh.....	0.0068	10.0	20.0	12.0
Sand passing 40 mesh.....	0.0150	15.0	25.0	20.0
Sand passing 10 mesh.....	0.065	15.0	40.0	20.0
Sand passing 4 mesh.....	0.185	10.0	22.0	20.0
Sand passing 2 mesh.....	0.380	0.0	10.0	8.0

Ordinarily this mixture is to be obtained by the use of rock, coarse sand, fine bank sand and limestone dust or cement.

All of the mineral ingredients except the dust shall be heated and mixed in a suitable drier to a temperature of from 300 to 350°F.. The bin containing the mineral shall be permanently equipped with a recording or an observation thermometer.

The asphaltic cement shall be added after it has been heated to a temperature not exceeding 360°F. The heating of the asphaltic cement must be by steam or if by direct fire vigorous mechanical stirring must be used. A recording thermometer should be used in the A. C. kettle and the aggregate.

The dust shall be added dry to each batch separately prior to the addition of the A. C. All materials shall be weighed.

The mixing shall be for a sufficient time to thoroughly and uniformly mix all materials and for a period of not less than one minute.

The temperature of the mixture shall be between 270°F and 350°F when it leaves the plant.

It shall be between 250°F and 350°F on the street (preferably 300°F).

The surface of the concrete shall be dry and clean at the time the surface mixture is applied.

The mixture shall be applied and raked to a uniform thickness, none being allowed to remain at the point of dumping and all lumps being thoroughly raked out.

The amount of hot mix applied shall be at least 210 pounds per square yard and shall be of a uniform thickness of 2 inches after rolling.

The compression shall be applied with a 5-ton roller until complete and sufficient in the judgment of the inspector and as indicated by the tests of the preceding day's laid surface. Hydraulic cement may be dusted over and rolled into the finished pavement.

The specific gravity of the compressed surface mixture shall average 2.20 or more and shall not at any time be less than 2.16. A piece of the compressed surface mixture after being placed in water for 24 hours shall not have absorbed water and shall not have become crumbly or weakened.

Kansas State Highway Commission Specifications for Road Oil

SPECIFICATION "A."

Road Oil for the Surface Treatment of Earth Roads.
(Cold Application.)

The road oil shall be homogeneous and free from water. It shall conform to the following requirements:

Specific gravity, 25°C/25°C (77°F/77°F)	Not less than 0.910
Specific viscosity at 40°C (104°F)	10.0 to 25.0
Loss at 163°C (325°F), 5 hours	Not over 25.0%
Total bitumen	Not less than 99.5%
Per cent of total bitumen insoluble in 86° B. Naphtha	Not less than 5.0%
Fixed carbon	Not less than 4.0%

SPECIFICATIONS "B."

Road Oil for the Surface Treatment of Earth Roads.
(Cold Application.)

The road oil shall be homogeneous and free from water. It shall conform to the following requirements:

Specific gravity, 25°C/25°C (77°F/77°F)	Not less than 0.890
Specific viscosity at 40°C (104°F)	10.0 to 25.0
Total bitumen	Not less than 99.5%
Percentage of residue of 100 penetration	40 to 60

SPECIFICATION "M1" ASPHALT BINDER.

The asphalt shall be homogeneous and free from water. It shall conform to the following requirements:

Specific gravity, 25°C/25°C(77°F/77°F)	Not less than 1.040
Flash point	Not less than 163°C (325°F)
Penetration at 25°C (77°F) 100 gm. 5 sec.	
When total bitumen is more than 90%	110 to 140
When total bitumen is 80% to 90%	90 to 120
When total bitumen is less than 80%	80 to 100
Loss at 163°C (325°F), 5 hours	Not over 4.0%
Penetration of residue at 25°C (77°F) 100 gms. 5 sec.	
When total bitumen is more than 80%	Not less than 50
When total bitumen is less than 80%	Not less than 40
Total bitumen:	
Bermudez products	Not less than 95.0%
Cuban products	Not less than 80.0%
Trinidad products	Not less than 65.0%
Per cent of total bitumen insoluble in 86° B. Naphtha	15.0 to 28.0
Fixed carbon	8.0% to 14.0%

Brittleness Test.—A cylindrical prism of the asphalt 1 centimeter in diameter after being maintained at a temperature of 5°C (41°F) for 20 minutes shall bend 180° at any point without checking or breaking. The bending shall take place in one continuous operation requiring not more than ten seconds.

SPECIFICATIONS "M2" ASPHALT BINDER.

The asphalt shall be homogeneous and free from water. It shall conform to the following requirements:

Specific gravity 25°C/25°C (77°F/77°F) . 1.020 to 1.080
Flash point............................Not less than 163°C (325°F)
Ductility at 25°C (77°F)...............Not less than 50 cm
Penetration at 25°C (77°F) 100 gm. 5 sec. 110 to 140
Loss at 163°C (325°F) 5 hrs...........Not over 3%
Penetration of residue at 25°C (77°F)
100 gms. 5 sec.........................Not less than 50
Total bitumen..........................Not less than 99.5%
Per cent of total bitumen insoluble in
86° B. Naphtha.........................15.0 to 28.0
Fixed carbon........................... 9.0% to 17.0%

Brittleness Test.—A cylindrical prism of the asphalt 1 centimeter in diameter after being maintained at a temperature of 5°C (41°F) for twenty (20) minutes shall bend 180° at any point without checking or breaking. The bending shall take place in one continuous operation requiring not more than ten seconds.

SPECIFICATIONS "M3" ASPHALT BINDER.

The asphalt shall be homogeneous and free from water. It shall conform to the following requirements:

Specific gravity 25°C/25°C (77°F/77°F) . 0.970 to 1.020
Flash point............................Not less than 200°C (392°F)
Ductility at 25°C (77°F)...............Not less than 15 cm
Penetration at 25°C (77°F) 100 gm. 5 sec. 80 to 100
Loss at 163°C (325°F) 5 hrs...........Not over 2.0%
Penetration of residue at 25°C (77°F)
100 gms. 5 sec.........................Not less than 50
Total bitumen..........................Not less than 99.5%
Per cent of total bitumen insoluble in
86° B. Naphtha.........................19.0% to 27.0%
Fixed Carbon .... 8.0% to 14.0%

Brittleness Test.—A cylindrical prism of the asphalt 1 centimeter in diameter after being maintained at a temperature of 5°C (41°F) for twenty (20) minutes shall bend 180° at any point without checking or breaking. The bending shall take place in one continuous operation requiring not more than ten seconds.

SPECIFICATIONS "MT" REFINED TAR BINDER.

The refined tar shall be homogeneous and free from water. It shall conform to the following requirements:

Specific gravity 25°C (77°F).........1.180 to 1.260
Float test 50°C (122°F)...............110 sec. to 150 sec.
Total distillate by weight: Not over
To 170°C (338°F)................. 1.0%
To 300°C (572°F).................15.0%
Specific gravity to total distillate 25°C
(77°F)...........................Not less than 1.030
Melting point of residue..............Not over 75°C (167°F)
Solubility in carbon disulphide..........77.0% to 88.0%
Inorganic matter (ash)................Not over 0.5%

SPECIFICATIONS "ST1"

Refined Tar for Surface Treatment of Bituminous or Water-Bound Macadam Roads.

(Hot Application.)

The refined tar shall be homogeneous and free from water. It shall conform to the following requirements:

Specific gravity 25°C/25°C (77°F/77°F)	1.180 to 1.250
Float test 32°C (90°F)	90 seconds to 150 seconds
Total distillate by weight:	Not over
To 170°C (338°F)	1.0%
To 300°C (572°F)	25.0%
Specific gravity of total distillate 25°C (77°F)	Not less than 1.030
Melting point of residue	Not over 75°C (167°F)
Solubility in carbon bisulphide	78.0% to 88.0%
Inorganic matter (ash)	Not over 0.5%

SPECIFICATIONS "ST2"

Refined Tar for Surface Treatment of Bituminous or Water-Bound Macadam Roads.

(Cold Application.)

The refined tar shall be homogeneous and shall conform to the following requirements:

Specific gravity 25°C/25°C (77°F/77°F)	1.120 to 1.200
Specific viscosity at 40°C (104°F)	4.0 to 12.0
Total distillate by weight:	Not over
To 170°C (338°F)	5.0%
To 300°C (572°F)	35.0%
Specific gravity of total distillate 25°C (77°F)	Not less than 1.010
Melting point of residue	Not over 65°C (149°F)
Solubility in carbon disulphide	88.0% to 96.0%
Inorganic matter (ash)	Not over 0.5%

SPECIFICATIONS "S1."

Heavy Oil for Surface Treatment of Bituminous or Water-Bound Macadam Roads.

(Hot Application.)

The road oil shall be homogeneous, free from water and shall not foam when heated to 150°C (302°F). It shall conform to the following requirements:

Specific gravity 25°C/25°C (77°F/77°F)	Not less than 0.980
Flash point	Not less than 150°C (302°F)
Specific viscosity to 100°C (212°F)	30.0 to 70.0
Float test at 50°C (122°F)	100 seconds to 20 seconds
Loss at 163°C (325°F) 5 hrs	Not over 5.0%
Float test of residue at 50°C (122°F)	120 seconds to 240 seconds
Total bitumen	Not less than 99.5%
Per cent of total bitumen insoluble in 86°B Naphtha	10.0 to 25.0%
Fixed carbon	7.0% to 15.0%

SPECIFICATIONS "S2."

Medium Oil for Surface Treatment of Bituminous or Water-Bound Macadam Roads.

(Hot Application.)

The road oil shall be homogeneous, free from water and shall not foam when heated to 100°C (212°F). It shall conform to the following requirements:

Specific gravity 25°C/25°C (77°F/77°F)	0.960 to 1.010
Flash point	Not less than 100°C (212°F)
Specific viscosity to 100°C (212°F)	5.0 to 15.0
Float test at 32°C (90°F)	30 seconds to 90 seconds
Loss at 163°C (325°F) 5 hrs	Not over 15.0%
Float test of residue at 50°C (122°F)	90 seconds to 180 seconds
Total bitumen	Not less than 99.5%
Per cent of total bitumen insoluble in 86°B Naphtha	7.0 to 20.0%
Fixed carbon	5.0% to 10.0%

SPECIFICATIONS "S3"

Light Oil for Surface Treatment of Bituminous or Water-Bound Macadam or of Gravel Roads.

(Cold Application.)

The road oil shall be homogeneous and free from water. It shall conform to the following requirements:

Specific gravity 25°C/25°C (77°F/77°F)	0.920 to 0.970
Specific viscosity at 25°C (77°F)	30.0 to 70.0
Loss at 163°C (325°F) 5 hrs	20.0% to 30.0%
Total bitumen	Not less than 99.5%
Per cent of total bitumen insoluble in 86°B Naphtha	5.0 to 20.0
Fixed carbon	4.0% to 10.0%

ASPHALT FILLER FOR BRICK.
(Mexican Type for Vertical Fiber Brick.)

The joints between the paving blocks next the curb, railroad tracks and around manholes, or other street structures, shall be filled with asphalt filler complying with the following requirements:

The asphalt filler shall be composed of asphalt, or asphalts properly fluxed, if flux is necessary to bring it to the proper consistency. It shall contain at least 99½ per cent bitumen soluble in carbon bisulphide. At least 99½ per cent of the contained bitumen soluble in carbon bisulphide shall be soluble in cold carbon tetrachloride.

The penetration shall conform to the following:

No. 2 Needle 5 Sec. 100 Grammes at 77°F 25 to 35.
No. 2 Needle 1 Min. 200 Grammes at 32°F not below 10.
No. 2 Needle 5 Sec. 50 Grammes at 115°F not above 90.

The above filler shall be waterproof, shall adhere strongly to the brick, both in the joints and on the surface, and shall remain ductile and pliable at all climatic temperatures to which it may be subjected. It shall not run in the joints during the hottest summer weather, nor become hard or brittle when cold.

The melting point shall not be less than 165°F nor more than 200°F. The brick shall be dry and the asphalt filler shall be poured at a temperature of not less than 350°, nor more than 450°F and by means of squeegees, especially adapted to the purpose, the joints shall be thoroughly filled and shall provide sufficient hot material on the top surface as will fully cover and penetrate the etched or reticular surface with a thin coat of the hot asphalt.

The minimum amount of coarse sand, clean and free from dust, necessary to keep the fresh asphalt from sticking to traffic shall be immediately applied.

ASPHALT FILLER FOR BRICK.
(Texaco Type for Vertical Fiber.)

The joints between the paving blocks next the curb, railroad tracks and around manholes, or other street structures, shall be filled with asphalt filler complying with the following requirements:

The asphalt filler shall be composed of asphalt, or asphalts properly fuxed, if flux is necessary to bring it to the proper consistency. It shall contain at least 98 per cent bitumen soluble in carbon bisulphide. At least 98½ per cent of the contained bitumen soluble in carbon bisulphide shall be soluble in cold carbon tetrachloride.

The penetration shall conform to the following:

No. 2 Needle 5 Sec. 100 Grammes at 77°F 25 to 60.
No. 2 Needle 1 Min. 200 Grammes at 32°F not below 10.
No. 2 Needle 5 Sec. 50 Grammes at 115°F not above 200.

The above filler shall be waterproof, shall adhere strongly to the brick, both in the joints and on the surface, and shall remain ductile and pliable at all climatic temperatures to which it may be subjected. It shall not run in the joints during the hottest summer weather, nor become hard or brittle when cold.

The melting point shall not be less than 150°F nor more than 225°F. The brick shall be dry and the asphalt filler shall be poured at a temperature of not less than 375°, nor more than 450°F and by means of squeegees, especially adapted to the purpose, the joints shall be thoroughly filled and shall provide sufficient hot material on the top surface as will fully cover and penetrate the etched or reticular surface with a thin coat of the hot asphalt.

The minimum amount of coarse sand, clean and free from dust, necessary to keep the fresh asphalt from sticking to traffic shall be immediately applied.

ASPHALT FILLER FOR BRICK.
(Sarco Type.)

The joints between the paving blocks next the curb, railroad tracks and around manholes, or other street structures, shall be filled with asphalt filler complying with the following requirements:

The asphalt filler shall be composed of asphalt containing at least 98 per cent of bitumen soluble in carbon bisulphide. At least 98½ per cent of the contained bitumen soluble in carbon bisulphide shall be soluble in cold carbon tetrachloride. The penetration shall be uniform in consistency and shall not vary more than seven and one-half (7½) points in penetration from the following standard:

The penetration shall conform to the following:

No. 2 Needle 1 Min. 200 Grammes at 32°F 30.
No. 2 Needle 5 Sec. 100 Grammes at 77°F 40.
No. 2 Needle 5 Sec. 50 Grammes at 115°F 60.

The above filler shall be waterproof, shall adhere strongly to the brick, both in the joints and on the surface, and shall remain ductile and pliable at all climatic temperatures to which it may be subjected. It shall not run in the joints during the hottest summer weather, nor become hard or brittle when cold.

The melting point shall be not less than 225°F, nor more than 275°F. The brick shall be dry and the asphalt filler shall be poured at a temperature of not less than 375°F, nor more than 450°F, and by means of squeegees, especially adapted to the purpose, the joints shall be thoroughly filled and shall provide sufficient hot material on the top surface as will fully cover the etched or reticular surface with a thin coat of the hot asphalt.

A top dressing of one-half (½) inch of coarse sand shall be spread immediately after the filler is applied and before the same has had its initial set, and shall immediately be rolled with a roller weighing not less than three nor more than five tons until the sand is thoroughly imbedded in the asphalt filler. As soon as the sand has been thoroughly ground into the top dressing of asphalt by traffic the surplus may then be swept off clean.

Chemical Nature of Cracking of Oil

When crude oil is subjected to ordinary distillation by fire the ht products naturally present in the oil are distilled off as such to a temperature of about 300°C (572°F) comprising both the gasoine and the kerosene. Above this temperature the hydrocarbons undergo partial decomposition while distilling, with the result that some light products are produced and distilled along with the heavy products. Olefins as well as paraffin compounds of lower molecular weight than the oil being heated are formed. By vigorous firing the entire oil residue may be distilled, leaving only a variable amount of residual carbon as a product of decomposition. The amount of carbon and gas formed by this pyrogenic decomposition s greater with the asphaltic or naphthene petroleums than with he paraffin base petroleums. A typical heavy Mid-Continent petroeum gives 4.5% of carbon and 4.0% of gas on distillation to coke or carbon. With pure paraffin base oils the amounts of carbon and gas formed are comparatively slight.

This property of all heavy petroleums in decomposing into hydrocarbons of lower molecular weight by heating is generally known as cracking. The chemical reactions involved in cracking are not definite. It was originally supposed that cracking involved the formation of a large amount of olefins according to the following reaction:

$$C_nH_{2n+2} = C_{n-m}H_{2(n-m)+2} + C_mH_{2m}$$

pecific illustration of which would be

$C_{15}H_{32}$	$=C_8H_{18}$	$+C_7H_{14}$
Pentadecane	=Octane	+Heptylene

This reaction does not, however, accord with the facts, since gas and carbon are always formed in varying amount. A reaction which corresponds to the yields as experimentally found under certain conditions is the following:

$$2C_nH_{2n+2} = 2C_{n-m}\ H_{2(n-m)+2} + mCH_4 + mC$$

or as a specific illustration

$C_{15}H_{32}$	$=C_8H_{18}$	$+7CH_4$	$+7C$
Pentadecane	=Octane	+Methane	+Carbon

Yet under certain other conditions the amount of gas formed is very small, indicating that the following reaction was partly carried out.

$$(2m+2)\quad C_nH_{2n+2} = (2n+2)\quad C_mH_{2n+2} + 2(n-m)C$$

or as an illustration

$9C_{15}H_{32}$	$=16\,C_8H_{18}$	$+7C$
Pentadecane	=Octane	+Carbon

This last reaction is also indicated by the yields of gasoline obtained from some crude oils given in the table on page 120.

Pure paraffin wax of melting point of 130°F and specific gravity of 0.892 on repeated cracking confined under pressure up to 57 atmospheres at temperature of 400°C and with a vapor space twice the volume of the liquid, yielded 32.5% by volume of gasoline of 0.724=63.4°Be′ gravity or 29.1% by weight by each treatment or a total of 94.7% by weight, or 104% by volume.

The amount produced on first six treatments was as follows:

First. . . . . .29.1% by weight of original paraffin
Second. . . . . .19.9% by weight of original paraffin
Third. . . . . .14.5% by weight of original paraffin
Fourth. . . . . 9.9% by weight of original paraffin
Fifth. . . . . 6.8% by weight of original paraffin
Sixth. . . . . 4.7% by weight of original paraffin

84.9%

The gasoline produced consisted of paraffin hydrocarbons as shown in curve on page 227.

That the cracking of oil is not simply a decomposition of the hydrocarbon molecules is shown by the curves on pages 211-2-3. These curves show the relation between the distilling temperature and the specific gravity of water white Cabin Creek distillate. Before cracking it had an end point of about 540°F and its heaviest ends had a specific gravity of 0.815. After cracking the end point was above 640°F and the end gravity above 0.900. Both heavier and higher boiling hydrocarbons as well as lighter and lower boiling hydrocarbons were produced simultaneously. There must have been polymerization to yield hydrocarbons of both higher boiling point and higher specific gravity. By continued cracking there may be made from water white distillate, solid and ductile asphaltic cement of typical conchoidal fracture. It may be that these polymerized products will make lubricating oils if they prove to be more resistant to heat decomposition and ordinary paraffin hydrocarbons.

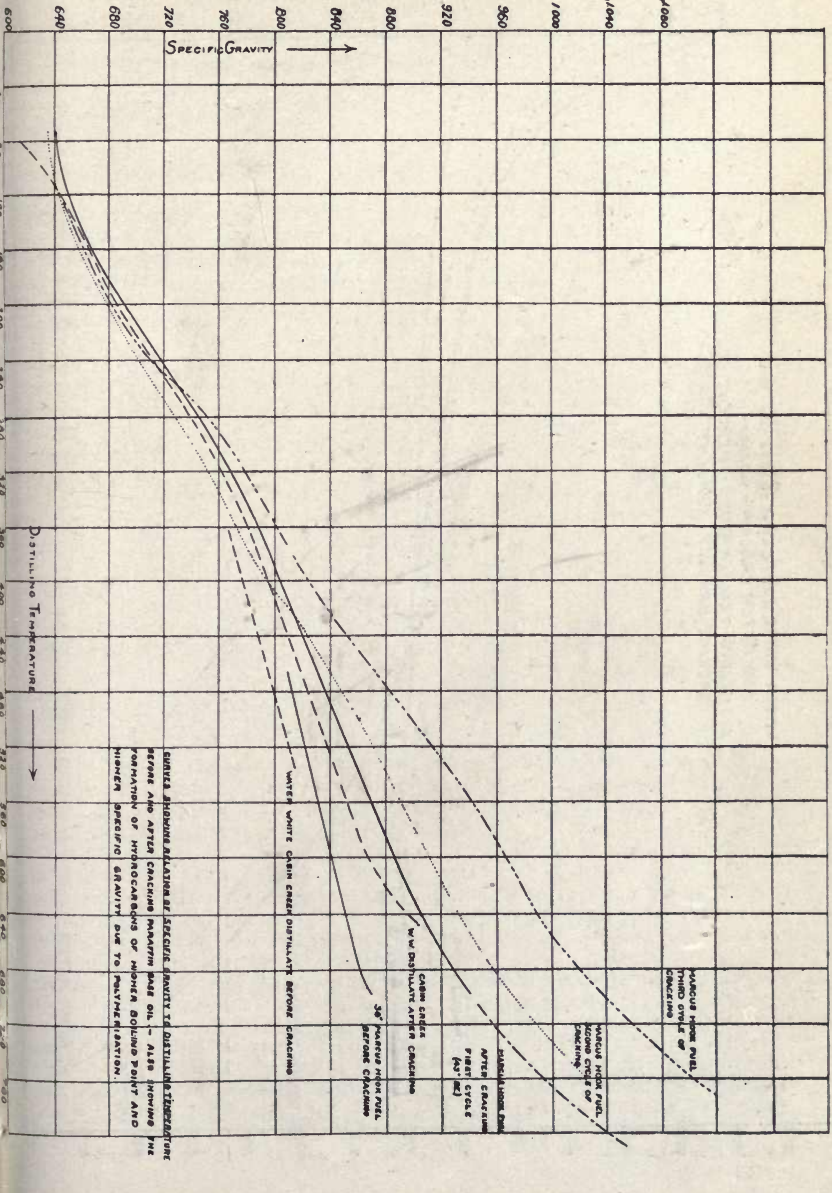
The gases produced by cracking likewise are not simple split-off hydrocarbons but vary according to the method of cracking. In liquid phase cracking the chief variation is in the olefin and hydrogen content. In a general way, there seems to be a tendency for low percentages of hydrogen to be associated with low percentages of olefins. A typical gas made in a Burton still gives the following analysis:

Methane and ethane (C_nH_{2n+2})	= 82.0%
Olefins	= 8.5%
Hydrogen	= 9.5%

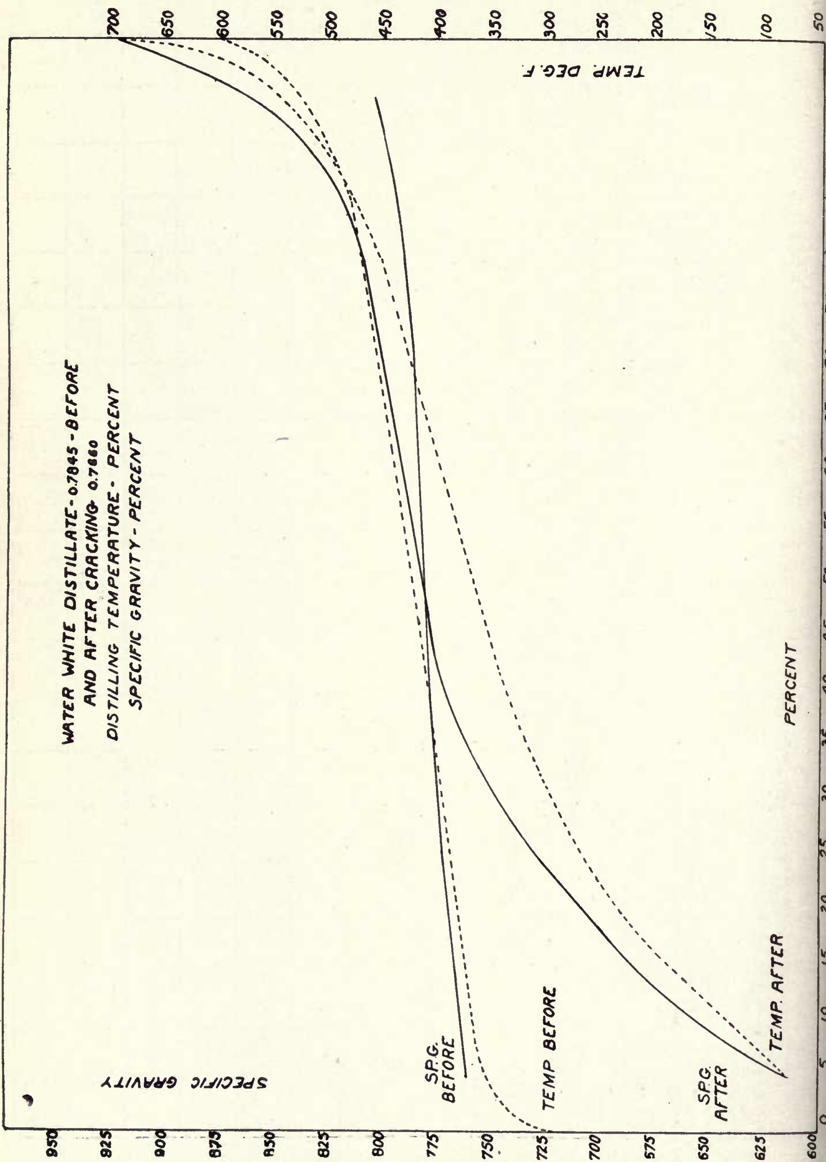
One of the problems in cracking is to limit the amount of hydrogen. This has been partially done by allowing the hydrogen to remain in contact with the cracked distillate under high pressure and at a temperature somewhat below the ordinary temperature of cracking. (See U. S. patent 1255138.)

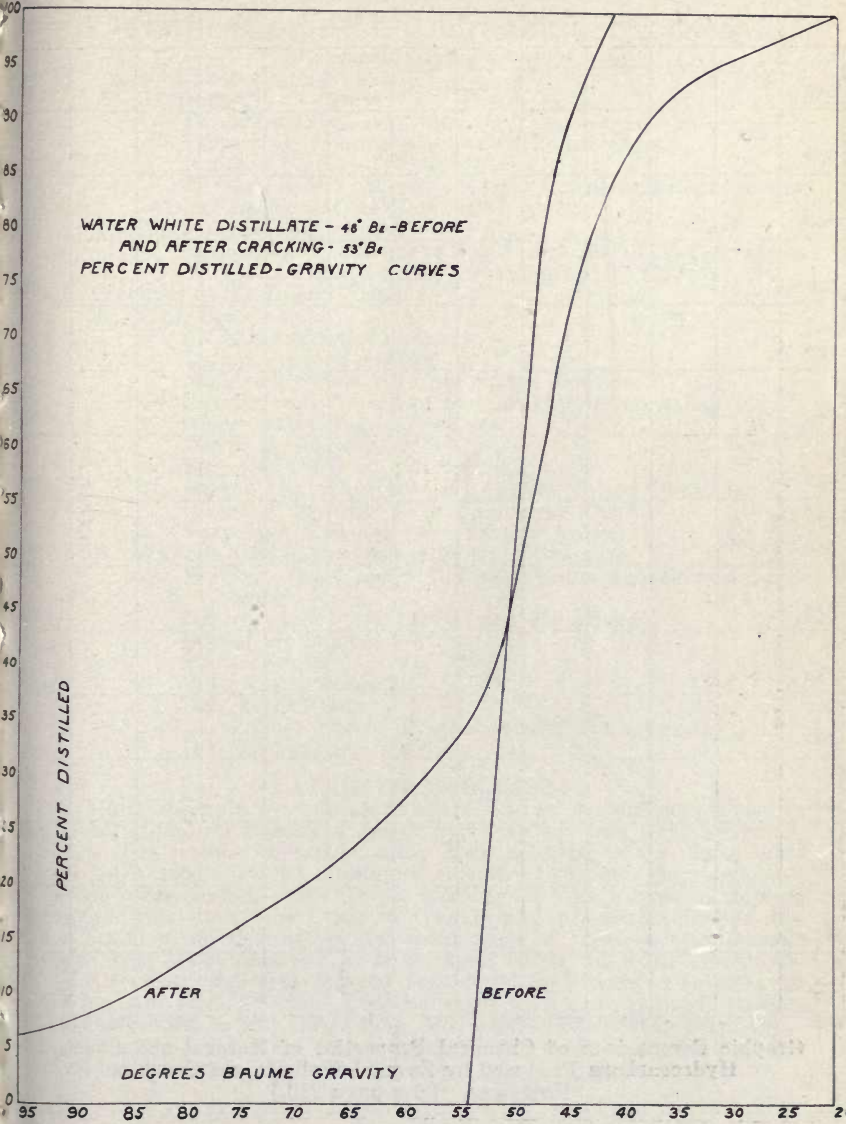
The chart on page 214 shows some of the relative properties of light hydrocarbons made by various processes used more or less in a commercial way for the production of gasoline from heavy oil. The smooth lines represent the distilling temperatures and the irregular lines represent the per cent of olefins in the fractions represented by the specific gravities indicated at the bottom of the chart. The per cent olefins or unsaturated hydrocarbons are shown at the right and the distilling temperatures are shown at the left.

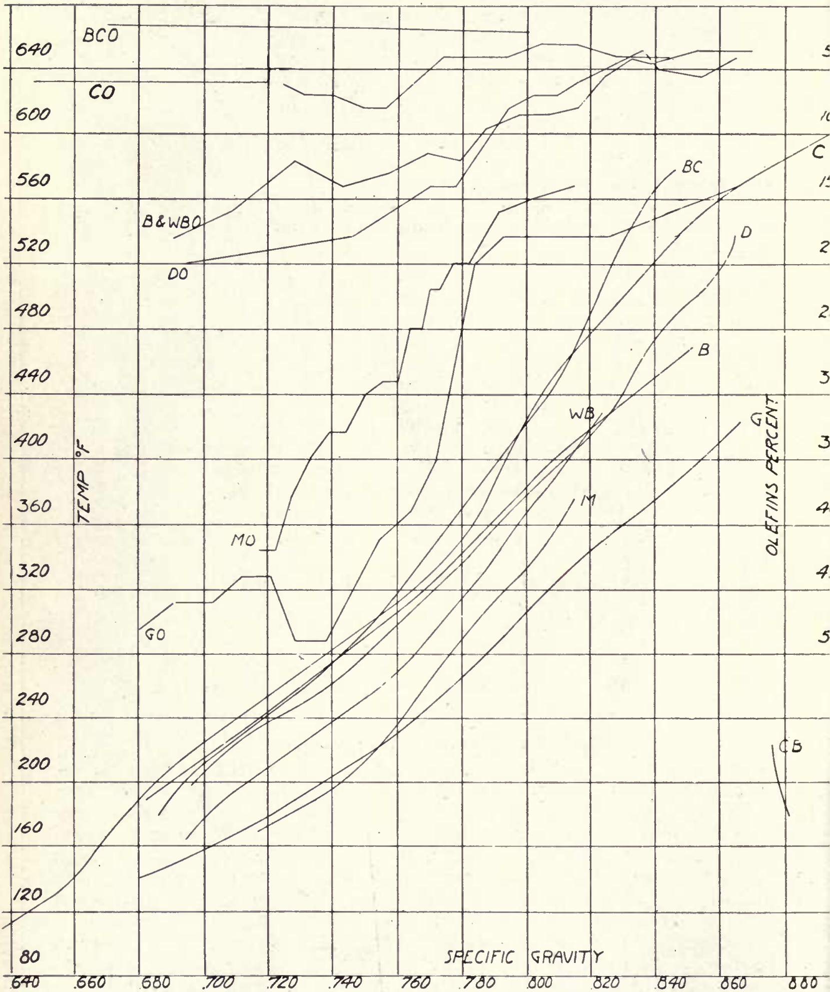
The product marked B C is Burkburnett crude oil, B C O being the olefin curve. C is a gasoline made by a certain type of very high pressure equilibrium cracking in the liquid phase. W B is gasoline made by the Benton process. B and D are gasolines made by 85-170 lbs. pressure distillation. M and G are gasolines made by cracking in the liquid phase. C B is coal tar benzol as sold for blending for motor use.



CURVES SHOWING RELATION OF SPECIFIC GRAVITY TO DISTILLING TEMPERATURE BEFORE AND AFTER CRACKING PARAFFIN BASE OIL.—ALSO SHOWING THE FORMATION OF HYDROCARBONS OF HIGHER BOILING POINT AND HIGHER SPECIFIC GRAVITY DUE TO POLYMERIZATION.


WATER WHITE DISTILLATE - 0.7845 - BEFORE
AND AFTER CRACKING 0.7880
DISTILLING TEMPERATURE - PERCENT
SPECIFIC GRAVITY - PERCENT
TEMP. DEG. F.
SPECIFIC GRAVITY
SP.G. BEFORE
TEMP BEFORE
SP.G. AFTER
TEMP. AFTER
PERCENT


WATER WHITE DISTILLATE - 46° Bé - BEFORE
AND AFTER CRACKING - 53° Bé
PERCENT DISTILLED-GRAVITY CURVES
PERCENT DISTILLED
DEGREES BAUME GRAVITY
AFTER
BEFORE
100
95
90
85
80
75
70
65
60
55
50
45
40
35
30
20
15
10
5
0
95
90
85
80
75
70
65
60
55
50
45
40
35
30
25



Graphic Comparison of Chemical Properties of Natural and Cracked Hydrocarbons Produced by Several Well Known Cracking Processes. (See page 210.)

Classification of Oil Cracking Processes

(Representative Patents)

I. Cracking in the vapor phase.
  A Atmospheric Pressure.
    Oil gas plants—very high temperature.
    Pintsch Gas Plants—very high temperature.
    Blaugas Plants—1000-12000°F.
    Parker (W.M.) process—at 1000°F with or without steam.
    Greenstreet—Cherry red with steam.
  B With Increased Pressure.
    Rittman process—above 950°F and 200-300 lbs. pressure.
    W. A. Hall process—1100°F and about 75 lbs. pressure.

II. Cracking in the Liquid Phase.
  A With Distillation.
    1. At Atmospheric Pressure.
      Luther Atwood (1860).
      McAfee Process with aluminum chloride.
      Russian and American Practice for illuminating oils.
    2. Above Atmospheric Pressure.
      Dewar & Redwood (1890).
      Bacon & Clark at 100-300 lbs.
      Burton (Standard Oil Co.) 650-850°F and 60-85 lbs.
      Dubbs, J. A., over 10 lbs. and over 300°F.
    3. Very high pressure (over 27 atmospheres).
  B Without Distillation and with High Pressure.
    1. Without vapor space for equilibrium (continuous processes).
      Benton (1886) 700-1000°F and 500 pounds.
      Goebel-Wellman.
      Mark (English).
    2. With Vapor Space.
      (a) Intermittent.
        Palmer (below 27 atmospheres for aromatics).
      (b) Continuous.

CATALYTIC PROCESSES

Many claims are made as to the virtue of certain substances in promoting the conversion of heavy hydrocarbons into light hydrocarbons. The writer has made many high pressure-liquid phase tests with such substances as aluminum chloride, hydrogen chloride, manganese oxide, nickel, copper, lime, mercury, sodium nitrate, aluminum powder, zinc dust, iron dust, iron oxide and platinized pumice and has found in no case either increased rates of reaction or increased yields over those obtained by heat alone under the same conditions.

Electrical processes are not considered by informed refiners on the basis of cost alone and none have yet been demonstrated as having any virtue, in fact, other than as a means of applying heat.

In some instances a sweeter and whiter product resulted by use of added chemicals than with heat alone.

No Model.)

G. L. BENTON.

PROCESS OF REFINING CRUDE PETROLEUM OIL.

No. 342,564. Patented May 25, 1886.

Fig. 1

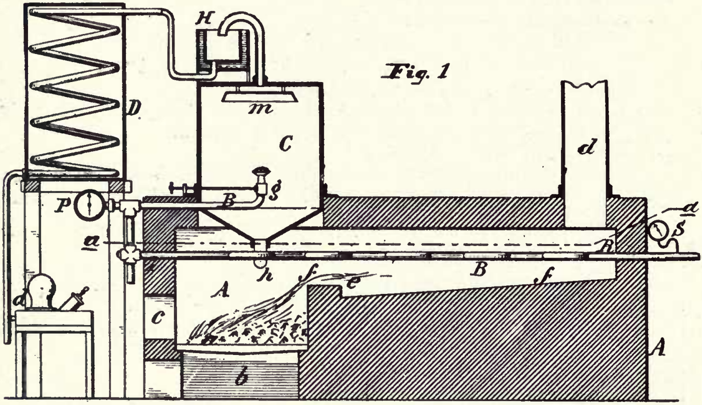


Fig. 2

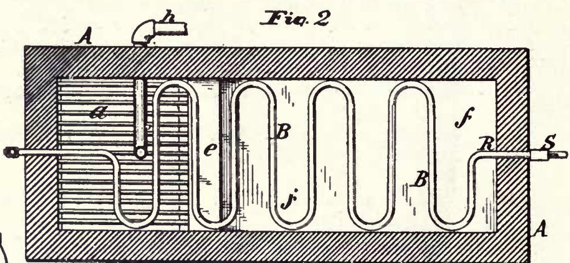
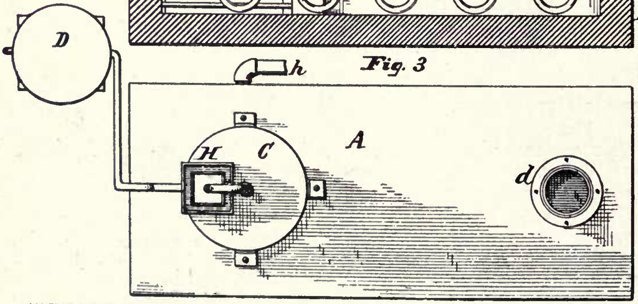


Fig. 3



WITNESSES
C. H. Woodruff Jr.
C. A. Woodruff

INVENTOR
George L. Benton
By J. Walter Douglass
Atty

Development of Commercial Practice in Cracking of Oil

It has been stated that the commercial cracking of oil was accidentally discovered in the winter of 1861 by a stillman at Newark, New Jersey. However, this is probably not the case, since a patent was granted to Luther Atwood, of New York, May 15, 1860, No. 28,246, in the U. S. Patent Office, which provides for the production of light hydrocarbon illuminating oils from heavy oils, paraffin, etc. The apparatus provides for the cooling of the heavy oil vapors and their return to the still for further cracking. This is all carried out at atmospheric pressure.

The first record of pressure distillation is apparently set forth by James Young in his patent, No. 3345 (English) of 1865, in which a distillation is described as being conducted in a vessel having a loaded valve or a partially closed stop cock through which the confined vapors escape under any desired pressure. Under these conditions, distillation takes place at higher temperature than the normal boiling points of the heavy hydrocarbons and partial cracking results. The patent was taken out for treatment of shale oil and in practice a pressure of 20 pounds to the square inch was recommended.

The first extremely high pressure process was that of Benton, U. S. patent No. 342,564, May 25, 1886. In this the oil is heated at a temperature of from 700 to 1000°F through a pipe not connected with a high pressure vapor chamber, but leading to a low pressure expansion chamber. The pressure used is as high as 500 pounds per square inch.

The most important patent in the present development of cracking processes is that issued to Dewar & Redwood which is described on the following two pages.

SPECIFICATIONS AND CLAIMS OF DEWAR & REDWOOD

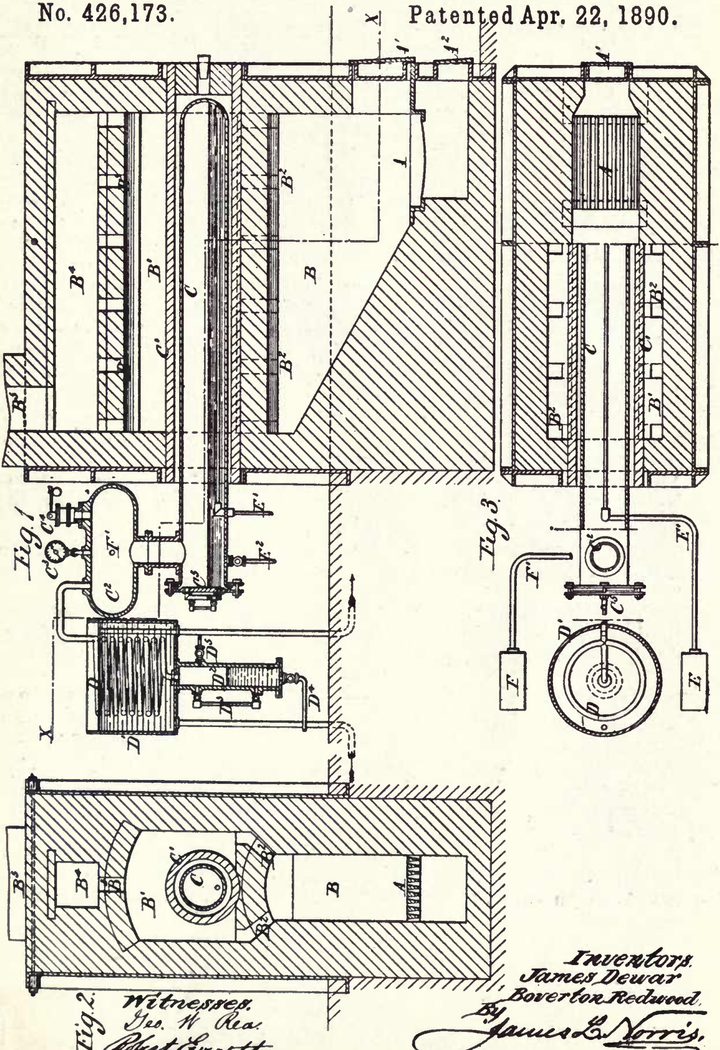
"In distilling mineral oils—such as natural petroleum or similar oil made from shale, coal or other bituminous substances—in order to separate the lighter oils, suitable for lamps and other purposes, from the heavier oils, there is frequently a very large residue of heavy oil. Attempts have been made to obtain lighter oils from such residues or from heavy natural petroleums by causing the vapor generated in the still-boiler to pass a heavily-loaded valve, so that the vaporization takes place under considerable pressure. It has also been proposed to arrange the still-boiler with its upper part cooled,

(No Model.)

J. DEWAR & B. REDWOOD.

APPARATUS FOR THE DISTILLATION OF MINERAL OILS AND LIKE PRODUCTS.

No. 426,173. Patented Apr. 22, 1890.



so that the less volatile portions of the vapor may become more or less condensed and fall back into the hot liquid below, this mode of operating being commonly termed "cracking". Both these methods are objectionable, the former on account of the irregularity of the distillation and the latter on account of the waste of heat in conducting the cracking process and the slowness and insufficiency of the results."

"Our invention relates to a method of conducting the distillation by suitable apparatus in such a manner that we get the benefit of regular vaporization and condensation under high pressure, and that we may at the same time get such advantage as can be obtained from cracking. For this purpose we arrange a suitable boiler or retort, and a condenser in free communication with one another, without interposing any valve between them; but we provide a regulated outlet for condensed liquid from the condenser. We charge and keep charged the space in the boiler or retort and condenser that is not occupied by liquid with gas under considerable pressure, it may be with air or it may be with carbonic-acid gas or other gas that cannot act chemically on the matter treated. The distillation and condensation being thus conducted under considerable pressure, which can be regulated at will, we obtain from the heavy residue a quantity of more or less light oil suitable for illuminating and other purposes, which cannot be obtained by distillation under atmospheric pressure. We may also arrange the still-head or upper part of the boiler or retort so as to operate according to the cracking method above referred to, the cracking in this case taking place under high pressure instead of being carried on under atmospheric pressure.

"The apparatus for effecting distillation in the manner described may be arranged in various ways. The accompanying drawings show one form of apparatus for this purpose.

"By a pipe and cock or a suitably loaded safety-valve D^5 gas may be withdrawn from the space above the liquid in the column D^2.

"By regulating the heat and pressure to which the retort is subjected the character of the distillate may be varied, and thus oils more or less light can be obtained to suit various uses. Also the proportions of the parts may be varied, and, if necessary, means of cooling may be applied to the still-head C^2.

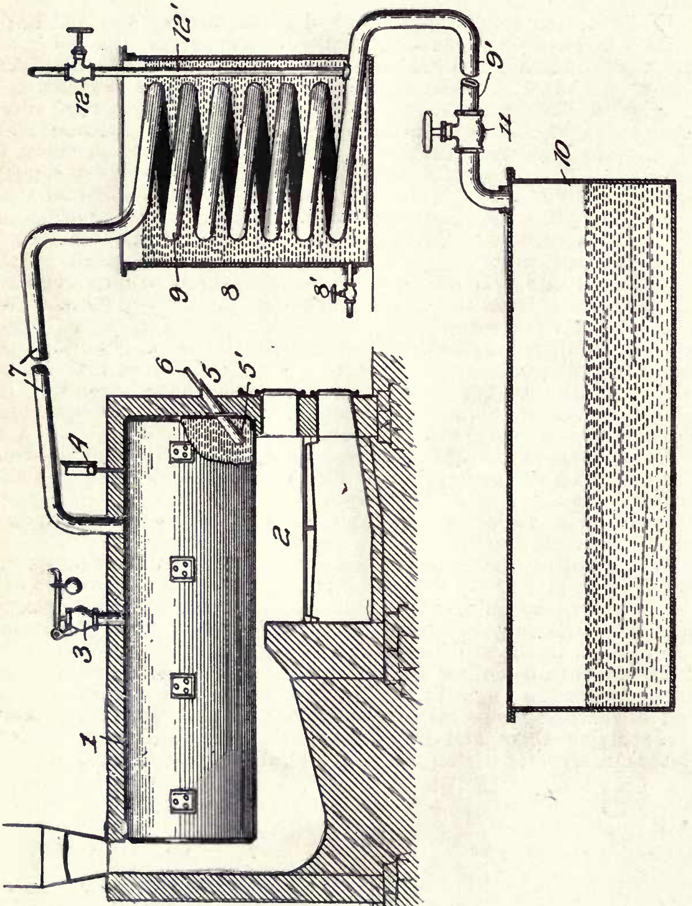
"Having thus described the nature of our invention and the manner of carrying the same into effect, we claim—the herein-described method of distilling mineral oils and like products, which consists in both vaporizing them and condensing the generated vapor under a regulated pressure of air or gas substantially as specified."

W. M. BURTON.

MANUFACTURE OF GASOLENE.

APPLICATION FILED JULY 3, 1912.

1,049,667. Patented Jan. 7, 1913.



Witnesses.

Inventor:
William M. Burton,
By Dyrenforth, Lee, Chritton & Wiles,
Attys.

THE BURTON PROCESS

This is the process by which much of the artificial gasoline now on the market is made.

The sketch in the patent is shown on the opposite page.

In the practical operation of this process a very hot furnace is required on account of the very great radiation of heat from the return conduit 7.

Novelty in this process is claimed to lie in the maintenance of pressure on the condenser, though this is done in the Dewar & Redwood process already described (q.v.). The fact remains, however, that the Burton process is being successfully operated on a large scale and presumably with profit. In one of the Burton patents (1,105,961) it is claimed that 63½% of the original charge of oil is converted into gasoline.

The actual operation of the Burton process has been described as follows.

The stills have a capacity of 200 barrels each and are heavy, horizontal steel cylinders, with walls one-half inch thick, thoroughly insulated with asbestos. From the top of the still is a long run-back, exposed to the air, which returns for cracking any undecomposed oil. The stills, the run-back and the condenser are all maintained under a pressure of about 85 pounds per square inch, the oil being heated to a temperature of about 750°F. Each still is charged every 48 hours, the yield being 57% of 51° naphtha. The carbon tends to be of a granular or mealy nature, rather than hard and adherent, and is cleaned out after each run.

Important modifications of the Burton process are shown in the Clark patents, 1,119,496, 1,129,034 and 1,132,163; A. S. Hopkins, 1,199,-464; R. E. Humphreys, 1,122,002, 1,122,003 and 1,119,700.

One of the Clark modifications allows the application of heat to tubes and seeks to overcome the danger of heating a large bulk of oil directly.

The Hopkins patent provides for introducing fresh oil supply into the run-back 7.

One of the Humphreys patents provides for plates in the bottom of the still to prevent the bad effect of carbon and to give a large metallic heating area.

The original Burton claims are as follows (Patent 1,049,667, filed July 3, 1912):

"1. The method of treating the liquid portions of the paraffin series of petroleum distillation having a boiling point upward of 500°F to obtain therefrom low-boiling point products of the same series, which consists in distilling at a temperature of from about 650 to about 850°F the volatile constituents of said liquid, conducting off and condensing said constituents and maintaining a pressure of from about 4 to about 5 atmospheres on said liquid of said vapors throughout their course to and while undergoing condensation.

2. The method of treating the liquid portions of the paraffin series of petroleum distillation having a boiling point of upward of 500°F to obtain therefrom low-boiling point products of the same series, which consists in distilling off at a temperature of from about 650 to 850°F the volatile constituents of said liquid, conducting off and condensing said constituents, maintaining a pressure of from about 4 to about 5 atmospheres on said liquid of said vapors throughout their course to and while undergoing condensation, and releasing from time to time accumulations of gas from the product of condensation."

ADVANTAGES OF LIQUID PHASE CRACKING

All processes of making gasoline which have not involved the treatment of the oil strictly in the liquid phase are said to have met with only a questionable degree of success.

While the cracking of oil in the vapor phase would be highly desirable if the product and other conditions were satisfactory, it has been claimed by many that the advantages of applying the heat to the liquid phase are as follows:

1. A lower temperature is sufficient to induce cracking.
2. The rate of reaction is greatly increased, being greater the higher the pressure within certain limits.
3. A product containing smaller amount of olefins and aromatics is produced.
4. A higher yield of refined gasoline is obtained.
5. There is a better economy of heat.
6. There is a selective action on the oil or heavy portions of the petroleum by reason of the automatic conversion of the desired product into the vapor phase, thus freeing it from further liability to decomposition.
7. There is a high oil capacity with small plant dimensions.
8. There is a perfect control of temperature.
9. There is a rapid and more complete absorption of heat from the furnace and less tendency to local overheating on account of the much higher specific heat of oil than of the oil vapor.
10. There is the possibility of operating either by intermittent charging or by continuous treatment and distillation.
11. The carbon is deposited in a suspended condition in the oil and not on the retaining walls.
12. There is the possibility of the use of the automatically developed pressure for mechanical and condensing purposes. The chief disadvantage in cracking oil in the vapor phase and under high pressure seems to be the danger attendant upon a possible failure of steel parts. (See page 225.)

Refinery Engineering Data on Distilling and Cracking of Petroleum

The total capacity of a horizontal still is approximately 0.14 d^2l, d being the diameter and l the length of the still in feet.

The heating area of a horizontal still is 1.0472 d l on the assumption that one-third of the shell is fired. In continuous stills a larger area may be fired on account of a higher minimum oil level.

Continuous stills give a greater crude oil capacity than batch stills on account of the time required for charging and discharging batch stills. The amount of benzine or crude gasoline distilled is 1.5 d l barrel per day with continuous operation and with no other products distilled.

The approximate amount of gasoline from crude oil stills per day per square foot of still bottom area not including charging time or time for bringing to distillation temperature is 1.0 barrel. This may vary according to the intensity of firing and the character of the crude.

The approximate total fuel consumption in producing one gallon of 58°Be′ gasoline in a still by cracking at 85 pounds pressure is 50,000 B. T. U. or 0.4 gallon of fuel oil.

The approximate total fuel consumption by properly cracking in tubes at 750 pounds pressure in producing one gallon of 58° Be′ gasoline is 20,000 B. T. U. or 0.15 gallon of fuel oil.

The report of the Western Petroleum Refiner's Association of September, 1919, on a pressure distillation process operating at 135 pounds per square inch pressure may be analyzed as follows:

0.164 gallon of 58°Be′ gasoline was produced per square foot of heating area per hour after the oil was brought to the cracking temperature.

0.8 gallon of fuel oil equivalent to 112,000 B. T. U. was required to produce 1 gallon of 58°Be′ gasoline.

200 cubic feet of gas was produced for each barrel of 58°Be′ gasoline.

7.0 pounds of still carbon was produced per barrel of 58°Be′ gasoline.

A typical composition of the so-called carbon deposited in cracking stills is as follows. This sample was extracted with 70°Be′ petroleum naphtha before testing:

Moisture (volatile at 105°C)	0.00%
Volatile (500°C)	13.08%
Fixed carbon	80.42%
Ash	6.50%
	100.00%
Sulphur	1.83%
Iron	2.76%

The following data represents the operation covering a long period of time of a very extensively used process for cracking oil, based on one still.

Gallons of oil charged	8,000 gallons
Gallons of oil run in	1,800 gallons
Gallons of oil treated	9,800 gallons

Average time feeding in oil	15 hours
Total hours distilled	37 hours
Pounds of coal used to distill	11,000 lbs. per run
Total distillate produced	5,295 gallons
Total 58.5° gasoline produced	3,018 gallons
% distillate	54.04%
% 58.5° gasoline in distillate	57.0%
% 58.5° gasoline of oil treated	30.8%
Amount of distillate per hour of distilling	143.1 gallons
% distillate of total charge per hour of distillation	1.46%
Amount of 58.5°Be′ gasoline per hour of distilling	81.6 gallons
% of 58.5° gasoline per hour of distilling	0.83%
Area of still bottom	270 sq. ft.
Gallons of 58.5° gasoline per hour per sq. ft. of heating area	0.302
Lbs. of coal per gallon of gasoline (58.5°)	3.625 lbs.
Equivalent gallons of fuel oil per gallon of 58.5° gasoline	0.25

CALCULATION OF HEAT EXCHANGES IN REFINERY CONDENSERS

In calculating amount of water required for condenser, use the following formula:

$$w = \frac{200\ g}{t_2 - t_1}$$

w = gallons of water required per hour.
t_1 = incoming temperature of condenser water.
t_2 = outgoing temperature of condenser water.
g = gallons of gasoline to be condensed per hour.

Heat absorbed in condensing 1 gallon of gasoline to 60° F = 1550 B. T. U.

Heat absorbed in condensing 1 gallon of kerosene to 60°F = 2400 B. T. U.

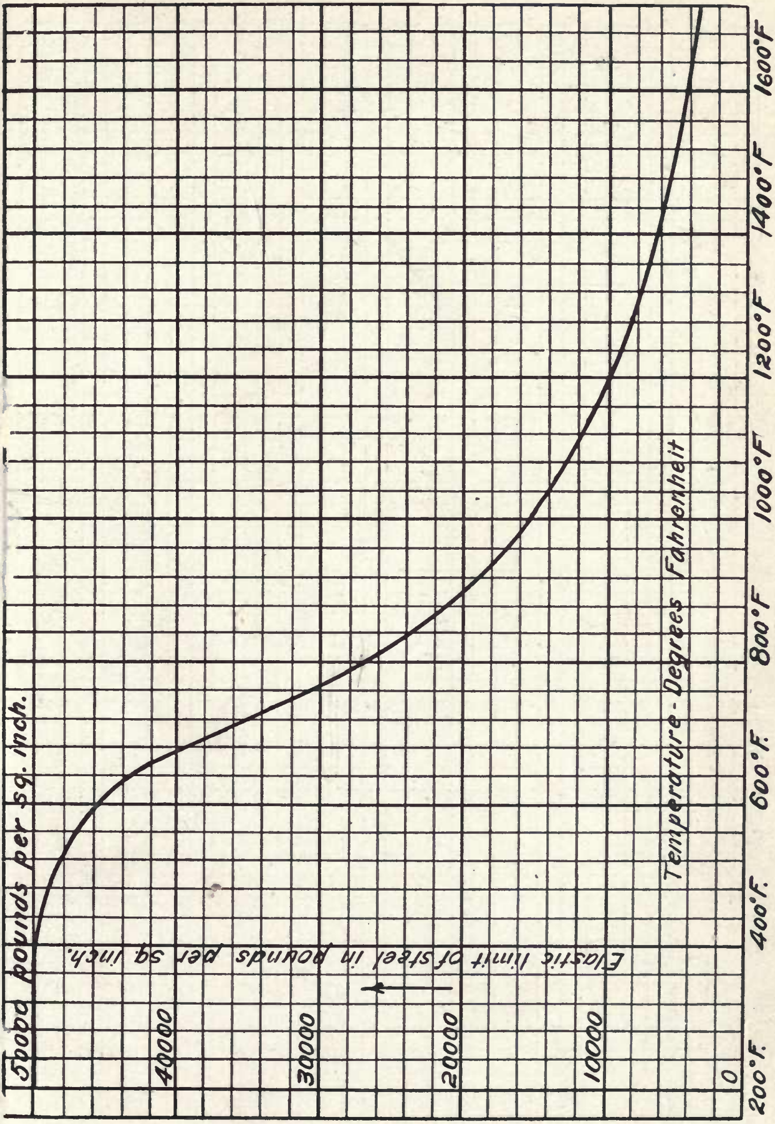
Heat absorbed by oil in distilling off 50% from it as gasoline and kerosene is 2100 B. T. U. per gallon of crude oil.

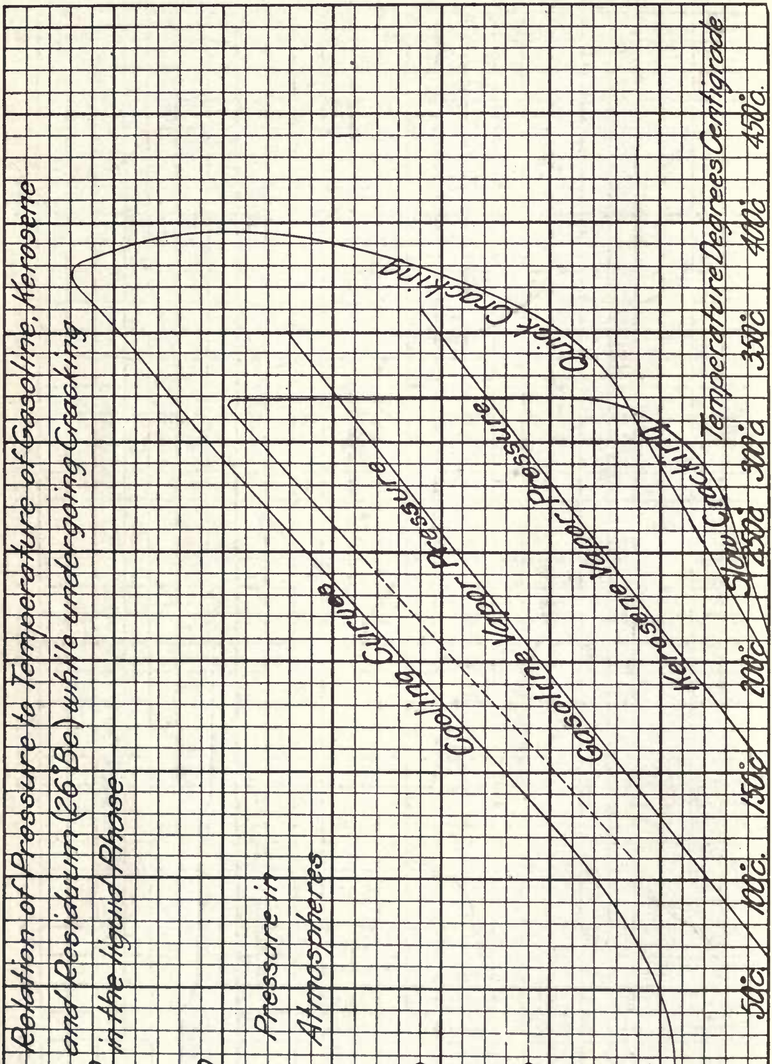
Heat absorbed by oil in distilling to coke is approximately 3000 B. T. U. per gallon.

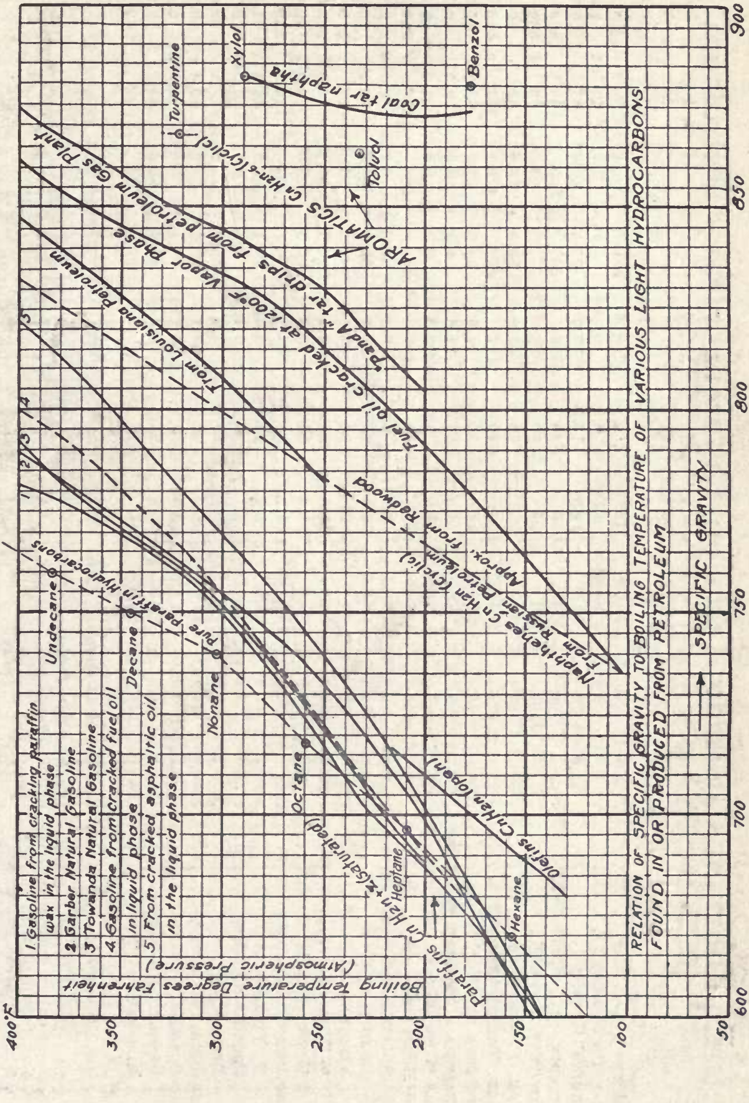
Amount of condenser surface required to properly condense one gallon of gasoline per hour = 2 sq. ft.; 1 gallon of kerosene per hour = 1 sq. ft. This is lessened with cold water and with larger quantities of water and varies with the length and cross section of the condenser tubes.

The cross section of the vapor line should be .05 sq. in. per gallon of gasoline per hour. The cross section of the condenser tubes may be reduced ½ after first ⅓ of length and ¼ more after second ⅓ of length.

The same water used for condensing the benzine or gasoline fraction in crude distillation may be used to condense the kerosene fraction.


50000 pounds per sq. inch.
40000
30000
20000
10000
0
Elastic limit of steel in pounds per sq. inch.
Temperature - Degrees Fahrenheit
200°F.
400°F.
600°F.
800°F
1000°F
1200°F
1400°F
1600°F


Relation of Pressure to Temperature of Gasoline, Kerosene
and Residuum (26° Be) while undergoing Cracking
in the liquid Phase
Pressure in
Atmospheres
0
10
20
30
40
50
60
50°c
100°c
150°c
200°c
250°c
300°c
350°c
400°c
450°c
Temperature Degrees Centigrade
Cooling Curve
Gasoline Vapor Pressure
Kerosene Vapor
Pressure
Vapor Pressure
Quick Cracking
Slow Cracking



RELATION OF SPECIFIC GRAVITY TO BOILING TEMPERATURE OF VARIOUS LIGHT HYDROCARBONS FOUND IN OR PRODUCED FROM PETROLEUM

Equilibrium Cracking Tests on Different Heavy Petroleum Hydrocarbons

Oil used	No. 1	No. 2	No. 3	No. 4	No. 5	No. 6	No. 7	No. 8	No. 9	No. 10
Specific Gravity	0.912	0.935	0.868	0.820	0.953	0.946	0.889	0.820	0.886	0.994
Baume' Gravity	23.5	19.7	31.3	40.8	16.9	18.0	27.5	40.8	31.6	10.8
Amount cc	500	500	500	500	500	500	500	500	500	500
Viscosity at 70°F	810	3360	183	solid	5400	1038	272	34	66	14500
Max. Pressure Atm	59	60	58	58	56	58.5	59.5	59.5	61	50
Max. Temperature °C	417	420	420	420	390	412	415	420	414	410
Pressure at 400°C Atms	54	55	56	54.5	55	54.5	54.5	53.0	55.0	45.0
Pressure after Cooling (Atms.)	10	10	9.5	6.0	11.5	11.5	9.5	6.0	9.0	12.5
Gas % by Weight	7	7	6.8	4.5	8.0	8.0	6.8	5.0	6.3	8.5
Oil Recovered—cc	465	460	495	493	440	442	470	482	470	350
Specific Gravity	0.862	0.862	0.824	0.775	0.917	0.887	0.861	0.803	0.842	0.898
Baume' Gravity	32.4	32.4	39.9	50.6	22.6	27.8	32.6	44.3	36.2	25.9
Viscosity at 70°F	47	47	38	38	100	47	42	34	37	110
% Volume	93.0	92.0	99.0	98.6	88.0	88.4	94.0	96.4	94.0	70.0
% Shrinkage	7.0	8.0	1.0	1.4	12.0	11.6	6.0	3.6	6.0	30.0
Gasoline (E.P. 410°F) cc	127	139.5	147	180.7	135.5	118	157	199	173	109
% Volume	25.4	27.9	29.4	36.1	27.1	23.6	31.4	39.8	34.6	21.8
Specific Gravity	0.743	0.746	0.745	0.724	0.753	0.753	0.754	0.767	0.748	0.746
Baume' Gravity	58.4	57.6	57.9	63.3	55.9	55.9	55.6	52.5	57.1	57.6
Residuum % Volume	67.6	64.1	69.6	62.5	60.9	64.8	68.6	56.6	59.4	48.2
Specific Gravity	0.926	0.926	0.886	0.820	0.962	0.944	0.911	0.845	0.925	0.982
Baume' Gravity	21.2	21.2	28.0	40.8	15.5	18.3	23.6	35.6	21.3	12.6
Viscosity at 70°F	135	178	70	104	414	218	88	38	86	530

No. 1 = Mid-Continent fuel oil average of 48 cars on Kansas City market.
No. 2 = Heavy Kansas crude oil from Allen County.
No. 3 = Garber residuum from Enid, Oklahoma.
No. 4 = Paraffin wax.
No. 5 = California crude oil.
No. 6 = California heat treated and skimmed.
No. 7 = Healdton crude.
No. 8 = Mid-Continent kerosene.
No. 9 = Mid-Continent gas oil.
No. 10 = Mexican flux oil (natural).

Effect of Varying Pressure on the Products of Cracking

KEROSENE.

Using kerosene of specific gravity 0.8155 in vessel with relation of vapor space to oil of 2 to 1.

Pressure, atmospheres	30	40	55	75	90
% distillate to 410°F	28.0	32.5	38.0	43.7	45.9
Shrinkage, volume %	0.0	0.4	2.4	5.0	7.0
Specific gravity of cracked oil	.810	.808	.807	.806	.805
Specific gravity of residue	.828	.833	.845	.871	.888
Cold pressure, atmospheres	2.5	4.0	6.5	10.0	11.8

FUEL OIL.

Fuel oil with specific gravity of 0.908 in vessel with relation of vapor space to oil of 2 to 1.

Pressure, atmospheres	30	40	55	75	90
% distillate to 410°F	14.3	22.3	25.4	32.5	38.7
Shrinkage, volume %	3.0	3.3	9.0	12.0	14.0
Specific gravity of cracked oil	.879	.869	.862	.837	.818
Specific gravity of residue	.914	.918	.926	.930	.932
Cold pressure, atmospheres	5	6	10	13	15.5

Properties of Water White Kerosene Distillate Before and After Cracking

(See page 212.)

%	Distilling Temperature Before Cracking	Distilling Temperature After Cracking	Gravity of Stream Before Cracking	Gravity of Stream After Cracking
0	294°F	Room	....	....
2.5	355	Room	....	....
5.0	363	80°F	.766 = 53.2°Be′	.614 = 98.9°Be′
7.5	366	105	.767 = 52.9°Be′	.634 = 91.7°Be′
10.0	367	130	.768 = 52.7°Be′	.654 = 84.8°Be′
12.5	370	158	.769 = 52.5°Be′	.667 = 80.6°Be′
15.0	379	188	.770 = 52.2°Be′	.680 = 76.6°Be′
17.5	381	218	.771 = 52.0°Be′	.695 = 72.1°Be′
20.0	382	237	.772 = 51.8°Be′	.710 = 67.8°Be′
22.5	384	256	.773 = 51.5°Be′	.720 = 65.0°Be′
25.0	391	269	.774 = 51.3°Be′	.730 = 63.3°Be′
27.5	395	282	.774 = 51.3°Be′	.739 = 59.9°Be′
30.0	399	296	.775 = 51.0°Be′	.749 = 57.4°Be′
32.5	402	310	.776 = 50.8°Be′	.756 = 55.6°Be′
35.0	406	319	.777 = 50.6°Be′	.764 = 53.7°Be′
37.5	408	328	.777 = 50.6°Be′	.769 = 52.5°Be′
40.0	410	340	.778 = 50.3°Be′	.775 = 51.0°Be′
42.5	414	352	.779 = 50.1°Be′	.777 = 50.6°Be′
45.0	417	359	.780 = 49.9°Be′	.780 = 49.9°Be′
47.5	420	366	.780 = 49.9°Be′	.782 = 49.4°Be′
50.0	423	371	.781 = 49.6°Be′	.785 = 48.7°Be′
52.5	425	376	.782 = 49.4°Be′	.787 = 48.3°Be′
55.0	431	386	.783 = 49.2°Be′	.790 = 47.6°Be′
57.5	433	396	.784 = 48.9°Be′	.792 = 47.1°Be′
60.0	437	405	.785 = 48.7°Be′	.793 = 46.9°Be′
62.5	440	414	.786 = 48.5°Be′	.795 = 46.4°Be′
65.0	444	418	.787 = 48.3°Be′	.798 = 45.8°Be′
67.5	448	422	.788 = 48.0°Be′	.798 = 45.8°Be′
70.0	453	429	.789 = 47.8°Be′	.800 = 45.4°Be′
72.5	457	436	.790 = 47.6°Be′	.802 = 44.9°Be′
75.0	462	443	.792 = 47.1°Be′	.805 = 44.2°Be′
77.5	468	450	.793 = 46.9°Be′	.808 = 43.6°Be′
80.0	473	459	.794 = 46.7°Be′	.812 = 42.7°Be′
82.5	479	468	.795 = 46.4°Be′	.817 = 41.7°Be′
85.0	485	484	.797 = 46.0°Be′	.823 = 40.4°Be′
87.5	493	500	.800 = 45.3°Be′	.830 = 38.9°Be′
90.0	506	523	.803 = 44.7°Be′	.837 = 37.5°Be′
92.5	516	547	.807 = 43.8°Be′	.851 = 34.7°Be′
95.0	533	600	.812 = 42.7°Be′	.866 = 31.9°Be′
97.5	560	648	....	.936 = 19.6°Be′
100.0	608	700	....	....
Gravity of sample			.7845 = 48.9°Be′	.766 = 53.2°Be′

FRACTIONAL GRAVITY DISTILLATION ANALYSIS

of Benton Process Gasoline; Specific Gravity, 0.758; °Be' U. S., 54.7 °Be' Tag, 55.1°; Olefins, 16.0%.

%	Time	Temp. °F.	Gravity of Fraction.	Gravity of Total Over	Gravity of Stream
	10:09				
0	10:14	85			
		155			
5	10:22	164	0.694=72.4°Be'	0.694=72.4°Be'	0.694=72.4°Be'
		171			
10	10:28	176	0.695=72.1°Be'	0.694=72.4°Be'	0.689=71.2°Be'
		184			
15	10:35	188	0.701=70.3°Be'	0.696=71.8°Be'	0.705=69.2°Be'
		193			
20	10:42	199	0.710=67.8°Be'	0.700=70.6°Be'	0.714=66.6°Be'
		206			
25	10:48	211	0.718=65.5°Be'	0.704=69.5°Be'	0.722=64.4°Be'
		216			
30	10:54	222	0.727=63.1°Be'	0.707=68.6°Be'	0.731=62.0°Be'
		228			
35	10:58	234	0.735=61.0°Be'	0.711=67.5°Be'	0.738=60°2Be'
		238			
40	11:03	244	0.742=59.2°Be'	0.715=66.4°Be'	0.745=58.4°Be'
		248			
45	11:09	254	0.748=57.6°Be'	0.719=65.3°Be'	0.751=56.9°Be'
		258			
50	11:14	264	0.755=55.9°Be'	0.722=64.4°Be'	0.758=55.1°Be'
		270			
55	11:19	278	0.761=54.4°Be'	0.729=62.6°Be'	0.770=52.2°Be'
		283			
60	11:25	290	0.767=52.9°Be'	0.729=62.6°Be'	0.770=52.2°Be'
		297			
65	11:29	306	0.773=51.5°Be'	0.732=61.8°Be'	0.776=50.8°Be'
		312			
70	11:34	320	0.779=50.1°Be'	0.736=60.7°Be'	0.781=49.6°Be'
		328			
75	11:41	336	0.784=48.9°Be'	0.739=59.9°Be'	0.788=48.0°Be'
		348			
80	11:46	362	0.793=46.9°Be'	0.742=59.2°Be'	0.797=46.0°Be'
		371			
85	11:53	388	0.801=45.1°Be'	0.746=58.1°Be'	0.808=43.6°Be'
		406			
90	11:59	428	0.815=42.1°Be'	0.749=57.4°Be'	0.823=40.4°Be'
		460			
95	12:05	492	0.832=38.5°Be'	0.754=56.1°Be'	

Remarks: 36 cc. residuum; loss, ½ %.

FRACTIONAL GRAVITY DISTILLATION ANALYSIS OF COAL TAR BENZOL.

Laboratory Number, 44118; Specific Gravity, 0.880; °Be′ U. S., 29.0°; Cold test, 40°F.

%	Time	Temp. °F.	Gravity of Fraction.	Gravity of Total Over	Gravity of Stream
	3:25				
0	3:31	173			
		178			
5	3:37	179	0.882=28.9°Be′	0.882=28.9°Be′	0.881=29.1°Be′
		180			
10	3:42	180	0.881=29.1°Be′	0.881=29.1°Be′	0.882=28.9°Be′
		180			
15	3:47	180	0.883=28.7°Be′	0.882=28.9°Be′	0.882=28.9°Be′
		180			
20	3:51	180	0.882=28.9°Be′	0.882=28.9°Be′	0.882=28.9°Be′
		180			
25	3:56	180	0.882=28.9°Be′	0.882=28.9°Be′	0.882=28.9°Be′
		180			
30	4:00	181	0.882=28.9°Be′	0.882=28.9°Be′	0.882=28.9°Be′
		181			
35	4:05	182	0.882=28.9°Be′	0.882=28.9°Be′	0.881=29.1°Be′
		182			
40	4:10	182	0.881=29.1°Be′	0.881=29.1°Be′	0.881=29.1°Be′
		182			
45	4:15	182	0.881=29.1°Be′	0.881=29.1°Be′	0.881=29.1°Be′
		182			
50	4:19	182	0.881=29.1°Be′	0.881=29.1°Be′	0.880=29.3°Be′
		183			
55	4:23	183	0.880=29.3°Be′	0.881=29.1°Be′	0.880=29.3°Be′
		183			
60	4:28	184	0.880=29.3°Be′	0.881=29.1°Be′	0.880=29.3°Be′
		184			
65	4:33	184	0.880=29.3°Be′	0.881=29.1°Be′	0.880=29.3°Be′
		185			
70	4:38	186	0.880=29.3°Be′	0.881=29.1°Be′	0.880=29.3°Be′
		186			
75	4:43	187	0.880=29.3°Be′	0.881=29.1°Be′	0.880=29.3°Be′
		188			
80	4:48	189	0.880=29.3°Be′	0.881=29.1°Be′	0.879=29.4°Be′
		190			
85	4:53	192	0.879=29.4°Be′	0.880=29.3°Be′	0.879=29.4°Be′
		196			
90	4:57	199	0.879=29.4°Be′	0.880=29.3°Be′	0.877=29.8°Be′
		205			
95	5:01	216	0.876=30.0°Be′	0.880=29.3°Be′	0.876=30.0′Be°
100	5:10	225	0.876=30.0°Be′	0.880=29.3°Be′	0.876=30.0′Be°

Information Concerning Oil Shales

The chief occurrences of oil shale in the United States are in Western Colorado—Northeastern Utah—Kentucky—Elko, Nevada—Great Falls, Montana—Parkfield, California—New Brunswick, Canada—Alabama—Tennessee and Virginia. It is estimated that in Colorado there are enough oil shales to produce 20,000 million barrels of oil and 300 million tons of ammonium sulphate.

The shale oil industry started in England in 1694. The oil was used for medicinal purposes, later for varnishes and in 1815 for ammonia.

The chief commercial operations on oil shale are in Scotland and were begun in 1847. These industries were demoralized when Pennsylvania petroleum first appeared on the market, but later recovered partially and are now operated with profit. The amount of oil obtainable from one ton of shale varies from one gallon to 90 gallons. In Scotland it is 23 gallons. In Colorado alone there is said to be enough shale to produce 20,000,000,000 barrels of oil and 300,000,000 tons of ammonium sulphate.

Gasoline made from shale is of inferior quality, containing large amounts of olefins and aromatic compounds and giving a large shrinkage on refining.

Shale oil is especially adapted to the uses to which the heavy products of petroleum are now put, such as fuel oil, paraffin wax, lubricants, gas oil and illuminating oil. It is not likely to be so satisfactory for the production of gasoline as is the cracking of heavy petroleums. The character of the oil recovered and the amount of ammonium sulphate produced from shale depend largely upon the method of distillation.

Oil shale rock is a tough brownish to black shale-like rock. As it naturally exists it contains no oil and oil cannot be extracted from it by solvents or by any of the means used for asphaltic sandstone or limestone. The oil is produced from complex organic matter by decomposing it at high temperatures.

The mineral base of oil shales is of the nature of kaolin and contains potash in water-insoluble form.

Cannel coal is of the same chemical nature as oil shale both as to the bitumen and the mineral matter. The hydrocarbons of oil shale and cannel coal more nearly approach petroleum than coal in their calorific value.

Unlike coal, cannel "coal" has no structure or evidence of the former presence of or origin from vegetable matter. It breaks with a conchoidal fracture and is usually free from mineral sulphides such as pyrites of iron. It commonly occurs on the top of the Mississippian (subcarboniferous) and may lie immediately above deposits of galena or sphalerite (zinc).

Presumptive Operation of 1000-Ton Shale Oil Plant in Western Colorado

(Based upon 1 ton of shale.)

Proceeds.	1918	1913
54 gallons of oil (405 lbs.)	$ 2.70	$ 1.00
34 pounds of ammonium sulphate	2.46	1.09
	$ 5.16	$ 2.09
Costs.		
*Cost of mining	$ 1.35	$ 0.90
Cost of distilling oil and ammonia	.65	.50
Cost of acid for ammonia	.55	.16
*Freight on acid to plant	.12	.12
Cost of preparation of ammonium sulphate for market	.10	.06
*Freight on ammonium sulphate to market	.17	.17
*Freight on oil	1.00	1.00
Overhead expense	.40	.25
	$ 4.34	$ 3.16

*Depend upon local conditions to a large extent.

PROFITS IN SHALE INDUSTRY BY COMPANIES IN SCOTLAND IN 1910

Companies.	Dividends.
Broxburn	17.5%
Oakland	15.0
Pumpherston	50.0
Tarbrax	15.0
Youngs	6.0
Delmeny	5.0

SHALE OIL PRODUCTS

Yields from "Oil Shale" from Colorado.

(100,000 million tons of shale of this quality are said to be available.)

Oil	= 405 lbs.	=54 gallons	=20.25%
Water	= 83 lbs.	=10 gallons	= 4.08%
Gas	=1605 cu. ft.		= 8.86%
Ammonium Sulphate=34 lbs. from nitrogen			= 0.90%
Carbon (not separable)=101 lbs.			= 5.05%
Mineral matter=1219.2 lbs.			=60.96%

COMPOSITION OF MINERAL ASH IN SHALE

Loss on ignition		= 11.05%
Silica	(SiO_2)	= 37.10%
Alumina	(Al_2O_3)	= 20.30%
Iron Oxide	(Fe_2O_3)	= 9.20%
Lime	(CaO)	= 12.05%
Magnesia	(MgO)	= 5.10%
Sulphur	(SO_3)	= 4.80%
Alkalies and difference		= 0.40%
		100.00%

PROPERTIES OF SHALE OIL

Commercial Fractions.

Naphtha (410°F) "gasoline"	10.0%	(46° Baume')
Burning oil	18.2%	
Gas and lubricating oil	61.8%	
Scale	10.0%	

Fractional Distillation of oil.

Fraction	Boiling Point	Specific Gravity (25°C)
0— 10	100°C	0.794=46.3°Be'
10— 20	194	0.822=40.3
20— 30	230	0.846=35.5
30— 40	255	0.867=31.5
40— 50	285	0.885=28.2
50— 60	309	0.899=25.7
60— 70	328	0.912=23.5
70— 80	337	0.900=25.5
80— 90	345	0.910=23.8
90—100	350	0.910=23.8

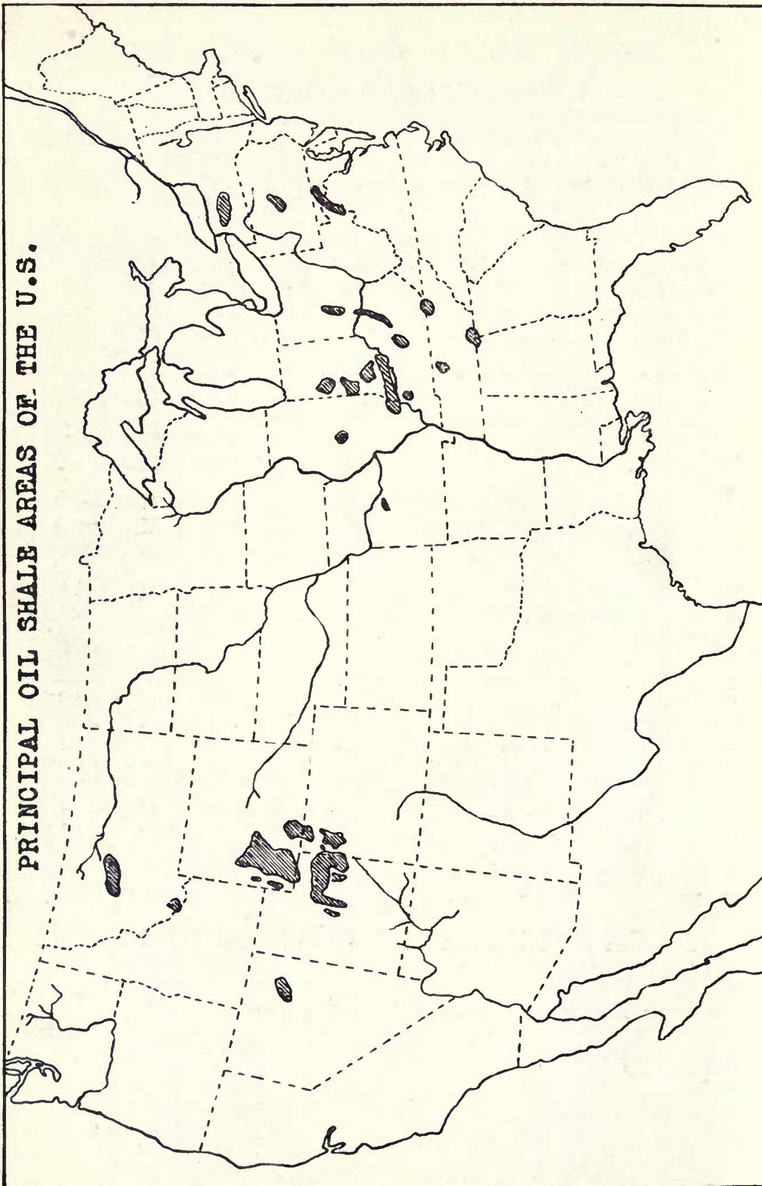
CANNEL COAL FROM CENTRAL MISSOURI

(Large quantities of this hydrocarbon are found in Missouri.)

	Sample a	Sample b
Moisture	8.14%	2.56%
Volatile hydrocarbons	41.16	44.78
Fixed carbon	36.63	42.72
Ash	14.07	9.94
	100.00	100.00
Fusing of bitumen	none	none
Total combustible	77.79	87.50
Heating value in B. T. U., per lb	12575	14095
B. T. U., per lb. of combustible	16165	16110
Sulphur	2.10%	1.70%
Nitrogen	1.50	1.65
Oil, per ton from retorts	64 gallons	72 gallons
Ammonium sulphate, per ton	50 pounds	55 pounds
Coke, per ton	1080 pounds	1200 pounds

COMPOSITION OF ASH IN CANNEL COAL

Silica	(SiO_2)	=43.28%	
Iron and	(Fe_2O_3)	=12.00	46.16
Alumina	(Al_2O_3)	=34.16	
Lime	(CaO)	= 1.49	
Magnesia	(MgO)	= 1.01	
Sulphur	(SO_3)	= 0.84	
Phosphorus	(P_2O_5)	= 0.73	
Potash	(K_2O)	= 3.00	



PRINCIPAL OIL SHALE AREAS OF THE U.S.

FRACTIONAL GRAVITY DISTILLATION ANALYSIS OF SHALE OIL BEFORE CRACKING.

Laboratory Number 46258, Original Shale Oil.
Specific Gravity, 0.920; °Be' U. S. 22.1°; °Be' Tag 22.3°.
Color, Brownish Black; Sulphur=0.49% B. T. U.%18,425.

%	Temp. °F.	Gravity of Fraction	Gravity of Total Over	Gravity of Stream
				0.790=47.6°Be'
5	330	0.790=47.6°Be'	0.790=47.6°Be'	0.802=44.9°Be'
	368			0.814=42.3°Be'
10	378	0.814=42.3°Be'	0.802=44.9°Be'	0.823=40.4°Be'
	398			0.833=38.3°Be'
15	413	0.833=38.3°Be'	0.812=42.7°Be'	0.839=37.1°Be'
	426			0.845=35.9°Be'
20	446	0.845=35.9°Be'	0.820=41.0°Be'	0.853=34.4°Be'
	464			0.861=32.8°Be'
25	479	0.861=32.8°Be'	0.828=39.4°Be'	0.869=31.3°Be'
	494			0.876=30.0°Be'
30	516	0.876=30.0°Be'	0.836=37.7°Be'	0.883=28.7°Be'
	530			0.890=27.5°Be'
35	543	0.890=27.5°Be'	0.844=36.1°Be'	0.895=26.6°Be'
	552			0.900=25.7°Be'
40	576	0.900=25.7°Be'	0.851=34.8°Be'	0.905=24.8°Be'
	586			0.909=24.1°Be'
45	599	0.909=24.2°Be'	0.857=33.6°Be'	0.910=24.0°Be'
	604			0.911=23.8°Be'
50	613	0.911=23.8°Be'	0.867=31.7°Be'	0.916=23.0°Be'
				0.922=21.9°Be'
55	Gas	0.922=21.9°Be'	0.872=30.7°Be'	0.928=21.0°Be'
				0.934=20.0°Be'
60	Gas	0.934=20.0°Be'	0.877=29.8°Be'	0.937=19.5°Be'
				0.940=19.1°Be'
65	Gas	0.940=19.0°Be'	0.882=28.9°Be'	0.943=18.5°Be'
				0.947=17.9°Be'
70	Gas	0.947=17.9°Be'	0.887=28.0°Be'	0.950=17.4°Be'

Summary:

Water. 2.1%
42.7° Benzine or Naphtha......... 12.9%
31° Illuminating oil, unrefined..... 25.0%
24° Gas. Oil or Distillate.......... 10.0%
18.5° Wax Distillate.............. 30.0%
Residue. 20.0%

Olefins. 58.0%
Aromatics. 27.0%
Naphthenes and Paraffins. 15.0%

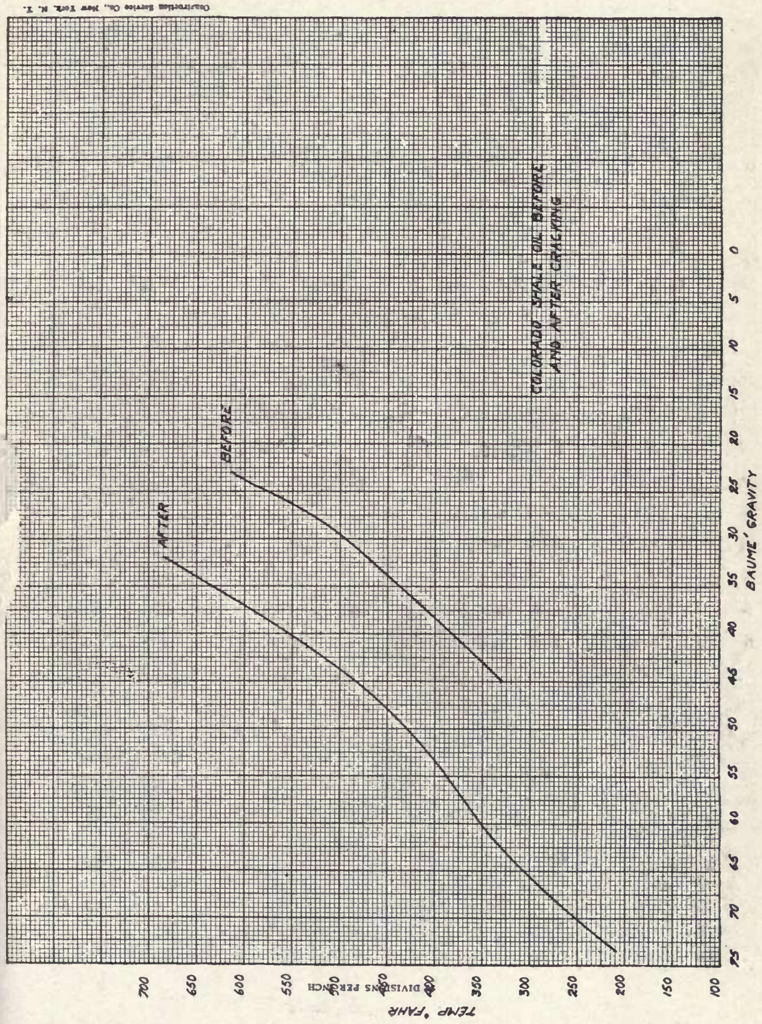
Ammonia in water portion = 0.442% as NH_3.

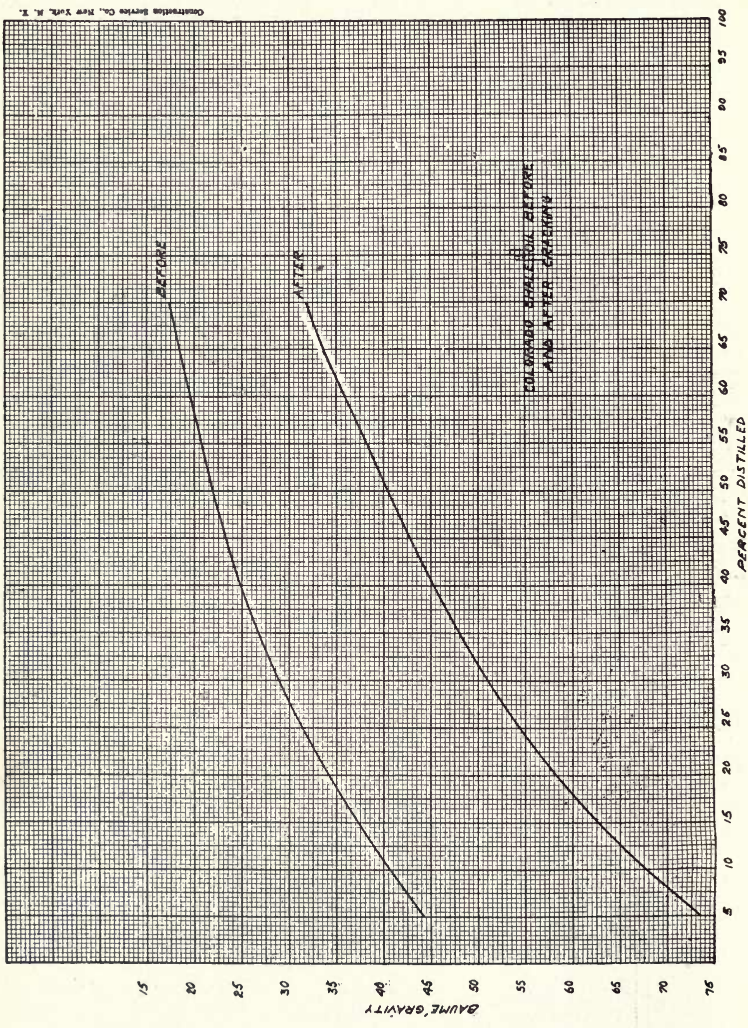
FRACTIONAL GRAVITY DISTILLATION ANALYSIS OF SHALE OIL RESIDUE.

Laboratory Number 46258, Shale Oil Residue Cracked at 800 lbs. Pressure.
Specific Gravity, 0.896; °Be′ U. S. 26.2; °Be′ Tag 26.4.
Color, Dark Red; Olefins 27.5%.

%	Temp. °F.	Gravity of Fraction	Gravity of Total Over	Gravity of Stream
0	119	....	....	....
				0.681=76.3° Be′
5	210	0.681=76.3° Be′	0.681=76.2° Be′	0.690=73.6° Be′
				0.699=70.9° Be′
10	281	0.717=65.8° Be′	0.699=70.9° Be′	0.710=67.8° Be′
				0.721=64.7° Be′
15	334	0.765=53.5° Be′	0.721=64.7° Be′	0.730=62.3° Be′
				0.740=59.7° Be′
20	368	0.798=45.8° Be′	0.740=59.7° Be′	0.748=57.7° Be′
				0.757=55.4° Be′
25	395	0.823=40.4° Be′	0.757=55.4° Be′	0.764=53.7° Be′
				0.771=52.0° Be′
30	435	0.846=35.7° Be′	0.771=52.0° Be′	0.777=50.6° Be′
				0.784=49.0° Be′
35	454	0.861=32.8° Be′	0.784=49.0° Be′	0.790=47.6° Be′
				0.796=46.2° Be′
40	486	0.881=29.1° Be′	0.796=46.2° Be′	0.801=45.1° Be′
				0.807=43.8° Be′
45	518	0.898=26.1° Be′	0.807=43.8° Be′	0.812=42.7° Be′
				0.818=41.5° Be′
50	543	0.911=23.8° Be′	0.818=41.5° Be′	0.823=40.4° Be′
				0.828=39.4° Be′
55	582	0.930=20.7° Be′	0.828=39.4° Be′	0.833=38.3° Be′
				0.838=37.3° Be′
60	623	0.945=18.2° Be′	0.838=37.3° Be′	0.844=36.1° Be′
				0.855=34.0° Be′
65	651	0.959=16.0° Be′	0.855=34.0° Be′	0.859=33.2° Be′
				0.862=32.6° Be′
70	679	0.965=15.1° Be′	0.862=32.6° Be′	0.865=32.0° Be′

Naphtha in oil charged........... None
Synthetic Oil—
Naphtha. 30.0%
Illuminants. 25.0%


COLORADO SHALE OIL BEFORE
AND AFTER CRACKING
BEFORE
AFTER
BAUME' GRAVITY
0 5 10 15 20 25 30 35 40 45 50 55 60 65 70 75
TEMP °FAHR
700 650 600 550 500 450 400 350 300 250 200 150 100
10 DIVISIONS PER INCH
Construction Service Co., New York, N. Y.


Construction Service Co., New York, N. Y.
COLORADO SHALE OIL BEFORE
AND AFTER CRACKING
BEFORE
AFTER
PERCENT DISTILLED
5 10 15 20 25 30 35 40 45 50 55 60 65 70 75 80 85 90 95 100
BAUME' GRAVITY
15 20 25 30 35 40 45 50 55 60 65 70 75

Products of Refining of Light Oil of Gas Works

	Carbon Disul-phide	Benzene	Toulene	M-zylene	Naph-thalene
Molecular weight.	76.12	78.05	92.06	106.08	128.06
Pounds per United States Gal. (60° F).	10.57	7.36	7.27	7.26	9.60
Specific gravity (0°C/4°C).............	1.2921	.8999	.8845	.8823	....
Specific gravity (10°C/4°C).............	1.2773	.8893	.8757	.8738	....
Specific gravity (15°C/4°C).............	1.2698	.8839	.8714	.8697	1.1517
Specific gravity (20°C/4°C).............	1.2623	.8786	.8659	.8655	....
Specific gravity (30°C/4°C).............	1.2473	.8679	.8573	.8574	....
Change of Spec. Grav. per 1°C..........	.00125	.0012	.0010	.00095	....
Boiling point at 760 mmHg (°C)........	46.2	80.36	110.3	139.1	217.7
Increase in boiling point (°mmHg)......	.041	.043	.047	.052	.059
Vapor pressure mmHg (0°C)............	127.9	26.63	7.20	1.75	.022
Vapor pressure mmHg (10°C)............	198.5	45.68	13.02	3.45	.047
Vapor pressure mmHg (15°C)............	244.1	58.90	17.22	4.74	.062
Vapor pressure mmHg (20°C)............	298.0	75.21	22.53	6.43	.080
Vapor pressure mmHg (30°C)............	434.6	119.34	37.46	11.43	.135
Pounds per cu. ft. vapor (60°F=30 in.)...	.202	.209	.244	.281	.339
Kil. per cu. m. vapor (0°C-760mm).......	3.42	3.54	4.14	4.76	5.72
Heat combustion (net) 15°C-760mmHg.					
Calories per kil. liquid.................	.3480	.9960	10.150	10.230	.9700
Calories per liter, liquid................	.4420	.8805	.8850	.8910	11.170
B. T. U. per pound, liquid..............	.6260	17.930	18.270	18.410	17.460
B. T. U. per U. S. gal., liquid..........	66.100	132.100	132.600	133.500	167.300
Calories per cu. meter, vapor..........	11.550	33.600	40.150	46.500	52.400
B. T. U. per cu. ft. vapor.............	.1300	.3780	.4500	.5210	.5910
Specific heat (calories per kil.)............	0.240	0.419	0.440	0.383	0.314
Heat of vaporiz. (calories per kil.)......	83.8	92.9	83.55	78.25	....
Sol. in water (22°C) grm. subs. in 100 gH2O.	.219	.072	Insol.	Insol.	Insol.
Grams H2O in 100g subs...............	.765	.241	Insol.	Insol.	Insol.
Melting point (°C)......................	—108.6	+5.4	—92.4	—54.8	+80.0

Gas-Manufacturing Processes in Use in the United States

The manufactured gas distributed in the United States is of three principal kinds: Coal gas, carbureted water gas and oil gas.

The manufacture of water gas consists essentially of an intermittent process in which a bed of anthracite coal or coke is brought to a high temperature by an air blast and then steam under pressure is blown through the fuel, forming carbon monoxide, hydrogen and a small amount of carbon dioxide by reaction with the carbon in the fuel. The resultant gas, called blue water gas, has a heating value of approximately 300 B.T.U. per cubic foot and almost no luminosity when burned in an open flame. It is conducted into a fire-brick-lined chamber called the carburetor, which contains staggered rows of fire bricks, called checker brick, heated to incandescence during the blow period. Gas oil or fuel is sprayed into the carburetor while the gas is passing through, forming an oil gas which enriches the blue water gas to any desired heating value or candlepower. Another checker-brick-filled chamber, called the superheater, converts most of the oil-gas vapors into permanent gases, which will not condense again upon cooling. During the formation of the oil gas certain portions of the hydrocarbons which compose the oil are changed in their composition to form benzol, toluol and related hydrocarbons called aromatic compounds. Considerable tar is formed at the same time. This is condensed, scrubbed and washed out of the gas by various means, but usually at a temperature which permits most of the aromatics to go forward with the gas. The sulphur in the gas is removed by iron-oxide purifiers and the gas is metered and leaves the plant at or slightly above atmospheric temperature.

The manufacture of coal gas is essentially different from that of water gas. In this process certain classes of bituminous coals are distilled in fire clay or silica retorts or ovens and the resulting gases are condensed, scrubbed, washed and purified to remove water vapor, tar, ammonia and sulphur. As in the water gas process, certain of the hydrocarbons given off by the coal are transformed by the heat of the retort to aromatic compounds. A small part of these aromatics is washed out of the gas by the wash water and tar, but the larger part remains in the gas. In fact, the cooling of the gas is usually so regulated that most of these substances will remain in the gas to increase its heating value and candlepower. Coal gas retorts take a variety of forms. Among these are coke ovens, chamber ovens, horizontal D-shaped retorts, vertical retorts, inclined retorts, etc. Even those of a given class differ among themselves in details of construction. In most of them the distillation is an intermittent process, but some continuous methods are used. In all these processes the gas produced consists of the same constituents in somewhat different proportions. The form of apparatus used in a given case depends largely upon economic considerations or is governed by certain special qualities which are desired in one or more of the products produced. In all of these coal gas processes coke remains in the retort after distillation. In some of them, as for example in coke ovens, coke is the principal product, but in city gas plants gas is the chief product. The operation is carried out in any case to give most satisfactory qualities to the principal product and at the same time obtain as high yields and good quality as possible of the secondary or by-products.

Mixed gas is usually understood to be a mixture of carbureted water gas and coal or coke-oven gas. It is supplied in many cities in the United States where the requirements permit of a mixed gas being supplied. The manufacturing installation for mixed gas is practically two complete installations, one for coal gas and one for carbureted water gas, with their auxiliary scrubbing, condensing, purifying, and metering apparatus entirely independent and separate. The manufactured mixed gas, however, is stored in common holders and delivered through a single distribution system. The coal and water gas thus supplement each other. The uniform but more cumbersome coal-gas production furnishes coke as fuel for the water-gas plant. This in turn takes care of the irregularities of the output, and, where necessary, increases the quality of the gas production, especially where a high candlepower standard is in force.

The oil gas process is at present confined chiefly to the Pacific Coast States, where comparatively cheap oil and expensive coal make the coal and water gas processes less feasible. In oil gas manufacture oil alone is used as fuel for heating the checker bricks of the fixing chambers and oil is sprayed by steam into the chambers where, in contact with the bricks, lampblack and permanent gases are formed. In this process also aromatic compounds are included among the constituents of the gas.

Note.—See Bulletin of Bureau of Standards.

Average Content of Light Oils in Various Gases

The amount of benzol and toluol formed in any one of these processes is by no means definite. It depends upon the operating conditions and the quality of the raw materials (coal or oil). It would therefore be impossible to predict exactly what the yield of products in a given case would be, but an extensive inquiry into the operation of a number of typical plants has given the following tabulation as the usual range of figures for the various processes. Individual results may vary widely from them in a particular case.

TABLE 1.—Approximate Yields of Crude Light Oil and Pure Products and Approximate Composition of Crude Light Oil.

APPROXIMATE YIELD OF CRUDE LIGHT OIL.

Coal gas.	
Horizontal retort	3.0-4.0 gallons per short ton coal carbonized
Continuous vertical retort	1.5-2.5 gallons per short ton coal carbonized
Inclined retort	1.8-2.3 gallons per short ton coal carbonized
Coke-oven gas, run of oven	2.6-3.6 gallons per short ton coal carbonized
Carbureted water gas	8-10 per cent of vol. of gas oil used
Oil gas	0.2-0.3 gal. per 1000 cu. ft. of gas.

APPROXIMATE COMPOSITION OF CRUDE LIGHT OIL.

	Benzol Per Cent	Toluol Per Cent	Solvent Naphtha, Wash Oil, Naphthalene, Per Cent
Coal gas:			
Horizontal retort	50	13-18	35
Continuous vertical retort	30	10-15	55
Inclined retort	45	13-18	40
Coke-oven gas, run of oven	50	14-18	35
Carbureted water gas	40	20-25	37
Oil gas	80	8-10	10

APPROXIMATE YIELD OF PURE PRODUCTS.

	Benzol	Toluol
Gallons per short ton coal carbonized:		
Coal gas—		
Horizontal retort	1.5	0.4-0.5
Continuous vertical retort	.6	.2- .3
Inclined retort	.9	.2- .4
Coke-oven gas, run of oven	1.5	.3- .5
Gallons per 1000 cubic feet of gas:		
Carbureted water gas	.15	.06-.10
Oil gas	.25	.02-.03

Paraffins	Specific Gravity	Degrees Boiling Point in Centigrade
N—heptane	0.712, at 16°C	97
Triethylmethane	.689, at 27°C	96
N—octane	.708, at 12.5°C	125
Diispbutyl	.714, at 0°C	108.5

Natural Gas

Natural gas is found trapped in the various strata of the earth, principally in sandstone formations of loose texture, in shale seams and in cavities. It is usually associated with petroleum or coal and occurs in the carboniferous strata or in more recent formations. In coal mines it constitutes what is known as fire damp, being given off from the exposed seams of coal. It is most commonly associated with petroleum in petroleum bearing sand and occupies the space in the sand above the oil. Occasionally it occurs in strata without any oil being present, in which case it is of a slightly different composition than the gas which is found in contact with the oil. In many cases it appears that the gas has been obtained from the atmosphere, the oxygen having been removed by its combination with reducible substances such as sulphides, leaving a residue of nitrogen. This gives to such natural gases the peculiarity of having a very large amount of nitrogen. Associated with the nitrogen there occasionally is found a small amount of Helium which is also an ordinary constituent of air in small quantities. It may be that the difference of solubility of the different gases of the air in water may account for the tendency of accumulation of Helium in such instances. As a rule, however, natural gas consists of hydrocarbons of the same type as petroleum and identical with the hydrocarbons which are given off by the cracking of petroleum.

The proportions in which the different hydrocarbons exist in ordinary gas such as is delivered to Kansas City, Missouri, is something like the following:

Methane	84.7%
Ethane	9.4%
Propane	3.0%
Butane	1.3%
Nitrogen	1.6%

This gas has the greater portion of the heavy hydrocarbons condensed out on account of the high pressure in the pipe lines. Such a gas is a mixture of methane with a varying amount of the other gases. As shown by the above table, the gases ethane, propane and butane furnish much of the heating value of the gas. A gas with a considerable amount of gasoline vapor in it will have a considerably higher heating value than one from which it has been removed, or known as a dry gas.

The compositions of the natural gas used in eight cities in the United States are as follows:

City	Methane Per Cent	Ethane Per Cent	Nitrogen Per Cent
Pittsburgh, Pa	79.2	19.6	1.2
Louisville, Ky.	77.8	20.4	1.8
Buffalo, N. Y.	79.9	15.2	4.9
Cincinnati, O.	89.8	19.5	.7
Cleveland, O	80.5	18.2	1.3
Springfield, O.	80.3	14.7	5.0
Columbus, O	80.4	18.1	1.5
Chelsea, Okla	75.4	17.7	6.6

These analyses were made by the ordinary combustion method and hence show only the two predominating paraffin hydrocarbons.

The composition of gases found in Kansas and Oklahoma as given by Allen and Lyder are shown by the following table:

Location	Methane	Ethane	Nitrogen	B.T.U. per Cubic Foot
Augusta, Kas.	10.54	1.64	87.69	129
Cowley County, Kas.	16.27	3.01	80.23	209
Chautauqua County, Kas.	42.38	1.85	55.29	441
Chautauqua County, Kas.	49.01	3.89	46.67	541
Elsworth, Kas.	61.09	1.09	37.20	609
Ponca City, Okla.	44.60	14.86	40.10	688
Kay County, Okla.	57.91	9.89	31.65	735
Chautauqua County, Kas.	85.53	0.15	12.95	839
Chautauqua County, Kas.	79.13	7.79	11.39	894
Butler County, Kas.	62.15	18.38	18.64	930
Montgomery County, Kas.	83.04	8.54	7.95	970
Blackwell, Okla.	70.69	18.65	9.32	1025
Cushing, Okla.	70.74	21.64	7.49	1059
Bartlesville, Okla.	70.50	24.60	3.21	1125

The presence of such a large amount of nitrogen in some cases makes the gas almost valueless unless some process is used whereby the nitrogen may be adapted to chemical processes.

While natural gas has a very high heating value in comparison with water gas, water gas has the advantage in that it gives a more intense flame. The comparison of various commercial gases is shown in the following table:

PROPERTIES OF NATURAL AND MANUFACTURED GASES.

Constituents	Avg. Pa. and W. Va.	Avg. Ohio and Ind.	Avg. Kansas	Avg. Coal Gas	Avg. Water Gas	Avg. Producer Gas from Bituminous Coal
Marsh gas, CH_4	80.85	83.60	93.65	40.00	2.00	2.05
Other hydrocarbons	14.00	.30	.25	4.00	.00	.04
Nitrogen	4.60	3.60	4.80	2.05	2.00	56.26
Carbonic acid CO_2	.00	.20	.30	.45	4.00	2.60
Carbonic oxide CO	.40	.50	1.00	6.00	45.50	27.00
Hydrogen	.10	1.50	.00	46.00	45.00	12.00
Hydrogen sulphide	.00	.15	.00	.00	.00	.00
Oxygen	trace	.15	.00	1.50	1.50	.05
Total	100.00	100.00	100.00	100.00	100.00	100.00
Pounds in 1,000 cu. ft.	47.50	48.50	49.00	33.00	45.60	75.00
Sp. grav. air being 1.00	0.624	0.637	0.645	0.435	0.600	0.935
B.T.U. per cu. ft.	1,145	1,095	1,100	755	350	155

(a) 1,000 cu. ft. of air at an atmospheric pressure of 14.7 pounds and at a temperature of 62°F weighs 76.1 pounds and is a mechanical mixture of 23 parts of oxygen and 77 parts of nitrogen by weight.

(b) B.T.U. equals British thermal units, which indicate the heat necessary to raise one pound of pure water at 39°F one degree.

Natural gas may have its origin from a sand which is entirely separated from sand containing oil or it may come from above the oil in the same sand as oil.

In the latter case the lighter portions of the oil will have been volatilized and carried into the gas. Such a gas is known as a "wet" gas. In other words, the wet gas is composed of the usual constituents of dry gas; that is, methane, ethane, propane and butane, and in addition pentane, hexane and heptane. These last three are liquid at ordinary temperatures and are the most desirable components of gasoline.

Gas coming from a sand containing no oil is "dry" gas and does not contain the pentane, hexane and heptane.

A "wet" gas coming from an unknown sand indicates the presence of oil in that sand.

In the ordinary oil well the gas is allowed to escape between the casing of the well and the tube which has been inserted for withdrawal of the oil. The gas so collecting in the casing is known as casinghead gas and may be used or allowed to escape.

This gas collecting in the casinghead of an oil well is "wet" gas and contains some of the gasoline from the oil. The gasoline which may be compressed from it or refrigerated from it is then known as "casinghead" gasoline.

The lighter the oil with which the casinghead gas has been associated, the greater ordinarily will be the amount of gasoline contained in the gas.

Ever since natural gas has been conducted in pipe lines it has been known that gasoline could be separated by pressure and much has been incidentally so produced. More recently the great demand for gasoline has encouraged the design of hundreds of special plants for the extraction of gasoline from natural gas.

In 1904, at Titusville, Pennsylvania, Fasenmeyer made casinghead gasoline by pumping the gas under pressure through a coil under water.

In the early methods pressures of about 50 pounds per square inch were used. Later condensing with a pressure of 400 pounds per square inch was found to produce too "wild" a gasoline or one that escaped too easily on handling. A pressure of 250 pounds per square inch is now used, and the pressure of the condensed liquid is controlled by absorbing it directly into heavier naphtha.

At first the compression was done in one stage, but it is the custom now to do it in two stages. The gravity of the product is from 80 to 100° Baumé.

The amount of casinghead gasoline present in a gas will depend upon the character of the oil associated with it, the temperature, the pressure, the compactness of the sand and the condition in the sand at the point tapped.

The amount of gasoline obtained from casinghead gas in the Mid-Continent field varies from ½ to 8 gallons per 1,000 cubic feet. A typical gas yields 2½ gallons per 1,000 cubic feet. Many yield 3 to 4 gallons per 1,000 cubic feet.

The total production of casinghead gasoline in the United States is shown on page 24.

The cost of plants for producing casinghead gasoline has varied from $12 to $25 per thousand cubic feet of gas handled, and the operation of the plants has been uniformly successful and highly profitable.

While the type of plant ordinarily constructed is for compression methods, it is probable that the absorption method will be more generally adopted. The operation of the absorption method is similar to that of extracting toluol from coal gas and may be applied to a natural gas capable of yielding 1 pint of gasoline per 1,000 cu. ft. By the use of the absorption process 50 million cu. ft. of natural gas would be available per day and 100 million gallons of light gasoline would be made.

Yield of Gasoline from Casinghead Natural Gas by Compression Method, Corresponding to Absorption and Specific Gravity Tests.

Absorption by Oil, per cent	Specific Gravity (Air=1)	Yield of Gasoline, Gallons per 1,000 Cubic Feet of Gas	Absorption by Oil, per cent	Specific Gravity (Air=1)	Yield of Gasoline, Gallons per 1,000 Cubic Feet of Gas
16	0.64	None	50	1.29	3.00
23	.83	1.00	48	1.37	3.50
30	.90	1.75	44	1.38	3.50
37	1.00	2.00	65	1.38	4.00
39	1.03	2.50	84	1.41	4.50
38	1.07	3.00	86	1.46	5.00
54	1.21	3.50			

One casinghead plant figures its probable yield of gasoline in relation to the gravity (G) of the air free gas as follows:

$$\text{Recovery in gallons per 1,000 cu. ft.} = \frac{2\,(15G - 10)}{3}$$

Two-thirds of this amount is marketed.

Helium in Natural Gas.

Locality	Helium	Nitrogen	Methane	Ethane
Dexter, Kansas	1.84%	82.70%	14.85%	0.41%
Eureka, Kansas	1.50	46.40	51.40	0.00
Fredonia, Kansas	0.61	16.40	82.25	0.00
Kansas City, Missouri	0.013	3.65	87.20	7.03

By H. P. Cady and D. F. McFarland.—J. A. C. S., Vol. 24, p. 1530, 1907.

The chief helium producing natural gas is in Kansas with smaller amounts in the gas at Petrolia, Texas.

Properties of Incombustible Gases in Natural Gas.

	Helium (He)	Nitrogen (N)
Combining weight	1.99	14.01
Molecular weight	3.99	28.02
Specific gravity (air = 1)	0.1368	0.96737
Liquefying point	—268.5°C	—195.5°C
Freezing point	—269.0°C	—210.5°C
Solubility in cold water	1.487%	2.348%
Absorption by platinum	great	little
Weight per cubic foot, pounds (Air = 0.080728)	.01105	.07831

Extracting Helium From Natural Gas

The process is essentially one of liquefaction by cold and pressure. All of the constituents in natural gas are liquefied except the helium and then separated from the latter.

When the armistice was signed about 45,000 cubic feet of helium had been extracted and was waiting shipment overseas. Several million dollars had been invested in plant equipment in Texas. The cost of extraction was estimated at 10c per cubic foot.

Natural gas to be valuable as a source of helium should contain at least 0.50 per cent of the gas. It is probable that even this quantity will offer great difficulty in the extraction work, although with experience and cheaper methods which will come with practice even smaller quantities may be valuable. The largest quantity ever discovered in natural gas is something over 2 per cent.

The presence of helium in natural gas was discovered by H. P. Cady and D. F. McFarland of the University of Kansas in 1907. (See Journal of American Chemical Society, Vol. XXIX, p. 1523, November, 1907.)

Lifting Power of Gases in Balloons.

	Pounds per 1,000 Cu. Ft.	Compared with Hydrogen
Hydrogen	75.138 lbs.	100.0 %
Helium	69.748 lbs.	92.84%
Ammonia	33.188 lbs.	44.16%
Natural gas (methane)	36.088 lbs.	48.03%

Gas Carbon Black From Natural Gas

About 1,000 cubic feet of natural gas of specific gravity of .86 are required to make one pound of carbon black.

The operation of making carbon black consists of burning the gas without air under a series of sheet iron shields which collect the carbon from the yellow flame.

The type of burner used is the old style lava tip originally used for lighting purposes with artificial gas. Many thousand tips are used at one plant.

The carbon is scraped off the shields and packed for shipment in 12½-pound sacks.

Plants of this character require very little labor and can be run under the supervision of the plant foreman, thus carrying little or no overhead expense.

Carbon black is mainly used in printers' ink and is a necessary article.

Carbon black is far superior for filler in rubber tires.

The market price of carbon black is from 12c to 25c per pound.

One thousand feet of natural gas contains 35 to 40 pounds of carbon. Practically no plants get over 2 pounds of gas carbon from 1,000 feet of gas, an average of about 1 pound. The smallest practical size unit should handle two million feet of gas per day, producing 2,000 to 3,000 pounds of carbon black. Ordinarily such a plant would cost not less than $60,000.

About Natural Gas and Its Usefulness

An average sample of natural gas has 950 B.T.U. per cubic foot.
1 lb. mill coal will evaporate 9 lbs. water.
1 gal. oil will evaporate 100 lbs. water.
1 cu. ft. gas will evaporate 0.85 water.
1 ton coal used under boilers = 18,500 cu. ft. of gas.
1 bbl. oil (42 gal.) under boilers = 5,000 cu. ft. of gas.
40 to 50 cu. ft. of gas = 1 boiler H.P.

Gas Engines:

Highest grade gas engines develop a brake H.P. on 8,500 B.T.U.
Average engine develops a H.P. on 10,500 B.T.U.
Oil well engine develops a H.P. on 20,000 B.T.U.
In a steam turbine plant of over 500 K.W. capacity 30 cu. ft. gas per K.W. is a fair average.
It requires 40,000 cu. ft. of gas to pump one million gallons of water against 200-foot head.

Brick Plants—Gas Used per Thousand Brick Made:

1,800 cubic feet for power.
1,800 cubic feet for drying.
15,000 cubic feet for kilns.

Ice Plants:

2,000 feet gas per ton of refrigeration.

Zinc Plants:

15,000 cubic feet for roasting per ton of metal produced.
65,000 cubic feet for smelting per ton of metal produced.
20,000 cubic feet for power and miscellaneous uses per ton of metal produced.

Cement Plants:

60 to 100 cubic feet per barrel for power.
80 to 100 cubic feet per barrel for roasters.
1,800 to 2,600 cubic feet per barrel for kilns.

Salt Plants:

Direct-fire pans, 9,000 cubic feet per ton.
Stream pans, 10,000 cubic feet per ton.
Single-effect vacuum pan, 15,000 cubic feet per ton.
Double-effect vacuum pan, 10,000 cubic feet per ton.
Triple-effect vacuum pan, 6,000 cubic feet per ton.

Flour Mills:

200 to 400 cubic feet per barrel.

Gas Compressors:

Horsepower required to compress 1,000 cu. ft. of gas per minute:

To 15 lbs.	50 H.P.	
To 30 lbs.	85 H.P.	
To 45 lbs.	111 H.P.	
To 60 lbs.	134 H.P.	
To 80 lbs.	117 H.P.	(2 stages)
To 100 lbs.	151 H.P.	(2 stages)
To 200 lbs.	212 H.P.	(2 stages)

Horsepower required to compress 1,000 cu. ft. of gas per hr.

To 15 lbs.	1 H.P.
To 30 lbs.	1.75 H.P.
To 45 lbs.	2.25 H.P.
To 60 lbs.	2.75 H.P.

The specific heat of average natural gas is 0.60 B.T.U. per pound, or 0.028 B.T.U. per cubic foot at 32°F.

Properties of Hydrocarbons Found in Natural Gas and Casinghead Gas

	Methane	Ethane	Propane	Butane	Pentane	Hexane	Heptane	Octane
Formula	CH_4	C_2H_6	C_3H_8	C_4H_{10}	C_5H_{12}	C_6H_{14}	C_7H_{16}	C_8H_{18}
Molecular weight	16.03	30.05	44.07	58.08	72.10	86.12	100.13	114.15
Specific gravity of liquid	....	.432= 194° Be'	.515= 142° Be'	.585= 109° Be'	.630= 92.2° Be'	.670= 78.9° Be'	.697= 70.9°	.718= 65.0°
Specific gravity of gas	0.555	1.049	1.526	2.008	2.496	2.982	3.467	3.952
Boiling point at atmospheric pressure	−165°C =265°F	−93°C =135°F	−45°C =49°F	+1°C =34°F	36.3°C =97°F	69°C= 156°F	98.4°C =200°F	125.5°C =258°F
Pressure to liquify at 60°F lbs.	....	475	105	35	6.5	1.8	0.5	0.15
Vapor pressure 70°F in percent of atmosphere	100+	100+	100+	100+	55	10	2.7	0.7
Gallons per 1000 cu. ft. @ B. P. reduced to 60°F	....	4.13	7.17	10.72	14.35	18.22	22.05	25.86
Weight per 1000 cu. ft. @ B. P. reduced to 60°F, lbs.	42	79.7	116	152.6	189.7	226.6	263.5	300
Shrinkage in volume by 1 gal. liquid removed per 1000 cu. ft.	....	....	....	....	7.0%	5.5%	4.5%	3.9%
Max. possible removable gal. per 1000 cu. ft. @ 70°F, gal.	....	....	....	....	7.8	1.8	0.6	0.18
Heating value in B. T. U. per cu. ft.	1065	1861	2685	3447	4250	5012	5780	6542
B. T. U. per lb.	25360	23350	23150	22590	22400	22120	21935	21807
Cu. ft. air to burn 1 cu. ft. gas	9.57	16.72	23.92	31.10	38.28	46.46	53.6	60.8
Carbon per cent	75.0	80.0	81.8	82.8	83.3	83.7	84.0	84.2
Explosive mixture per cent in air, maximum	14.5	5.0	3.5	3.0	2.5	2.2	1.9	1.6
Minimum	5.6	3.0	2.1	1.6	1.3	....	....	....

Gasoline and Natural Gas Explosions

An explosion or a detonation is a chemical reaction which goes on with increasing velocity and is accompanied by a rise of temperature. The lowest temperature at which combustion or explosion of a mixture may take place is called the ignition temperature. This varies greatly with different kinds of gases, being with ordinary hydrocarbon gases, such as natural gas, about 650°C. The vapors of some substances such as carbon bisulphide and hydrogen sulphide are capable of ignition at much lower temperatures, even as low as 100°C. Some gases even inflame spontaneously at room temperature. These are phosphorous dihydride, boron and silicon hydride and cacodyl. Ordinarily, explosive mixtures are ignited by the presence of a flame or spark at any point in the mixture ordinarily greater than .2 of a millimeter in length. In order that the gaseous mixture explodes it is necessary that the heat generated by the local combustion be greater than the heat absorbed by the surrounding gases. This means of course that if the mixture is heated to a high temperature it will be more readily explosive though the pressure will exert very little influence. An excess of either the combustible agent or the oxidizing agent in the mixture will have the same cooling effect that is exerted by any inert gas. The result is that the limits of explosibility of various mixtures of combustible gases and air are dependent upon the heat generated by the combination and by the heat absorbed in raising the temperature of the gases. For ordinary gases the following limits hold as to the range of combustion with combustible mixtures when air is the oxidizing agent:

Limits of Explosibility of Mixtures of Combustible Gases and Air

Gasoline vapor	1.5— 6.0%	by volume of mixture
Methane	5.5—14.5	by volume of mixture
Ethane	2.5— 5.0	by volume of mixture
Natural gas	5.0—12.0	by volume of mixture
Acetylene	3.0—73.0	by volume of mixture
Artificial Illuminating gas	7.0—21.0	by volume of mixture
Hydrogen	5.0—72.0	by volume of mixture
Carbon Monoxide	15.0—73.0	by volume of mixture
Blast furnace gas	36.0—65.0	by volume of mixture
Water gas	9.0—55.0	by volume of mixture
Coal gas	6.0—29.0	by volume of mixture
Ethene	4.0—22.0	by volume of mixture

The striking back of a flame in a burner is caused by the presence of an explosive mixture in the burner. While the usual rate of striking back of the flame or the propagation of an explosion is over 6000 feet per second and about seven times the rate of sound in the same medium; this rate exists only when there is no retardation of the explosive wave caused by the cooling effect of the orifice or tube through which it passes.

Testing of Capacity of Casinghead Gas Wells

To use the orifice well tester the specific gravity of the gas must be taken. This is fully described on page 350.

To test a well, close all openings but one or if the well is shut in at the casinghead, blow off the well before inserting the orifice well tester. Allow the well to blow into the atmosphere for half an hour or until there is no appreciable decrease in the volume of the gas flowing from it. Screw in the orifice well tester, which carries a two-inch thread, and allow the gas to flow into the atmosphere through the proper size of orifice.

Connect a syphon gauge to the nipple on the side of the orifice well tester, using a short piece of common three-eighths-inch rubber hose. The syphon gauge should be filled with water up to the zero mark on the scale. If the well appears to be large use the large-sized orifice. To correctly determine the proper size of orifice it is necessary to read the gauge and note the height of the water in the glass. Read both sides of the scale and add them together. In other words, measure the difference between the two water levels which is the true pressure in inches of water. By referring to tables that accompany each instrument, or as found on pages 263-5 the flow of a well for a twenty-four hour period will be found under the proper gravity and opposite the pressure.

The specific gravity bottle can be used to take the water pressure of the gas flowing through the orifice in place of the syphon gauge. In this case measure the difference between the two levels of the water.

Use as large an orifice as possible so as not to permit the gas to create a back pressure in the well. A back pressure in the well will decrease the flow of the gas.

NATURAL GAS PRODUCED IN THE UNITED STATES IN 1916.

State	Quantity M.cu.ft.	Price, cents per M.cu.ft.	Value
West Virginia	299,318,907	15.90	47,603,396
Pennsylvania	129,925,150	18.74	24,344,324
Oklahoma	123,517,358	9.70	11,983,774
Ohio	69,888,070	22.32	15,601,144
Louisiana	32,080,975	8.29	2,660,445
Kansas	31,710,438	15.31	4,855,389
California	31,643,266	17.19	5,440,277
Texas	15,809,579	18.89	3,143,871
New York	8,594,187	29.37	2,524,115
Illinois	3,533,701	11.22	396,357
Arkansas	2,387,935	10.13	241,896
Kentucky	2,106,542	35.73	752,635
Indiana	1,715,499	29.34	503,373
Wyoming and Colorado	575,044	14.97	86,077
Montana	213,315	18.21	38,855
Dakotas and Alabama	77,478	40.75	31,573
Missouri	69,236	25.41	17,594
Tennessee	2,000	57.50	1,150
Michigan	1,298	73.04	948
Iowa	275	100.00	275
Totals	753,170,253	15.96	120,227,468

SPECIFIC HEAT OF GASES ENCOUNTERED IN NATURAL GAS AND "CRACKED" GAS.

(H. L. Payne, J. A. & Appl. Chem.)

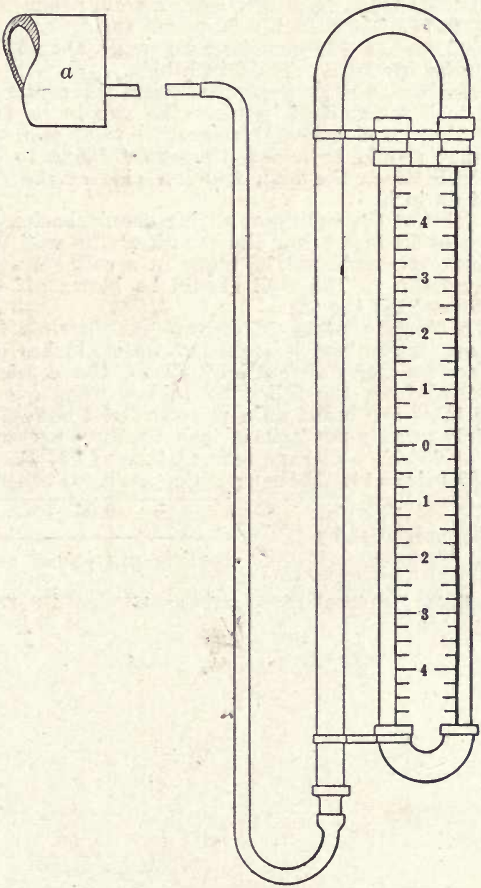
	B. T. U. per lb. per 1°F	B. T. U per lb. per 1°F
Air.	0.234	0.018
Carbon dioxide.	0.234	0.027
Carbonic oxide.	0.245	0.019
Hydrogen.	3.41	0.019
"Illuminants".	0.404	0.040
Methane.	0.593	0.027
Nitrogen.	0.244	0.019
Oxygen.	0.217	0.019
Aqueous vapor.	0.480	.....

CALORIFIC VALUE OF NATURAL AND OIL GASES IN BRITISH THERMAL UNITS PER CUBIC FOOT.

Name	Symbol	60°F Initial	32°F Initial 32°F Final	Ignition Point °F
Hydrogen.	H_2	326.2	345.4	1085
Carbonic oxide.	CO	323.5	341.2	1200
Methane.	CH_4	1009.2	1065.0	1230
Illuminants.		......	2000.0	....
Ethane.	C_2H_6	1764.4	1861.0	1140
Propane.	C_3H_8	2521	2657.0	1015
Butane.	C_4H_{10}	3274	3441.0	....
Pentane.	C_5H_{12}	......	4255.0	....
Hexane.	C_6H_{14}	......	5017.0	1400
Ethylene.	C_2H_4	1588	1674.0	1010
Propylene.	C_3H_6	2347.2	2509.0	940
Benzene.	C_6H_6	3807.4	4012.0	....
Acetylene.	C_2H_2	1476.7	1477.0	788

Pitot Tube for Testing Open Flow of Gas Wells

The most accurate way of testing the flow of a gas well is by means of the Pitot tube, which is an instrument for determining the velocity of flowing gas by means of its momentum. The instrument,



Pitot Tube.

as shown in figure usually consists of a small tube, with one end bent at right angles, which is inserted in the flowing gas, just inside the pipe or tubing *a*, at a point between one-third and one-fourth of the pipe's diameter from the outer edge of the pipe. The plane of the opening in the tube is held at right angles to the flowing gas. At a convenient distance, varying from 1 to 2 feet, an inverted siphon or U-shaped gage, usually half filled with mercury or water, is attached to the other end. If the pressure of the flow is more than 5 pounds per square inch, a pressure gage is required.

In small-sized wells with a flow of not more than 4,000,000 cubic feet per 24 hours, a 12-inch U-gage with water can be used for flows ranging from 4,000,000 to 15,000,000 feet, mercury in a 12-inch U-gage; for 15,000,000 to 35,000,000 feet, a 50-pound spring gage, and for more than 35,000,000 feet, a 100-pound spring gage should be used. The foregoing figures are based on a 6-inch hole.

For convenience, a scale graduated from the center in inches and tenths of an inch is attached between the two limbs of the U-gage. The distance above and below this center line at which the liquid in the gage stands should be added, the object being to determine the exact distance between the high and low side of the fluid in inches and tenths of an inch.

The top joint of the tubing or casing should be free from fittings for a distance of 10 feet below the mouth of the well where the test is made. The test should not be made in a collar or gate or at the mouth of any fitting. The well should be blown off at least three hours prior to making the test.

After the velocity pressure of the gas flowing from the well tubing has been determined in inches of water, inches of mercury, or pounds per square inch, as outlined above, the corresponding flow may be obtained from the following table*. The quantities of gas stated in the table are based on a pressure of 4 ounces above atmospheric, or 14.65 pounds per square inch absolute pressure, a flowing temperature of 60° F., a storage temperature of 60° F., and a specific gravity of 0.60 (air = 1). If the specific gravity is other than 0.60 the flow should be multiplied by

$$\sqrt{\frac{0.60}{\text{specific gravity of gas}}}.$$

*Westcott, H. P.: Handbook of Natural Gas, 1915, pp. 176, 177.

Table for Determining [illegible] Gas Wells by Means of Pitot Tube.

(Figures show the rate of flow of gas o[illegible] specific gravity from gas well tubing of different sizes in cubic feet per 24 hours for different pressures.)

Pressure			Volume of Gas, in Cubic Feet per 24 Hours, Discharged Through—				Pressure.	Volume of gas, in cubic feet per 24 hours, discharged through—			
Inches of Water	Inches of Mercury	Pounds per Square Inch	1-Inch Tubing	2-Inch Tubing	3-Inch Tubing	4-Inch Tubing	Pounds per square inch.	1-inch tubing.	2-inch tubing.	3-inch tubing.	4-inch tubing.
0.10	....	....	11,880	47,520	106,920	190,080	2.75	321,000	1,284,000	2,889,000	5,136,000
.20	....	....	17,130	68,544	154 224	274,176	3.	340,200	1,360,800	3,061,800	5,443,200
.30	....	....	20,568	82,272	185,112	329,088	3.25	354,120	1,416,480	3,187,080	5,665,920
.40	....	....	23,520	94,080	211,680	376,320	3.50	367,680	1,470,720	3,309,120	5,882,880
.50	....	....	26,544	106,176	238,896	424,704	3.75	380,400	1,521,600	3,423,600	6,086,400
.60	....	....	29,112	116,448	262,008	465,792	4.00	392,880	1,571,520	3,535,920	6,286,080
.7	....	....	31,440	125,760	282,960	503,040	4.25	405,000	1,620,000	3,645,000	6,480,000
.8	....	....	33,624	134,496	302,616	537,984	4.50	416,640	1,666,560	3,749,760	6,666,240
.9	....	....	35,640	142,560	320,760	570,240	4.75	428,280	1,713,120	3,854,520	6,852,480
1.0	....	....	37,320	149.280	335,880	597,120	5.00	439,920	1,759,680	3,959,280	7,038,720
1.25	....	....	41,712	166,848	375,408	667,392	6	476,040	1,904,160	4,284,360	7,616,640
1.5	....	....	45,960	183,840	413,640	735,360	7	517,320	2,069,280	4,655,880	8,277,120
1.75	0.12	....	49,680	198,720	447,120	794,880	8	542,400	2,169,600	4,881,600	8,678,400
2.0	.147	....	53,136	212,544	478,224	850,176	9	569,640	2,278,650	5,126,760	9,114,240
2.5	.184	....	59,400	237,600	534,600	950,400	10	595,560	2,382,240	5.360,040	9,528,960
3.0	.22	.108	65,088	260,352	585,792	1,041,408	11	621,960	2,487,840	5,597,640	9,951,360
3.5	.257	.126	70,272	281,088	632,448	1,124,352	12	642,600	2,570,400	5,783,400	10,281,600
4.0	.294	.144	75,120	300,480	676,080	1,201,920	13	664,680	2,658,720	5,982,120	10,634,880
4.5	.331	.162	79,704	318,810	717,336	1,275,261	14	683,880	2,735,520	6,154,920	10,942,080
5.0	.368	.18	84,000	336,000	756,000	1,344,000	15	703,080	2,812,320	6,327,720	11,249,280
6.	.441	.216	92,016	368,060	828,144	1,472,256	16	721,080	2,884,320	6,489,720	11,537,280
7.	.515	.252	99,360	397,440	894,240	1,589,760	17	738,120	2,952,480	6,643,080	11,809,920
8.	.588	.288	106,272	425,088	956,448	1,700,352	18	753,960	3,015,840	6,785,640	12,063,360
9.	.662	.324	112,656	450,624	1,013,904	1,802,496	20	785,520	3,142,080	7,069,680	12,568,320
10.	.736	.36	118,800	475.200	1,069,200	1,900,800	22	803,280	3,213,120	7,229,520	12,852,480
11.	.8	.396	125,160	500,640	1,126,440	2,002,560	25	854,880	3,419,520	7,693,920	13.678,080
12.	.88	.432	130,128	520,512	1,171,152	2,082,048	30	910,680	3,642,720	8,196,120	14,570,880
....	1.02	.5	138,960	555,840	1,250,640	2,223,360	35	960,960	3,843,840	8,648,640	15,375,360
....	1.52	.75	170,280	681,120	1,532,520	2,724,480	40	1,006,680	4,026,720	9,060,120	16,106,880
....	2.03	1.00	196,680	786,720	1,770,120	3,146,880	45	1,046,520	4.186,080	9.418,680	16,744,320
....	2.54	1.25	219,960	879,840	1,979,640	3,519,360	50	1,081,920	4.327,680	9,737,280	17,310,720
....	3.05	1.5	240,720	962,880	2,166,480	3,851,520	60	1,137,120	4.548 480	10,234,080	18,193,920
....	3.56	1.75	259,920	1,039,680	2,339,280	4,158,720	75	1,223,400	5.217,600	11,010,000	19,574,400
....	4.07	2.00	272,640	1,090,560	2,453,760	4,362,240	90	1,304,400	5,217,600	11,739,600	20,870,400
....	4.57	2.25	294,600	1,178,400	2,651,400	4,713,600	100	1,336,920	5,347,680	12,032,280	21,390,720
....	5.08	2.50	310,800	1,243,200	2,797,200	4,972,800					

For pipe diameters other than those given in the preceding table, the following multipliers should be applied to the figures for 1-inch tubing given in the table.

Multipliers for Pipe Diameters Ranging from 1½ to 12 inches.

Diameter of pipe, inches.	Multiplier.	Diameter of pipe, inches.	Multiplier.	Diameter of pipe, inches.	Multiplier.
1½	2.25	5	25	8	64
2½	6.25	5⅝	31.64	8¼	68
4¼	18	6	36	9	81
4⅝	21.39	6¼	39	10	100
		6⅝	43.9	12	144

Flow of Gas in Pipes—Low Pressure

The following formulae are intended for low pressure distribution of gas, with comparatively small differences between the initial and final pressures:

Pole's Formula $$Q = 1350 \sqrt{\frac{d^5h}{sl}}$$

Molesworth's Formula $$Q = 1000 \sqrt{\frac{d^5h}{sl}}$$

Gill's Formula $$Q = 1291 \sqrt{\frac{d^5h}{s(1+d)}}$$

Where Q = quantity of gas discharged in cubic feet per hour.
d = inside diameter of pipe in inches.
h = pressure in inches of water.
s = specific gravity of gas, air being 1.
l = length of main in yards.

Oliphant's Formula. A formula determined by F. H. Oliphant for the discharge of gas when the specific gravity is 0.60 is

$$Q = 42a \sqrt{\frac{P_1^2 - P_2^2}{L}}$$

Where Q = discharge in cubic feet per hour at atmospheric pressure.
P_1 = initial pressure in pounds per square inch (absolute).
P_2 = final pressure in pounds per square inch (absolute).
L = length of main in miles.
a = coefficient (see table below).

For gas of any other specific gravity, s, multiply the discharge by $\sqrt{\frac{0.60}{s}}$, for temperature of flowing gas when observed above 60°F deduct 1 per cent for each 5° and add a like amount for temperatures less than 60°F.

According to Oliphant, the discharge is not strictly proportional to $\sqrt{d^5}$. Using a coefficient of unity for 1-inch pipe he gives

$$a = \sqrt{d^5 + \frac{d^6}{30}}$$

Values of Coefficient "a"

Inside diameter inches	a	Inside diameter inches	a	Inside diameter inches	a
¼	.0317	3	16.5	12	556
½	.1810	4	34.1	16	1160
¾	.5012	5	60	18	1570
1	1.00	5⅝	81	20	2055
1½	2.93	6	95	24	3285
2	5.92	8	198	30	5830
2½	10.37	10	350	36	9330

For 15 inch outside diameter pipe, 14½ inches inside dia. **a** = 863
For 16 inch outside diameter pipe, 15¼ inches inside dia. **a** = 1025
For 18 inch outside diameter pipe, 17¼ inches inside dia. **a** = 1410
For 20 inch outside diameter pipe, 19¼ inches inside dia. **a** = 1860

Capacity of Pipe Lines

(Metric Metal Works.)

Tables to Find the Cubic Feet, per Day of 24 Hours, of Gas of .6 Specific Gravity at Certain Pressure in Pipe Lines of Various Diameter and Lengths.

Select in table A the number opposite the gauge pressures, in pounds, then from table B select the number opposite the length of line in miles. Multiply these two numbers together and result is the cubic feet that a 1-inch line will discharge for the pressures and length named in twenty-four hours. If the diameter of the pipe is other than one inch, select the number in table C which corresponds with the diameter and multiply this number by the discharge for one inch already secured. The result is the quantity in cubic feet in twenty-four hours discharged by a line whose diameter was selected.

If there are other pressures and lengths not given in the table they can be secured by interpolation. Example—Suppose it is required to find the discharge per day of twenty-four hours of a pipe line having an intake of 200-pound gauge pressure and 25 pounds at the discharge end, the length being 20 miles, and the diameter 8 inches. In table A we find opposite 200 and 25 the number 211.25, and in table B opposite 20 miles, 22.5, multiplying these two numbers the result being 47,637 cubic feet that under the above condition of pressure and length a 1-inch pipe would convey, but the required diameter is 8 inches. Under this number in table C it will be found that 198 corresponds; therefore 47,637 × 198 = 9,433,126, which is the cubic feet discharged in 24 hours.

If the pressure were twenty pounds instead of twenty-five at the discharge end it would be found very closely by adding the figures opposite 15 and 25 and dividing by 2, the result would be 9,469,154.

TABLE A.

Intake, Lbs.	Discharge, Lbs.	Resultant	Intake, Lbs.	Discharge, Lbs.	Resultant	Intake, Lbs.	Discharge, Lbs.	Resultant
1	¼	4.7	40	5	51.2	110	75	86.8
1	½	3.9	40	10	49.0	110	85	75.0
2	½	6.9	40	15	46.1	110	100	49.0
2	1	4.7	40	20	42.4	125	5	138.6
2	1½	4.0	40	25	37.8	125	15	136.8
3	1	8.1	40	30	31.6	125	25	134.2
3	2	5.8	40	35	22.9	125	35	130.8
4	1	10.1	50	5	61.8	125	50	124.0
4	2	8.4	50	10	60.0	125	75	107.2
4	3	6.0	50	15	57.7	125	100	79.8
5	1	11.8	50	20	54.8	125	110	63.1
5	2	10.4	50	25	51.2	135	5	148.7
5	3	8.6	50	30	46.9	135	15	147.0
5	4	6.2	50	35	41.5	135	25	144.6
6	1	13.4	50	40	34.6	135	35	141.4
6	3	10.6	50	45	25.0	135	50	135.2
6	5	6.3	60	5	72.3	135	75	120.0
7	1	14.9	60	10	70.7	135	100	96.3
7	3	12.5	60	15	68.8	150	5	163.8
7	5	9.0	60	20	66.3	150	15	162.3
7	6	6.5	60	25	63.4	150	25	160.1
8	1	16.3	60	30	60.0	150	40	155.6
8	3	14.1	60	40	51.0	150	50	151.7
8	5	11.2	60	50	37.4	150	75	138.3
8	7	6.6	60	55	26.9	150	100	118.3
9	1	17.6	70	5	82.6	150	120	94.9
9	3	15.6	70	10	81.2	175	5	188.9
9	5	13.1	70	20	77.5	175	15	187.6
9	8	6.8	70	30	72.1	175	25	185.7
10	1	19.2	70	40	64.8	175	35	183.3
10	2	18.3	70	50	54.7	175	50	178.5
10	4	16.3	70	60	40.0	175	75	167.3
10	6	13.6	80	5	92.8	175	100	151.2
10	8	9.8	80	10	91.6	175	150	94.2
10	9	7.0	80	20	88.3	200	5	214.1
12	1	21.8	80	30	83.7	200	15	212.9
12	3	20.1	80	40	77.5	200	25	211.3
12	6	17.0	80	50	69.2	200	35	209.1
12	8	14.1	80	60	58.3	200	50	204.9
12	10	10.2	80	70	42.4	200	75	195.3
15	1	25.4	90	5	103.1	200	100	181.7
15	3	24.0	90	10	102.0	200	125	163.2
15	6	21.4	90	20	99.0	200	150	137.9
15	9	18.0	90	30	94.9	200	175	100.6
15	12	13.1	90	40	89.4	200	190	64.8
20	1	31.1	90	50	82.5	220	5	234.2
20	4	29.4	90	60	73.5	220	15	233.1
20	8	26.4	90	70	61.6	220	25	231.6
20	10	24.5	90	80	44.7	220	35	229.6
20	15	18.0	100	5	113.3	220	50	225.8
20	18	11.7	100	10	112.3	220	75	217.1
25	1	36.7	100	15	111.0	220	100	204.9
25	3	35.7	100	20	109.5	220	125	188.8
25	6	34.0	100	25	107.8	220	150	167.3
25	10	31.2	100	35	103.6	220	175	138.3
25	15	26.5	100	50	94.9	220	200	94.9
25	18	22.6	100	75	71.6	230	5	244.1
30	1	42.1	100	85	56.8	230	15	243.2
30	3	41.2	100	95	33.5	230	25	241.7
30	6	39.8	110	5	123.4	230	35	239.8
30	10	37.4	110	15	121.4	230	50	236.2
30	15	33.5	110	25	118.4	230	75	227.9
30	20	28.3	110	35	114.6	230	100	216.3
30	25	20.0	110	50	106.8	230	150	181.5

TABLE A—Continued.

Intake, Lbs.	Discharge, Lbs.	Resultant	Intake, Lbs.	Discharge, Lbs.	Resultant	Intake, Lbs.	Discharge, Lbs.	Resultant
230	200	117.5	325	250	213.0	400	225	338.6
230	215	84.4	325	275	177.5	400	250	319.4
250	5	264.2	325	285	160.0	400	275	296.9
250	15	263.3	325	300	128.0	400	300	270.2
250	25	262.0	350	5	364.5	400	325	238.0
250	35	260.2	350	15	363.8	400	350	197.5
250	50	256.9	350	25	362.8	400	375	141.9
250	75	249.3	350	35	361.6	425	5	439.6
250	100	238.8	350	50	359.2	425	15	439.0
250	125	225.0	350	75	353.7	425	25	438.2
250	150	207.4	350	100	346.4	425	35	437.2
250	175	184.7	350	125	337.1	425	50	435.2
250	200	154.9	350	150	325.6	425	75	430.7
250	230	101.0	350	175	311.7	425	100	424.7
275	5	289.3	350	200	295.0	425	125	417.1
275	15	288.4	350	225	275.0	425	150	407.9
275	25	287.2	350	250	251.0	425	175	396.9
275	35	285.7	350	275	221.6	425	200	383.9
275	50	282.6	350	300	184.4	425	225	368.8
275	75	275.7	350	325	132.8	425	250	351.3
275	100	266.2	375	5	389.5	425	275	330.9
275	150	238.5	375	15	388.8	425	300	307.2
275	200	194.6	375	25	387.9	425	325	279.3
275	250	117.8	375	35	386.8	425	350	245.7
300	5	314.4	375	50	384.6	425	375	203.7
300	15	313.6	375	75	379.5	425	400	146.2
300	25	312.5	375	100	372.7	450	5	464.6
300	35	311.0	375	125	364.0	450	15	464.0
300	50	308.2	375	150	353.4	450	25	463.3
300	75	301.9	375	175	340.6	450	35	462.3
300	100	293.8	375	200	325.4	450	50	460.4
300	125	282.2	375	225	307.4	450	75	456.2
300	150	268.3	375	250	286.1	450	100	450.5
300	175	251.3	375	275	260.8	450	125	443.4
300	200	230.2	375	300	230.0	450	150	434.7
300	250	170.3	375	325	191.1	450	175	424.4
300	275	123.0	375	350	137.4	450	200	412.3
325	5	339.4	400	5	414.5	450	225	398.3
325	15	338.7	400	15	413.9	450	250	382.1
325	25	337.6	400	25	413.1	450	275	363.5
325	35	336.3	400	35	412.0	450	300	342.1
325	50	333.7	400	50	409.9	450	325	317.2
325	75	327.9	400	75	405.1	450	350	288.1
325	100	320.0	400	100	398.8	450	375	253.2
325	125	309.8	400	125	390.2	450	400	209.8
325	150	297.3	400	150	380.8	450	425	150.4
325	175	281.9	400	175	369.0	475	50	485.7
325	200	263.4	400	200	355.0	500	50	510.0

TABLE B.

Miles	Multipliers	Miles	Multipliers	Miles	Multipliers
⅛	2880.	19	231.2	61	129.1
¼	2016.	20	225.5	62	128.1
⅜	1652.4	21	220.1	63	126.9
½	1419.7	22	214.9	64	126.0
⅝	1275.9	23	210.0	65	125.1
¾	1158.6	24	205.7	66	124.1
⅞	1083.7	25	201.6	67	123.1
1	1008.0	26	197.6	68	122.2
1½	826.2	27	193.8	69	121.3
1¾	763.6	28	190.5	70	120.4
2	714.9	29	187.0	72	118.7
2½	638.0	30	183.9	74	117.2
2¾	607.2	31	181.0	76	115.6
3	582.7	32	178.0	78	114.2
3½	539.0	33	175.6	80	112.7
4	504.0	34	172.9	82	111.2
4½	475.5	35	170.3	84	109.9
5	450.0	36	168.0	86	108.7
5½	428.9	37	165.8	88	107.5
6	411.4	38	163.6	90	106.2
6½	395.3	39	161.3	92	105.1
7	380.4	40	159.5	94	103.9
7½	367.9	41	157.5	96	102.9
8	356.2	42	155.6	98	101.8
8½	345.2	43	153.7	100	100.8
9	336.0	44	152.0	102	99.8
9½	327.3	45	150.2	105	98.3
10	319.0	46	148.7	107	97.5
10½	311.1	47	146.9	110	96.0
11	303.6	48	145.4	112	95.3
11½	297.3	49	144.0	115	93.9
12	291.3	50	142.6	118	92.8
12½	284.7	51	141.2	120	92.0
13	276.4	52	139.8	122	91.2
13½	274.6	53	138.5	125	90.2
14	269.5	54	137.1	130	88.4
14½	264.6	55	135.8	135	86.8
15	260.5	56	134.8	140	85.2
15½	255.8	57	133.5	145	83.7
16	252.0	58	132.3	150	82.3
17	244.7	59	131.2	...	.....
18	237.5	60	130.1	...	.....

TABLE C.

Multipliers for diameters other than 1 inch.

¼ inch = .0317	3 inch = 16.50	12 inch = 556
½ inch = .1810	4 inch = 34.10	16 inch = 1160
¾ inch = .5012	5 inch = 60.00	18 inch = 1570
1 inch = 1.0000	5⅝ inch = 81.00	20 inch = 2055
1½ inch = 2.9300	6 inch = 95.00	24 inch = 3285
2 inch = 5.9200	8 inch = 198.00	30 inch = 5830
2½ inch = 10.3700	10 inch = 350.00	36 inch = 9330

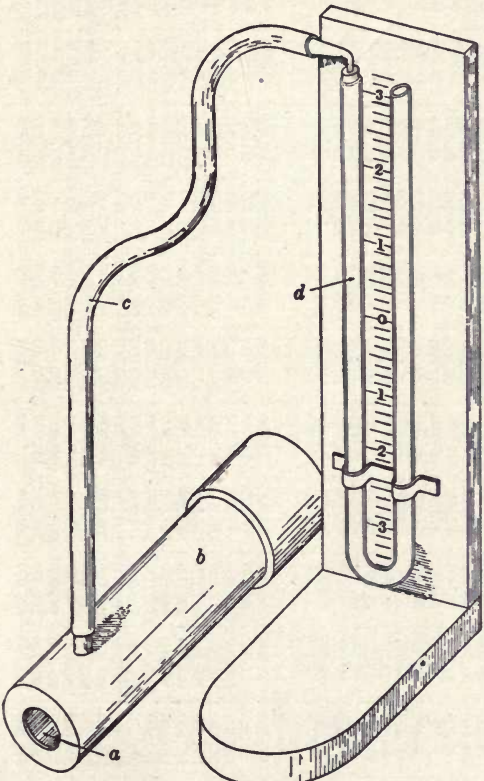
For wrought iron pipes greater than 12 inches in diameter the measure is taken from outside, and for pipes of ordinary thickness the corresponding inside diameters and multipliers are as follows:

Outside dia. of 15-inch pipe gives 14¼ in. inside dia. = 863
Outside dia. of 16-inch pipe gives 15¼ in. inside dia. = 1025
Outside dia. of 18-inch pipe gives 17¼ in. inside dia. = 1410
Outside dia. of 20-inch pipe gives 19¼ in. inside dia. = 1860

Measuring the Flow of Natural Gas

ORIFICE METER.

An instrument known as the orifice meter, for testing small flows of natural gas, is shown in the figure. This instrument is simple in construction, consisting of a short 2-inch nipple, b, with pipe thread on one end and a thin plate disk on the other. The disk carries a 1-inch orifice, a, and a hose connection, c, for taking the pressure. The meter is especially intended for testing small gas wells and "casinghead" gas from oil wells. As a rule the flow of gas from an oil well is rather small, and it is not advisable to test the flow with a Pitot tube such as is used in testing large gas wells. In using the orifice tester, it is necessary to know the specific gravity of the gas in order to obtain the flow.



Orifice meter for testing small flows of natural gas.

Before the orifice well tester is attached to the casinghead the well should be permitted to blow into the atmosphere until the head of the gas is reduced and the flow has become normal. Then the tester is attached by simply screwing it into the end of a 3-foot length of 2-inch pipe and the pressure is read in inches of water on the siphon gage, d. In the tables* on pages 262-3, the flow of the well with values for the gas of different gravities is opposite the gage reading. The orifice in the instrument should be kept dry and uninjured; otherwise the gage reading will not be correct.

*Westcott H. P.: Handbook of Natural Gas, 1915, pp. 545-548.

Capacities of Orifices for Testing Flows of Natural Gas From Small Gas Wells and Casinghead Gas From Oil Wells.

(Temperature, 60°F.; atmospheric pressure, 14.4 pounds per square inch.)
ONE-INCH ORIFICE IN PLATE ⅛ INCH THICK.

Pressure	Capacity in Cubic Feet per 24 Hours, at Specific Gravity of—															
	0.6	0.65	0.7	0.75	0.8	0.85	0.9	0.95	1	1.05	1.1	1.15	1.2	1.3	1.4	1.5
ches of Water																
....	26,400	25,440	24,500	23,660	22,920	22,220	21,600	21,020	20,520	20,010	19,560	19,120	18,720	18,000	17,320	16,750
....	37,510	36,040	34,750	33,600	32,520	31,530	30,640	29,800	29,080	28,360	27,720	27,120	26,540	25,480	24,570	23,760
....	46,440	44,640	43,000	41,540	30,240	39,020	37,940	36,880	36,000	35,130	34,320	33,550	32,850	31,560	30,400	29,370
....	52,630	50,590	48,740	47,060	45,600	44,200	42,980	41,800	40,800	39,790	38,880	38,040	37,220	35,760	34,460	33,310
....	57,880	55,630	53,610	51,790	50,160	48,640	47,280	45,980	44,880	43,770	42,760	41,830	40,940	39,360	37,920	36,620
....	63,140	60,720	58,480	56,490	54,720	53,060	51,600	50,180	48,960	47,760	46,650	45,640	44,680	42,960	41,370	39,960
....	68,110	65,470	63,090	60,910	59,040	57,210	55,630	54,120	52,800	51,500	50,320	49,220	48,190	46,320	44,610	43,100
....	73,050	70,220	67,680	65,350	63,310	61,390	59,680	58,050	56,640	55,240	54,000	52,800	51,690	49,690	47,850	46,220
....	77,680	74,680	72,000	69,500	67,340	65,280	63,480	61,720	60,240	58,800	57,430	56,160	54,960	52,800	50,880	49,170
....	82,340	79,150	76,270	73,650	71,370	69,190	67,270	65,420	63,840	62,280	60,860	59,520	58,240	55,900	53,920	52,100
....	86,680	83,320	80,300	77,540	75,120	72,840	70,800	68,880	67,200	65,560	64,080	62,660	61,320	58,920	56,780	54,860
....	90,720	87,190	84,000	81,140	78,600	76,220	74,110	72,000	70,320	68,610	67,030	65,560	64,170	61,680	59,400	57,400
ches of lercury																
½..........	67,200	64,600	62,300	60,100	58,200	56,500	54,900	53,400	52,100	50,800	49,600	48,600	47,500	45,700	44,000	42,500
....	95,200	91,500	88,200	85,100	82,500	80,000	77,800	75,600	73,800	72,000	70,300	68,800	67,300	64,700	62,300	60,200
½..........	116,600	112,000	108,000	104,300	101,000	97,900	95,300	92,600	90,400	88,200	86,200	84,300	82,500	79,200	76,300	73,800
....	134,600	129,400	124,700	120,400	116,700	113,100	110,000	107,000	104,400	101,800	99,500	97,300	95,300	91,500	88,200	85,200
½..........	145,600	139,900	134,900	130,200	126,200	122,400	118,900	115,700	112,900	110,100	107,600	105,300	103,000	99,000	95,400	92,200
....	164,900	158,500	152,700	147,500	142,900	138,600	134,700	131,000	127,800	124,700	121,800	119,200	116,600	112,000	108,000	104,300
½..........	178,200	171,300	165,100	159,400	154,500	149,800	145,600	141,600	138,200	134,800	131,700	128,800	126,100	121,200	116,700	112,800
....	190,400	183,000	176,400	170,300	165,000	160,000	155,600	151,300	147,600	144,000	140,700	137,600	134,700	129,400	124,700	120,500
....	212,900	204,600	197,200	190,400	184,500	178,900	174,000	169,200	165,000	161,000	157,300	153,900	150,600	144,700	139,400	134,700
....	233,200	224,100	216,000	208,600	202,100	195,900	190,500	185,300	180,800	176,400	172,300	168,600	165,000	158,500	152,700	147,600
....	251,900	242,100	233,400	225,300	218,300	211,700	205,800	200,200	195,300	190,000	186,200	182,100	178,200	171,200	165,000	159,400
....	269,400	258,900	249,500	240,900	233,400	226,400	220,100	214,000	208,800	203,700	199,100	194,700	190,600	183,100	176,400	170,560
....	285,700	274,600	264,700	255,600	247,600	240,100	233,500	227,000	221,500	216,100	211,200	206,500	202,100	194,200	187,100	180,800
....	301,200	289,500	279,000	269,400	261,000	253,100	246,100	239,300	233,500	227,800	222,600	217,700	213,100	204,700	197,300	190,600
....	315,800	303,600	292,500	282,500	273,700	265,400	258,000	250,900	244,800	238,900	233,400	228,300	223,400	214,700	206,800	199,900
....	328,400	315,700	304,200	293,800	284,600	276,000	268,400	261,000	254,600	248,400	242,700	237,400	232,400	223,300	215,100	207,900

Capacities of Orifices for Testing Flows of Natural Gas From Small Gas Wells and Casinghead Gas From Oil Wells.—Continued.

ONE-HALF INCH ORIFICE IN PLATE ⅛ INCH THICK.

Pressure	Capacity in Cubic Feet per 24 Hours, at Specific Gravity of—															
	0.6	0.65	0.7	0.75	0.8	0.85	0.9	0.95	1	1.05	1.1	1.15	1.2	1.3	1.4	1.5
...ches of Water																
½	4,490	4,320	4,160	4,020	3,890	3,770	3,670	3,570	3,480	3,400	3,320	3,250	3,180	3,050	2,940	2,840
	6,260	6,010	5,790	5,600	5,440	5,260	5,110	4,970	4,850	4,730	4,620	4,520	4,420	4,250	4,100	3,960
½	7,900	7,590	7,310	7,070	6,840	6,640	6,450	6,280	6,120	5,970	5,830	5,710	5,590	5,370	5,170	5,000
	9,140	8,780	8,460	8,170	7,910	7,680	7,460	7,260	7,080	6,910	6,750	6,600	6,460	6,210	5,980	5,780
½	10,220	9,820	9,470	9,140	8,850	8,590	8,350	8,120	7,920	7,730	7,550	7,380	7,230	6,950	6,690	6,470
	11,150	10,720	10 330	9,980	9,660	9,370	9,110	8,860	8,640	8,430	8,240	8,060	7,890	7,580	7,300	7,050
½	12,020	11,550	11,130	10,750	10,410	10,100	9,810	9,550	9,310	9,090	8,880	8,680	8,500	8,170	7,870	7,600
	12,800	12,290	11,850	11,440	11,080	10,750	10,450	10,170	9,910	9,670	9,450	9,240	9,050	8,690	8,380	8,090
½	13,480	12,950	12,480	12,050	11,670	11,320	11,000	10,710	10,440	10,190	9,950	9,730	9,530	9,160	8,820	8,520
	14,130	13,570	13,080	12,640	12,230	11,870	11,530	11,230	10,940	10,680	10,430	10,200	9,990	9,600	9,250	8,930
½	14,690	14,110	13,600	13,130	12,720	12,340	11,990	11,670	11,380	11,100	10,850	10,610	10,380	9,989	9,610	9,290
	15,210	14,620	14,080	13,610	13,170	12,780	12,420	12,090	11,780	11,500	11,230	10,990	10,760	10,330	9,960	9,620

THREE-EIGHTHS INCH ORIFICE IN PLATE ⅛ INCH THICK.

Pressure	0.6	0.65	0.7	0.75	0.8	0.85	0.9	0.95	1	1.05	1.1	1.15	1.2	1.3	1.4	1.5
½	2,270	2,180	2,100	2,030	1,970	1,910	1,850	1,810	1,760	1,720	1,680	1,640	1,610	1,540	1,490	1,440
	3,460	3,320	3,200	3,090	3,000	2,910	2,820	2,750	2,680	2,670	2,550	2,500	2,450	2,350	2,260	2,190
½	4,310	4,140	3,990	3,860	3,730	3,620	3,520	3,420	3,339	3,260	3,180	3,110	3,050	2,430	2,820	2,730
	4,830	4,640	4,470	4,320	4,180	4,060	3,910	3,840	3,740	3,650	3,560	3,490	3,410	3,280	3,160	3,950
½	5,400	5,190	5,000	4,830	4,680	4,540	4,410	4,290	4,186	4,080	3,990	3,900	3,820	3,670	3,540	3,420
	5,770	5,550	5,350	5,170	5,000	4,850	4,720	4,590	4,474	4,370	4,260	4,170	4,080	3,920	3,780	3,650
½	6,290	6,050	5,830	5,630	5,450	5,290	5,140	5,000	4,875	4,760	4,650	4,550	4,450	4,270	4,120	3,980
	6,650	6,390	6,160	5,950	5,760	5,590	5,430	5,280	5,152	5,030	4,910	4,800	4,700	4,520	4,350	4,210
½	7,210	6,930	6,680	6,450	6,240	6,060	5,890	5,730	5,585	5,450	6,330	5,210	5,100	4,900	4,720	4,560
	7,680	7,380	7,110	6,870	6,650	6,450	6,270	6,100	5,946	5,800	5,670	5,540	5,430	5,210	5,020	4,850
½	8,100	7,790	7,500	7,250	7,020	6,810	6,620	6,440	6,278	6,130	5,980	5,850	5,730	5,510	5,310	5,130
	8,290	7,970	7,680	7,420	7,180	6,970	6,770	6,500	6,423	6,270	6,120	5,990	5,860	5,630	5,430	5,240

Orifice Capacity

Diameter Inches		Area	Morse Drill Gage Size	Cubic Feet Per Hour		
Frac.	Decimal	Square Inch		Coal Gas 0.43 sp. gr. 2″ Press	Water Gas 0.62 sp. gr. 2″ Press	Natural Gas 0.62 sp. gr. 4½ Oz. Press
	0.0135	0.000143	80	1.04	0.86	1.67
	0.0145	0.000165	79	1.16	0.97	1.89
1/64	0.0156	0.00019	....	1.26	1.05	2.05
	0.016	0.00020	78	1.32	1.10	2.14
	0.018	0.00025	77	1.35	1.13	2.20
	0.020	0.00031	76	1.62	1.35	2.63
	0.021	0.00035	75	1.80	1.52	2.96
	0.0225	0.00040	74	2.16	1.80	3.51
	0.024	0.00045	73	2.29	1.90	3.70
	0.025	0.00049	72	2.46	2.05	4.00
	0.026	0.00053	71	2.70	2.25	4.38
	0.028	0.00062	70	2.79	2.33	4.54
	0.0292	0.00067	69	3.08	2.57	4.97
	0.031	0.00075	68	3.23	2.70	5.26
1/32	0.031	0.00076	....	3.26	2.73	5.32
	0.032	0.00080	67	3.42	2.85	5.56
	0.033	0.00086	66	3.53	2.94	5.73
	0.035	0.00096	65	3.69	3.08	6.00
	0.036	0.00102	64	3.86	3.23	6.30
	0.037	0.00108	63	4.05	3.38	6.60
	0.038	0.00113	62	4.11	3.51	6.84
	0.039	0.00119	61	4.50	3.75	7.31
	0.040	0.00126	60	4.95	4.12	8.04
	0.041	0.00132	59	5.22	4.35	8.48
	0.042	0.00138	58	5.40	4.50	8.77
	0.043	0.00145	57	5.67	4.71	9.2
	0.0465	0.00170	56	6.57	5.47	10.6
3/64	0.0469	0.00173	....	6.75	5.63	11.0
	0.0520	0.0021	55	8.9	6.75	13.2
	0.0550	0.0023	54	9.0	7.50	14.6
	0.0595	0.0028	53	10.8	9.0	17.5
1/16	0.0625	0.0031	....	11.7	9.7	19.0
	0.0635	0.0032	52	11.9	9.9	19.3
	0.0670	0.0035	51	12.6	10.5	20.5
	0.070	0.0038	50	13.5	11.2	21.8
	0.0730	0.0042	49	14.4	12.0	23.4
	0.076	0.0043	48	15.3	12.7	24.8
5/64	0.0781	0.0048	....	15.7	13.1	25.5
	0.0785	0.0018	47	15.8	13.2	25.7
	0.081	0.0051	46	16	13.5	26
	0.082	0.0053	45	17	14.3	28
	0.086	0.0058	44	18	15	29
	0.089	0.0062	43	19	16.5	32
	0.0935	0.0069	42	20	17	33
3/32	0.0937	0.0069	....	21	18	35
	0.096	0.0072	41	22	19	37
	0.098	0.0075	40	23	20	39
	0.0995	0.0078	39	24	20.5	40
	0.1015	0.0081	38	25	21	41
	0.104	0.0085	37	26	22	43
	0.1065	0.0090	36	27	22.5	44
7/64	0.1093	0.0094	....	28	23	45
	0.110	0.0095	35	29	24	47
	0.111	0.0097	34	30	25	49
	0.113	0.0100	33	31	26	51
	0.116	0.0106	32	32	27	53

ORIFICE CAPACITY—Continued.

Diameter Inches		Area	Morse Drill Gage Size	Cubic Feet Per Hour		
Frac.	Decimal	Square Inch		Coal Gas 0.43 sp. gr. 2″ Press	Water Gas 0.62 sp. gr. 2″ Press	Natural Gas 0.62 sp. gr. 4½ Oz. Press
	0.120	0.0113	31	33	28	55
1/8	0.125	0.0123	....	36	30	58
	0.1285	0.0130	30	39	32	62
	0.136	0.0145	29	43	35	68
	0.1405	0.0155	28	44	37	72
9/64	0.1406	0.0155	....	45	38	74
	0.144	0.0163	27	47	39	76
	0.147	0.0174	26	48	40	78
	0.1495	0.0175	25	51	42	82
	0.152	0.0181	24	52	43	84
	0.154	0.0186	23	53	44	86
5/32	0.156	0.0192	....	54	45	88
	0.157	0.0192	22	55	46	90
	0.159	0.0198	21	57	47	91
	0.161	0.0203	20	58	48	94
	0.166	0.0216	19	60	50	97
	0.1695	0.0226	18	62	52	101
11/64	0.1719	0.0232	....	63	53	103
	0.173	0.0235	17	65	54	105
	0.177	0.0246	16	68	56	109
	0.180	0.0254	15	69	58	113
	0.182	0.0260	14	71	59	115
	0.185	0.0269	13	72	61	119
3/16	0.1875	0.0276	....	75	62	121
	0.189	0.0280	12	76	63	123
	0.191	0.0286	11	77	64	125
	0.1935	0.0294	10	79	66	129
	0.196	0.0302	9	80	67	131
	0.199	0.0311	8	83	69	134
	0.201	0.0317	7	84	70	136
13/64	0.203	0.0324	....	86	71	138
	0.204	0.0327	6	87	72	140
	0.205	0.0332	5	89	74	144
	0.209	0.0343	4	93	77	150
	0.213	0.0356	3	95	79	154
7/32	0.2187	0.0375	....	97	80	156
	0.221	0.0384	2	99	82	160
	0.228	0.0408	1	104	86	168
15/64	0.2344	0.0442	....	108	90	175
1/4	0.250	0.0491	....	119	99	193
17/64	0.2656	0.0554	....	131	109	212
9/32	0.2812	0.0621	....	142	119	232
19/64	0.2969	0.0692	....	153	128	250
5/16	0.3125	0.0767	....	164	136	265
21/64	0.3281	0.0845	....	176	146	285
11/32	0.3437	0.0928	....	187	155	302
23/64	0.3594	0.1014	....	198	165	322
3/8	0.375	0.1104	....	209	174	340
25/64	0.3906	0.1198	....	221	184	360
13/32	0.4062	0.1296	....	231	193	376
27/64	0.4219	0.1398	....	241	201	392
7/16	0.4375	0.1503	....	254	211	412
29/64	0.4531	0.1612	....	264	220	430
15/32	0.4687	0.1725	....	277	230	448
31/64	0.4844	0.1843	....	286	239	466
1/2	0.500	0.1963	....	299	249	485
33/64	0.5156	0.2088	....	309	257	500
17/32	0.5312	0.2216	....	320	267	520
35/64	0.5469	0.2349	....	331	276	539
9/16	0.5625	0.2485	....	340	285	556
37/64	0.5781	0.2625	....	353	295	576
19/32	0.5937	0.2769	....	365	303	590

ORIFICE CAPACITY—Continued.

Diameter Inches		Area	Morse Drill Gage Size	Cubic Feet Per Hour		
Frac.	Decimal	Square Inch		Coal Gas 0.43 sp. gr. 2″ Press	Water Gas 0.62 sp. gr. 2″ Press	Natural Gas 0.62 sp. gr. 4½ Oz. Press
39/69	0.6094	0.2917	....	376	313	610
5/8	0.625	0.3068	....	387	323	630
41/64	0.6406	0.3223	....	399	333	650
21/32	0.6562	0.3382	....	410	341	665
43/64	0.0719	0.3546	....	421	350	682
11/16	0.6875	0.3712	....	431	369	720
45/64	0.7031	0.3883	....	443	370	722
23/32	0.7187	0.4057	....	454	378	737
47/64	0.7344	0.4236	....	466	387	755
3/4	0.750	0.4418	....	476	397	774
49/64	0.7656	0.4604	....	488	406	792
25/32	0.7812	0.4794	....	499	415	810
51/64	0.7969	0.4988	....	510	424	827
13/16	0.8125	0.5185	....	520	433	845
53/64	0.8281	0.5386	....	532	443	865
27/32	0.8438	0.5591	....	543	453	884
25/64	0.8594	0.5801	....	554	461	900
7/8	0.875	0.6013	....	565	472	920
57/64	0.8906	0.6229	....	576	480	938
29/32	0.9062	0.6450	....	588	490	955
59/64	0.9219	0.6675	....	599	500	976
15/16	0.9375	0.6903	....	510	507	985
61/64	0.9531	0.7134	....	620	517	1010
31/32	0.9687	0.7371	....	632	526	1025
63/64	0.9844	0.7611	....	644	536	1047
1	1.0000	0.7854	....	655	545	1062

NOTE:—The above table is based upon data obtained from gas orifices that are ordinarily used in gas appliances such as the ones used in Hale Gas Mixers.

ARTIFICIAL GAS:—The above figures are based upon 2-inch pressure; for higher pressures these figures should be increased by a percentage as shown below:

3-inch = 25 %
4-inch = 50
5-inch = 62.5
6-inch = 75
7-inch = 87.5
10-inch = 120
12-inch = 140
16-inch = 180
20-inch = 210

NATURAL GAS:—The above figures for natural gas are based on a gas under 4½ oz. pressure having a specific gravity of 0.62, which is the ordinary gravity of natural gas sold in cities supplied by gas from the Mid Continent, Pennsylvania and West Virginia fields. When the pressure is greater than 4½ oz. the figures in the table should be increased as shown below:

5 oz. = 10%
6 oz. = 20
7 oz. = 30
8 oz. = 39
9 oz. = 47.5
10 oz. = 60

Outline of Methods of Analysis of Petroleum Products

1. Specific Gravity and Baume' Gravity.
   A. With the hydrometer for fluid petroleum products.
   B. With the picnometer.
   C. With the Westphal balance.
   D. For asphalt and semi-solid petroleum products by fluid suspension.
   E. For rigid asphalt surface mixtures.
2. Color of Petroleum.
   A. By the Saybolt Chromometer.
   B. By the Lovibond Tintometer.
   C. With Potassium Bichromate solutions.
   D. With Iodine solutions.
3. Odor of oil.
4. Transparency.
5. Viscosity or Fluidity.
   A. With the Saybolt Universal Viscosimeter (A. S. T. M.), the Engler and the Redwood.
   B. Ubbelohde Viscosimeter for thin petroleum products.
   C. MacMichael disk friction viscosimeter.
   D. Float test for viscosity of road oils.
   E. Zero Viscosity for semi-solid petroleum products.
6. Melting Point.
   A. Ring and Ball Method (A. S. T. M.).
   B. Cube Method.
   C. "General Electric" method.
   D. Titer method for wax.
7. Cold Test.
   A. Cloud test.
   B. Pour test.
   C. Cold test.
8. Water and Bottom Settlings.
   A. By centrifuge.
   B. By distillation.
9. Distillation tests of Petroleum.
   A. Proximate distillation for water, gasoline, kerosene and residuum.
   B. End point distillation (A. S. T. M. and Bureau of Mines).
   C. Fractional—Gravity distillation analysis.
   D. Fractional—Sample distillation.
10. Flash and Burning Points.
    A. Illuminating oils with closed tester.
    (Standard A. S. T. M.—"Tag" tester.)
    B. All types of Petroleum products with the Elliott or New York closed tester.
    C. Lubricants and asphalt with Cleveland open cup.
11. Pressure—heat tests.
    A. Cracking test under high pressure and temperature.
    B. Vapor pressure test at high pressure.
    C. Vapor pressure of casinghead and light gasoline.

12. Carbon residue.
    A. Conradson Carbon test (A. S. T. M.).
    B. Fixed carbon and ash in asphalt.
13. Emulsification test of lubricating oils.
14. Heat of combustion.
    A. By bomb calorimeter.
    B. By calculation from gravity.
15. Sulphur in petroleum products.
    A. By bomb calorimeter.
    B. By Eschka method.
    C. By Parr chemical bomb.
16. Ultimate Analysis.
    A. Carbon and Hydrogen.
    B. Nitrogen.
17. Doctor test for refined distillates.
18. Olefins, ethylenes or unsaturated hydrocarbons.
    A. Babcock method (B. of M.).
    B. Cylinder method (Egloff).
    C. Refining loss.
19. Aromatic and paraffin hydrocarbons in petroleum.
    A. Nitrating method.
    B. Distillation method.
20. Free acid in petroleum products.
21. Floc test.
22. Corrosion and Gumming test of gasoline.
23. Penetration or Consistency of asphalt.
24. Ductility of asphalt.
25. Resistance of asphalt and oil to evaporation.
26. Determination of natural asphalt or semi-solid hydrocarbons in petroleum.
27. Solubility of asphalt.
    A. In Petroleum ether—Petrolenes and Asphaltenes.
    B. In Carbon bisulphide—total bitumen.
    C. In Carbon tetrachloride—non-carbenes.
28. Resistance of asphalt to oxidation.
29. Paraffin wax or scale determination.
30. Bitumen and grading of asphalt-mineral mixtures.
    A. By burning.
    B. By extraction.
31. Tensile and Cementing strength of asphaltic surface mixture.
32. Specific Gravity of Gas.
    A. Effusion or Viscosity method.
    B. Edwards Gas balance.
33. Gasoline determination in gas (see also specific gravity).
    A. By absorption test.
    B. Freezing test.
34. Complete Chemical Analysis of Gas with preparation of reagents.
35. Heat of Combustion of Gas.
    A. By the calorimeter.
    B. By oxygen consumption.
    C. By calculation from chemical analysis.

Note.—The Kansas City Testing Laboratory will give information to anyone concerning supply houses from whom any of the following oil testing instruments may be obtained.

Index to Applications of Methods of Analysis

Product	Routine test	Occasional test	Rarely used	Can be used but not specially adapted
A. Crude Petroleum	1, 2, 3, 4, 8, 9A	5A, 9C, 14 15, 26, 29	2D, 7B, 9D, 10B, 16, 18	5D, 9B, 11, 12, 13, 19, 25
B. Gasoline, Benzine and Naphtha	1, 2, 3, 4, 9B, 11C 17, 18, 22	9C, 14, 19, 20	5B, 7A, 15, 16	9D, 10
C. Kerosene and Illuminating Oils	1, 2, 3, 4, 5B, 7, 9B 10A, 15, 17, 21	10B, 14A, 20, 22	9C, 11B, 16, 18, 19	12A, 13
D. Gas Oil, Straw Oil, Absorption Oil	1, 2, 3, 4, 7, 9C, 10 14, 15	5, 11A, 12A, 13, 17, 18	16, 19, 20, 21	
E. Lubricants, Paraffin Oil..	1, 2, 3, 4, 5A, 7, 10 12A, 13 15, 20	14, 17, 18	16, 19, 21	9, 11, 22
F. Fuel Oil, Diesel Engine Oil ...	1, 4, 7, 8, 10, 14, 15	5, 11, 26 27A, 29	2D, 3, 9, 12, 16, 18, 19	13
G. Road Oil, Flux Oil	1AB, 3, 5AD, 8, 10, 12, 25, 26, 27	7B, 14, 15, 29	2D, 11, 16	13, 28, 5A
H. Asphalt and Pitch	1D, 5E, 6, 8B, 12, 23, 24, 25, 27	10, 15, 28, 29	2D, 3, 14 16	5A
I. Wax	1D, 2, 3, 4 6D	25	11A, 12A, 14, 15, 16, 17, 18, 19, 20	7A, 10
J. Grease	1, 2, 3, 4, 5CDE, 8, 12B, 27	25	16	6, 7, 10
K. Asphalt Surface Mix	1E, 30, 31			
L. Gas	32, 33, 34, 35	16		

Note:—See special specifications for other tests of Petroleum Products.

1. Specific Gravity and Baume' Gravity.

A. With the hydrometer.

Specific gravity is the relation by weight of the same volume of oil and of water. Unless some other temperature is specifically mentioned the gravity refers to 60°F. Specific gravity is determined by means of the hydrometer, the Westphal balance, the picnometer and by displacement methods. The absolute specific gravity scale is not commonly used in the oil industry. Instead, the Baume' gravity scale, an entirely arbitrary standard, is used. Two Baume' gravity scales are in use in the oil industry; one is that adopted by the U. S. Bureau of Standards and its relation to specific gravity is indicated by the following formula:

$$\text{Specific Gravity} = \frac{140}{130 + \text{Baume}'^{\circ}}$$ for liquids lighter than water.

Another scale possibly more commonly used is that of instruments made by the Tagliabue Mfg. Co., which is based upon the following relation to specific gravity:

$$\text{Specific Gravity} = \frac{141.5}{131.5 + \text{Baume}'^{\circ}}$$ for liquids lighter than water.

The difference between the two readings varies from nothing with very heavy oils to as much as 0.5°Be' for ordinary gasoline. When the oil is heavier than water a different formula is used for calculating the Baume' gravity, the following being in general use:

$$\text{Degrees Baume}' = 145 - \frac{145}{\text{Specific Gravity}}$$ for liquids heavier than water.

Oils heavier than water are not commonly encountered. The method of using the hydrometer is the same in all cases whether its reading is in terms of the U. S. Bureau of Standards Baume' scale, the Tagliabue Baume' scale, Baume' scale for liquids heavier than water, or for direct specific gravity. The ideal instrument for all purposes is of course that reading directly in specific gravity. By the use of tables these readings can be converted into the Baume' reading desired and without any misunderstanding as to which scale is intended.

The correct method of reading the hydrometer is illustrated in Figs. 1 and 2, page 275. The sample of oil is placed in a clear jar or cylinder and the hydrometer carefully immersed in it to a point slightly below that to which it naturally sinks and is then allowed to float freely. The reading should not be taken until the oil and the hydrometer are free from air bubbles and are at rest.

In taking the reading the eye should be placed slightly below the plane of the surface of the oil (Fig. 1) and then raised slowly until this surface, seen as an ellipse, becomes a straight line (Fig. 2). The point at which this line cuts the hydrometer scale should be taken as the reading of the instrument (Fig. 2).

In case the oil is not sufficiently clear to allow the reading to be made as above described, it will be necessary to read from above the oil surface and to estimate as accurately as possible the point to which the oil rises on the hydrometer stem. It should be remembered, however, that the instrument is calibrated to give correct indications when read at the principal surface of the liquid. It will be necessary, therefore, to correct the reading at the upper meniscus by an amount equal to the height to which the oil creeps up on the stem of the hydrometer. The amount of this correction may be determined with sufficient accuracy for most purposes by taking a few readings on the upper and the lower meniscus in a clear oil and noting the differences.

A specific gravity hydrometer will read too low and a Baume' hydrometer too high when read at the upper edge of the meniscus. The correction for meniscus height should therefore be added to a specific gravity reading and subtracted from a Baume' reading.

The magnitude of the correction will obviously depend upon the length and value of the subdivisions of the hydrometer scale and must be determined in each case for the particular hydrometer in question.

Specific gravity and Baume' gravity readings of oil are conveniently taken at room temperature and these readings must be converted to the gravity at 60°F. As a general rule it may be said that petroleum oil expands with heat so that 0.0004 must be added as a correction to the specific gravity readings for each degree Fahr. that the oil is above 60°F or must be subtracted for each degree Fahr. below 60°F. On the Baume' scale .1°Be' may be subtracted for each degree Fahr. above 60°F or added for each degree Fahr. below 60°F. For exact temperature corrections for specific gravity, see pages 334 to 418. For exact temperature corrections for Baume' gravity, see pages 376-383. For conversions of Baume' to and from specific gravity, see pages 370-375.

1B. Specific Gravity with the picnometer.

Various types of picnometers may be used for this purpose, each of which has special advantages. Some are plain bottles with capillary openings in a well made ground glass stopper; others have graduated tubes in the stoppers, vacuum walls and inserted thermometers. The Sprengel picnometer is particularly adapted to the handling of very viscous oils as it prevents the including of air bubbles in the instrument. With any of the various types the perfectly dry and clean picnometer is weighed at 60°F to the nearest 0.0001 gram. It is filled with distilled water at 60°F and weighed. It is then dried completely and filled with the oil to be tested at 60°F. The net weight of the oil divided by the net weight of the distilled water gives the specific gravity of the oil. For conversion into degrees Baume' the formulae given on page 272 or the tables given on pages 370 to 375 are used.

1C. Specific Gravity with the Westphal balance.

This is a very convenient instrument where a great variety of petroleum products are to be tested as it covers any range of specific gravity and can be used for practically any type of material. Its character is shown by the figures on page 273. The oil is put into the jar and the weights or riders are adjusted on the beam until the pointer is in exact poise. The readings are in specific gravity based on a water temperature of 60°F at which temperature the instrument is standardized. The specific gravity may be converted to Baume' scale with the tables.

1D. **Specific Gravity** for semi-solid petroleum materials.

A convenient method of taking the specific gravity of asphaltic cement and similar semi-solid petroleum materials is the following (see upper figure on page 277). Roll up a ball of the asphalt about 1 cm. in diameter, being careful that no water is included. Place this in a cylinder of cold distilled water from which the air has been removed by previous boiling. If the ball of asphalt floats, denatured alcohol is added until it shows no tendency to go either up or down when placed in the middle of the cylinder. The specific gravity of the liquid is then taken with the Westphal balance or with the hydrometer. If the ball of asphalt sinks a saturated solution of sodium chloride or common salt is added until the asphalt when placed in the center of the cylinder shows no tendency to go either up or down. The specific gravity is taken with a hydrometer for liquids heavier than water or with the Westphal balance. It is necessary in performing this test that the bubbles of air which tend to adhere to the surface of the asphalt be occasionally removed and that the solution be thoroughly mixed. The usual temperature required for the gravity of this material is 77°F or 25°C.

1E. **Specific Gravity** of solid oil materials.

A fragment of bituminous material is suspended by means of a silk thread from a hook of one pan support of the balance and about ½ inch above the pan and weighed. This weight is "a." It is then immersed in water at 25°C and suspended, the water container not being allowed to touch the balance and is weighed again. This weight is "b." The specific gravity is $\frac{a}{a-b}$ (see lower figure on page 277).

The sample of asphaltic surface mixture for this test should be cut out of the street after the pavement has been rolled and cooled. This test is a very good measure of the all around quality of the work. The sample is weighed in the air and in water, the weight in air divided by the loss of weight in water gives the specific gravity. This times 62.4 gives the weight per cubic foot and times 93.6 gives the weight per square yard of 2-inch surface.

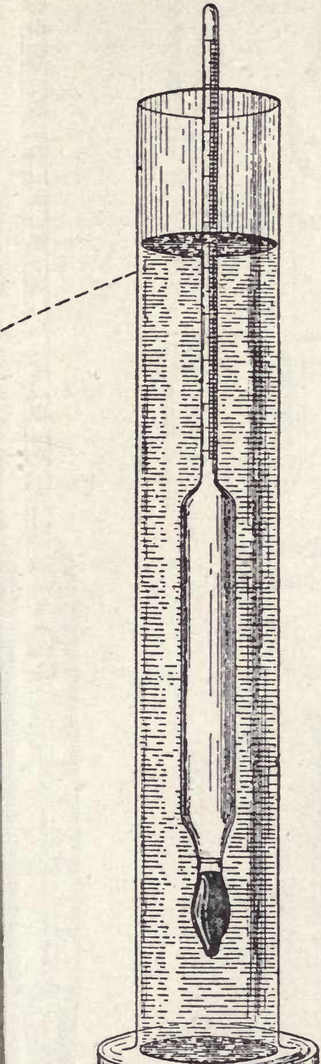


Fig. 1.

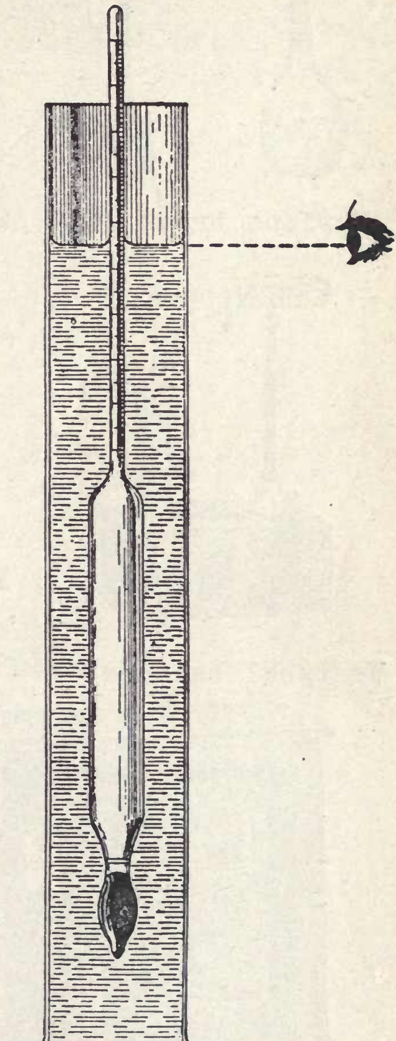
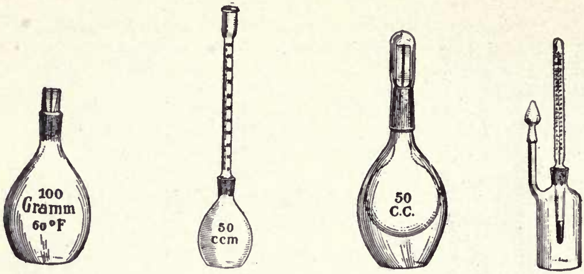
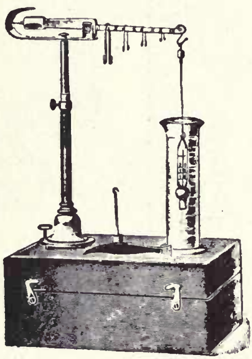
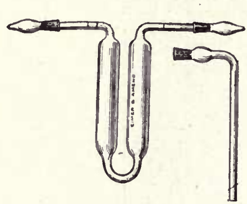


Fig. 2.



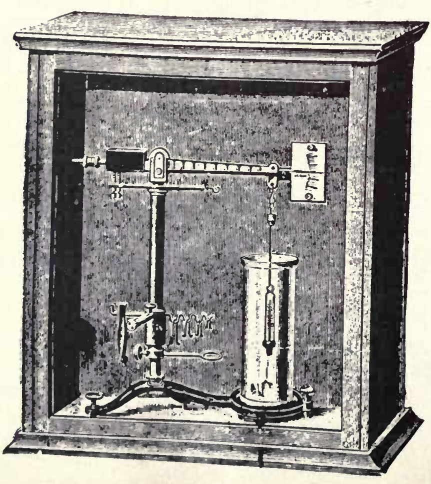
Various types of picnometers

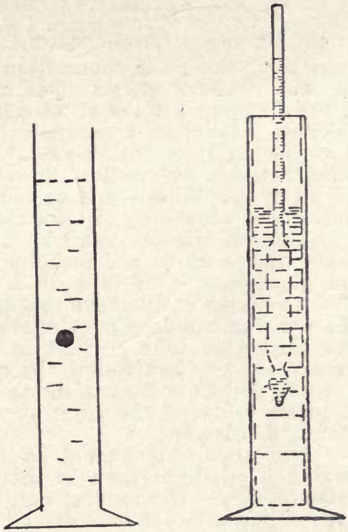




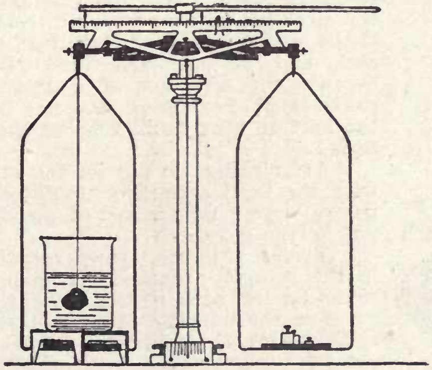
Sprengel
Picnometer

Westphal balance





Specific Gravity of Asphaltic Cement.



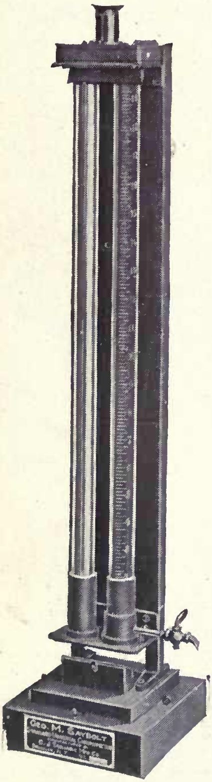
Specific Gravity by Displacement.

2A. METHOD FOR DETERMINING THE COLOR OF REFINED PETROLEUM.

(Saybolt Universal Chromometer.)

The apparatus consists of two color comparison tubes, one being arranged for insertion of a standard yellow glass in the bottom, the other being graduated for different lengths of oil column (see figure).

Two like-colored yellow glass discs are supplied with each Chromometer. By the use of one singly or both together, color shades can be definitely determined between below Zero to + 25—Zero being Standard White and + 21 Water White—and as indicated by the accompanying table of inches corresponding to color shades.



Saybolt Chromometer.

The two glasses shall be used to determine color shades up to and including + 15, and only one glass from + 16 to + 25.

An excess of oil above that necessary to equal the working standard in color should be filled into the graduated tube so that in drawing off the excess, the eye can follow the color of oil under examination from dark to lighter, thereby making it easier to detect the point at which the oil and standard coincide.

The apparatus should be set at a window having a one-light sash so that a good light is reflected from the mirror, but not in the direct rays of the sun, and care should be taken that no colored light is reflected toward the instrument from surrounding buildings, tanks or other objects.

To clean the Chromometer before making a new test, simply allow some of the oil to be tested to run through the graduated tube. Even this need not be done between tests of similar oils if the previous oil is well drained through the pet cock, and the tube well filled with the next oil, because the influence of a drop or two of the previous oil remaining can not be seen against the half or nearly full tube of the next oil to be tested.

After using, do not let the instrument stand with the light reflecting up the tubes but move the reflecting mirror out of place, or better yet, put on the cover.

When not in use, always put the color glasses in the pockets prepared for them which will be found on the back of the upright.

For the purpose of most easily determining color shades, the column of oil when nearing the point of coincidence with the standard glass discs, shall be lowered shade by shade by use of the pet cock, until a point is reached where it is questionable as to which is the lighter or darker shade.

Then lower the column of oil one shade more and if the oil column now shows without doubt whiter than the standard glass disc, the colorating of the oil shall be one shade above this last whiter point, or in other words, at the question point, where it was impossible to detect any difference between the oil and the glass disc.

TABLE OF COLOR SHADES.

	Inches of Oil in Tube	Color Shades
	20	25
Use One Disc.	18	24
	16	23
	14	22
	12	21 = water white
	10-6/8	20
	9-4/8	19
	8-2/8	18
	7-2/8	17
	6-2/8	16
Use Two Discs.	10-4/8	+15
	9-6/8	+14
	9-0/8	+13
	8-2/8	+12
	7-6/8	+11
	7-2/8	+10
	6-6/8	+ 9
	6-4/8	+ 8
	6-2/8	+ 7
	6-0/8	+ 6
	5-6/8	+ 5
	5-4/8	+ 4
	5-2/8	+ 3
	5-0/8	+ 2
	4-6/8	+ 1
	4-4/8	0 = Standard white
	4-2/8	— 1
	4-0/8	— 2
	3-6/8	— 3
	3-5/8	— 4
	3-4/8	— 5
	3-3/8	— 6
	3-2/8	— 7
	3-1/8	— 8
	3-0/8	— 9

It is evident that no oils are to be compared with one disc unless they positively show whiter at 10-4/8 inches with two discs.

Moreover, a full tube (20 inches) of white oil that shows whiter than one (1) disc must rate + 25 and up (better than + 25).

2-B. COLOR BY LOVIBOND TINTOMETER.

The Lovibond color units and divisions are shown below, together with the color, series and number of each glass. These slides are used for determining the color of the refined products—gasoline, naphtha and kerosene.

Lovibond color unites with specifications for the slides:

Slide	Color	Series	Number
Water White....	Yellow	510	2.3
	Red	200	1.6
1 to 12.0........	Amber	500	0.1 to 12.0

If the oil is darker than the water white glass, slides are added to the slot containing the standard water white until the color of the oil is matched. When the .2 slide is added in this manner, the color is reported as W.W. — 0.2, the minus sign indicating that the oil is darker than the standard water white. If the color of the oil is lighter than that of the water white glass, additional slides are placed in the slots in front of the oil and should the color be matched in this manner with, say the .5 slide and the .2 slide, the color is reported W.W. + 0.70.

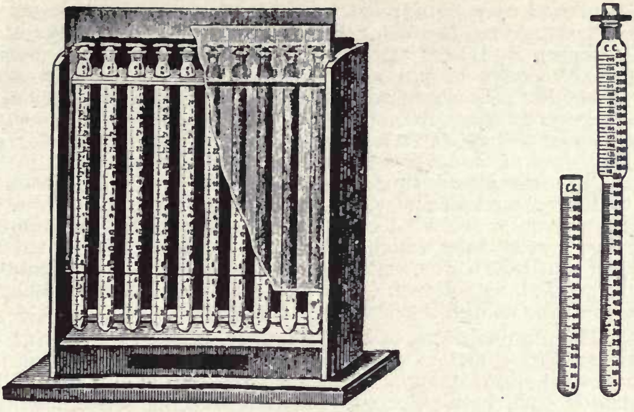
The color equivalent of water white, the standard color for gasoline and naphtha, has been defined as the equivalent of a column 404.6 mm. long of a 0.00027% acidulated solution of potassium chromate. A potassium bichromate solution, however, duplicates the tint of refined petroleum products more closely than the lower oxide. In standardizing the Stammer and Hellige colorimeters, L. Ubbelohde used a solution of 0.06 gram of potassium bichromate in one liter of water as the standard color.

2-C. COLOR WITH POTASSIUM BICHROMATE SOLUTIONS.

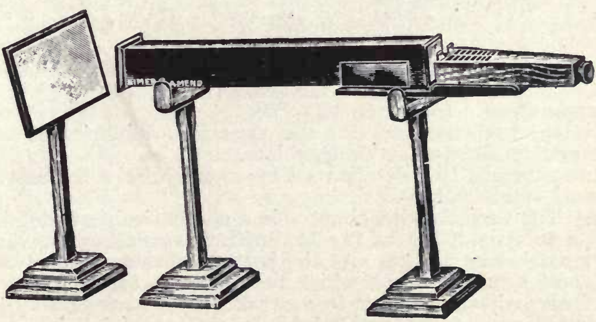
Comparison between Saybolt and Lovibond colorimeter values with equivalent potassium bichromate solutions.

In the absence of an instrument, standard acidulated solutions may be prepared to correspond with the solutions indicated in the following table. Each of these solutions when placed in four-ounce sample bottles and marked with the equivalent Saybolt and Lovibond values may be used to match samples.

Potassium Bichromate Mgm. per liter of 1% H_2SO_4 Solution.	Lovibond Colorimeter 18 cells with W.W. Slide	Saybolt Colorimeter
2.0	W.W. 1 0.5	1 25 (light)
2.9	W.W.	1 24 (light)
3.8	W.W. — 0.3	1 23
4.7	W.W. — 0.5	1 22
5.6	W.W. — 0.8	1 21
6.5	W.W. — 1.3	1 20
7.5	W.W. — 1.5	1 19
8.5	W.W. — 2.0	1 18
9.5	W.W. — 2.2	1 17 (light)
10.5	W.W. — 2.8	1 16 (light)
11.5	W.W. — 3.0	1 16
12.5	W.W. — 3.8	1 15
13.5	W.W. — 4.5	1 14
14.5	W.W. — 5.2	1 13
15.5	W.W. — 5.7	1 13
16.5	W.W. — 6.0	1 12
17.5	W.W. — 6.5	1 11
18.6	W.W. — 6.9	1 10
19.7	W.W. — 7.4	1 9
20.8	W.W. — 9.0	1 8
21.9	W.W. — 9.4	1 7
23.0	W.W. — 10.0	1 6
24.1	W.W. — 10.2	1 5
25.3	W.W. — 11.0	1 3
26.6	W.W. — 11.0	1 3
28.0	W.W. — 11.2	1 1 (light)



Color comparison tubes for the determination of the color of petroleum products by the iodine method.



Lovibond Tintometer.

2-D. COLOR OF OIL BY IODINE METHOD.

This method may be applied to all dark colored petroleum products. In determining the color by the iodine method a solution is made containing in 1 liter of very pure distilled water, 10 grams of iodine and 20 grams of potassium iodide. This is kept in a glass stoppered bottle. The apparatus necessary is that indicated on page 281 which may be a set of carbon color tubes or two tubes such as are required in the determination of manganese in steel. For crude oil, road oil, fuel oil and other black oils a dilution of 1-1000 in colorless benzol is made by diluting 1 cc. to 10 cc. of benzol and then 1 cc. of this to 100 cc. with benzol. This is thoroughly mixed in one of the glass stoppered color tubes. 1 cc. of the standard iodine solution is put into the large color tube which holds 250 cc. It is diluted with distilled water until its color matches that of the oil under test. The color is calculated, as follows: I = milligrams of iodine in 100 cc. of water in the tube containing the diluted iodine.

d = The number of cc. of benzol to 1 cc. of oil.

Color = I (d + 1).

For gas oil, lubricating oils and yellow oils, a dilution of 1-100 with benzol is sufficient. For gasoline, naphtha, kerosene and illuminating oils there is no dilution with benzol, the comparison being made directly.

The terms applied to the color of crude oil are black, brownish black, blackish brown, brown, reddish brown, green, greenish brown, brownish green and bluish green. The kerosene is spoken of as being water white, superfine white, prime white, standard white, prime light straw, light straw and straw. Other colors are designated by yellow, dark yellow, reddish yellow, brownish yellow, yellowish brown, brown, red, blood red and yellowish red.

3. ODOR OF OIL.

The odor of oil may be spoken of as sweet, ethereal, aromatic, tarry, fatty, creosotic, acid, sour, sulphurous, sulphuretted hydrogen, pyridine and pungent.

4. TRANSPARENCY OF OILS.

Transparency may be expressed by the thickness of oil in centimeters through which the filament of a 50 watt Mazda electric lamp is visible. It may be also noted whether the oil is fluorescent and the character of the fluorescence, whether bluish, greenish or yellowish by reflected light; also whether any turbidity is of a smoky, granular or flocculent character.

5-A. VISCOSITY OF LIQUID PETROLEUM PRODUCTS. (SAYBOLT UNIVERSAL.)

The apparatus is shown on page 285.

This is the tentative test for the viscosity of lubricants adopted by the American Society for Testing Materials:

1. Viscosity shall be determined by means of the Saybolt standard universal viscosimeter.

2. (a) The Saybolt viscosimeter is made entirely of metal. The standard oil tube is fitted at the top with an overflow cup and the tube is surrounded by a bath. 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, 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 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 and operated by two turn-table handles. The temperatures in the standard oil tube and in the bath are shown by thermometers. The bath may be heated by a gas ring burner, steam U-tube, or electric heater. The standard oil tube is cleaned by means of a tube cleaning plunger, and all oil entering the standard oil tube shall be strained through a 30-mesh brass wire strainer. A stop watch is used for taking the time of flow of the oil and a pipette, fitted with a rubber suction bulb, is used for draining the overflow cup of the standard oil tube.

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

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

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

To make the test, heat the oil to the necessary temperature and clean out the standard oil tube with the plunger, using some of the oil to be tested. Place the cork stopper into the lower end of the air chamber at the bottom of the standard oil tube. The stopper should be sufficiently inserted to prevent the escape of air, but should not touch the small outlet tube of the standard oil tube. Heat the oil to be tested, outside the viscosimeter, to slightly below the temperature at which the viscosity is to be determined and pour it into the standard oil tube until it ceases to overflow into the overflow cup.

By means of the oil tube thermometer keep the oil in the standard oil tube well stirred and also stir well the oil in the bath. It is extremely important that the temperature of the oil in the oil bath be maintained constant during the entire time consumed in making the test. When the temperature of the oil in the bath and in the standard oil tube are constant and the oil in the standard oil tube is at the desired temperature, withdraw the oil tube thermometer; quickly remove the surplus oil from the overflow cup by means of a pipette so that the level of the oil in the overflow cup is below the level of the oil in the tube proper; place the 60-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 approximate factors for conversion of readings of the Saybolt Universal to other instruments are as follows:

	°F 70	°F 100	°F 212	°F 338
To MacMichael.	.50	.55	.60	.65
To Saybolt "A".	.50	1.00	....	....
To Saybolt "C".	....	....	.46	.72
To Engler.	.035	.030	.028	.027
To Tagliabue.	.25	.28	.51	....
To Penn. R. R. Pipet	.30	.47	.51	.94
To Scott.	.13	.13	....	....
To Redwood.	.83	.85	.88	.90
To Magruder Plunger.	1.25	1.04	2.00	....
To Ostwald.	1.90	1.85	1.68	1.30

These values are not exact as they vary greatly with the actual viscosity readings. For exact conversion to Engler and Redwood values, see page 287.

70°F may be used for light oils, gas oils, "straw" oils, engine oils, dynamo oils, auto oils, cottonseed oils and the like.

100°F may be used for Engine oils, machine oils and occasionally cylinder oils.

212°F may be used for cylinder oils, road oil, other heavy oils and asphaltic fluxes.

338°F may be used for asphalt, fluxes, paraffin wax and residues.

Other viscosimeters in use are the Engler, Tagliabue, Scott, Redwood, Penn. Ry. pipet, McMichael, Lamansky-Nobel, Ostwald, Martens, Stormer, Ubbelohde, Lepenau, Kuenkler, Albrecht, Arvine, Barbey, Cockrell, Doolittle, Gibbs, Mason, Napier, Nasmyth, Phillips, Reischauer, Magruder (see page 286).

The Engler viscosimeter is used most extensively in Germany and its dimensions are as follows:

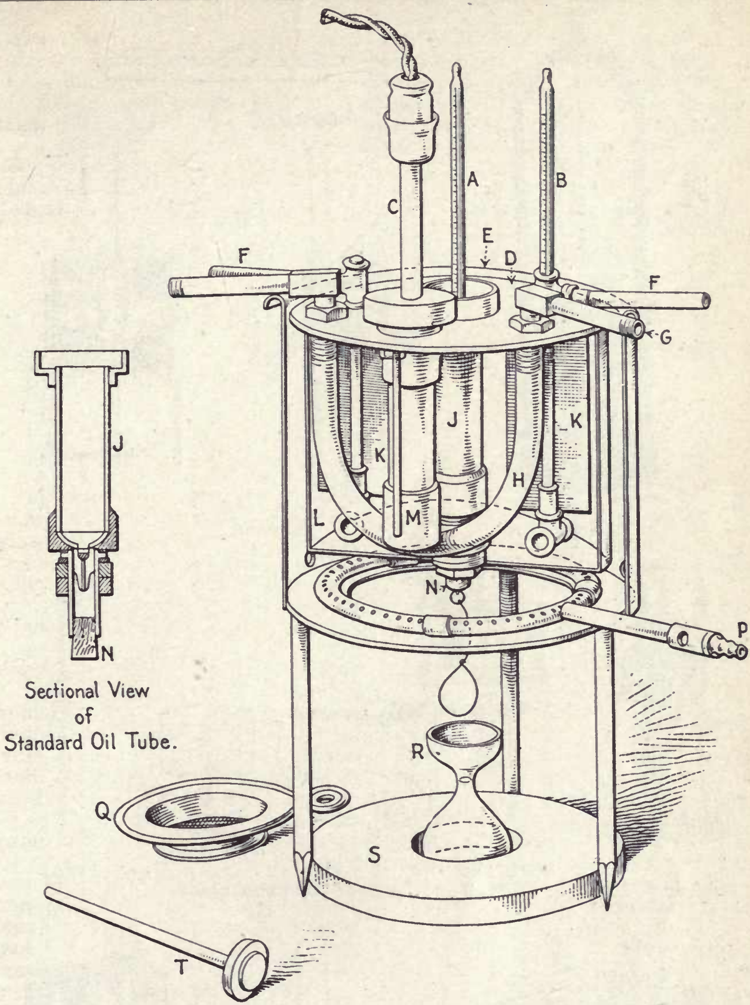
Inside diameter of the inside vessel for oil	106 mm
Height of vessel below overflow	25 mm
Length of the oil jet	20 mm
Inside diameter of the oil jet upper end	2.9 mm
Inside diameter of the oil jet lower end	2.8 mm
Length of jet projecting from lower part of outer vessel	3.0 mm
Width of jet.	4.5 mm

The quotient of the time of outflow of 200 cc. of oil divided by the time of outflow of 200 cc. of water is taken as a measure of the viscosity or is the so-called Engler degree.*

The Redwood viscosimeter‡ is used extensively in England and its value can be calculated from the Engler or the Saybolt in the tables on pages 288-9.

*Holde, Examination of Hydrocarbon Oils.

‡Redwood, Treatise on Petroleum.

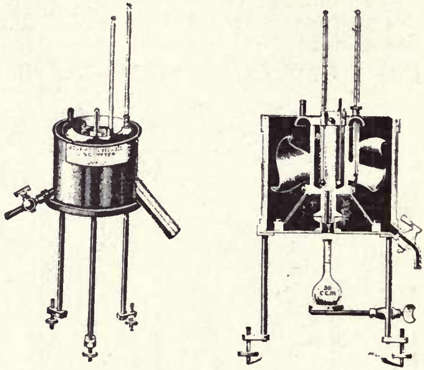


A *Oil Tube Thermometer.*
B *Bath Thermometer.*
C *Electric Heater.*
D *Turntable Cover.*
E *Overflow Cup.*
F *Turntable Handles.*
G *Steam Inlet or Outlet*
H *Steam U–Tube.*
J *Standard Oil Tube.*
K *Stirring Paddles.*
L *Bath Vessel.*
M *Electric Heater Receptacle.*
N *Outlet Cork Stopper.*
P *Gas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

Sectional View of Saybolt Standard Universal Viscosimeter

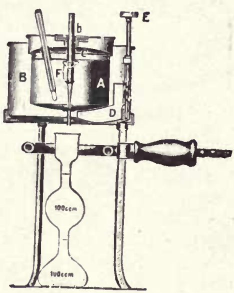
Ostwald

Stormer

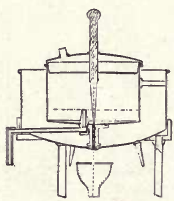


Redwood

Engler



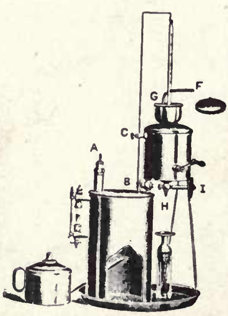
Modified Engler



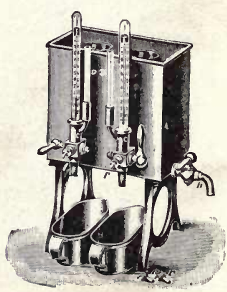
Ubbelohde

Penn. R.R. Pipet

Scott



Tagliabue



Lepenau

VISCOSIMETERS

Factors to Reduce Saybolt Times to Engler Numbers or to Redwood Times

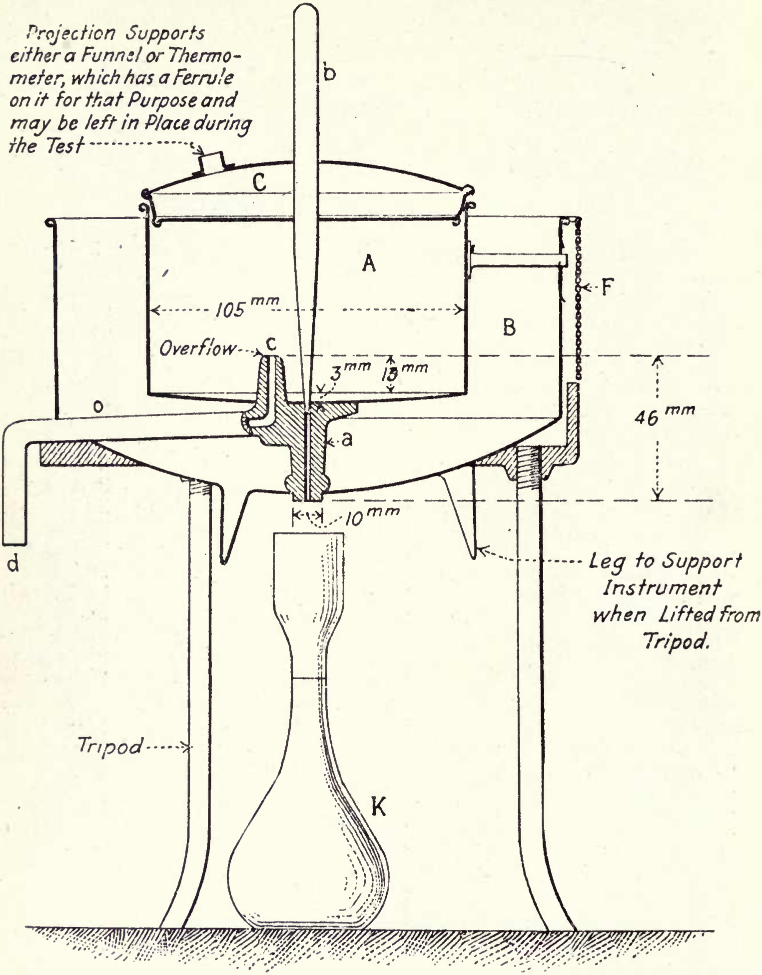
Saybolt Time, Seconds	Factor to Reduce Saybolt Time to Engler Number	Factor to Reduce Saybolt Time to Redwood Time
28	0.0357	0.95
30	0.0352	0.95
32	0.0346	0.94
34	0.0342	0.94
36	0.0337	0.94
38	0.0334	0.93
40	0.0330	0.93
42	0.0327	0.92
44	0.0323	0.92
46	0.0320	0.91
48	0.0317	0.91
50	0.0314	0.90
55	0.0308	0.90
60	0.0302	0.89
65	0.0297	0.88
70	0.0293	0.87
75	0.0289	0.86
80	0.0286	0.86
85	0.0284	0.86
90	0.0282	0.85
95	0.0280	0.85
100	0.0297	0.85
110	0.0276	0.85
120	0.0274	0.84
130	0.0272	0.84
140	0.0271	0.84
160	0.0269	0.84
180	0.0268	0.84
200	0.0267	0.84
...	......	....
1800	0.0267	0.84

Factors to Reduce Redwood Times to Saybolt Times or to Engler Numbers

Redwood Time	Factors to Reduce Redwood Time to Saybolt Time	Factors to Reduce Redwood Time to Engler Number
26	1.05	0.0377
28	1.05	0.0372
30	1.06	0.0368
32	1.06	0.0364
34	1.07	0.0361
36	1.07	0.0358
38	1.08	0.0355
40	1.09	0.0353
42	1.10	0.0351
44	1.10	0.0349
46	1.11	0.0347
48	1.12	0.0345
50	1.13	0.0344
55	1.14	0.0340
60	1.15	0.0337
65	1.16	0.0335
70	1.16	0.0333
75	1.17	0.0331
80	1.18	0.0330
85	1.18	0.0329
90	1.18	0.0328
95	1.19	0.0327
100	1.19	0.0326
110	1.19	0.0325
120	1.20	0.0324
130	1.20	0.0322
140	1.20	0.0321
160	1.20	0.0321
180	1.20	0.0320
...	....	.....
1500	1.20	0.0320

Factors to Reduce Engler Numbers to Saybolt or to Redwood Times

Engler Number	Factors to Reduce Engler Number to Saybolt Time	Factors to Reduce Engler Number to Redwood Time
1.00	28.1	26.7
1.05	28.4	27.0
1.10	28.8	27.2
1.15	29.1	27.4
1.20	29.5	27.6
1.25	29.8	27.8
1.30	30.1	28.0
1.35	30.4	28.2
1.40	30.8	28.3
1.45	31.1	28.5
1.50	31.5	28.6
1.60	32.0	28.8
1.70	32.5	29.0
1.80	33.0	29.2
1.90	33.5	29.4
2.00	33.9	29.6
2.10	34.2	29.7
2.20	34.5	29.9
2.30	34.8	30.0
2.40	35.1	30.1
2.50	35.3	30.2
2.60	35.5	30.3
2.70	35.7	30.3
2.80	35.9	30.4
2.90	36.1	30.4
3.00	36.2	30.5
3.50	36.7	30.7
4.00	37.0	30.9
4.50	37.3	31.1
5.00	37.4	31.2
6.00	37.5	31.3
....	....	....
50.00	37.5	31.3



A. Brass Oil Container.
B. Bath.
C. Cover of Oil Container.
a. Capillary.
b. Ivory or Wooden Skewer.
c-o-d. Overflow Channel.
F Plumb-bob for Leveling Instrument.
K. Flask holding 100 cu.cm at 20 deg. Centigrade.

The Ubbelohde Viscosimeter.

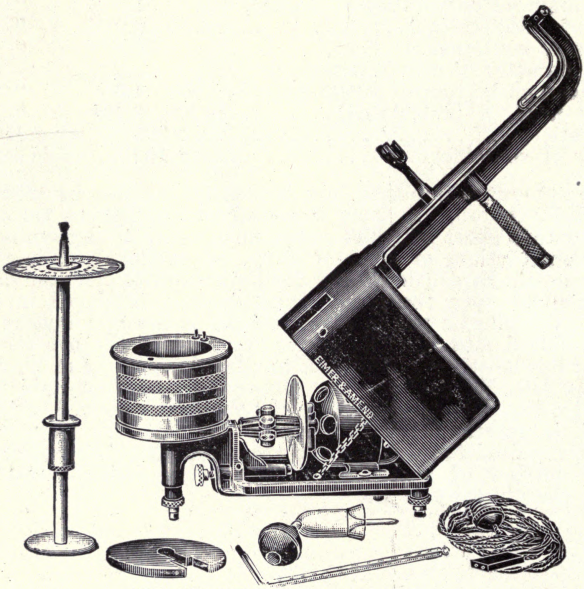
5-B. METHOD FOR DETERMINING THE VISCOSITY OF KEROSENE AND GASOLINE.

The apparatus used for this test is essentially that described on pages 55, 56 and 57 of Holde's "Examination of Hydrocarbon Oils." A diagram of the apparatus is shown on page 290. The instrument is known as the Ubbelohde viscosimeter.

The dimensions are as follows:

	Normal Instrument	
Inner diameter of outlet tube at top......	0.125	centimeters
Inner diameter of outlet tube at bottom....	0.125	"
Outside diam. of outlet tube at bottom, d_1..	1.0	"
Length of outlet tube, 1..................	3.0	"
Diameter of container, D.................	10.5	"
Outside diameter of overflow pipe, d_2......	...	
Initial head on bottom of outlet tube, h_1...	4.6	"
Average head, h (calculated)............	3.992	"
Water rate.............................	200	seconds
Capacity of container....................	132	cubic centimeters

The apparatus is placed in a horizontal position by means of the plummet F, the outflow tube is examined by looking through from the top with a sheet of white paper underneath to determine if there are any obstructions or dirt. If dirty, the outflow tube is cleaned by drawing a silk thread back and forth through it. Water or cracked ice, depending upon the temperature desired, is placed in the outer vessel B, the plug is put in place and an excess of kerosene or gasoline introduced into A. The excess runs out of the overflow pipe C. The plug b is loosened sufficiently to allow just a drop of liquid to pass out to the jet. When the proper temperature has been maintained for 15 minutes the plug is withdrawn and the time required to fill the 100 cc. flask is determined with the stop watch. This time divided by the time required for water gives the viscosity. For example, if the time of outflow of kerosene is 320 seconds and the water is 200 seconds, the viscosity is 1.6.



The MacMichael Viscosimeter

5-C. VISCOSITY WITH THE MacMICHAEL VISCOSIMETER.

In the MacMichael Viscosimeter a disk is suspended in a cup of fluid. The force exerted by the rotation of the fluid on the plunger is measured. This force is equal and opposite to that applied to the cup. Viscosities of oils are quickly and easily obtained at normal temperatures, also at very high and very low temperatures.

The disk is suspended in the cup of fluid by a torsion wire about ten inches long running down through the stem of the plunger and fastened near the bottom. The head of the torsion wire is triangular and is held between two grooved pins at the top of the standard. The cup and plunger may be removed and replaced without manipulating any catches or fastenings. All surfaces are smooth and rounded and may be easily cleaned.

The cup is oil jacketed, being formed of two pieces of heavy spun brass. Within the oil jacket is immersed an electric heating coil. This coil draws current from the same line as the motor, only one connection being necessary. The fluid to be tested is heated in place, no other heating device being required. The operation is very rapid. Stirring is effected by a slight vertical movement of the plunger. For low temperature work, the fluid and the adjacent parts are chilled in an ice bath or brine solution.

A bent thermometer inserted through an opening in the cover indicates the temperature, the bulb being immersed in the liquid. The temperature during test may be controlled to within a small fraction of one degree.

The graduated dial at the top of the plunger is secured to the stem by a friction disk, permitting the adjustment of the zero mark to its proper location. The fine adjustment is effected by means of the steel wire pointer at the head of the standard. The dash pot on the stem of the plunger is frictionless and automatic in action, requiring no attention from the operator. Its function is to check incipient vibrations and to permit quicker readings by damping the action.

The speed control is of the phonograph type and gives excellent results. The motor is furnished for 110 or 220 volts either A. C. or D. C. and is adapted for ordinary lighting circuits. Variations in voltage do not affect the accuracy of the determinations.

In operating, the cup is filled to the mark on the side with the oil or asphalt to be tested. This requires about 100 cc. The temperature is raised or lowered by means of the heating coils. The deflection noted on the dial is the viscosity of the fluid.

The operation is very rapid, so that the drop in temperature on ordinary work is entirely negligible. For extreme accuracy, the temperature may be raised slightly above the desired point, and an allowance made for the drop up to the moment of reading. This will seldom be found necessary in actual practice. The readings are in degrees of angular deflection, 300° to the circle, designated as °M. The practical working unit is 1/1000 of the absolute unit. As water at 20°C or 68°F has exactly 1/100 of the absolute unit of viscosity, water at this temperature reads 10°M. Thus by shifting the decimal point practical units, absolute units and specific viscosity may be obtained at one reading. Readings are taken directly from the dial, no intermediate calculations being required.

5-D. FLOAT TEST (VISCOSITY) OF PETROLEUM RESIDUES.

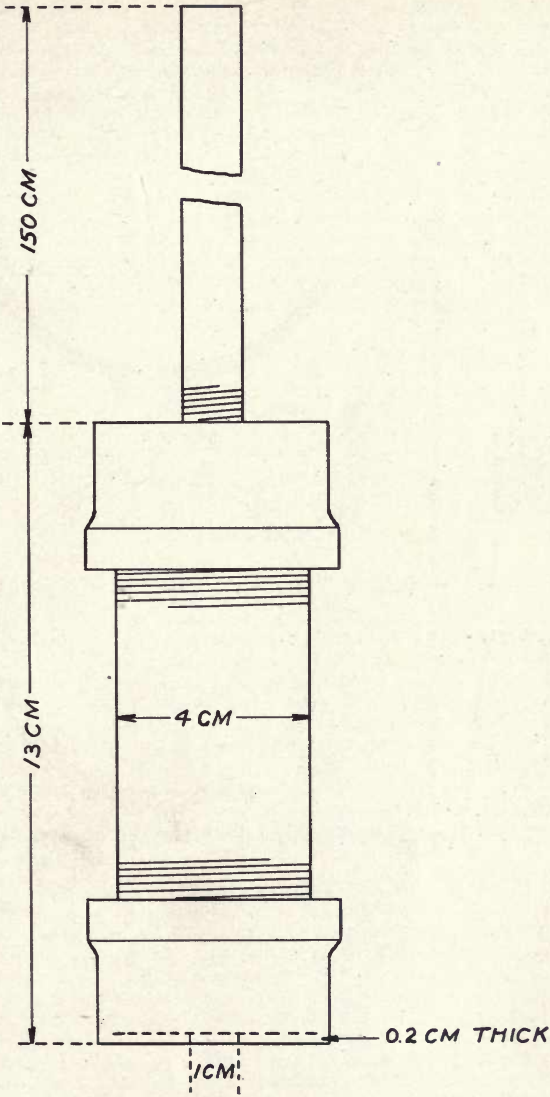
The special apparatus for the float test consists of an aluminum saucer having a diameter of 8.89 centimeters and a depth of 2.54 cm. and a radius of curvature of 5.16 cm. At the bottom there is an opening into which a collar may be screwed. This conical collar is 2.22 cm. long, is 0.95 cm. in diameter at the small end, 1.27 cm. in diameter at the large end and has a wall 0.13 cm. thick. /This apparatus and method of operating is shown in the figures on page 296

In making the test the brass conical collar is placed with the small end down on a brass plate which has been previously amalgamated with mercuric chloride. A small quantity of the material to be tested is carefully heated until quite fluid. It is then poured into the collar until slightly more than level with the top. The collar and plate are placed in ice water until rigid. The excess of material protruding from the collar is cut off with a warm knife. A pan of water is now heated to the desired temperature. The material should be kept in the ice water at least 15 minutes at a temperature of 5°C. The collar with the material is quickly screwed into the aluminum float which is immediately placed in the warm bath. As the plug of material becomes warm and fluid it is forced upward and out of the collar until the water gains entrance to the saucer and causes it to sink. The time in seconds between placing the apparatus on the water and when the water breaks through the residue is determined with the stop watch and is recorded as the measure of the consistency of the material. Unless otherwise specified, the float test is made at 50°C, but it would necessarily be higher with the more viscous materials.

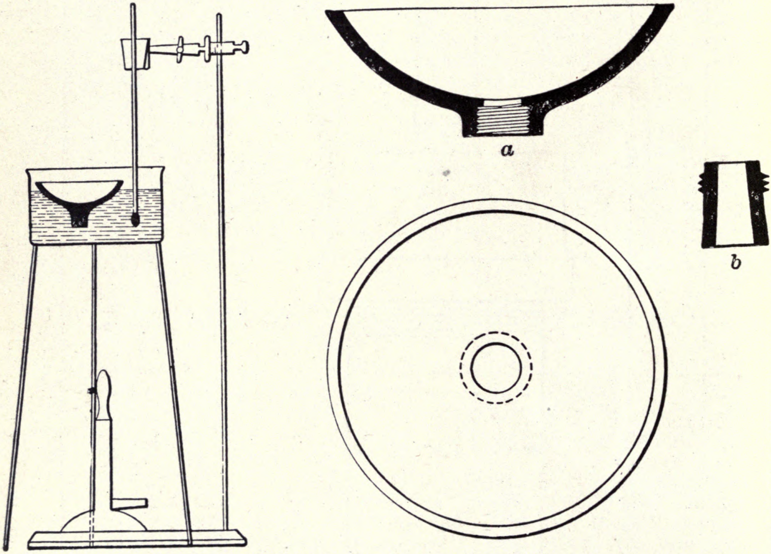
5-E. ZERO VISCOSITY FOR SEMI-SOLID PETROLEUM PRODUCTS.

The apparatus used is a cylinder as shown in the sketch and may be constructed from ordinary iron pipe. The cylinder is 4 cm. in diameter and 13 cm. long with an opening centrally located in the bottom 1 cm. in diameter and with lips 2 mm. thick. A tube 150 cm. long is screwed into the cap on the top.

In making the test the melted asphalt is poured into the cylinder with the cap off of the top and the 1 cm. opening on the flat surface. It is cooled and topped with more asphalt, the cap is put on with 150 cm. tube and the cylinder is packed in pulverized ice and supported horizontally so that the bottom rests on a circular ring at least 1 cm. high which keeps the ice away from the orifice. The tube is filled with mercury and after some of the asphalt has protruded from the orifice it is trimmed off flush with the outer edge. The apparatus is now supported vertically at the temperature of 0°C for 5 hours. The weight of asphalt or bituminous material protruding from the orifice after this time expressed in decigrams is the zero viscosity.



ZERO VISCOSITY



New York Testing Laboratory Float Apparatus

6-A. MELTING POINT OF BITUMINOUS MATERIALS. (SOFTENING POINT.) (Ring and Ball Method.)

The apparatus consists of a brass ring ⅝-inch in diameter, ¼-inch deep, 3/32-inch wall suspended 1 inch above the bottom of the beaker; a steel ball ⅜-inch in diameter weighing between 3.45 and 3.50 grams, a standardized thermometer and a 600 cc. glass beaker.

Carefully melt the sample and fill the ring with the material to be tested, removing any excess. Place the ball in the center of the ring and suspend in the beaker containing 400 cc. of water at a temperature of 5°C. Set the thermometer bulb within ½ inch of the sample and at the same level. Apply heat uniformly, preferably with a 200 watt electric hot plate over the bottom of the beaker sufficiently to raise the temperature of the water 5°C per minute. Record the temperature at starting the test and every minute thereafter until the test is completed. The softening point is the temperature at which the specimen touches the bottom of the beaker. For temperatures above 99°C glycerin should be used instead of water. Tests should check within 3°C.

6-B. MELTING POINT OF BITUMINOUS MATERIALS. (Cube Method.)

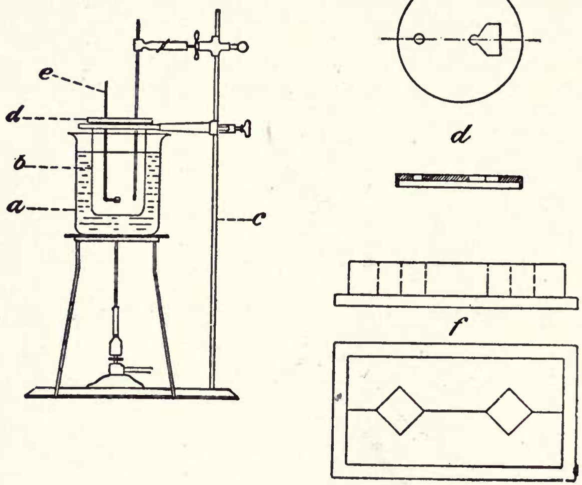
The bituminous material is carefully melted and poured into the ½-inch brass cubical mold which has been amalgamated with mercury and which is set on an amalgamated brass plate. The hot material should slightly more than fill the mold and when cold the excess may be cut off with a hot spatula. The cube is removed from the mold and fastened upon the lower arm of a No. 12 wire B. & S. gauge bent at right angles and suspended beside a thermometer in a tall covered beaker of 400 cc. capacity.

This tall form beaker is set in an 800 cc. low form beaker which is arranged for the application of heat. The wire is passed through the center of the two opposite faces of the cube which is suspended with its base one inch above the bottom of the inside beaker. The inner beaker cover has two openings, one for the wire and one for the thermometer. The wire is held in place by a cork in the cover. The bulb of the thermometer is level with the cube and at an equal distance from the sides of the beaker. Heat is applied to the liquid in the outer vessel in such manner that the thermometer registers an increase of 5°C per minute and the temperature at which the bitumen touches a piece of paper placed in the bottom of the beaker is taken as the melting point. Determinations should check within 2°. The temperature at the beginning of the test should be approximately room temperature.

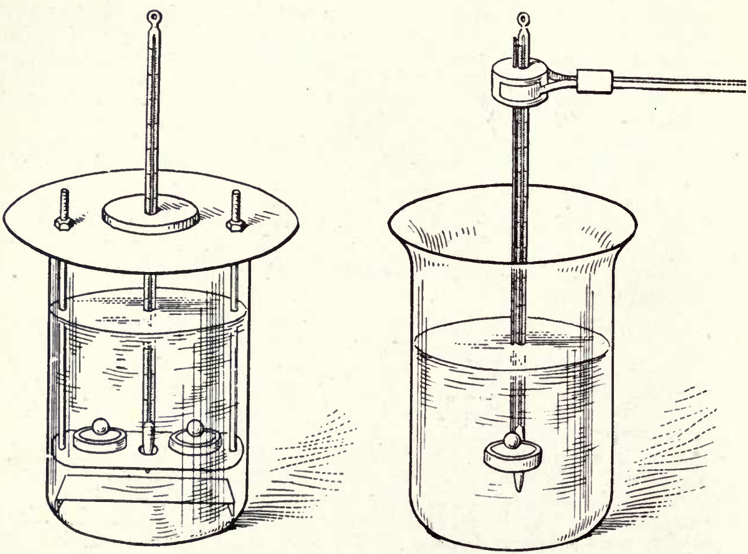
6-C. MELTING POINT OF BITUMINOUS MATERIALS. (General Electric Method.)

Mold one gram of the bituminous material so that it completely and uniformly covers the short bulb of a thermometer graduated to at least 500°F. Fit this thermometer with a cork into a ⅝ x 6-inch test tube with a side tubulation or air vent so that the bulb of the thermometer is ¾-inch from the bottom of the tube. Support the thermometer and tube with a clamp and immerse the tube to a depth of four inches in 400 cc. of commercial concentrated sulphuric acid in a 600 cc. beaker. The beaker of sulphuric acid is heated by direct contact with an electric hot plate of 220 watt capacity and 4½ inches in diameter.

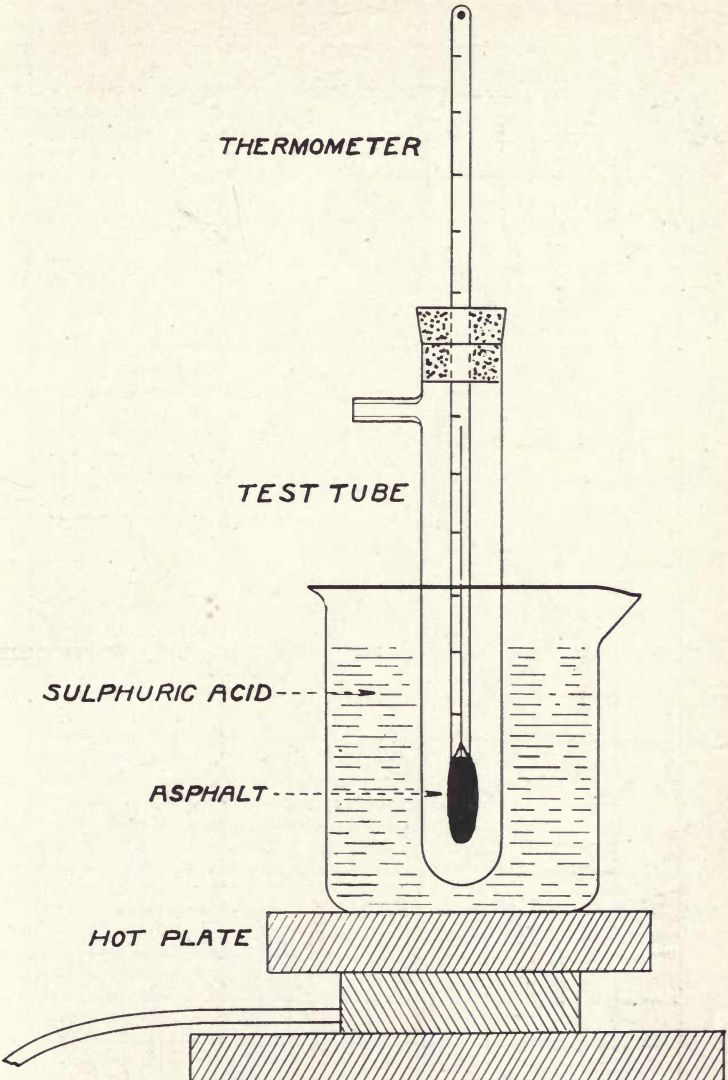
The melting point is taken from readings of the thermometer when the bituminous material flows sufficiently that a tear strikes the bottom of the tube.



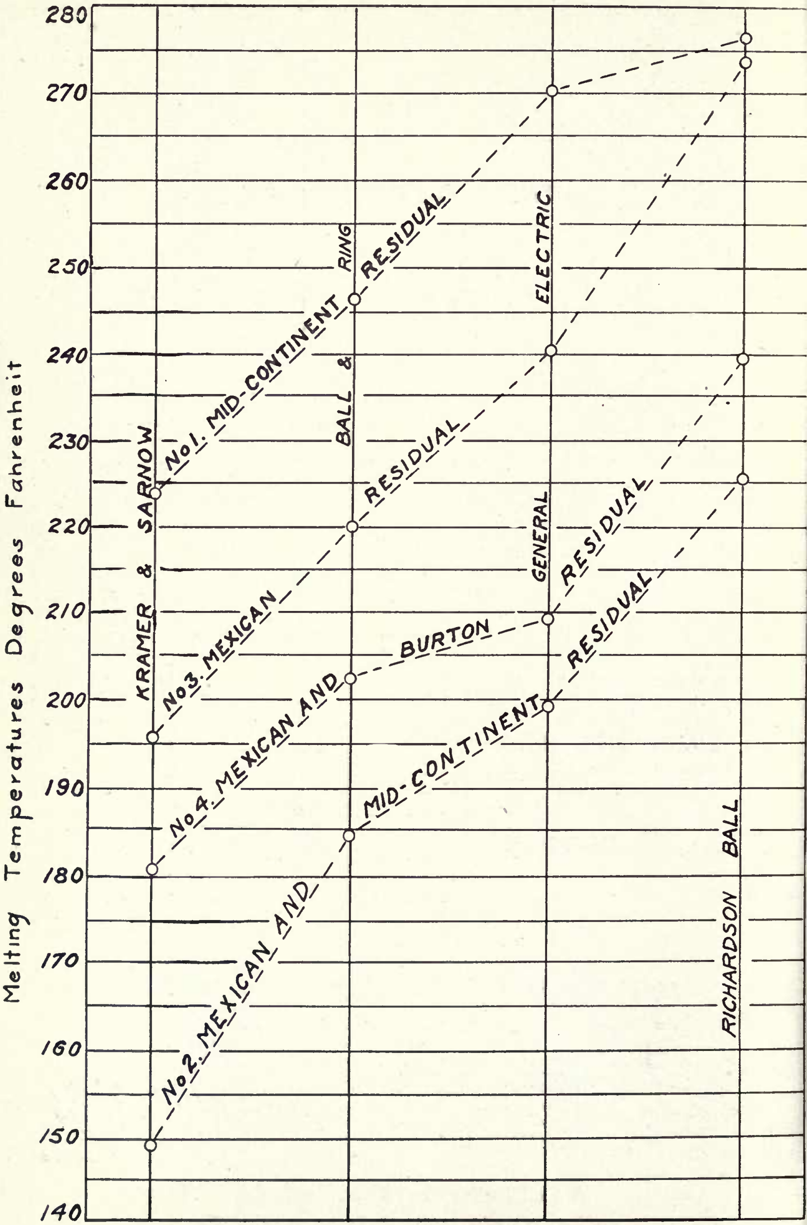
Melting Point—Cube Method



Melting Point—Ring and Ball Method



MELTING POINT - G.E. METHOD.



COMPARISON OF MELTING POINT DETERMINATIONS.

6-D. METHOD OF DETERMINING THE MELTING POINT OF PARAFFIN WAX.

Use the apparatus consisting of a 1x8 inch test tube fitted into a bottle all as shown on page 302.

Pour the melted paraffin into the test tube to a depth of three inches and insert a special wax or titer test thermometer graduated to .1°F. Place it exactly in the center of the tube so that the bottom of the thermometer is one-half inch from the bottom of the test tube. Let the apparatus stand in a warm place preferably in a blood temperature incubator or at 100°F and take readings of the thermometer every minute.

Continue the readings until the wax is nearly solid.

The melting point is the average of the three one-minute readings which are most nearly identical. In the case of high melting point wax these readings are practically identical. In the case of low melting point wax there would be some difference in the readings.

This method is graphically illustrated on page 303.

Note.—See Scientific Paper No. 340 of U. S. Bureau of Standards, Sept. 12, 1919.

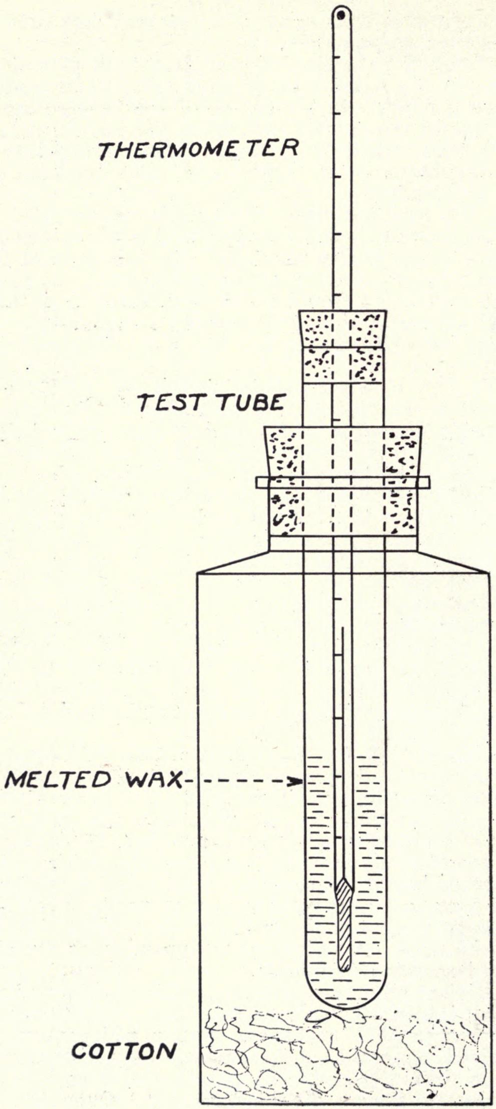
7-A. CLOUD, POUR AND COLD TESTS OF PETROLEUM OILS.

Put the oil to be tested in a glass jar or bottle approximately 1¼ inches inside diameter and 5 inches high, to a height of about 1¼ inches or sufficient to reach ¼-inch above the mercury bulb of the thermometer. The thermometer should have a bulb about ⅜-inch long and is held centrally in the jar with a tightly fitting cork and with the lower end of the bulb ½-inch from the bottom of the jar.

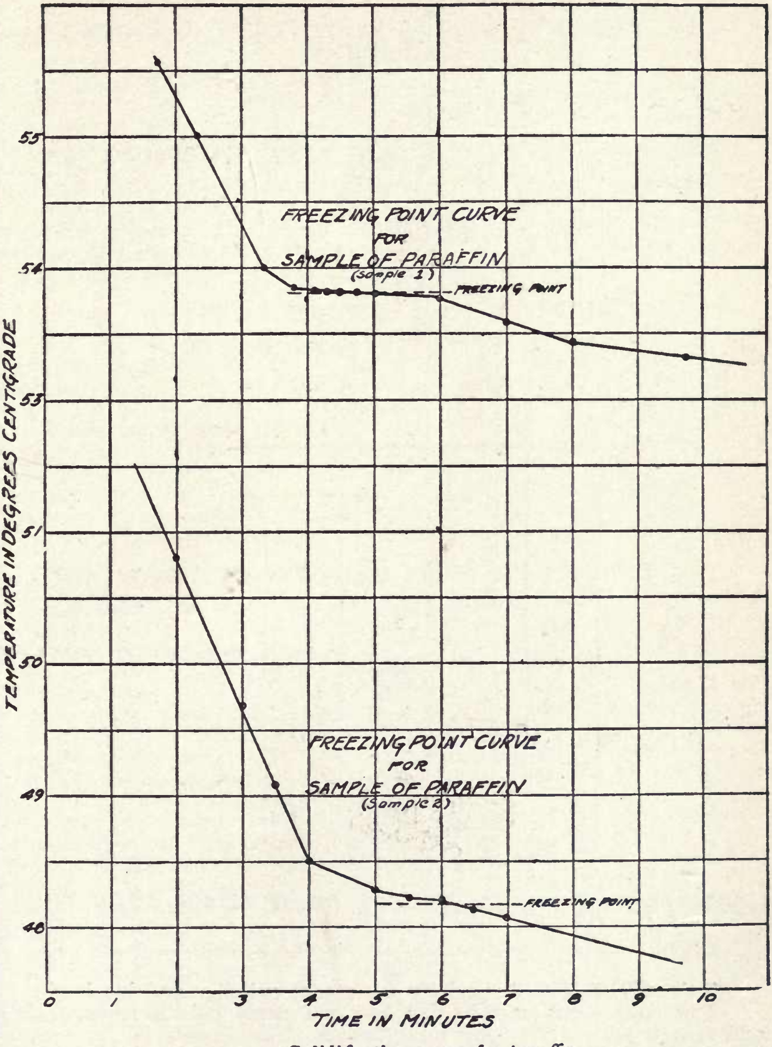
Now place the cold test bottle in a metal or glass jacket about 5 inches high having a diameter about ½-inch greater than the outside diameter of the bottle. A disc of cork ¼-inch in thickness is placed in the bottom of the jar. Put the apparatus in the refrigerating mixture and place the bottle so that it does not touch the jacket. At every drop in temperature of 2°F when near the expected cloud test, remove the jar from the jacket, being careful not to disturb the oil by moving the thermometer. When the lower half of the sample becomes opaque through chilling, read the thermometer. This temperature is the cloud test of the oil.

7-B. For the **POUR TEST** (usually called Cold Test) continue the cloud test, and at each drop in temperature of 5°F remove the bottle from the jacket and tilt it until the oil begins to flow. When the oil has become solid around the thermometer and will not flow, the previous 5° point shall be taken as the pour test. For oil solidifying above 35°F pounded ice may be used for the refrigerating mixture. For temperatures below this and down to —5°F a mixture of 2 parts of pulverized ice and 1 part of salt may be used. From —5°F and to —25°F a mixture of equal parts of pulverized ice and calcium chloride may be used. A universal frozen mixture for all these temperatures can be made as follows:

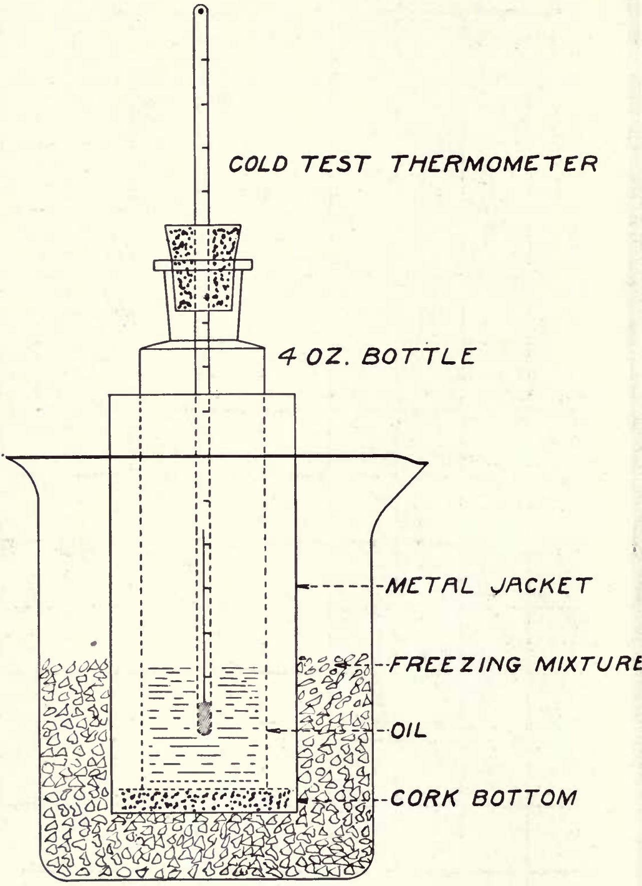
Put a sufficient amount of dry acetone into a covered metal beaker. Put the beaker into an ice salt mixture and when the temperature of the acetone reaches 10°F or below, slowly add carbon dioxide snow until the desired temperature is reached. A temperature as low as —70°F can be thus attained. To get the solid carbon dioxide snow invert an ordinary carbon dioxide cylinder. Open the valve slowly and let the liquid run out into a close mesh bag. By rapid evaporation the carbon dioxide becomes solid. (Continued p. 304.)



MELTING POINT OF PARAFFIN WAX



Solidification curves for paraffin



APPARATUS FOR CLOUD TEST, POUR TEST, COLD TEST.

7-C. **COLD TEST** specially for steam cylinder and black oils. The same bottle used in the pour and cloud tests is filled ¼ full and frozen with a freezing mixture. A thermometer is then introduced into the frozen mass and after it has become cold the bottle containing the solidified oil is removed from the cooling mixture. The solidified oil is thoroughly stirred with the thermometer until the mass will run from one end of the bottle to the other and at this moment the temperature indicated is recorded. This reading is the cold test of the oil.

8-A. SEDIMENT, WATER, DIRT AND BOTTOM SETTLINGS IN PETROLEUM.

(Apparatus is shown on page 337.)

50 cc. of the oil are thoroughly mixed with 50 cc. of benzol and the mixture is poured into a 100 cc. graduated V-shaped centrifuge tube such as is shown on page 337. This is exactly counter-balanced and run in the electric centrifuge at a speed of approximately 2,000 R. P. M. for 5 minutes or until there is a sharp line of demarkation between the sediment or dirt, the water and the oil, if any water or dirt are present. The amount of sediment or dirt is read off by volume and expressed in percentage by volume. The water is also expressed in percentage by volume.

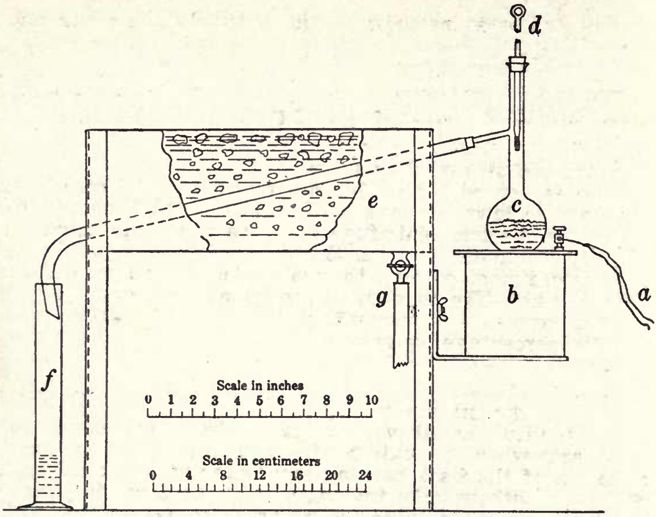
8-B. WATER BY DISTILLATION OF PETROLEUM.

100 cc. of the oil are placed in a flask connected to a distillation apparatus as shown on page 308. This is heated until foaming starts when an auxiliary flame is applied to all parts of the upper portion of the flask causing any water vapor to pass over into the condenser without allowing water to collect in the neck of the flask. This heating also tends to prevent the extension of the foam into the condenser. The flame beneath the flask must be applied very gently. This is continued until all foaming ceases and all water has been distilled over from the condenser. The number of cubic centimeters of water collected in the receiver is the percentage of water.

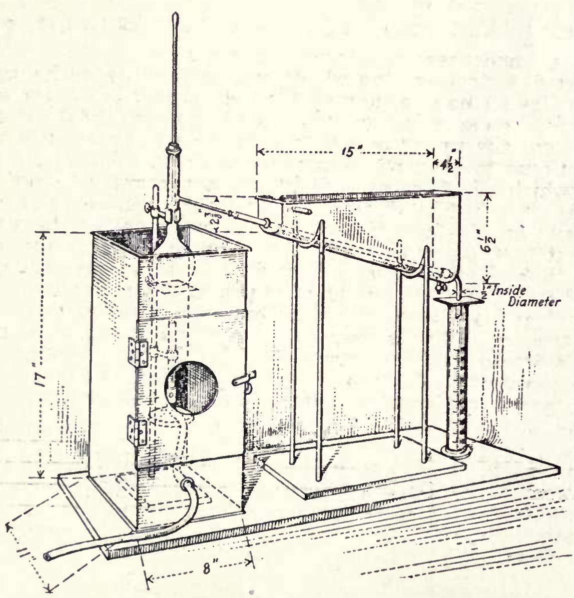
9-A. PROXIMATE DISTILLATION OF PETROLEUM.

400 cc. of the petroleum are poured into a 1,000 cc. flask which is connected to a condenser (as shown on page 310). The thermometer is inserted so that the top of the bulb is just below the outlet of the flask. The flame is gradually applied to the oil so that any foaming will tend to make itself evident. If there is foaming it will be necessary to heat the upper portion of the flask. Before the application of the flame to prevent foaming, it is necessary to get the temperature at which the first drop falls into the receiver. This is the initial boiling point. The distillate is collected until a temperature of 410°F is reached when distillation is proceeding at the rate of 5 cc. per minute. The fraction collected up to this temperature is the gasoline or naphtha, the gravity of which is determined. If the gravity is less than 57, it is classified as naphtha, if above this, it is classified as gasoline. The distillation is continued at the same rate until a temperature of 572°F is reached. This fraction is kerosene and its gravity is determined. The residue in the flask is fuel oil and is used for the determination of wax or asphalt, gas oil or lubricants. The information given by this distillation is:

Water			——%
Gasoline	(——410°F)	(Gr. = —— = ——Be°)	——%
Kerosene	(410 —572°F)	(Gr. = —— = ——Be°)	——%
Fuel Oil—Residuum		(Gr. = —— = ——Be°)	——%
			100.0%



—Apparatus used by the Bureau of Mines for distillation test of gasoline. *a* Wires connecting with electric mains through a suitable rheostat. *b* Electric heater. *c* Engler distillation flask filled with charge of gasoline partly distilled. *d* Thermometer. *e* Condenser, with trough filled with ice and water. *f* Receiving graduate. *g* Cock for draining condenser trough.



American Society for Testing Materials Apparatus.

9B. END POINT DISTILLATION TEST OF GASOLINE, NAPHTHA AND BENZINE.

This method is essentially that of the American Society for Testing Materials, page 606 of 1918 Book of Standards, and is the method given by the Bureau of Mines in Technical Paper 166 with slight modifications.

The apparatus used in the distillation is as follows: The flask used shall be the standard 100 cc. Engler flask. The dimensions are as follows:

	Cm.	Inches
Diameter of bulb	6.5	2.56
Diameter of neck	1.6	0.63
Length of neck	15.0	5.91
Length of water tube	10.0	3.94
Diameter of vapor tube	0.6	0.24

Position of vapor tube 9 cm. (3.55 in.) above surface of oil when flask contains its charge of 100 cc. The tube is approximately in the middle of the neck.

The flask shall be supported on a ring of asbestos having a circular opening 1¼ in. in diameter; this means that only this limited portion of the flask is to be heated. The use of a sand bath is not approved.

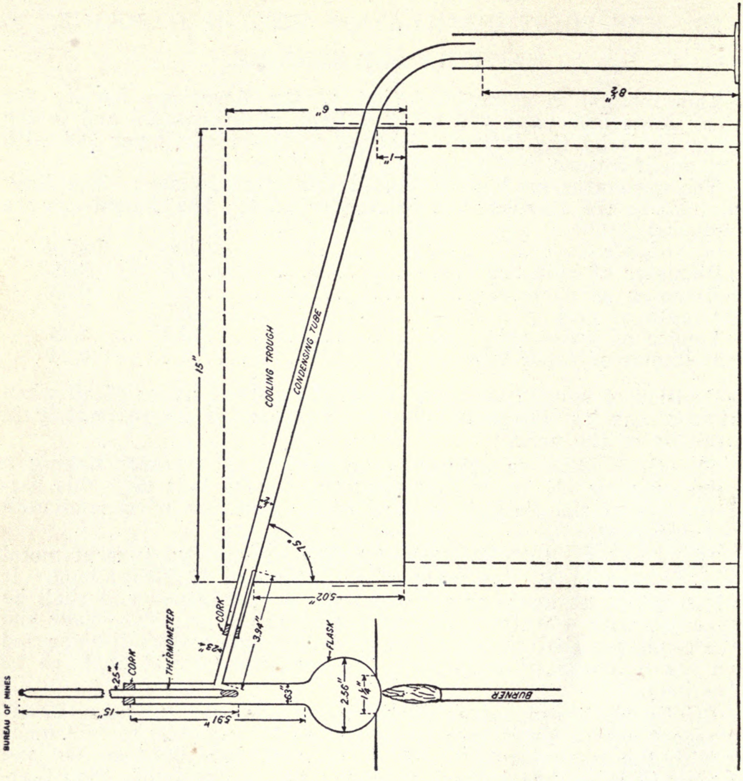
The condenser tube shall consist of a thin walled tube of metal (brass or copper) ½ inch internal diameter and 22 inches long. It shall be set at an angle of 75° from the perpendicular and shall be surrounded with a water jacket of the trough type. The lower end of the condenser shall be cut off at an acute angle and shall be curved down for a length of 3 inches. The condenser jacket shall be 15 inches long.

Briefly the thermometer should be an accurate "nitrogen-filled" instrument with a short bulb (length 10 to 15 mm. 0.39 to 0.59 inch) and with the mark for 35°C (95°F) at a distance between 100 and 120 mm. (3.94 to 4.73 inches) from the top of the bulb. The thermometer should be scaled for total immersion.

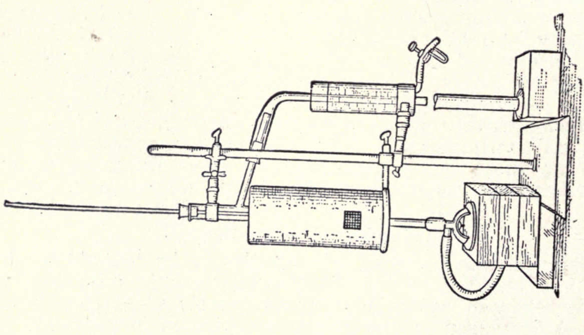
The above requirements insure that the lowest temperatures registered may be read above the cork of the distillation flask and variations because of the so-called "stem correction" will always be practically the same. The stem correction should not be applied but it should be understood that the results of distillations are expressed in terms of thermometer readings, not of actual temperatures. The use of partial-immersion thermometers is not recommended for distillations as these instruments are no more likely to agree with one another than are the more common total immersion thermometers.

Method of Distillation.

Pour some of the gasoline or naphtha to be tested through the condenser tube just before the distillation flask is connected with it and allow it to drain before placing the receiver. Likewise the distillation flask is rinsed out with the gasoline or naphtha to be distilled and drained before the charge of 100 cc. is added to it. The 100 cc. graduated cylinder may be used without drying as the receiving vessel for the distillation.



APPARATUS FOR DISTILLATION TESTS OF GASOLINE.



Water in Crude Oil

The thermometer bulb should be covered with a thin film of absorbent cotton. This keeps the glass always wet with the condensate from the vapor and thus prevents possible fluctuations in the temperature. It also tends to prevent superheating of the bulb at the end of the distillation and thus makes possible an accurate determination of the dry point.

Heat should be applied to the flask in regulated degree, care being taken that the whole distillation from beginning to end shall proceed at a rate of not less than 4 nor more than 5 cc. a minute (about 2 to 3 drops per second). Readings of the thermometer shall be made as each 5% distills. The temperature at which the first drop falls from the exit of the condenser tube is the initial boiling point.

The dry point, end point or highest temperature reading at the end of the distillation shall also be recorded. It is the temperature when the last drop is vaporized and a puff of white vapor appears in the flask. The distillation loss shall be determined by adding the percentage of residue in the distilling flask, after cooling, to the percentage of total distillates held in the receiver. If the distillation loss is over 3%, a check distillation shall be made, as excessive loss may indicate that the rate of distillation at the beginning was too rapid. In case the magnitude of the loss is confirmed this fact is of importance in indicating that the gasoline contains very volatile constituents, particularly those derived from added casinghead gasoline.

The condenser trough shall be filled with a mixture of finely cracked ice and water (not dry cracked ice) and during the distillation sufficient ice shall be kept in the trough to prevent the temperature of the cooling water exceeding 4°C (39°F).

If distillations are made at high altitudes or when barometric pressures are low, allowances may be made for this factor. In general, recording the barometric pressure read at the time of the distillation will suffice and it is recommended that whenever there is possibility of dispute over the results of a distillation this should be done.

In finishing the distillation there is always a small amount of naphtha remaining in the flask in the vapor phase in excess of that required to wet the inside of the flask. If the residue in the flask has not been poured into the receiver the end point of 98% is to be read as 100% and any loss is to be calculated as the difference between the 98% and the amount actually recovered after the condenser tube has thoroughly drained.

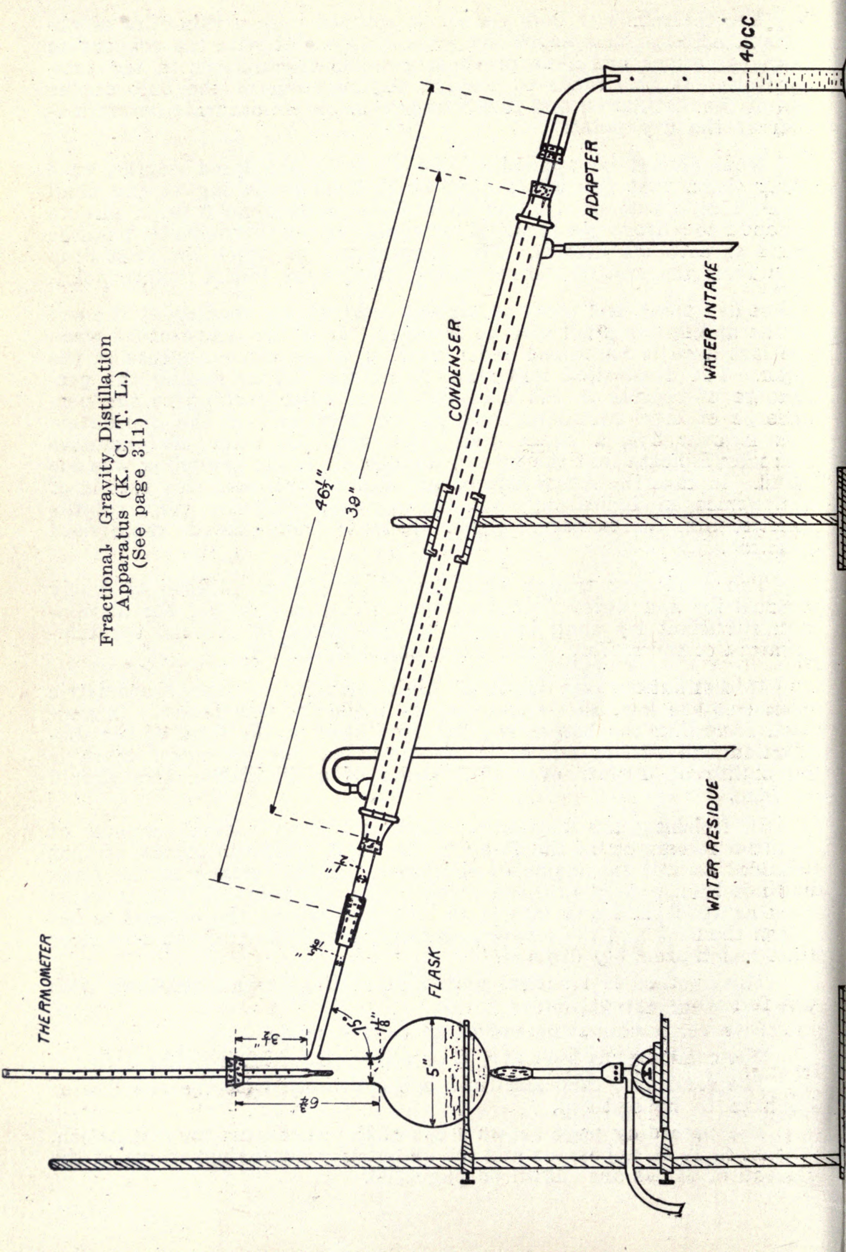
This method is identical with that of the Bureau of Mines with the following exceptions:

Five cc. readings instead of 10 cc. are made.

The condenser is kept at 4°C or below (B. of M. is below 8°C).

The condenser tube and flask are moistened with the gasoline or naphtha to be distilled.

The preceding page shows a cut of the apparatus for distillation. The A. S. T. M. apparatus and the electrically heated apparatus of the Bureau of Mines are shown on page 306.



Fractional Gravity Distillation Apparatus (K. C. T. L.)
(See page 311)

9C. FRACTIONAL GRAVITY DISTILLATION OF PETROLEUM.

Use a 1,000 cc. distilling flask of heavy pyrex glass having a diameter of 13 centimeters, a neck 17 centimeters long with a 3 centimeter diameter and with a side tubulus 8 centimeters above the body of the flask. The tubulus is set at approximately 75° to the neck of the flask. The condenser tube is 36 inches long and the water jacket is 30 inches long. The details of the set-up are shown on page 310.

The oil to be used should be as nearly as possible free from water. Eight hundred cubic centimeters are poured into the distillation flask, the thermometer used is preferably for 5 inch immersion reading to 750°F. It is inserted so that the top of the mercury bulb is even with the bottom of the tubulus and is in the center of the neck of the flask.

Distillation is begun using a smoky flame of a strong Tirrell burner, the flask being supported on a ring as shown in the diagram. The burner is protected from air drafts and the flask is blanketed with asbestos paper if necessary. The flame is controlled by a screw pinch cock on the rubber tubing.

The temperature at which the first drop falls from the condenser is the initial boiling point. The rate of distillation after the first 5% is 8 cubic centimeters or 1% per minute. Five per cent fractions are collected in the 100 cubic centimeter cylinder. These 40 cubic centimeters are poured into a 50 cc. graduate, allowing the distillate to mix thoroughly. The specific gravity is taken and the corrections are made to 60°F. The end point of each 2½% fraction is recorded and the distillation is continued, taking the gravity of each 5% fraction. In operating on a crude oil in which the natural content is desired, the distillation with straight fire is stopped when the first fraction with a temperature above 572°F is completed. Beyond this temperature inert gas, such as natural gas, coal gas or carbon dioxide is introduced sufficiently to carry the distillation at the same rate of speed but such that the temperature at no time exceeds 650°F. After the gas is used the water is removed from the condenser and the condenser tube is kept warm to prevent wax occluding the tube.

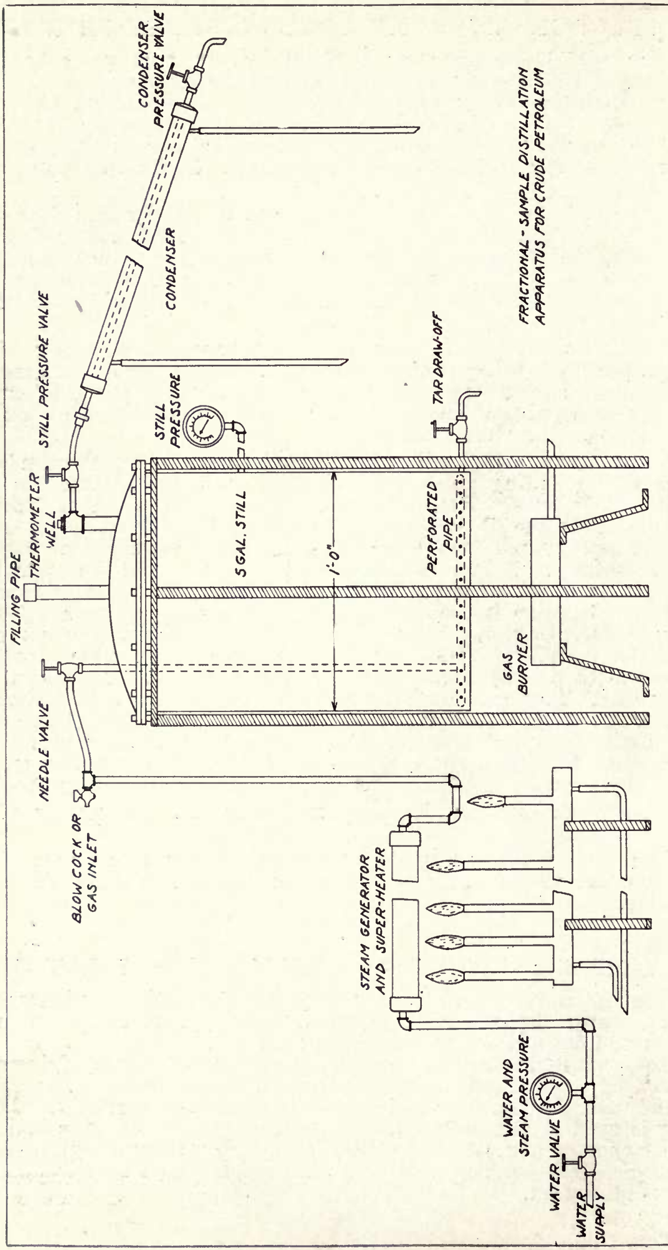
Ninety per cent should be carried over and the gravity of the residue taken.

The data obtained by this distillation is shown on pages 122 to 127 for crude oil, on pages 231-2 for gasoline and page 230 for heavy distillate.

9D. SAMPLE PREPARATION DISTILLATION OF CRUDE OIL.

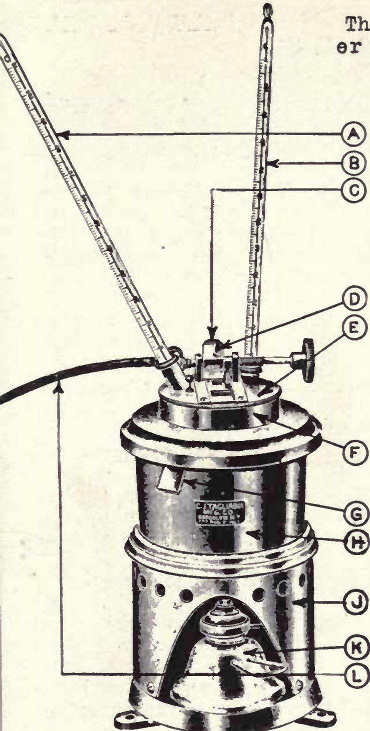
The apparatus consists of a 5-gallon steel still, condenser, gas burner, water supply under pressure, steam producers, superheater gauges and connections as shown on page 312.

Ten thousand cubic centimeters is a convenient charge, giving a 5% fraction of 500 cc., which is sufficient for special tests. The still is covered with chicken wire and asbestos cement for insulation. Direct firing is used until a temperature of slightly above 500°F is indicated in the vapor or a gravity of 40°Be′ (0.825 specific gravity) is shown in the distillate fraction. At this temperature superheated steam or gas is introduced.



FRACTIONAL - SAMPLE DISTILLATION APPARATUS FOR CRUDE PETROLEUM

The "TAG" standard closed flash tester for volatile inflammable liquids



(A) Thermometer, indicating the temperature of the oil.

(B) Thermometer, indicating the temperature of the water bath.

(C) A miniature oil well to supply the test flame when gas is not available, mounted on the axis about which the test-flame burner is rotated, which axis is hollow and provided with connection on one end for gas hose, and provided also with needle valve for controlling gas supply, when gas is available, the gas passing through the empty oil well.

(D) Gas or oil tip for test flame.

(E) Cover for oil cup, provided with three openings, which are in turn covered by a movable slide operated by a knurled hand knob, which also operates the test flame burner in unison with the movable slide, so that by turning this knob, the test flame is lowered into the middle opening in the cover, at the same time that this opening is uncovered by the movement of the slide.

(F) Oil cup (which cannot be seen in the illustration), of standardized size, weight and shape, fitting into the top of the water bath.

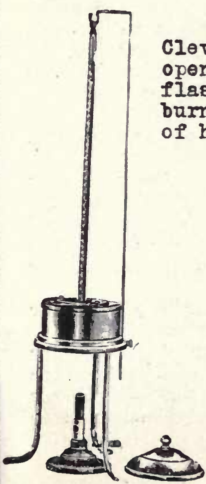
(G) Overflow spout.

(H) Water bath, of copper, fitting into the top of the body, and provided with an overflow spout and openings in its top, to receive the oil cup and water bath thermometer.

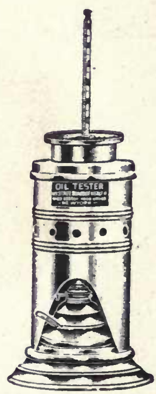
(J) Body of metal, attached to substantial cast metal base provided with three feet.

(K) Alcohol lamp for heating the water bath.

(L) Gas hose.



Cleveland open tester for flash point and burning point of heavy oils.



New York closed tester for all types of oils.
(Elliott)

10A. FLASH POINT OF KEROSENE AND OTHER VOLATILE INFLAMMABLE LIQUIDS.

(With Standard "TAG" Closed Tester.)

This is essentially in accordance with the method of the American Society for Testing Materials, Tentative Standards, 1917, pages 445-6.

The test must be performed in a dim light so as to see the flash plainly.

Surround the tester on three sides with an inclosure to keep away drafts. A shield about 18 inches square and 2 feet high, open in front, is satisfactory. See that tester sets firmly and level.

For accuracy, the flash point thermometers which are especially designed for the instrument should be used as the position of the bulb of the thermometer in the oil cup is essential.

Put the water-bath thermometer in place. Place a receptacle under the overflow spout to catch the overflow. Fill the water bath with water at such a temperature that when testing is started, the temperature of the water bath will be at least 10°C below the probable flash point of the oil to be tested.

Put the oil cup in place in the water bath. Measure 50 cc. of the oil to be tested in a pipet or a graduate and place in oil cup. The temperature of the oil must be at least 10°C below its probable flash point when testing is started. Destroy any bubbles on the surface of the oil. Put on cover with flash point thermometers in place and gas tube attached. Light pilot light on cover and adjust flame to size of the small white bead on cover.

Light and place the heating lamp, filled with alcohol in base of tester and see that it is centrally located. Adjust flame of alcohol lamp so that temperature of oil in cup rises at the rate of about 1°C (1.8°F) per minute or not faster than 1°C (1.8°F) nor slower than 0.9°C (1.6°F) per minute.

Record the "time of applying the heating lamp," record the "temperature of the water bath at start," record the "temperature of the oil sample at start."

When the temperature of the oil reaches about 5°C below the probable flash point of the oil, turn the knob on the cover so as to introduce the test flame into the cup and turn it promptly back again. Do not let it snap back. The time consumed in turning the knob down and back should be about one full second, or the time required to pronounce distinctly the words "one thousand and one."

Record the "time of making the first introduction of the test flame" and record the "temperature of the oil sample at time of first test."

Repeat the application of the test flame at every 0.5°C rise in temperature of the oil until there is a flash of the oil within the cup. Do not be misled by an enlargement of the test flame or halo around it when entered into the cup or by slight flickering of the flame; the true flash consumes the gas in the top of the cup and causes a very slight puff.

Record the "time at which the flash point is reached," and the "flash point."

If the rise in temperature of the oil from the "time of making the first introduction of the test flame" to the "time at which the flash point is reached" was faster than 1.1°C or slower than 0.9°C per minute, the test should be questioned and the alcohol heating lamp adjusted so as to correct the rate of heating. It will be found that the wick of this lamp can be so accurately adjusted as to give a uniform rate of rise in temperature of 1°C per minute and remain so.

Repeat Tests.—It is not necessary to turn off the test flame with the small regulating valve on the cover, but leave it adjusted to give the proper size of flame.

Having completed the preliminary test, remove the heating lamp, lift up the oil cup cover and wipe off the thermometer bulb. Lift out the oil cup and empty and carefully wipe it. Throw away all oil samples after once using in making test.

Pour cold water into the water bath, allowing it to overflow into the receptacle until the temperature of the water in the bath is lowered to 8°C below the flash point of the oil as shown by the previous test. With cold water of nearly constant temperature it will be found that a uniform amount will be required to reduce the temperature of the water bath to the required point.

Place the oil cup back in the bath and measure into it a 50 cc. charge of fresh oil. Destroy any bubbles on the surface of the oil, put on the cover with its thermometer, put in the heating lamp, record time and temperature of oil and water and proceed to repeat test as described above. Introduce test flame for first time at a temperature 5°C below the flash point obtained on the previous test.

Precautions.—Be sure to record barometric pressure either from laboratory barometer or from nearest Weather Bureau station. Record temperature of room.

Note and record any flickering of the test flame or slight preliminary flashes when the test flame is introduced into the cup before the proper flash occurs. Record time and temperature of such flickers or slight flashes if they occur.

10B. FLASH AND BURNING POINT OF ALL TYPES OF PETROLEUM OILS AND ASPHALTS.

(With New York or Elliott Closed Tester.)

The bath surrounding the oil cup is filled with very high flash fluid oil or is left unfilled if the oil to be tested has a very high flash point. The oil cup is filled with the material to be tested to within 3 millimeters of the flange joining the cup and the vapor chamber above. The glass cover is then placed on the oil cup and the thermometer adjusted so that its bulb is just covered by the oil or bitumen. The flame is applied to the bath in such manner that the temperature is raised at the rate of about 5°C per minute. Every half minute the testing flame is inserted in the opening in the cover and about halfway between the surface of the material and the cover. The first appearance of a faint bluish flame on the entire surface of the bitumen or oil shows that the flash point has been reached, and this temperature is recorded.

The burning point of the material is now obtained by removing the glass cover and replacing the thermometer in the frame. The temperature is raised at the same rate and material tested as before. The temperature at which the oil or bitumen ignites and burns is recorded as the burning point. The flame should be extinguished with the metal cover very promptly after the burning point is reached.

10C. FLASH AND BURNING POINT OF LUBRICANTS.
(With the Cleveland Open Cup.)

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

The **burning point** of the oil is obtained by continuing the test and noting the temperature at which the vapor arising from the surface of the oil ignites and burns continuously. The thermometer is quickly withdrawn and the metal cover used to extinguish the flame.

CONVERSION OF BAROMETRIC PRESSURE IN CENTIMETERS TO INCHES.

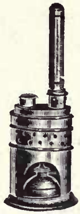
	0	1	2	3	4	5	6	7	8	9
70	27.559	27.598	27.638	27.677	27.716	27.756	27.795	27.835	27.874	27.913
71	27.953	27.992	28.031	28.071	28.110	28.150	28.139	28.228	28.268	28.307
72	28.346	28.386	28.425	28.465	28.504	28.543	28.583	28.622	28.661	28.701
73	28.740	28.779	28.819	28.858	28.898	28.937	28.976	29.016	29.055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

CORRECTIONS OF FLASH POINT FOR NORMAL BAROMETRIC PRESSURES.

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

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

Abel-Pensky



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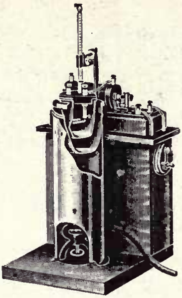
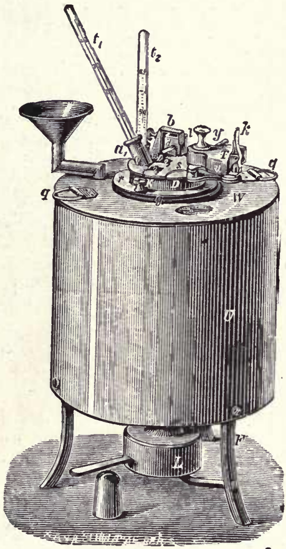
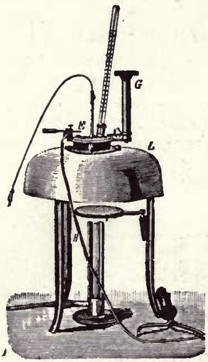


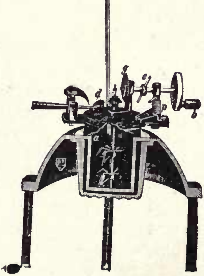
Scott



Abel



Pensky-Martens



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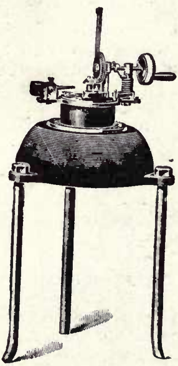


VARIOUS FLASH AND FIRE TESTERS.

11A. CRACKING TEST FOR HEAVY PETROLEUM HYDROCARBONS. (See P. 320.)

The apparatus is set up as shown in sketch. (a) is a cylindrical tube tested out to a pressure of 3,000 pounds such as is ordinarily used for dispensing oxygen gas. (b) is a thermometer well or plug with a tapered thread and of sufficient length that it protrudes well into the interior of the vessel (a). This plug has an opening from the outside into which the thermometer (c) is inserted. This mercury thermometer is graduated preferably in single degrees Centigrade and is of borosilicate glass, nitrogen filled and reading up to a temperature of 550°C. (d) is an extra heavy ammonia pipe fitting connected to a valve (e) and a pressure gauge (f). Pressure gauge (f) should read to at least 200 atmospheres or 200 kilograms per square centimeter. Heat is applied by gas burners (g) such as are used in combustion furnaces and the whole apparatus is supported on a stand with the end carrying the pressure gauge slightly elevated.

The capacity of the bomb is 1,500 to 1,600 cubic centimeters and 500 cc. of oil to be tested are poured into it at a temperature of approximately 20°C. The plug (b) is inserted and screwed in very tightly, using Stilson wrenches. The threads on the plug may be dressed with a mixture of equal parts of glycerin, litharge and copper oxide. The flame is applied so that it does not excessively heat the portion of the container not in contact with the oil. The total time consumed for the test after the beginning of the application of the heat should be between 55 minutes and 70 minutes. The heating is carried on until a pressure of 55 atmospheres is attained, based on a temperature of 400°C. It is desirable to keep the container covered with a sheet of asbestos during the operation. The temperature should not ordinarily exceed 420°C. The apparatus is cooled to about 20°C before opening.

The constants in this test are the dimensions of the apparatus, the amount of oil used, the rate of application of heat and maximum pressure at 400°C.

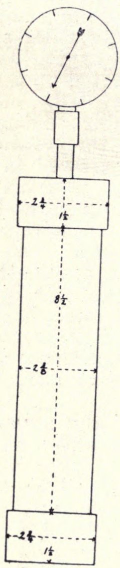
The variables are the percentage by volume of oil recovered after cracking, the amount of carbon formed, the amount of gas formed, the specific gravity of the gasoline and the total yield of gasoline. (See proximate distillation of crude oil.)

Variations are due to the character of the oil treated, the specific gravity of the gasoline being higher, the recovery higher, the carbon and gas formation less and the total amount of oil recovered greater with paraffin base and with low gravity oils than with naphthene base and high gravity oils.

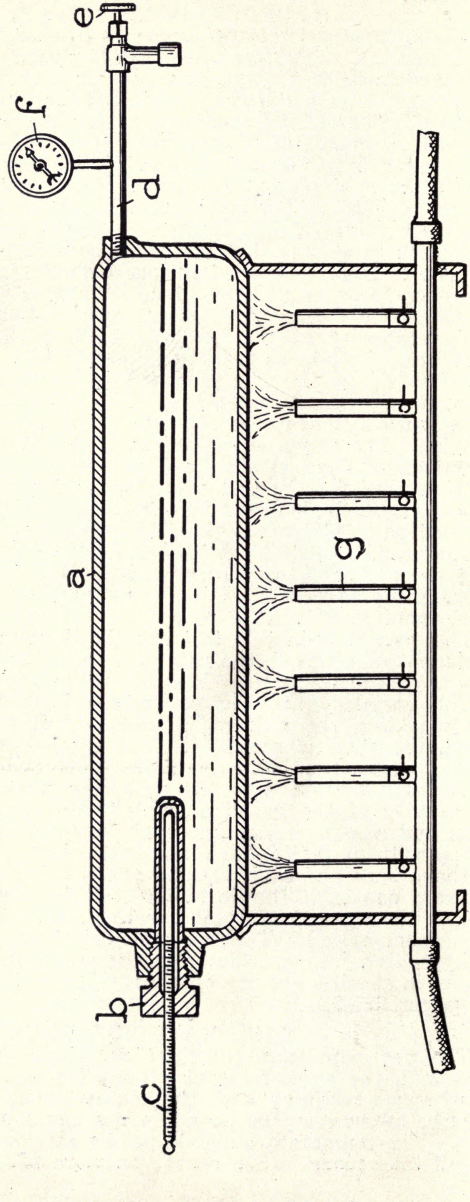
From one such equilibrium test it is possible to approximately estimate the amount of total gasoline which it would be possible to obtain from an oil. This may be calculated from one equilibrium test by taking into consideration the shrinkage on cracking and the increase in specific gravity of the residue above 210°C after cracking. (See pages 228-9.)

11B. VAPOR PRESSURE.

The vapor pressure of light petroleum hydrocarbons is determined with the same apparatus used for making the cracking test. The pressure readings with the corresponding temperature readings should be taken every 30 pounds and a curve plotted for intermediate points. The temperature should not be carried above 350°C as cracking will take place. (See curves on page 226.)



Vapor Pressure Tester.



Pressure Cracking Apparatus

11C. VAPOR PRESSURE TESTS FOR LIGHT GASOLINE MADE FROM GAS.

(See Westcott, Handbook of Casinghead Gasoline.)

Apparatus shown on page 320 consists of iron or steel pipe of 2 inch size, with caps screwed on ends. Upper cap has 0.25 inch nipple screwed in and is connected by a coupling to a 3 inch 30 lb. pressure gauge. Gauge is known as Inspector's Gas Gauge. All joints must be entirely tight. Joints between large pipe and caps are best sealed with solder. Approximate external dimensions are indicated on sketch. In addition to apparatus indicated in test, there is also required a tin cylinder for filling test tube, 12 by 3 inches, that can be slipped over outside of tube for convenience in carrying when not in use. The tin cylinder is provided with a lip for pouring. A small tin cover 0.75 inch deep, fitting over the bottom of the tin cylinder may be removed and used for measuring off one-tenth capacity of test tube. A small tin funnel 2.5 inches in diameter with stem 3 inches long and three-sixteenths inch in diameter should be used.

Remove the gauge from the tube and fill tube to 90 per cent of its capacity. Fill tube preferably by lowering it into the storage tank in upright position by means of a cord or wire. Leave the tube entirely immersed for several minutes, withdraw it and pour off sufficient liquid so that tube will contain 90% of its capacity. A small measure having capacity of 10% of the test tube should be used for that purpose.

In case it is impracticable to lower the tube into the storage tank, draw the liquid off into the vessel of capacity about equal to the test tube. Pour liquid into the test tube until about half filled. Shake tube and contents gently in order to bring both to the same temperature. After standing for several minutes, pour out all the liquid from the tube. Draw another sample from the storage tank into the cylinder and pour through funnel into the tube until the latter is entirely full. Withdraw one-tenth as before. Screw gauge tightly into position, using a little liquid shellac on joint to insure a tight fit.

Immerse the tube in water at temperature of 70°F and allow it to remain for five minutes. Then remove it from the water and unscrew the gauge sufficiently to relieve the pressure indicated by the gauge for a period of 20 seconds and screw the gauge tightly into the tube again. Then place the tube in water at a temperature of 100°F (90°F from Nov. 1st to March 1st). The level of the water must be just below the lower edge of the pressure gauge. Stir the water continually and maintain the temperature exactly constant for ten minutes, then tap the gauge lightly with the finger and read the pressure.

A correction of pressure figures should be made according to the initial temperature of the gasoline. This correction should be as follows:

For tests on samples taken at a temperature of 50 to 59°F, inc., deduct 1 lb.

For tests on samples taken at a temperature of 40 to 49°F, inc., deduct 2 lbs.

For tests on samples taken at a temperature below 40°F, deduct 3 lbs.

The gravity of the liquid, the temperature of liquid gas placed in test tube, the pressure at 70°F before venting tube, the corrected pressure at 100°F (90°F from Nov. 1st to March 1st) after venting at 70°F should all be recorded.

12A. CARBON RESIDUE IN LUBRICANTS AND DISTILLATES. (Conradson Method.)

The apparatus 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.

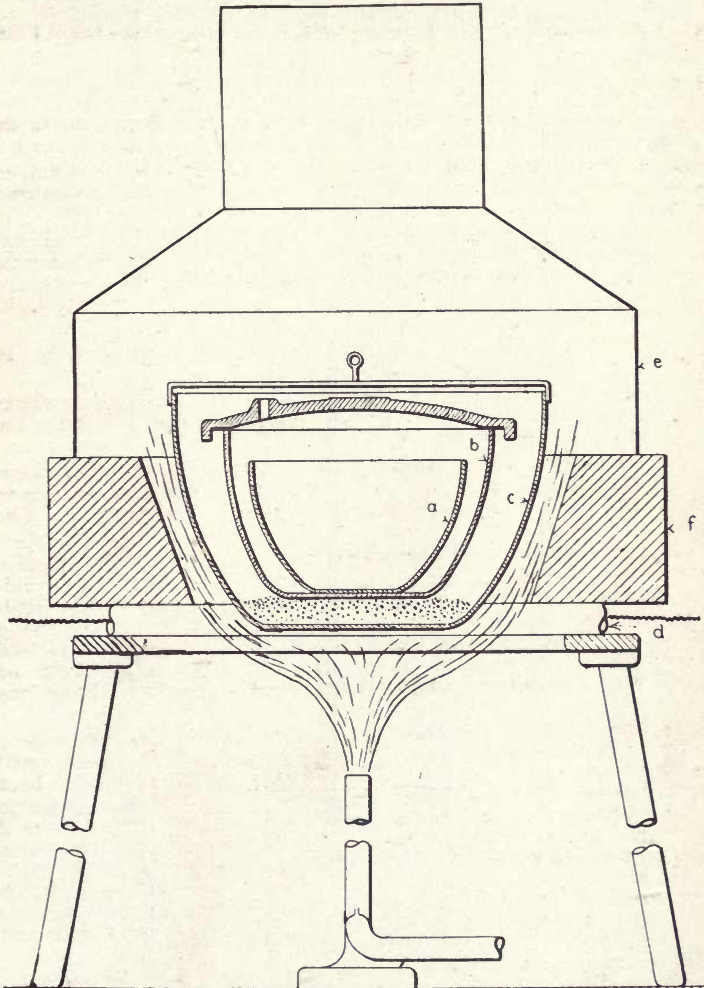
(e) Sheet iron or asbestos hood provided with a chimney about 2 to 2½ inches high, 2⅛ to 2¼ inches in diameter to distribute the heat uniformly during the process.

(f) Asbestos or hollow sheet iron block, 6 to 7 inches square, 1¼ to 1½ inches high, provided with opening in center 3¼ inches in diameter at the bottom and 3½ inches in diameter at the top. 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 Fig. 1, 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 inches 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 dessicator 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. (See A. S. T. M. 1918 Standards, page 620.)

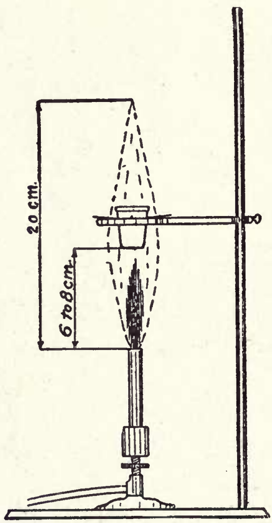


Conradson Carbon Test for Lubricants

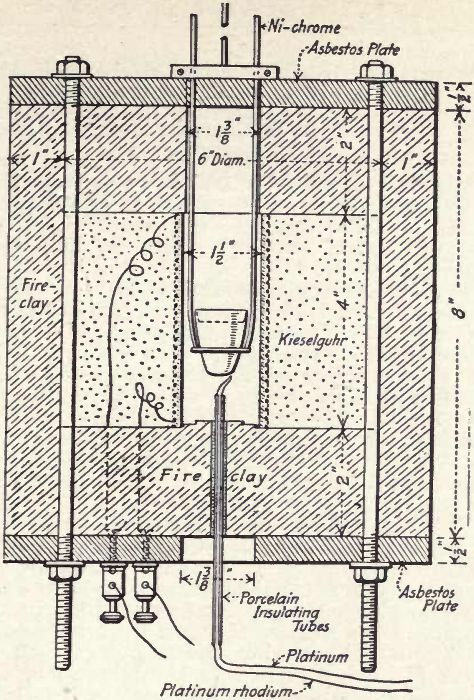
12B. FIXED CARBON AND ASH IN OIL AND BITUMINOUS MATERIALS.

The apparatus used is that shown below, or if the apparatus used for the analysis of coal is available, the special furnace shown on page 325 may be used, or the electric furnace shown on page 348, such as is used for burning out mineral aggregates, is quite satisfactory.

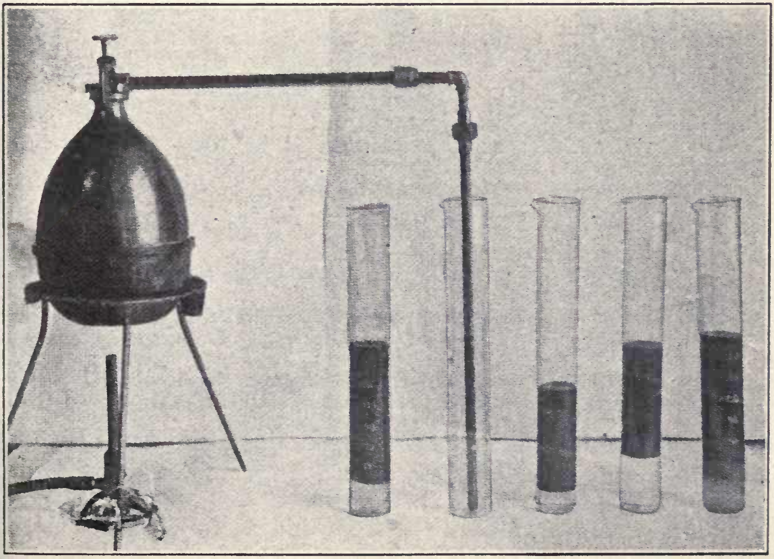
Between .4500 and .5500 gram of the material is placed in a 20-gram platinum crucible having a tightly fitting cover. It is heated for seven minutes with the full flame of a Bunsen burner, as shown, or at 950°C in the electric furnace. With the open flame the crucible should be supported with its bottom 6 or 8 cm. above the top of the burner and the flame should be at least 20 cm. high when burning freely. A shield is used to protect from drafts. The crucible while remaining covered is placed in a dessicator, cooled and weighed, then ignited with lid removed until nothing but the ash remains. The loss is the fixed carbon and the residue is the ash.



Apparatus for the Determination of Fixed Carbon



Electric Furnace for Fixed Carbon



13. EMULSIFICATION OF MINERAL LUBRICATING OILS. (A. S. T. M.—1916.)

P. H. Conradson.

Apparatus.

The apparatus consists of a 4-pint copper retort, provided with a delivery tube, which is joined to a metal or glass pipe having an inside diameter of about 5/16 in. and about 15 in. long from the elbow. The lower end of this pipe is cut off diagonally to prevent thumping.

The glass cylinders are graduated to 250 cc. They have an inside diameter of about 1 7/16 in. and a length of about 9½ in. from the bottom to the 250 cc. mark. They are 11½ to 12 in. in over-all length, and are made of thin glass, with a flat bottom.

In place of a copper retort for the generation of steam, a glass flask or any other suitable source of steam supply may be used; likewise, ordinary 250 cc. graduated glass cylinders, of dimensions given above, may be used where emulsion tests are required only occasionally.

Method of Testing.

The cylinder is filled with distilled water up to the 20 cc. mark, then 100 cc. of the oil to be tested are added. To churn the mixture, steam at ordinary pressure is conducted through this oil-water mixture for ten minutes. The amount of steam passed through is regulated in such a way so as to prevent the mixture from splashing over the top of the cylinder, but the rate may be as rapid as is practical. This is easily regulated by the height of the gas flame.

The churning is begun from the time the temperature of the mixture has reached 200°F, or when the steam as such passes off the mixture. It usually takes from 1 to 1½ minutes to reach this temperature, depending somewhat on the body or viscosity of the oil. However, even churning with steam for 15 minutes does not seem to make any difference in the results.

When the churning is completed, the cylinder is immersed for one hour in a water bath, kept at a temperature of 130°F. During this time the cylinder and its contents are momentarily inspected at intervals to note the behavior of the oil mixture. At the expiration of one hour the cylinder is removed from the water bath and the contents are examined for the following:

1. The number of cubic centimeters of separated clear or turbid water.
2. The number of cubic centimeters of separated emulsified layer.
3. The number of cubic centimeters of separated clear or turbid oil above the emulsified layer; and
4. The percentage of water or moisture in the separated oil above the emulsified layer.

The number of cubic centimeters and condition of the emulsified layer is an indication of the emulsion-forming property, or quality of the oil.

The number of cubic centimeters of clear or turbid oil above the emulsified layer, less the percentage of water or moisture contained in the oil, is the percentage of demulsibility of the oil.

The condition of the separated water or watery liquid under the emulsified layer, if any, gives an indication also of the behavior of the oil in actual service.

The amount of water held in the oil above the emulsified layer may be determined as follows:

The oil above the emulsified layer after the expiration of the test is carefully drawn off and shaken; then 20 cc. are mixed with 80 cc. of 88° Baume′ gasoline (from Pennsylvania Crude) in a graduated, flat-glass precipitating tube having the lower end drawn out. The oil-gasoline mixture is kept at a temperature not over 80°F for one hour, or the water or watery liquid may be separated from the oil-gasoline mixture by means of a centrifuge. The amount of water or watery liquid is read off and calculated to percentage by volume and subtracted from the oil above the emulsified layer. Of course, this determination is only necessary when the oil above the emulsified layer appears to contain an appreciable amount of water.

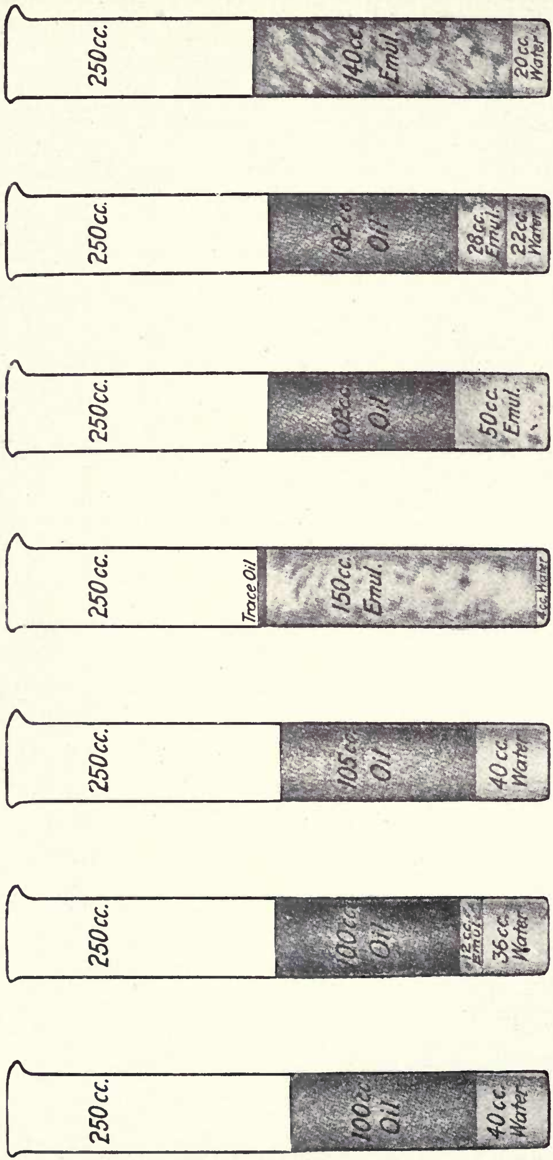
Interpretation of Results.

Page 328 illustrates the behavior of seven representative oils with this method, as they appear after expiration of the tests.

Table I gives detailed results of tests of these oils. The first turbine oil shows the oil entirely free from emulsifying property or elements, only retaining a very small percentage of moisture or water after the expiration of the test. The second turbine oil shows quite

TABLE I.—EMULSIFICATION TESTS OF LUBRICATING OILS.

Oil No.	Kind of oil	Separated water, etc.	Condition of Water	Emulsified layer, etc.	Kind of emulsion	Separated oil, etc.	Condition of oil	Moisture in oil %	Demulsibility %
1	Turbine	40	Clear	None	.....	100	Slightly turbid	0.2	99.8
2	Turbine	36	Slightly turbid	12	Light foamy	100	Turbid	1.0	99.0
3	Crank case	40	Clear	None	.....	105	Very turbid	5.0	95.0
4	Crank case	4	Clear	150	Heavy thick	Trace	Practically all emulsion	...	0.0
5	Engine	None	.....	50	Thick milky	102	Very turbid	4.0	96.0
6	Engine	22	Clear	28	Light foamy	102	Turbid	3.0	97.0
7	Spindle	20	Milky	140	Thick milky	None	All emulsion	...	0.0



Results of Emulsification Tests

a little of emulsified layer, but the condition of the emulsifier layer is light and foamy, not compact or creamy. The amount of water or moisture retained in the oil is much higher than in the first oil.

Consider next the two samples of crank-case oil: The first oil shows ready separation of water, which is clear and has no emulsified layer, but the oil after the test retains about 5 per cent of water. With the other crank-case oil only a very few cubic centimeters of water are separated at the expiration of the test, and a very large amount of emulsified layer of a heavy thick nature is shown; in fact the whole mixture is a heavy emulsion without separation.

The first sample of engine oil shows at the end of the test a thick milky emulsion with practically no separation of water, and the separated oil above the emulsified layer about 4 per cent of water. The second sample of engine oil shows considerable amount of separation of water and much smaller amount of emulsified layer; this layer is of a light foamy nature.

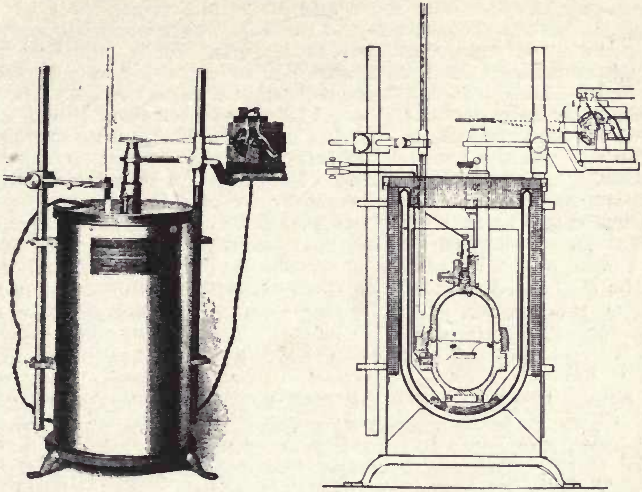
It should be particularly noticed in these two cases that while 100 cc. of oil were used in the tests, 102 cc. of separated turbid oil were found; deducting the amount of moisture or water found in the separated oil, 4 and 3 per cent, respectively, gives 96 and 97 per cent of demulsibility. This is a clear illustration of the importance of giving a complete statement in the report of the behavior of the oil or oils in the emulsifying test, as simply stating the percentage of demulsibility is clearly insufficient, and in cases of this kind would be seriously misleading.

14. HEATING VALUE OR CALORIFIC VALUE OF PETROLEUM PRODUCTS.

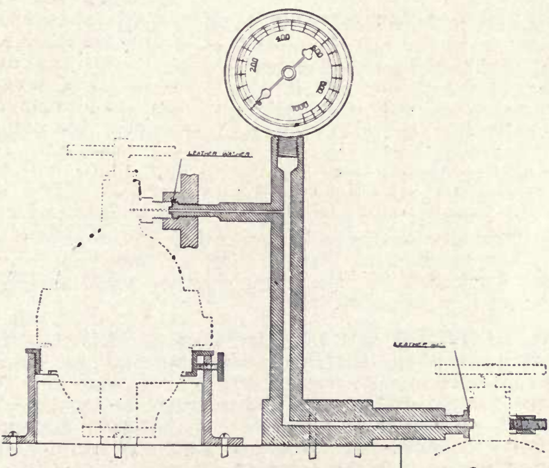
The apparatus used for the heating value, calorific value or British thermal units of petroleum products are shown on pages 331 and 334.

Any type of oxygen bomb calorimeter is satisfactory. Among these are the Atwater, Mahler, Parr and Kroeker bombs. The so-called Parr chemical calorimeter is not satisfactory either in operation or results when applied to oil. The description of the operation of one bomb calorimeter is typical of all.

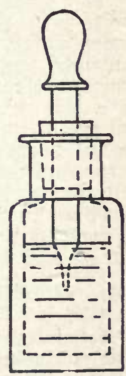
The lower half of the bomb is placed in the cast iron holder. About one gram of the oil is weighed to the nearest 0.0001 gram into the fuel pan and is placed in the bomb on the fuel pan holder. If the oil is volatile it is not advisable to pour the fuel directly into the fuel pan. For this purpose, small gelatine capsules weighing .1 gm. are used and may be filled with ignited asbestos and into this the light oil is discharged from a weighing pipet. The capsule is immediately closed leaving a minimum amount of air space. A similar capsule has been previously weighed and its calorific value determined. A stock of standardized capsules should be kept on hand in an air tight receptacle. The platinum fuse wire is cut equal in length to the taper pin wrench which is connected to the terminal being careful that it does not touch the pan. The wire is bent down so that it is covered by the oil or by the lips of the capsule. The upper half of the bomb is carefully fitted on the lead gasket to the lower half. The nut is screwed down over the upper half being careful not to cross the threads. The bomb nut is now tightened by the use of the long wrench, being careful to cause no sudden jerking or vibrating which will throw the oil from the pan. The bomb is now carefully lifted out and placed on the swivel table and connected with the oxygen piping. The valve in the top of the bomb is opened about one turn and the valve in the oxygen cylinder is carefully and slowly opened so that the pressure in the bomb as shown by the indicator rises to 300 pounds. The bomb valve is now closed and the oxygen cylinder valve is closed. Exactly 1900 grams of water at a temperature of about 4° below room temperature is weighed into the calorimeter water bucket. This is placed in the calorimeter container. The bomb is connected with the electric wire and is introduced into the water being careful to place it in the center of the bucket. Two 100 watt lamps placed in parallel are in series with the fuse wire when a 110 volt circuit is used for firing. The stirring motor is placed in series with a 60 watt lamp on a 110 volt circuit. The cover is put on, the connections to the bomb wire are made and the stirrer is introduced as far down as it will go. It should not touch the bomb. The thermometer is introduced and stirring is continued for about 5 minutes. The temperature is read and the stirring continued for exactly 5 minutes and the temperature is again read and the charge is fired by quickly throwing in the switch and withdrawing it. The stirring is continued for 5 minutes, the temperature being read at minute intervals or at the end of 5 minutes unless extreme accuracy is required. The stirrer is then run for an additional 5 minutes and the temperature is again read. The thermometer is corrected in accordance with the corrections furnished by the Bureau of Standards. The radiation corrections may be applied to each one minute interval



Calorimeter Equipped With Vacuum Walled Jacket



Oxygen Connection



Weighing Bottle
for Liquid Fuels, etc

but for ordinary purposes 1/5 of the radiation for the 5 minute period before firing is applied on the 5 minute period immediately after firing and 4/5 of the radiation in the third 5 minute period is applied on the 5 minute period immediately after firing. The calorimeter constant (usually about 2400) is determined by a blank test using exactly 1 gram of benzoic acid. This constant always remains the same with the same calorimeter but must be determined each time a change is made in the calorimeter. In the case of oil in which it has been necessary to use the capsule the correction made must be applied for the calorific value of the capsule. This is most conveniently applied to the corrected net rise in temperature of the thermometer. To convert British thermal units per pound to calories per gram, multiply by 5/9. To obtain the water evaporative power, multiply the B. T. U. per pound by 1.035. To obtain the B. T. U. per gallon, multiply the B. T. U. per pound by the weight per gallon.

An approximation of the heating value of fuel oil can be obtained by the following formula:

B. T. U. in lbs. per gallon = 18700 + 40 (°Be′—10).

15-A. SULPHUR FROM THE BOMB CALORIMETER.

The calorimeter is opened by gradually allowing the pressure to diminish and the bomb is carefully and thoroughly washed out with distilled water. The pan is placed in the beaker with the washings and about 10 cc. of hydrochloric acid is added. The contents of the beaker are treated with bromine, heated to boiling temperature for about 10 minutes, filtered and washed and the sulphur in the filtrate precipitated with 10 cc. of barium chloride solution. The precipitated barium sulphate is filtered, washed and weighed in the usual manner. The weight of the barium sulphate × 13.733 and divided by the weight of the sample gives the percentage of sulphur in the oil.

15-B. SULPHUR BY THE ESCHKA METHOD.

This method is not good for oils, in most instances giving a low result, but may be used where accuracy is not necessary. Weigh out approximately 1 gram of the oil and mix it with 2.5 grams of sodium carbonate and 5 grams of calcined magnesia in a platinum dish or crucible. Heat gradually increasing the temperature until the mass has a low red color and the mixture on cooling has a grayish tint. Cool and wash into a 500 cc. beaker with distilled water and add about 1 cc. of bromine. Mix until the bromine is thoroughly dissolved and allow some time for the bromine to react. Now add hydrochloric acid until the reaction is decidedly acid, the beaker being covered in the meantime to prevent any mechanical loss. Filter off and wash any undissolved residue. Precipitate in the usual manner with barium chloride and weigh as barium sulphate.

15-C. SULPHUR WITH THE PARR CHEMICAL CALORIMETER.

Weigh 0.25 — 0.40 gram of the oil from a weighing pipet into the Parr chemical bomb container along with a mixture of 1 gram of 100 mesh potassium chlorate and 1 full measure, using the cup furnished with the instrument, of pure sodium peroxide. Add 0.2500 gm. of sulphur free lampblack. Immediately close and lock the bomb and be sure that the spring in the plunger valve is strong. Shake thoroughly until the lampblack, the oil, the potassium chlorate and the sodium peroxide are thoroughly mixed. Place the bomb in the calorimeter with the stirring wings adjusted on it and add 2000 cc. of water.

Put the cover on the calorimeter and introduce the thermometer and stir. Heat a hot wire slug about ¼-inch long and when red, quickly introduce into the stem of the calorimeter. As quickly as possible with a quick thrust of the plunger allow it to fall into the bomb. Stir until the temperature ceases to rise. Remove the bomb, open it and place it in a beaker. Pour boiling hot water into it until effervescence ceases. Rinse off the bomb into the beaker and remove the wire. Add hydrochloric acid until acid in reaction.

Filter, wash and to the filtrate add barium chloride. Boil a few minutes, allow to stand hot at least 15 minutes or until the supernatent liquid is clear, filter off the barium sulphate and weigh it in the usual manner. The barium sulphate $\times$ 13.73 divided by the weight of the oil taken is the percentage of sulphur.

16-A. CARBON AND HYDROGEN IN PETROLEUM PRODUCTS.

The most convenient method is to burn the oil in a special calorimeter bomb of the type of the Kroeker (see page 334).

The bomb must be perfectly dried on the inside by drawing dry air through the apparatus.

Approximately one gram of oil is now burned exactly as in the determination of heat of combustion (which see).

The bomb is taken from the calorimeter and is connected on the tube side with Drechsel bottles containing moist soda lime in the first bottle and calcium chloride in the second bottle. The outlet of the bomb is now connected in series with a U tube containing granulated zinc to decompose any acid formed in the combustion, with a glass stoppered U tube filled with calcium chloride of about 10 mesh size, with a glass stoppered U tube filled in the first arm with soda lime containing 10% water and the upper part of the second arm with calcium chloride connected then with an aspirator bottle.

The outlet of the bomb is gradually opened so that at least 10 minutes is required to release all of the pressure.

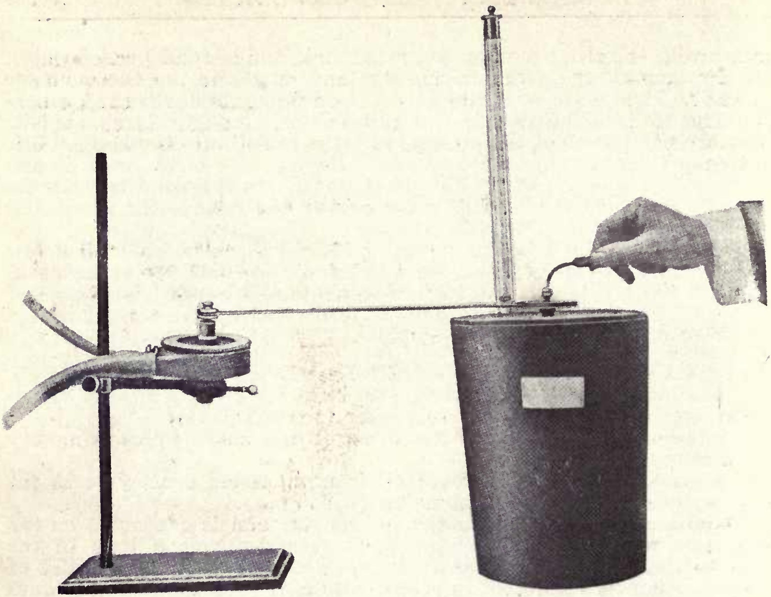
The bomb is now heated and the aspirator is run at such a rate that about five gallons of air are drawn through the bomb during a period of between one and two hours. The carbon is calculated from the increase in weight of the soda lime U tube and the hydrogren is calculated from the increase in weight of the calcium chloride U tube.

$$\frac{CO_2 \times 27.273}{\text{weight of sample}} = \%\ \text{carbon}$$

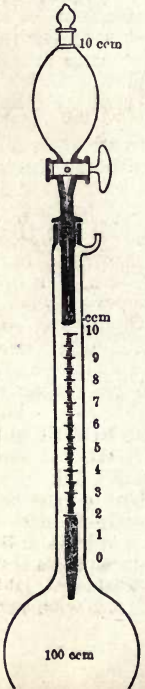
$$\frac{H_2O \times 11.190}{\text{weight of sample}} = \%\ \text{hydrogen}$$

16-B. DETERMINATION OF NITROGEN IN PETROLEUM OR ASPHALT. BY THE KJELDAHL METHOD.

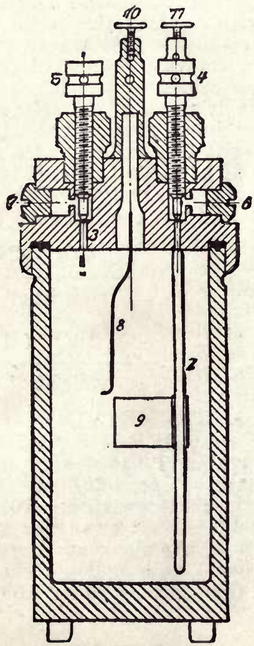
5 grams of the sample are weighed into a pyrex Kjedahl digesting flask. 50 cc. of the digestion mixture composed of concentrated sulphuric acid containing 20% of phosphorous pentoxide is added to the flask. About one-third gram of mercuric oxide is added and the contents of the flask are heated with a strong flame until the solution has become pale yellow or colorless. The digested material is now cooled, diluted with about 150 cc. of water and neutralized with strong



Parr Apparatus for Sulphur



Flask for Aromatics



Kroeker Bomb

caustic soda solution. Zinc shavings and some Potassium sulphide are added. The flask is quickly connected with the condenser tube and the ammonia is distilled off into a 25 cc. of N/10 sulphuric acid. The excess of acid is titrated with N/10 alkali. Each cubic centimeter of sulphuric acid consumed is equivalent to .001404 gram of nitrogen.

17. DOCTOR TEST FOR GASOLINE.

Reagent.

Sodium plumbite or "doctor" solution—Dissolve 125 grams of sodium hydroxide (NaOH) in a liter of distilled water. Add 70 grams of litharge (PbO) and shake vigorously for 15 or 30 minutes or let stand with occasional shaking for at least a day. Allow to settle and decant 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.

Test.

Shake vigorously for about 15 seconds two volumes of gasoline and one volume of the "doctor" solution. Note color. A small pinch of flowers of sulphur should be added and the tube again shaken for 15 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.

Interpretation.

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."

18-A. OLEFINS OR UNSATURATED HYDROCARBONS AND REFINING LOSS IN PETROLEUM PRODUCTS.

Use apparatus and equipment as shown on page 337.

Method using a Babcock cream bottle.

Weigh up a clean and dry 30% Babcock cream bottle, add to it exactly 5 cc. of the oil to be tested. Weigh again giving the amount of oil used. Cool in ice water and add 10 cc. of concentrated commercial sulphuric acid, letting the acid run down the sides of the bottle. Shake while cooling in the ice water. Keep stoppered with a rubber stopper. Let stand for ½ hour with occasional shaking and constant cooling. Add sufficient concentrated sulphuric acid (commercial) to bring the reading about to the top of the scale on the neck of the bottle. Centrifuge for five minutes in the No. 1 centrifuge with the resistance at the first notch from the left. This gives a speed of 1000 R. P. M. Keep the rubber stopper in while centrifuging so that there will be no evaporation. The stopper shall be large enough so that it is not forced into the bottle.

The reading on the neck of the bottle divided by 5 is the net amount of saturated hydrocarbons contained. This multiplied by 20 and take from 100 gives the per cent of unsaturated hydrocarbons. For great accuracy the oil may be corrected for specific gravity and temperature and for the amount adhering to the sides of the pipet in which case the weighings are used. The waste acid from the Babcock bottle is poured into a bottle from which the sulphuric acid may be recovered by separating the oil and oxidising the organic material in the acid.

18-B. METHOD USING A 10 CC. GLASS STOPPERED CYLINDER. (Egloff.)

Use apparatus and equipment as shown on page 337.

Add exactly 5 cc. of the oil to be tested to the cylinder and 2 cc. of sulphuric acid of gravity 1.84. Shake thoroughly for about 5 minutes and place in centrifuge and centrifuge at the rate of 1000 R. P. M. for 5 minutes. The shrinkage of the oil in cubic centimeters $\times$ 20 is the percentage of olefins.

18-C. REFINING LOSS OF PETROLEUM PRODUCTS.

Use the color tube as shown on page 281.

To a 50 cc. color tube that is graduated in .1 cc. and glass stoppered, add 45.0 cc. of the oil. Add exactly 1 cc. of 66° Baume' sulphuric acid. Shake thoroughly for about 5 minutes. Set vertically in a rack for at least one hour and preferably over night. The increase in volume of the acid in the bottom of the tube x 2-2/9 is the refining loss.

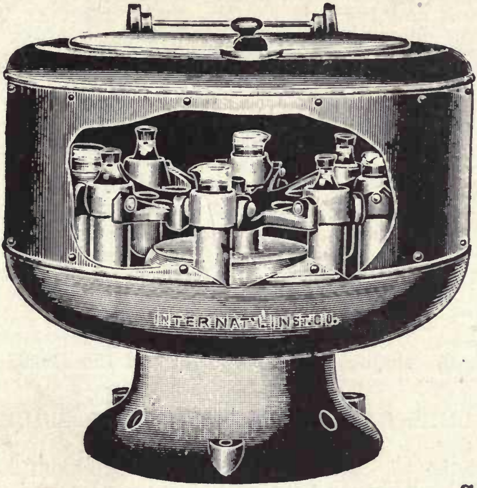
19-A. METHOD FOR DETERMINING AROMATIC AND PARAFFIN HYDROCARBONS IN PETROLEUM PRODUCTS.

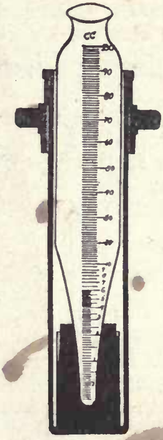
The apparatus is shown in the figure on page 334. The flask containing 30 cc. of fuming nitric acid (specific gravity 1.52) is cooled to —10°C by a salt ice freezing mixture. The separatory funnel is filled to the 10 cc. mark with the oil under test. The oil is ru[n] drop by drop with continuous shaking into the cooled acid during [a] period of not less than 45 minutes. With uncracked petroleu[m] products 15 minutes is sufficient. The mixture is allowed to stan[d] 15 minutes after completion of the reaction and then enough nitri[c] acid (ordinary concentrated) at —10° temperature is added to the contents of the flask until the oil under the surface is brought into the graduated neck. The volume is read when the neck is at room temperature, the body of the flask being in the freezing mixture. This volume represents the paraffin hydrocarbons.

The mixture is transferred to a separatory funnel, the lower layer run off into a 500 cc. measuring flask containing 150 cc. of water. The neck should be graduated for a 10 cc. portion into 1/10th cc. The temperature will rise in proportion to the amount of olefins and aromatics present and more or less oil will separate according to the amount of paraffin hydrocarbons present.

The unattacked oily layer in the separatory funnel is washed with water and then examined for specific gravity and boiling point. The aqueous layer of nitric acid is warmed for 15 minutes to dissolve as completely as possible the resinous substances formed. The cooled liquid is shaken with 100 cc. of ether, the aqueous layer separated and the ether layer again washed free from acid with water, then with a solution of caustic potash containing 50 grams of KCH in 500 cc. of water with 50 cc. of alcohol.

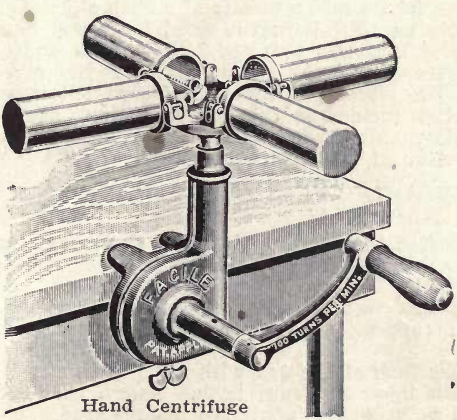
The caustic potash is drawn off and again the ether layer is washed with water. It is now dried with calcium chloride, filtered, the ether evaporated and the residue weighed. The residue consists of reddish brown oil, aromatic nitro-derivatives. The weight divided by 1.15 gives the percentage of aromatic hydrocarbons.



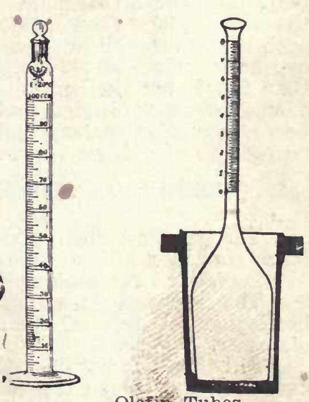


Good type of electric centrifuge.

Centrifuge tube for water and "B.S or sediment.



Hand Centrifuge



Olefin Tubes

The difference between the aromatic and cyclic hydrocarbons and the paraffin hydrocarbons and 100% is the amount of olefins. This may be checked by direct determination as shown under olefins.

19-B. SHORT METHOD FOR AROMATIC AND CYCLIC HYDROCARBONS.

Distillation of 800 cc. of the hydrocarbons under examination may be made in a 1 liter distilling flask in accordance with the apparatus set forth on page 310. Cuts may be made at 95°, 120° and 150°C and the percentage of aromatic compounds calculated from the specific gravity using the following specific gravities as the basis:

Temperature of Cut	Specific Gravity of Aromatic Hydrocarbon	Specific Gravity of Non-Aromatic Hydrocarbon
95°C	0.880	0.720
120°C	0.871	0.730
150°C	0.869	0.760

This is in accordance with the Bulletin No. 114 of the Bureau of Mines, page 95.

20. FREE ACID IN LUBRICATING AND OTHER PETROLEUM OILS.

Weigh 10 grams of the oil into an Erlenmeyer flask. Add 50 cc. of 95% denatured alcohol which has been previously neutralized with dilute caustic soda. Heat over a gauze to the boiling point. Shake thoroughly to dissolve the acid. Titrate while hot with N/10 caustic soda using phenolphthalein as indicator shaking thoroughly after each addition of NaOH, continuing to the first persistent pink color. Express results in terms of oleic acid. 1 cc. of N/10 NaOH = 0.0292 gm. of oleic acid.

21. FLOC 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.

22. CORROSION AND GUMMING TEST OF GASOLINE AND NAPHTHA.

The gasoline when subjected to the corrosion test shall show no 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 within ⅜ths 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 blackened.

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.

23. PENETRATION OF PETROLEUM ASPHALTS AND OTHER BITUMINOUS MATERIALS.

The apparatus used for this test is that shown on page 340.

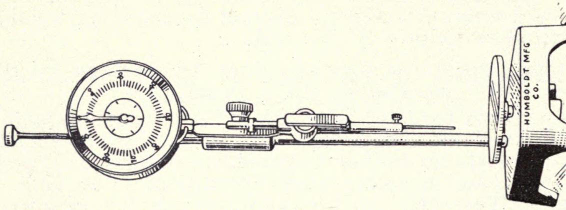
The penetration is the consistency of a bituminous material expressed as the distance that a standard needle vertically penetrates a sample of the material under known conditions of loading, time and temperature. When the conditions of test are not specifically mentioned the load, time and temperature are understood to be 100 grams, 5 seconds, 25°C (77°F) respectively and the units of penetration indicate hundredths of a centimeter. The container for holding the material to be tested should be a flat bottomed cylindrical dish 2 3/16 inches in diameter and 1⅜ inches deep or the American Can Co. Gill style ointment box, deep pattern, 3 ounce capacity.

The needle is a cylindrical steel rod 2 inches long and with a diameter of 0.04 inch and turned on one end to a sharp point having a taper of ¼-inch. The bath for the sample and the penetrometer should hold at least 10 liters of water. The sample should be melted at the lowest possible temperature and stirred until it is homogeneous and free from air bubbles. It is then poured into the sample container to a depth of about ¾-inch and is allowed to cool for one hour in the air. It is now placed in the water bath maintained within 0.1°C of the temperature of penetration for one hour.

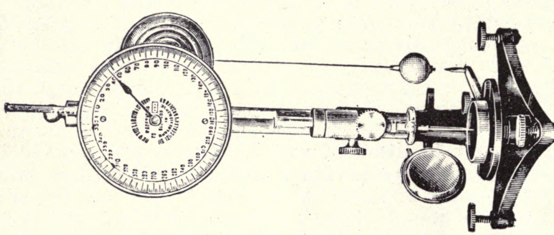
In making the test, the sample is immersed in water and the needle loaded with the specified weight is adjusted to make contact with the surface of the sample. This may be accomplished by making contact of the actual needle point with its image reflected by the surface of the sample or contact may be meted by slightly turning the container so that a faint scratch on the surface of the bitumen is observed. The needle is then released for the specified time and the distance measured by the means provided with the machine. At least three tests shall be made at different points on the surface of the sample and after each test the needle shall be wiped clean of all bituminous matter. The reported penetration is the average of at least three tests whose values do not differ more than four points between the maximum and minimum. Other conditions for penetrations particularly for oil asphalt filler and roofing material shall be the following:

At 0°C (32°F) 200 grams weight 60 seconds.

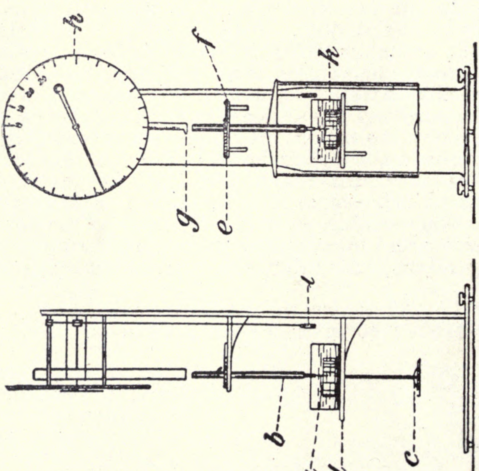
At 46.1°C (115°F) 50 gram weight 5 seconds.



Humboldt Penetrometer



N. Y. T. L. Penetrometer



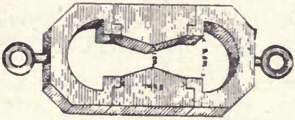
—Dow Penetration Machine.

24. DUCTILITY OF SEMI-SOLID BITUMINOUS MATERIALS.

The apparatus used for this test is shown on page 342.

It consists of a machine for uniformly pulling a cylinder or briquet of the asphaltic cement at a slow rate of speed until it breaks. Two types of molds for the sample are used, one is a square mold having a cross section of 1 sq. cm. at its narrowest point, the other is a round mold separated by a cylindrical section of 1 cm. diameter. Either mold is used on the same machine.

The asphalt is carefully melted as in the penetration test and the mold is completely filled so that it bulges at the top enough to allow for shrinkage. The brass is amalgamated with mercury to prevent sticking. The temperature at which the test is made should correspond to that temperature at which the sample being tested has a penetration of 50°. The rate of pulling may be either the slow rate of 5 cm. per minute or the fast rate of 60 cm. per minute, the machine being adapted for either speed. The pulling is continued until the thread of asphalt breaks. The distance that it has been drawn out without breaking, expressed in centimeters is the ductility. By the square mold ductility a result is obtained which is about 3½ times that of the round ductility.



Square Ductility Mold

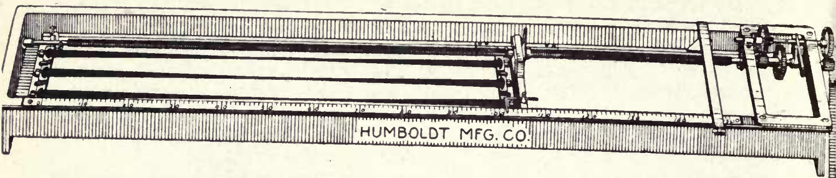
25. LOSS ON HEATING OF OIL AND ASPHALTIC COMPOUNDS.

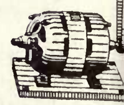
The loss in weight by oil and asphaltic compounds when they are heated in an oven at a temperature of 163°C (325°F) is determined on 50 grams of the water free substance contained in a flat bottomed dish, the inside dimensions of which are approximately 2 3/16 inches in diameter and 1⅜ inches deep (this is the 3 ounce Gill style ointment box, deep pattern).

The oven in which the substance is to be heated is brought to temperature before the sample is introduced and the temperature of the sample under test shall be regarded as that of a similar quantity of the same material immediately adjoining it in the oven in which the bulb of a standardized thermometer is immersed. The oven may be any well constructed type either circular or rectangular and the source of heat may be either gas or electricity. The samples under test rest in the same relative position in a single row upon a perforated shelf 9.75 inches in diameter as shown on page 343. A good type of oven is also shown on same page. The shelf is suspended by a vertical shaft midway in the oven which is revolved by mechanical means at the rate of from 5 to 6 R. P. M.

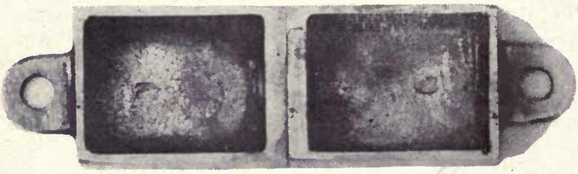
26. ASPHALT IN OIL AND ASPHALTIC COMPOUNDS.

50 grams of the crude oil, fuel oil, lubricating oil, road oil or other material are weighed into a 3 ounce Gill style ointment box, deep pattern, and placed in an oven heated either by electricity or gas and with good circulation to a temperature of approximately 500°F. Heat is maintained until the consistency of the residue is such that at a temperature of 77°F it has a penetration of 100. The amount of asphalt is reported in terms of the 100° penetration material.





Ductility Machine



Round Ductility Mold

27-A. ASPHALTENES IN OIL AND ASPHALTIC PRODUCTS (SOLUBILITY IN PETROLEUM NAPHTHA).

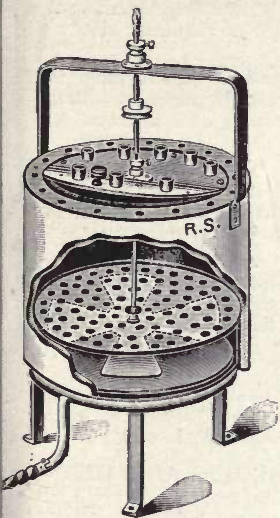
Weigh up one gram of the oil or asphaltic material into a 150 cc. Erlenmeyer flask. Add exactly 100 cc. of paraffin base petroleum naphtha of a gravity of 38°Be′. Shake until the material is well disintegrated and allow to stand for at least 5 hours and preferably over night, the flask being tightly corked. Prepare a Gooch crucible having a uniform layer of asbestos fiber in the bottom about ⅛-inch thick. Dry and ignite the prepared crucible. Place the crucible in a vacuum filter as shown in the figure on page 346 and pour the petroleum naphtha solution of the material through it. Drain the Erlenmeyer flask as thoroughly as possible and rinse out with 100 cc. of 88°Be′ petroleum naphtha so that the last of the naphtha is not stained with the bituminous material. Care must be taken to prevent undue disturbance of the asbestos mat. Draw air through the residue on the Gooch crucible for a minute with a suction pump and place it in the drying oven at 105°C for ½ hour. Weigh, ignite and weigh again. The difference between the two weighings is the asphaltene. This taken from the original may also be recorded as the solubility in petroleum ether.

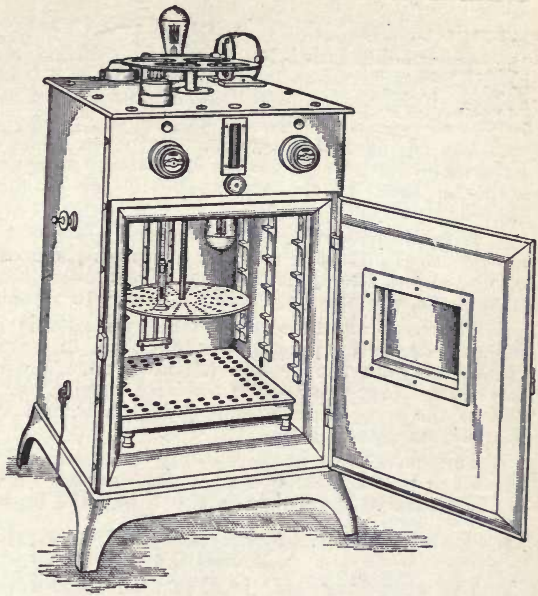
27-B. SOLUBILITY IN CARBON BISULPHIDE. (TOTAL BITUMEN.)

This test is performed in the same way as for asphaltenes or solubility in petroleum naphtha except that a 5-gram sample is preferably used. The same apparatus is used.

27-C.—SOLUBILITY IN CARBON TETRACHLORIDE.

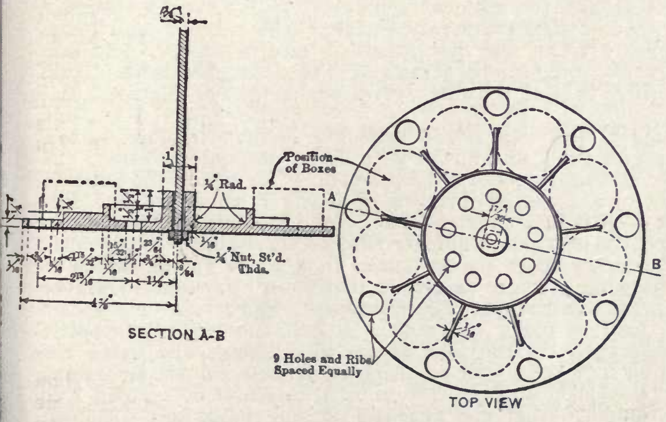
This test is performed in exactly the same manner as with carbon bisulphide except that the flask containing the carbon tetrachloride must be kept in a dark place. The difference between the solubility in carbon bisulphide and carbon tetrachloride represents the CARBENES.





Gas oven Electric oven

Ovens for determination of loss on heating at 325°F.



Detail of shelf used in loss test.

28. RESISTANCE OF ASPHALTIC CEMENT TO OXIDATION.

After being subjected to the following tests the film of asphalt should be brilliant and lustrous, should not be scaly and fragile, should adhere firmly to the metal and should not be dull and cheesy in texture.

A strip of thin sheet iron 2 inches wide and 6 inches long is covered on its lower 4 inches with the melted asphaltic cement. This strip is placed in an oven at 275°F for 15 minutes and allowed to thoroughly drain.

It is removed from the oven and allowed to cool, then placed in an electrically heated oven at a temperature of 450°F for one hour. At the end of the hour, the door of the oven is opened and the heat is turned off, the specimen being allowed to remain in the oven.

The oven shall be one having an outside diameter of 12x12x12 inches with an opening in the top 1 cm. in diameter, the heating elements being in the bottom of the oven. The resistance shall be so distributed that the heat is uniform throughout the oven. The lower end of the strip shall be suspended so that it is at least 3 cm. from the bottom of the oven.

The resistance is preferably so arranged that three different heats can be maintained with a snap switch such that the lowest heat is 325°F, the medium heat is 400°F and the highest heat is 450°F.

29. PARAFFIN WAX OR SCALE IN PETROLEUM AND BITUMINOUS PRODUCTS.

The apparatus used is shown on page 347.

Instead of the metal retort, a glass distilling flask with a glass air condenser may be used if desired. 100 grams of the oil, bitumen or material under examination are weighed into the retort and distilled as rapidly as possible to dry coke. The distillate is caught in a 150 cc. Erlenmeyer flask, the weight of which has been previously ascertained. During the early stages of distillation a cold, damp towel wrapped around the stem of the retort will serve to condense the distillate. After high temperatures have been reached, this towel may be removed. When the distillation is completed, the distillate is allowed to cool to room temperature and is then weighed in the flask. This weight minus that of the flask gives the weight of the total distillate.

Five grams of the well mixed distillate is then weighed into a 100 cc. Erlenmeyer flask and mixed with 25 cc. of Squibb's ether. 25 cc. of Squibb's absolute alcohol is then added, after which the flask is packed closely in a freezing mixture of finely crushed ice and salt maintained at —18°C in a quart tin cup. After remaining 30 minutes in this mixture, the solution is quickly filtered through a No. 575 C. S. & S. 9 cm. hardened filter paper placed in a glass funnel which is packed in a freezing mixture as shown in figure. Vacuum should be employed to hasten filtration. The freezing-mixture reservoir shown in the figure may be made by cutting in half a round glass bottle measuring approximately 120 millimeters in diameter and using the upper half in an inverted position. Any precipitate remaining on the paper should be washed until free from oil with about 50 cc. of a 1 to 1 mixture of Squibb's ether and absolute alcohol cooled to —18°C.

After the paper has been sucked dry, it should be removed from the funnel and the adhering paraffin scale should be scraped off into a weighed crystallizing dish and dried on a steam bath. The dish and contents should then be cooled in a dessicator and weighed.

The weight of the paraffin scale so obtained, divided by the weight of the distillate taken and multiplied by the percentage of the total distillate obtained from the original sample, equals the percentage of the paraffin scale.

30-A. BITUMEN AND GRADING OF ASPHALT SURFACE MIXTURE.

The asphaltic surface is softened by warming and is thoroughly mixed. 100.0 grams are weighed into a thin porcelain dish. This is placed in a gas or electric muffle, as shown on page 348, and heated with good aeration at a temperature not exceeding 700°C, preferably about 500°C, or at a barely perceptible red heat.

It is well to use a pyrometer in the muffle. Usually about two hours is required for the complete combustion of the carbonaceous material. The dish and contents are now removed from the muffle, allowed to cool and weighed. The loss in weight is the percentage of bitumen. The mineral matter is now screened through a nest of screens containing the 1, 2, 4, 10, 20, 40, 80, 200 meshes to the lineal inch. The amount passing each screen and retained on the next is recorded. The exact description of the sizes is as follows:

Mesh	Opening in Inches	Opening in Millimeters	Diameter of Wire, Inch
1	1.050	26.67	0.149
2	0.525	13.33	0.105
4	0.1850	4.699	0.065
10	0.0650	1.651	0.035
20	0.0340	0.864	0.016
40	0.0150	0.381	0.010
80	0.0068	0.173	0.00575
200	0.0029	0.074	0.0021

30-B. BITUMEN AND GRADING OF ASPHALTIC SURFACE MIXTURE BY EXTRACTION.

The bituminous mixture should be warmed until it may be readily broken apart by hand, without fracturing any of the stony particles.

Five hundred grams of the disintegrated mixture should be packed as tightly as possible in the wire basket and then covered with a disc of cotton or felt of one-quarter inch to one-half inch thickness.

One hundred and seventy-five to two hundred cc. of carbon disulphide, carbon tetrachloride, chloroform, or benzole is placed in the inside vessel in which the wire basket is suspended.

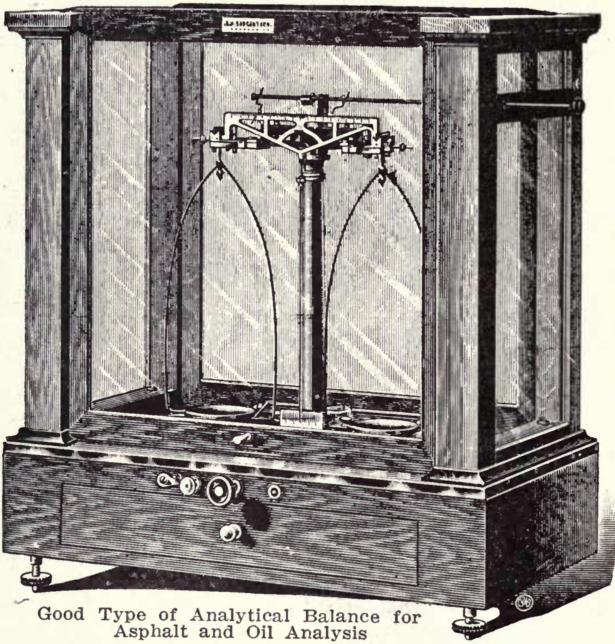
Cool water should be circulated through the inverted cone condenser, which is also the cover of the apparatus, and is not intended to fit tight.

A 16 c. p. carbon filament incandescent lamp is the source of heat.

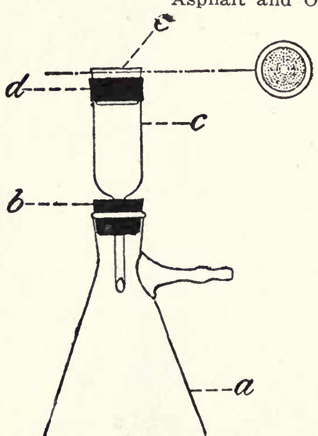
A 500-gram sample of mixture should extract clean with carbon disulphide in about three hours. From 200 to 300 grams of asphalt block or Topeka type mixture is a sufficiently large sample for that type of mixture.

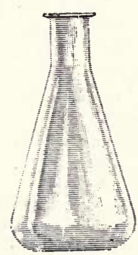
After extraction, the solvent and matter removed from the sample during the analysis should be burnt to recover any fine mineral particles which may have passed into the extract.

This method has the advantage of giving the true soluble bitumen and of leaving the mineral matter in such condition that it is more easily screened. However, it has the disadvantage of requiring a longer time, a considerable amount of solvent and of giving slightly higher results in percentage of bitumen unless the extracted matter is burned out. Extraction may also be made by the Rotarex centrifuge.



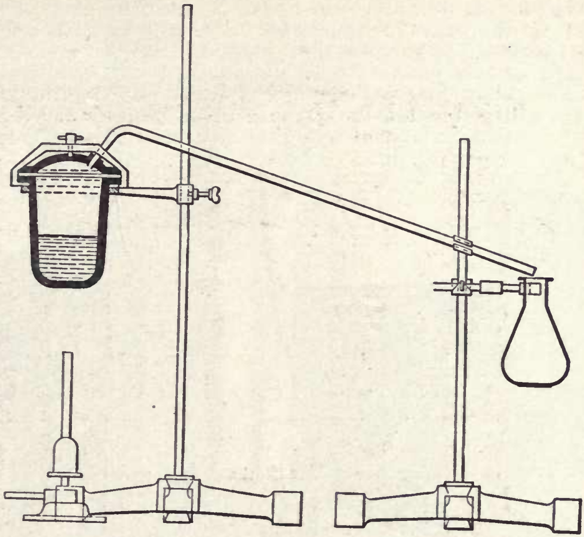
Good Type of Analytical Balance for Asphalt and Oil Analysis



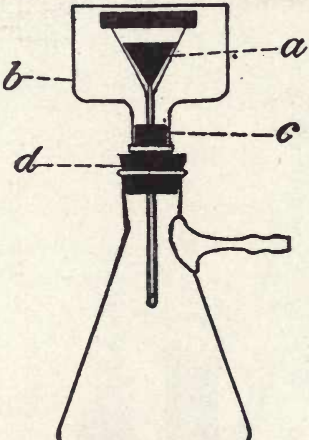


Erlenmeyer Flask

Suction Flask For Solubility Tests



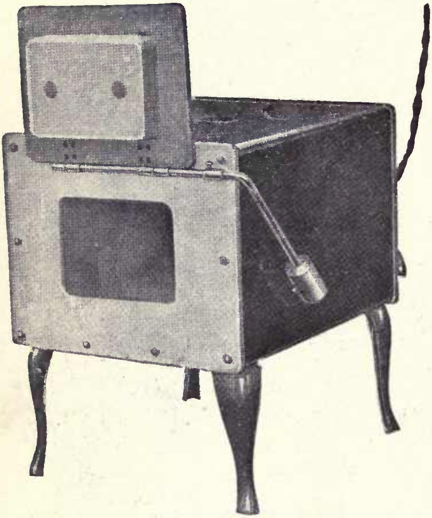
Paraffin Scale Distillation



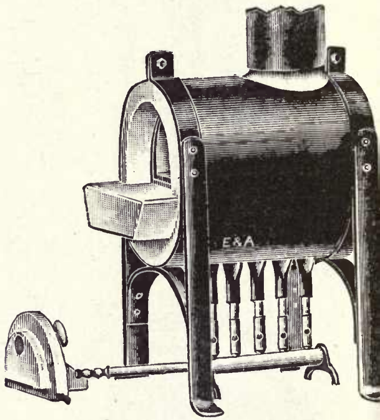
Paraffin Filter Flask

31. TENSILE STRENGTH OF BITUMINOUS SURFACE MIXTURE.

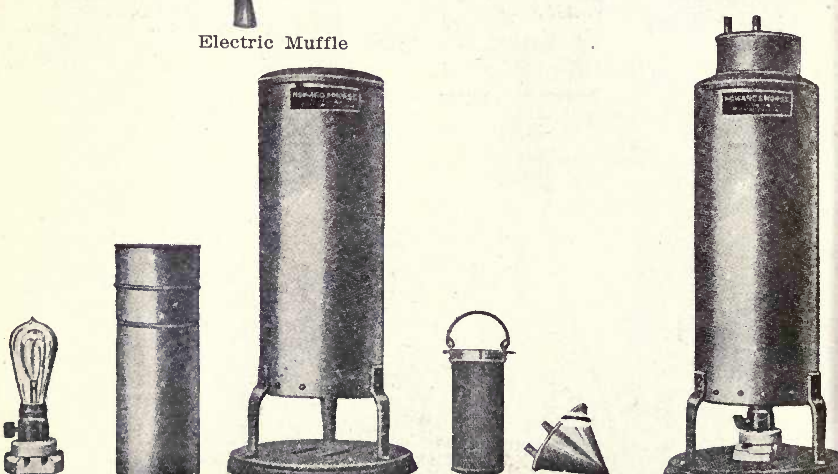
The surface mixture to be tested is heated to over 240°F to soften it and is thoroughly compressed into a standard cement testing briquet mold. The mold is then packed in ice for at least two hours. It is now quickly put in the tensile strength machine used for testing portland cement and pulled until it fails. Good bituminous surface mixture will give a tensile strength of as high as 600 lbs. per sq. in. Poorly cemented material will give a tensile strength usually lower than 200 lb. per sq. in.



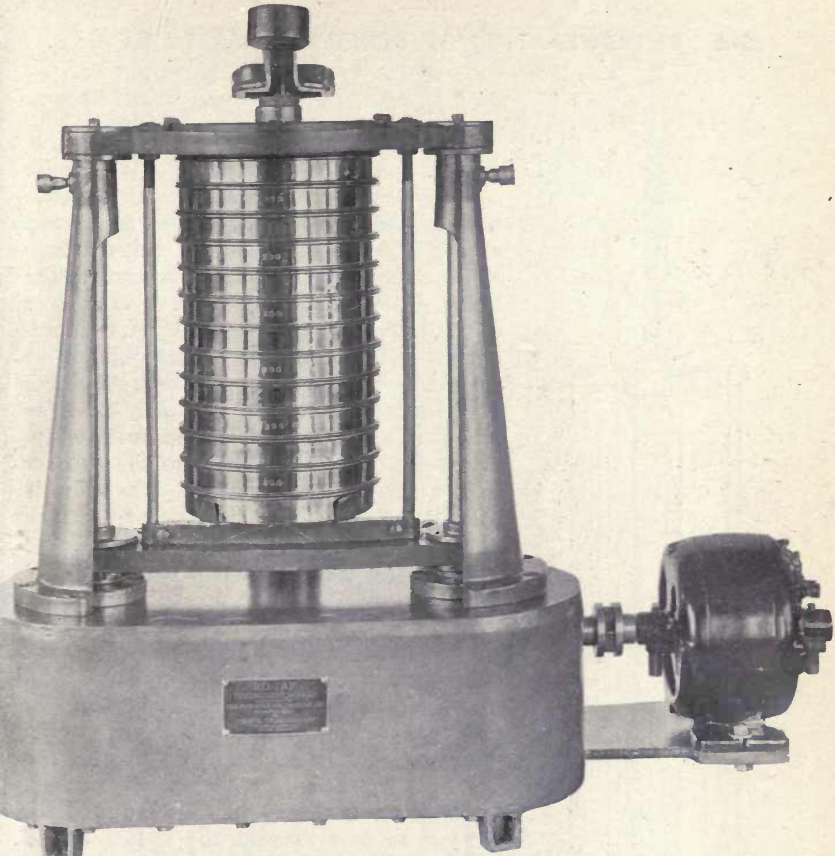
Electric Muffle



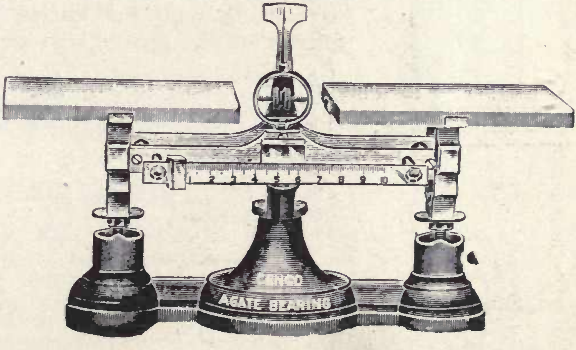
Gas Muffle



N. Y. T. L. Surface Mix Extractor.

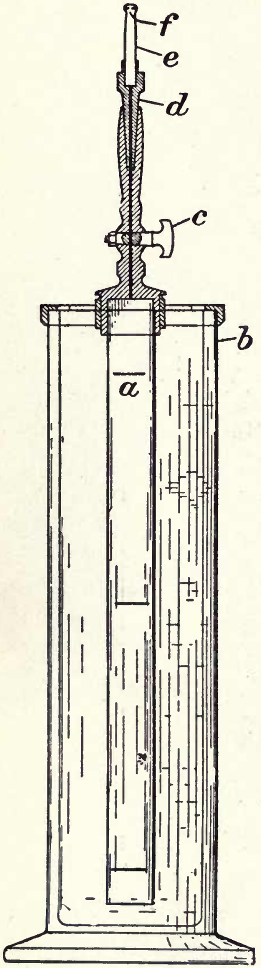


Surface Mix Sieve Shaker



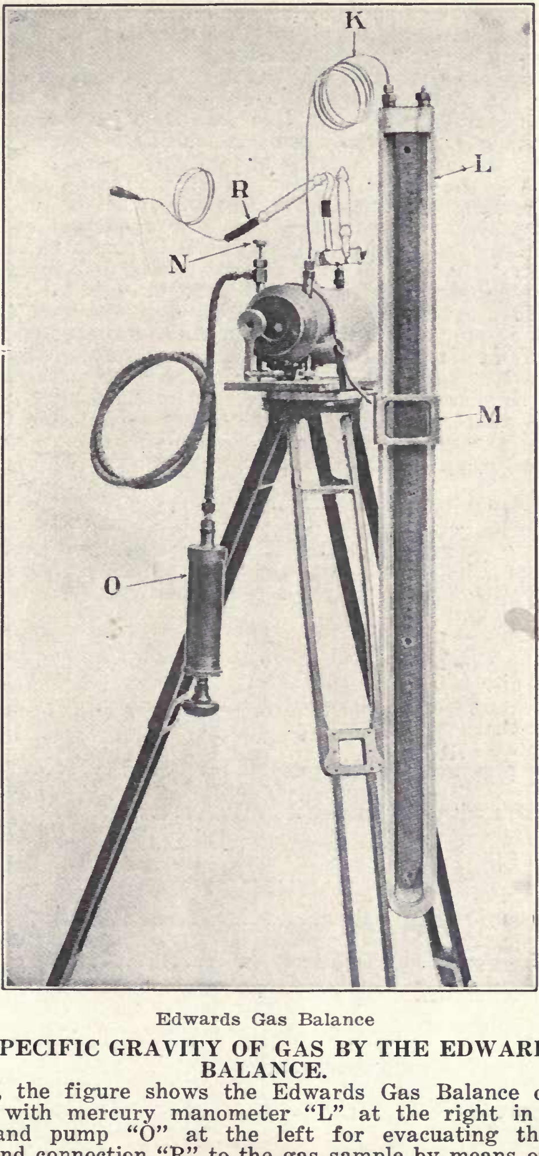
Mineral Aggregate Grading Balance

32-A. DETERMINATION OF SPECIFIC GRAVITY OF GAS.



The apparatus consists of a glass jar, b, with a metal top into which fits a brass column having suspended from its base a long, graduated tube, a, and at its top a cock, c, and a ground-joint socket d, into which sets a socket holding a small glass tip, e, closed at the top with a thin piece of platinum, f. In this platinum is a minute hole to permit the passage of gas or air at a very slow rate. All the metal parts are nickeled. The mode of operation is as follows: The glass jar is filled with water to the top graduation mark of the tube or to a point a little above it. The tube is then withdrawn so that it may be filled with air. The cock on the standard is then closed and the tube is replaced with air. The cock is then opened, and the number of seconds required for the water to pass from the lowest graduation mark to the graduation mark above it is recorded with a stop watch. The tube is then withdrawn and filled with gas and the procedure repeated. The specific gravity (air=1) is obtained by dividing the gas time squared by the air time squared. Thus, if A represents the time required for the gas to pass through the orifice, and B represents the time required for the air to pass through the orifice, the specific gravity of the gas will be represented by

$$\left\{\frac{A}{B}\right\}^2$$



Edwards Gas Balance

32-B. SPECIFIC GRAVITY OF GAS BY THE EDWARDS GAS BALANCE.

Above, the figure shows the Edwards Gas Balance completely assembled with mercury manometer "L" at the right in the foreground, hand pump "O" at the left for evacuating the balance chamber, and connection "R" to the gas sample by means of the stop cock on the back end of the balance chamber. On page 353 is shown the balance beam consisting of an air tight bulb of spun brass, counter-weighted with adjustable balancing weights. The bearing points are also adjustable, allowing the center of gravity of the beam to be raised or lowered, thus providing a control of the sensibility. The needle points rest on glass bearings.

The beam is adjusted so that it will come to equilibrium in atmosphere with the counter-weight end slightly below a horizontal plane through the bearing points. In this position a partial vacuum is required to bring it to a level position which position is effected by bringing into alignment the cross hair mounted permanently on glass and the line on the end of the balance beam. The air that is allowed into the chamber when making this balance must be drawn through some drying agent assuring dry air. The vacuum reading is then observed on the "U" gauge. This should be repeated and checked. The balancing chamber is then purged of air and the gas allowed to fill it to a pressure sufficient to bring the beam to the same position of equilibrium again. The pressure is then observed on the "U" gauge. These pressures are then reduced to absolute pressure, knowing the barometric pressure at the time of making the test. The specific gravity of the gas is the quotient of the absolute air pressure divided by the absolute gas pressure. (Air=1.000.)

a = Barometric pressure.
b = Balancing pressure air.
c = Balancing pressure gas.

$$\text{Specific gravity} = \frac{a-b}{a-c}$$

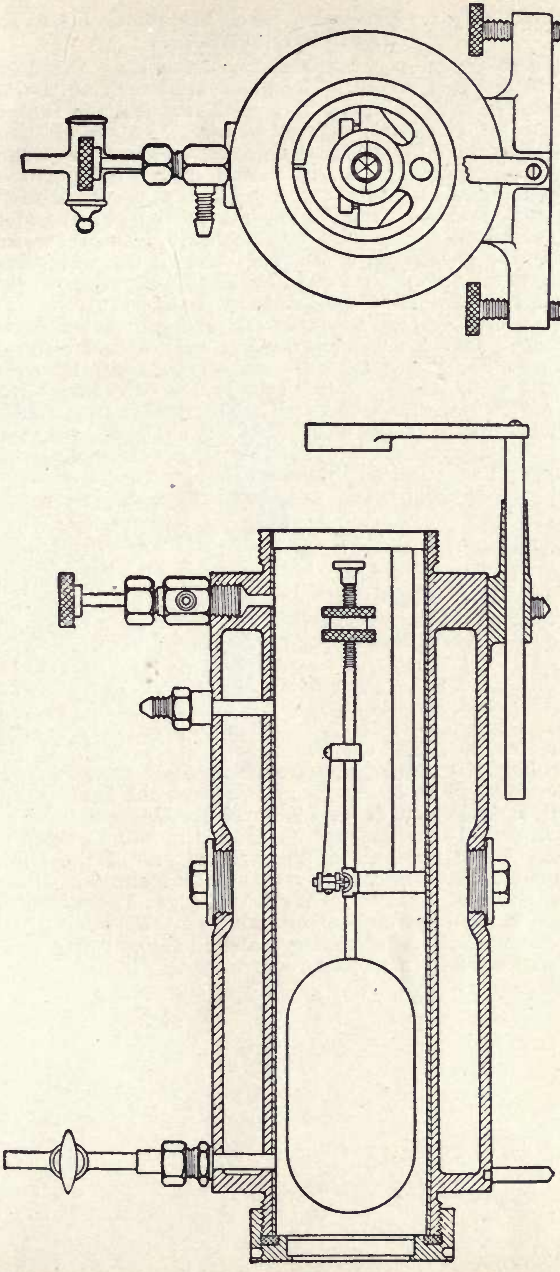
When air is present in gas it is determined with an Orsat apparatus, or other convenient apparatus. The correction of the observed specific gravity to the actual specific gravity is made with following formula:

$$g = \frac{100\ d - a}{100 - a}$$

a = % air.
d = determined or observed specific gravity.
g = actual specific gravity.

Example:—

Barometric pressure (millimeters)		756.4
Gage readings with air (millimeters)	396.7 390.3	
Pressure (milimeters)		—6.4
Total pressure (millimeters		750.0
Gage readings with gas (millimeters)	189.3 597.4	
Pressure (millimeters)		+408.1
Total Pressure (millimeters)		1164.5
Specific gravity	$\frac{750.0}{1164.5}$ =0.6441	



Construction of Edwards Gas Balance

33-A. ABSORPTION METHOD FOR TESTING NATURAL AND CASINGHEAD GAS.

Fill the two-armed pipet commonly known as the Hofman apparatus with distilled water. The glass stop cock at the top of the closed graduated arm is a two-way cock, so that the tube above the stop cock can be completely cleared of air. The end of the stop cock through which the outside discharge takes place is closed with a rubber tube and pinch cock. A funnel is set on top of the tube, water is introduced and the tube is washed out with distilled water. The pinch cock is closed, the funnel is removed and the gas is introduced in the usual manner by displacement with water until about 50 cc. are in the graduated arm. The level of the water is made the same in the two arms and the reading of the quantity of gas is made after it has adjusted itself to the room temperature.

25 cc. of Claroline oil or straw oil are introduced into the open arm. The open arm is now stoppered or held with the thumb so that no air can gain access and the oil is shaken over into the other arm so that it overlies the water. The water is now withdrawn through the stop cock at the lower end of the U. The arm is now filled and kept filled with Claroline or straw oil shaking until the gas ceases to be absorbed. The absorption is calculated in percentage.

The amount of gasoline that may be obtained by absorption from the gas may be approximately calculated from the following table:

Casinghead Gas Yield.

Absorption Percentage	Yield of Gasoline Gallons per 1000 Cu. Ft. of Gas
25	.50
30	.75
35	1.50
40	2.00
50	2.50
60	3.50
80	5.00

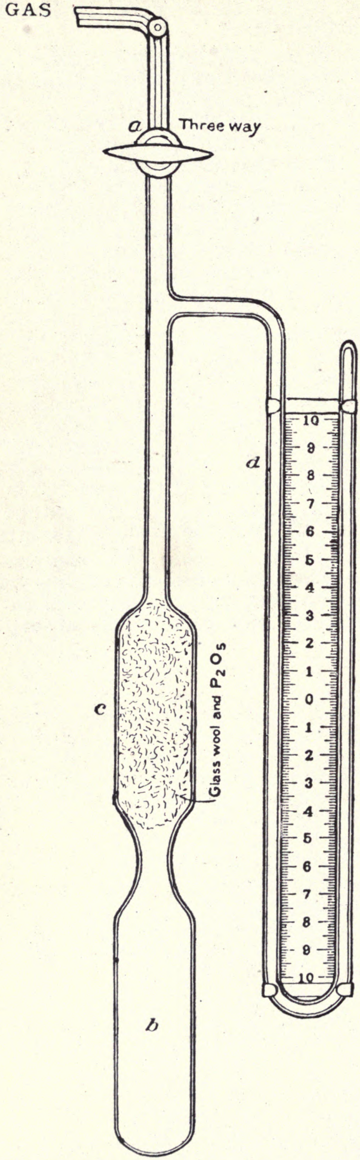
One gallon of gasoline obtained from 1000 cu. ft. of gas reduces the volume about 25 to 30 cu. ft. and reduces the heating value about 75 to 100 B. T. U. per cu. ft. or 7½ to 10%. One gallon of gasoline at 20c a gallon would then extract .6c from the value of gas at 20c per 1000 cu. ft. About one-half of the natural gas of the United States contains gasoline in commercially obtainable quantity. Some casinghead gas such as at Sisterville, West Va., gives 13 gallons of gasoline per 1000 cu. ft. and has a heating value of 2500 B. T. U. per cu. ft. Shellac is the best thread dressing material for gasoline and oil joints since it is not soluble in gasoline nor water.

33-B. FREEZING METHOD FOR TESTING NATURAL GAS FOR GASOLINE CONTENT.

This method is from Technical Paper 104, Bureau of Mines, page 26. The sample of natural gas or casinghead gas is introduced in the usual manner into the apparatus shown on page 356.

In this apparatus (a) is a three-way stop cock, (c) is a tube filled with glass wool and phosphorus pentoxide for the purpose of drying, (b) is a portion of tube which is introduced into liquid air, (d) is a manometer tube containing mercury and is closed at the further end.

In filling the manometer, the apparatus must be completely exhausted of its air. Sufficient mercury is introduced so that its level rests at the zero point of the scale when under a vacuum. The three-way stop cock at (a) connects to the vacuum pump and to the gas sample container. The sample of gas is drawn in at ordinary atmospheric pressure and the stop cock (a) is closed and the bulb (b) is introduced into the cooling medium. The temperature below 100°C is taken. At this temperature all of the gasoline constituents are completely liquefied. While maintained at this low temperature, the vapor above the liquefied gasoline is exhausted with the vacuum pump thus removing the non-condensible gas. The bulb is now taken out of the refrigerant and allowed to warm up to the temperature at the beginning of the test. The mercury level in the manometer is read, the pressure indicated being the partial pressure of the gasoline in the sample before the dry gas had been removed. The percentage by volume of gasoline vapor is $\frac{100\ a}{b}$, a being the partial pressure of the gasoline vapor after the test, b being the original atmospheric pressure of the sample. The percentage of gasoline vapor gives the number of pints of gasoline that may be expected in the manufacture of gasoline from the gas under test by the absorption process.



Freezing Method for Gasoline in Gas.

34. COMPLETE ANALYSIS OF GAS.

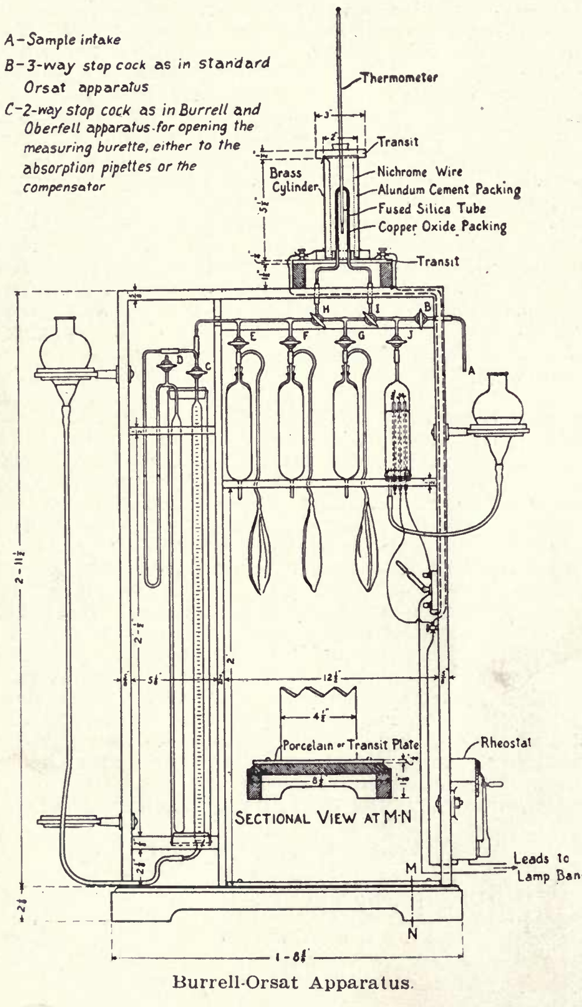
This apparatus is that described in the Journal of Industrial & Engineering Chemistry by G. A. Burrell and G. G. Oberfell, Vol. 8, page 229.

It is designed for the analysis of a gas mixture containing carbon dioxide, unsaturated hydrocarbons, principally ethylene, oxygen, carbon monoxide, methane, ethane, hydrogen and nitrogen.

In the analysis the capillary train and U tube are swept free of gases by drawing a sample of air into the buret and passing it into the alkaline pyrogallate pipet G to remove oxygen. The residual nitrogen is then passed into all the pipets and through the CuO tube to sweep out other gases that may have been contained therein. The electric current is now turned on the electric heating oven, the temperature having been established by previous experiments. About a 100 watt furnace is required. The temperature desired is between 275 and 300°C. Some of the gas mixture is now drawn into the buret, measured and passed into the pipets E, F and G for the removal respectively of carbon dioxide, illuminants, and oxygen. After these constitutents have been removed the stop cocks H, I and J are turned so that communication is made between the buret and the pipet corresponding to J and through the CuO tube. The gas mixture is passed back and forth through the tube furnace until no further diminution in volume is noted by reading the gas volume in the buret. 15 minutes is usually required, the carbon monoxide being converted to carbon dioxide and the hydrogen to H_2O. The CO burns more rapidly if any hydrogen is present. When the gas is cooled and no further contraction takes place the remaining volume is read in the buret. The carbon dioxide is now removed by placing the gas mixture into the KOH pipet E. After the hydrogen and carbon monoxide have been determined the residual gas is placed in the KOH pipet for storage and the stop cock is closed. Enough oxygen to burn the paraffin hydrocarbons is then drawn into the buret, measured and passed into the slow combustion pipet J and the platinum spiral is heated to almost white heat. The residual gas is now withdrawn from the pipet E into the buret and from there slowly passed at the rate of not more than 10 cc. per minute into the pipet J. While operating it is well to cover the slow combustion pipet with gauze as occasionally if the gas is passed in too rapidly an explosion takes place. After combustion is complete, the contraction and the carbon dioxide are measured and the gas again passed into the slow combustion pipet and burned again. A small amount of further contraction may take place but may be ignored unless excessive.

For calculation of results the following example and formulae are useful:

(Continued on page 359.)



Burrell-Orsat Apparatus.

Analysis of Gas From Pressure Stills.

a.	Volume of sample taken	44.1 cc
b.	Volume after KOH absorption	44.0 cc
c.	**Carbon Dioxide — CO_2**	0.1 cc = 0.22%
d.	Volume after Br_2 or Oleum absorption	39.4 cc
e.	**Olefins or illuminants**	4.6 cc = 10.43%
f.	Volume after alkaline pyrogallate absorption	39.3 cc
g.	**Oxygen, O_2**	0.1 cc = 0.22%
h.	Volume after burning in CuO	35.2 cc
i.	**Hydrogen, H_2**	4.1 cc = 9.30%
j.	Volume after absorption in KOH	35.0 cc
k.	**Carbon Monoxide CO**	0.2 cc = 0.45%
l.	Volume taken for slow combustion	17.5 cc
m.	Oxygen added	75.6 cc
n.	Total volume	93.1 cc
o.	Volume after burning	61.5 cc
p.	Contraction from burning	32.6 cc
q.	Volume after KOH absorption	45.0 cc
r.	Contraction from CO_2	16.5 cc
s.	**Methane in sample**	16.0 cc = 72.56%
t.	**Ethane in sample**	0.3 cc = 1.36%
u.	**Nitrogen in sample**	1.2 cc = 5.46%

To calculate amount of methane in the sample from the contraction from burning, "p," and the absorption with KOH, "r," use the following formulae:

$$\text{Methane (s)} = \frac{4p - 5r}{3}$$

$$\text{Ethane (t)} = \frac{4r - 2p}{3}$$

or to obtain % in original gas

$$\%\ \text{Methane} = \frac{100\ js}{al}$$

$$\%\ \text{Ethane} = \frac{100\ jt}{al}$$

$$\%\ \text{Nitrogen} = \frac{100\ ju}{al}$$

REAGENTS USED IN GAS ANALYSIS.

(1) Potassium Hydroxide.

(a) For carbon dioxide determination.

500 grams of commercial potassium hydroxide are dissolved in 1 liter of distilled water. 1 cc. of this solution absorbs 40 cc. of CO_2.

(b) For the preparation of potassium pyrogallate for oxygen testing.

120 grams of potassium hydrate are dissolved in 100 cc. of water. 5 grams of crystalline pyrogallic acid are used with 100 cc. of this solution.

(2) Potassium Pyrogallate.

This solution is prepared when used except for charging absorption pipet. Five grams mixed with 100 cc. of potassium hydrate (b) gives a solution in which 1 cc. absorbs 2 cc. of oxygen.

(3) Sodium Hydroxide.

One hundred grams are dissolved in 300 grams of water and may be used instead of potassium hydrate where given above.

(4) Cuprous Chloride.

Method of preparation is to place a layer of copper oxide about ⅜ inch deep in the bottom of a two-liter acid bottle. Add an excess of long pieces of heavy copper wire reaching from the top to the bottom of the bottle and fill the bottle with hydrochloric acid of about 1.10 specific gravity. The absorption capacity of this reagent is 4 cc. of carbon monoxide CO for each 1 cc. of reagent. Metallic copper must always be maintained with the reagent to keep it in good condition.

(5) Ammoniacal Cuprous Chloride.

The acid cuprous chloride as prepared above is treated with ammonia until a faint odor of ammonia is perceptible. Likewise an excess of copper wire is maintained. The absorption capacity is 1 cc. of CO to 1 cc. of reagent.

(6) Sodium Hypobromite.

This is made of two solutions, one containing 100 grams of caustic soda with 250 cc. of distilled water, making 284 cc. of solution. The other, 25 grams of liquid bromine, 25 grams of potassium bromine and 200 cc. of water. The two solutions are not mixed until ready to use when equal parts are mixed. This reagent is very good for the determination of illuminants.

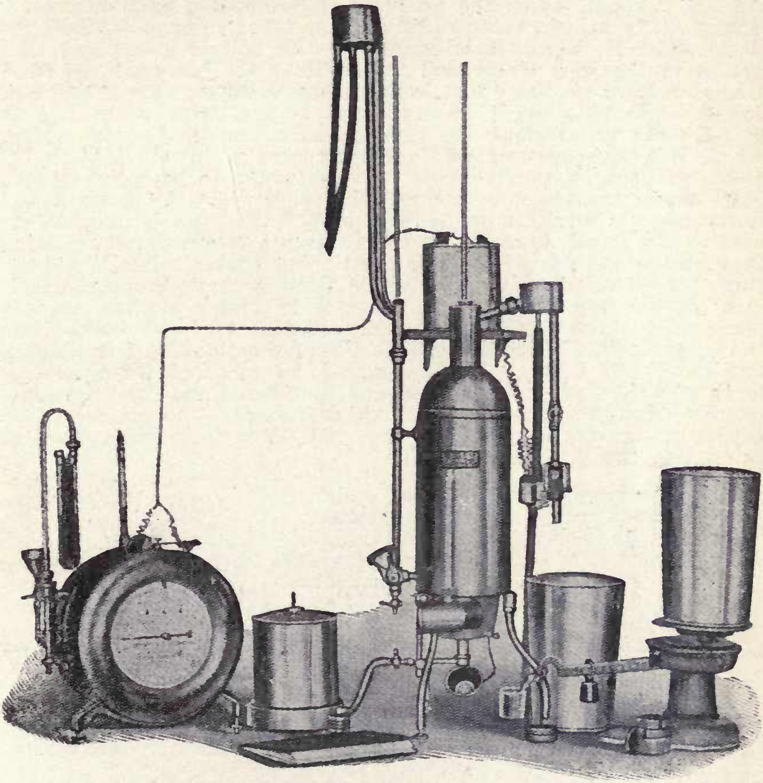
(7) Fuming Sulphuric Acid.

Ordinary concentrated sulphuric acid is mixed with an equal weight of sulphuric anhydride. One cc. of this reagent absorbs 8 cc. of olefins or illuminants.

(8) Palladium Chloride.

Five grams of palladium wire are dissolved in a solution of 30 cc. of hydrochloric acid and 2 cc. of nitric acid.

The solution is evaporated to dryness on a water bath, 5 cc. of hydrochloric acid are added and 25 cc. of water and complete solution is made. The solution is diluted to 750 cc. It contains one per cent palladous chloride and 1 cc. absorbs 2/3 of 1 cc. of hydrogen.



Sargent Gas Calorimeter.

35A. DETERMINATION OF THE HEATING VALUE OF GAS.

The most common instruments used for determining heating value of gas are the Junker, the Parr and the Sargent calorimeters. The Sargent is a very convenient instrument and is described as follows:

The figure on page 363 shows a section of the calorimeter body in which the inlet body has a constant heat at the wier A, the temperature of which is taken at B, passes down the tube C and enters the calorimeter at D. The quantity of water admitted is regulated by the graduated cock between C and D. When water reached D it is spread by the baffle plates E and F and flows upward around the tubes G through which the products of combustion pass downward. The partially heated water on leaving the tubes spreads out over the dome sheet H, where it is heated by the hottest gases and then passes to the wier K through the baffle plate I around the thermometer J, where the outlet temperature is taken. From the wier K it overflows to the waste until test begins, after which it goes through the cock below the wier to the automatic tipping bucket, which is a two-compartment funnel mounted on pivots held in extreme position by the latch so that the water to be weighed runs from one compartment to the receiving pail, while the meter needle is making one revolution or a tenth of a foot of gas is burned. As soon as the circuit is closed by the meter needle the current passing through the solenoid adjacent to the tipping bucket raises the armature, permitting the weight of water flowing through one compartment of the tipping bucket to swing it to a new position, thereby discharging water for the next tenth of a foot of gas burned into the empty pail. While this pail is filling the filled pail is weighed and the B. T. U. may be determined and recorded while another tenth of a foot of gas is burned and continuous and correct results may be obtained and recorded as long as desired. The general set-up of the calorimeter is shown on page 361. The following method of calculating the B. T. U. is used:

t_1 = temperature of incoming water.
t_2 = temperature of outgoing water.
w = pounds of water passed through.
c = pounds of water condensed (average for each 0.1 cu. ft.).
From which B. T. U. per cubic foot =
$10\,(w + c + 0.02)\,(t_2 - t_1) - 9704\,c.$
Example:
$t_1 = 63.0°F.$
$t_2 = 111.0°F.$
w = 1.7531 lbs.
c = 0.0091 lb.

$10\,(1.7531 + 0.0091 + 0.02)\,(111.0 - 63.0) - (9704)\,(.0091) = 855.3 - 88.3 = 767$ B. T. U. per cubic foot.

35-B. APPROXIMATE HEATING VALUE OF NATURAL GAS BY CALCULATION.

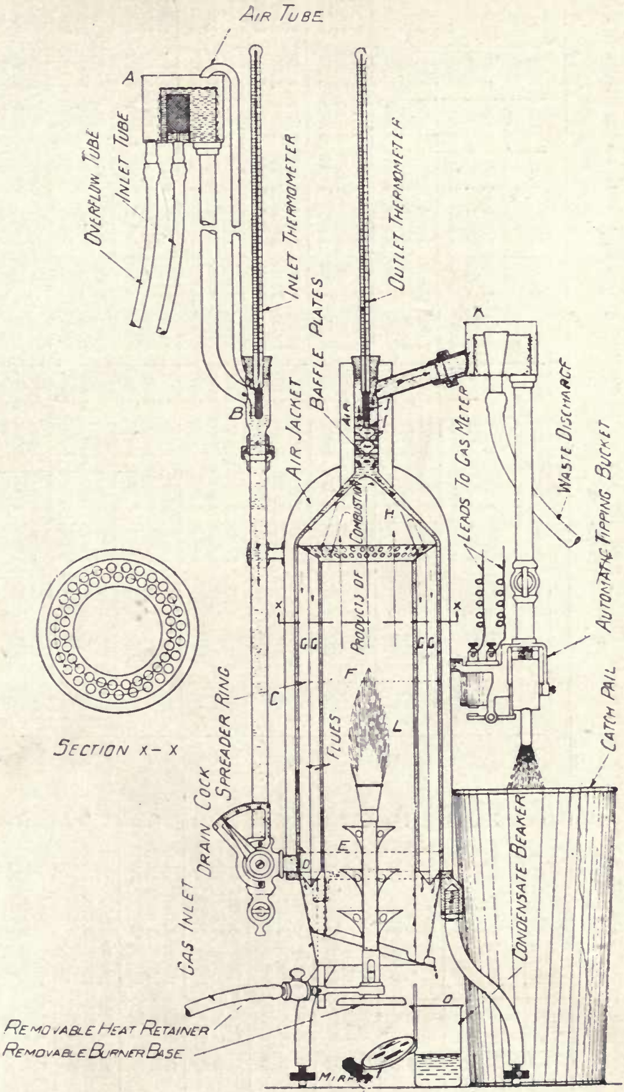
The natural gas is burned with an excess of oxygen in a regular combustion pipet J as shown in the apparatus on page 358.

B. T. U. per cu. ft. is equal to $504 \frac{V}{V_n}$ where V_o = volume of oxygen consumed in burning V_n volumes of natural gas.

35-C. B. T. U. OF GAS BY CALCULATION FROM ANALYSIS.

The heating value of natural gas or any other gas may be calculated as follows:

Percentage of illuminates x 20.00 =
Percentage of CO x 3.41 =
Percentage of CH_4 x 10.65 =
Percentage of H_2 x 3.45 =
The sum of these is the B. T. U. per cubic ft. =



Sectional Elevation
Sargent Automatic Gas Calorimeter

Factors for reduction volume of gas to 60°F. and 30 in. of mercury pressure and saturation with moisture.

TEMPERATURE °F.	BAROMETER																			
	28.6	28.7	28.8	28.9	29.0	29.1	29.2	29.3	29.4	29.5	29.6	29.7	29.8	29.9	30.0	30.1	30.2	30.3	30.4	30.5
53	0.969	0.973	0.976	0.980	0.983	0.986	0.990	0.993	0.997	1.000	1.004	1.007	1.011	1.014	1.018	1.021	1.025	1.028	1.031	1.035
52	0.971	0.975	0.978	0.982	0.985	0.989	0.992	0.996	0.999	1.003	1.006	1.010	1.013	1.017	1.020	1.024	1.027	1.031	1.034	1.038
51	0.974	0.977	0.981	0.984	0.988	0.991	0.995	0.998	1.002	1.005	1.009	1.012	1.016	1.019	1.023	1.026	1.030	1.033	1.037	1.040
50	0.976	0.980	0.983	0.987	0.990	0.994	0.997	1.001	1.004	1.008	1.011	1.015	1.018	1.022	1.025	1.029	1.032	1.036	1.039	1.043
49	0.979	0.982	0.986	0.989	0.993	0.996	1.000	1.003	1.007	1.010	1.014	1.017	1.021	1.024	1.028	1.031	1.035	1.038	1.042	1.045
48	0.981	0.985	0.988	0.992	0.995	0.999	1.002	1.006	1.009	1.013	1.016	1.020	1.023	1.027	1.030	1.034	1.037	1.041	1.044	1.048
47	0.984	0.987	0.991	0.994	0.998	1.001	1.005	1.008	1.012	1.015	1.019	1.022	1.026	1.029	1.033	1.036	1.040	1.043	1.047	1.050
46	0.986	0.990	0.993	0.997	1.000	1.004	1.007	1.011	1.014	1.018	1.021	1.025	1.028	1.032	1.035	1.039	1.042	1.046	1.049	1.053
45	0.989	0.992	0.996	0.999	1.003	1.006	1.010	1.013	1.017	1.020	1.024	1.027	1.031	1.034	1.038	1.041	1.045	1.048	1.052	1.056
44	0.991	0.994	0.998	1.001	1.005	1.008	1.012	1.015	1.019	1.022	1.026	1.029	1.033	1.036	1.040	1.043	1.047	1.050	1.054	1.058
43	0.993	0.997	1.001	1.004	1.008	1.011	1.015	1.018	1.022	1.025	1.029	1.032	1.036	1.039	1.043	1.046	1.050	1.053	1.057	1.060
42	0.995	0.999	1.003	1.006	1.010	1.013	1.017	1.020	1.024	1.027	1.031	1.034	1.038	1.041	1.045	1.048	1.052	1.055	1.059	1.063
41	0.998	1.001	1.005	1.009	1.012	1.016	1.019	1.023	1.026	1.030	1.034	1.037	1.041	1.044	1.048	1.051	1.055	1.058	1.062	1.065
40	1.000	1.004	1.007	1.011	1.014	1.018	1.021	1.025	1.028	1.032	1.036	1.039	1.043	1.046	1.050	1.053	1.057	1.060	1.064	1.068
39	1.002	1.006	1.010	1.013	1.017	1.020	1.024	1.028	1.031	1.035	1.038	1.042	1.045	1.049	1.052	1.056	1.059	1.063	1.066	1.070
38	1.005	1.009	1.012	1.016	1.020	1.023	1.027	1.030	1.034	1.037	1.041	1.044	1.048	1.051	1.055	1.058	1.062	1.065	1.069	1.073
37	1.007	1.011	1.015	1.018	1.022	1.025	1.029	1.032	1.036	1.039	1.043	1.046	1.050	1.053	1.057	1.060	1.064	1.068	1.072	1.076
36	1.009	1.013	1.017	1.020	1.024	1.027	1.031	1.035	1.038	1.042	1.045	1.049	1.052	1.056	1.060	1.063	1.067	1.071	1.074	1.078
35	1.012	1.015	1.019	1.022	1.026	1.030	1.033	1.037	1.041	1.044	1.048	1.051	1.055	1.058	1.062	1.065	1.069	1.073	1.077	1.081
34	1.014	1.018	1.022	1.025	1.029	1.032	1.036	1.040	1.043	1.047	1.050	1.054	1.057	1.061	1.064	1.068	1.072	1.075	1.079	1.083
33	1.016	1.020	1.024	1.027	1.031	1.034	1.038	1.042	1.046	1.049	1.053	1.056	1.060	1.063	1.067	1.070	1.074	1.078	1.082	1.086
32	1.019	1.023	1.027	1.030	1.034	1.037	1.041	1.044	1.048	1.051	1.055	1.058	1.062	1.066	1.069	1.073	1.077	1.081	1.085	1.089
31	1.021	1.025	1.029	1.032	1.036	1.039	1.043	1.047	1.050	1.054	1.057	1.061	1.064	1.068	1.072	1.075	1.079	1.083	1.087	1.091
30	1.023	1.027	1.031	1.034	1.038	1.042	1.045	1.049	1.053	1.056	1.060	1.063	1.067	1.071	1.074	1.078	1.082	1.086	1.090	1.094

Temperature °F.	Barometer 28.6	28.7	28.8	28.9	29.0	29.1	29.2	29.3	29.4	29.5	29.6	29.7	29.8	29.9	30.0	30.1	30.2	30.3	30.4	30.5
107	0.816	0.820	0.823	0.826	0.829	0.832	0.835	0.838	0.841	0.844	0.847	0.851	0.854	0.857	0.860	0.864	0.86	0.870	0.874	0.877
106	0.820	0.823	0.826	0.829	0.832	0.835	0.838	0.841	0.844	0.847	0.851	0.854	0.857	0.860	0.863	0.867	0.870	0.874	0.878	0.881
105	0.823	0.827	0.830	0.833	0.836	0.839	0.842	0.845	0.848	0.851	0.855	0.858	0.861	0.864	0.867	0.871	0.874	0.878	0.881	0.884
104	0.827	0.830	0.833	0.836	0.839	0.842	0.845	0.848	0.851	0.854	0.858	0.861	0.864	0.867	0.871	0.874	0.878	0.881	0.884	0.887
103	0.830	0.834	0.837	0.840	0.843	0.847	0.849	0.852	0.855	0.858	0.862	0.865	0.868	0.871	0.874	0.878	0.881	0.885	0.888	0.891
102	0.834	0.837	0.840	0.843	0.847	0.850	0.853	0.856	0.859	0.862	0.865	0.868	0.871	0.874	0.878	0.881	0.885	0.888	0.891	0.894
101	0.837	0.840	0.843	0.846	0.850	0.853	0.856	0.859	0.862	0.865	0.868	0.872	0.875	0.878	0.882	0.885	0.888	0.891	0.895	0.898
100	0.840	0.843	0.846	0.849	0.853	0.856	0.859	0.862	0.865	0.868	0.872	0.875	0.878	0.881	0.885	0.888	0.891	0.895	0.898	0.901
99	0.844	0.847	0.850	0.853	0.857	0.860	0.863	0.866	0.869	0.872	0.876	0.879	0.882	0.885	0.889	0.892	0.895	0.898	0.902	0.905
98	0.847	0.850	0.853	0.856	0.860	0.863	0.866	0.869	0.872	0.875	0.879	0.882	0.885	0.888	0.892	0.895	0.898	0.902	0.905	0.908
97	0.850	0.853	0.856	0.859	0.863	0.866	0.870	0.873	0.876	0.879	0.882	0.885	0.888	0.891	0.894	0.898	0.901	0.905	0.908	0.911
96	0.854	0.857	0.860	0.863	0.867	0.870	0.873	0.876	0.879	0.882	0.886	0.889	0.892	0.895	0.898	0.901	0.904	0.908	0.911	0.914
95	0.857	0.860	0.863	0.866	0.870	0.873	0.876	0.879	0.882	0.885	0.889	0.892	0.895	0.898	0.901	0.904	0.908	0.911	0.914	0.918
94	0.860	0.863	0.866	0.869	0.873	0.876	0.879	0.882	0.885	0.888	0.892	0.895	0.898	0.901	0.904	0.907	0.911	0.914	0.918	0.921
93	0.863	0.866	0.869	0.872	0.876	0.879	0.883	0.886	0.889	0.891	0.895	0.898	0.901	0.904	0.907	0.910	0.914	0.918	0.921	0.924
92	0.866	0.869	0.872	0.875	0.879	0.882	0.885	0.889	0.892	0.894	0.898	0.902	0.904	0.907	0.910	0.914	0.917	0.921	0.924	0.928
91	0.869	0.872	0.875	0.879	0.882	0.885	0.889	0.892	0.895	0.898	0.902	0.905	0.908	0.911	0.914	0.917	0.921	0.924	0.928	0.931
90	0.872	0.875	0.878	0.881	0.885	0.888	0.892	0.895	0.898	0.901	0.905	0.908	0.911	0.914	0.917	0.920	0.924	0.927	0.931	0.934
89	0.875	0.878	0.882	0.885	0.889	0.892	0.895	0.898	0.901	0.904	0.907	0.910	0.914	0.917	0.920	0.923	0.927	0.931	0.934	0.937
88	0.878	0.881	0.885	0.888	0.892	0.895	0.898	0.901	0.904	0.907	0.910	0.913	0.917	0.920	0.923	0.926	0.930	0.934	0.937	0.940
87	0.881	0.884	0.888	0.891	0.895	0.898	0.901	0.904	0.907	0.910	0.913	0.916	0.920	0.923	0.926	0.929	0.933	0.937	0.940	0.943
86	0.884	0.887	0.890	0.894	0.898	0.901	0.904	0.907	0.910	0.913	0.916	0.919	0.923	0.926	0.929	0.932	0.936	0.940	0.943	0.946
85	0.887	0.890	0.893	0.896	0.900	0.903	0.906	0.909	0.913	0.916	0.919	0.922	0.926	0.929	0.932	0.936	0.939	0.943	0.946	0.949
84	0.889	0.893	0.896	0.899	0.903	0.906	0.909	0.912	0.915	0.919	0.922	0.925	0.928	0.932	0.935	0.939	0.942	0.946	0.949	0.952
83	0.892	0.895	0.899	0.902	0.906	0.909	0.912	0.915	0.918	0.921	0.924	0.928	0.931	0.935	0.938	0.942	0.945	0.949	0.952	0.955
82	0.895	0.898	0.901	0.905	0.908	0.911	0.914	0.918	0.921	0.924	0.927	0.931	0.934	0.937	0.941	0.945	0.948	0.951	0.954	0.958
81	0.898	0.901	0.905	0.908	0.911	0.914	0.917	0.921	0.924	0.927	0.930	0.934	0.937	0.940	0.944	0.948	0.951	0.954	0.957	0.960

TEMPERATURE °F.	BAROMETER 28.6	28.7	28.8	28.9	29.0	29.1	29.2	29.3	29.4	29.5	29.6	29.7	29.8	29.9	30.0	30.1	30.2	30.3	30.4	30.5
80	0.901	0.904	0.907	0.910	0.914	0.917	0.920	0.923	0.927	0.930	0.933	0.937	0.940	0.943	0.946	0.950	0.954	0.957	0.960	0.963
79	0.904	0.907	0.910	0.914	0.917	0.920	0.923	0.926	0.930	0.933	0.936	0.939	0.943	0.946	0.949	0.953	0.956	0.960	0.963	0.967
78	0.906	0.909	0.913	0.916	0.919	0.923	0.926	0.929	0.932	0.936	0.939	0.942	0.946	0.949	0.952	0.956	0.959	0.962	0.966	0.969
77	0.909	0.912	0.915	0.919	0.922	0.925	0.928	0.931	0.935	0.938	0.942	0.945	0.948	0.951	0.955	0.958	0.962	0.965	0.968	0.972
76	0.911	0.915	0.918	0.921	0.925	0.928	0.931	0.935	0.938	0.941	0.944	0.948	0.951	0.954	0.958	0.961	0.964	0.968	0.971	0.975
75	0.914	0.917	0.921	0.924	0.928	0.931	0.934	0.937	0.940	0.943	0.947	0.950	0.954	0.957	0.960	0.963	0.967	0.971	0.974	0.978
74	0.917	0.920	0.924	0.927	0.930	0.933	0.937	0.940	0.943	0.947	0.950	0.953	0.957	0.960	0.963	0.966	0.970	0.973	0.977	0.980
73	0.920	0.923	0.926	0.930	0.933	0.936	0.940	0.943	0.946	0.949	0.953	0.956	0.960	0.963	0.966	0.969	0.972	0.976	0.980	0.983
72	0.922	0.925	0.929	0.932	0.935	0.939	0.942	0.945	0.949	0.952	0.955	0.959	0.962	0.965	0.968	0.972	0.975	0.979	0.982	0.986
71	0.925	0.928	0.931	0.935	0.938	0.941	0.945	0.948	0.951	0.954	0.958	0.961	0.965	0.968	0.971	0.975	0.978	0.981	0.985	0.989
70	0.927	0.931	0.934	0.937	0.941	0.944	0.947	0.950	0.954	0.957	0.960	0.964	0.967	0.970	0.974	0.977	0.980	0.984	0.988	0.991
69	0.930	0.933	0.937	0.940	0.944	0.947	0.950	0.953	0.957	0.960	0.963	0.967	0.970	0.973	0.977	0.980	0.983	0.987	0.990	0.994
68	0.932	0.936	0.939	0.942	0.946	0.949	0.952	0.956	0.959	0.962	0.966	0.969	0.972	0.976	0.979	0.983	0.986	0.989	0.993	0.997
67	0.935	0.938	0.942	0.945	0.949	0.952	0.955	0.959	0.962	0.965	0.968	0.972	0.975	0.979	0.982	0.985	0.989	0.992	0.996	1.000
66	0.938	0.941	0.944	0.948	0.951	0.954	0.958	0.961	0.964	0.968	0.971	0.974	0.978	0.981	0.985	0.988	0.992	0.995	0.998	1.002
65	0.941	0.944	0.947	0.950	0.954	0.957	0.960	0.963	0.967	0.970	0.973	0.977	0.980	0.984	0.987	0.991	0.994	0.997	1.001	1.005
64	0.943	0.946	0.949	0.953	0.956	0.959	0.963	0.966	0.969	0.973	0.976	0.980	0.983	0.986	0.990	0.994	0.997	1.000	1.004	1.008
63	0.945	0.949	0.952	0.955	0.959	0.962	0.965	0.969	0.972	0.975	0.979	0.982	0.985	0.989	0.993	0.996	1.000	1.003	1.006	1.010
62	0.947	0.951	0.954	0.958	0.961	0.964	0.968	0.971	0.975	0.978	0.981	0.985	0.988	0.991	0.995	0.999	1.002	1.005	1.009	1.013
61	0.950	0.954	0.957	0.961	0.964	0.967	0.971	0.974	0.977	0.981	0.984	0.987	0.991	0.994	0.998	1.001	1.005	1.008	1.011	1.015
60	0.952	0.956	0.959	0.963	0.966	0.969	0.973	0.976	0.980	0.983	0.986	0.990	0.993	0.997	1.000	1.004	1.007	1.010	1.014	1.017
59	0.955	0.959	0.962	0.966	0.969	0.972	0.976	0.979	0.983	0.986	0.989	0.992	0.995	0.999	1.003	1.006	1.010	1.013	1.016	1.020
58	0.957	0.961	0.964	0.968	0.971	0.975	0.978	0.981	0.985	0.988	0.992	0.995	0.998	1.002	1.005	1.009	1.012	1.016	1.019	1.023
57	0.960	0.963	0.967	0.970	0.974	0.977	0.980	0.984	0.988	0.991	0.994	0.997	1.000	1.004	1.007	1.011	1.014	1.018	1.021	1.025
56	0.962	0.966	0.969	0.973	0.976	0.979	0.982	0.986	0.990	0.993	0.996	1.000	1.003	1.007	1.010	1.014	1.017	1.021	1.024	1.028
55	0.965	0.968	0.972	0.975	0.979	0.982	0.985	0.989	0.993	0.996	0.999	1.002	1.005	1.009	1.013	1.016	1.020	1.023	1.027	1.030
54	0.967	0.970	0.974	0.977	0.981	0.984	0.988	0.991	0.995	0.998	1.001	1.005	1.008	1.012	1.015	1.019	1.022	1.026	1.029	1.033

Comparison of Temperatures by the Fahrenheit and Centigrade Scales

Cent.	Fahr.	Cent.	Fahr.	Cent.	Fahr.	Cent.	Fahr.
—273°	—459.4						
Absolute Zero							
—200°	—328.0	— 5.6	+22.0	15.6	60.0	36.1	97.0
Temperature of		— 5.0	+23.0	16.0	60.8	36.7	98.0
Liquid Air		— 4.4	+24.0	16.1	61.0	37.0	98.6
—130°	—202.0	— 4.0	+24.8	16.7	62.0	37.2	99.0
Pure Grain Alcohol		— 3.9	+25.0	17.0	62.6	37.8	100.0
Freezes		— 3.3	+26.0	17.2	63 0	38.0	100.4
—70°	—94.0	— 3.0	+26.6	17.8	64.0	38.3	101.0
Ammonia Freezes		— 2.8	+27.0	18.0	64.4	38.9	102.0
—(75°C)		— 2.2	+28.0	18.3	65.0	39.0	102.2
—40°	—40.	— 2.0	+28.4	18.9	66.0	39.4	103.0
Mercury Freezes		— 1.7	+29.0	19.0	66.2	40.0	104.0
(—39.5C)		— 1.1	+30.0	19.4	67.0	40.6	105.0
—30°	—22	— 1.0	+30.2	20.0	68.0	41.0	105.8
Ammonia Liquefies		— 0.6	+31.0	20.6	69.0	41.1	106.0
at —33.7°C		0.	+32.0	21.0	69.8	41.7	107.0
—28	—18.4	+ 0.6	+33.0	21.1	70.0	42.0	107.6
—26	—14.8	1.0	33.8	21.7	71.0	42.2	108.0
—24	—11.2	1.1	34.0	22.0	71.6	42.8	109.0
—22	— 7.6	1.7	35.0	22.2	72.0	43.0	109.4
—20	— 4.0	2.0	35.6	22.8	73.0	43.3	110.0
—19	— 2.2	2.2	36.0	23.0	73.4	43.9	111.0
—18	— 0.4	2.8	37.0	23.3	74.0	44.0	111.2
—17.8	— 0.0	3.0	37.4	23.9	75.0	44.4	112.0
—17.2	+ 1.0	3.3	38.0	24.0	75.2	45.0	113.0
—17.0	+ 1.4	3.9	39.0	24.4	76.0	45.6	114.0
—16.7	+ 2.0	4.0	39.2	25.0	77.0	46.0	114.8
—16.1	+ 3.0	4.4	40.0	25.6	78.0	46.1	115.0
—16.0	+ 3.2	5.0	41.0	26.0	78.8	46.7	116.0
—15.6	+ 4.0	5.6	42.0	26.1	79.0	47.0	116.6
—15.0	+ 5.0	6.0	42.8	26.7	80.0	47.2	117.0
—14.4	+ 6.0	6.1	43.0	27.0	80.6	47.8	118.0
—14.0	+ 6.8	6.7	44.0	27.2	81.0	48.0	118.4
—13.9	+ 7.0	7.0	44.6	27.8	82.0	48.3	119.0
—13.3	+ 8.0	7.2	45.0	28.0	82.4	48.9	120.0
—13.0	+ 8.6	7.8	46.0	28.3	83.0	49.0	120.2
—12.8	+ 9.0	8.0	46.4	28.9	84.0	49.4	121.0
—12.2	+10.0	8.3	47.0	29.0	84.2	50.0	122.0
—12.0	+10.4	8.9	48.0	29.4	85.0	50.6	123.0
—11.7	+11.0	9.0	48.2	30.0	86.0	51.0	123.8
—11.1	+12.0	9.4	49.0	30.6	87.0	51.1	124.0
—11.0	+12.2	10.0	50.0	31.0	87.8	51.7	125.0
—10.6	+13.0	10.6	51.0	31.1	88.0	52.0	125.6
—10.0	+14.0	11.0	51.8	31.7	89.0	52.2	126.0
— 9.4	+15.0	11.1	52.0	32.0	89.6	52.8	127.0
— 9.0	+15.8	11.7	53.0	32.2	90.0	53.0	127.4
— 8.9	+16.0	12.0	53.6	32.8	91.0	53.3	128.0
— 8.3	+17.0	12.2	54.0	33.0	91.4	53.9	129.0
— 8.0	+17.6	12.8	55.0	33.3	92.0	54.0	129.2
— 7.8	+18.0	13.0	55.4	33.9	93.0	54.4	130.0
— 7.2	+19.0	13.3	56.0	34.0	93.2	55.0	131.0
— 7.0	+19.4	13.9	57.0	34.4	94.0	55.6	132.0
— 6.7	+20.0	14.0	57.2	35.0	95.0	56.0	132.8
— 6.1	+21.0	14.4	58.0	35.6	96.0	56.1	133.0
— 6.0	+21.2	15.0	59.0	36.0	96.8	56.7	134.0

Temperature Conversion Tables

Cent.	Fahr.	Cent.	Fahr.	Cent.	Fahr.	Cent.	Fahr.
57.0	134.6	77.8	172.0	98.3	209.0	119.0	246.2
57.2	135.0	78.0	172.4	98.9	210.0	119.4	247.0
57.8	136.0	78.3	173.0	99.0	210.2	120.0	248.0
58.0	136.4	78.9	174.0	99.4	211.0	120.6	249.0
58.3	137.0	79.0	174.2	100.0	212.0	121.0	249.8
58.9	138.0	79.4	175.0	100.6	213.0	121.1	250.0
59.0	138.2	80.0	176.0	101.0	213.8	121.7	251.0
59.4	139.0	80.6	177.0	101.1	214.0	122.0	251.6
60.0	140.0	81.0	177.8	101.7	215.0	122.2	252.0
60.6	141.0	81.1	178.0	102.0	215.6	122.8	253.0
61.0	141.8	81.7	179.0	102.2	216.0	123.0	253.4
61.1	142.0	82.0	179.6	102.8	217.0	123.3	254.0
61.7	143.0	82.2	180.0	103.0	217.4	123.9	255.0
62.0	143.6	82.8	181.0	103.3	218.0	124.0	255.2
62.2	144.0	83.0	181.4	103.9	219.0	124.4	256.0
62.8	145.0	83.3	182.0	104.0	219.2	125.0	257.0
63.0	145.4	83.9	183.0	104.4	220.0	125.6	258.0
63.0	146.0	84.0	183.2	105.0	221.0	126.0	258.8
63.9	147.0	84.4	184.0	105.6	222.0	126.1	259.0
64.0	147.2	85.0	185.0	106.0	222.8	126.7	260.0
64.4	148.0	85.6	186.0	106.1	223.0	127.0	260.6
65.0	149.0	86.0	186.8	106.7	224.0	127.2	261.0
65.6	150.0	86.1	187.0	107.0	224.6	127.8	262.0
66.0	150.8	86.7	188.0	107.2	225.0	128.0	262.4
66.1	151.0	87.0	188.6	107.8	226.0	128.3	263.0
66.7	152.0	87.2	189.0	108.0	226.4	128.9	264.0
67.0	152.6	87.8	190.0	108.3	227.0	129.0	264.2
67.2	153.0	88.0	190.4	108.9	228.0	129.4	265.0
67.8	154.0	88.3	191.0	109.0	228.2	130.0	266.0
68.0	154.4	88.9	192.0	109.4	229.0	130.6	267.0
68.3	155.0	89.0	192.2	110.0	230.0	131.0	267.8
68.9	156.0	89.4	193.0	110.6	231.0	131.1	268.0
69.0	156.2	90.0	194.0	111.0	231.8	131.7	269.0
69.4	157.0	90.6	195.0	111.1	232.0	132.0	269.6
70.0	158.0	91.0	195.8	111.7	233.0	132.2	270.0
70.6	159.0	91.1	196.0	112.0	233.6	132.8	271.0
71.0	159.8	91.7	197.0	112.2	234.0	133.0	271.4
71.1	160.0	92.0	197.6	112.8	235.0	133.3	272.0
71.7	161.0	92.2	198.0	113.0	235.4	133.0	273.0
72.0	161.6	92.8	199.0	113.3	236.0	134.0	273.2
72.2	162.0	93.0	199.4	113.9	237.0	134.4	274.0
72.8	163.0	93.3	200.0	114.0	227.2	135.0	275.0
73.0	163.4	93.9	201.0	114.4	238.0	135.6	276.0
73.3	164.0	94.0	201.2	115.0	239.0	136.0	276.8
73.9	165.0	94.4	202.0	115.6	240.0	136.1	277.0
74.0	165.2	95.0	203.0	116.0	240.8	136.7	278.0
74.4	166.0	95.6	204.0	116.1	241.0	137.0	278.6
75.0	167.0	96.0	204.8	116.7	242.0	137.2	279.0
75.6	168.0	96.1	205.0	117.0	242.6	137.8	280.0
76.0	168.8	96.7	206.0	117.2	243.0	138.0	280.4
76.1	169.0	97.0	206.6	117.8	244.0	138.3	281.0
76.7	170.0	97.2	207.0	118.0	244.4	138.9	282.0
77.0	170.6	97.8	208.0	118.3	245.0	139.0	282.2
77.2	171.6	98.0	208.4	118.9	246.0	139.4	283.0

TEMPERATURE CONVERSION TABLES—Continued.

Cent.	Fahr.	Cent.	Fahr.	Cent.	Fahr.	Cent.	Fahr.
140.0	284.0	215.0	419.0	590.0	1094.0	1360.0	2480.0
140.6	285.0	220.0	428.0	600.0	1112.0	1380.0	2516.0
141.0	285.8	225.0	437.0	610.0	1130.0	1400.0	2552.0
141.1	286.0	230.0	446.0	620.0	1148.0	1420.0	2588.0
141.7	287.0	235.0	455.0	630.0	1166.0	1440.0	2624.0
142.0	287.6	240.0	464.0	640.0	1184.0	1460.0	2660.0
142.2	288.0	245.0	473.0	650.0	1202.0	1480.0	2696.0
142.8	289.0	250.0	482.0	660.0	1220.0	1500.0	2732.0
143.0	289.4	254.0	489.2	670.0	1238.0	1520.0	2768.0
143.3	290.0	255.0	491.0	680.0	1256.0	1540.0	2804.0
143.9	291.0	260.0	500.0	690.0	1274.0	1560.0	2840.0
144.0	291.2	265.0	509.0	700.0	1292.0	1580.0	2876.0
144.4	292.0	270.0	518.0	710.0	1310.0	1600.0	2912.0
145.0	293.0	275.0	527.0	720.0	1328.0	1620.0	2918.0
145.6	294.0	280.0	536.0	730.0	1346.0	1640.0	2984.0
146.0	294.8	283.0	541.4	740.0	1364.0	1660.0	3020.0
146.1	295.0	285.0	545.0	750.0	1382.0	1680.0	3056.0
146.7	296.0	288.0	550.4	760.0	1400.0	1700.0	3092.0
147.0	296.6	290.0	554.0	770.0	1418.0	1720.0	3128.0
147.2	297.0	295.0	563.0	780.0	1436.0	1740.0	3164.0
147.8	298.0	300.0	572.0	790.0	1454.0	1760.0	3200.0
148.0	298.4	305.0	581.0	800.0	1472.0	1780.0	3236.0
148.3	299.0	310.0	590.0	810.0	1490.0	1800.0	3272.0
148.9	300.0	315.0	599.0	820.0	1508.0	1825.0	3317.0
149.0	300.2	320.0	608.0	830.0	1526.0	1850.0	3362.0
149.4	301.0	325.0	617.0	840.0	1544.0	1875.0	3407.0
150.0	302.0	330.0	626.0	850.0	1562.0	1900.0	3452.0
152.0	305.6	335.0	635.0	860.0	1580.0	1925.0	3497.0
154.0	309.2	340.0	644.0	870.0	1598.0	1950.0	3542.0
156.0	312.8	345.0	653.0	880.0	1616.0	1975.0	3587.0
158.0	316.4	350.0	662.0	890.0	1634.0	2000.0	3632.0
160.0	320.0	360.0	680.0	900.0	1652.0	2400.0	3812.0
162.0	323.6	370.0	698.0	920.0	1688.0	2500.0	4532.0
164.0	327.2	380.0	716.0	940.0	1724.0	3000.0	5432.0
166.0	330.8	390.0	734.0	960.0	1760.0	3500.0	6332.0
168.0	334.4	400.0	752.0	980.0	1796.0	4000.0	7232.0
170.0	338.0	410.0	770.0	1000.0	1832.0	5000.0	9032.0
172.0	341.6	420.0	788.0	1020.0	1868.0	6000.0	10832.0
174.0	345.2	430.0	806.0	1040.0	1904.0		
176.0	348.8	440.0	824.0	1060.0	1940.0		
178.0	352.4	450.0	842.0	1080.0	1976.0		
180.0	356.0	460.0	860.0	1100.0	2012.0		
182.0	359.6	470.0	878.0	1120.0	2048.0		
184.0	363.2	480.0	896.0	1140.0	2084.0		
186.0	366.8	490.0	914.0	1160.0	2120.0		
188.0	370.4	500.0	932.0	1180.0	2156.0		
190.0	374.0	510.0	950.0	1200.0	2192.0		
192.0	377.6	520.0	968.0	1220.0	2228.0		
194.0	381.2	530.0	986.0	1240.0	2264.0		
196.0	384.8	540.0	1004.0	1260.0	2300.0		
198.0	388.4	550.0	1022.0	1280.0	2336.0		
200.0	392.0	560.0	1040.0	1300.0	2372.0		
205.0	401.0	570.0	1058.0	1320.0	2408.0		
210.0	410.0	580.0	1076.0	1340.0	2444.0		

TEMPERATURE READING CONVERSION FACTORS.

Temp. Centigrade = 5/9 (F.—32) = 5/4 R.
Temp. Fahrenheit = 9/5 C. + 32 = 9/4 R. + 32.
Temp. Reaumur = 4/5 C. = 4/9 (F.—32).

BAUME', SPECIFIC GRAVITY AND POUNDS PER GALLON. (U. S. BUREAU OF STANDARDS.)

	0	1	2	3	4	5	6	7	8	9
10	1.0000	.9993	.9986	.9979	.9972	.9964	.9957	.9950	.9943	.9936
	8.325	8.322	8.317	8.311	8.305	8.299	8.293	8.287	8.281	8.275
11	.9929	.9922	.9915	.9908	.9901	.9894	.9887	.9880	.9873	.9866
	8.269	8.263	8.258	8.252	8.246	8.240	8.234	8.228	8.223	8.217
12	.9859	.9852	.9815	.9838	.9831	.9825	.9818	.9811	.9804	.9797
	8.211	8.205	8.194	8.194	8.188	8.182	8.176	8.171	8.165	8.159
13	.9790	.9783	.9777	.9770	.9763	.9756	.9749	.9743	.9736	.9729
	8.153	8.148	8.142	8.137	8.131	8.125	8.119	8.114	8.108	8.102
14	.9722	.9715	.9709	.9702	.9695	.9688	.9682	.9675	.9669	.9662
	8.096	8.091	8.086	8.080	8.074	8.069	8.063	8.058	8.052	8.047
15	.9655	.9649	.9642	.9635	.9629	.9622	.9615	.9609	.9602	.9596
	8.041	8.035	8.030	8.024	8.019	8.013	8.007	8.002	7.997	7.991
16	.9589	.9582	.9582	.9569	.9563	.9556	.9550	.9543	.9537	.9530
	7.986	7.980	7.975	7.969	7.964	7.959	7.653	7.948	7.942	7.937
17	.9524	.9517	.9511	.9504	.9498	.9492	.9485	.9479	.9472	.9466
	7.931	7.926	7.921	7.915	7.910	7.904	7.899	7.894	7.888	7.883
18	.9459	.9453	.9447	.9440	.9434	.9428	.9421	.9415	.9409	.9402
	7.877	7.872	7.867	7.861	7.856	7.851	7.846	7.841	7.835	7.830
19	.9396	.9390	.9383	.9377	.9371	.9365	.9358	.9352	.9346	.9340
	7.825	7.820	7.814	7.809	7.804	7.799	7.793	7.788	7.783	7.778
20	.9333	.9327	.9321	.9315	.9309	.9302	.9296	.9290	.9284	.9278
	7.772	7.767	7.762	7.757	7.752	7.747	7.742	7.736	7.731	7.726
21	.9272	.9265	.9259	.9253	.9247	.9241	.9235	.9229	.9223	.9217
	7.721	7.716	7.711	7.706	7.701	7.696	7.690	7.685	7.680	7.675
22	.9211	.9204	.9198	.9192	.9186	.9180	.9174	.9168	.9162	.9156
	7,670	7.665	7.660	7.655	7.650	7.645	7.640	7.635	7.630	7.625
23	.9150	.9144	.9138	.9132	.9126	.9121	.9115	.9109	.9103	.9097
	7.620	7.615	7.610	7.605	7.600	7.595	7.590	7.585	7.580	7.575
24	.9091	.9085	.9079	.9073	.9067	.9061	.9056	.9050	.9044	.9038
	7.570	7.565	7.561	7.556	7.551	7.546	7.541	7.536	7.531	7.526
25	.9032	.9026	.9021	.9015	.9009	.9003	.8997	.8992	.8986	.8980
	7.522	7.517	7.512	7.507	7.502	7.497	7.493	7.488	7.483	7.478
26	.8974	.8969	.8963	.8957	.8951	.8946	.8940	.8934	.8929	.8923
	7.473	7.469	7.464	7.459	7.454	7.449	7.445	7.440	7.435	7.430
27	.8917	.8912	.8906	.8900	.8895	.8889	.8883	.8878	.8872	.8866
	7.425	7.421	7.416	7.411	7.407	7.402	7.397	7.393	7.388	7.383
28	.8861	.8855	.8850	.8844	.8838	.8833	.8827	.8822	.8816	.8811
	7.378	7.374	7.369	7.365	7.360	7.355	7.351	7.346	7.341	7.337
29	.8805	.8799	.8794	.8788	.8783	.8777	.8772	.8766	.8761	.8755
	7.332	7.328	7.323	7.318	7.314	7.309	7.305	7.300	7.295	7.291
30	.8750	.8745	.8739	.8734	.8728	.8723	.8717	.8712	.8706	.8701
	7.286	7.282	7.277	7.273	7.268	7.264	7.259	7.254	7.249	7.245
31	.8696	.8690	.8685	.8679	.8674	.8669	.8663	.8658	.8653	.8647
	7.241	7.236	7.232	7.227	7.223	7.218	7.214	7.210	7.205	7.201
32	.8642	.8637	.8631	.8626	.8621	.8615	.8610	.8605	.8600	.8594
	7.196	7.192	7.187	7.183	7.178	7.173	7.169	7.165	7.161	7.156
33	.8589	.8584	.8578	.8573	.8568	.8563	.8557	.8552	.8547	.8542
	7.152	7.147	7.143	7.139	7.134	7.130	7.125	7.121	7.117	7.113
34	.8537	.8531	.8526	.8521	.8516	.8511	.8505	.8500	.8496	.8490
	7.108	7.104	7.100	7.095	7.091	7.087	7.082	7.078	7.074	7.069
35	.8485	.8480	.8475	.8469	.8464	.8459	.8454	.8449	.8444	.8439
	7.065	7.061	7.057	7.052	7.048	7.044	7.039	7.035	7.031	7.027
36	.8434	.8429	.8424	.8419	.8413	.8408	.8403	.8398	.8393	.8388
	7.022	7.018	7.014	7.010	7.006	7.001	6.997	6.993	6.989	6.985
37	.8383	.8378	.8373	.8368	.8363	.8358	.8353	.8348	.8343	.8338
	6.980	6.976	6.972	6.968	6.964	6.960	6.955	6.951	6.947	6.943
38	.8333	.8328	.8323	.8318	.8314	.8309	.8304	.8299	.8294	.8289
	6.939	6.935	6.930	6.926	6.922	6.918	6.914	6.910	6.906	6.902

BAUME', SPECIFIC GRAVITY AND POUNDS PER GALLON—Con.
U. S. BUREAU OF STANDARDS—Con.

	0	1	2	3	4	5	6	7	8	9
39	.8284 6.898	.8279 6.894	.8274 6.889	.8269 6.885	.8264 6.881	.8260 6.877	.8255 6.873	.8250 6.869	.8245 6.865	.8240 6.861
40	.8235 6.857	.8230 6.853	.8226 6.849	.8221 6.845	.8216 6.841	.8211 6.837	.8206 6.833	.8202 6.829	.8197 6.825	.8192 6.821
41	.8187 6.817	.8182 6.813	.8178 6.809	.8173 6.805	.8168 6.801	.8163 6.797	.8159 6.793	.8154 6.789	.8149 6.785	.8144 6.781
42	.8140 6.777	.8135 6.773	.8130 6.769	.8125 6.765	.8121 6.761	.8116 6.758	.8111 6.754	.8107 6.750	.8102 6.746	.8097 6.742
43	.8092 6.738	.8088 6.734	.8083 6.730	.8078 6.726	.8074 6.722	.8069 6.718	.8065 6.715	.8060 6.711	.8055 6.707	.8051 6.703
44	.8046 6.699	.8041 6.695	.8037 6.691	.8032 6.688	.8028 6.684	.8023 6.680	.8018 6.676	.8014 6.672	.8009 6.668	.8005 6.665
45	.8000 6.661	.7995 6.657	.7991 6.653	.7986 6.649	.7982 6.646	.7977 6.642	.7973 6.638	.7968 6.634	.7964 6.630	.7959 6.627
46	.7955 6.623	.7950 6.619	.7946 6.616	.7941 6.612	.7937 6.608	.7932 6.604	.7928 6.600	.7923 6.597	.7919 6.593	.7914 6.589
47	.7910 6.586	.7905 6.582	.7901 6.578	.7896 6.574	.7892 6.571	.7887 6.567	.7883 6.563	.7878 6.560	.7874 6.556	.7870 6.552
48	.7865 6.548	.7861 6.545	.7856 6.541	.7852 6.537	.7848 6.534	.7843 6.530	.7839 6.526	.7834 6.523	.7830 6.519	.7826 6.515
49	.7821 6.511	.7817 6.508	.7812 6.504	.7808 6.501	.7804 6.497	.7799 6.494	.7795 6.490	.7791 6.486	.7786 6.483	.7782 6.479
50	.7778 6.476	.7773 6.472	.7769 6.468	.7765 6.465	.7761 6.461	.7756 6.458	.7752 6.454	.7748 6.450	.7743 6.447	.7739 6.443
51	.7735 6.440	.7731 6.436	.7726 6.432	.7722 6.429	.7717 6.425	.7713 6.421	.7709 6.418	.7705 6.415	.7701 6.411	.7697 6.408
52	.7692 6.404	.7688 6.401	.7684 6.397	.7680 6.394	.7675 6.390	.7671 6.387	.7667 6.383	.7663 6.380	.7659 6.376	.7654 6.373
53	.7650 6.369	.7646 6.366	.7642 6.362	.7638 6.359	.7634 6.355	.7629 6.351	.7625 6.348	.7621 6.345	.7617 6.341	.7613 6.338
54	.7609 6.334	.7605 6.331	.7600 6.327	.7596 6.324	.7592 6.321	.7588 6.317	.7584 6.314	.7580 6.311	.7576 6.307	.7572 6.304
55	.7568 6.300	.7563 6.296	.7559 6.293	.7555 6.290	.7551 6.287	.7547 6.283	.7543 6.280	.7539 6.276	.7535 6.273	.7531 6.270
56	.7527 6.266	.7523 6.263	.7519 6.250	.7515 6.256	.7511 6.253	.7507 6.249	.7503 6.246	.7499 6.243	.7495 6.240	.7491 6.236
57	.7487 6.233	.7483 6.229	.7479 6.226	.7475 6.223	.7471 6.219	.7467 6.216	.7463 6.213	.7459 6.209	.7455 6.206	.7451 6.203
58	.7447 6.199	.7443 6.196	.7439 6.193	.7435 6.190	.7431 6.186	.7427 6.183	.7423 6.180	.7419 6.176	.7415 6.173	.7411 6.170
59	.7407 6.166	.7403 6.163	.7400 6.160	.7396 6.157	.7392 6.154	.7388 6.150	.7384 6.147	.7380 6.144	.7376 6.141	.7372 6.137
60	.7368 6.134	.7365 6.131	.7361 6.128	.7357 6.124	.7353 6.121	.7349 6.118	.7345 6.115	.7341 6.112	.7338 6.108	.7334 6.105
61	.7330 6.102	.7326 6.099	.7322 6.096	.7318 6.093	.7315 6.090	.7311 6.086	.7307 6.983	.7303 6.080	.7299 6.077	.7295 6.073
62	.7292 6.070	.7288 6.067	.7284 6.064	.7280 6.060	.7277 6.057	.7273 6.054	.7269 6.051	.7265 6.948	.7261 6.045	.7258 6.042
63	.7254 6.038	.7250 6.035	.7246 6.032	.7243 6.029	.7239 6.026	.7235 6.023	.7231 6.020	.7228 6.017	.7224 6.014	.7220 6.010
64	.7216 6.007	.7213 6.004	.7209 6.001	.7205 5.998	.7202 5.995	.7198 5.992	.7194 5.989	.7191 5.986	.7187 5.983	.7183 5.980
65	.7179 5.976	.7176 5.973	.7172 5.970	.7168 5.967	.7165 5.964	.7161 5.961	.7157 5.958	.7154 5.955	.7150 5.952	.7147 5.949
66	.7143 5.946	.7139 5.943	.7136 5.940	.7132 5.937	.7128 5.934	.7125 5.931	.7121 5.928	.7117 5.925	.7114 5.922	.7110 5.919
67	.7107 5.916	.7103 5.913	.7099 5.910	.7096 5.907	.7092 5.904	.7089 5.901	.7085 5.898	.7081 5.895	.7078 5.892	.7074 5.889

BAUME', SPECIFIC GRAVITY AND POUNDS PER GALLON—Con
U. S. BUREAU OF STANDARDS—Con.

	0	1	2	3	4	5	6	7	8	9
68	.7071	.7067	.7064	.7060	.7056	.7053	.7049	.7046	.7042	.7039
	5.886	5.883	5.880	5.877	5.874	5.871	5.868	5.865	5.862	5.859
69	.7035	.7032	.7028	.7025	.7021	.7018	.7014	.7011	.7007	.7004
	5.856	5.853	5.850	5.848	5.845	5.842	5.839	5.836	5.833	5.830
70	.7000	.6997	.6993	.6990	.6986	.6983	.6979	.6976	.6972	.6669
	5.827	5.824	5.821	5.818	5.815	5.812	5.810	5.807	5.804	5.801
71	.6965	.6962	.6958	.6955	.6951	.6948	.6944	.6941	.6938	.6934
	5.798	5.795	5.792	5.789	5.786	5.784	5.781	5.778	5.775	5.772
72	.6931	.6927	.6924	.6920	.6917	.6914	.6910	.6907	.6903	.6900
	5.769	5.766	5.763	5.760	5.758	5.755	5.752	5.749	5.746	5.744
73	.6897	.6893	.6890	.6886	.6883	.6880	.6876	.6873	.6869	.6866
	5.741	5.738	5.735	5.732	5.729	5.727	5.724	5.721	5.718	5.715
74	.6863	.6859	.6856	.6853	.6849	.6846	.6843	.6839	.6836	.6833
	5.712	5.710	5.707	5.704	5.701	5.698	5.696	5.693	5.690	5.687
75	.6829	.6826	.6823	.6819	.6816	.6813	.6809	.6806	.6803	.6799
	5.685	5.682	5.679	5.676	5.673	5.671	5.668	5.665	5.662	5.660
76	.6796	.6793	.6790	.6786	.6783	.6780	.6776	.6773	.6770	.6767
	5.657	5.654	5.652	5.649	5.646	5.643	5.640	5.638	5.635	5.632
77	.6763	.6760	.6757	.6753	.6750	.6747	.6744	.6740	.6737	.6734
	5.629	5.627	5.624	5.621	5.618	5.616	5.613	5.610	5.608	5.605
78	.6731	.6728	.6724	.6721	.6718	.6715	.6711	.6708	.6705	.6702
	5.602	5.600	5.597	5.594	5.592	5.589	5.586	5.584	5.581	5.578
79	.6699	.6695	.6692	.6689	.6686	.6683	.6679	.6676	.6673	.6670
	5.576	5.573	5.570	5.568	5.565	5.562	5.560	5.557	5.554	5.552
80	.6667	.6663	.6660	.6657	.6654	.6651	.6648	.6645	.6641	.6638
	5,549	5.546	5.543	5.541	5.538	5.536	5.533	5.531	5.528	5.525
81	.6635	.6632	.6629	.6626	.6623	.6619	.6616	.6613	.6610	.6607
	5.522	5.520	5.517	5.515	5.512	5.510	5.507	5.504	5.502	5.490
82	.6604	.6601	.6598	.6594	.6591	.6588	.6585	.6582	.6579	.6576
	5.497	5.494	5.491	5.489	5.486	5.484	5.481	5.478	5.476	5.473
83	.6573	.6570	.6567	.6564	.6560	.6557	.6554	.6551	.6548	.6545
	5.471	5.468	5.466	5.463	5.460	5.458	5.455	5.453	5.450	5.448
84	.6542	.6539	.6536	.6533	.6530	.6527	.6524	.6521	.6518	.6515
	5.445	5.443	5.440	5.437	5.435	5.432	5.430	5.427	5.425	5.422
85	.6512	.6509	.6506	.6503	.6500	.6497	.6494	.6490	.6487	.6484
	5.420	5.417	5.415	5.412	5.410	5.407	5.405	5.402	5.400	5.397
86	.6482	.6479	.6476	.6473	.6470	.6467	.6464	.6461	.6558	.6455
	5.395	5.392	5.390	5.387	5.385	5.382	5.380	5.377	5.375	5.372
87	.6452	.6449	.6446	.6443	.6440	.6437	.6434	.6431	.6428	.6425
	5.370	5.367	5.365	5.362	5.360	5.357	5.355	5.352	5.350	5.347
88	.6422	.6419	.6416	.6413	.6410	.6407	.6404	.6401	.6399	.6396
	5.345	5.343	5.340	5.338	5.335	5.333	5.330	5.328	5.325	5.323
89	.6393	.6390	.6387	.6384	.6391	.6378	.6375	.6372	.6369	.6367
	5.320	5.318	5.316	5.313	5.311	5.308	5.306	5.304	5.301	5.299
90	.6364	.6361	.6358	.6355	.6352	.6349	.6346	.6343	.6341	.6338
	5.296	5.294	5.291	5.289	5.286	5.284	5.281	5.279	5.277	5.275
91	.6335	.6332	.6329	.6326	.6323	.6321	.6318	.6315	.6312	.6309
	5.272	5.270	5.267	5.265	5.263	5.261	5.258	5.256	5.253	5.251
92	.6306	.6303	.6301	.6298	.6295	.6292	.6289	.6286	.6284	.6281
	5.248	5.246	5.214	5.241	5.239	5.236	5.234	5.232	5.230	5.227
93	.6278	.6275	.6272	.6270	.6267	.6264	.6261	.6258	.6256	.6253
	5.225	5.222	5.220	5.218	5.216	5.213	5.210	5.208	5.206	5.204
94	.6250	.6247	.6214	.6242	.6239	.6236	.6233	.6231	.6228	.6225
	5.201	5.199	5.196	5.194	5.192	5.190	5.187	5.185	5.183	5.180
95	.6222	.6219	.6217	.6214	.6211	.6208	.6206	.6203	.6200	.6197
	5.178	5.176	5.174	5.171	5.169	5.166	5.164	5.162	5.160	5.157
96	.6195	.6192	.6189	.6186	.6184	.6181	.6178	.6176	.6173	.6170
	5.155	5.153	5.150	5.148	5.146	5.144	5.142	5.140	5.137	5.135
97	.6167	.6165	.6162	.6159	.6157	.6154	.6151	.6148	.6146	.6143
	5.132	5.130	5.128	5.126	5.124	5.121	5.119	5.116	5.114	5.112
98	.6140	.6138	.6135	.6132	.6130	.6127	.6124	.6122	.6119	.6116
	5.110	5.108	5.106	5.103	5.101	5.099	5.096	5.094	5.092	5.090
99	.6114	.6111	.6108	.6106	.6103	.6100	.6098	.6095	.6092	.6090
	5.088	5.085	5.083	5.081	5.079	5.076	5.074	5.072	5.070	5.068
100	.6087	....	....	....	....	....	....	....	....	....
	5.066	....	....	....	....	....	....	....	....	....

BAUME', SPECIFIC GRAVITY AND POUNDS PER GALLON. (MODULUS 141.5 TAGLIABUE.)

	0	1	2	3	4	5	6	7	8	9
10	1.0000	.9993	.9986	.9979	.9972	.9965	.9958	.9951	.9944	.9937
	8.331	8.325	8.319	8.314	8.308	8.302	8.296	8.290	8.284	8.279
11	.9930	.9923	.9916	.9909	.9902	.9895	.9888	.9881	.9874	.9868
	8.273	8.267	8.261	8.255	8.249	8.244	8.238	8.232	8.226	8.221
12	.9861	.9854	.9847	.9840	.9833	.9826	.9820	.9813	.9806	.9799
	8.215	8.209	8.204	8.198	8.192	8.186	8.181	8.175	8.169	8.164
13	.9792	.9786	.9779	.9772	.9765	.9759	.9752	.9745	.9738	.9732
	8.158	8.153	8.147	8.141	8.135	8.130	8.124	8.119	8.113	8.108
14	.9725	.9718	.9712	.9705	.9698	.9692	.9685	.9679	.9672	.9665
	8.102	8.096	8.091	8.085	8.079	8.074	8.069	8.064	8.058	8.052
15	.9659	.9652	.9646	.9639	.9632	.9626	.9619	.9613	.9606	.9600
	8.047	8.041	8.036	8.030	8.024	8.019	8.014	8.009	8.003	7.998
16	.9593	.9587	.9580	.9574	.9567	.9561	.9554	.9548	.9542	.9535
	7.992	7.987	7.981	7.976	7.970	7.965	7.959	7.954	7.949	7.944
17	.9529	.9522	.9516	.9509	.9503	.9497	.9490	.9484	.9478	.9471
	7.939	7.933	7.928	7.922	7.917	7.912	7.906	7.901	7.896	7.890
18	.9465	.9459	.9452	.9446	.9440	.9433	.9427	.9421	.9415	.9408
	7.885	7.880	7.874	7.869	7.864	7.859	7.854	7.849	7.844	7.838
19	.9402	.9396	.9390	.9383	.9377	.9371	.9365	.9359	.9352	.9346
	7.833	7.828	7.823	7.817	7.812	7.807	7.802	7.797	7.791	7.786
20	.9340	.9334	.9328	.9322	.9315	.9309	.9303	.9297	.9291	.9285
	7.781	7.776	7.771	7.766	7.760	7.755	7.750	7.745	7.740	7.735
21	.9279	.9273	.9267	.9260	.9254	.9248	.9242	.9236	.9230	.9224
	7.730	7.725	7.720	7.715	7.710	7.705	7.700	7.695	7.690	7.685
22	.9218	.9212	.9206	.9200	.9194	.9188	.9182	.9176	.9170	.9165
	7.680	7.675	7.670	7.665	7.660	7.655	7.650	7.645	7.640	7.635
23	.9159	.9153	.9147	.9141	.9135	.9129	.9123	.9117	.9111	.9106
	7.630	7.625	7.620	7.615	7.610	7.605	7.600	7.595	7.590	7.586
24	.9100	.9094	.9088	.9082	.9076	.9071	.9065	.9059	.9053	.9047
	7.581	7.576	7.571	7.566	7.561	7.557	7.552	7.547	7.542	7.537
25	.9042	.9036	.9030	.9024	.9018	.9013	.9007	.9001	.8996	.8990
	7.533	7.528	7.523	7.518	7.513	7.509	7.504	7.499	7.495	7.490
26	.8984	.8978	.8973	.8967	.8961	.8956	.8950	.8944	.8939	.8933
	7.485	7.480	7.475	7.471	7.465	7.461	7.456	7.451	7.447	7.442
27	.8827	.8922	.8916	.8911	.8905	.8899	.8894	.8888	.8883	.8877
	7.437	7.433	7.428	7.424	7.419	7.414	7.410	7.405	7.400	7.395
28	.8871	.8866	.8860	.8855	.8849	.8844	.8838	.8833	.8827	.8822
	7.390	7.386	7.381	7.377	7.372	7.368	7.363	7.359	7.354	7.350
29	.8816	.8811	.8805	.8800	.8794	.8789	.8783	.8778	.8772	.8767
	7.345	7.340	7.335	7.331	7.326	7.322'	7.318	7.313	7.308	7.304
30	.8762	.8756	.8751	.8745	.8740	.8735	.8729	.8724	.8718	.8713
	7.300	7.295	7.290	7.285	7.281	7.277	2.272	7.268	7.263	7.259
31	.8708	.8702	.8697	.8692	.8686	.8681	.8676	.8670	.8665	.8660
	7.255	7.250	7.245	7.241	7.236	7.232	7.228	7.223	7.219	7.215
32	.8654	.8649	.8644	.8639	.8633	.8628	.8623	.8618	.8612	.8607
	7.210	7.205	7.201	7.197	7.192	7.188	7.184	7.180	7.175	7.170
33	.8602	.8597	.8591	.8586	.8581	.8576	.8571	.8565	.8560	.8555
	7.166	7.162	7.157	7.153	7.149	7.145	7.141	7.136	7.131	7.127
34	.8550	.8545	.8540	.8534	.8529	.8524	.8519	.8514	.8509	.8504
	7.123	7.119	7.115	7.110	7.106	7.101	7.097	7.093	7.089	7.085
35	.8498	.8493	.8488	.8483	.8478	.8473	.8468	.8463	.8458	.8453
	7.080	7.076	7.071	7.067	7.063	7.059	7.055	7.051	7.046	7.042
36	.8448	.8443	.8438	.8433	.8428	.8423	.8418	.8413	.8408	.8403
	7.038	7.034	7.030	7.026	7.021	7.017	7.013	7.009	7.005	7.001
37	.8398	.8393	.8388	.8383	.8378	.8373	.8368	.8363	.8358	.8353
	6.996	6.992	6.988	6.984	6.980	6.976	6.971	6.967	6.963	6.959
38	.8348	.8343	.8338	.8333	.8328	.8324	.8319	.8314	.8309	.8304
	6.955	6.951	6.946	6.942	6.938	6.935	6.931	6.926	6.922	6.918

BAUME', SPECIFIC GRAVITY AND POUNDS PER GALLON—Con. (MODULUS 141.5.)

	0	1	2	3	4	5	6	7	8	9
39	.8299 6.914	.8294 6.910	.8289 6.906	.8285 6.902	.8280 6.898	.8275 6.894	.8270 6.890	.8265 6.886	.8260 6.881	.8256 6.878
40	.8251 6.874	.8246 6.870	.8241 6.866	.8236 6.861	.8232 6.858	.8227 6.854	.8222 6.850	.8217 6.846	.8212 6.841	.8208 6.838
41	.8203 6.834	.8198 6.830	.8193 6.826	.8189 6.822	.8184 6.818	.8179 6.814	.8174 6.810	.8170 6.806	.8165 6.802	.8160 6.798
42	.8156 6.795	.8151 6.791	.8146 6.786	.8142 6.783	.8137 6.779	.8132 6.775	.8128 6.771	.8123 6.767	.8118 6.763	.8114 6.760
43	.8109 6.756	.8104 6.751	.8100 6.748	.8095 6.744	.8090 6.740	.8086 6.736	.8081 6.732	.8076 6.728	.8072 6.725	.8067 6.721
44	.8063 6.717	.8058 6.713	.8053 6.709	.8049 6.706	.8044 6.701	.8040 6.698	.8035 6.694	.8031 6.691	.8026 6.868	.8022 6.683
45	.8017 6.679	.8012 6.675	.8008 6.671	.8003 6.667	.7999 6.664	.7994 6.660	.7990 6.656	.7985 6.652	.9781 6.649	.7976 6.645
46	.7972 6.641	.7967 6.637	.7963 6.634	.7958 6.630	.7954 6.626	.7949 6.623	.7945 6.619	.7941 6.616	.7936 6.611	.7932 6.608
47	.7927 6.604	.7923 6.601	.7918 6.596	.7914 6.593	.7909 6.589	.7905 6.586	.7901 6.582	.7896 6.578	.7892 6.575	.7887 6.571
48	.7883 6.567	.7879 6.564	.7874 6.560	.7870 6.556	.7865 6.552	.7861 6.549	.7857 6.546	.7852 6.542	.7848 6.538	.7844 6.535
49	.7839 6.531	.7835 6.527	.7831 6.524	.7826 6.520	.7822 6.517	.7818 6.513	.7813 6.500	.7809 6.506	.7805 6.502	.7800 6.498
50	.7796 6.495	.7792 6.492	.7788 6.488	.7783 6.484	.7779 6.481	.7775 6.477	.7770 6.473	.7766 6.470	.7762 6.467	.7758 6.463
51	.7753 6.459	.7749 6.456	.7745 6.452	.7741 6.449	.7736 6.445	.7732 6.442	.7728 6.438	.7724 6.435	.7720 6.432	.7715 6.427
52	.7711 6.424	.7707 6.421	.7703 6.417	.7699 6.414	.7694 6.410	.7690 6.407	.7686 6.403	.7682 6.400	.7678 6.397	.7674 6.393
53	.7669 6.389	.7665 6.386	.7661 6.382	.7657 6.379	.7653 6.376	.7649 6.372	.7645 6.369	.7640 6.365	.7636 6.362	.7632 6.358
54	.7628 6.355	.7624 6.352	.7620 6.348	.7616 6.345	.7612 6.342	.7608 6.338	.7603 6.334	.7599 6.331	.7595 6.327	.7591 6.324
55	.7587 6.321	.7583 6.317	.7579 6.314	.7575 6.311	.7571 6.307	.7567 6.304	.7563 6.301	.7559 6.297	.7555 6.294	.7551 6.291
56	.7547 6.287	.7543 6.284	.7539 6.281	.7535 6.277	.7531 6.274	.7527 6.271	.7523 6.267	.7519 6.264	.7515 6.261	.7511 6.257
57	.7507 6.254	.7503 6.251	.7499 6.247	.7495 6.244	.7491 6.241	.7487 6.237	.7483 6.234	.7479 6.231	.7475 6.227	.7471 6.224
58	.7467 6.221	.7463 6.217	.7459 6.214	.7455 62.11	.7451 6.207	.7447 6.204	.7443 6.201	.7440 6.198	.7436 6.195	.7432 6.191
59	.7428 6.188	.7424 6.185	.7420 6.182	.7416 6.178	.7412 6.175	.7408 6.172	.7405 6.169	.7401 6.166	.7397 6.162	.7393 6.159
60	.7389 6.156	.7385 6.152	.7381 6.149	.7377 6.146	.7374 6.143	.7370 6.140	.7366 6.137	.7362 6.133	.7358 6.130	.7354 6.127
61	.7351 6.124	.7347 6.121	.7343 6.117	.7339 6.114	.7335 6.111	.7332 6.108	.7328 6.105	.7324 6.102	.7320 6.098	.7316 6.095
62	.7313 6.092	.7309 6.089	.7305 6.086	.7301 6.082	.7298 6.080	.7294 6.077	.7290 6.073	.7286 6.070	.7283 6.067	.7279 6.064
63	.7275 6.061	.7271 6.057	.7268 6.055	.7264 6.052	.7260 6.048	.7256 6.045	.7253 6.042	.7249 6.039	.7245 6.036	.7242 6.033
64	.7238 6.030	.7234 6.027	.7230 6.023	.7227 6.021	.7223 6.017	.7219 6.014	.7216 6.012	.7212 6.008	.7208 6.005	.7205 6.002
65	.7201 5.999	.7197 5.996	.7194 5.993	.7190 5.990	.7186 5.987	.7183 5.984	.7179 5.981	.7175 5.977	.7172 5.975	.7168 5.972
66	.7165 5.969	.7161 5.966	.7157 5.962	.7154 5.960	.7150 5.957	.7146 5.953	.7143 5.951	.7139 5.948	.7136 5.945	.7132 5.942
67	.7128 5.938	.7125 5.936	.7121 5.933	.7118 5.930	.7114 5.927	.7111 5.924	.7107 5.921	.7103 5.918	.7100 5.915	.7096 5.912

BAUME', SPECIFIC GRAVITY AND POUNDS PER GALLON—Con.
(MODULUS 141.5.)

	0	1	2	3	4	5	6	7	8	9
68	.7093 5.909	.7089 5.906	.7086 5.903	.7082 5.900	.7079 5.898	.7075 5.894	.7071 5.891	.7068 5.888	.7064 5.885	.7061 5.883
69	.7057 5.879	.7054 5.877	.7050 5.873	.7047 5.871	.7043 5.868	.7040 5.865	.7036 5.862	.7033 5.859	.7029 5.856	.7026 5.853
70	.7022 5.850	.7019 5.848	.7015 5.844	.7012 5.842	.7008 5.838	.7005 5.836	.7001 5.833	.6998 5.830	.6995 5.828	.6991 5.824
71	.6988 5.822	.6984 5.818	.6981 5.816	.6977 5.813	.6974 5.810	.6970 5.807	.6967 5.804	.6964 5.802	.6960 5.798	.6957 5.796
72	.6953 5.793	.6950 5.790	.6946 5.787	.6943 5.784	.6940 5.782	.6936 5.778	.6933 5.776	.6929 5.773	.6926 5.770	.6923 5.768
73	.6919 5.764	.6916 5.762	.6912 5.758	.6909 5.756	.6906 5.753	.6902 5.750	.6899 5.748	.6896 5.745	.6892 5.742	.6889 5.739
74	.6886 5.737	.6882 5.733	.6879 5.731	.6876 5.728	.6872 5.725	.6869 5.723	.6866 5.720	.6862 5.717	.6859 5.714	.6856 5.712
75	.6852 5.708	.6849 5.706	.6846 5.703	.6842 5.700	.6839 5.698	.6836 5.695	.6832 5.692	.6829 5.689	.6826 5.687	.6823 5.684
76	.6819 5.681	.6816 5.678	6813 5.676	.6809 5.673	.6806 5.670	.6803 5.668	.6800 5.665	.6796 5.662	.6793 5.659	.6790 5.657
77	.6787 5.654	.6783 5.651	.6780 5.648	.6777 5.646	.6774 5.643	.6770 5.640	.6767 5.638	.6764 5.635	.6761 5.633	.6757 5.629
78	.6754 5.627	.6751 5.624	.6748 5.622	.6745 5.619	.6741 5.616	.6738 5.613	.6735 5.611	.6732 5.608	.6728 5.605	.6725 5.603
79	.6722 5.600	.6719 5.597	.6716 5.595	.6713 5.593	.6709 5.589	.6706 5.587	.6703 5.584	.6700 5.582	.6697 5.579	.6693 5.576
80	.6690 5.573	.6687 5.571	.6684 5.568	.6681 5.566	.6678 5.563	.6675 5.561	.6671 5.558	.6668 5.555	.6665 5.553	.6662 5.550
81	.6659 5.548	.6656 5.545	.6653 5.543	.6649 5.540	.6646 5.537	.6643 5.534	.6640 5.532	.6637 5.529	.6634 5.527	.6631 5.524
82	.6628 5.522	.6625 5.519	.6621 5.516	.6618 5.513	.6615 5.511	.6612 5.508	.6609 5.506	.6606 5.503	.6603 5.501	.6600 5.498
83	.6597 5.496	.6594 5.493	.6591 5.491	.6588 5.488	.6584 5.485	.6581 5.483	.6578 5.480	.6575 5.478	.6572 5.475	.6569 5.473
84	.6566 5.470	.6563 5.468	.6560 5.465	.6557 5.463	.6554 5.460	.6551 5.458	.6548 5.455	.6545 5.453	.6542 5.450	.6539 5.448
85	.6536 5.445	.6533 5.443	.6530 5.440	.6527 5.438	.6524 5.435	.6521 5.433	.6518 5.430	.6515 5.428	.6512 5.425	.6509 5.423
86	.6506 5.420	.6503 5.418	.6500 5.415	.6497 5.419	.6494 5.410	.6491 5.408	.6488 5.405	.6485 5.403	.6482 5.400	.6479 5.398
87	.6476 5.395	.6473 5.393	.6470 5.390	.6467 5.388	.6464 5.385	.6461 5.383	.6458 5.380	.6455 5.378	.6452 5.375	.6449 5.373
88	.6446 5.370	.6444 5.368	.6441 5.366	.6438 5.363	.6435 5.361	.6432 5.358	.6429 5.356	.6426 5.353	.6423 5.351	.6420 5.349
89	.6417 5.346	.6414 5.344	.6411 5.341	.6409 5.339	.6406 5.237	.6403 5.334	.6400 5.332	.6397 5.329	.6394 5.327	.6391 5.324
90	.6388 5.322	.6385 5.319	.6382 5.317	.6380 5.315	.6377 5.313	.6374 5.310	.6371 5.308	.6368 5.305	.6365 5.303	.6362 5.300
91	.6360 5.299	.6357 5.296	.6354 5.294	.6351 5.291	.6348 5.289	.6345 5.286	.6342 5.284	.6340 5.282	.6337 5.279	.6334 5.277
92	.6331 5.274	.6328 5.272	.6325 5.269	.6323 5.268	.6320 5.265	.6317 5.263	.6314 5.260	.6311 5.258	.6309 5.256	.6306 5.254
93	.6303 5.251	.6300 5.249	.6297 5.246	.6294 5.244	.6292 5.242	.6289 5.239	.6286 5.237	.6283 5.234	.6281 5.233	.6278 5.230
94	.6275 5.228	.6272 5.225	.6269 5.223	.6267 5.221	.6264 5.219	.6261 5.216	.6258 5.214	.6256 5.212	.6253 5.209	.6250 5.207
95	.6247 5.204	.6244 5.202	.6242 5.200	.6239 5.198	.6236 5.195	.6233 5.193	.6231 5.191	.6228 5.189	.6225 5.186	.6223 5.184
96	.6220 5.182	.6217 5.179	.6214 5.177	.6212 5.175	.6209 5.173	.6206 5.170	.6203 5.168	.6201 5.166	.6198 5.164	.6195 5.161
97	.6193 5.159	.6190 5.157	.6187 5.154	.6184 5.152	.6182 5.150	.6179 5.148	.6176 5.145	.6174 5.144	.6171 5.141	.6168 5.139
98	.6166 5.137	.6163 5.134	.6160 5.132	.6158 5.130	.6155 5.128	.6152 5.125	.6150 5.124	.6147 5.121	.6144 5.119	.6141 5.116
99	.6139 5.114	.6136 5.112	.6134 5.110	.6131 5.108	.6128 5.105	.6126 5.104	.6123 5.101	.6120 5.099	.6118 5.097	.6115 5.094

[This table shows the degrees Baumé at 60° F of oils having, at the designated temperatures, the observed degrees Baumé indicated. For example, if the observed degrees Baumé is 20.0 at 78° F, the true degrees Baumé at 60° F will be 19.0. Intermediate values not given in the table may be conveniently interpolated. For example, if the observed degrees Baumé is 20.4 at 78° F, the true degrees Baumé at 60° F will be 19.4. The headings "Observed degrees Baumé" and "Observed temperature" signify the true indication of the hydrometer and the true temperature of the oil—that is, the observed readings corrected, if necessary, for instrumental errors.]

Observed temperature in °F	Observed degrees Baumé									
	17.0	18.0	19.0	20.0	21.0	22.0	23.0	24.0	25.0	26.0
	Corresponding degrees Baumé at 60° F									
30	18.6	19.7	20.7	21.7	22.7	23.7	24.8	25.8	26.9	27.9
32	18.6	19.6	20.6	21.6	22.6	23.6	24.7	25.7	26.8	27.8
34	18.5	19.5	20.5	21.5	22.5	23.5	24.6	25.6	26.7	27.7
36	18.3	19.4	20.4	21.4	22.4	23.4	24.5	25.5	26.5	27.5
38	18.2	19.3	20.3	21.3	22.3	23.3	24.4	25.4	26.4	27.4
40	18.1	19.1	20.1	21.2	22.2	23.2	24.2	25.2	26.2	27.2
42	18.0	19.0	20.0	21.1	22.1	23.1	24.1	25.1	26.1	27.1
44	17.9	18.9	19.9	20.9	21.9	22.9	23.9	24.9	26.0	27.0
46	17.8	18.8	19.8	20.8	21.8	22.8	23.8	24.8	25.9	26.9
48	17.6	18.7	19.7	20.7	21.7	22.7	23.7	24.7	25.8	26.8
50	17.5	18.6	19.6	20.6	21.6	22.6	23.6	24.6	25.6	26.6
52	17.4	18.5	19.5	20.5	21.5	22.5	23.5	24.5	25.5	26.5
54	17.3	18.3	19.3	20.3	21.3	22.3	23.3	24.3	25.4	26.4
56	17.2	18.2	19.2	20.2	21.2	22.2	23.2	24.2	25.3	26.3
58	17.1	18.1	19.1	20.1	21.1	22.1	23.1	24.1	25.1	26.1
60	17.0	18.0	19.0	20.0	21.0	22.0	23.0	24.0	25.0	26.0
62		17.9	18.9	19.9	20.9	21.9	22.9	23.9	24.9	25.9
64		17.8	18.8	19.8	20.8	21.8	22.8	23.8	24.7	25.7
66		17.7	18.7	19.7	20.7	21.7	22.7	23.7	24.6	25.6
68		17.6	18.6	19.5	20.5	21.5	22.5	23.5	24.5	25.5
70		17.5	18.5	19.4	20.4	21.4	22.4	23.4	24.4	25.4
72		17.4	18.4	19.3	20.3	21.3	22.3	23.3	24.3	25.3
74		17.2	18.2	19.2	20.2	21.2	22.2	23.2	24.1	25.1
76		17.2	18.1	19.1	20.1	21.1	22.1	23.1	24.0	25.0
78		17.1	18.0	19.0	19.9	20.9	21.9	22.9	23.9	24.9
80			17.9	18.9	19.8	20.8	21.8	22.8	23.8	24.8
82			17.8	18.8	19.7	20.7	21.7	22.7	23.7	24.7
84			17.7	18.7	19.6	20.6	21.6	22.6	23.5	24.5
86			17.6	18.6	19.5	20.5	21.5	22.5	23.4	24.4
88			17.5	18.4	19.4	20.4	21.3	22.3	23.3	24.3
90			17.3	18.3	19.3	20.3	21.2	22.2	23.2	24.2
92			17.2	18.2	19.2	20.2	21.1	22.1	23.1	24.1
94			17.1	18.1	19.1	20.1	21.0	22.0	23.0	24.0
96			17.0	18.0	19.0	20.0	20.9	21.9	22.8	23.8
98				17.9	18.8	19.8	20.8	21.8	22.7	23.7
100				17.8	18.7	19.7	20.7	21.7	22.6	23.6
102				17.7	18.6	19.6	20.5	21.5	22.5	23.5
104				17.6	18.5	19.5	20.4	21.4	22.4	23.4
106				17.5	18.4	19.4	20.3	21.3	22.3	23.3
108				17.3	18.2	19.2	20.2	21.2	22.2	23.1
110				17.2	18.1	19.1	20.1	21.1	22.0	23.0
112				17.1	18.0	19.0	20.0	21.0	21.9	22.9
114				17.0	17.9	18.9	19.9	20.9	21.8	22.8
116					17.8	18.8	19.8	20.8	21.7	22.7
118					17.7	18.7	19.6	20.6	21.5	22.5
120					17.6	18.6	19.5	20.5	21.4	22.4

Observed temperature in °F	Observed degrees Baumé									
	27.0	28.0	29.0	30.0	31.0	32.0	33.0	34.0	35.0	36.0
	Corresponding degrees Baumé at 60° F									
30	29.0	30.0	31.0	32.0	33.1	34.1	35.2	36.2	37.3	38.3
32	28.8	29.8	30.9	31.9	33.0	34.0	35.0	36.0	37.1	38.1
34	28.7	29.7	30.8	31.8	32.8	33.8	34.8	35.8	36.9	38.0
36	28.5	29.5	30.6	31.6	32.7	33.7	34.7	35.7	36.8	37.8
38	28.4	29.4	30.5	31.5	32.5	33.5	34.5	35.5	36.6	37.7
40	28.3	29.3	30.4	31.4	32.4	33.4	34.4	35.4	36.5	37.5
42	28.2	29.2	30.2	31.2	32.2	33.2	34.3	35.3	36.3	37.3
44	28.1	29.1	30.1	31.1	32.1	33.1	34.2	35.2	36.2	37.2
46	27.9	28.9	29.9	30.9	31.9	32.9	34.0	35.0	36.1	37.1
48	27.8	28.8	29.8	30.8	31.8	32.8	33.9	34.9	35.9	36.9
50	27.6	28.6	29.7	30.7	31.7	32.7	33.7	34.7	35.7	36.7
52	27.5	28.5	29.6	30.6	31.6	32.6	33.6	34.6	35.6	36.6
54	27.4	28.4	29.4	30.4	31.4	32.4	33.4	34.4	35.4	36.4
56	27.3	28.3	29.3	30.3	31.3	32.3	33.3	34.3	35.3	36.3
58	27.1	28.1	29.1	30.1	31.1	32.1	33.1	34.1	35.1	36.1
60	27.0	28.0	29.0	30.0	31.0	32.0	33.0	34.0	35.0	36.0
62	26.9	27.9	28.9	29.9	30.9	31.9	32.9	33.9	34.9	35.9
64	26.7	27.7	28.7	29.7	30.7	31.7	32.7	33.7	34.7	35.7
66	26.6	27.6	28.6	29.6	30.6	31.6	32.6	33.6	34.6	35.6
68	26.5	27.5	28.4	29.4	30.4	31.4	32.4	33.4	34.4	35.4
70	26.4	27.4	28.3	29.3	30.3	31.3	32.2	33.2	34.2	35.2
72	26.3	27.3	28.2	29.2	30.2	31.2	32.1	33.1	34.1	35.1
74	26.1	27.1	28.1	29.1	30.1	31.1	32.0	33.0	33.9	34.9
76	26.0	27.0	27.9	28.9	29.9	30.9	31.8	32.8	33.8	34.8
78	25.8	26.8	27.8	28.8	29.8	30.8	31.7	32.7	33.6	34.6
80	25.7	26.7	27.7	28.7	29.7	30.7	31.6	32.6	33.5	34.5
82	25.6	26.6	27.6	28.6	29.5	30.5	31.5	32.5	33.4	34.4
84	25.5	26.5	27.5	28.5	29.4	30.4	31.3	32.3	33.2	34.2
86	25.4	26.4	27.3	28.3	29.2	30.2	31.2	32.2	33.1	34.1
88	25.2	26.2	27.2	28.2	29.1	30.1	31.0	32.0	33.0	34.0
90	25.1	26.1	27.0	28.0	29.0	30.0	30.9	31.9	32.9	33.9
92	25.0	26.0	26.9	27.9	28.9	29.9	30.8	31.8	32.7	33.7
94	24.9	25.9	26.8	27.8	28.8	29.8	30.7	31.6	32.6	33.6
96	24.7	25.7	26.7	27.7	28.6	29.6	30.5	31.5	32.5	33.5
98	24.6	25.6	26.6	27.6	28.5	29.5	30.4	31.4	32.3	33.3
100	24.5	25.5	26.4	27.4	28.3	29.3	30.3	31.3	32.2	33.2
102	24.4	25.4	26.3	27.3	28.2	29.2	30.2	31.2	32.1	33.0
104	24.3	25.3	26.2	27.1	28.1	29.1	30.0	31.0	31.9	32.9
106	24.2	25.2	26.1	27.0	28.0	29.0	29.9	30.9	31.8	32.7
108	24.0	25.0	25.9	26.9	27.8	28.8	29.7	30.7	31.6	32.6
110	23.9	24.9	25.8	26.8	27.7	28.7	29.6	30.6	31.5	32.5
112	23.8	24.8	25.7	26.7	27.6	28.6	29.5	30.4	31.3	32.3
114	23.7	24.7	25.6	26.6	27.5	28.4	29.3	30.3	31.2	32.2
116	23.6	24.6	25.5	26.4	27.3	28.3	29.2	30.2	31.1	32.1
118	23.4	24.4	25.3	26.3	27.2	28.2	29.1	30.1	31.0	32.0
120	23.3	24.3	25.2	26.2	27.1	28.1	29.0	30.0	30.9	31.9

Observed temperature in ° F	Observed degrees Baumé									
	37.0	38.0	39.0	40.0	41.0	42.0	43.0	44.0	45.0	46.0
	Corresponding degrees Baume at 60° F									
30	39.3	40.3	41.4	42.4	43.5	44.5	45.6	46.6	47.7	48.7
32	39.2	40.2	41.3	42.3	43.4	44.3	45.4	46.4	47.5	48.5
34	39.0	40.0	41.1	42.1	43.2	44.2	45.3	46.3	47.3	48.3
36	38.9	39.9	41.0	42.0	43.1	44.0	45.1	46.1	47.2	48.2
38	38.7	39.7	40.8	41.8	42.9	43.9	45.0	46.0	47.0	48.0
40	38.5	39.5	40.6	41.6	42.7	43.7	44.8	45.8	46.8	47.8
42	38.4	39.4	40.5	41.5	42.5	43.5	44.6	45.6	46.6	47.6
44	38.2	39.2	40.3	41.3	42.4	43.4	44.4	45.4	46.4	47.4
46	38.1	39.1	40.1	41.1	42.2	43.2	44.2	45.2	46.2	47.2
48	37.9	38.9	39.9	40.9	42.0	43.0	44.1	45.1	46.1	47.1
50	37.8	38.8	39.8	40.8	41.8	42.8	43.9	44.9	45.9	46.9
52	37.6	38.6	39.6	40.7	41.7	42.6	43.7	44.7	45.7	46.7
54	37.4	38.4	39.5	40.5	41.5	42.5	43.5	44.5	45.5	46.5
56	37.3	38.3	39.3	40.3	41.3	42.2	43.3	44.3	45.3	46.3
58	37.1	38.1	39.1	40.1	41.1	42.1	43.1	44.1	45.2	46.2
60	37.0	38.0	39.0	40.0	41.0	42.0	43.0	44.0	45.0	46.0
62	36.9	37.9	38.9	39.9	40.9	41.9	42.9	43.9	44.9	45.9
64	36.7	37.7	38.7	39.7	40.7	41.7	42.7	43.7	44.7	45.7
66	36.6	37.6	38.6	39.5	40.5	41.5	42.5	43.5	44.5	45.5
68	36.4	37.4	38.4	39.4	40.4	41.4	42.4	43.3	44.3	45.3
70	36.2	37.2	38.2	39.2	40.2	41.2	42.2	43.1	44.1	45.1
72	36.1	37.1	38.1	39.1	40.0	41.0	42.0	43.0	44.0	45.0
74	35.9	36.9	37.9	38.9	39.8	40.8	41.8	42.8	43.8	44.8
76	35.8	36.8	37.8	38.7	39.7	40.7	41.7	42.7	43.6	44.6
78	35.6	36.6	37.6	38.6	39.5	40.5	41.5	42.5	43.4	44.4
80	35.5	36.5	37.5	38.5	39.4	40.4	41.3	42.3	43.2	44.2
82	35.3	36.3	37.3	38.3	39.2	40.2	41.2	42.2	43.1	44.1
84	35.2	36.2	37.2	38.2	39.1	40.1	41.0	42.0	42.9	43.9
86	35.1	36.1	37.0	38.0	38.9	39.9	40.9	41.9	42.8	43.8
88	34.9	35.9	36.9	37.9	38.8	39.8	40.7	41.7	42.6	43.6
90	34.8	35.8	36.7	37.7	38.6	39.6	40.5	41.5	42.5	43.5
92	34.6	35.6	36.6	37.6	38.5	39.5	40.4	41.4	42.3	43.3
94	34.5	35.5	36.4	37.4	38.3	39.3	40.2	41.2	42.2	43.2
96	34.4	35.4	36.3	37.3	38.2	39.2	40.1	41.1	42.0	43.0
98	34.2	35.2	36.1	37.1	38.0	39.0	39.9	40.9	41.8	42.8
100	34.1	35.1	36.0	37.0	37.9	38.9	39.8	40.7	41.6	42.6
102	33.9	34.9	35.8	36.8	37.7	38.7	39.6	40.6	41.5	42.5
104	33.8	34.8	35.7	36.7	37.6	38.6	39.5	40.4	41.3	42.3
106	33.6	34.6	35.5	36.5	37.4	38.4	39.3	40.3	41.2	42.2
108	33.5	34.5	35.4	36.4	37.3	38.3	39.2	40.1	41.0	42.0
110	33.4	34.4	35.3	36.3	37.2	38.1	39.0	40.0	40.9	41.8
112	33.2	34.2	35.1	36.1	37.0	38.0	38.9	39.8	40.7	41.6
114	33.1	34.1	35.0	36.0	36.9	37.8	38.7	39.7	40.6	41.5
116	33.0	34.0	34.9	35.9	36.8	37.7	38.6	39.5	40.4	41.4
118	32.9	33.9	34.8	35.7	36.6	37.5	38.4	39.4	40.3	41.2
120	32.8	33.7	34.6	35.6	36.5	37.4	38.3	39.2	40.1	41.0

Observed temperature in °F	Observed degrees Baume									
	47.0	48.0	49.0	50.0	51.0	52.0	53.0	54.0	55.0	56.0
	Corresponding degrees Baumé at 60° F									
30	49.8	50.8	51.9	53.0	54.1	55.1	56.2	57.3	58.4	59.4
32	49.6	50.6	51.7	52.8	53.9	54.9	56.0	57.1	58.2	59.2
34	49.4	50.4	51.5	52.6	53.7	54.7	55.8	56.8	57.9	58.9
36	49.3	50.3	51.4	52.4	53.5	54.5	55.6	56.6	57.7	58.7
38	49.1	50.1	51.2	52.2	53.3	54.3	55.4	56.4	57.5	58.5
40	48.9	49.9	51.0	52.0	53.0	54.1	55.2	56.2	57.2	58.2
42	48.7	49.7	50.8	51.8	52.8	53.8	54.9	56.0	57.0	58.0
44	48.5	49.5	50.6	51.6	52.6	53.6	54.7	55.7	56.8	57.8
46	48.3	49.3	50.4	51.4	52.4	53.4	54.5	55.5	56.5	57.5
48	48.1	49.1	50.2	51.2	52.2	53.2	54.2	55.2	56.3	57.3
50	47.9	48.9	50.0	51.0	52.0	53.0	54.0	55.0	56.1	57.1
52	47.7	48.7	49.8	50.8	51.8	52.8	53.8	54.8	55.9	56.9
54	47.6	48.6	49.6	50.6	51.6	52.6	53.6	54.6	55.6	56.6
56	47.4	48.4	49.4	50.4	51.4	52.4	53.4	54.4	55.4	56.4
58	47.2	48.2	49.2	50.2	51.2	52.2	53.2	54.2	55.2	56.2
60	47.0	48.0	49.0	50.0	51.0	52.0	53.0	54.0	55.0	56.0
62	46.9	47.9	48.8	49.8	50.8	51.8	52.8	53.8	54.8	55.8
64	46.7	47.7	48.6	49.6	50.6	51.6	52.6	53.6	54.6	55.6
66	46.5	47.5	48.4	49.4	50.4	51.4	52.4	53.4	54.4	55.4
68	46.3	47.3	48.3	49.3	50.3	51.3	52.2	53.2	54.2	55.2
70	46.1	47.1	48.1	49.1	50.1	51.1	52.0	53.0	54.0	55.0
72	46.0	47.0	47.9	48.9	49.9	50.9	51.8	52.8	53.8	54.8
74	45.8	46.8	47.7	48.7	49.7	50.7	51.6	52.6	53.5	54.5
76	45.6	46.6	47.5	48.5	49.5	50.5	51.4	52.4	53.3	54.3
78	45.4	46.4	47.3	48.3	49.3	50.3	51.2	52.2	53.1	54.1
80	45.2	46.2	47.2	48.2	49.1	50.1	51.0	52.0	52.9	53.9
82	45.1	46.1	47.0	48.0	48.9	49.9	50.8	51.8	52.7	53.7
84	44.9	45.9	46.8	47.8	48.7	49.7	50.6	51.6	52.5	53.5
86	44.7	45.7	46.6	47.6	48.5	49.5	50.4	51.4	52.3	53.3
88	44.5	45.5	46.4	47.4	48.3	49.3	50.2	51.2	52.1	53.1
90	44.4	45.4	46.3	47.3	48.2	49.2	50.1	51.0	51.9	52.9
92	44.2	45.2	46.1	47.1	48.0	49.0	49.9	50.9	51.8	52.7
94	44.1	45.1	46.0	46.9	47.8	48.8	49.7	50.7	51.6	52.5
96	43.9	44.9	45.8	46.7	47.6	48.6	49.5	50.5	51.4	52.3
98	43.7	44.7	45.6	46.6	47.5	48.4	49.3	50.3	51.2	52.1
100	43.5	44.5	45.4	46.4	47.3	48.3	49.2	50.1	51.0	51.9
102	43.4	44.3	45.2	46.2	47.1	48.1	49.0	49.9	50.8	51.7
104	43.2	44.1	45.0	46.0	46.9	47.9	48.8	49.7	50.6	51.5
106	43.1	44.0	44.9	45.8	46.7	47.7	48.6	49.5	50.4	51.3
108	42.9	43.9	44.8	45.7	46.6	47.5	48.4	49.4	50.3	51.2
110	42.7	43.7	44.6	45.6	46.5	47.4	48.3	49.2	50.1	51.0
112	42.5	43.5	44.4	45.4	46.3	47.2	48.1	49.0	49.9	50.8
114	42.4	43.4	44.3	45.3	46.2	47.1	48.0	48.8	49.7	50.6
116	42.3	43.3	44.2	45.1	46.0	46.9	47.8	48.6	49.5	50.4
118	42.1	43.1	44.0	44.9	45.8	46.7	47.6	48.4	49.3	50.2
120	41.9	42.9	43.8	44.7	45.6	46.5	47.4	48.2	49.1	50.0

Observed temperature in ° F	Observed degrees Baumé									
	57.0	58.0	59.0	60.0	61.0	62.0	63.0	64.0	65.0	66.0
	Corresponding degrees Baumé at 60° F									
30	60.5	61.6	62.7	63.7	64.8	65.8	66.9	67.9	69.0	70.0
32	60.3	61.3	62.4	63.4	64.5	65.5	66.6	67.7	68.8	69.8
34	60.0	61.0	62.1	63.1	64.2	65.2	66.3	67.4	68.5	69.5
36	59.8	60.8	61.9	62.9	64.0	65.0	66.1	67.1	68.2	69.2
38	59.5	60.5	61.6	62.6	63.7	64.7	65.8	66.8	67.9	68.9
40	59.3	60.3	61.4	62.4	63.5	64.5	65.5	66.5	67.6	68.6
42	59.1	60.1	61.2	62.2	63.3	64.3	65.3	66.3	67.4	68.4
44	58.9	59.9	61.0	62.0	63.0	64.0	65.0	66.0	67.1	68.1
46	58.6	59.6	60.7	61.7	62.7	63.7	64.8	65.8	66.8	67.8
48	58.4	59.4	60.4	61.4	62.5	63.5	64.5	65.5	66.5	67.5
50	58.1	59.1	60.2	61.2	62.2	63.2	64.2	65.2	66.2	67.2
52	57.9	58.9	60.0	61.0	62.0	63.0	64.0	65.0	66.0	67.0
54	57.7	58.7	59.8	60.8	61.8	62.8	63.8	64.8	65.8	66.8
56	57.5	58.5	59.5	60.5	61.5	62.5	63.6	64.6	65.6	66.6
58	57.3	58.3	59.3	60.3	61.3	62.3	63.3	64.3	65.3	66.3
60	57.0	58.0	59.0	60.0	61.0	62.0	63.0	64.0	65.0	66.0
62	56.8	57.8	58.8	59.8	60.8	61.8	62.7	63.7	64.7	65.7
64	56.6	57.6	58.6	59.6	60.5	61.5	62.5	63.5	64.5	65.5
66	56.4	57.4	58.3	59.3	60.3	61.3	62.3	63.3	64.2	65.2
68	56.1	57.1	58.1	59.1	60.1	61.1	62.1	63.1	64.0	65.0
70	55.9	56.9	57.9	58.9	59.8	60.8	61.8	62.8	63.8	64.8
72	55.7	56.7	57.7	58.7	59.6	60.6	61.6	62.6	63.5	64.5
74	55.5	56.5	57.4	58.4	59.3	60.3	61.3	62.3	63.2	64.2
76	55.3	56.3	57.2	58.2	59.1	60.1	61.0	62.0	63.0	64.0
78	55.0	56.0	57.0	58.0	58.9	59.9	60.8	61.8	62.8	63.8
80	54.8	55.8	56.8	57.8	58.7	59.7	60.6	61.6	62.6	63.6
82	54.6	55.6	56.5	57.5	58.4	59.4	60.4	61.4	62.3	63.3
84	54.4	55.4	56.3	57.3	58.2	59.2	60.1	61.1	62.0	63.0
86	54.2	55.2	56.1	57.1	58.0	59.0	59.9	60.9	61.8	62.8
88	54.0	55.0	55.9	56.9	57.8	58.8	59.7	60.6	61.5	62.5
90	53.8	54.8	55.7	56.7	57.6	58.6	59.5	60.4	61.3	62.3
92	53.6	54.6	55.5	56.5	57.4	58.4	59.3	60.2	61.1	62.1
94	53.4	54.3	55.2	56.2	57.1	58.1	59.0	59.9	60.8	61.8
96	53.2	54.1	55.0	56.0	56.9	57.9	58.8	59.7	60.6	61.6
98	53.0	53.9	54.8	55.8	56.7	57.6	58.5	59.5	60.4	61.3
100	52.8	53.7	54.6	55.6	56.5	57.4	58.3	59.3	60.2	61.1
102	52.6	53.5	54.4	55.4	56.3	57.2	58.1	59.0	59.9	60.9
104	52.4	53.3	54.2	55.2	56.1	57.0	57.9	58.8	59.7	60.7
106	52.2	53.1	54.0	55.0	55.9	56.8	57.7	58.6	59.5	60.4
108	52.1	53.0	53.9	54.8	55.7	56.6	57.5	58.4	59.3	60.2
110	51.9	52.8	53.7	54.6	55.5	56.4	57.3	58.2	59.1	60.0
112	51.7	52.6	53.5	54.4	55.2	56.2	57.1	58.0	58.9	59.8
114	51.5	52.4	53.3	54.2	55.1	56.0	56.9	57.8	58.7	59.6
116	51.3	52.2	53.1	54.0	54.9	55.8	56.7	57.6	58.4	59.3
118	51.1	52.0	52.9	53.8	54.7	55.6	56.5	57.4	58.2	59.1
120	50.9	51.8	52.7	53.6	54.5	55.4	56.3	57.2	58.0	58.9

Observed temperature in ° F	Observed degrees Baumé									
	67.0	68.0	69.0	70.0	71.0	72.0	73.0	74.0	75.0	76.0
	Corresponding degrees Baumé at 60° F									
30	71.1	72.1	73.2	74.3	75.4	76.4	77.5	78.5	79.6	80.7
32	70.9	71.9	73.0	74.0	75.1	76.1	77.2	78.2	79.3	80.4
34	70.6	71.6	72.7	73.7	74.8	75.8	76.9	77.9	79.0	80.1
36	70.3	71.3	72.4	73.4	74.5	75.5	76.6	77.6	78.7	79.7
38	70.0	71.0	72.1	73.1	74.2	75.2	76.3	77.3	78.4	79.4
40	69.7	70.7	71.8	72.8	73.9	74.9	76.0	77.0	78.1	79.1
42	69.4	70.4	71.5	72.5	73.6	74.6	75.7	76.7	77.8	78.8
44	69.1	70.1	71.2	72.2	73.3	74.3	75.4	76.4	77.5	78.5
46	68.8	69.8	70.9	71.9	73.0	74.0	75.1	76.1	77.1	78.1
48	68.6	69.6	70.6	71.6	72.7	73.7	74.8	75.8	76.8	77.8
50	68.3	69.3	70.4	71.4	72.5	73.5	74.5	75.5	76.5	77.5
52	68.0	69.0	70.1	71.1	72.2	73.2	74.2	75.2	76.2	77.2
54	67.8	68.8	69.9	70.9	71.9	72.9	73.9	74.9	75.9	76.9
56	67.6	68.6	69.6	70.6	71.6	72.6	73.6	74.6	75.6	76.6
58	67.3	68.3	69.3	70.3	71.3	72.3	73.3	74.3	75.3	76.3
60	67.0	68.0	69.0	70.0	71.0	72.0	73.0	74.0	75.0	76.0
62	66.7	67.7	68.7	69.7	70.7	71.7	72.7	73.7	74.7	75.7
64	66.4	67.4	68.4	69.4	70.4	71.4	72.4	73.4	74.4	75.4
66	66.2	67.2	68.2	69.2	70.1	71.1	72.1	73.1	74.1	75.1
68	66.0	67.0	67.9	68.9	69.8	70.8	71.8	72.8	73.8	74.8
70	65.7	66.7	67.6	68.6	69.5	70.5	71.5	72.5	73.5	74.5
72	65.4	66.4	67.4	68.4	69.3	70.3	71.2	72.2	73.2	74.2
74	65.2	66.2	67.2	68.2	69.1	70.1	71.0	72.0	72.9	73.9
76	64.9	65.9	66.9	67.9	68.8	69.8	70.8	71.8	72.7	73.7
78	64.7	65.6	66.6	67.6	68.5	69.5	70.5	71.5	72.4	73.4
80	64.5	65.4	66.4	67.4	68.3	69.3	70.2	71.2	72.1	73.1
82	64.2	65.2	66.1	67.1	68.0	69.0	69.9	70.9	71.8	72.8
84	63.9	64.9	65.8	66.8	67.7	68.7	69.6	70.6	71.5	72.5
86	63.7	64.7	65.6	66.6	67.5	68.4	69.3	70.3	71.3	72.3
88	63.4	64.4	65.3	66.3	67.2	68.2	69.1	70.1	71.0	72.0
90	63.2	64.2	65.1	66.1	67.0	68.0	68.9	69.9	70.8	71.7
92	63.0	64.0	64.9	65.8	66.7	67.7	68.6	69.6	70.5	71.4
94	62.7	63.7	64.6	65.6	66.5	67.4	68.3	69.3	70.2	71.1
96	62.5	63.5	64.4	65.4	66.3	67.2	68.1	69.0	69.9	70.8
98	62.2	63.2	64.1	65.1	66.0	66.9	67.8	68.8	69.7	70.6
100	62.0	63.0	63.9	64.9	65.8	66.7	67.6	68.5	69.4	70.4
102	61.8	62.8	63.7	64.6	65.5	66.4	67.3	68.2	69.1	70.1
104	61.6	62.5	63.4	64.3	65.2	66.1	67.0	67.9	68.8	69.8
106	61.3	62.3	63.2	64.1	65.0	65.9	66.8	67.7	68.6	69.5
108	61.1	62.0	62.9	63.8	64.8	65.7	66.6	67.5	68.4	69.3
110	60.9	61.8	62.7	63.6	64.5	65.4	66.3	67.2	68.1	69.0
112	60.7	61.6	62.5	63.3	64.2	65.2	66.1	67.0	67.8	68.7
114	60.5	61.4	62.3	63.1	64.0	64.9	65.8	66.7	67.6	68.5
116	60.2	61.1	62.0	62.9	63.8	64.7	65.6	66.5	67.4	68.3
118	60.0	60.9	61.8	62.7	63.6	64.5	65.4	66.8	67.1	68.0
120	59.8	60.7	61.6	62.5	63.3	64.2	65.1	66.0	66.8	67.7

Observed temperature in °F	Observed degrees Baumé									
	77.0	78.0	79.0	80.0	81.0	82.0	83.0	84.0	85.0	86.0
	Corresponding degrees Baumé at 60° F									
30	81.8	82.9	84.0	85.0	86.1	87.1	88.2	89.3	90.4	91.5
32	81.5	82.6	83.7	84.7	85.8	86.8	87.9	89.0	90.1	91.1
34	81.2	82.2	83.3	84.3	85.4	86.4	87.5	88.6	89.7	90.7
36	80.8	81.9	83.0	84.0	85.1	86.1	87.2	88.2	89.3	90.3
38	80.5	81.5	82.6	83.6	84.7	85.7	86.8	87.8	88.9	89.9
40	80.1	81.1	82.2	83.2	84.3	85.3	86.4	87.4	88.5	89.5
42	79.8	80.8	81.9	82.9	84.0	85.0	86.1	87.1	88.2	89.2
44	79.5	80.5	81.6	82.6	83.7	84.7	85.8	86.8	87.8	88.8
46	79.2	80.2	81.3	82.3	83.4	84.4	85.4	86.5	87.5	88.5
48	78.9	79.9	81.0	82.0	83.0	84.0	85.1	86.1	87.1	88.1
50	78.6	79.6	80.6	81.6	82.6	83.6	84.7	85.7	86.7	87.7
52	78.2	79.2	80.3	81.3	82.3	83.3	84.3	85.3	86.3	87.3
54	77.9	78.9	79.9	81.0	82.0	83.0	84.0	85.0	86.0	87.0
56	77.6	78.6	79.6	80.6	81.6	82.6	83.7	84.7	85.7	86.7
58	77.3	78.3	79.3	80.3	81.3	82.3	83.3	84.3	85.3	86.3
60	77.0	78.0	79.0	80.0	81.0	82.0	83.0	84.0	85.0	86.0
62	76.7	77.7	78.7	79.7	80.7	81.7	82.7	83.7	84.7	85.7
64	76.4	77.4	78.4	79.4	80.4	81.4	82.3	83.4	84.3	85.3
66	76.1	77.1	78.1	79.1	80.0	81.0	82.0	83.0	84.0	85.0
68	75.8	76.8	77.7	78.7	79.7	80.7	81.7	82.7	83.7	84.7
70	75.5	76.5	77.4	78.4	79.4	80.4	81.4	82.4	83.3	84.3
72	75.2	76.2	77.1	78.1	79.1	80.1	81.1	82.1	83.0	84.0
74	74.9	75.9	76.8	77.8	78.8	79.8	80.7	81.7	82.7	83.7
76	74.6	75.6	76.5	77.5	78.4	79.4	80.4	81.4	82.4	83.4
78	74.3	75.3	76.2	77.2	78.1	79.1	80.1	81.1	82.0	83.0
80	74.0	75.0	75.9	76.9	77.8	78.8	79.8	80.8	81.7	82.7
82	73.7	74.7	75.6	76.6	77.5	78.5	79.4	80.4	81.3	82.3
84	73.4	74.5	75.3	76.3	77.2	78.2	79.1	80.1	81.0	82.0
86	73.2	74.1	75.0	76.0	76.9	77.9	78.8	79.8	80.7	81.7
88	72.9	73.9	74.8	75.8	76.7	77.6	78.5	79.5	80.4	81.4
90	72.6	73.6	74.5	75.5	76.4	77.3	78.2	79.2	80.1	81.1
92	72.3	73.3	74.2	75.2	76.1	77.0	77.9	78.9	79.8	80.8
94	72.0	73.0	73.9	74.9	75.8	76.7	77.6	78.6	79.5	80.5
96	71.7	72.7	73.6	74.6	75.5	76.4	77.3	78.3	79.2	80.2
98	71.5	72.4	73.3	74.3	75.2	76.1	77.0	78.0	78.9	79.8
100	71.2	72.1	73.0	74.0	74.9	75.8	76.7	77.6	78.5	79.5
102	71.0	71.9	72.8	73.7	74.6	75.5	76.4	77.3	78.2	79.2
104	70.7	71.6	72.5	73.4	74.3	75.2	76.1	77.0	77.9	78.8
106	70.4	71.3	72.2	73.1	74.0	74.9	75.8	76.7	77.6	78.5
108	70.1	71.0	71.9	72.8	73.7	74.6	75.5	76.4	77.3	78.2
110	69.8	70.7	71.6	72.5	73.4	74.3	75.2	76.1	77.0	77.9
112	69.6	70.5	71.4	72.3	73.2	74.1	74.9	75.8	76.7	77.6
114	69.4	70.3	71.2	72.1	72.9	73.8	74.6	75.5	76.4	77.3
116	69.1	70.0	70.9	71.8	72.6	73.5	74.3	75.2	76.1	77.0
118	68.8	69.7	70.6	71.5	72.3	73.2	74.0	74.9	75.8	76.7
120	68.5	69.4	70.3	71.2	72.0	72.9	73.7	74.6	75.5	76.4

Observed temperature in ° F	Observed degrees Baumé									
	87.0	88.0	89.0	90.0	91.0	92.0	93.0	94.0	95.0	96.0
	Corresponding degrees Baumé at 60° F									
30	92.6	93.6	94.7	95.7						
32	92.2	93.2	94.3	95.3						
34	91.8	92.9	93.9	94.9	95.9					
36	91.4	92.5	93.6	94.6	95.6					
38	91.0	92.1	93.2	94.2	95.2					
40	90.6	91.7	92.8	93.8	94.9	95.9				
42	90.3	91.3	92.4	93.4	94.5	95.5				
44	89.9	90.9	92.0	93.0	94.1	95.1	96.1			
46	89.6	90.6	91.7	92.7	93.7	94.7	95.7			
48	89.2	90.2	91.3	92.3	93.3	94.3	95.3			
50	88.8	89.8	90.9	91.9	92.9	93.9	94.9	95.9		
52	88.4	89.4	90.5	91.5	92.5	93.5	94.5	95.5		
54	88.0	89.0	90.1	91.1	92.1	93.1	94.1	95.1		
56	87.7	88.7	89.7	90.7	91.7	92.7	93.7	94.7	95.7	
58	87.3	88.3	89.4	90.4	91.4	92.4	93.4	94.4	95.4	
60	87.0	88.0	89.0	90.0	91.0	92.0	93.0	94.0	95.0	96.0
62	86.7	87.7	88.6	89.6	90.6	91.6	92.6	93.6	94.6	95.6
64	86.3	87.3	88.3	89.3	90.3	91.3	92.2	93.2	94.2	95.2
66	86.0	87.0	88.0	89.0	89.9	90.9	91.8	92.8	93.8	94.8
68	85.6	86.6	87.6	88.6	89.5	90.5	91.4	92.4	93.4	94.4
70	85.3	86.3	87.3	88.3	89.2	90.1	91.0	92.0	93.0	94.0
72	85.0	86.0	86.9	87.9	88.8	89.8	90.7	91.7	92.7	93.7
74	84.6	85.6	86.5	87.5	88.4	89.4	90.3	91.3	92.3	93.3
76	84.3	85.3	86.2	87.2	88.1	89.1	90.0	91.0	92.0	93.0
78	84.0	85.0	85.9	86.9	87.8	88.7	89.6	90.6	91.6	92.6
80	83.6	84.6	85.5	86.5	87.4	88.4	89.3	90.2	91.2	92.2
82	83.2	84.2	85.1	86.1	87.0	88.0	88.9	89.8	90.8	91.8
84	82.9	83.8	84.7	85.7	86.6	87.6	88.5	89.4	90.4	91.4
86	82.6	83.5	84.4	85.4	86.3	87.3	88.2	89.1	90.0	91.0
88	82.3	83.2	84.1	85.1	86.0	87.0	87.9	88.8	89.7	90.7
90	82.0	82.9	83.8	84.8	85.7	86.6	87.5	88.4	89.3	90.3
92	81.7	82.6	83.5	84.4	85.3	86.2	87.1	88.1	89.0	90.0
94	81.3	82.2	83.1	84.1	85.0	85.9	86.8	87.7	88.6	89.6
96	81.0	81.9	82.8	83.7	84.6	85.6	86.5	87.4	88.3	89.3
98	80.7	81.6	82.5	83.4	84.3	85.2	86.1	87.0	88.0	89.0
100	80.4	81.3	82.2	83.1	84.0	84.9	85.8	86.7	87.6	88.6
102	80.1	81.0	81.9	82.8	83.7	84.6	85.5	86.4	87.3	88.3
104	79.7	80.6	81.5	82.5	83.4	84.3	85.2	86.1	87.0	87.9
106	79.4	80.3	81.2	82.1	83.0	83.9	84.8	85.7	86.6	87.6
108	79.1	80.0	80.9	81.8	82.7	83.6	84.5	85.4	86.3	87.2
110	78.8	79.7	80.6	81.5	82.4	83.3	84.2	85.1	86.0	86.9
112	78.5	79.4	80.3	81.2	82.1	83.0	83.8	84.7	85.6	86.6
114	78.2	79.1	80.0	80.9	81.7	82.6	83.5	84.4	85.3	86.2
116	77.9	78.8	79.7	80.6	81.4	82.3	83.2	84.1	85.0	85.9
118	77.5	78.4	79.3	80.2	81.1	82.0	82.8	83.7	84.6	85.6
120	77.2	78.1	79.0	79.9	80.8	81.7	82.5	83.4	84.3	85.2

Reduction of Specific Gravity Readings to 60°F

(This table shows the specific gravities at 60°/60°F of oils having, at the designated temperatures, the observed specific gravities indicated. For example, if the observed specific gravity is 0.610 at 80°F, the true specific gravity at 60°/60°F will be 0.621. The headings "Observed specific gravity" and "Observed temperature" signify the true indication of the hydrometer and the true temperature of the oil; that is, the observed readings corrected, if necessary, for instrumental errors.)

Observed temperature in °F	Observed specific gravities									
	0.610	0.611	0.612	0.613	0.614	0.615	0.616	0.617	0.618	0.619
	Corresponding specific gravities at 60°/60° F									
62	....	....	....	....	....	....	....	....	....	0.6200
64	....	....	....	....	....	....	....	....	0.6200	.6210
66	....	....	....	....	....	....	....	0.6200	.6210	.6220
68	....	....	....	....	....	0.6200	.6205	.6215	.6225	.6235
70	....	....	....	....	0.6200	.6210	.6215	.6225	.6235	.6245
72	....	....	....	0.6200	.6210	.6220	.6225	.6235	.6245	.6255
74	....	....	0.6200	.6210	.6220	.6230	.6235	.6245	.6255	.6265
76	....	0.6200	.6210	.6220	.6230	.6240	.6245	.6255	.6265	.6275
78	0.6200	.6210	.6220	.6230	.6240	.6250	.6255	.6265	.6275	.6285
80	.621	.622	.623	.624	.625	.626	.626	.627	.628	.629
82	.622	.623	.624	.625	.626	.627	.628	.629	.630	.631
84	.623	.624	.625	.626	.627	.628	.629	.630	.631	.632
86	.624	.625	.626	.627	.628	.629	.630	.631	.632	.633
88	.625	.626	.627	.628	.629	.630	.631	.632	.633	.634
90	.626	.627	.628	.629	.630	.631	.632	.633	.634	.635
92	.627	.628	.629	.630	.631	.632	.633	.634	.635	.636
94	.628	.629	.630	.631	.632	.633	.634	.635	.636	.637
96	.629	.630	.631	.632	.633	.634	.635	.636	.637	.638
98	.630	.631	.632	.633	.634	.635	.636	.637	.638	.639
100	.631	.632	.633	.634	.635	.636	.637	.638	.639	.640
102	.632	.633	.634	.635	.636	.637	.638	.639	.640	.641
104	.633	.634	.635	.636	.637	.638	.639	.640	.641	.642
106	.634	.635	.636	.637	.638	.639	.640	.641	.642	.643
108	.635	.636	.637	.638	.639	.640	.641	.642	.643	.644
110	.636	.637	.638	.639	.640	.641	.642	.643	.644	.645
112	.637	.638	.639	.640	.641	.642	.643	.644	.645	.646
114	.638	.639	.640	.641	.642	.643	.644	.645	.646	.647
116	.639	.640	.641	.642	.643	.644	.645	.646	.647	.648
118	.640	.641	.642	.643	.644	.645	.646	.647	.648	.649
120	.641	.642	.643	.644	.645	.646	.647	.648	.649	.650

REDUCTION OF SPECIFIC GRAVITY READINGS TO 60°F—Con.

Observed temperature in °F	Observed specific gravities									
	0.620	0.621	0.622	0.623	0.624	0.625	0.626	0.627	0.628	0.629
	Corresponding specific gravities at 60°/60° F									
44	......	......	......	......	......	......	......	......	......	0.6200
46	......	......	......	......	......	......	......	......	0.6200	.6210
48	......	......	......	......	......	......	......	0.6200	.6210	.6220
50	......	......	......	......	......	0.6200	0.6205	.6215	.6225	.6235
52	......	......	......	......	0.6200	.6210	.6220	.6230	.6240	.6250
54	......	......	......	0.6200	.6210	.6220	.6230	.6240	.6250	.6260
56	......	......	0.6200	.6210	.6220	.6230	.6240	.6250	.6260	.6270
58	......	0.6200	.6210	.6220	.6230	.6240	.6250	.6260	.6270	.6280
60	0.6200	.6210	.6220	.6230	.6240	.6250	.6260	.6270	.6280	.6290
62	.6210	.6220	.6230	.6240	.6250	.6260	.6270	.6280	.6290	.6300
64	.6220	.6230	.6240	.6250	.6260	.6270	.6280	.6290	.6300	.6310
66	.6230	.6240	.6250	.6260	.6270	.6280	.6290	.6300	.6310	.6320
68	.6245	.6255	.6265	.6275	.6285	.6295	.6305	.6315	.6325	.6335
70	.6255	.6265	.6275	.6285	.6295	.6305	.6315	.6325	.6335	.6345
72	.6265	.6275	.6285	.6295	.6305	.6315	.6325	.6335	.6345	.6355
74	.6275	.6285	.6295	.6305	.6315	.6325	.6335	.6345	.6355	.6365
76	.6285	.6295	.6305	.6315	.6325	.6335	.6345	.6355	.6365	.6375
78	.6295	.6305	.6315	.6325	.6335	.6345	.6355	.6365	.6375	.6385
80	.630	.631	.632	.633	.634	.635	.636	.637	.638	.639
82	.632	.633	.634	.635	.636	.637	.637	.638	.639	.640
84	.633	.634	.635	.636	.637	.638	.638	.639	.640	.641
86	.634	.635	.636	.637	.638	.639	.639	.640	.641	.642
88	.635	.636	.637	.638	.639	.640	.640	.641	.642	.643
90	.636	.637	.638	.639	.640	.641	.641	.642	.643	.644
92	.637	.638	.639	.640	.641	.642	.642	.643	.644	.645
94	.638	.639	.640	.641	.642	.643	.643	.644	.645	.646
96	.639	.640	.641	.642	.643	.644	.644	.645	.646	.647
98	.640	.641	.642	.643	.644	.645	.645	.646	.647	.648
100	.641	.642	.643	.644	.645	.646	.646	.647	.648	.649
102	.642	.643	.644	.645	.646	.647	.647	.648	.649	.650
104	.643	.644	.645	.646	.647	.648	.648	.649	.650	.651
106	.644	.645	.646	.647	.648	.649	.649	.650	.651	.652
108	.645	.646	.647	.648	.649	.650	.650	.651	.652	.653
110	.646	.647	.648	.649	.650	.651	.651	.652	.653	.654
112	.647	.648	.649	.650	.651	.652	.652	.653	.654	.655
114	.648	.649	.650	.651	.652	.653	.653	.654	.655	.656
116	.649	.650	.651	.652	.653	.654	.654	.655	.656	.657
118	.650	.651	.652	.653	.654	.655	.655	.656	.657	.658
120	.651	.652	.653	.654	.655	.656	.656	.657	.658	.659

REDUCTION OF SPECIFIC GRAVITY READINGS TO 60°F—Con.

Observed temperature in °F	Observed specific gravities									
	0.630	0.631	0.632	0.633	0.634	0.635	0.636	0.637	0.638	0.639
	Corresponding specific gravities at 60°/60° F									
30..........	....	....	....	....	....	....	0.620	0.621	0.622	0.623
32..........	....	....	....	....	....	0.620	.621	.622	.623	.624
34..........	....	....	....	....	0.620	.621	.622	.623	.624	.625
36..........	....	....	....	0.620	.621	.622	.623	.624	.625	.626
38..........	....	....	0.620	.621	.622	.623	.624	.625	.626	.627
40..........	....	0.6200	.6210	.6220	.6230	.6240	.6255	.6265	.6275	.6285
42..........	0.6200	.6210	.6220	.6230	.6240	.6250	.6265	.6275	.6285	.6295
44..........	.6210	.6220	.6230	.6240	.6250	.6260	.6275	.6285	.6295	.6305
46..........	.6220	.6230	.6240	.6250	.6260	.6270	.6285	.6295	.6305	.6315
48..........	.6230	.6240	.6250	.6260	.6270	.6280	.6295	.6305	.6315	.6325
50..........	.6245	.6255	.6265	.6275	.6285	.6295	.6305	.6315	.6325	.6335
52..........	.6260	.6270	.6280	.6290	.6300	.6310	.6320	.6330	.6340	.6350
54..........	.6270	.6280	.6290	.6300	.6310	.6320	.6330	.6340	.6350	.6360
56..........	.6280	.6290	.6300	.6310	.6320	.6330	.6340	.6350	.6360	.6370
58..........	.6290	.6300	.6310	.6320	.6330	.6340	.6350	.6360	.6370	.6380
60..........	.6300	.6310	.6320	.6330	.6340	.6350	.6360	.6370	.6380	.6390
62..........	.6310	.6320	.6330	.6340	.6350	.6360	.6370	.6380	.6390	.6400
64..........	.6320	.6330	.6340	.6350	.6360	.6370	.6380	.6390	.6400	.6410
66..........	.6330	.6340	.6350	.6360	.6370	.6380	.6390	.6400	.6410	.6420
68..........	.6345	.6355	.6365	.6375	.6385	.6395	.6400	.6410	.6420	.6430
70..........	.6355	.6365	.6375	.6385	.6395	.6405	.6410	.6420	.6430	.6440
72..........	.6365	.6375	.6385	.6395	.6405	.6415	.6420	.6430	.6440	.6450
74..........	.6375	.6385	.6395	.6405	.6415	.6425	.6430	.6440	.6450	.6460
76..........	.6385	.6395	.6405	.6415	.6425	.6435	.6440	.6450	.6460	.6470
78..........	.6395	.6405	.6415	.6425	.6435	.6445	.6450	.6460	.6470	.6480
80..........	.640	.641	.642	.643	.644	.645	.646	.647	.648	.649
82..........	.641	.642	.643	.644	.645	.646	.647	.648	.649	.650
84..........	.642	.643	.644	.645	.646	.647	.648	.649	.650	.651
86..........	.643	.644	.645	.646	.647	.648	.649	.650	.651	.652
88..........	.644	.645	.646	.647	.648	.649	.650	.651	.652	.653
90..........	.645	.646	.647	.648	.649	.650	.651	.652	.653	.654
92..........	.646	.647	.648	.649	.650	.651	.652	.653	.654	.655
94..........	.647	.648	.649	.650	.651	.652	.653	.654	.655	.656
96..........	.648	.649	.650	.651	.652	.653	.654	.655	.656	.657
98..........	.649	.650	.651	.652	.653	.654	.655	.656	.657	.658
100..........	.650	.651	.652	.653	.654	.655	.656	.657	.658	.659
102..........	.651	.652	.653	.654	.655	.656	.657	.658	.659	.660
104..........	.652	.653	.654	.655	.656	.657	.658	.659	.660	.661
106..........	.653	.654	.655	.656	.657	.658	.659	.660	.661	.662
108..........	.654	.655	.656	.657	.658	.659	.660	.661	.662	.663
110..........	.655	.656	.657	.658	.659	.660	.661	.662	.663	.664
112..........	.656	.657	.658	.659	.660	.661	.662	.663	.664	.665
114..........	.657	.658	.659	.660	.661	.662	.663	.664	.665	.666
116..........	.658	.659	.660	.661	.662	.663	.664	.665	.666	.667
118..........	.659	.660	.661	.662	.663	.664	.665	.666	.667	.668
120..........	.660	.661	.662	.663	.664	.665	.666	.667	.668	.669

REDUCTION OF SPECIFIC GRAVITY READINGS TO 60°F—Con.

Observed temperature in °F	Observed specific gravities									
	0.640	0.641	0.642	0.643	0.644	0.645	0.646	0.647	0.648	0.649
	Corresponding specific gravities at 60°/60° F									
30..........	0.624	0.625	0.626	0.627	0.628	0.629	0.630	0.631	0.632	0.633
32..........	.625	.626	.627	.628	.629	.630	.631	.632	.633	.634
34..........	.626	.627	.628	.629	.630	.631	.632	.633	.634	.635
36..........	.627	.628	.629	.630	.631	.632	.633	.634	.635	.636
38..........	.628	.629	.630	.631	.632	.633	.634	.635	.636	.637
40..........	.6295	.6305	.6315	.6325	.6335	.6345	.6355	.6365	.6375	.6385
42..........	.6305	.6315	.6325	.6335	.6345	.6355	.6365	.6375	.6385	.6395
44..........	.6315	.6325	.6335	.6345	.6355	.6365	.6375	.6385	.6395	.6405
46..........	.6325	.6335	.6345	.6355	.6365	.6375	.6385	.6395	.6405	.6415
48..........	.6335	.6345	.6355	.6365	.6375	.6385	.6395	.6405	.6415	.6425
50..........	.6345	.6355	.6365	.6375	.6385	.6395	.6410	.6420	.6430	.6440
52..........	.6360	.6370	.6380	.6390	.6400	.6410	.6420	.6430	.6440	.6450
54..........	.6370	.6380	.6390	.6400	.6410	.6420	.6430	.6440	.6450	.6460
56..........	.6380	.6390	.6400	.6410	.6420	.6430	.6440	.6450	.6460	.6470
58..........	.6390	.6400	.6410	.6420	.6430	.6440	.6450	.6460	.6470	.6480
60..........	.6400	.6410	.6420	.6430	.6440	.6450	.6460	.6470	.6480	.6490
62..........	.6410	.6420	.6430	.6440	.6450	.6460	.6470	.6480	.6490	.6500
64..........	.6420	.6430	.6440	.6450	.6460	.6470	.6480	.6490	.6500	.6510
66..........	.6430	.6440	.6450	.6460	.6470	.6480	.6490	.6500	.6510	.6520
68..........	.6440	.6450	.6460	.6470	.6480	.6490	.6500	.6510	.6520	.6530
70..........	.6450	.6460	.6470	.6480	.6490	.6500	.6510	.6520	.6530	.6540
72..........	.6460	.6470	.6480	.6490	.6500	.6510	.6520	.6530	.6540	.6550
74..........	.6470	.6480	.6490	.6500	.6510	.6520	.6530	.6540	.6550	.6560
76..........	.6480	.6490	.6500	.6510	.6520	.6530	.6540	.6550	.6560	.6570
78..........	.6490	.6500	.6510	.6520	.6530	.6540	.6550	.6560	.6570	.6580
80..........	.650	.651	.652	.653	.654	.655	.656	.657	.658	.659
82..........	.651	.652	.653	.654	.655	.656	.657	.658	.659	.660
84..........	.652	.653	.654	.655	.656	.657	.658	.659	.660	.661
86..........	.653	.654	.655	.656	.657	.658	.659	.660	.661	.662
88..........	.654	.655	.656	.657	.658	.659	.660	.661	.662	.663
90..........	.655	.656	.657	.658	.659	.660	.661	.662	.663	.664
92..........	.656	.657	.658	.659	.660	.661	.662	.663	.664	.665
94..........	.657	.658	.659	.660	.661	.662	.663	.664	.665	.666
96..........	.658	.659	.660	.661	.662	.663	.664	.665	.666	.667
98..........	.659	.660	.661	.662	.663	.664	.665	.666	.667	.668
100..........	.660	.661	.662	.663	.664	.665	.666	.667	.668	.669
102..........	.661	.662	.663	.664	.665	.666	.667	.668	.669	.670
104..........	.662	.663	.664	.665	.666	.667	.668	.669	.670	.671
106..........	.663	.664	.665	.666	.667	.668	.669	.670	.671	.672
108..........	.664	.665	.666	.667	.668	.669	.670	.671	.672	.673
110..........	.665	.666	.667	.668	.669	.670	.671	.672	.673	.674
112..........	.666	.667	.668	.669	.670	.671	.672	.673	.674	.675
114..........	.667	.668	.669	.670	.671	.672	.673	.674	.675	.676
116..........	.668	.669	.670	.671	.672	.673	.674	.675	.676	.677
118..........	.669	.670	.671	.672	.673	.674	.675	.676	.677	.678
120..........	.670	.671	.672	.673	.674	.675	.676	.677	.678	.679

REDUCTION OF SPECIFIC GRAVITY READINGS TO 60°F—Con.

Observed temperature in °F	Observed specific gravities									
	0.650	0.651	0.652	0.653	0.654	0.655	0.656	0.657	0.658	0.659
	Corresponding specific gravities at 60°/60° F									
30..........	0.634	0.635	0.636	0.637	0.638	0.639	0.640	0.641	0.642	0.643
32..........	.635	.636	.637	.638	.639	.640	.641	.642	.643	.644
34..........	.636	.637	.638	.639	.640	.641	.642	.643	.644	.645
36..........	.637	.638	.639	.640	.641	.642	.643	.644	.645	.646
38..........	.638	.639	.640	.641	.642	.643	.644	.645	.646	.647
40..........	.6395	.6405	.6415	.6425	.6435	.6445	.6455	.6465	.6475	.6485
42..........	.6405	.6415	.6425	.6435	.6445	.6455	.6465	.6475	.6485	.6495
44..........	.6415	.6425	.6435	.6445	.6455	.6465	.6475	.6485	.6495	.6505
46..........	.6425	.6435	.6445	.6455	.6465	.6475	.6485	.6495	.6505	.6515
48..........	.6435	.6445	.6455	.6465	.6475	.6485	.6495	.6505	.6515	.6525
50..........	.6450	.6460	.6470	.6480	.6490	.6500	.6510	.6520	.6530	.6540
52..........	.6460	.6470	.6480	.6490	.6500	.6510	.6520	.6530	.6540	.6550
54..........	.6470	.6480	.6490	.6500	.6510	.6520	.6530	.6540	.6550	.6560
56..........	.6480	.6490	.6500	.6510	.6520	.6530	.6540	.6550	.6560	.6570
58..........	.6490	.6500	.6510	.6520	.6530	.6540	.6550	.6560	.6570	.6580
60..........	.6500	.6510	.6520	.6530	.6540	.6550	.6560	.6570	.6580	.6590
62..........	.6510	.6520	.6530	.6540	.6550	.6560	.6570	.6580	.6590	.6600
64..........	.6520	.6530	.6540	.6550	.6560	.6570	.6580	.6590	.6600	.6610
66..........	.6530	.6540	.6550	.6560	.6570	.6580	.6590	.6600	.6610	.6620
68..........	.6540	.6550	.6560	.6570	.6580	.6590	.6600	.6610	.6620	.6630
70..........	.6550	.6560	.6570	.6580	.6590	.6600	.6610	.6620	.6630	.6640
72..........	.6560	.6570	.6580	.6590	.6600	.6610	.6620	.6630	.6640	.6650
74..........	.6570	.6580	.6590	.6600	.6610	.6620	.6630	.6640	.6650	.6660
76..........	.6580	.6590	.6600	.6610	.6620	.6630	.6640	.6650	.6660	.6670
78..........	.6590	.6600	.6610	.6620	.6630	.6640	.6650	.6660	.6670	.6680
80..........	.660	.661	.662	.663	.664	.665	.666	.667	.668	.669
82..........	.661	.662	.663	.664	.665	.666	.667	.668	.669	.670
84..........	.662	.663	.664	.665	.666	.667	.668	.669	.670	.671
86..........	.663	.664	.665	.666	.667	.668	.669	.670	.671	.672
88..........	.664	.665	.666	.667	.668	.669	.670	.671	.672	.673
90..........	.665	.666	.667	.668	.669	.670	.671	.672	.673	.674
92..........	.666	.667	.668	.669	.670	.671	.672	.673	.674	.675
94..........	.667	.668	.669	.670	.671	.672	.673	.674	.675	.676
96..........	.668	.669	.670	.671	.672	.673	.674	.675	.676	.677
98..........	.669	.670	.671	.672	.673	.674	.675	.676	.677	.678
100..........	.670	.671	.672	.673	.674	.675	.676	.677	.678	.679
102..........	.671	.672	.673	.674	.675	.676	.677	.678	.679	.680
104..........	.672	.673	.674	.675	.676	.677	.678	.679	.680	.681
106..........	.673	.674	.675	.676	.677	.678	.679	.680	.681	.682
108..........	.674	.675	.676	.677	.678	.679	.679	.680	.681	.682
110..........	.675	.676	.677	.678	.679	.680	.680	.681	.682	.683
112..........	.676	.677	.678	.679	.680	.681	.681	.682	.683	.684
114..........	.677	.678	.679	.680	.681	.682	.682	.683	.684	.685
116..........	.678	.679	.680	.681	.682	.683	.683	.684	.685	.686
118..........	.679	.680	.681	.682	.683	.684	.684	.685	.686	.687
120..........	.680	.681	.682	.683	.684	.685	.685	.686	.687	.688

REDUCTION OF SPECIFIC GRAVITY READINGS TO 60°F—Con.

Observed temperature in °F	Observed specific gravities									
	0.660	0.661	0.662	0.663	0.664	0.665	0.666	0.667	0.668	0.669
	Corresponding specific gravities at 60°/60° F									
30	0.664	0.645	0.646	0.647	0.648	0.649	0.650	0.651	0.652	0.653
32	.645	.646	.647	.648	.649	.650	.651	.652	.653	.654
34	.646	.647	.648	.649	.650	.651	.652	.653	.654	.655
36	.647	.648	.649	.650	.651	.652	.653	.654	.655	.656
38	.648	.649	.650	.651	.652	.653	.655	.656	.657	.658
40	.6495	.6505	.6515	.6525	.6535	.6545	.6560	.6570	.6580	.6590
42	.6505	.6515	.6525	.6535	.6545	.6555	.6570	.6580	.6590	.6600
44	.6515	.6525	.6535	.6545	.6555	.6565	.6580	.6590	.6600	.6610
46	.6525	.6535	.6545	.6555	.6565	.6575	.6590	.6600	.6610	.6620
48	.6535	.6545	.6555	.6565	.6575	.6585	.6600	.6610	.6620	.6630
50	.6550	.6560	.6570	.6580	.6590	.6600	.6610	.6620	.6630	.6640
52	.6560	.6570	.6580	.6590	.6600	.6610	.6620	.6630	.6640	.6650
64	.6570	.6580	.6590	.6600	.6610	.6620	.6630	.6640	.6650	.6660
56	.6580	.6590	.6600	.6610	.6620	.6630	.6640	.6650	.6660	.6670
58	.6590	.6600	.6610	.6620	.6630	.6640	.6650	.6660	.6670	.6680
60	.6600	.6610	.6620	.6630	.6640	.6650	.6660	.6670	.6680	.6690
62	.6610	.6620	.6630	.6640	.6650	.6660	.6670	.6680	.6690	.6700
64	.6620	.6630	.6640	.6650	.6660	.6670	.6680	.6690	.6700	.6710
66	.6630	.6640	.6650	.6660	.6670	.6680	.6690	.6700	.6710	.6720
68	.6640	.6650	.6660	.6670	.6680	.6690	.6700	.6710	.6720	.6730
70	.6650	.6660	.6670	.6680	.6690	.6700	.6710	.6720	.6730	.6740
72	.6660	.6670	.6680	.6690	.6700	.6710	.6720	.6730	.6740	.6750
74	.6670	.6680	.6690	.6700	.6710	.6720	.6730	.6740	.6750	.6760
76	.6680	.6690	.6700	.6710	.6720	.6730	.6740	.6750	.6760	.6770
78	.6690	.6700	.6710	.6720	.6730	.6740	.6750	.6760	.6770	.6780
80	.670	.671	.672	.673	.674	.675	.676	.677	.678	.679
82	.671	.672	.673	.674	.675	.676	.677	.678	.679	.680
84	.672	.673	.674	.675	.676	.677	.678	.679	.680	.681
86	.673	.674	.675	.676	.677	.678	.679	.680	.681	.682
88	.674	.675	.676	.677	.678	.679	.679	.680	.681	.682
90	.675	.676	.677	.678	.679	.680	.680	.681	.682	.683
92	.676	.677	.678	.679	.680	.681	.681	.682	.683	.684
94	.677	.678	.679	.680	.681	.682	.682	.683	.684	.685
96	.678	.679	.680	.681	.682	.683	.683	.684	.685	.686
98	.679	.680	.681	.682	.683	.684	.684	.685	.686	.687
100	.680	.681	.682	.683	.684	.685	.685	.686	.687	.688
102	.681	.682	.683	.684	.685	.686	.686	.687	.688	.689
104	.682	.683	.684	.685	.686	.687	.687	.688	.689	.690
106	.683	.684	.685	.686	.687	.688	.688	.689	.690	.691
108	.683	.684	.685	.686	.687	.688	.689	.690	.691	.692
110	.684	.685	.686	.687	.688	.689	.690	.691	.692	.693
112	.685	.686	.687	.688	.689	.690	.691	.692	.693	.694
114	.686	.687	.688	.689	.690	.691	.692	.693	.694	.695
116	.687	.688	.689	.690	.691	.692	.693	.694	.695	.696
118	.688	.689	.690	.691	.692	.693	.694	.695	.696	.697
120	.689	.690	.691	.692	.693	.694	.695	.696	.697	.698

REDUCTION OF SPECIFIC GRAVITY READINGS TO 60°F—Con.

Observed temperature in °F	Observed specific gravities									
	0.670	0.671	0.672	0.673	0.674	0.675	0.676	0.677	0.678	0.679
	Corresponding specific gravities at 60°/60° F									
30	0.654	0.655	0.656	0.657	0.658	0.659	0.661	0.662	0.663	0.664
32	.655	.656	.657	.658	.659	.660	.662	.663	.664	.665
34	.656	.657	.658	.659	.660	.661	.663	.664	.665	.666
36	.657	.658	.659	.660	.661	.662	.664	.665	.666	.667
38	.659	.660	.661	.662	.663	.664	.665	.666	.667	.668
40	.6600	.6610	.6620	.6630	.6640	.6650	.6660	.6670	.6680	.6690
42	.6610	.6620	.6630	.6640	.6650	.6660	.6670	.6680	.6690	.6700
44	.6620	.6630	.6640	.6650	.6660	.6670	.6680	.6690	.6700	.6710
46	.6630	.6640	.6650	.6660	.6670	.6680	.6690	.6700	.6710	.6720
48	.6640	.6650	.6660	.6670	.6680	.6690	.6700	.6710	.6720	.6730
50	.6650	.6660	.6670	.6680	.6690	.6700	.6710	.6720	.6730	.6740
52	.6660	.6670	.6680	.6690	.6700	.6710	.6720	.6730	.6740	.6750
54	.6670	.6680	.6690	.6700	.6710	.6720	.6730	.6740	.6750	.6760
56	.6680	.6690	.6700	.6710	.6720	.6730	.6740	.6750	.6760	.6770
58	.6690	.6700	.6710	.6720	.6730	.6740	.6750	.6760	.6770	.6780
60	.6700	.6710	.6720	.6730	.6740	.6750	.6760	.6770	.6780	.6790
62	.6710	.6720	.6730	.6740	.6750	.6760	.6770	.6780	.6790	.6800
64	.6720	.6730	.6740	.6750	.6760	.6770	.6780	.6790	.6800	.6810
66	.6730	.6740	.6750	.6760	.6770	.6780	.6790	.6800	.6810	.6820
68	.6740	.6750	.6760	.6770	.6780	.6790	.6800	.6810	.6820	.6830
70	.6750	.6760	.6770	.6780	.6790	.6800	.6810	.6820	.6830	.6840
72	.6760	.6770	.6780	.6790	.6800	.6810	.6820	.6830	.6840	.6850
74	.6770	.6780	.6790	.6800	.6810	.6820	.6830	.6840	.6850	.6860
76	.6780	.6790	.6800	.6810	.6820	.6830	.6835	.6845	.6855	.6865
78	.6790	.6800	.6810	.6820	.6830	.6840	.6845	.6855	.6865	.6875
80	.680	.681	.682	.683	.684	.685	.685	.686	.687	.688
82	.681	.682	.683	.684	.685	.686	.686	.687	.688	.689
84	.682	.683	.684	.685	.686	.687	.687	.688	.689	.690
86	.683	.684	.685	.686	.687	.688	.688	.689	.690	.691
88	.683	.684	.685	.686	.687	.688	.689	.690	.691	.692
90	.684	.685	.686	.687	.688	.689	.690	.691	.692	.693
92	.685	.686	.687	.688	.689	.690	.691	.692	.693	.694
94	.686	.687	.688	.689	.690	.691	.692	.693	.694	.695
96	.687	.688	.689	.690	.691	.692	.693	.694	.695	.696
98	.688	.689	.690	.691	.692	.693	.694	.695	.696	.697
100	.689	.690	.691	.692	.693	.694	.695	.696	.697	.698
102	.690	.691	.692	.693	.694	.695	.696	.697	.698	.699
104	.691	.692	.693	.694	.695	.696	.697	.698	.699	.700
106	.692	.693	.694	.695	.696	.697	.698	.699	.700	.701
108	.693	.694	.695	.696	.697	.698	.699	.700	.701	.702
110	.694	.695	.696	.697	.698	.699	.700	.701	.702	.703
112	.695	.696	.697	.698	.699	.700	.701	.702	.703	.704
114	.696	.697	.689	.699	.700	.701	.702	.703	.704	.705
116	.697	.698	.699	.700	.701	.702	.702	.703	.704	.705
118	.698	.699	.700	.701	.702	.703	.703	.704	.705	.706
120	.699	.700	.701	.702	.703	.704	.704	.705	.706	.707

REDUCTION OF SPECIFIC GRAVITY READINGS TO 60°F—Con.

Observed temperature in °F	Observed specific gravities									
	0.680	0.681	0.682	0.683	0.684	0.685	0.686	0.687	0.688	0.689
	Corresponding specific gravities at 60°/60° F									
30..........	0.665	0.666	0.667	0.668	0.669	0.670	0.671	0.672	0.673	0.674
32..........	.666	.667	.668	.669	.670	.671	.672	.673	.674	.675
34..........	.667	.668	.669	.670	.671	.672	.673	.674	.675	.676
36..........	.668	.669	.670	.671	.672	.673	.674	.675	.676	.677
38..........	.669	.670	.671	.672	.673	.674	.675	.676	.677	.678
40..........	.6700	.6710	.6720	.6730	.6740	.6750	.6760	.6770	.6780	.6790
42..........	.6710	.6720	.6730	.6740	.6750	.6760	.6770	.6780	.6790	.6800
44..........	.6720	.6730	.6740	.6750	.6760	.6770	.6780	.6790	.6800	.6810
46..........	.6730	.6740	.6750	.6760	.6770	.6780	.6790	.6800	.6810	.6820
48..........	.6740	.6750	.6760	.6770	.6780	.6790	.6800	.6810	.6820	.6830
50..........	.6750	.6760	.6770	.6780	.6790	.6800	.6810	.6820	.6830	.6840
52..........	.6760	.6770	.6780	.6790	.6800	.6810	.6820	.6830	.6840	.6850
54..........	.6770	.6780	.6790	.6800	.6810	.6820	.6830	.6840	.6850	.6860
56..........	.6780	.6790	.6800	.6810	.6820	.6830	.6840	.6850	.6860	.6870
58..........	.6790	.6800	.6810	.6820	.6830	.6840	.6850	.6860	.6870	.6880
60..........	.6800	.6810	.6820	.6830	.6840	.6850	.6860	.6870	.6880	.6890
62..........	.6810	.6820	.6830	.6840	.6850	.6860	.6870	.6880	.6890	.6900
64..........	.6820	.6830	.6840	.6850	.6860	.6870	.6880	.6890	.6900	.6910
66..........	.6830	.6840	.6850	.6860	.6870	.6880	.6890	.6900	.6910	.6920
68..........	.6840	.6850	.6860	.6870	.6880	.6890	.6900	.6910	.6920	.6930
70..........	.6850	.6860	.6870	.6880	.6890	.6900	.6910	.6920	.6930	.6940
72..........	.6860	.6870	.6880	.6890	.6900	.6910	.6920	.6930	.6940	.6950
74..........	.6870	.6880	.6890	.6900	.6910	.6920	.6925	.6935	.6945	.6955
76..........	.6875	.6885	.6895	.6905	.6915	.6925	.6935	.6945	.6955	.6965
78..........	.6885	.6895	.6905	.6915	.6925	.6935	.6945	.6955	.6965	.6975
80..........	.689	.690	.691	.692	.693	.694	.695	.696	.697	.698
82..........	.690	.691	.692	.693	.694	.695	.696	.697	.698	.699
84..........	.691	.692	.693	.694	.695	.696	.697	.698	.699	.700
86..........	.692	.693	.694	.695	.696	.697	.698	.699	.700	.701
88..........	.693	.694	.695	.696	.697	.698	.699	.700	.701	.702
90..........	.694	.695	.696	.697	.698	.699	.700	.701	.702	.703
92..........	.695	.696	.697	.698	.699	.700	.701	.702	.703	.704
94..........	.696	.697	.698	.699	.700	.701	.702	.703	.704	.705
96..........	.697	.698	.699	.700	.701	.702	.703	.704	.705	.706
98..........	.698	.699	.700	.701	.702	.703	.704	.705	.706	.707
100..........	.699	.700	.701	.702	.703	.704	.705	.706	.707	.708
102..........	.700	.701	.702	.703	.704	.705	.706	.707	.708	.709
104..........	.701	.702	.703	.704	.705	.706	.707	.708	.709	.710
106..........	.702	.703	.704	.705	.706	.707	.708	.709	.710	.711
108..........	.703	.704	.705	.706	.707	.708	.708	.709	.710	.711
110..........	.704	.705	.706	.707	.708	.709	.709	.710	.711	.712
112..........	.705	.706	.707	.708	.709	.710	.710	.711	.712	.713
114..........	.706	.707	.708	.709	.710	.711	.711	.712	.713	.714
116..........	.706	.707	.708	.709	.710	.711	.712	.713	.714	.715
118..........	.707	.708	.709	.710	.711	.712	.713	.714	.715	.716
120..........	.708	.709	.710	.711	.712	.713	.714	.715	.716	.717

REDUCTION OF SPECIFIC GRAVITY READINGS TO 60°F—Con.

Observed temperature in °F	Observed specific gravities									
	0.690	0.691	0.692	0.693	0.694	0.695	0.696	0.697	0.698	0.699
	Corresponding specific gravities at 60°/60° F									
30..........	0.675	0.676	0.677	0.678	0.679	0.680	0.681	0.682	0.683	0.684
32..........	.676	.677	.678	.679	.680	.681	.682	.683	.684	.685
34..........	.677	.678	.679	.680	.681	.682	.683	.684	.685	.686
36..........	.678	.679	.680	.681	.682	.683	.684	.685	.686	.687
38..........	.679	.680	.681	.682	.683	.684	.685	.686	.687	.688
40..........	.6800	.6810	.6820	.6830	.6840	.6850	.6865	.6875	.6885	.6895
42..........	.6810	.6820	.6830	.6840	.6850	.6860	.6875	.6885	.6895	.6905
44..........	.6820	.6830	.6840	.6850	.6860	.6870	.6885	.6895	.6905	.6915
46..........	.6830	.6840	.6850	.6860	.6870	.6880	.6895	.6905	.6915	.6925
48..........	.6840	.6850	.6860	.6870	.6880	.6890	.6900	.6910	.6920	.6930
50..........	.6850	.6860	.6870	.6880	.6890	.6900	.6910	.6920	.6930	.6040
52..........	.6860	.6870	.6880	.6890	.6900	.6910	.6920	.6930	.6940	.6950
54..........	.6870	.6880	.6890	.6900	.6910	.6920	.6930	.6940	.6950	.6960
56..........	.6880	.6890	.6900	.6910	.6920	.6930	.6940	.6950	.6960	.6970
58..........	.6890	.6900	.6910	.6920	.6930	.6940	.6950	.6960	.6970	.6980
60..........	.6900	.6910	.6920	.6930	.6940	.6950	.6960	.6970	.6980	.6990
62..........	.6910	.6920	.6930	.6940	.6950	.6960	.6970	.6980	.6990	.7000
64..........	.6920	.6930	.6940	.6950	.6960	.6970	.6980	.6990	.7000	.7010
66..........	.6930	.6940	.6950	.6960	.6970	.6980	.6990	.7000	.7010	.7020
68..........	.6940	.6950	.6960	.6970	.6980	.6990	.7000	.7010	.7020	.7030
70..........	.6950	.6960	.6970	.6980	.6990	.7000	.7010	.7020	.7030	.7040
72..........	.6960	.6970	.6980	.6990	.7000	.7010	.7015	.7025	.7035	.7045
74..........	.6965	.6975	.6985	.6995	.7005	.7015	.7025	.7035	.7045	.7055
76..........	.6975	.6985	.6995	.7005	.7015	.7025	.7035	.7045	.7055	.7065
78..........	.6985	.6995	.7005	.7015	.7025	.7035	.7045	.7055	.7065	.7075
80..........	.699	.700	.701	.702	.703	.704	.705	.706	.707	.708
82..........	.700	.701	.702	.703	.704	.705	.706	.707	.708	.709
84..........	.701	.702	.703	.704	.705	.706	.707	.708	.709	.710
86..........	.702	.703	.704	.705	.706	.707	.708	.709	.710	.711
88..........	.703	.704	.705	.706	.707	.708	.709	.710	.711	.712
90..........	.704	.705	.706	.707	.708	.709	.710	.711	.712	.713
92..........	.705	.706	.707	.708	.709	.710	.711	.712	.713	.714
94..........	.706	.707	.708	.709	.710	.711	.712	.713	.714	.715
96..........	.707	.708	.709	.710	.711	.712	.712	.713	.714	.715
98..........	.708	.709	.710	.711	.712	.713	.713	.714	.715	.716
100..........	.709	.710	.711	.712	.713	.714	.714	.715	.716	.717
102..........	.710	.711	.712	.713	.714	.715	.715	.716	.717	.718
104..........	.711	.712	.713	.714	.715	.716	.716	.717	.718	.719
106..........	.712	.713	.714	.715	.716	.717	.717	.718	.719	.720
108..........	.712	.713	.714	.715	.716	.717	.718	.719	.720	.721
110..........	.713	.714	.715	.716	.717	.718	.719	.720	.721	.722
112..........	.714	.715	.716	.717	.718	.719	.720	.721	.722	.723
114..........	.715	.716	.717	.718	.719	.720	.721	.722	.723	.724
116..........	.716	.717	.718	.719	.720	.721	.722	.723	.724	.725
118..........	.717	.718	.719	.720	.721	.722	.722	.723	.724	.725
120..........	.718	.719	.720	.721	.722	.723	.723	.724	.725	.726

REDUCTION OF SPECIFIC GRAVITY READINGS TO 60°F—Con.

Observed temperature in °F	Observed specific gravities									
	0.700	0.701	0.702	0.703	0.704	0.705	0.706	0.707	0.708	0.709
	Corresponding specific gravities at 60°/60° F									
30	0.685	0.686	0.687	0.688	0.689	0.690	0.691	0.692	0.693	0.694
32	.686	.687	.688	.689	.690	.691	.692	.693	.694	.695
34	.687	.688	.689	.690	.691	.692	.693	.694	.695	.696
36	.688	.689	.690	.691	.692	.693	.694	.695	.696	.697
38	.689	.690	.691	.692	.693	.694	.695	.696	.697	.698
40	.6905	.6915	.6925	.6935	.6945	.6955	.6965	.6975	.6985	.6995
42	.6915	.6925	.6935	.6945	.6955	.6965	.6975	.6985	.6995	.7005
44	.6925	.6935	.6945	.6955	.6965	.6975	.6985	.6995	.7005	.7015
46	.6935	.6945	.6955	.6965	.6975	.6985	.6995	.7005	.7015	.7025
48	.6940	.6950	.6960	.6970	.6980	.6990	.7005	.7015	.7025	.7035
50	.6950	.6960	.6970	.6980	.6990	.7000	.7015	.7025	.7035	.7045
52	.6960	.6970	.6980	.6990	.7000	.7010	.7025	.7035	.7045	.7055
54	.6970	.6980	.6990	.7000	.7010	.7020	.7030	.7040	.7050	.7060
56	.6980	.6990	.7000	.7010	.7020	.7030	.7040	.7050	.7060	.7070
58	.6990	.7000	.7010	.7020	.7030	.7040	.7050	.7060	.7070	.7080
60	.7000	.7010	.7020	.7030	.7040	.7050	.7060	.7070	.7080	.7090
62	.7010	.7020	.7030	.7040	.7050	.7060	.7070	.7080	.7090	.7100
64	.7020	.7030	.7040	.7050	.7060	.7070	.7080	.7090	.7100	.7110
66	.7030	.7040	.7050	.7060	.7070	.7080	.7090	.7100	.7110	.7120
68	.7040	.7050	.7060	.7070	.7080	.7090	.7095	.7105	.7115	.7125
70	.7050	.7060	.7070	.7080	.7090	.7100	.7105	.7115	.7125	.7135
72	.7055	.7065	.7075	.7085	.7095	.7105	.7115	.7125	.7135	.7145
74	.7065	.7075	.7085	.7095	.7105	.7115	.7125	.7135	.7145	.7155
76	.7075	.7085	.7095	.7105	.7115	.7125	.7135	.7145	.7155	.7165
78	.7085	.7095	.7105	.7115	.7125	.7135	.7145	.7155	.7165	.7175
80	.709	.710	.711	.712	.713	.714	.715	.716	.717	.718
82	.710	.711	.712	.713	.714	.715	.716	.717	.718	.719
84	.711	.712	.713	.714	.715	.716	.717	.718	.719	.720
86	.712	.713	.714	.715	.716	.717	.718	.719	.720	.721
88	.713	.714	.715	.716	.717	.718	.719	.720	.721	.722
90	.714	.715	.716	.717	.718	.719	.720	.721	.722	.723
92	.715	.716	.717	.718	.719	.720	.720	.721	.722	.723
94	.716	.717	.718	.719	.720	.721	.721	.722	.723	.724
96	.716	.717	.718	.719	.720	.721	.722	.723	.724	.725
98	.717	.718	.719	.720	.721	.722	.723	.724	.725	.726
100	.718	.719	.720	.721	.722	.723	.724	.725	.726	.727
102	.719	.720	.721	.722	.723	.724	.725	.726	.727	.728
104	.720	.721	.722	.723	.724	.725	.726	.727	.728	.729
106	.721	.722	.723	.724	.725	.726	.727	.728	.729	.730
108	.722	.723	.724	.725	.726	.727	.728	.729	.730	.731
110	.723	.724	.725	.726	.727	.728	.729	.730	.731	.732
112	.724	.725	.726	.727	.728	.729	.730	.731	.732	.733
114	.725	.726	.727	.728	.729	.730	.731	.732	.733	.734
116	.726	.727	.728	.729	.730	.731	.731	.732	.733	.734
118	.726	.727	.728	.729	.730	.731	.732	.733	.734	.735
120	.727	.728	.729	.730	.731	.732	.733	.734	.735	.736

REDUCTION OF SPECIFIC GRAVITY READINGS TO 60°F—Con.

Observed temperature in °F	Observed specific gravities									
	0.710	0.711	0.712	0.713	0.714	0.715	0.716	0.717	0.718	0.719
	Corresponding specific gravities at 60°/60° F									
30..........	0.695	0.696	0.967	0.698	0.699	0.700	0.701	0.702	0.703	0.704
32..........	.696	.697	.698	.699	.700	.701	.702	.703	.704	.705
34..........	.697	.698	.699	.700	.701	.702	.703	.704	.705	.706
36..........	.698	.699	.700	.701	.702	.703	.704	.705	.706	.707
38..........	.699	.700	.701	.702	.703	.704	.705	.706	.707	.708
40..........	.7005	.7015	.7025	.7035	.7045	.7055	.7065	.7075	.7085	.7095
42..........	.7015	.7025	.7035	.7045	.7055	.7065	.7075	.7085	.7095	.7105
44..........	.7025	.7035	.7045	.7055	.7065	.7075	.7085	.7095	.7105	.7115
46..........	.7035	.7045	.7055	.7065	.7075	.7085	.7095	.7105	.7115	.7125
48..........	.7045	.7055	.7065	.7075	.7085	.7095	.7105	.7115	.7125	.7135
50..........	.7055	.7065	.7075	.7085	.7095	.7105	.7115	.7125	.7135	.7145
52..........	.7065	.7075	.7085	.7095	.7105	.7115	.7125	.7135	.7145	.7155
54..........	.7070	.7080	.7090	.7100	.7100	.7120	.7130	.7140	.7150	.7160
56..........	.7080	.7090	.7100	.7110	.7120	.7130	.7140	.7150	.7160	.7170
58..........	.7090	.7100	.7110	.7120	.7130	.7140	.7150	.7160	.7170	.7180
60..........	.7100	.7110	.7120	.7130	.7140	.7150	.7160	.7170	.7180	.7190
62..........	.7110	.7120	.7130	.7140	.7150	.7160	.7170	.7180	.7190	.7200
64..........	.7120	.7130	.7140	.7150	.7160	.7170	.7180	.7190	.7200	.7210
66..........	.7130	.7140	.7150	.7160	.7170	.7180	.7185	.7195	.7205	.7215
68..........	.7135	.7145	.7155	.7165	.7175	.7185	.7195	.7205	.7215	.7225
70..........	.7145	.7155	.7165	.7175	.7185	.7195	.7205	.7215	.7225	.7235
72..........	.7155	.7165	.7175	.7185	.7195	.7205	.7215	.7225	.7235	.7245
74..........	.7165	.7175	.7185	.7195	.7205	.7215	.7225	.7235	.7245	.7255
76..........	.7175	.7185	.7195	.7205	.7215	.7225	.7235	.7245	.7255	.7265
78..........	.7185	.7195	.7205	.7215	.7225	.7235	.7245	.7255	.7265	.7275
80..........	.719	.720	.721	.722	.723	.724	.725	.726	.727	.728
82..........	.720	.721	.722	.723	.724	.725	.726	.727	.728	.729
84..........	.721	.722	.723	.724	.725	.726	.727	.728	.729	.730
86..........	.722	.723	.724	.725	.726	.727	.728	.729	.730	.731
88..........	.723	.724	.725	.726	.727	.728	.729	.730	.731	.732
90..........	.724	.725	.726	.727	.728	.729	.729	.730	.731	.732
92..........	.724	.725	.726	.727	.728	.729	.730	.731	.732	.733
94..........	.725	.726	.727	.728	.729	.730	.731	.732	.733	.734
96..........	.726	.727	.728	.729	.730	.731	.732	.733	.734	.735
98..........	.727	.728	.729	.730	.731	.732	.733	.734	.735	.736
100..........	.728	.729	.730	.731	.732	.733	.734	.735	.736	.737
102..........	.729	.730	.731	.732	.733	.734	.735	.736	.737	.738
104..........	.730	.731	.732	.733	.734	.735	.736	.737	.738	.739
106..........	.731	.732	.733	.734	.735	.736	.737	.738	.739	.740
108..........	.732	.733	.734	.735	.736	.737	.737	.738	.739	.740
110..........	.733	.734	.735	.736	.737	.738	.738	.739	.740	.741
112..........	.734	.735	.736	.737	.738	.739	.739	.740	.741	.742
114..........	.734	.735	.736	.737	.738	.739	.740	.741	.742	.743
116..........	.735	.736	.737	.738	.739	.740	.741	.742	.743	.744
118..........	.736	.737	.738	.739	.740	.741	.742	.743	.744	.745
120..........	.737	.738	.739	.740	.741	.742	.742	.743	.744	.745

REDUCTION OF SPECIFIC GRAVITY READINGS TO 60°F—Con.

Observed temperature in °F	Observed specific gravities									
	0.720	0.721	0.722	0.723	0.724	0.725	0.726	0.727	0.728	0.729
	Corresponding specific gravities at 60°/60° F									
30..........	0.705	0.706	0.707	0.708	0.709	0.710	0.712	0.713	0.714	0.715
32..........	.706	.707	.708	.709	.710	.711	.713	.714	.715	.716
34..........	.707	.708	.709	.710	.711	.712	.714	.715	.716	.717
36..........	.708	.709	.710	.711	.712	.713	.715	.716	.717	.718
38..........	.709	.710	.711	.712	.713	.714	.716	.717	.718	.719
40..........	.7105	.7115	.7125	.7135	.7145	.7155	.7165	.7175	.7185	.7195
42..........	.7115	.7125	.7135	.7145	.7155	.7165	.7175	.7185	.7195	.7205
44..........	.7125	.7135	.7145	.7155	.7165	.7175	.7185	.7195	.7205	.7215
46..........	.7135	.7145	.7155	.7165	.7175	.7185	.7195	.7205	.7215	.7225
48..........	.7145	.7155	.7165	.7175	.7185	.7195	.7205	.7215	.7225	.7235
50..........	.7155	.7165	.7175	.7185	.7195	.7205	.7215	.7225	.7235	.7245
52..........	.7165	.7175	.7185	.7195	.7205	.7215	.7225	.7235	.7245	.7255
54..........	.7170	.7180	.7190	.7200	.7210	.7220	.7230	.7240	.7250	.7260
56..........	.7180	.7190	.7200	.7210	.7220	.7230	.7240	.7250	.7260	.7270
58..........	.7190	.7200	.7210	.7220	.7230	.7240	.7250	.7260	.7270	.7280
60..........	.7200	.7210	.7220	.7230	.7240	.7250	.7260	.7270	.7280	.7290
62..........	.7210	.7220	.7230	.7240	.7250	.7260	.7270	.7280	.7290	.7300
64..........	.7220	.7230	.7240	.7250	.7260	.7270	.7280	.7290	.7300	.7310
66..........	.7225	.7235	.7245	.7255	.7265	.7275	.7285	.7295	.7305	.7315
68..........	.7235	.7245	.7255	.7265	.7275	.7285	.7295	.7305	.7315	.7325
70..........	.7245	.7255	.7265	.7275	.7285	.7295	.7305	.7315	.7325	.7335
72..........	.7255	.7265	.7275	.7285	.7295	.7305	.7315	.7325	.7335	.7345
74..........	.7265	.7275	.7285	.7295	.7305	.7315	.7325	.7335	.7345	.7355
76..........	.7275	.7285	.7295	.7305	.7315	.7325	.7330	.7340	.7350	.7360
78..........	.7285	.7295	.7305	.7315	.7325	.7335	.7340	.7350	.7360	.7370
80..........	.729	.730	.731	.732	.733	.734	.735	.736	.737	.738
82..........	.730	.731	.732	.733	.734	.735	.736	.737	.738	.739
84..........	.731	.732	.733	.734	.735	.736	.737	.738	.739	.740
86..........	.732	.733	.734	.735	.736	.737	.737	.738	.739	.740
88..........	.733	.734	.735	.736	.737	.738	.738	.739	.740	.741
90..........	.733	.734	.735	.736	.737	.738	.739	.740	.741	.742
92..........	.734	.735	.736	.737	.738	.739	.740	.741	.742	.743
94..........	.735	.736	.737	.738	.739	.740	.741	.742	.743	.744
96..........	.736	.737	.738	.739	.740	.741	.742	.743	.744	.745
98..........	.737	.738	.739	.740	.741	.742	.743	.744	.745	.746
100..........	.738	.739	.740	.741	.742	.743	.743	.744	.745	.746
102..........	.739	.740	.741	.742	.743	.744	.744	.745	.746	.747
104..........	.740	.741	.742	.743	.744	.745	.745	.746	.747	.748
106..........	.741	.742	.743	.744	.745	.746	.746	.747	.748	.749
108..........	.741	.742	.743	.744	.745	.746	.747	.748	.749	.750
110..........	.742	.743	.744	.745	.746	.747	.748	.749	.750	.751
112..........	.743	.744	.745	.746	.747	.748	.749	.750	.751	.752
114..........	.744	.745	.746	.747	.748	.749	.749	.750	.751	.752
116..........	.745	.746	.747	.748	.749	.750	.750	.751	.752	.753
118..........	.746	.747	.748	.749	.750	.751	.751	.752	.753	.754
120..........	.746	.747	.748	.749	.750	.751	.752	.753	.754	.755

REDUCTION OF SPECIFIC GRAVITY READINGS TO 60°F—Con.

Observed temperature in °F	Observed specific gravities									
	0.730	0.731	0.732	0.733	0.734	0.735	0.736	0.737	0.738	0.739
	Corresponding specific gravities at 60°/60° F									
30..........	0.716	0.717	0.718	0.719	0.720	0.721	0.722	0.723	0.724	0.725
32..........	.717	.718	.719	.720	.721	.722	.723	.724	.725	.726
34..........	.718	.719	.720	.721	.722	.723	.724	.725	.726	.727
36..........	.719	.720	.721	.722	.723	.724	.725	.726	.727	.728
38..........	.720	.721	.722	.723	.724	.725	.726	.727	.728	.729
40..........	.7205	.7215	.7225	.7235	.7245	.7255	.7270	.7280	.7290	.7300
42..........	.7215	.7225	.7235	.7245	.7255	.7265	.7275	.7285	.7295	.7305
44..........	.7225	.7235	.7245	.7255	.7265	.7275	.7285	.7295	7305	.7315
46..........	.7235	.7245	.7255	.7265	.7275	.7285	.7295	.7305	.7315	.7325
48..........	.7245	.7255	.7265	.7275	.7285	.7295	.7305	.7315	.7325	.7335
50..........	.7255	.7265	.7275	.7285	.7295	.7305	.7315	.7325	.7335	.7345
52..........	.7265	.7275	.7285	.7295	.7305	.7315	.7325	.7335	.7345	.7355
54..........	.7270	.7280	.7290	.7300	.7310	.7320	.7330	.7340	.7350	.7360
56..........	.7280	.7290	.7300	.7310	.7320	.7330	.7340	.7350	.7360	.7370
58..........	.7290	.7300	.7310	.7320	.7330	.7340	.7350	.7360	.7370	.7380
60..........	.7300	.7310	.7320	.7330	.7340	.7350	.7360	.7370	.7380	.7390
62..........	.7310	.7320	.7330	.7340	.7350	.7360	.7370	.7380	.7390	.7400
64..........	.7320	.7330	.7340	.7350	.7360	.7370	.7375	.7385	.7395	.7405
66..........	.7325	.7335	.7345	.7355	.7365	.7375	.7385	.7395	.7405	.7415
68..........	.7335	.7345	.7355	.7365	.7375	.7385	.7395	.7405	.7415	.7425
70..........	.7345	.7355	.7365	.7375	.7385	.7395	.7405	.7415	.7425	.7435
72..........	.7355	.7365	.7375	.7385	.7395	.7405	.7410	.7420	.7430	.7440
74..........	.7365	.7375	.7385	.7395	.7405	.7415	.7420	.7430	.7440	.7450
76..........	.7370	.7380	.7390	.7400	.7410	.7420	.7430	.7440	.7450	.7460
78..........	.7380	.7390	.7400	.7410	.7420	.7430	.7440	.7450	.7460	.7470
80..........	.739	.740	.741	.742	.743	.744	.744	.745	.746	.747
82..........	.740	.741	.742	.743	.744	.745	.745	.746	.747	.748
84..........	.741	.742	.743	.744	.745	.746	.746	.747	.748	.749
86..........	.741	.742	.743	.744	.745	.746	.747	.748	.749	.750
88..........	.742	.743	.744	.745	.746	.747	.748	.749	.750	.751
90..........	7.43	.744	.745	.746	.747	.748	.749	.750	.751	.752
92..........	.744	.745	.746	.747	.748	.749	.750	.751	.752	.753
94..........	.745	.746	.747	.748	.749	.750	.751	.752	.753	.754
96..........	.746	.747	.748	.749	.750	.751	.751	.752	.753	.754
98..........	.747	.748	.749	.750	.751	.752	.752	.753	.754	.755
100..........	.747	.748	.749	.750	.751	.752	.753	.754	.755	.756
102..........	.748	.749	.750	.751	.752	.753	.754	.755	.756	.757
104..........	.749	.750	.751	.752	.753	.754	.755	.756	.757	.758
106..........	.750	.751	.752	.753	.754	.755	.756	.757	.758	.759
108..........	.751	.752	.753	.754	.755	.756	.756	.757	.758	.759
110..........	.752	.753	.754	.755	.756	.757	.757	.758	.759	.760
112..........	.753	.754	.755	.756	.757	.758	.758	.759	.760	.761
114..........	.753	.754	.755	.756	.757	.758	.759	.760	.761	.762
116..........	.754	.755	.756	.757	.758	.759	.760	.761	.762	.763
118..........	.755	.756	.757	.758	.759	.760	.761	.762	.763	.764
120..........	.756	.757	.758	.759	.760	.761	.761	.762	.763	.764

REDUCTION OF SPECIFIC GRAVITY READINGS TO 60°F—Con.

Observed temperature in °F	Observed specific gravities									
	0.740	0.741	0.742	0.743	0.744	0.745	0.746	0.747	0.748	0.749
	Corresponding specific gravities at 60°/60° F									
30..........	0.726	0.727	0.728	0.729	0.730	0.731	0.732	0.733	0.734	0.735
32..........	.727	.728	.729	.730	.731	.732	.733	.734	.735	.736
34..........	.728	.729	.730	.731	.732	.733	.734	.735	.736	.737
36..........	.729	.730	.731	.732	.733	.734	.735	.736	.737	.738
38..........	.730	.731	.732	.733	.734	.735	.736	.737	.738	.739
40..........	.7310	.7320	.7330	.7340	.7350	.7360	.7370	.7380	.7390	.7400
42..........	.7315	.7325	.7335	.7345	.7355	.7365	.7380	.7390	.7400	.7410
44..........	.7325	.7335	.7345	.7355	.7365	.7375	.7390	.7400	.7410	.7420
46..........	.7335	.7345	.7355	.7365	.7375	.7385	.7400	.7410	.7420	.7430
48..........	.7345	.7355	.7365	.7375	.7385	.7395	.7405	.7415	.7425	.7435
50..........	.7355	.7365	.7375	.7385	.7395	.7405	.7415	.7425	.7435	.7445
52..........	.7365	.7375	.7385	.7395	.7405	.7415	.7425	.7435	.7445	.7455
54..........	.7370	.7380	.7390	.7400	.7410	.7420	.7435	.7445	.7455	.7465
56..........	.7380	.7390	.7400	.7410	.7420	.7430	.7440	.7450	.7460	.7470
58..........	.7390	.7400	.7410	.7420	.7430	.7440	.7450	.7460	.7470	.7480
60..........	.7400	.7410	.7420	.7430	.7440	.7450	.7460	.7470	.7480	.7490
62..........	.7410	.7420	.7430	.7440	.7450	.7460	.7470	.7480	.7490	.7500
64..........	.7415	.7425	.7435	.7445	.7455	.7465	.7475	.7485	.7495	.7505
66..........	.7425	.7435	.7445	.7455	.7465	.7475	.7485	.7495	.7505	.7515
68..........	.7435	.7445	.7455	.7465	.7475	.7485	.7495	.7505	.7515	.7525
70..........	.7445	.7455	.7465	.7475	.7485	.7495	.7505	.7515	.7525	.7535
72..........	.7450	.7460	.7470	.7480	.7490	.7500	.7510	.7520	.7530	.7540
74..........	.7460	.7470	.7480	.7490	.7500	.7510	.7520	.7530	.7540	.7550
76..........	.7470	.7480	.7490	.7500	.7510	.7520	.7530	.7540	.7550	.7560
78..........	.7480	.7490	.7500	.7510	.7520	.7530	.7540	.7550	.7560	.7570
80..........	.748	.749	.750	.751	.752	.753	.754	.755	.756	.757
82..........	.749	.750	.751	.752	.753	.754	.755	.756	.757	.758
84..........	.750	.751	.752	.753	.754	.755	.756	.757	.758	.759
86..........	.751	.752	.753	.754	.755	.756	.757	.758	.759	.760
88..........	.752	.753	.754	.755	.756	.757	.758	.759	.760	.761
90..........	.753	.754	.755	.756	.757	.758	.759	.760	.761	.762
92..........	.754	.755	.756	.757	.758	.759	.759	.760	.761	.762
94..........	.755	.756	.757	.758	.759	.760	.760	.761	.762	.763
96..........	.755	.756	.757	.758	.759	.760	.761	.762	.763	.764
98..........	.756	.757	.758	.759	.760	.761	.762	.763	.764	.765
100..........	.757	.758	.759	.760	.761	.762	.763	.764	.765	.766
102..........	.758	.759	.760	.761	.762	.763	.764	.765	.766	.767
104..........	.759	.760	.761	.762	.763	.764	.764	.765	.676	.767
106..........	.760	.761	.762	.763	.764	.765	.765	.766	.767	.768
108..........	.760	.761	.762	.763	.764	.765	.766	.767	.768	.769
110..........	.761	.762	.763	.764	.765	.766	.767	.768	.769	.770
112..........	.762	.763	.764	.765	.766	.767	.768	.769	.770	.771
114..........	.763	.764	.765	.766	.767	.768	.768	.769	.770	.771
116..........	.764	.765	.766	.767	.768	.769	.769	.770	.771	.772
118..........	.765	.766	.767	.768	.769	.770	.770	.771	.772	.773
120..........	.765	.766	.767	.768	.769	.770	.771	.772	.773	.774

REDUCTION OF SPECIFIC GRAVITY READINGS TO 60°F—Con.

Observed temperature in °F	Observed specific gravities									
	0.750	0.751	0.752	0.753	0.754	0.755	0.756	0.757	0.758	0.759
	Corresponding specific gravities at 60°/60° F									
30..........	0.736	0.737	0.738	0.739	0.740	0.741	0.742	0.743	0.744	0.745
32..........	.737	.738	.739	.740	.741	.742	.743	.744	.745	.746
34..........	.738	.739	.740	.741	.742	.743	.744	.745	.746	.747
36..........	.739	.740	.741	.742	.743	.744	.745	.746	.747	.748
38..........	.740	.741	.742	.743	.744	.745	.746	.747	.748	.749
40..........	.7410	.7420	.7430	.7440	.7450	.7460	.7475	.7485	.7495	.7505
42..........	.7420	.7430	.7440	.7450	.7460	.7470	.7480	.7490	.7500	.7510
44..........	.7430	.7440	.7450	.7460	.7470	.7480	.7490	.7500	.7510	.7520
46..........	.7440	.7450	.7460	.7470	.7480	.7490	.7500	.7510	.7520	.7530
48..........	.7445	.7455	.7465	.7475	.7485	.7495	.7510	.7520	.7530	.7540
50..........	.7455	.7465	.7475	.7485	.7495	.7505	.7515	.7525	.7535	.7545
52..........	.7465	.7475	.7485	.7495	.7505	.7515	.7525	.7535	.7545	.7555
54..........	.7475	.7485	.7495	.7505	.7515	.7525	.7535	.7545	.7555	.7565
56..........	.7480	.7490	.7500	.7510	.7520	.7530	.7540	.7550	.7560	.7570
58..........	.7490	.7500	.7510	.7520	.7530	.7540	.7550	.7560	.7570	.7580
60..........	.7500	.7510	.7520	.7530	.7540	.7550	.7560	.7570	.7580	.7590
62..........	.7510	.7520	.7530	.7540	.7550	.7560	.7570	.7580	.7590	.7600
64..........	.7515	.7525	.7535	.7545	.7555	.7565	.7575	.7585	.7595	.7605
66..........	.7525	.7535	.7545	.7555	.7565	.7575	.7585	.7595	.7605	.7615
68..........	.7535	.7545	.7555	.7565	.7575	.7585	.7590	.7600	.7610	.7620
70..........	.7545	.7555	.7565	.7575	.7585	.7595	.7600	.7610	.7620	.7630
72..........	.7550	.7560	.7570	.7580	.7590	.7600	.7610	.7620	.7630	.7640
74..........	.7560	.7570	.7580	.7590	.7600	.7610	.7615	.7625	.7635	.7645
76..........	.7570	.7580	.7590	.7600	.7610	.7620	.7625	.7635	.7645	.7655
78..........	.7580	.7590	.7600	.7610	.7620	.7630	.7635	.7645	.7655	.7665
80..........	.758	.759	.760	.761	.762	.763	.764	.765	.766	.767
82..........	.759	.760	.761	.762	.763	.764	.765	.766	.767	.768
84..........	.760	.761	.762	.763	.764	.765	.766	.767	.768	.769
86..........	.761	.762	.763	.764	.765	.766	.767	.768	.769	.770
88..........	.762	.763	.764	.765	.766	.767	.767	.768	.769	.770
90..........	.763	.764	.765	.766	.767	.768	.768	.769	.770	.771
92..........	.763	.764	.765	.766	.767	.768	.769	.770	.771	.772
94..........	.764	.765	.766	.767	.768	.769	.770	.771	.772	.773
96..........	.765	.766	.767	.768	.769	.770	.771	.772	.773	.774
98..........	.766	.767	.768	.769	.770	.771	.771	.772	.773	.774
100..........	.767	.768	.769	.770	.771	.772	.772	.773	.774	.775
102..........	.768	.769	.770	.771	.772	.773	.773	.774	.775	.776
104..........	.768	.769	.770	.771	.772	.773	.774	.775	.776	.777
106..........	.769	.770	.771	.772	.773	.774	.775	.776	.777	.778
108..........	.770	.771	.772	.773	.774	.775	.775	.776	.777	.778
110..........	.771	.772	.773	.774	.775	.776	.776	.777	.778	.779
112..........	.772	.773	.774	.775	.776	.777	.777	.778	.779	.780
114..........	.772	.773	.774	.775	.776	.777	.778	.779	.780	.781
116..........	.773	.774	.775	.776	.777	.778	.779	.780	.781	.782
118..........	.774	.775	.776	.777	.778	.779	.780	.781	.782	.783
120..........	.775	.776	.777	.778	.779	.780	.780	.781	.782	.783

REDUCTION OF SPECIFIC GRAVITY READINGS TO 60°F—Con.

Observed temperature in °F	Observed specific gravities									
	0.760	0.761	0.762	0.763	0.764	0.765	0.766	0.767	0.768	0.769
	Corresponding specific gravities at 60°/60° F									
30..........	0.746	0.747	0.748	0.749	0.750	0.751	0.753	0.754	0.755	0.756
32..........	.747	.748	.749	.750	.751	.752	.754	.755	.756	.757
34..........	.748	.749	.750	.751	.752	.753	.755	.756	.757	.758
36..........	.749	.750	.751	.752	.753	.754	.756	.757	.758	.759
38..........	.750	.751	.752	.753	.754	.755	.757	.758	.759	.760
40..........	.7515	.7525	.7535	.7545	.7555	.7565	.7575	.7585	.7595	.7605
42..........	.7520	.7530	.7340	.7550	.7560	.7570	.7585	.7595	.7605	.7615
44..........	.7530	.7540	.7550	.7560	.7570	.7580	.7590	.7600	.7610	.7620
46..........	.7540	.7550	.7560	.7570	.7580	.7590	.7600	.7610	.7620	.7630
48..........	.7550	.7560	.7570	.7580	.7590	.7600	.7610	.7620	.7630	.7640
50..........	.7555	.7565	.7575	.7585	.7595	.7605	.7620	.7630	.7640	.7650
52..........	.7565	.7575	.7585	.7595	.7605	.7615	.7625	.7635	.7645	.7655
54..........	.7575	.7585	.7595	.7605	.7615	.7625	.7635	.7645	.7655	.7665
56..........	.7580	.7590	.7600	.7610	.7620	.7630	.7645	.7655	.7665	.7675
58..........	.7590	.7600	.7610	.7620	.7630	.7640	.7650	.7660	.7670	.7680
60..........	.7600	.7610	.7620	.7630	.7640	.7650	.7660	.7670	.7680	.7690
62..........	.7610	.7620	.7630	.7640	.7650	.7660	.7670	.7680	.7690	.7700
64..........	.7615	.7025	.7635	.7645	.7655	.7665	.7675	.7685	.7695	.7705
66..........	.7625	.7635	.7645	.7655	.7665	.7675	.7685	.7695	.7705	.7715
68..........	.7630	.7640	.7650	.7660	.7670	.7680	.7690	.7700	.7710	.7720
70..........	.7640	.7650	.7660	.7670	.7680	.7690	.7700	.7710	.7720	.7730
72..........	.7650	.7660	.7670	.7680	.7690	.7700	.7710	.7720	.7730	.7740
74..........	.7655	.7665	.7675	.7685	.7695	.7705	.7715	.7725	.7735	.7745
76..........	.7665	.7675	.7685	.7695	.7705	.7715	.7725	.7735	.7745	.7755
78..........	.7675	.7685	.7695	.7705	.7715	.7725	.7735	.7745	.7755	.7765
80..........	.768	.769	.770	.771	.772	.773	.774	.775	.776	.777
82..........	.769	.770	.771	.772	.773	.774	.775	.776	.777	.778
84..........	.770	.771	.772	.773	.774	.775	.776	.777	.778	.779
86..........	.771	.772	.773	.774	.775	.776	.776	.777	.778	.778
88..........	.771	.772	.773	.774	.775	.776	.777	.778	.779	.780
90..........	.772	.773	.774	.775	.776	.777	.778	.779	.780	.781
92..........	.773	.774	.775	.776	.777	.778	.779	.780	.781	.782
94..........	.774	.775	.776	.777	.778	.779	.780	.781	.782	.783
96..........	.775	.776	.777	.778	.779	.780	.780	.781	.782	.783
98..........	.775	.776	.777	.778	.779	.780	.781	.782	.783	.784
100..........	.776	.777	.778	.779	.780	.781	.782	.783	.784	.785
102..........	.777	.778	.779	.780	.781	.782	.783	.784	.785	.786
104..........	.778	.779	.780	.781	.782	.783	.784	.785	.786	.787
106..........	.779	.780	.781	.782	.783	.784	.784	.785	.786	.787
108..........	.779	.780	.781	.782	.783	.784	.785	.786	.787	.788
110..........	.780	.781	.782	.783	.784	.785	.786	.787	.788	.789
112..........	.781	.782	.783	.784	.785	.786	.787	.788	.789	.790
114..........	.782	.783	.784	.785	.786	.787	.787	.788	.789	.790
116..........	.783	.784	.785	.786	.787	.788	.788	.789	.790	.791
118..........	.784	.785	.786	.787	.788	.789	.789	.790	.791	.792
120..........	.784	.785	.786	.787	.788	.789	.790	.791	.792	.793

REDUCTION OF SPECIFIC GRAVITY READINGS TO 60°F—Con.

Observed temperature in °F	Observed specific gravities									
	0.770	0.771	0.772	0.773	0.774	0.775	0.776	0.777	0.778	0.779
	Corresponding specific gravities at 60°/60° F									
30..........	0.757	0.758	0.759	0.760	0.761	0.762	0.763	0.764	0.765	0.766
32..........	.758	.759	.760	.761	.762	.763	.764	.765	.766	.767
34..........	.759	.760	.761	.762	.763	.764	.765	.766	.767	.768
36..........	.760	.761	.762	.763	.764	.765	.766	.767	.768	.769
38..........	.761	.762	.763	.764	.765	.766	.767	.768	.769	.770
40..........	.7615	.7625	.7635	.7645	.7655	.7665	.7675	.7685	.7695	.7705
42..........	.7625	.7635	.7645	.7655	.7665	.7675	.7685	.7695	.7705	.7715
44..........	.7630	.7640	.7650	.7665	.7670	.7680	.7695	.7705	.7715	.7725
46..........	.7640	.7650	.7660	.7670	.7680	.7690	.7700	.7710	.7720	.7730
48..........	.7650	.7660	.7670	.7680	.7690	.7700	.7710	.7720	.7730	.7740
50..........	.7660	.7670	.7680	.7690	.7700	.7710	.7720	.7730	.7740	.7750
52..........	.7665	.7675	.7685	.7695	.7705	.7715	7725	.7735	.7745	.7755
54..........	.7675	.7685	.7695	.7705	.7715	.7725	.7735	.7745	.7755	.7765
56..........	.7685	.7695	.7705	.7715	7725	.7735	.7745	.7755	.7765	.7775
58..........	.7690	.7700	.7710	.7720	.7730	.7740	.7750	.7760	.7770	.7780
60..........	.7700	.7710	.7720	.7730	.7740	.7750	.7760	.7770	.7780	.7790
62..........	.7710	.7720	.7730	.7740	.7750	.7760	.7770	.7780	.7790	.7800
64..........	.7715	.7725	.7735	.7745	.7755	.7765	.7775	.7785	.7795	.7805
66..........	.7725	.7735	.7745	.7755	.7765	.7775	.7785	.7795	.7805	.7815
68..........	.7730	.7740	.7750	.7760	.7770	.7780	.7790	.7800	.7810	.7820
70..........	.7740	.7750	.7760	.7770	.7780	.7790	.7800	.7810	.7820	.7830
72..........	.7750	.7760	.7770	.7780	.7790	.7800	.7810	.7820	.7830	.7840
74..........	.7755	.7765	.7775	.7785	.7795	.7805	.7815	.7825	.7835	.7845
76..........	.7765	.7775	.7785	.7795	.7805	.7815	.7825	.7835	.7845	.7855
78..........	.7775	.7785	.7795	.7805	.7815	.7825	.7835	.7845	.7855	.7865
80..........	.778	.779	.780	.781	.782	.783	.784	.785	.786	.787
82..........	.779	.780	.781	.782	.783	.784	.785	.786	.787	.788
84..........	.780	.781	.782	.783	.784	.785	.785	.786	.787	.788
86..........	.780	.781	.782	.783	.784	.785	.786	.787	.788	.789
88..........	.781	.782	.783	.784	.785	.786	.787	.788	.789	.790
90..........	.782	.783	.784	.785	.786	.787	.788	.789	.790	.791
92..........	.783	.784	.785	.786	.787	.788	.789	.790	.791	.792
94..........	.784	.785	.786	.787	.788	.789	.789	.790	.791	.792
96..........	.784	.785	.786	.787	.788	.789	.790	.791	.792	.793
98..........	.785	.786	.787	.788	.789	.790	.791	.792	.793	.794
100..........	.786	.787	.788	.789	.790	.791	.792	.793	.794	.795
102..........	.787	.788	.789	.790	.791	.792	.792	.793	.794	.795
104..........	.788	.789	.790	.791	.792	.793	.793	.794	.795	.796
106..........	.788	.789	.790	.791	.792	.793	.794	.795	.796	.797
108..........	.789	.790	.791	.792	.793	.794	.795	.796	.797	.798
110..........	.790	.791	.792	.793	.794	.795	.795	.796	.797	.798
112..........	.791	.792	.793	.794	.795	.796	.796	.797	.798	.799
114..........	.791	.792	.793	.794	.795	.796	.797	.798	.799	.800
116..........	.792	.793	.794	.795	.796	.797	.798	.799	.800	.801
118..........	.793	.794	.795	.796	.797	.798	.799	.800	.801	.802
120..........	.794	.795	.796	.797	.798	.799	.799	.800	.801	.802

REDUCTION OF SPECIFIC GRAVITY READINGS TO 60°F—Con.

Observed temperature in °F	Observed specific gravities									
	0.780	0.781	0.782	0.783	0.784	0.785	0.786	0.787	0.788	0.789
	Corresponding specific gravities at 60°/60° F									
30..........	0.767	0.768	0.769	0.770	0.771	0.772	0.773	0.774	0.775	0.776
32..........	.768	.769	.770	.771	.772	.773	.774	.775	.776	.777
34..........	.769	.770	.771	.772	.773	.774	.775	.776	.777	.778
36..........	.770	.771	.772	.773	.774	.775	.776	.777	.778	.779
38..........	.771	.772	.773	.774	.775	.776	.777	.778	.779	.780
40..........	.7715	.7725	.7735	.7745	.7755	.7765	.7780	.7790	.7800	.7810
42..........	.7725	.7735	.7745	.7755	.7765	.7775	.7785	.7795	.7805	.7815
44..........	.7735	.7745	.7755	.7765	.7775	.7785	.7795	.7805	.7815	.7825
46..........	.7740	.7750	.7760	.7770	.7780	.7790	.7805	.7815	.7825	.7835
48..........	.7750	.7760	.7770	.7780	.7790	.7800	.7810	.7820	.7830	.7840
50..........	.7760	.7770	.7780	.7790	.7800	.7810	.7820	.7830	.7840	.7850
52..........	.7765	.7775	.7785	.7795	.7805	.7815	.7830	.7840	.7850	.7860
54..........	.7775	.7785	.7795	.7805	.7815	.7825	.7835	.7845	.7855	.7865
56..........	.7785	.7795	.7805	.7815	.7825	.7835	.7845	.7855	.7865	.7875
58..........	.7790	.7800	.7810	.7820	.7830	.7840	.7850	.7860	.7870	.7880
60..........	.7800	.7810	.7820	.7830	.7840	.7850	.7860	.7870	.7880	.7890
62..........	.7810	.7820	.7830	.7840	.7850	.7860	.7865	.7875	.7885	.7895
64..........	.7815	.7825	.7835	.7845	.7855	.7865	.7875	.7885	.7895	.7905
66..........	.7825	.7835	.7845	.7855	.7865	.7875	.7885	.7895	.7905	.7915
68..........	.7830	.7840	.7850	.7860	.7870	.7880	.7890	.7900	.7910	.7920
70..........	.7840	.7850	.7860	.7870	.7880	.7890	.7900	.7910	.7920	.7930
72..........	.7850	.7860	.7870	.7880	.7890	.7900	.7905	.7915	.7925	.7935
74..........	.7855	.7865	.7875	.7885	.7895	.7905	.7915	.7925	.7935	.7945
76..........	.7865	.7875	.7885	.7895	.7905	.7915	.7925	.7935	.7945	.7955
78..........	.7875	.7885	.7895	.7905	.7915	.7925	.7930	.7940	.7450	.7960
80..........	.788	.789	.790	.791	.792	.793	.794	.795	.796	.797
82..........	.789	.790	.791	.792	.793	.794	.794	.795	.796	.797
84..........	.789	.790	.791	.792	.793	.794	.795	.796	.797	.798
86..........	.790	.791	.792	.793	.794	.795	.796	.797	.798	.799
88..........	.791	.792	.793	.794	.795	.796	.797	.798	.799	.800
90..........	.792	.793	.794	.795	.796	.797	.798	.799	.800	.801
92..........	.793	.794	.795	.796	.797	.798	.798	.799	.800	.801
94..........	.793	.794	.795	.796	.797	.798	.799	.800	.801	.802
96..........	.794	.795	.796	.797	.798	.799	.800	.801	.802	.803
98..........	.795	.796	.797	.798	.799	.800	.801	.802	.803	.804
100..........	.796	.797	.798	.799	.800	.801	.801	.802	.803	.804
102..........	.796	.797	.798	.799	.800	.801	.802	.803	.804	.805
104..........	.797	.798	.799	.800	.801	.802	.803	.804	.805	.806
106..........	.798	.799	.800	.801	.802	.803	.804	.805	.806	.807
108..........	.799	.800	.801	.802	.803	.804	.804	.805	.806	.807
110..........	.799	.800	.801	.802	.803	.804	.805	.806	.807	.808
112..........	.800	.801	.802	.803	.804	.805	.806	.807	.808	.809
114..........	.801	.802	.803	.804	.805	.806	.807	.808	.809	.810
116..........	.802	.803	.804	.805	.806	.807	.807	.808	.809	.810
118..........	.803	.804	.805	.806	.807	.808	.808	.809	.810	.811
120..........	.803	.804	.805	.806	.807	.808	.809	.810	.811	.812

REDUCTION OF SPECIFIC GRAVITY READINGS TO 60°F—Con.

Observed temperature in °F	Observed specific gravities									
	0.790	0.791	0.792	0.793	0.794	0.795	0.796	0.797	0.798	0.799
	Corresponding specific gravities at 60°/60° F									
30..........	0.777	.0778	0.779	0.780	0.781	0.782	0.784	0.785	0.786	0.787
32..........	.778	.779	.780	.781	.782	.783	.784	.785	.786	.787
34..........	.779	.780	.781	.782	.783	.784	.785	.786	.787	.788
36..........	.780	.781	.782	.783	.784	.785	.786	.787	.788	.789
38..........	.781	.782	.783	.784	.785	.786	.787	.788	.789	.790
40..........	.7820	.7830	.7840	.7850	.7860	.7870	.7880	.7890	.7900	.7910
42..........	.7825	.7835	.7845	.7855	.7865	.7875	.7890	.7900	.7910	.7920
44..........	.7835	.7845	.7855	.7865	.7875	.7885	.7895	.7905	.7915	.7925
46..........	.7845	.7855	.7865	.7875	.7885	.7895	.7905	.7915	.7925	.7935
48..........	.7850	.7860	.7870	.7880	.7890	.7900	.7910	.7920	.7930	.7940
50..........	.7860	.7870	.7880	.7890	.7900	.7910	.7920	.7930	.7940	.7950
52..........	.7870	.7880	.7890	.7900	.7910	.7920	.7930	.7940	.7950	.7960
54..........	.7875	.7885	.7895	.7905	.7915	.7925	.7935	.7945	.7955	.7965
56..........	.7885	.7895	.7905	.7915	.7925	.7935	.7945	.7955	.7965	.7975
58..........	.7890	.7900	.7910	.7920	.7930	.7940	.7955	.7965	.7975	.7985
60..........	.7900	.7910	.7920	.7930	.7940	.7950	.7960	.7970	.7980	.7990
62..........	.7905	.7915	.7925	.7935	.7945	.7955	.7965	.7975	.7985	.7995
64..........	.7915	.7925	.7935	.7945	.7955	.7965	.7975	.7985	.7995	.8005
66..........	.7925	.7935	.7945	.7955	.7965	.7975	.7985	.7995	.8005	.8015
68..........	.7930	.7940	.7950	.7960	.7970	.7980	.7990	.8000	.8010	.8020
70..........	.7940	.7950	.7960	.7970	.7980	.7990	.8000	.8010	.8020	.8030
72..........	.7945	.7955	.7965	.7975	.7985	.7995	.8005	.8015	.8025	.8035
74..........	.7955	.7965	.7975	.7985	.7995	.8005	.8015	.8025	.8035	.8045
76..........	.7965	.7975	.7985	.7995	.8005	.8015	.8020	.8030	.8040	.8050
78..........	.7970	.7980	.7990	.8000	.8010	.8020	.8030	.8040	.8050	.8060
80..........	.798	.799	.800	.801	.802	.803	.804	.805	.806	.807
82..........	.798	.799	.800	.801	.802	.803	.804	.805	.806	.807
84..........	.799	.800	.801	.802	.803	.804	.805	.806	.807	.808
86..........	.800	.801	.802	.803	.804	.805	.806	.807	.808	.809
88..........	.801	.802	.803	.804	805	.806	.807	.808	.809	.810
90..........	.802	.803	.804	.805	.806	.807	.808	.809	.810	.811
92..........	.802	.803	.804	.805	.806	.807	.808	.809	.810	.811
94..........	.803	.804	.805	.806	.807	.808	.809	.810	.811	.812
96..........	.804	.805	.806	.807	.808	.809	.810	.811	.812	.813
98..........	.805	.806	.807	.808	.809	.810	.811	.812	.813	.814
100..........	.805	.806	.807	.808	.809	.810	.811	.812	.813	.814
102..........	.806	.807	.808	.809	.810	.811	.812	.813	.814	.815
104..........	.807	.808	.809	.810	.811	.812	.813	.814	.815	.816
106..........	.808	.809	.810	.811	.812	.813	.813	.814	.815	.816
108..........	.808	.809	.810	.811	.812	.813	.814	.815	.816	.817
110..........	.809	.810	.811	.812	.813	.814	.815	.816	.817	.818
112..........	.810	.811	.812	.813	.814	.815	.816	.817	.818	.819
114..........	.811	.812	.813	.814	.815	.816	.816	.817	.818	.819
116..........	.811	.812	.813	.814	.815	.816	.817	.818	.819	.820
118..........	.812	.813	.814	.815	.816	.817	.818	.819	.820	.821
120..........	.813	.814	.815	.816	.817	.818	.819	.820	.821	.822

REDUCTION OF SPECIFIC GRAVITY READINGS TO 60°F—Con.

Observed temperature in °F	Observed specific gravities									
	0.800	0.801	0.802	0.803	0.804	0.805	0.806	0.807	0.808	0.809
	Corresponding specific gravities at 60°/60° F									
30..........	0.788	0.789	0.790	0.791	0.792	0.793	0.794	0.795	0.796	0.797
32..........	.788	.789	.790	.791	.792	.793	.795	.796	.797	.798
34..........	.789	.790	.791	.792	.793	.794	.795	.796	.797	.798
36..........	.790	.791	.792	.793	.794	.795	.796	.797	.798	.799
38..........	.791	.792	.793	7.94	.795	.796	.797	.798	.799	.800
40..........	.7920	.7930	.7940	.7450	.7960	.7970	.7980	.7990	.8000	.8010
42..........	.7930	.7940	.7950	.7960	.7970	.7980	.7990	.8000	.8010	.8020
44..........	.7935	.7945	.7955	.7965	.7975	.7985	.7995	.8005	.8015	.8025
46..........	.7945	.7955	.7965	.7975	.7985	.7995	.8005	.8015	.8025	.8035
48..........	.7950	.7960	.7970	.7980	.7990	.8000	.8010	.8020	.8030	.8040
50..........	.7960	.7970	.7980	.7990	.8000	.8010	.8020	.8030	.8040	.8050
52..........	.7970	.7980	.7990	.8000	.8010	.8020	.8030	.8040	.8050	.8060
54..........	.7975	.7985	.7995	.8005	.8015	.8025	.8035	.8045	.8055	.8065
56..........	.7985	.7995	.8005	.8015	.8025	.8035	.8045	.8055	.8065	.8075
58..........	.7995	.8005	.8015	.8025	.8035	.8045	.8055	.8065	.8075	.8085
60..........	.8000	.8010	.8020	.8030	.8040	.8050	.8060	.8070	.8080	.8090
62..........	.8005	.8015	.8025	.8035	.8045	.8055	.8065	.8075	.8085	.8095
64..........	.8015	.8025	.8035	.8045	.8055	.8065	.8075	.8085	.8095	.8105
66..........	.8025	.8035	.8045	.8055	.8065	.8075	.8085	.8095	.8105	.8115
68..........	.8030	.8040	.8050	.8060	.8070	.8080	.8090	.8100	.8110	.8120
70..........	.8040	.8050	.8060	.8070	.8080	.8090	.8100	.8110	.8120	.8130
72..........	.8045	.8055	.8065	.8075	.8085	.8095	.8105	.8115	.8125	.8135
74..........	.8055	.8065	.8075	.8085	.8095	.8105	.8115	.8125	.8135	.8145
76..........	.8065	.8075	.8085	.8095	.8105	.8115	.8120	.8130	.8140	.8150
78..........	.8070	.8080	.8090	.8100	.8110	.8120	.8130	.8140	.8150	.8160
80..........	.808	.809	.810	.811	.812	.813	.813	.814	.815	.816
82..........	.808	.809	.810	.811	.812	.813	.814	.815	.816	.817
84..........	.809	.810	.811	.812	.813	.814	.815	.816	.817	.818
86..........	.810	.811	.812	.813	.814	.815	.816	.817	.818	.819
88..........	.811	.812	.813	.814	.815	.816	.816	.817	.818	.819
90..........	.812	.813	.814	.815	.816	.817	.817	.818	.819	.820
92..........	.812	.813	.814	.815	.816	.817	.818	.819	.820	.821
94..........	.813	.814	.815	.816	.817	.818	.819	.820	.821	.822
96..........	.814	.815	.816	.817	.818	.819	.819	.820	.821	.822
98..........	.815	.816	.817	.818	.819	.820	.820	.821	.822	.823
100..........	.815	.816	.817	.818	.819	.820	.821	.822	.823	.824
102..........	.816	.817	.818	.819	.820	.821	.822	.823	.824	.825
104..........	.817	.818	.819	.820	.821	.822	.822	.823	.824	.825
106..........	.817	.818	.819	.820	.821	.822	.823	.824	.825	.826
108..........	.818	.819	.820	.821	.822	.823	.824	.825	.826	.827
110..........	.819	.820	.821	.822	.823	.824	.825	.826	.827	.828
112..........	.820	.821	.822	.823	.824	.825	.825	.826	.827	.828
114..........	.820	.821	.822	.823	.824	.825	.826	.827	.828	.829
116..........	.821	.822	.823	.824	.825	.826	.827	.828	.829	.830
118..........	.822	.823	.824	.825	.826	.827	.828	.829	.830	.831
120..........	.823	.824	.825	.826	.827	.828	.828	.829	.830	.831

REDUCTION OF SPECIFIC GRAVITY READINGS TO 60°F—Con.

Observed temperature in °F	Observed specific gravities									
	0.810	0.811	0.812	0.813	0.814	0.815	0.816	0.817	0.818	0.819
	Corresponding specific gravities at 60°/60° F									
30..........	0.798	0.799	0.800	0.801	0.802	0.803	0.804	0.805	0.806	0.807
32..........	.799	.800	.801	.802	.803	.804	.805	.806	.807	.808
34..........	.799	.800	.801	.802	.803	.804	.806	.807	.808	.809
36..........	.800	.801	.802	.803	.804	.805	.807	.808	.809	.810
38..........	.801	.802	.803	.804	.805	.806	.808	.809	.810	.811
40..........	.8020	.8030	.8040	.8050	.8060	.8070	.8085	.8095	.8105	.8115
42..........	.8030	.8040	.8050	.8060	.8070	.8080	.8090	.8100	.8110	.8120
44..........	.8035	.8045	.8055	.8065	.8075	.8085	.8100	.8110	.8120	.8130
46..........	.8045	.8055	.8065	.8075	.8085	.8095	.8105	.8115	.8125	.8135
48..........	.8050	.8060	.8070	.8080	.8090	.8100	.8115	.8125	.8135	.8145
50..........	.8060	.8070	.8080	.8090	.8100	.8110	.8120	.8130	.8140	.8150
52..........	.8070	.8080	.8090	.8100	.8110	.8120	.8130	.8140	.8150	.8160
54..........	.8075	.8085	.8095	.8105	.8115	.8125	.8135	.8145	.8155	.8165
56..........	.8085	.8095	.8105	.8115	.8125	.8135	.8145	.8155	.8165	.8175
58..........	.8095	.8105	.8115	.8125	.8135	.8145	.8155	.8165	.8175	.8185
60..........	.8100	.8110	.8120	.8130	.8140	.8150	.8160	.8170	.8180	.8190
62..........	.8105	.8115	.8125	.8135	.8145	.8155	.8165	.8175	.8185	.8195
64..........	.8115	.8125	.8135	.8145	.8155	.8165	.8175	.8185	.8195	.8205
66..........	.8125	.8135	.8145	.8155	.8165	.8175	.8180	.8190	.8200	.8210
68..........	.8130	.8140	.8150	.8160	.8170	.8180	.8190	.8200	.8210	.8220
70..........	.8140	.8150	.8160	.8170	.8180	.8190	.8200	.8210	.8220	.8230
72..........	.8145	.8155	.8165	.8175	.8185	.8195	.8205	.8215	.8225	.8235
74..........	.8155	.8165	.8175	.8185	.8195	.8205	.8215	.8225	.8235	.8245
76..........	.8160	.8170	.8180	.8190	.8200	.8210	.8220	.8230	.8240	.8250
78..........	.8170	.8180	.8190	.8200	.8210	.8220	.8230	.8240	.8250	.8260
80..........	.817	.818	.819	.820	.821	.822	.823	.824	.825	.826
82..........	.818	.819	.820	.821	.822	.823	.824	.825	.826	.827
84..........	.819	.820	.821	.822	.823	.824	.825	.826	.827	.828
86..........	.820	.821	.822	.823	.824	.825	.826	.827	.828	.829
88..........	.820	.821	.822	.823	.824	.825	.826	.827	.828	.829
90..........	.821	.822	.823	.824	.825	.826	.827	.828	.829	.830
92..........	.822	.823	.824	.825	.826	.827	.828	.829	.830	.831
94..........	.823	.824	.825	.826	.827	.828	.828	.829	.830	.831
96..........	.823	.824	.825	.826	.827	.828	.829	.830	.831	.832
98..........	.824	.825	.826	.827	.828	.829	.830	.831	.832	.833
100..........	.825	.826	.827	.828	.829	.830	.831	.832	.833	.834
102..........	.826	.827	.828	.829	.830	.831	.831	.832	.833	.834
104..........	.826	.827	.828	.829	.830	.831	.832	.833	.834	.835
106..........	.827	.828	.829	.830	.831	.832	.833	.834	.835	.836
108..........	.828	.829	.830	.831	.832	.833	.834	.835	.836	.837
110..........	.829	.830	.831	.832	.833	.834	.834	.835	.836	.837
112..........	.829	.830	.831	.832	.833	.834	.835	.836	.837	.838
114..........	.830	.831	.832	.833	.834	.835	.836	.837	.838	.839
116..........	.831	.832	.833	.834	.835	.836	.836	.837	.838	.839
118..........	.832	.833	.834	.835	.836	.837	.837	.838	.839	.840
120..........	.832	.833	.834	.835	.836	.837	.838	.839	.840	.841

REDUCTION OF SPECIFIC GRAVITY READINGS TO 60°F—Con.

Observed temperature in °F	Observed specific gravities									
	0.820	0.821	0.822	0.823	0.824	0.825	0.826	0.827	0.828	0.829
	Corresponding specific gravities at 60°/60° F									
30	0.808	0.809	0.810	0.811	0.812	0.813	0.814	0.815	0.816	0.817
32	.809	.810	.811	.812	.813	.814	.815	.816	.817	.818
34	.810	.811	.812	.813	.814	.815	.816	.817	.818	.819
36	.811	.812	.813	.814	.815	.816	.817	.818	.819	.820
38	.812	.813	.814	.815	.816	.817	.818	.819	.820	.821
40	.8125	.8135	.8145	.8155	.8165	.8175	.8185	.8195	.8205	.8215
42	.8130	.8140	.8150	.8160	8170	.8180	.8190	.8200	.8210	.8220
44	.8140	.8150	.8160	.8170	.8180	.8190	.8200	.8210	.8220	.8230
46	.8145	.8155	.8165	.8175	.8185	.8195	.8205	.8215	.8225	.8235
48	.8155	.8165	.8175	.8185	.8195	.8205	.8215	.8225	.8235	.8240
50	.8160	.8170	.8180	.8190	.8200	.8210	.8220	.8230	.8240	.8250
52	.8170	.8180	.8190	.8200	.8210	.8220	.8230	.8240	.8250	.8260
54	.8175	.8185	.8195	.8205	.8215	.8225	.8240	.8250	.8260	.8270
56	.8185	.8195	.8205	.8215	.8225	.8235	.8245	.8255	.8265	.8275
58	.8195	.8205	.8215	.8225	.8235	.8245	.8255	.8265	.8275	.8285
60	.8200	.8210	.8220	.8230	.8240	.8250	.8260	.8270	.8280	.8290
62	.8205	.8215	.8225	.8235	.8245	.8255	.8265	.8275	.8285	.8295
64	.8215	.8225	.8235	.8245	.8255	.8265	.8275	.8285	.8295	.8305
66	.8220	.8230	.8240	.8250	.8260	.8270	.8280	.8200	.8300	.8310
68	.8230	.8240	.8250	.8260	.8270	.8280	.8290	.8300	.8310	.8320
70	.8240	.8250	.8260	.8270	.8290	.8290	.8300	.8310	.8320	.8330
72	.8245	.8255	.8265	.8275	.8285	.8295	.8305	.8315	.8325	.8335
74	.8255	.8265	.8275	.8285	.8295	.8305	.8315	.8325	.8335	.8345
76	.8260	.8270	.8280	.8290	.8300	.8310	.8320	.8330	.8340	.8350
78	.8270	.8280	.8290	.8300	.8310	.8320	.8330	.8340	.8350	.8360
80	.827	.828	.829	.830	.831	.832	.833	.834	.835	.836
82	.828	.829	.830	.831	.832	.833	.834	.835	.836	.837
84	.829	.830	.831	.832	.833	.834	.835	.836	.837	.838
86	.830	.831	.832	.833	.834	.835	.835	.836	.837	.838
88	.830	.831	.832	.833	.834	.835	.836	.837	.838	.839
90	.831	.832	.833	.834	.835	.836	.837	.838	.839	.840
92	.832	.833	.834	.835	.836	.837	.838	.839	.840	.841
94	.832	.833	.834	.835	.836	.837	.838	.839	.840	.841
96	.833	.834	.835	.836	.837	.838	.839	.840	.841	.842
98	.834	.835	.836	.837	.838	.839	.840	.841	.842	.843
100	.835	.836	.837	.838	.839	.840	.840	.841	.842	.843
102	.835	.836	.837	.838	.839	.840	.841	.842	.843	.844
104	.836	.837	.838	.839	.840	.841	.842	.843	.844	.845
106	.837	.838	.839	.840	.841	.842	.843	.844	.845	.846
108	.838	.839	.840	.841	.842	.843	.843	.844	.845	.846
110	.838	.839	.840	.841	.842	.843	.844	.845	.846	.847
112	.839	.840	.841	.842	.843	.844	.845	.846	.847	.848
114	.840	.841	.842	.843	.844	.845	.846	.847	.848	.849
116	.840	.841	.842	.843	.844	.845	.846	.847	.848	.849
118	.841	.842	.843	.844	.845	.846	.847	.848	.849	.850
120	.842	.843	.844	.845	.846	.847	.848	.849	.850	.851

REDUCTION OF SPECIFIC GRAVITY READINGS TO 60°F—Con.

Observed temperature in °F	Observed specific gravities									
	0.830	0.831	0.832	0.833	0.834	0.835	0.836	0.837	0.838	0.839
	Corresponding specific gravities at 60°/60° F									
30..........	0.818	0.819	0.820	0.821	0.822	0.823	0.824	0.825	0.826	0.827
32..........	.819	.820	.821	.822	.823	.824	.825	.826	.827	.828
34..........	.820	.821	.822	.823	.824	.825	.826	.827	.828	.829
36..........	.821	.822	.823	.824	.825	.826	.827	.828	.829	.830
38..........	.822	.823	.824	.825	.826	.827	.828	.829	.830	.831
40..........	.8225	.8235	.8245	.8255	.8265	.8275	.8285	.8295	.8305	.8315
42..........	.8230	.8240	.8250	.8260	.8270	.8280	.8295	.8305	.8315	.8325
44..........	.8240	.8250	.8260	.8270	.8280	.8290	.8300	.8310	.8320	.8330
46..........	.8245	.8255	.8265	.8275	.8285	.8295	.8305	.8315	.8325	.8335
48..........	.8255	.8265	.8275	.8285	.8290	.8305	.8315	.8325	.8335	.8345
50..........	.8260	.8270	.8280	.8290	.8300	.8310	.8325	.8335	.8345	.8355
52..........	.8270	.8280	.8290	.8300	8310	.8320	.8330	.8340	.8350	.8360
54..........	.8280	.8290	.8300	.8310	8320	.8330	.8340	.8350	.8360	.8370
56..........	.8285	.8295	.8305	.8315	.8325	.8335	.8345	.8355	.8365	.8375
58..........	.8295	.8305	.8315	.8325	.8335	.8345	.8355	.8365	.8375	.8385
60..........	.8300	.8310	.8320	.8330	.8340	.8350	.8360	.8370	.8380	.8390
62..........	.8305	.8315	.8325	.8335	.8345	.8355	.8365	.8375	.8385	.8390
64..........	.8315	.8325	.8335	.8345	.8355	.8365	.8375	.8385	.8395	.8400
66..........	.8320	.8330	.8340	.8350	.8360	.8370	.8380	.8390	.8400	.8410
68..........	.8330	.8340	.8350	.8360	.8370	.8380	.8390	.8400	.8410	.8420
70..........	.8340	.8350	.8360	.8370	.8380	.8390	.8400	.8410	.8420	.8430
72..........	.8345	.8355	.8365	.8375	.8385	.8395	.8405	.8415	.8425	.8435
74..........	.8355	.8365	.8375	.8385	.8395	.8405	.8415	.8425	.8435	.8445
76..........	.8360	.8370	.8380	.8390	.8400	.8410	.8420	.8430	.8440	.8450
78..........	.8370	.8380	.8390	.8400	.8410	.8420	.8430	.8440	.8450	.8460
80..........	.837	.838	.839	.840	.841	.842	.843	.844	.845	.846
82..........	.838	.839	.840	.841	.842	.843	.844	.845	.846	.847
84..........	.839	.840	.841	.842	.843	.844	.845	.846	.847	.848
86..........	.839	.840	.841	.842	.843	.844	.845	.846	.847	.848
88..........	.840	.841	.842	.843	.844	.845	.846	.847	.848	.849
90..........	.841	.842	.843	.844	.845	.846	.847	.848	.849	.850
92..........	.842	.843	.844	.845	.846	.847	.848	.849	.850	.851
94..........	.842	.843	.844	.845	.846	.847	.848	.849	.850	.851
96..........	.843	.844	.845	.846	.847	.848	.849	.850	.851	.852
98..........	.844	.845	.846	.847	.848	.849	.850	.851	.852	.853
100..........	.844	.845	.846	.847	.848	.849	.850	.851	.852	.853
102..........	.845	.846	.847	.848	.849	.850	.851	.852	.853	.854
104..........	.846	.847	.848	.849	.850	.851	.852	.853	.854	.855
106..........	.847	.848	.849	.850	.851	.852	.853	.854	.855	.856
108..........	.847	.848	.849	.850	.851	.852	.853	.854	.855	.856
110..........	.848	.849	.850	.851	.852	.853	.854	.855	.856	.857
112..........	.849	.850	.851	.852	.853	.854	.855	.856	.857	.858
114..........	.850	.851	.852	.853	.854	.855	.855	.856	.857	.858
116..........	.850	.851	.852	.853	.854	.855	.856	.857	.858	.859
118..........	.851	.852	.853	.854	.855	.856	.857	.858	.859	.860
120..........	.852	.853	.854	.855	.856	.857	.858	.859	.860	.861

REDUCTION OF SPECIFIC GRAVITY READINGS TO 60°F—Con.

Observed temperature in °F	Observed specific gravities									
	0.840	0.841	0.842	0.843	0.844	0.845	0.846	0.847	0.848	0.849
	Corresponding specific gravities at 60°/60° F									
30..........	0.828	0.829	0.830	0.831	0.832	0.833	0.835	0.836	0.837	0.838
32..........	.829	.830	.831	.832	.833	.834	.835	.836	.837	.838
34..........	.830	.831	.832	.833	.834	.835	.836	.837	.838	.839
36..........	.831	.832	.833	.834	.835	.836	.837	.838	.839	.840
38..........	.832	.833	.834	.835	.836	.837	.838	.839	.840	.841
40..........	.8325	.8335	.8345	.8355	.8365	.8375	.8385	.8395	.8405	.8415
42..........	.8335	.8345	.8355	.8365	.8375	.8385	.8395	.8405	.8415	.8425
44..........	.8340	.8350	.8360	.8370	.8380	.8390	.8400	.8410	.8420	.8430
46..........	.8345	.8355	.8365	.8375	.8385	.8395	.8410	.8420	.8430	.8440
48..........	.8355	.8365	.8375	.8385	.8395	.8405	.8415	.8425	.8435	.8445
50..........	.8365	.8375	.8385	.8395	.8405	.8415	.8425	.8435	.8445	.8455
52..........	.8370	.8380	.8390	.8400	.8410	.8420	.8430	.8440	.8450	.8460
54..........	.8380	.8390	.8400	.8410	.8420	.8430	.8440	.8450	.8460	.8470
56..........	.8385	.8395	.8405	.8415	.8425	.8435	.8445	.8455	.8465	.8475
58..........	.8395	.8405	.8415	.8425	.8435	.8445	.8455	.8465	.8475	.8485
60..........	.8400	.8410	.8420	.8430	.8440	.8450	.8460	.8470	.8480	.8490
62..........	.8405	.8415	.8425	.8435	.8445	.8455	.8465	.8475	.8485	.8495
64..........	.8415	.8425	.8435	.8445	.8455	.8465	.8475	.8485	.8495	.8505
66..........	.8420	.8430	.8440	.8450	.8460	.8470	.8480	.8490	.8500	.8510
68..........	.8430	.8440	.8450	.8460	.8470	.8480	.8490	.8500	.8510	.8520
70..........	.8440	.8450	.8460	.8470	.8480	.8490	.8500	.8510	.8520	.8530
72..........	.8445	.8455	.8465	.8475	.8485	.8495	.8505	.8515	.8525	.8535
74..........	.8455	.8465	.8475	.8485	.8495	.8505	.8510	.8520	.8530	.8540
76..........	.8460	.8470	.8480	.8490	.8500	.8510	.8520	.8530	.8540	.8550
78..........	.8470	.8480	.8490	.8500	.8510	.8520	.8525	.8535	.8545	.8555
80..........	.847	.848	.849	.850	.851	.852	.853	.854	.855	.856
82..........	.848	.849	.850	.851	.852	.853	.854	.855	.856	.857
84..........	.849	.850	.851	.852	.853	.854	.855	.856	.857	.858
86..........	.849	.850	.851	.852	.853	.854	.855	.856	.857	.858
88..........	.850	.851	.852	.853	.854	.855	.856	.857	.858	.859
90..........	.851	.852	.853	.854	.855	.856	.857	.858	.859	.860
92..........	.852	.853	.854	.855	.856	.857	.857	.858	.859	.860
94..........	.852	.853	.854	.855	.856	.857	.858	.859	.860	.861
96..........	.853	.854	.855	.856	.857	.858	.859	.860	.861	.862
98..........	.854	.855	.856	.857	.858	.859	.860	.861	.862	.863
100..........	.854	.855	.856	.857	.858	.859	.860	.861	.862	.863
102..........	.855	.856	.857	.858	.859	.860	.861	.862	.863	.864
104..........	.856	.857	.858	.859	.860	.861	.862	.863	.864	.865
106..........	.857	.858	.859	.860	.861	.862	.862	.863	.864	.865
108..........	.857	.858	.859	.860	.861	.862	.863	.864	.865	.866
110..........	.858	.859	.860	.861	.862	.863	.864	.865	.866	.867
112..........	.859	.860	.861	.862	.863	.864	.865	.866	.867	.868
114..........	.859	.860	.861	.862	.863	.864	.865	.866	.867	.868
116..........	.860	.861	.862	.863	.864	.865	.866	.867	.868	.869
118..........	.861	.862	.863	.864	.865	.866	.867	.868	.869	.870
120..........	.862	.863	.864	.865	.866	.867	.868	.869	.870	.871

REDUCTION OF SPECIFIC GRAVITY READINGS TO 60°F—Con.

Observed temperature in °F	Observed specific gravities									
	0.850	0.851	0.852	0.853	0.854	0.855	0.856	0.857	0.858	0.859
	Corresponding specific gravities at 60°/60° F									
30..........	0.839	0.840	0.841	0.842	0.843	0.844	0.845	0.846	0.847	0.848
32..........	.839	.840	.841	.842	.843	.844	.845	.846	.847	.848
34..........	.840	.841	.842	.843	.844	.845	.846	.847	.848	.849
36..........	.841	.842	.843	.844	.845	.846	.847	.848	.849	.850
38..........	.842	.843	.844	.845	.846	.847	.848	.849	.850	.851
40..........	.8425	.8435	.8445	.8455	.8465	.8475	.8485	.8495	.8505	.8515
42..........	.8435	.8445	.8455	.8465	.8475	.8485	.8495	.8505	.8515	.8525
44..........	.8440	.8450	.8460	.8470	.8480	.8490	.8500	.8510	.8520	.8530
46..........	.8450	.8460	.8470	.8480	.8490	.8500	.8510	.8520	.8530	.8540
48..........	.8455	.8465	.8475	.8485	.8495	.8505	.8515	.8525	.8535	.8545
50..........	.8465	.8475	.8485	.8495	.8505	.8515	.8525	.8535	.8545	.8555
52..........	.8470	.8480	.8490	.8500	.8510	.8520	.8530	.8540	.8550	.8560
54..........	.8480	.8490	.8500	.8510	.8520	.8530	.8540	.8550	.8560	.8570
56..........	.8485	.8495	.8505	.8515	.8525	.8535	.8545	.8555	.8565	.8575
58..........	.8495	.8505	.8515	.8525	.8535	.8545	.8555	.8565	.8575	.8585
60..........	.8500	.8510	.8520	.8530	.8540	.8550	.8560	.8570	.8580	.8590
62..........	.8505	.8515	.8525	.8535	.8545	.8555	.8565	.8575	.8585	.8595
64..........	.8515	.8525	.8535	.8545	.8555	.8565	.8575	.8585	.8595	.8605
66..........	.8520	.8530	.8540	.8550	.8560	.8570	.8580	.8590	.8600	.8610
68..........	.8530	.8540	.8550	.8560	.8570	.8580	.8590	.8600	.8610	.8620
70..........	.8540	.8550	.8560	.8570	.8580	.8590	.8595	.8605	.8615	.8625
72..........	.8545	.8555	.8565	.8575	.8585	.8595	.8605	.8615	.8625	.8635
74..........	.8550	.8560	.8570	.8580	.8590	.8600	.8610	.8620	.8630	.8640
76..........	.8560	.8570	.8580	.8590	.8600	.8610	.8620	.8630	.8640	.8650
78..........	.8565	.8575	.8585	.8595	.8605	.8615	.8625	.8635	.8645	.8655
80..........	.857	.858	.859	.860	.861	.862	.863	.864	.865	.866
82..........	.858	.859	.860	.861	.862	.863	.864	.865	.866	.867
84..........	.859	.860	.861	.862	.863	.864	.864	.865	.866	.867
86..........	.859	.860	.861	.862	.863	.864	.865	.866	.867	.868
88..........	.860	.861	.862	.863	.864	.865	.866	.867	.868	.869
90..........	.861	.862	.863	.864	.865	.866	.867	.868	.869	.870
92..........	.861	.862	.863	.864	.865	.866	.867	.868	.869	.870
94..........	.862	.863	.864	.865	.866	.867	.868	.869	.870	.871
96..........	.863	.864	.865	.866	.867	.868	.869	.870	.871	.872
98..........	.864	.865	.866	.867	.868	.869	.869	.870	.871	.872
100..........	.864	.865	.866	.867	.868	.869	.870	.871	.872	.873
102..........	.865	.866	.867	.868	.869	.870	.871	.872	.873	.874
104..........	.866	.867	.868	.869	.870	.871	.872	.873	.874	.875
106..........	.866	.867	.868	.869	.870	.871	.872	.873	.874	.875
108..........	.867	.868	.869	.870	.871	.872	.873	.874	.875	.876
110..........	.868	.869	.870	.871	.872	.873	.874	.875	.876	.877
112..........	.869	.870	.871	.872	.873	.874	.874	.875	.876	.877
114..........	.869	.870	.871	.872	.873	.874	.875	.876	.877	.878
116..........	.870	.871	.872	.873	.874	.875	.876	.877	.878	.879
118..........	.871	.872	.873	.874	.875	.876	.877	.878	.879	.880
120..........	.872	.873	.874	.875	.876	.877	.877	.878	.879	.880

REDUCTION OF SPECIFIC GRAVITY READINGS TO 60°F—Con.

Observed temperature in °F	Observed specific gravities 0.860	0.861	0.862	0.863	0.864	0.865	0.866	0.867	0.868	0.869
	Corresponding specific gravities at 60°/60° F									
30..........	0.849	0.850	0.851	0.852	0.853	0.854	0.855	0.856	0.857	0.858
32..........	.849	.850	.851	.852	.853	.854	.856	.857	.858	.859
34..........	.850	.851	.852	.853	.854	.855	.856	.857	.858	.859
36..........	.851	.852	.853	.854	.855	.856	.857	.858	.859	.860
38..........	.852	.853	.854	.855	.856	.857	.858	.859	.860	.861
40..........	.8525	.8535	.8545	.8555	.8565	.8575	.8585	.8595	.8605	.8615
42..........	.8535	.8545	.8555	.8565	.8575	.8585	.8595	.8605	.8615	.8625
44..........	.8540	.8550	.8560	.8570	.8580	.8590	.8600	.8610	.8620	.8630
46..........	.8550	.8560	.8570	.8580	.8590	.8600	.8610	.8620	.8630	.8640
48..........	.8555	.8565	.8575	.8585	.8595	.8605	.8615	.8625	.8635	.8645
50..........	.8565	.8575	.8585	.8595	.8605	.8615	.8625	.8635	.8645	.8655
52..........	.8570	.8580	.8590	.8600	.8610	.8620	.8630	.8640	.8650	.8660
54..........	.8580	.8590	.8600	.8610	.8620	.8630	.8640	.8650	.8660	.8670
56..........	.8585	.8595	.8605	.8615	.8625	.8635	.8645	.8655	.8665	.8675
58..........	.8595	.8605	.8615	.8625	.8635	.8645	.8655	.8665	.8675	.8685
60..........	.8600	.8610	.8620	.8630	.8340	.8650	.8660	.8670	.8680	.8690
62..........	.8605	.8615	.8625	.8635	.8645	.8655	.8665	.8675	.8685	.8695
64..........	.8615	.8625	.8635	.8645	.8655	.8665	.8675	.8685	.8695	.8705
66..........	.8620	.8630	.8640	.8650	.8660	.8670	.8680	.8690	.8700	.8710
68..........	.8630	.8640	.8650	.8660	.8670	.8680	.8690	.8700	.8710	.8720
70..........	.8635	.8645	.8655	.8665	.8675	.8685	.8695	.8705	.8715	.8725
72..........	.8645	.8655	.8665	.8675	.8685	.8695	.8705	.8715	.8725	.8735
74..........	.8650	.8660	.8670	.8680	.8690	.8700	.8710	.8720	.8730	.8740
76..........	.8600	.8670	.8680	.8690	.8700	.8710	.8720	.8730	.8740	.8750
78..........	.8665	.8675	.8685	.8695	.8705	.8715	.8725	.8735	.8745	.8755
80..........	.867	.868	.869	.870	.871	.872	.873	.874	.875	.876
82..........	.868	.869	.870	.871	.872	.873	.874	.875	.876	.877
84..........	.868	.869	.870	.871	.872	.873	.874	.875	.876	.877
86..........	.869	.870	.871	.872	.873	.874	.875	.876	.877	.878
88..........	.870	.871	.872	.873	.874	.875	.876	.877	.878	.879
90..........	.871	.872	.873	.874	.875	.876	.877	.878	.879	.880
92..........	.871	.872	.873	.874	.875	.876	.877	.878	.879	.880
94..........	.872	.873	.874	.875	.876	.877	.878	.879	.880	.881
96..........	.873	.874	.875	.876	.877	.878	.879	.880	.881	.882
98..........	.873	.874	.875	.876	.877	.878	.879	.880	.881	.882
100..........	.874	.875	.876	.877	.878	.879	.880	.881	.882	.883
102..........	.875	.876	.877	.878	.879	.880	.881	.882	.883	.884
104..........	.876	.877	.878	.879	.880	.881	.882	.883	.884	.885
106..........	.876	.877	.878	.879	.880	.881	.882	.883	.884	.885
108..........	.877	.878	.879	.880	.881	.882	.883	.884	.885	.886
110..........	.878	.879	.880	.881	.882	.883	.884	.885	.886	.887
112..........	.878	.879	.880	.881	.882	.883	.884	.885	.886	.887
114..........	.879	.880	.881	.882	.883	.884	.885	.886	.887	.888
116..........	.880	.881	.882	.883	.884	.885	.886	.887	.888	.889
118..........	.881	.882	.883	.884	.885	.886	.886	.887	.888	.889
120..........	.881	.882	.883	.884	.885	.886	.887	.888	.889	.890

REDUCTION OF SPECIFIC GRAVITY READINGS TO 60°F—Con.

Observed temperature in °F	Observed specific gravities									
	0.870	0.871	0.872	0.873	0.874	0.875	0.876	0.877	0.878	0.879
	Corresponding specific gravities at 60°/60° F									
30..........	0.859	0.860	0.861	0.862	0.863	0.864	0.865	0.866	0.867	0.868
32..........	.860	.861	.862	.863	.864	.865	.866	.867	.868	.869
34..........	.860	.861	.862	.863	.864	.865	.866	.867	.868	.869
36..........	.861	.862	.863	.864	.865	.866	.867	.868	.869	.870
38..........	.862	.863	.864	.865	.866	.867	.868	.869	.870	.871
40..........	.8625	.8635	.8645	.8655	.8665	.8675	.8690	.8700	.8710	.8720
42..........	.8635	.8645	.8655	.8665	.8675	.8685	.8695	.8705	.8715	.8725
44..........	.8640	.8650	.8660	.8670	.8680	.8690	.8700	.8710	.8720	.8730
46..........	.8650	.8660	.8670	.8680	.8690	.8700	.8710	.8720	.8730	.8740
48..........	.8655	.8665	.8675	.8685	.8695	.8705	.8715	.8725	.8735	.8745
50..........	.8665	.8675	.8685	.8695	.8705	.8715	.8725	.8735	.8745	.8755
52..........	.8670	.8680	.8690	.8700	.8710	.8720	.8730	.8740	.8750	.8760
54..........	.8680	.8690	.8700	.8710	.8720	.8730	.8740	.8750	.8760	.8770
56..........	.8685	.8695	.8705	.8715	.8725	.8735	.8745	.8755	.8765	.8775
58..........	.8695	.8705	.8715	.8725	.8735	.8745	.8755	.8765	.8775	.8785
60..........	.8700	.8710	.8720	.8730	.8740	.8750	.8760	.8770	.8780	.8790
62..........	.8705	.8715	.8725	.8735	.8745	.8755	.8765	.8775	.8785	.8795
64..........	.8715	.8725	.8735	.8745	.8755	.8765	.8775	.8785	.8795	.8805
66..........	.8720	.8730	.8740	.8750	.8760	.8770	.8780	.8790	.8800	.8810
68..........	.8730	.8740	.8750	.8760	.8770	.8780	.8790	.8800	.8810	.8820
70..........	.8735	.8745	.8755	.8765	.8775	.8785	.8795	.8805	.8815	.8825
72..........	.8745	.8755	.8765	.8775	.8785	.8795	.8805	.8815	.8825	.8835
74..........	.8750	.8760	.8770	.8780	.8790	.8800	.8810	.8820	.8830	.8840
76..........	.8760	.8770	.8780	.8790	.8800	.8810	.8820	.8830	.8840	.8850
78..........	.8765	.8775	.8785	.8795	.8805	.8815	.8825	.8835	.8845	.8855
80..........	.877	.878	.879	.880	.881	.882	.883	.884	.885	.886
82..........	.878	.879	.880	.881	.882	.883	.884	.885	.886	.887
84..........	.878	.879	.880	.881	.882	.883	.884	.885	.886	.887
86..........	.879	.880	.881	.882	.883	.884	.885	.886	.887	.888
88..........	.880	.881	.882	.883	.884	.885	.886	.887	.888	.889
90..........	.881	.882	.883	.884	.885	.886	.887	.888	.889	.890
92..........	.881	.882	.883	.884	.885	.886	.887	.888	.889	.890
94..........	.882	.883	.884	.885	.886	.887	.888	.889	.890	.891
96..........	.883	.884	.885	.886	.887	.888	.889	.890	.891	.892
98..........	.883	.884	.885	.886	.887	.888	.889	.890	.891	.892
100..........	.884	.885	.886	.887	.888	.889	.890	.891	.892	.893
102..........	.885	.886	.887	.888	.889	.890	.891	.892	.893	.894
104..........	.886	.887	.888	.889	.890	.891	.891	.892	.893	.894
106..........	.886	.887	.888	.889	.890	.891	.892	.893	.894	.895
108..........	.887	.888	.889	.890	.891	.892	.893	.894	.895	.896
110..........	.888	.889	.890	.891	.892	.893	.894	.895	.896	.897
112..........	.888	.889	.890	.891	.892	.893	.894	.895	.896	.897
114..........	.889	.890	.891	.892	.803	.894	.895	.896	.897	.898
116..........	.890	.891	.892	.893	.894	.895	.896	.897	.898	.899
118..........	.890	.891	.892	.893	.894	.895	.896	.897	.898	.899
120..........	.891	.892	.893	.894	.895	.896	.897	.898	.899	.900

REDUCTION OF SPECIFIC GRAVITY READINGS TO 60°F—Con.

Observed temperature in °F	Observed specific gravities									
	0.880	0.881	0.882	0.883	0.884	0.885	0.886	0.887	0.888	0.889
	Corresponding specific gravities at 60°/60° F									
30	0.869	0.870	0.871	0.872	0.873	0.874	0.875	0.876	0.877	0.878
32	.870	.871	.872	.873	.874	.875	.876	.877	.878	.879
34	.870	.871	.872	.873	.874	.875	.876	.877	.878	.879
36	.871	.872	.873	.874	.875	.876	.877	.878	.879	.880
38	.872	.873	.874	.875	.876	.877	.878	.879	.880	.881
40	.8730	.8740	.8750	.8760	.8770	.8780	.8790	.8800	.8810	.8820
42	.8735	.8745	.8755	.8765	.8775	.8785	.8795	.8805	.8815	.8825
44	.8740	.8750	.8760	.8770	.8780	.8790	.8800	.8810	.8820	.8830
46	.8750	.8760	.8770	.8780	.8790	.8800	.8810	.8820	.8830	.8840
48	.8755	.8765	.8775	.8785	.8795	.8805	.8815	.8825	.8835	.8845
50	.8765	.8775	.8785	.8795	.8805	.8815	.8825	.8835	.8845	.8855
52	.8770	.8780	.8790	.8800	.8810	.8820	.8830	.8840	.8850	.8860
54	.8780	.8790	.8800	.8810	.8820	.8830	.8840	.8850	.8860	.8870
56	.8785	.8795	.8805	.8815	.8825	.8835	.8845	.8855	.8865	.8875
58	.8795	.8805	.8815	.8825	.8835	.8845	.8855	.8865	.8875	.8885
60	.8800	.8810	.8820	.8830	.8840	.8850	.8860	.8870	.8880	.8890
62	.8805	.8815	.8825	.8835	.8845	.8855	.8865	.8875	.8885	.8895
64	.8815	.8825	.8835	.8845	.8855	.8865	.8875	.8885	.8895	.8905
66	.8820	.8830	.8840	.8850	.8860	.8870	.8880	.8890	.8900	.8910
68	.8830	.8840	.8850	.8860	.8870	.8880	.8890	.8900	.8910	.8920
70	.8835	.8845	.8855	.8865	.8875	.8885	.8895	.8905	.8915	.8925
72	.8845	.8855	.8865	.8875	.8885	.8895	.8900	.8910	.8920	.8930
74	.8850	.8860	.8870	.8880	.8890	.8900	.8910	.8920	.8930	.8940
76	.8860	.8870	.8880	.8890	.8900	.8910	.8915	.8925	.8935	.8945
78	.8865	.8875	.8885	.8895	.8905	.8915	.8925	.8935	.8945	.8955
80	.887	.888	.889	.890	.891	.892	.893	.894	.895	.896
82	.888	.889	.890	.891	.892	.893	.894	.895	.896	.897
84	.888	.889	.890	.891	.892	.893	.894	.895	.896	.897
86	.889	.890	.891	.892	.893	.894	.895	.896	.897	.898
88	.890	.891	.892	.893	.894	.895	.896	.897	.898	.899
90	.891	.892	.893	.894	.895	.896	.896	.897	.898	.899
92	.891	.892	.893	.894	.895	.896	.897	.898	.899	.900
94	.892	.893	.894	.895	.896	.897	.898	.899	.900	.901
96	.893	.894	.895	.896	.897	.898	.899	.900	.901	.902
98	.893	.894	.895	.896	.897	.898	.899	.900	.901	.902
100	.894	.895	.896	.897	.898	.899	.900	.901	.902	.903
102	.895	.896	.897	.898	.899	.900	.901	.902	.903	.904
104	.895	.896	.897	.898	.899	.900	.901	.902	.903	.904
106	.896	.897	.898	.899	.900	.901	.902	.903	.904	.905
108	.897	.898	.899	.900	.901	.902	.903	.904	.905	.906
110	.898	.899	.900	.901	.902	.903	.903	.904	.905	.906
112	.898	.899	.900	.901	.902	.903	.904	.905	.906	.907
114	.899	.900	.901	.902	.903	.904	.905	.906	.907	.908
116	.900	.901	.902	.903	.904	.905	.905	.906	.907	.908
118	.900	.901	.902	.903	.904	.905	.906	.907	.908	.909
120	.901	.902	.903	.904	.905	.906	.907	.908	.909	.910

REDUCTION OF SPECIFIC GRAVITY READINGS TO 60°F—Con.

Observed temperature in °F	Observed specific gravities									
	0.890	0.891	0.892	0.893	0.894	0.895	0.896	0.897	0.898	0.899
	Corresponding specific gravities at 60°/60° F									
30..........	0.879	0.880	0.881	0.882	0.883	0.884	0.885	0.886	0.887	0.888
32..........	.880	.881	.882	.883	.884	.885	.886	.887	.888	.889
34..........	.880	.881	.882	.883	.884	.885	.886	.887	.888	.889
36..........	.881	.882	.883	.884	.885	.886	.887	.888	.889	.890
38..........	.882	.883	.884	.885	.886	.887	.888	.889	.890	.891
40..........	.8830	.8840	.8850	.8860	.8870	.8880	.8890	.8900	.8910	.8920
42..........	.8840	.8850	.8860	.8870	.8880	.8885	.8895	.8905	.8915	.8925
44..........	.8840	.8850	.8860	.8870	.8880	.8890	.8900	.8910	.8920	.8930
46..........	.8850	.8860	.8870	.8880	.8890	.8900	.8910	.8920	.8930	.8940
48..........	.8855	.8865	.8875	.8885	.8895	.8905	.8915	.8925	.8935	.8945
50..........	.8865	.8875	.8885	.8895	.8905	.8915	.8925	.8935	.8945	.8955
52..........	.8870	.8880	.8890	.8900	.8910	.8920	.8930	.8940	.8950	.8960
54..........	.8880	.8890	.8900	.8910	.8920	.8930	.8940	.8950	.8960	.8970
56..........	.8885	.8895	.8905	.8915	.8925	.8935	.8945	.8955	.8965	.8975
58..........	.8895	.8905	.8915	.8925	.8935	.8945	.8955	.8965	.8975	.8985
60..........	.8900	.8910	.8920	.8930	.8940	.8950	.8960	.8970	.8980	.8990
62..........	.8905	.8915	.8925	.8935	.8945	.8955	.8965	.8975	.8985	.8995
64..........	.8915	.8925	.8935	.8945	.8955	.8965	.8975	.8985	.8995	.9005
66..........	.8920	.8930	.8940	.8950	.8960	.8970	.8980	.8990	.9000	.9010
68..........	.8930	.8940	.8950	.8960	.8970	.8980	.8990	.9000	.9010	.9020
70..........	.8935	.8945	.8955	.8965	.8975	.8985	.8995	.9005	.9015	.9025
72..........	.8940	.8950	.8960	.8970	.8980	.8990	.9000	.9010	.9020	.9030
74..........	.8950	.8960	.8970	.8980	.8990	.9000	.9010	.9020	.9030	.9040
76..........	.8955	.8965	.8975	.8985	.8995	.9005	.9015	.9025	.9035	.9045
78..........	.8965	.8975	.8985	.8995	.9005	.9015	.9025	.9035	.9045	.9055
80..........	.897	.898	.899	.900	.901	.902	.903	.904	.905	.906
82..........	.898	.899	.900	.901	.902	.903	.903	.904	.905	.906
84..........	.898	.899	.900	.901	.902	.903	.904	.905	.906	.907
86..........	.899	.900	.901	.902	.903	.904	.905	.906	.907	.908
88..........	.900	.901	.902	.903	.904	.905	.906	.907	.908	.909
90..........	.900	.901	.902	.903	.904	.905	.906	.907	.908	.909
92..........	.901	.902	.903	.904	.905	.906	.907	.908	.909	.910
94..........	.902	.903	.904	.905	.906	.907	.908	.909	.910	.911
96..........	.903	.904	.905	.906	.907	.908	.909	.910	.911	.912
98..........	.903	.904	.905	.906	.907	.908	.909	.910	.911	.912
100..........	.904	.905	.906	.907	.908	.909	.910	.911	.912	.913
102..........	.905	.906	.907	.908	.909	.910	.911	.912	.913	.914
104..........	.905	.906	.907	.908	.909	.910	.911	.912	.913	.914
106..........	.906	.907	.908	.909	.910	.911	.912	.913	.914	.915
108..........	.907	.908	.909	.910	.911	.912	.913	.914	.915	.916
110..........	.907	.908	.909	.910	.911	.912	.913	.914	.915	.916
112..........	.908	.909	.910	.911	.912	.913	.914	.915	.916	.917
114..........	.909	.910	.911	.912	.913	.914	.915	.916	.917	.918
116..........	.909	.910	.911	.912	.913	.914	.915	.916	.917	.918
118..........	.910	.911	.912	.913	.914	.915	.916	.917	.918	.919
120..........	.911	.912	.913	.914	.915	.916	.917	.918	.919	.920

REDUCTION OF SPECIFIC GRAVITY READINGS TO 60°F—Con.

Observed temperature in °F	Observed specific gravities									
	0.900	0.901	0.902	0.903	0.904	0.905	0.906	0.907	0.908	0.909
	Corresponding specific gravities at 60°/60° F									
30	0.889	0.890	0.891	0.892	0.893	0.894	0.895	0.896	0.897	0.898
32	.890	.891	.892	.893	.894	.895	.896	.897	.898	.899
34	.890	.891	.892	.893	.894	.895	.896	.897	.898	.899
36	.891	.892	.893	.894	.895	.896	.897	.898	.899	.900
38	.892	.893	.894	.895	.896	.897	.898	.899	.900	.901
40	.8930	.8940	.8950	.8960	.8970	.8980	.8990	.9000	.9010	.9020
42	.8935	.8945	.8955	.8965	.8975	.8985	.8995	.9005	.9015	.9025
44	.8940	.8950	.8960	.8970	.8980	.8990	.9005	.9015	.9025	.9035
46	.8950	.8960	.8970	.8980	.8990	.9000	.9010	.9020	.9030	.9040
48	.8955	.8965	.8975	.8985	.8995	.9005	.9015	.9025	.9035	.9045
50	.8965	.8975	.8985	.8995	.9005	.9015	.9025	.9035	.9045	.9055
52	.8970	.8980	.8990	.9000	.9010	.9020	.9030	.9040	.9050	.9060
54	.8980	.8990	.9000	.9010	.9020	.9030	.9040	.9050	.9060	.9070
56	.8985	.8995	.9005	.9015	.9025	.9035	.9045	.9055	.9065	.9075
58	.8995	.9005	.9015	.9025	.9035	.9045	.9055	.9065	.9075	.9085
60	.9000	.9010	.9020	.9030	.9040	.9050	.9060	.9070	.9080	.9090
62	.9005	.9015	.9025	.9035	.9045	.9055	.9065	.9075	.9085	.9095
64	.9015	.9025	.9035	.9045	.9055	.9065	.9075	.9085	.9095	.9105
66	.9020	.9030	.9040	.9050	.9060	.9070	.9080	.9090	.9100	.9110
68	.9030	.9040	.9050	.9060	.9070	.9080	.9090	.9100	.9110	.9120
70	.9035	.9045	.9055	.9065	.9075	.9085	.9095	.9105	.9115	.9125
72	.9040	.9050	.9060	.9070	.9080	.9090	.9100	.9110	.9120	.9130
74	.9050	.9060	.9070	.9080	.9090	.9100	.9110	.9120	.9130	.9140
76	.9055	.9065	.9075	.9085	.9095	.9105	.9115	.9125	.9135	.9145
78	.9065	.9075	.9085	.9095	.9105	.9115	.9125	.9135	.9145	.9155
80	.907	.908	.909	.910	.911	.912	.913	.914	.915	.916
82	.907	.908	.909	.910	.911	.912	.913	.914	.915	.916
84	.908	.909	.910	.911	.912	.913	.914	.915	.916	.917
86	.909	.910	.911	.912	.913	.914	.915	.916	.917	.918
88	.910	.911	.912	.913	.914	.915	.916	.917	.918	.919
90	.910	.911	.912	.913	.914	.915	.916	.917	.918	.919
92	.911	.912	.913	.914	.915	.916	.917	.918	.919	.920
94	.912	.913	.914	.915	.916	.917	.918	.919	.920	.921
96	.913	.914	.915	.916	.917	.918	.918	.919	.920	.921
98	.913	.914	.915	.916	.917	.918	.919	.920	.921	.922
100	.914	.915	.916	.917	.918	.919	.920	.921	.922	.923
102	.915	.916	.917	.918	.919	.920	.921	.922	.923	.924
104	.915	.916	.917	.918	.919	.920	.921	.922	.923	.924
106	.916	.917	.918	.919	.920	.921	.922	.923	.924	.925
108	.917	.918	.919	.920	.921	.922	.923	.924	.925	.926
110	.917	.918	.919	.920	.921	.922	.923	.924	.925	.926
112	.918	.919	.920	.921	.922	.923	.924	.925	.926	.927
114	.919	.920	.921	.922	.923	.924	.925	.926	.927	.928
116	.919	.920	.921	.922	.923	.924	.925	.926	.927	.928
118	.920	.921	.922	.923	.924	.925	.926	.927	.928	.929
120	.921	.922	.923	.924	.925	.926	.927	.928	.929	.930

REDUCTION OF SPECIFIC GRAVITY READINGS TO 60°F—Con.

Observed temperature in °F	Observed specific gravities									
	0.910	0.911	0.912	0.913	0.914	0.915	0.916	0.917	0.918	0.919
	Corresponding specific gravities at 60°/60° F									
30..........	0.899	0.900	0.901	0.902	0.903	0.904	0.905	0.906	0.907	0.908
32..........	.900	.901	.902	.903	.904	.905	.906	.907	.908	.909
34..........	.900	.901	.902	.903	.904	.905	.906	.907	.908	.909
36..........	.901	.902	.903	.904	.905	.906	.907	.908	.909	.910
38..........	.902	.903	.904	.905	.906	.907	.908	.909	.910	.911
40..........	.9030	.9040	.9050	.9060	.9070	.9080	.9090	.9100	.9110	.9120
42..........	.9035	.9045	.9055	.9065	.9075	.9085	.9095	.9105	.9115	.9125
44..........	.9045	.9055	.9065	.9075	.9085	.9095	.9105	.9115	.9125	.9135
46..........	.9050	.9060	.9070	.9080	.9090	.9100	.9110	.9120	.9130	.9140
48..........	.9055	.9065	.9075	.9085	.9095	.9105	.9115	.9125	.9135	.9145
50..........	.9065	.9075	.9085	.9095	.9105	.9115	.9125	.9135	.9145	.9155
52..........	.9070	.9080	.9090	.9100	.9110	.9120	.9130	.9140	.9150	.9160
54..........	.9080	.9090	.9100	.9110	.9120	.9130	.9140	.9150	.9160	.9170
56..........	.9085	.9095	.9105	.9115	.9125	.9135	.9145	.9155	.9165	.9175
58..........	.9095	.9105	.9115	.9125	.9135	.9145	.9155	.9165	.9175	.9185
60..........	.9100	.9110	.9120	.9130	.9140	.9150	.9160	.9170	.9180	.9190
62..........	.9105	.9115	.9125	.9135	.9145	.9155	.9165	.9175	.9185	.9195
64..........	.9115	.9125	.9135	.9145	.9155	.9165	.9175	.9185	.9195	.9205
66..........	.9120	.9130	.9140	.9150	.9160	.9170	.9180	.9190	.9200	.9210
68..........	.9130	.9140	.9150	.9160	.9170	.9180	.9190	.9200	.9210	.9220
70..........	.9135	.9145	.9155	.9165	.9175	.9185	.9195	.9205	.9215	.9225
72..........	.9140	.9150	.9160	.9170	.9180	.9190	.9200	.9210	.9220	.9230
74..........	.9150	.9160	.9170	.9180	.9190	.9200	.9210	.9220	.9230	.9240
76..........	.9155	.9165	.9175	.9185	.9195	.9205	.9215	.9225	.9235	.9245
78..........	.9165	.9175	.9185	.9195	.9205	.9215	.9225	.9235	.9245	.9255
80..........	.917	.918	.919	.920	.921	.922	.923	.924	.925	.926
82..........	.917	.918	.919	.920	.921	.922	.923	.924	.925	.926
84..........	.918	.919	.920	.921	.922	.923	.924	.925	.926	.927
86..........	.919	.920	.921	.922	.923	.924	.925	.926	.927	.928
88..........	.920	.921	.922	.923	.924	.925	.926	.927	.928	.929
90..........	.920	.921	.922	.923	.924	.925	.926	.927	.928	.929
92..........	.921	.922	.923	.924	.925	.926	.927	.928	.929	.930
94..........	.922	.923	.924	.925	.926	.927	.928	.929	.930	.931
96..........	.922	.923	.924	.925	.926	.927	.928	.929	.930	.931
98..........	.923	.924	.925	.926	.927	.928	.929	.930	.931	.932
100..........	.924	.925	.926	.927	.928	.929	.930	.931	.932	.933
102..........	.925	.926	.927	.928	.929	.930	.931	.932	.933	.934
104..........	.925	.926	.927	.928	.929	.930	.931	.932	.933	.934
106..........	.926	.927	.928	.929	.930	.931	.932	.933	.934	.935
108..........	.927	.928	.929	.930	.931	.932	.933	.934	.935	.936
110..........	.927	.928	.929	.930	.931	.932	.933	.934	.935	.936
112..........	.928	.929	.930	.931	.932	.933	.934	.935	.936	.937
114..........	.929	.930	.931	.932	.933	.934	.935	.936	.937	.938
116..........	.929	.930	.931	.932	.933	.934	.935	.936	.937	.938
118..........	.930	.931	.932	.933	.934	.935	.936	.937	.938	.939
120..........	.931	.932	.933	.934	.935	.936	.937	.938	.939	.940

REDUCTION OF SPECIFIC GRAVITY READINGS TO 60°F—Con.

Observed temperature in °F	Observed specific gravities									
	0.920	0.921	0.922	0.923	0.924	0.925	0.926	0.927	0.928	0.929
	Corresponding specific gravities at 60°/60° F									
30..........	0.909	0.910	0.911	0.912	0.913	0.914	0.915	0.916	0.917	0.918
32..........	.910	.911	.912	.913	.914	.915	.916	.917	.918	.919
34..........	.910	.911	.912	.913	.914	.915	.916	.917	.918	.919
36..........	.911	.912	.913	.914	.915	.916	.917	.918	.919	.920
38..........	.912	.913	.914	.915	.916	.917	.918	.919	.920	.921
40..........	.9130	.9140	.9150	.9160	.9170	.9180	.9190	.9200	.9210	.9220
42..........	.9135	.9145	.9155	.9165	.9175	.9185	.9195	.9205	.9215	.9225
44..........	.9145	.9155	.9165	.9175	.9185	.9195	.9205	.9215	.9225	.9235
46..........	.9150	.9160	.9170	.9180	.9190	.9200	.9210	.9220	.9230	.9240
48..........	.9155	.9165	.9175	.9185	.9195	.9205	.9215	.9225	.9235	.9245
50..........	.9165	.9175	.9185	.9195	.9205	.9215	.9225	.9235	.9245	.9255
52..........	.9170	.9180	.9190	.9200	.9210	.9220	.9230	.9240	.9250	.9260
54..........	.9180	.9190	.9200	.9210	.9220	.9230	.9240	.9250	.9260	.9270
56..........	.9185	.9195	.9205	.9215	.9225	.9235	.9245	.9255	.9265	.9275
58..........	.9195	.9205	.9215	.9225	.9235	.9245	.9255	.9265	.9275	.9285
60..........	.9200	.9210	.9220	.9230	.9240	.9250	.9260	.9270	.9280	.9290
62..........	.9205	.9215	.9225	.9235	.9245	.9255	.9265	.9275	.9285	.9295
64..........	.9215	.9225	.9235	.9245	.9255	.9265	.9275	.9285	.9295	.9305
66..........	.9220	.9230	.9240	.9250	.9260	.9270	.9280	.9290	.9300	.9310
68..........	.9230	.9240	.9250	.9260	.9270	.9280	.9290	.9300	.9310	.9320
70..........	.9235	.9245	.9255	.9265	.9275	.9285	.9295	.9305	.9315	.9325
72..........	.9240	.9250	.9260	.9270	.9280	.9290	.9300	.9310	.9320	.9330
74..........	.9250	.9260	.9270	.9280	.9290	.9300	.9310	.9320	.9330	.9340
76..........	.9255	.9265	.9275	.9285	.9295	.9305	.9315	.9325	.9335	.9345
78..........	.9265	.9275	.9285	.9295	.9305	.9315	.9325	.9335	.9345	.9355
80..........	.927	.928	.929	.930	.931	.932	.933	.934	.935	.936
82..........	.927	.928	.929	.930	.931	.932	.933	.934	.935	.936
84..........	.928	.929	.930	.931	.932	.933	.934	.935	.936	.937
86..........	.929	.930	.931	.932	.033	.934	.935	.936	.937	.938
88..........	.930	.931	.932	.933	.934	.935	.936	.937	.938	.939
90..........	.930	.931	.932	.933	.934	.935	.936	.937	.938	.939
92..........	.931	.932	.933	.934	.935	.936	.937	.938	.939	.940
94..........	.932	.933	.934	.935	.936	.937	.938	.939	.940	.941
96..........	.932	.933	.934	.935	.936	.937	.938	.939	.940	.941
98..........	.933	.934	.935	.936	.937	.938	.939	.940	.941	.942
100..........	.934	.935	.936	.937	.938	.939	.940	.941	.942	.943
102..........	.935	.936	.937	.938	.939	.940	.940	.941	.942	.943
104..........	.935	.936	.937	.938	.939	.940	.941	.942	.943	.944
106..........	.936	.937	.938	.939	.940	.941	.942	.943	.944	.945
108..........	.937	.938	.939	.940	.941	.942	.943	.944	.945	.946
110..........	.937	.938	.939	.940	.941	.942	.943	.944	.945	.946
112..........	.938	.939	.940	.941	.942	.943	.944	.945	.946	.947
114..........	.939	.940	.941	.942	.943	.944	9.45	9.46	.947	.948
116..........	.939	.940	.941	.942	.943	.944	9.45	9.46	.947	.948
118..........	.940	.941	.942	.943	.944	.945	.946	.947	.948	.949
120..........	.941	.942	.943	.944	.945	.946	.947	.948	.949	.950

REDUCTION OF SPECIFIC GRAVITY READINGS TO 60°F—Con.

Observed temperature in °F	Observed specific gravities									
	0.930	0.931	0.932	0.933	0.934	0.935	0.936	0.937	0.938	0.939
	Corresponding specific gravities at 60°/60° F									
30	0.919	0.920	0.921	0.922	0.923	0.924	0.925	0.926	0.927	0.928
32	.920	.921	.922	.923	.924	.925	.926	.927	.928	.929
34	.920	.921	.922	.923	.924	.925	.926	.927	.928	.929
36	.921	.922	.923	.924	.925	.926	.927	.928	.929	.930
38	.922	.923	.924	.925	.926	.927	.928	.929	.930	.931
40	.9230	.9240	.9250	.9260	.9270	.9280	.9290	.9300	.9310	.9320
42	.9235	.9245	.9255	.9265	.9275	.9285	.9295	.9305	.9315	.9325
44	.9245	.9255	.9265	.9275	.9285	.9295	.9305	.9315	.9325	.9335
46	.9250	.9260	.9270	.9280	.9290	.9300	.9310	.9320	.9330	.9340
48	.9255	.9265	.9275	.9285	.9295	.9305	.9320	.9330	.9340	.9350
50	.9265	.9275	.9285	.9295	.9305	.9315	.9325	.9335	.9345	.9355
52	.9270	.9280	.9290	.9300	.9310	.9320	.9330	.9340	.9350	.9360
54	.9280	.9290	.9300	.9310	.9320	.9330	.9340	.9350	.9360	.9370
56	.9285	.9295	.9305	.9315	.9325	.9335	.9345	.9355	.9365	.9375
58	.9295	.9305	.9315	.9325	.9335	.9345	.9355	.9365	.9375	.9385
60	.9300	.9310	.9320	.9330	.9340	.9350	.9360	.9370	.9380	.9390
62	.9305	.9315	.9325	.9335	.9345	.9355	.9365	.9375	.9385	.9395
64	.9315	.9325	.9335	.9345	.9355	.9365	.9375	.9385	.9395	.9405
66	.9320	.9330	.9340	.9350	.9360	.9370	.9380	.9390	.9400	.9410
68	.9330	.9340	.9350	.9360	.9370	.9380	.9390	.9400	.9410	.9420
70	.9335	.9345	.9355	.9365	.9375	.9385	.9395	.9405	.9415	.9425
72	.9340	.9350	.9360	.9370	.9380	.9390	.9400	.9410	.9420	.9430
74	.9350	.9360	.9370	.9380	.9390	.9400	.9410	.9420	.9430	.9440
76	.9355	.9365	.9375	.9385	.9395	.9405	.9415	.9425	.9435	.9445
78	.9365	.9375	.9385	.9395	.9405	.9415	.9425	.9435	.9445	.9455
80	.937	.938	.939	.940	.941	.942	.943	.944	.945	.946
82	.937	.938	.939	.940	.941	.942	.943	.944	.945	.946
84	.938	.939	.940	.941	.942	.943	.944	.945	.946	.947
86	.939	.940	.941	.942	.943	.944	.945	.946	.947	.948
88	.940	.941	.942	.943	.944	.945	.946	.947	.948	.949
90	.940	.941	.942	.943	.944	.945	.946	.947	.948	.949
92	.941	.942	.943	.944	.945	.946	.947	.948	.949	.950
94	.942	.943	.944	.945	.946	.947	.948	.949	.950	
96	.942	.943	.944	.945	.946	.947	.948	.949		
98	.943	.944	.945	.946	.947	.948	.949	.950		
100	.944	.945	.946	.947	.948	.949	.950			
102	.944	.945	.946	.947	.948	.950				
104	.945	.946	.947	.948	.949					
106	.946	.947	.948	.949	.950					
108	.947	.948	.949	.950						
110	.947	.948	.949							
112	.948	.949	.950							
114	.949	.950								
116	.949									
118	.950									

REDUCTION OF SPECIFIC GRAVITY READINGS TO 60°F—Con.

Observed temperature in °F	Observed specific gravities									
	0.940	0.941	0.942	0.943	0.944	0.945	0.946	0.947	0.948	0.949
	Corresponding specific gravities at 60°/60° F									
30..........	0.929	0.930	0.931	0.932	0.933	0.934	0.935	0.936	0.937	0.938
32..........	.930	.931	.932	.933	.934	.935	.936	.937	.938	.939
34..........	.930	.931	.932	.933	.934	.935	.936	.937	.938	.939
36..........	.931	.932	.933	.934	.935	.936	.937	.938	.939	.940
38..........	.932	.933	.934	.935	.936	.937	.938	.939	.940	.941
40..........	.9330	.9340	.9350	.9360	.9370	.9380	.9390	.9400	.9410	.9420
42..........	.9335	.9345	.9355	.9365	.9375	.9385	.9395	.9405	.9415	.9425
44..........	.9345	.9355	.9365	.9375	.9385	.9395	.9405	.9415	.9425	.9435
46..........	.9350	.9360	.9370	.9380	.9390	.9400	.9410	.9420	.9430	.9440
48..........	.9360	.9370	.9380	.9390	.9400	.9410	.9420	.9430	.9440	.9450
50..........	.9365	.9375	.9385	.9395	.9405	.9415	.9425	.9435	.9445	.9455
52..........	.9370	.9380	.9390	.9400	.9410	.9420	.9430	.9440	.9450	.9460
54..........	.9380	.9390	.9400	.9410	.9420	.9430	.9440	.9450	.9460	.9470
56..........	.9385	.9395	.9405	.9415	.9425	.9435	.9445	.9455	.9465	.9475
58..........	.9395	.9405	.9415	.9425	.9435	.9445	.9455	.9465	.9475	.9485
60..........	.9400	.9410	.9420	.9430	.9440	.9450	.9460	.9470	.9480	.9490
62..........	.9405	.9415	.9425	.9435	.9445	.9455	.9465	.9475	.9485	.9495
64..........	.9415	.9425	.9435	.9445	.9455	.9465	.9475	.9485	.9495	.9500
66..........	.9420	.9430	.9440	.9450	.9460	.9470	.9480	.9490	.9500	
68..........	.9430	.9440	.9450	.9460	.9470	.9480	.9490	.9500		
70..........	.9435	.9445	.9455	.9465	.9475	.9485	.9495			
72..........	.9440	.9450	.9460	.9470	.9480	.9490	.9500			
74..........	.9450	.9460	.9470	.9480	.9490	.9500				
76..........	.9455	.9465	.9475	.9485	.9495					
78..........	.9465	.9475	.9485	.9495	.9500					
80..........	.947	.948	.949	.950						
82..........	.947	.948	.949							
84..........	.948	.949	.950							
86..........	.949	.950								
88..........	.950									

REDUCTION OF SPECIFIC GRAVITY READINGS TO 60°F—Con.

Observed temperature in °F	Observed specific gravities									
	0.950	0.951	0.952	0.953	0.954	0.955	0.956	0.957	0.958	0.959
	Corresponding specific gravities at 60°/60° F									
30..........	0.939	0.940	0.941	0.942	0.943	0.944	0.945	0.946	0.947	0.948
32..........	.940	.941	.942	.943	.944	.945	.946	.947	.948	.949
34..........	.940	.941	.942	.943	.944	.945	.946	.947	.948	.949
36..........	.941	.942	.943	.944	.945	.946	.947	.948	.949	.950
38..........	.942	.913	.944	.945	.946	.947	.948	.949	.950	
40..........	.9430	.9440	.9450	.9460	.9470	.9480	.9490	.9500		
42..........	.9435	.9445	.9455	.9465	.9475	.9485	.9495			
44..........	.9445	.9455	.9465	.9475	.9485	.9495	.9500			
46..........	.9450	.9460	.9470	.9480	.9490	.9500				
48..........	.9460	.9470	.9480	.9490	.9500					
50..........	.9465	.9475	.9485	.9495						
52..........	.9470	.9480	.9490	.9500						
54..........	.9480	.9490	.9500							
56..........	.9485	.9495								
58..........	.9495	.9500								
60..........	.9500									

Specific Gravity Tables

Equivalent of Degrees Baume′ (American Standard) and Specific Gravity at 60°F.

$$\text{Degrees Baume}' = 145 - \frac{145}{\text{Sp. Gr.}}$$ For Liquids Heavier than Water

Degrees Baume′	Specific Gravity	Degrees Baume′	Specific Gravity	Degrees Baume′	Specific Gravity	Degrees Baume′	Specific Gravity
0.0	1.0000	.7	1.0262	.4	1.0538	.1	1.0829
.1	1.0007	.8	1.0269	.5	1.0545	.2	1.0837
.2	1.0014	.9	1.0276	.6	1.0553	.3	1.0845
.3	1.0021	4.0	1.0284	.7	1.0561	.4	1.0853
.4	1.0028	.1	1.0291	.8	1.0569	.5	1.0861
.5	1.0035	.2	1.0298	.9	1.0576	.6	1.0870
.6	1.0042	.3	1.0306	8.0	1.0584	.7	1.0878
.7	1.0049	.4	1.0313	.1	1.0592	.8	1.0886
.8	1.0055	.5	1.0320	.2	1.0599	.9	1.0894
.9	1.0062	.6	1.0328	.3	1.0607	12.0	1.0902
1.0	1.0069	.7	1.0335	.4	1.0615	.1	1.0910
.1	1.0076	.8	1.0342	.5	1.0623	.2	1.0919
.2	1.0083	.9	1.0350	.6	1.0630	.3	1.0927
.3	1.0090	5.0	1.0357	.7	1.0638	.4	1.0935
.4	1.0097	.1	1.0365	.8	1.0646	.5	1.0943
.5	1.0105	.2	1.0372	.9	1.0654	.6	1.0952
.6	1.0112	.3	1.0379	9.0	1.0662	.7	1.0960
.7	1.0119	.4	1.0387	.1	1.0670	.8	1.0968
.8	1.0126	.5	1.0394	.2	1.0677	.9	1.0977
.9	1.0133	.6	1.0402	.3	1.0685	13.0	1.0985
2.0	1.0140	.7	1.0409	.4	1.0693	.1	1.0993
.1	1.0147	.8	1.0417	.5	1.0701	.2	1.1002
.2	1.0154	.9	1.0424	.6	1.0709	.3	1.1010
.3	1.0161	6.0	1.0432	.7	1.0717	.4	1.1018
.4	1.0168	.1	1.043[illegible]	.8	1.0725	.5	1.1027
.5	1.0175	.2	1.0447	.9	1.0733	.6	1.1035
.6	1.0183	.3	1.0454	10.0	1.0741	.7	1.1043
.7	1.0190	.4	1.0462	.1	1.0749	.8	1.1052
.8	1.0197	.5	1.0469	.2	1.0757	.9	1.1060
.9	1.0204	.6	1.0477	.3	1.0765	14.0	1.1069
3.0	1.0211	.7	1.0484	.4	1.0773	.1	1.1077
.1	1.0218	.8	1.0492	.5	1.0781	.2	1.1086
.2	1.0226	.9	1.0500	.6	1.0789	.3	1.1094
.3	1.0233	7.0	1.0507	.7	1.0797	.4	1.1103
.4	1.0240	.1	1.0515	.8	1.0805	.5	1.1111
.5	1.0247	.2	1.0522	.9	1.0813	.6	1.1120
.6	1.0255	.3	1.0530	11.0	1.0821	.7	1.1128

EQUIVALENT BAUME' DEGREES—Con.

Degrees Baume'	Specific Gravity	Degrees Baume'	Specific Gravity	Degrees Baume'	Specific Gravity	Degrees Baume'	Specific Gravity
.8	1.1137	.2	1.1526	.6	1.1944	28.0	1.2393
.9	1.1145	.3	1.1535	.7	1.1954	.1	1.2404
15.0	1.1154	.4	1.1545	.8	1.1964	.2	1.2414
.1	1.1162	.5	1.1554	.9	1.1974	.3	1.2425
.2	1.1171	.6	1.1563	24.0	1.1983	.4	1.2436
.3	1.1180	.7	1.1572	.1	1.1993	.5	1.2446
.4	1.1188	.8	1.1581	.2	1.2003	.6	1.2457
.5	1.1197	.9	1.1591	.3	1.2013	.7	1.2468
.6	1.1206	20.0	1.1600	.4	1.2023	.8	1.2478
.7	1.1214	.1	1.1609	.5	1.2033	.9	1.2489
.8	1.1223	.2	1.1619	.6	1.2043	29.0	1.2500
.9	1.1232	.3	1.1628	.7	1.2053	.1	1.2511
16.0	1.1240	.4	1.1637	.8	1.2063	.2	1.2522
.1	1.1249	.5	1.1647	.9	1.2073	.3	1.2532
.2	1.1258	.6	1.1656	25.0	1.2083	.4	1.2543
.3	1.1267	.7	1.1665	.1	1.2093	.5	1.2554
.4	1.1275	.8	1.1675	.2	1.2104	.6	1.2565
.5	1.1284	.9	1.1684	.3	1.2114	.7	1.2576
.6	1.1293	21.0	1.1694	.4	1.2124	.8	1.2587
.7	1.1302	.1	1.1703	.5	1.2134	.9	1.2598
.8	1.1310	.2	1.1712	.6	1.2144	30.0	1.2609
.9	1.1319	.3	1.1722	.7	1.2154	.1	1.2620
17.0	1.1328	.4	1.1731	.8	1.2164	.2	1.2631
.1	1.1337	.5	1.1741	.9	1.2175	.3	1.2642
.2	1.1346	.6	1.1750	26.0	1.2185	.4	1.2653
.3	1.1355	.7	1.1760	.1	1.2195	.5	1.2664
.4	1.1364	.8	1.1769	.2	1.2205	.6	1.2675
.5	1.1373	.9	1.1779	.3	1.2216	.7	1.2686
.6	1.1381	22.0	1.1789	.4	1.2226	.8	1.2697
.7	1.1390	.1	1.1798	.5	1.2236	.9	1.2708
.8	1.1399	.2	1.1808	.6	1.2247	31.0	1.2719
.9	1.1408	.3	1.1817	.7	1.2257	.1	1.2730
18.0	1.1417	.4	1.1827	.8	1.2267	.2	1.2742
.1	1.1426	.5	1.1837	.9	1.2278	.3	1.2753
.2	1.1435	.6	1.1846	27.0	1.2288	.4	1.2764
.3	1.1444	.7	1.1856	.1	1.2299	.5	1.2775
.4	1.1453	.8	1.1866	.2	1.2309	.6	1.2787
.5	1.1462	.9	1.1876	.3	1.2319	.7	1.2798
.6	1.1472	23.0	1.1885	.4	1.2330	.8	1.2809
.7	1.1481	.1	1.1895	.5	1.2340	.9	1.2821
.8	1.1490	.2	1.1905	.6	1.2351	32.0	1.2832
.9	1.1499	.3	1.1915	.7	1.2361	.1	1.2843
19.0	1.1508	.4	1.1924	.8	1.2372	.2	1,2855
.1	1.1517	.5	1.1934	.9	1.2383	.3	1.2866

EQUIVALENT BAUME′ DEGREES—Con.

Degrees Baume′	Specific Gravity	Degrees Baume′	Specific Gravity	Degrees Baume′	Specific Gravity	Degrees Baume′	Specific Gravity
.4	1.2877	.8	1.3401	.2	1.3969	.6	1.4588
.5	1.2889	.9	1.3414	.3	1.3983	.7	1.4602
.6	1.2900	37.0	1.3426	.4	1.3996	.8	1.4617
.7	1.2912	.1	1.3438	.5	1.4010	.9	1.4632
.8	1.2923	.2	1.3451	.6	1.4023	46.0	1.4646
.9	1.2935	.3	1.3463	.7	1.4037	.1	1.4661
33.0	1.2946	.4	1.3476	.8	1.4050	.2	1.4676
.1	1.2958	.5	1.3488	.9	1.4064	.3	1.4691
.2	1.2970	.6	1.3501	42.0	1.4078	.4	1.4706
.3	1.2981	.7	1.3514	.1	1.4091	.5	1.4721
.4	1.2993	.8	1.3526	.2	1.4105	.6	1.4736
.5	1.3004	.9	1.3539	.3	1.4119	.7	1.4751
.6	1.3016	38.0	1.3551	.4	1.4133	.8	1.4766
.7	1.3028	.1	1.3564	.5	1.4146	.9	1.4781
.8	1.3040	.2	1.3577	.6	1.4160	47.0	1.4796
.9	1.3051	.8	1.3553	.7	1.4174	.1	1.4811
34.0	1.3063	.4	1.3602	.8	1.4188	.2	1.4826
.1	1.3075	.5	1.3615	.9	1.4202	.3	1.4841
.2	1.3087	.6	1.3628	43.0	1,4216	.4	1.4857
.3	1.3098	.7	1.3641	.1	1.4230	.5	1.4872
.4	1.3110	.8	1.3653	.2	1.4244	.6	1.4887
.5	1.3122	.9	1.3666	.3	1.4258	.7	1.4902
.6	1.3134	39.0	1.3679	.4	1.4272	.8	1.4918
.7	1.3146	.1	1.3692	.5	1.4286	.9	1.4933
.8	1.3158	.2	1.3705	.6	1.4300	48.0	1.4948
9	1.3170	.3	1.3718	.7	1.4314	.1	1.4964
35.0	1.3182	.4	1.3731	.8	1.4328	.2	1.4979
.1	1.3194	.5	1.3744	.9	1.4342	.3	1.4995
.2	1.3206	.6	1.3757	44.0	1.4356	.4	1.5010
.3	1.3218	.7	1.3770	.1	1.4371	.5	1.5026
.4	1.3230	.8	1.3783	.2	1.4385	.6	1.5041
.5	1.3242	.9	1.3796	.3	1.4399	.7	1.5057
.6	1.3254	40.0	1.3810	.4	1.4414	.8	1.5073
.7	1.3266	.1	1.3823	.5	1.4428	.9	1.5088
.8	1.3278	.2	1.3836	.6	1.4442	49.0	1.5104
.9	1.3291	.3	1.3849	.7	1.4457	.1	1.5120
36.0	1.3303	.4	1.3862	.8	1.4471	.2	1.5136
.1	1.3315	.5	1,3876	.9	1.4486	.3	1.5152
.2	1.3327	.6	1.3889	45.0	1.4500	.4	1.5167
.3	1.3329	.7	1.3902	.1	1.4515	.5	1.5183
.4	1.3352	.8	1.3916	.2	1.4529	.6	1.5199
.5	1.3364	.9	1.3828	.3	1.4544	.7	1.5215
.6	1.3376	41.0	1.3942	.4	1.4558	.8	1.5231
.7	1.3389	.1	1.3956	.5	1.4573	.9	1.5247

EQUIVALENT BAUME′ DEGREES—Con.

Degrees Baume′	Specific Gravity	Degrees Baume′	Specific Gravity	Degrees Baume′	Specific Gravity	Degrees Baume′	Specific Gravity
50.0	1.5263	.1	1.6129	.1	1.7079	.1	1.8148
.1	1.5279	.2	1.6147	.2	1.7099	.2	1.8170
.2	1.5295	.3	1.6165	.3	1.7119	.3	1.8193
.3	1.5312	.4	1.6183	.4	1.7139	.4	1.8216
.4	1.5328	.5	1.6201	.5	1.7160	.5	1.8239
.5	1.5344	.6	1.6219	.6	1.7180	.6	1.8262
.6	1.5360	.7	1.6237	.7	1.7200	.7	1.8285
.7	1.5376	.8	1.6256	.8	1.7221	.8	1.8308
.8	1.5393	.9	1.6459	.9	1.7241	.9	1.8331
.9	1.5409	56.0	1.6292	61.0	1.7262	66.0	1.8354
51.0	1.5426	.1	1.6310	.1	1.7282	.1	1.8378
.1	1.5442	.2	1.6329	.2	1.7303	.2	1.8401
.2	1.5458	.3	1.6347	.3	1.7324	.3	1.8424
.3	1.5475	.4	1.6366	.4	1.7344	.4	1.8448
.4	1.5491	.5	1.6384	.5	1.7365	.5	1.8471
.5	1.5508	.6	1.6403	.6	1.7386	.6	1.8495
.6	1.5525	.7	1.6421	.7	1.7407	.7	1.8519
.7	1.5541	.8	1.6440	.8	1.7428	.8	1.8542
.8	1.5558	.9	1.6459	.9	1.7449	9	1.8566
.9	1.5575	57.0	1.6477	62.0	1.7470	67.0	1.8590
52.0	1.5591	.1	1.6496	.1	1.7491	.1	1.8614
.1	1.5608	.2	1.6515	.2	1.7512	.2	1.8638
.2	1.5625	.3	1.6534	.3	1.7533	.3	1.8662
.3	1.5642	.4	1.6553	.4	1.7554	.4	1.8686
.4	1.5659	.5	1.6571	.5	1.7576	.5	1.8710
.5	1.5676	.6	1.6590	.6	1.7597	.6	1.8734
.6	1.5693	.7	1.6609	.7	1.7618	.7	1.8758
.7	1.5710	.8	1.6628	.8	1.7640	.8	1.8782
.8	1.5727	.9	1.6459	.9	1.7661	.9	1.8807
.9	1.5744	58.0	1.6667	63.0	1.7683	68.0	1.8831
53.0	1.5761	.1	1.6686	.1	1.7705	.1	1.8856
.1	1.5778	.2	1.6705	.2	1.7726	.2	1.8880
.2	1.5795	.3	1.6724	.3	1.7748	.3	1,8905
.3	1.5812	.4	1.6744	.4	1.7770	.4	1.8930
.4	1.5830	.5	1.6763	.5	1.7791	.5	1.8954
.5	1.5847	.6	1.6782	.6	1.7813	.6	1.8979
.6	1.5864	.7	1.6802	.7	1.7835	.7	1.9004
.7	1.5882	.8	1.6821	.8	1.7857	.8	1.9029
.8	1.5899	.9	1.6841	.9	1.7879	.9	1.9054
.9	1.5917	59.0	1.6860	64.0	1.7901	69.0	1.9079
54.0	1.5934	.1	1.6880	.1	1.7923	.1	1.9104
.1	1.5952	.2	1.6900	.2	1.7946	.2	1.9129
.2	1.5969	.3	1.6919	.3	1.7968	.3	1.9155
.3	1.5987	.4	1,6939	.4	1.7990	.4	1.9180
.4	1.6004	.5	1.6959	.5	1.8012	.5	1.9205
.5	1.6022	.6	1.6979	.6	1.8035	.6	1.9231
.6	1.6040	.7	1.6999	.7	1.8057	.7	1.9256
.7	1.6058	.8	1.7019	.8	1.8080	.8	1.9282
.8	1.6075	.9	1.7039	.9	1.8102	.9	1.9308
.9	1.6093	60.0	1.7059	65.0	1.8125	70.0	1.9333
55.0	1.6111						

Specific Gravity and Content of Sulphuric Acid

Specific Gravity 15°	100 parts by weight correspond to		1 liter contains grams		Specific Gravity 15°	100 parts by weight correspond to		1 liter contains grams	
4° in vacuo	% SO_3	% H_2SO_4	SO_3	H_2SO_4	4° in vacuo	% SO_3	% H_2SO_4	SO_3	H_2SO_4
1.000	0.07	0.09	1	1	1.190	21.26	26.04	253	310
1.005	0.68	0.83	7	8	1.195	21.78	26.68	260	319
1.010	1.28	1.57	13	16	1.200	22.30	27.30	268	328
1.015	1.88	2.30	19	23	1.205	22.82	27.95	275	337
1.020	2.47	3.03	25	31	1.210	23.33	28.58	282	346
1.025	3.07	3.76	32	39	1.215	23.84	29.21	290	355
1.030	3.67	4.40	38	46	1.220	24.36	29.84	297	364
1.035	4.27	5.23	44	54	1.225	24.88	30.48	305	373
1.040	4.87	5.96	51	62	1.230	25.39	31.11	312	382
1.045	5.45	6.67	57	71	1.235	25.88	31.70	320	391
1.050	6.02	7.37	63	77	1.240	26.35	32.28	327	400
1.055	6.59	8.07	70	85	1.245	26.83	32.86	334	409
1.060	7.16	8.77	76	93	1.250	27.29	33.43	341	418
1.065	7.73	9.47	82	102	1.255	27.76	34.00	348	426
1.070	8.32	10.19	89	109	1.260	28.22	34.57	356	435
1.075	8.90	10.90	96	117	1.265	28.69	35.14	363	444
1.080	9.47	11.60	103	125	1.270	29.15	35.71	370	454
1.085	10.04	12.30	109	133	1.275	29.62	36.29	377	462
1.090	10.60	12.99	116	142	1.280	30.10	36.87	385	472
1.095	11.16	13.67	122	150	1.285	30.57	37.45	393	481
1.100	11.71	14.35	129	158	1.290	31.04	38.03	400	490
1.105	12.27	15.03	136	166	1.295	31.52	38.61	408	500
1.110	12.82	15.71	143	175	1.300	31.99	39.19	416	510
1.115	13.36	16.36	149	183	1.305	32.46	39.77	424	519
1.120	13.89	17.01	156	191	1.310	32.94	40.35	432	529
1.125	14.42	17.66	162	199	1.315	33.41	40.93	439	538
1.130	14.95	18.31	169	207	1.320	33.88	41.50	447	548
1.135	15.48	18.96	176	215	1.325	34.35	42.08	455	557
1.140	16.01	19.61	183	223	1.330	34.80	42.66	462	507
1.145	16.54	20.26	189	231	1.335	35.27	43.20	471	577
1.150	17.07	20.91	196	239	1.340	35.71	43.74	479	586
1.155	17.59	21.55	203	248	1.345	36.14	44.28	486	596
1.160	18.11	22.19	210	257	1.350	36.58	44.82	494	605
1.165	18.64	22.83	217	266	1.355	37.02	45.35	502	614
1.170	19.16	23.47	224	275	1.360	37.45	45.88	509	624
1.175	19.69	24.12	231	283	1.365	37.89	46.41	517	633
1.180	20.21	24.76	238	292	1.370	38.32	46.94	525	643
1.185	20.73	25.40	246	301	1.375	38.75	47.47	533	653

SPECIFIC GRAVITY AND CONTENT OF SULPHURIC ACID—Con.

Specific Gravity 15°/4° in vacuo	100 parts by weight correspond to		1 liter contains grams		Specific Gravity 15°/4° in vacuo	100 parts by weight correspond to		1 liter contains grams	
	% SO_3	% H_2SO_4	SO_3	H_2SO_4		% SO_3	% H_2SO_4	SO_3	H_2SO_4
1.380	39.18	48.00	541	662	1.675	61.20	74.97	1025	1256
1.385	39.62	48.53	549	672	1.680	61.57	75.42	1034	1267
1.390	40.05	49.06	557	682	1.685	61.93	75.86	1043	1278
1.395	40.48	49.50	564	692	1.690	62.29	76.30	1053	1289
1.400	40.91	50.11	573	702	1.695	62.64	76.73	1062	1301
1.405	41.33	50.63	581	711	1.700	63.00	77.17	1071	1312
1.410	41.76	51.15	589	721	1.705	63.35	77.60	1080	1323
1.415	42.17	51.66	597	730	1.710	63.70	78.04	1089	1334
1.420	42.57	52.15	604	740	1.715	64.07	78.48	1099	1346
1.425	42.96	52.63	612	750	1.720	64.43	78.92	1108	1357
1.430	43.36	53.11	620	759	1.725	64.78	79.36	1118	1369
1.435	43.75	53.59	628	769	1.730	65.14	79.80	1127	1381
1.440	44.14	54.07	636	779	1.735	65.50	80.24	1136	1392
1.445	44.53	54.55	643	789	1.740	65.86	80.68	1146	1404
1.450	44.92	55.03	651	798	1.745	66.22	81.12	1156	1416
1.455	45.31	55.50	659	808	1.750	66.58	81.56	1165	1427
1.460	45.69	55.97	667	817	1.755	66.94	82.00	1175	1439
1.465	46.07	56.43	675	827	1.760	67.30	82.44	1185	1451
1.470	46.45	56.90	683	837	1.765	67.65	82.88	1194	1463
1.475	46.83	57.37	691	846	1.770	68.02	83.32	1204	1475
1.480	47.21	57.83	699	856	1.775	68.49	83.90	1216	1489
1.485	47.57	58.28	707	865	1.780	68.98	84.50	1228	1504
1.490	47.95	58.74	715	876	1.785	69.47	85.10	1240	1519
1.495	48.34	59.22	723	885	1.790	69.96	85.70	1252	1534
1.500	48.73	59.70	731	896	1.795	70.46	86.30	1265	1549
1.505	49.12	60.18	739	906	1.800	70.94	86.90	1277	1564
1.510	49.51	60.65	748	916	1.805	71.50	87.60	1291	1581
1.515	49.89	61.12	756	926	1.810	72.08	88.30	1305	1598
1.520	50.28	61.59	764	936	1.815	72.69	89.05	1319	1621
1.525	50.66	62.06	773	946	1.820	73.51	90.05	1338	1639
1.530	51.04	62.53	781	957	1.821	73.63	90.20	1341	1643
1.535	51.43	63.00	789	967	1.822	73.80	90.40	1345	1647
1.540	51.78	63.43	797	977	1.823	73.96	90.60	1348	1651
1.545	52.12	63.85	805	987	1.824	74.12	90.80	1352	1656
1.550	52.46	64.26	813	996	1.825	74.29	91.00	1356	1661
1.555	52.79	64.67	821	1006	1.826	74.49	91.25	1360	1666
1.560	53.12	65.08	829	1015	1.827	74.69	91.50	1364	1671
1.565	53.46	65.49	837	1025	1.828	74.86	91.70	1368	1676
1.570	53.80	65.90	845	1035	1.829	75.03	91.90	1372	1681
1.575	54.13	66.30	853	1044	1.830	75.19	92.10	1376	1685
1.580	54.46	66.71	861	1054	1.831	75.35	92.30	1380	1690
1.585	54.80	67.13	869	1064	1.832	75.53	92.52	1384	1695
1.590	55.18	67.59	877	1075	1.833	75.72	92.75	1388	1700
1.595	55.55	68.05	886	1085	1.834	75.96	93.05	1393	1706
1.600	55.93	68.51	897	1096	1.835	76.27	93.43	1400	1713
1.605	56.30	68.97	904	1107	1.836	76.57	93.80	1405	1722
1.610	56.68	69.43	913	1118	1.837	76.90	94.20	1412	1730
1.615	57.05	69.89	921	1128	1.838	77.23	94.60	1419	1739
1.620	57.40	70.32	930	1139	1.839	77.55	95.00	1426	1748
1.625	57.75	70.74	938	1150	1.840	78.04	95.60	1436	1759
1.630	58.09	71.16	947	1160	1.8405	78.33	95.95	1441	1765
1.635	58.43	71.57	955	1170	1.8410	79.19	97.00	1458	1786
1.640	58.77	71.99	964	1181	1,8415	79.76	97.70	1469	1799
1.645	59.10	72.40	972	1192	1.8410	80.16	98.20	1476	1808
1.650	59.45	72.82	981	1202	1.8405	80.57	98.70	1483	1816
1.655	59.78	73.23	989	1212	1.8400	80.98	99.20	1490	1825
1.660	60.11	73.64	998	1222	1.8395	81.18	99.45	1494	1830
1.665	60.46	74.07	1007	1233	1.8390	81.39	90.70	1497	1834
1.670	60.82	74.51	1016	1244	1.8385	81.59	99.95	1500	1838

Percentage of Sulphur Trioxide and Sulphuric Acid in Fuming Sulphuric Acid

Total SO_3 as found by titration	The acid contains %		Total SO_3 as found by titration	The acid contains %		Total as found by titration	The acid contains %	
	H_2SO_4	SO_3		H_2SO_4	SO_3		H_2SO_4	SO_3
81.8326	100	0	87.8775	66	34	93.9389	33	67
81.8163	99	1	88.0612	65	35	94.1224	32	68
82.0000	98	2	88.2448	64	36	94.3061	31	69
82.1836	97	3	88.4285	63	37	94.4897	30	70
82.3374	96	4	88.6122	62	38	94.6734	29	71
82.5510	95	5	88.7959	61	39	94.8571	28	72
82.7346	94	6	88.9795	60	40	95.0408	27	73
82.9183	93	7	89.1632	59	41	95.2244	26	74
83.1020	92	8	89.3469	58	42	95.4081	25	75
83.2857	91	9	89.5306	57	43	95.5918	24	76
83.4693	90	10	89.7142	56	44	95.7755	23	77
83.6530	89	11	89.8979	55	45	95.9591	22	78
83.8367	88	12	90.0816	54	46	96.1428	21	79
84.0204	87	13	90.2653	53	47	96.3265	20	80
84.2040	86	14	90.4489	52	48	96.5102	19	81
84.3877	85	15	90.6326	51	49	96.6938	18	82
84.5714	84	16	90.8163	50	50	96.8775	17	83
84.7551	83	17	91.0000	49	51	97.0612	16	84
84.9387	82	18	91.1836	48	52	97.2448	15	85
85.1224	81	19	91.3673	47	53	97.4285	14	86
85.3061	80	20	91.5510	46	54	97.6122	13	87
85.4897	79	21	91.7346	45	55	97.7959	12	88
85.6734	78	22	91.9183	44	56	97.9795	11	89
85.8571	77	23	92.1020	43	57	98.1632	10	90
86.0408	76	24	92.2857	42	58	98.3469	9	91
86.2244	75	25	92.4693	41	59	98.5306	8	92
86.4081	74	26	92.6530	40	60	98.7142	7	93
86.5918	73	27	92.8367	39	61	98.8979	6	94
86.7755	72	28	93.0204	38	62	99.0816	5	95
86.9591	71	29	93.2040	37	63	99.2753	4	96
87.1428	70	30	93.3877	36	64	99.4489	3	97
87.3265	69	31	93.5714	35	65	99.6326	2	98
87.5102	68	32	93.7551	34	66	99.8163	1	99
87.6938	67	33						

Sodium Hydroxide Solution at 15°C (Caustic Soda)

LUNGE.

Specific Gravity	Degrees Baume'	Degrees Twaddell	Per Cent Na_2O.	Per Cent NaOH.	1 Liter Contains Grams	
					Na_2O.	NaOH.
1.007	1.0	1.4	0.47	0.61	4	6
1.014	2.8	2.9	0.93	1.20	9	12
1.022	3.1	4.4	1.55	2.00	16	21
1.029	4.1	5.8	2.10	2.70	22	28
1.036	5.1	7.2	2.60	3.35	27	35
1.045	6.2	9.0	3.10	4.00	32	42
1.052	7.2	10.4	3.60	4.64	38	49
1.060	8.2	12.0	4.10	5.29	43	56
1.067	9.1	13.4	4.55	5.87	49	63
1.075	10.1	15.0	5.08	6.55	55	70
1.083	11.1	16.6	5.67	7.31	61	79
1.091	12.1	18.2	6.20	8.00	68	87
1.100	13.2	20.0	6.73	8.68	74	95
1.108	14.1	21.6	7.30	9.42	81	104
1.116	15.1	23.2	7.80	10.06	87	112
1.125	16.1	25.0	8.50	10.97	96	123
1.134	17.1	26.8	9.18	11.84	104	134
1.142	18.0	28.4	9.80	12.64	112	144
1.152	19.1	30.4	10.50	13.55	121	156
1.162	20.2	32.4	11.14	14.37	129	167
1.171	21.2	34.2	11.73	15.13	137	177
1.180	22.1	36.0	12.33	15.91	146	188
1.190	23.1	38.0	13.00	16.77	155	200
1.200	24.2	40.0	13.70	17.67	164	212
1.210	25.2	42.0	14.40	18.58	174	225
1.220	26.1	44.0	15.18	19.58	185	239
1.231	27.2	46.2	15.96	20.59	196	253
1.241	28.2	48.2	16.76	21.42	208	266
1.252	29.2	50.4	17.55	22.64	220	283
1.263	30.2	52.6	18.35	23.67	232	299
1.274	31.2	54.8	19.23	24.81	245	316
1.285	32.2	57.0	20.00	25.80	257	332
1.297	33.2	59.4	20.80	26.83	270	348
1.308	34.1	61.6	21.55	27.80	282	364
1.320	35.2	64.0	22.35	28.83	295	381
1.332	36.1	66.4	23.20	29.93	309	399
1.345	37.2	69.0	24.20	31.22	326	420
1.357	38.1	71.4	25.17	32.47	342	441
1.370	39.2	74.0	26.12	33.69	359	462
1.383	40.2	76.6	27.10	34.96	375	483
1.397	41.2	79.4	28.10	36.25	392	506
1.410	42.2	82.0	29.05	37.47	410	528
1.424	43.2	84.8	30.08	38.80	428	553
1.438	44.2	87.6	31.00	39.99	446	575
1.453	45.2	90.6	32.10	41.41	466	602
1.468	46.2	93.6	33.20	42.83	487	629
1.483	47.2	96.6	34.40	44.38	510	658
1.498	48.2	99.6	35.70	46.15	535	691
1.514	49.2	102.8	36.90	47.60	559	721
1.530	50.2	106.0	38.00	49.02	581	750

Table of Chloride of Calcium Solution

Specific Gravity at 64 Degrees F.	Degree Beaume at 64 Degrees F.	Degree Salometer at 64 Degrees F.	Per Cent of $CaCl_2$	Freezing Point in Degrees F.	Ammonia Gauge Pressure Pounds per Square Inch
1.007	1	4	0.943	+31.20	46
1.014	2	8	1.886	+30.40	45
1.021	3	12	2.829	+29.60	44
1.028	4	16	3.772	+28.80	43
1.035	5	20	4.715	+23.00	42
1.043	6	24	5.658	+26.89	41
1.050	7	28	6.601	+25.78	40
1.058	8	32	7.544	+24.67	38
1.065	9	36	8.487	+23.56	37
1.073	10	40	9.430	+22.09	35.5
1.081	11	44	10.373	+20.62	34
1.089	12	48	11.316	+19.14	32.5
1.097	13	52	12.259	+17.67	30.5
1.105	14	56	13.202	+15.75	29
1.114	15	60	14.145	+13.82	27
1.122	16	64	15.088	+11.80	25
1.131	17	68	16.031	+ 9.96	23.5
1.140	18	72	16.974	+ 7.68	21.5
1.149	19	76	17.917	+ 5.40	20
1.158	20	80	18.860	+ 3.12	18
1.167	21	84	19.803	— 0.84	15
1.176	22	88	20.746	— 4.44	12.5
1.186	23	92	21.689	— 8.03	10.5
1.196	24	96	22.632	—11.63	8
1.205	25	100	23.575	—15.23	6
1.215	26	104	24.518	—19.56	4
1.225	27	108	25.461	—24.43	1.5
1.236	28	112	26.404	—29.29	1″ vacuum
1.246	29	116	27.347	—35.30	5″ vacuum
1.257	30	120	28.290	—41.32	8.5″ vacuum
1.268	31	......	29.233	—47.66	12″ vacuum
1.279	32	......	30.176	—54.00	15″ vacuum
1.290	33	......	31.119	—44.32	10″ vacuum
1.302	34	......	32.062	—34.66	4″ vacuum
1.313	35	......	33.	—25.00	1.5 pounds

Table of Brine Solution

(CHLORIDE OF SODIUM—COMMON SALT.)

Per Cent of Salt by Weight	Degrees on Salometer at 60 Degrees Fahr.	Specific Gravity at 60 Degrees Fahr.	Specific Heat	Weight of One Gallon	Pounds of Salt in One Gallon	Pounds of Water in One Gallon	Weight of One Cubic Foot	Pounds of Salt in One Cubic Foot	Pounds of Water in One Cubic Foot	Freezing Point Degrees Fahr.
0	0	1.	1.	8.35	0.	8.35	62.4	0.	62.4	32.
1	4	1.007	0.992	8.4	0.084	8.316	62.8	0.628	62.172	31.8
5	20	1.037	0.96	8.65	0.432	8.218	64.7	3.237	61.465	25.4
10	40	1.073	0.892	8 95	0.895	8 055	66.95	6.695	60.253	18.6
15	60	1.115	0.855	9.3	1.395	7.905	69.57	10.435	59.134	12.2
20	80	1.150	0.829	9.6	1.92	7.68	71.76	14.352	57.408	6.86
25	100	1.191	0.783	9.94	2.485	7.455	74.26	18.565	55.695	1.00

The Metric System, Fundamental Equivalents

The fundamental unit of the metric system is the Meter—the unit of length. From this the units of capacity (Liter) and of weight (Gram) were derived. All other units are the decimal subdivisions or multiples of these. These three units are simply related, e. g., for all practical purposes one Cubic Decimeter equals one Liter and one Liter of water weighs one Kilogram. The metric tables are formed by combining the words "Meter," "Gram," and "Liter" with the six numerical prefixes, as in the following tables:

Prefixes.	Meaning.			Units.
milli-	= one thousandth	..1/1000	0.001	
centi-	= one hundredth	..1/100	0.01	"meter" for length
deci-	= one tenth.	......1/10	0.1	
Unit	= one.		1.	"gram" for weight or mass
deka-	= ten	............10/1	10.	
hecto-	= one hundred	....100/1	100.	"liter" for capacity
kilo-	= one thousand	...1000/1	1000.	

All lengths, areas, and cubic measures in the following tables are derived from the international meter, the legal equivalent being 1 Meter = 39.37 Inches (law of July 28, 1866). In 1893 the United States Office of Standard Weights and Measures was authorized to derive the yard from the meter, using for the purpose the relation legalized in 1866, 1 Yard = 3600/3937 Meter.

The customary weights derived from the international kilogram are based on the value of 1 avoirdupois pound = 453.5924277 grams. This value is carried out farther than that given in the law, but is in accord with the latter as far as it is there given. The value of the troy pound is based upon the relation just mentioned and also the equivalent 5760/7000 avoirdupois pounds equal 1 troy pound.

In the following tables the metric unit has been selected as the common unit so that conversions may be made through the metric unit.

LINEAR DIMENSIONS—CONVERSION FACTORS.

Cm. to A.	A.	A. to Cm.
$1.0000 \cdot 10^{-5}$	KILOMETER = 0.62137 — U. S. miles = 3280.83 ft.	$1.0000 \cdot 10^{5}$
$1.0000 \cdot 10^{-2}$ (*a*)	METER = 3.28083 ft. = 39.37 inches (legal)	$1.0000 \cdot 10^{2}$
1.0000	CENTIMETER = 0.3937 inch = 10 millimeters	1.0000
$1.0000 \cdot 10$	MILLIMETER = 0.03937 inch = 1000 microns	$1.0000 \cdot 10^{-1}$
$1.0000 \cdot 10^{4}$	MICRON = 0.00003937 inch = 1000 millimicrons	$1.0000 \cdot 10^{-4}$
$1.0000 \cdot 10^{7}$	MILLIMICRON or MICROMILLIMETER = 10 A. U	$1.0000 \cdot 10^{-7}$
$1.0000 \cdot 10^{8}$	ANGSTROM UNIT = 3.932×10^{-9} inch	$1.0000 \cdot 10^{-8}$
$6.2137 \cdot 10^{-6}$	MILE (Statute) = 5280 feet = 1.609347 kilom	$1.6093 \cdot 10^{5}$
$1.9883 \cdot 10^{-3}$	ROD or PERCH = 16.5 feet	$5.029 \cdot 10^{2}$
$1.0936 \cdot 10^{-2}$	YARD = 3 feet	$9.144 \cdot 10$
$3.28083 \cdot 10^{-2}$	FOOT = 12 inches	$3.0480 \cdot 10$
$3.937 \cdot 10^{-1}$	INCH = 0.083333 ft.	2.5400
$3.937 \cdot 10^{2}$	MIL = 1/1000 inch	$2.5400 \cdot 10^{-3}$
$8.983 \cdot 10^{-8}$	1° LONGITUDE AT EQUATOR = 69.1713 Statute Miles	$1.1132 \cdot 10^{7}$
$2.0712 \cdot 10^{-6}$	LEAGUE = 3 Statute Miles	$4.8280 \cdot 10^{5}$
$5.3959 \cdot 10^{-6}$	KNOT, NAUTICAL MILE, SEA MILE = 6080.2 (Geographical Mile)	$1.85325 \cdot 10^{5}$
$5.3957 \cdot 10^{-6}$	BRITISH NAUTICAL MILE = 6080.4006466 + feet	$1.85319 \cdot 10^{5}$
$4.97 \cdot 10^{-5}$	FURLONG = 660 feet = 10 chains	$2.01168 \cdot 10^{4}$
$2.7340 \cdot 10^{-4}$	1 CABLE LENGTH = 120 feet	$3.6576 \cdot 10^{3}$
$5.468 \cdot 10^{-3}$	U. S. FATHOM = 6 feet	$1.8288 \cdot 10^{2}$
$4.9709 \cdot 10^{-4}$	CHAIN = 66 feet = 100 links	$2.01168 \cdot 10^{3}$
$4.97 \cdot 10^{-2}$	LINK = 7.92 inches	$2.01168 \cdot 10$
$1.118 \cdot 10^{-2}$	VARA = 33⅓ inches	$8.4760 \cdot 10$
$2.734 \cdot 10^{-4}$	BOLT = 40 yards	$3.7576 \cdot 10^{3}$
$1.1811 \cdot 10^{-1}$	BARLEY CORN = ⅓ inch	8.4667
$4.3744 \cdot 10^{-2}$	SPAN = 9 inches	$2.2860 \cdot 10$
$9.8425 \cdot 10^{-2}$	HAND = 4 inches	$1.0160 \cdot 10$
$1.312 \cdot 10^{-1}$	PALM = 3 inches	7.6200
4.7244	LINE = 1/12 inch	$2.1167 \cdot 10^{-1}$
$2.834 \cdot 10$	POINT = 1/72 inch	$3.5278 \cdot 10^{-2}$

(*a*) Note $10^{-5} = 1/10^{5} = 1/100000 = 0.00001$.

SQUARE MEASURE, SURFACES, AREAS.

Sq. cm. to A.	A.	A. to sq. cm.
$1.000 \cdot 10^{-8}$	HECTARE = 2.471043930 acres	$1.000 \cdot 10^{8}$
$1.000 \cdot 10^{-6}$ (*a*)	ARE or AR = 119.59852621 sq. yd	$1.000 \cdot 10^{6}$
$1.000 \cdot 10^{-10}$	SQUARE KILOMETER = 0.386100614 sq. miles	$1.000 \cdot 10^{10}$
$1.000 \cdot 10^{-4}$	SQUARE METER = 10.76386735908 sq. ft.	$1.000 \cdot 10^{4}$
1.000	SQUARE CENTIMETER = 0.15499968997 sq. in.	1.000
$1.000 \cdot 10^{2}$	SQUARE MILLIMETER = 0.001550 sq. in.	$1.000 \cdot 10^{-2}$
$1.0725017 \cdot 10^{-12}$	1 TOWNSHIP = 36 square miles	$9.3239945 \cdot 10^{11}$
$3.86100614 \cdot 10^{-11}$	SQUARE MILE = 640 acres = 2.78784×10^{7} sq. in.	$2.58999847 \cdot 10^{10}$
$2.47104393 \cdot 10^{-8}$	ACRE = 10 sq. chains = 43560 sq. ft. = 0.0015625 sq. mi.	$4.0468726 \cdot 10^{7}$
$3.953670288 \cdot 10^{-6}$	SQ. ROD or POLE = 272.25 sq. ft. = 0.00625 A	$2.52929537 \cdot 10^{5}$
$1.19598526 \cdot 10^{-4}$	SQUARE YARD = 9 sq. ft. = 1296 sq. in.	$8.3613 \cdot 10^{3}$
$1.0763867359 \cdot 10^{-3}$	SQUARE FOOT = 144 sq. in. = 3.58701×10^{-8} sq. mi.	$9.29034 \cdot 10^{2}$
$1.5499968 \cdot 10^{-1}$	SQUARE INCH = 0.0069444 sq. ft. = 2.491×10^{-10} sq. mi.	6.4516
$1.5499968 \cdot 10^{5}$	SQUARE MIL = 0.000001 sq. in.	$6.4516 \cdot 10^{-6}$
$1.2705 \cdot 10^{5}$	CIRCULAR MIL = (wire) = 0.00000122 sq. in.	$7.871 \cdot 10^{-6}$
$2.47104393 \cdot 10^{-7}$	SQUARE CHAIN = 4356 sq. ft. = 0.1 acres	$4.0468726 \cdot 10^{6}$
$2.47104393 \cdot 10^{-4}$	SQUARE LINK = 62.7264 sq. in. = 0.4356 sq. ft.	$4.0468726 \cdot 10^{3}$
$1.0764 \cdot 10^{-5}$	1 SQUARE (roofs and floors) = 100 sq. ft.	$9.29034 \cdot 10^{4}$

(*a*) $10^{-8} = 1/10^{8} = 1/100000000 = 0.00000001$

VOLUME, CAPACITY, CUBIC CONTENTS, SPACE.

Cubic centimeter to A.	A.	A. to cubic centimeter.
1.000	CUBIC CENTIMETER = 16.23 minims = 0.0610 cu. in.	1.0000
$1.000 \cdot 10^{-3}$	LITER = 1.056681868 U. S. Qt. = 61.023 cu. in.	$1.000 \cdot 10^{3}$
$1.000 \cdot 10^{-6}$	CUBIC METER = 264.4 U. S. Gal. = 35.3165 cu. ft. (Kiloliter) (stere) = 1.307942772 cu. yd.	$1.000 \cdot 10^{6}$
$6.1023377953 \cdot 10^{-2}$	CUBIC INCH = 0.553 fld. oz. = 0.00058 cu. ft.	$1.6387 \cdot 10$
$3.532 \cdot 10^{-5}$	CUBIC FOOT = 7.48 U. S. Gal. = 1728 cu. in.	$2.8317 \cdot 10^{4}$
$1.308 \cdot 10^{-9}$	CUBIC YARD = 20.197 U. S. Gal. = 27 cu. ft.	$7.64559 \cdot 10^{5}$

U. S. LIQUID AND APOTHECARY MEASURE.

$1.623 \cdot 10$	MINIM = about 1 drop = 0.00376 cu. in.	$6.16119 \cdot 10^{-2}$
$2.705 \cdot 10^{-1}$	FLUID DRAM = 60 minims = 0.2256 cu. in.	3.6967
$8.116 \cdot 10^{-1}$	SCRUPLE = 20 minims = 0.0752 cu. in.	1.2322
$3.3815 \cdot 10^{-2}$	FLUID OUNCE = 8 drams = 1.805 cu. in.	$2.9573 \cdot 10$
$8.454 \cdot 10^{-3}$	GILL = 4 ounces = 7.220 cu. in.	$1.1829 \cdot 10^{2}$
$2.113 \cdot 10^{-3}$	PINT = 16 ounces = 28.88 cu. in.	$4.73179 \cdot 10^{2}$
$1.056 \cdot 10^{-3}$	QUART = 2 pints = 57.76 cu. in.	$9.46358 \cdot 10^{2}$
$2.641704673 \cdot 10^{-4}$	GALLON = 4 quarts = 0.1337 cu. ft. = 231 cu. in.	$3.78543 \cdot 10^{3}$
$8.387 \cdot 10^{-6}$	BARREL (wine) = 31½ gallons = 4.205 cu. ft.	$1.1924 \cdot 10^{5}$
$4.193 \cdot 10^{-6}$	HOGSHEAD = 63 gallons = 8.410 cu. ft.	$2.3848 \cdot 10^{5}$
$6.297 \cdot 10^{-6}$	BARREL (petroleum) = 42 gal. = 5.615 cu. ft.	$1.58984 \cdot 10^{5}$
$6.297 \cdot 10^{-6}$	TIERCE = 42 gal. = 5.615 cu. ft.	$1.5898 \cdot 10^{5}$
$3.148 \cdot 10^{-6}$	PUNCHEON = 84 gallons = 11.23 cu. ft.	$3.176 \cdot 10^{5}$

U. S. DRY MEASURE.

Cubic centimeter to A.	A.	A. to cubic centimeter.
$1.816 \cdot 10^{-3}$	PINT = 33.6 cu. in.	$5.506 \cdot 10^{2}$
$9.08 \cdot 10^{-4}$	QUART = 1.101 liters = 67.2 cu. in.	$1.10123 \cdot 10^{3}$
$2.27 \cdot 10^{-4}$	GALLON = 4.4049 liters = 268.8 cu. in.	$4.40492 \cdot 10^{3}$
$1.13 \cdot 10^{-4}$	PECK = 8.8098 liters = 537.6 cu. in.	$8.80984 \cdot 10^{3}$
$2.837742299 \cdot 10^{-5}$	BUSHEL = 9.31 U. S. Gal. = 2150.4 cu. in.	$3.523928 \cdot 10^{4}$
$9.418 \cdot 10^{-6}$	BARREL (flour) 196 lbs. = 88.904 kgm. = 7056 cu. in. = 408 cu. ft.	$1.06180 \cdot 10^{5}$
$8.849 \cdot 10^{-5}$	BARREL (cement) = 376 lbs. = 170.551 kgm. = 4.0 cu. ft.	$1.13 \cdot 10^{5}$

BRITISH LIQUID AND DRY MEASURE.

$1.693 \cdot 10$	MINIMS = about 1 drop = 0.00361 cu. in.	$5.9192 \cdot 10^{-2}$
$2.8219 \cdot 10^{-1}$	DRACHM = 60 minims = 0.2166 cu. in.	3.54958
$3.527 \cdot 10^{-2}$	OUNCE = 8 drachms = 1.733 cu. in.	$2.839661 \cdot 10$
$1.7608 \cdot 10^{-3}$	PINT = 20 ounces = 34.67 cu. in.	$5.6793 \cdot 10^{2}$
$8.804 \cdot 10^{-4}$	QUART = 1.136 liters = 69.34 cu. in.	$1.13586 \cdot 10^{3}$
$2.201 \cdot 10^{-4}$	GALLON = 4.543 liters = 277.274 cu. in.	$4.54345797 \cdot 10^{3}$
$1.1005 \cdot 10^{-4}$	PECK = 2 gallons = 554.4 cu. in.	$9.08692 \cdot 10^{3}$
$2.75121 \cdot 10^{-5}$	BUSHEL = 8 gallons = 2218.2 cu. in.	$3.63477 \cdot 10^{4}$
$6.87802 \cdot 10^{-6}$	COOMB = 4 bushels = 5.1347 cu. ft.	$1.453908 \cdot 10^{5}$
$3.43901 \cdot 10^{-6}$	QUARTER = 8 bushels = 10.269 cu. ft.	$2.907816 \cdot 10^{5}$

MISCELLANEOUS.

$5.085 \cdot 10^{-3}$	BOARD FOOT (1′ × 1′ × 1″) = 144 cu. in.	$1.96642 \cdot 10^{2}$
$2.760 \cdot 10^{-7}$	CORD (4′ × 4′ × 8′) = 128 cu. ft.	$3.6246 \cdot 10^{6}$
$8.1034 \cdot 10^{-10}$	ACRE FOOT = 362000 U. S. Gal. = 43560 cu. ft.	$1.2335 \cdot 10^{9}$
$8.88 \cdot 10^{-7}$	U. S. SHIPPING TON = 40 cu. ft.	$1.13268 \cdot 10^{6}$
$8.409 \cdot 10^{-7}$	1 BRITISH SHIPPING TON = 42 cu. ft.	$1.1893 \cdot 10^{6}$

U. S. liquid measure × 1.2003 = British liquid and dry of same denomination.
U. S. dry measure × 1.032 = British liquid and dry of same denomination.

WEIGHTS—CONVERSION FACTORS.

Grams to A.	A.	A. to grams.
1.000	GRAM (1 cc. water at 4°C.) = 15.432 grains	1.0000
$1.000 \cdot 10^{3}$	MILLIGRAM = 0.015432 grain	$1.0000 \cdot 10^{-3}$
$1.0000 \cdot 10^{-3}$	KILOGRAM = 2.679 T. lbs. = 2.204622341 Av. lbs.	$1.0000 \cdot 10^{3}$
$1.000 \cdot 10^{-5}$ (*a*)	QUINTAL (100 kilograms) = 2.2046 cwt.	$1.0000 \cdot 10^{5}$
$1.000 \cdot 10^{-6}$	METRIC TON = 1.1023 ton (short) = 2204.6 lbs	$1.0000 \cdot 10^{6}$
$1.5432 \cdot 10$	GRAIN (T. Ap. Av.) = 0.0020835 ounce (T.)	$6.4799 \cdot 10^{-2}$
$6.430 \cdot 10^{-1}$	PENNYWEIGHT (T.) = 24.0 grains	1.5552
$6.43 \cdot 10^{-2}$	CARET (T.) = 10.0 pwt.	$1.5552 \cdot 10$
$7.716 \cdot 10$	SCRUPLE (Ap.) = 20.0 grains	1.2960
$2.572 \cdot 10$	DRAM (Ap.) = 60.0 grains	3.8879
$3.215 \, . \, 10^{-2}$	OUNCE (T.) = 1.09714 + oz. Av. = 480 grains	31.1035
$2.68 \, . \, 10^{-3}$	POUND (T.) = 0.822857 lb. Av. = 12 oz. Troy	$3.732714662 \cdot 10^{2}$
$3.5273990 \cdot 10^{-2}$	OUNCE (Av.) = 0.911450 oz. T. = 437.5 grains	$2.834952673 \cdot 10$
$2.2046244 \cdot 10^{-3}$	POUND (Av.) = 1.2153 lbs. T. = 16 oz. Av. = 7000 grains	$4.535924277 \cdot 10^{2}$
$2.2046244 \cdot 10^{-5}$	HUNDRED WEIGHT (short) = 100 lbs	$4.5359 \cdot 10^{4}$
$1.968414 \cdot 10^{-5}$	HUNDRED WEIGHT (long) = 112 lbs	$5.0802 \cdot 10^{4}$
$1.1023122 \cdot 10^{-6}$	TON (U. S. short) = 2000 lbs	$9.07184 \cdot 10^{5}$
$0.9845 \cdot 10^{-6}$	TON (British long) = 2240 lbs	$1.016 \cdot 10^{6}$
$3.937 \cdot 10^{-5}$	STONE = 14 lbs	$6.3503 \cdot 10^{3}$
$7.874 \cdot 10^{-5}$	QUARTER = 25 lbs	$1.13368 \cdot 10^{4}$
4.8665	CARAT (precious stones) = 3.1713 grains	$2.055 \cdot 10^{-1}$
0.03429	ASSAY TON (metallurgists) = oz. Av. = 0.885188 oz. Troy	$2.91667 \cdot 10$

T. = Troy. Ap. = Apothecary. Av. = Avoirdupois.

(*a*) $10^{-3} = 1/10^{3} = 1/1000 = 0.001$.

WORK CONVERSIONS.

	1. Erg.*	2. Joule.	3. Kilojoule.	4. Watt hour.	5. K. W. hour.	6. H. P. hour.
1. Erg.	1.0000	10^{-7} (*a*)	$1.000 \cdot 10^{-10}$	$2.778 \cdot 10^{-11}$	$2.778 \cdot 10^{-14}$	$3.725 \cdot 10^{-14}$
2. Joule.	10^7	1.0000	10^{-3}	$2.778 \cdot 10^{-4}$	$2.778 \cdot 10^{-7}$	$3.725 \cdot 10^{-7}$
3. Kilojoule.	10^{10}	10^3	1.0000	$2.778 \cdot 10^{-1}$	$2.778 \cdot 10^{-4}$	$3.725 \cdot 10^{-4}$
4. Watt hour.	$3.6 \cdot 10^{10}$	3600.00	3.600	1.000	$1.000 \cdot 10^{-3}$	$1.341 \cdot 10^{-3}$
5. Kilowatt hr.	$3.6 \cdot 10^{13}$	$3.6 \cdot 10^6$	3600.000	1000.000	1.000	1.3411128
6. Horse-power hr.	$2.684 \cdot 10^{13}$	$2.684 \cdot 10^6$	$2.684 \cdot 10^3$	745.6494	0.7456494	1.0000
7. Foot pound.	$1.3544 \cdot 10^7$	1.3544	$1.3544 \cdot 10^{-3}$	$3.762 \cdot 10^{-4}$	$3.762 \cdot 10^{-7}$	$5.046 \cdot 10^7$
8. Caloric (gm.).	$4.189 \cdot 10^7$	4.189	$4.189 \cdot 10^{-3}$	$1.163 \cdot 10^{-3}$	$1.163 \cdot 10^{-6}$	$1.500 \cdot 10^{-6}$
9. Brit. Thermal Units	$1.0553 \cdot 10^{10}$	1055.3	1.0553	$2.931 \cdot 10^{-1}$	$2.931 \cdot 10^{-4}$	$3.931 \cdot 10^{-4}$
10. Cu. ft. water fall—1 ft. (4°C.).	8.463	84.63	0.08463	$2.351 \cdot 10^{-2}$	$2.351 \cdot 10^{-5}$	$3.153 \cdot 10^{-5}$
11. Kilogram-meter.	$9.8062 \cdot 10^7$	9.8062	$9.8062 \cdot 10^{-3}$	$2.724 \cdot 10^{-3}$	$2.724 \cdot 10^{-6}$	$3.653 \cdot 10^{-6}$

*The work done by one dyne acting through one centimeter is an erg.
(a) $10^7 = 1/10^7 = 1/10,000,000 = 0.0000001$.

	7. Foot Lb.	8. Calorie (15°C).	9. B. T. U.	10. Cu.ft. H_2O 1 ft.	11. Kgm. meter
1. Erg.	$7.384 \cdot 10^{-8}$	$2.387 \cdot 10^{-8}$	$9.476 \cdot 10^{-11}$	$1.1812 \cdot 10^{-9}$	$1.0197 \cdot 10^{-8}$
2. Joule.	$7.384 \cdot 10^{-1}$	$2.387 \cdot 10^{-1}$	$9.476 \cdot 10^{-4}$	$1.1812 \cdot 10^{-2}$	$1.0197 \cdot 10^{-1}$
3. Kilojoule.	$7.384 \cdot 10^2$	$2.387 \cdot 10^2$	$9.476 \cdot 10^{-1}$	$1.1812 \cdot 10$	$1.0197 \cdot 10^2$
4. Watt hour.	$2.658 \cdot 10^3$	$8.594 \cdot 10^8$	3.4115	$4.2525 \cdot 10$	$3.671 \cdot 10^2$
5. K. W. hr.	$2.658 \cdot 10^{-6}$	$8.594 \cdot 10^5$	$3.411 \cdot 10^3$	$4.2525 \cdot 10^4$	$3.671 \cdot 10^5$
6. H. P. hr.	$1.982 \cdot 10^6$	$6.407 \cdot 10^5$	$2.543 \cdot 10^3$	$3.170 \cdot 10^4$	$2.737 \cdot 10^5$
7. Ft. pound.	1.000	$3.233 \cdot 10^{-1}$	$1.2835 \cdot 10^{-3}$	$1.600 \cdot 10^{-2}$	$1.381 \cdot 10^{-1}$
8. Calorie.	3.093	1.0000	$3.969 \cdot 10^{-3}$	$4.948 \cdot 10^{-2}$	$4.272 \cdot 10^{-1}$
9. B. T. U.	$7.794 \cdot 10^2$	$2.520 \cdot 10^2$	1.000	$1.247 \cdot 10$	$1.076 \cdot 10^9$
10. Cu.ft. H_2O 1 ft.	$6.250 \cdot 10$	$2.021 \cdot 10$	$8.022 \cdot 10^{-2}$	1.0000	8.630
11. Kgm.-meter.	7.241	2.341	$9.292 \cdot 10^{-3}$	$1.1582 \cdot 10^{-1}$	1.0000

PRESSURE CONVERSIONS.

	1. Cm. H_2O.	2. In H_2O.	3. Ft. H_2O.	4. Mm. Hg.	5. Cm. Hg.	6. In Hg.
1. Cm. water 4° C....	1.0000	0.3937	0.03281	0.7356	0.07356	0.02896
2. Inches of water...	2.540	1.0000	0.08333	1.8685	0.18685	0.07356
3. Feet of water....	30.48	12.00	1.0000	22.42	2.242	0.8826
4. Mm. of mercury...	1.3595	0.5353	0.4461	1.0000	0.10000	0.03937
5. Cm. of mercury...	13.595	5.353	4.461	10.00	1.0000	0.39370
6. In. of mercury....	34.54	13.595	1.1330	25.40	2.540	1.0000
7. Gm. per sq. cm....	1.000	0.3937	0.03281	0.7356	0.07356	0.02896
8. Kg. per sq. cm....	1000.0000	393.7	32.81	735.6	73.56	28.96
9. Oz. per sq. in.....	4.394	1.7300	0.14416	3.232	0.3232	0.12725
10. Lbs. per sq. in.....	70.32	27.68	2.307	5.171	0.5171	2.036
11. Oz. per sq. ft.....	0.03052	0.012012	0.0010012	0.02245	$2.245 \cdot 10^{-3}$	$8.836 \cdot 10^{-4}$
12. Lbs. per sq. ft.....	0.4885	0.1923	0.01602	0.3591	0.03591	0.014137
13. Dynes per sq. cm..	$1.0197 \cdot 10^{-3}$	$4.0145 \cdot 10^{-4}$	$3.3455 \cdot 10^{-5}$	$7.500 \cdot 10^{-4}$	$7.500 \cdot 10^{-5}$	$2.952 \cdot 10^{-5}$
14. Atmospheres*	1033.29	406.806	33.9005	760.00	76.000	29.9212

Mercury at 0° C. Water at 4° C.

*Atmosphere is the pressure exerted by a column of mercury 76.0 cm. high at 0° C. at sea level and in a latitude of 45° upon the area of one square centimeter.

PRESSURE CONVERSIONS—Continued.

	7. Gms/cm.²	8. Kgm./gm².	9. Oz./in².	10. Lbs./in².	11. Oz./ft².	12. Lbs./ft².	13. Dynes/cm².	14. Atmospheres.
1........	1.0000	0.001000	0.2276	0.01422	32.77	2.048	980.62	$9.679 \cdot 10^{-4}$
2........	2.540	0.002540	0.5780	0.036125	83.23	5.205	2492.0	0.002458
3........	30.48	0.03048	6.937	0.4335	998.8	62.43	29890.0	0.02950
4........	1.3595	0.0013595	0.3094	0.01934	44.56	2.785	1333.3	0.0013159
5........	13.595	0.013595	3.094	0.1934	445.6	27.85	13333.0	0.013159
6........	34.54	0.03454	7.860	0.4912	1131.7	70.73	33865.0	0.03342
7........	1.000	0.001	0.2276	0.014223	32.770	2.048	980.62	$9.679 \cdot 10^{-4}$
8........	1000.0	1.0000	227.6	14.223	32770.0	2048.0	980620.0	0.9679
9........	4.394	$4.394 \cdot 10^{-3}$	1.0000	0.06250	144.0	9.000	4309.5	0.0042525
10........	70.32	0.07032	16.000	1.0000	2304.2	144.00	68950.0	0.06805
11........	0.03052	$3.052 \cdot 10^{-5}$	$6.946 \cdot 10^{-3}$	$4.340 \cdot 10^{-4}$	1.0000	0.06250	29.93	$2.9533 \cdot 10^{-5}$
12........	0.4885	$4.885 \cdot 10^{-4}$	0.11112	0.006944	16.000	1.000	478.9	$4.725 \cdot 10^{-4}$
13........	$1.0197 \cdot 10^{-3}$	$1.019 \cdot 10^{-6}$	$2.3208 \cdot 10^{-4}$	$1.4504 \cdot 10^{-5}$	$3.3410 \cdot 10^{-2}$	$2.088 \cdot 10^{-3}$	1.0	$9.868 \cdot 10^{-7}$
14........	1033.29	1.03329	235.152	14.697	33861.9	2116.37	1013295.0	1.00000

COMPARATIVE TEMPERATURE DEGREES.

	Degrees Absolute	Degrees Cent.	Degrees Fahr.	Degrees Reaumur.
Degrees Absolute................	1.0	1.0	9/5	4/5
Degrees Centigrade..............	1.0	1.0	9/5	4/5
Degrees Fahrenheit..............	5/9	5/9	1.0	4/9
Degrees Reaumur................	5/4	5/4	9/4	1.0

COMPARATIVE TEMPERATURE POINTS.

Absolute zero = —273° Centigrade = —459.4° Fahr. = —218.4° Reaum.
Freezing water = 0° C. = 273° A. = 32° F. = 0° R.
Boiling water = 100° C. = 373° A. = 212° F. = 80° R.

HEAT QUANTITY CONVERSION FACTORS.

One British Thermal Unit = 251.995 × calories (gm.) = 0.251995 × Cal. Large.
One gram caloric = 0.00396832 British Thermal Units.
One B. T. U. per pound = 5/9 calorie per gram.
One calorie per gram = 1.8 B. T. U. per pound.

TIME CONVERSION FACTORS.

One year = 365 days, 5 hours, 48 minutes, 48 seconds = 12 calendar months.
= 52.1693 + weeks = 8765.8133 + hrs. = 525948.8 minutes = 31556928 seconds.
One week 7 days = 168 hrs. = 10080 minutes = 604800 seconds.
One day = 24 hours = 1440 minutes = 86400 seconds.
One hour = 60 minutes = 3600 seconds.
One minute = 60 seconds.

VELOCITY CONVERSION FACTORS.

	Mi./hr. 1.	Ft./sec. 2.	Km./hr. 3.	M/sec. 4.	Mi./da. 5.	Km./da. 6.
1. Miles per hour...	1.0000	1.4667	1.6093	0.44704	24.00	38.62
2. Feet per second...	0.6819	1.0000	1.0973	0.30480	16.37	26.33
3. Kilometers/hour .	0.6214	0.9114	1.0000	0.2778	14.913	24.00
4. Meters per second.	2.237	3.281	3.600	1.0000	53.69	86.40
5. Miles per day....	0.04167	0.06112	0.06706	0.01863	1.0000	1.609
6. Kilometers/day ..	0.02589	0.03797	0.04167	0.01157	0.6214	1.0000

CONVERSION FACTORS FOR MONEY.

$ to A.	A.		A. to $.
1.000	Dollar (U. S.)		1.000
100.000	Cent (U. S.)		0.010
0.196	Guinea (English)	= 21 shillings	5.10972
0.2055	Pound Sterling (Sovereign)	= 20 shillings	4.8665
4.11	Shilling (s)	= 12 pence	0.24331
40.93	Penny (d)	= 4 farthings	0.02028
163.72	Farthing	= 1/4 penny	0.00507
0.822	Crown	= 5 shillings	1.21660
4.200	Mark (Germany)	= 100 pfennigs	0.238
420.0	Pfennig		0.00238
5.182	Franc (France)	= 100 centimes	0.193
518.2	Centime		0.00193

CLASSIFICATION OF U. S. PATENTS ON PETROLEUM REFINING.

A. Water separation, dehydration, de-emulsification, heating and physical purification of oil and bottom settlings.
B. Cracking, conversion, and decomposition processes.
C. Paraffin and wax.
D. Chemical treatment of petroleum.
  1. Acid or alkali.
  2. Other than acid or alkali.
E. Asphalt.
  1. Compositions.
  2. Production.
  3. Refining.
F. Simple distillation.
  1. Fire.
  2. Steam.
  3. Gas.
  4. Air.
  5. Vacuum.
    I. Batch.
    II. Continuous.
G. Coal oil, Kerosene and Illuminating oils.
H. Oil-fire prevention, extinction and storage.
I. Recovery of acid-sludge and alkali-sludge.
J. Gasoline production and treatment.
K. Gas.
  1. Production.
  2. Treatment.
  3. Production of carbon black.
L. Chemical products.
M. Patented blends and compounds.
N. Testing apparatus.
O. Lubricating oils.
P. Electrical processes.
Q. Transporting oil.
R. Methods of removing carbon and coke.
S. Mechanical appliances in oil refining, and processes. (Not covering any particular operation.)
T. Plastics.
U. Condensers and condensing.
V. Desulphurizing and deodorizing.
W. Oil shales, oil sands and coals.

UNITED STATES PETROLEUM PATENTS.

Name	Number	Date	Class
Aab., Geo. & S. K. Campbell	369,902	Sept. 13, 1887	C
Adair, James.	35,497	June 10, 1862	U
Adair, Jas. & Tweddle, H. W. C.	56,343	July 17, 1866	F
Adair, Thos. D.	1,106,352	Aug. 4, 1914	A
Adams, Chas.	52,509	Feb. 13, 1866	C
Adams, J. H.	976,975	Nov. 29, 1910	B
Adams, Henry W.	12,614	Apr. 3, 1855	O
Adamson, Wm.	45,007	Nov. 15, 1864	D 1
Adiassewich, Alexander	629,536	July 25, 1899	F
Alberger, J. L.	37,798	Mar. 3, 1863	G, B
Alexander, Clive M.	1,230,975	June 26, 1917	B
Alexander, Jas. H.	229,297	June 29, 1880	F
Alexander, Jas. H. & Eberhard	156,265	Oct. 27, 1874	F
Alexander, Robt.	435,198	Aug. 26, 1890	E 3
Alkemade, J. von R.	1,007,600	Oct. 14, 1913	C
Allen, George.	182,625	Sept. 26, 1876	A, O
Allan, D. M., Jr.	1,187,979	June 20, 1916	D 1
Alter, David & Hill, S. A.	20,026	Apr. 27, 1858	F
Alvord, Clark.	213,157	Mar. 11, 1879	R
Ambruson, H. J.	1,252,642	Jan. 8, 1918	K 1
Amend, Otto P.	747,348	Dec. 22, 1903	D 1, V
Amend, Otto P.	480,312	Aug. 9, 1892	V, D 1, B
Amend, Otto P.	480,311	Aug. 9, 1892	V, D 1, B
Amend, Otto P.	551,941	Dec. 24, 1895	V, D 1
Amend, Otto P.	601,331	Mar. 29, 1898	V, D 1
Amend, Otto P.	747,347	Dec. 22, 1903	V, D 1
Andrews, Saml.	58,197	Sept. 25, 1866	F 1, I
Andrews, Saml.	69,745	Oct. 15, 1867	S
Angus, H. R.	407,274	July 16, 1880	F
Anthony, C. E.	620,082	Feb. 21, 1899	B, T
Archbold, Geo.	503,028	Aug. 8, 1893	E 1
Archer, Wm.	44,137	Sept. 6, 1864	F
Artmann, Carl.	1,031,227	July 2, 1912	E 1
Arvine, Freeling W.	629,059	July 18, 1899	A
Arvine, Freeling W.	431,795	July 8, 1890	G, N
Ash, Horace W.	779,197	Jan. 3, 1905	E 2, F
Ash, Horace W.	779,198	Jan. 3, 1905	E 2, F
Ash, Horace W.	757,387	Apr. 12, 1904	F 1
Ashworth, A. A.	1,300,548	Apr. 15, 1919	S
Andrews and Averill	1,312,467	Apr. 10, 1860	S
Atwood, Luther.	27,767	Oct. 19, 1858	F 2
Atwood, Luther.	21,805	Dec. 28, 1858	B
Atwood, Luther.	22,406	Dec. 28, 1858	B
Atwood, Luther.	22,407	Feb. 22, 1859	B
Atwood, Luther.	23,006	Mar. 29, 1859	B
Atwood, Luther.	23,337	May 15, 1860	G
Atwood, Luther.	28,246	May 29, 1860	G, B
Atwood, Luther.	28,448	Apr. 10, 1860	F
Atwood, Luther.	27,768	Mar. 26, 1861	U
Atwood, Luther.	31,858	Aug. 12, 1856	B,2D 1
Atwood, L. & Atwood, W.	15,506	Aug. 12, 1856	W, F
Atwood, L. & Atwood, W.	15,505	Apr. 6, 1880	G
Atwood, William.	226,151	Apr. 20, 1901	A
Aukerman, Cal. M.	572,882	Aug. 5, 1919	B
Bacon, Brooks & Clark	1,131,309	Mar. 9, 1915	J, B
Bacon & Clark	1,101,482	June 23, 1914	B
Backhaus, Arthur A.	1,271,114	July 2, 1918	M
Backhaus, Arthur A.	1,271,115	July 2, 1918	M
Backhaus, A. A.	1,296,902	Mar. 11, 1919	M
Barber, Guy M.	1,251,952	Jan. 1, 1918	S
Baillard, Chas. L.	340,411	Apr. 20, 1886	D 1
Baker, Leslie A.	299,611	June 3, 1884	A
Barnes, Wm. T.	24,920	Aug. 2, 1859	U
Barnes, Wm. T.	24,921	Aug. 2, 1859	G
Barrett, Michael.	59,531	Nov. 6, 1866	I
Barron, Thos. J.	46,987	Mar. 28, 1865	M
Barnickel, W. S.	1,093,098	Apr. 14, 1914	A, D 1
Barnickel, W. S.	1,223,659	Apr. 24, 1917	A, D 1
Barnickel, W. S.	1,223,660	Apr. 24, 1917	A
Bartels, E.	1,115,887	Nov. 3, 1914	H

UNITED STATES PETROLEUM PATENTS—Con.

Name	Number	Date	Class
Barstow, Frank Q.	181,814	Sept. 5, 1876	C
Barthel, Peter.	135,879	Feb. 18, 1873	E 1, 3
Baskerville, Chas.	1,231,985	July 3, 1917	I
Bassett, R. D.	1,120,669	Dec. 15, 1914	J
Bassett, R. D.	1,120,670	Dec. 15, 1914	J
Bates, H. F.	1,046,541	Dec. 10, 1912	K 1
Baum, E. P.	1,109,103	Sept. 1, 1914	A
Baynes, R. & Fearenside, J.	299,324	May 27, 1884	D 2
Bell, A. F. L.	581,451	Apr. 27, 1897	E 3, 2
Bell, A. F. L.	581,592	Apr. 13, 1897	E 3
Bell, A. F. L.	617,712	Jan. 17, 1899	E 2, 3
Bell, A. F. L.	1,231,695	July 3, 1917	B, R
Bell, A. F. L.	655,430	Aug. 7, 1900	E 2, 3
Bell, A. F. L.	505,416	Sept. 19, 1893	E 2, 3
Bellingrath, Leonard, Jr.	20,465	June 1, 1858	F 1, 4
Bending, Wm. P.	998,670	July 25, 1911	A
Benham, E. B.	1,262,576	Apr. 9, 1918	K 1
Berg, Friedrich.	645,743	Mar. 20, 1900	F 2, 1
Berg, Friedrich.	560,463	May 19, 1896	D 1
Berg, F.	736,479	Aug. 18, 1903	V, D 1
Berg, F.	736,480	Aug. 18, 1903	V
Berg, F.	623,066	Apr. 11, 1890	D 1
Berg, H. J.	93,952	Aug. 24, 1869	F 1, H
Bibby, John & Lapham, A.	48,896	July 25, 1865	F 1
Bicknell, John E.	313,979	Mar. 17, 1885	F 2
Bicknell, John E.	400,042	Mar. 26, 1889	C
Bicknell, John E.	400,043	Mar. 26, 1889	C
Birge, Wm. H.	175,014	Mar. 21, 1876	F 2
Blackmore, H. S.	486,554	Nov. 22, 1892	U
Blackmore, H. S.	793,026	June 20, 1905	V, D 1
Blair, John B.	139,654	June 10, 1873	N
Bloede, Victor G.	159,887	Feb. 16, 1875	F
Blumenthal, Leon.	312,605	Feb. 24, 1885	G
Boleg, Friedrich.	761,939	June 7, 1904	M
Boote, A. J. & Kittredge, H. G.	620,882	Mar. 14, 1899	V, D 1
Bower, Henry.	230,171	July 20, 1880	I
Beckley, R. E.	1,127,722	Feb. 9, 1915	B
Bending, Wm. P.	1,144,522	June 29, 1915	D 1
Benham, E. B.	1,040,124	Oct. 1, 1912	B
Butcher, J. A.	1,311,753	July 29, 1919	H
Benhoff, Geo. F., Jr., & Jensen, J. O.	1,181,564	May 2, 1916	F 2
Benton, G. L.	342,564	May 25, 1886	B
Benton, G. L.	342,565	May 25, 1886	B
Berend, Ludwig.	1,167,373	Jan. 11, 1916	D 1
Blacher, L. & Sztencel, S.	856,276	Apr. 26, 1910	I
Black, J. C.	968,640	Aug. 30, 1910	D 1
Black, J. C.	1,152,478	Sept. 7, 1915	F 3
Black, J. C.	1,164,162	Dec. 14, 1915	D 2, F 3
Blowski, Jno. & Blowski, A.	1,186,373	June 6, 1916	I
Born, Sidney.	1,234,124	July 24, 1917	F 1, H, S
Borrman, C. H.	1,220,067	Mar. 20, 1917	F 2, H
Bowman, F.	12,852	May 15, 1855	F 1, 1
Brace, H. B. & Swart, Wm. T.	54,495	May 8, 1866	M, G
Brackebusch, Hans.	275,565	Apr. 10, 1883	D 1
Bradford, Geo.	806,116	Nov. 21, 1905	F 1, 5
Bragg, John.	604,515	May 24, 1898	V, D 1
Braggins, Edw.	46,633	Mar. 7, 1865	F 5
Braun, Otto.	243,496	June 28, 1881	U
Breinig, Revere	306,897	Oct. 21, 1884	I
Brooks, Essex & Smith	1,191,916	July 18, 1916	L
Brooks and Smith	1,231,123	June 26, 1917	L
Brickman, Saml.	1,279,506	Sept. 24, 1918	F
Brown, Arthur L.	1,234,862	July 31, 1917	D 2
Brown, Ernest.	1,225,569	May 8, 1917	D 2
Brown, D. P. & Neeley, J. W.	361,671	Apr. 26, 1887	F 1, 2
Brown, E. G. Cammann, O. N. & Willcox, O.	510,672	Dec. 12, 1893	F 1, 2, 4
Brown, L. W.	994,100	May 30, 1911	A
Brown, W. A.	1,309,794	July 15, 1919	A
Brown, Wm.	10,055	Sept. 27, 1853	C, W

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Name	Number	Date	Class
Brownlee, R. H. & Uhlinger	1,265,043	May 7, 1918	K 3, B
Brownlee, R. H.	1,308,161	July 1, 1919	F
Brucke, Otto.	963,510	July 5, 1910	A
Brundred, Wm. J.	148,806	Mar. 24, 1974	F 2
Bullard, John.	34,195	Jan. 21, 1862	G
Burcey, Chas. J. T.	122,810	Jan. 16, 1872	F
Burch, Eli F.	1,238,101	Aug. 28, 1917	O, T
Burdon, J., W. M. & M. M.	1,112,051	Sept. 29, 1914	K 1
Burghardt, C. A.	309,027	Dec. 9, 1884	U
Burk, H. R.	284,811	Sept. 11, 1883	G
Burke, A. M. & Wright, S.	65,999	June 25, 1867	D 1
Burket, D. M. & Gray, J. C.	57,285	Aug. 21, 1866	O
Burrows, H. G.	998,937	July 25, 1911	F 2, II
Burton, W. M.	1,055,707	Mar. 11, 1913	B, E 2
Burton, W. M.	1,049,667	Jan. 7, 1913	B, J
Burton, W. M.	1,105,961	Aug. 4, 1914	J, B
Burton, W. M.	1,112,113	Sept. 29, 1914	C, B
Burton, W. M.	1,167,884	Jan. 11, 1916	B
Burwell, A. W. & Sherman, L. O.	738,656	Sept. 8, 1903	V, D 1
Bush, Asa A.	269,382	Dec. 19, 1882	F 1
Busse, Heinrich.	376,289	Jan. 10, 1888	T
Byerley, Francis X.	347,288	Aug. 10, 1886	C, F
Byerley, F. X.	524,120	Aug. 7, 194	E 2, 3, F
Byerley, F. X.	547,329	Oct. 1, 1895	F 4, 2
Byerley, F. X.	244,431	July 19, 1881	C
Byerley, F. X.	132,353	Oct. 22, 1872	C
Byerley, F. X.	164,672	June 22, 1875	C
Biggins, James E.	1,274,976	Aug. 6, 1918	B
Black, John C.	1,275,648	Aug. 13, 1918	J
Boyle, Alex. M.	1,276,866	Aug. 27, 1918	W
Buerger, C. B.	1,302,761	May 6, 1919	S
Calkins, A. C.	779,398	Jan. 3, 1905	B
Calkins, A. C.	769,681	Sept. 6, 1904	D 1
Campbell, Andrew.	999,628	Aug. 1, 1911	C
Cantour, David.	552,206	Jan. 14, 1896	F
Carman, F. J.	501,988	July 25, 1893	V
Carpenter, Calvin, Jr.	82,083	Sept. 15, 1868	O
Carter, G. F.	680,639	Aug. 13, 1901	S
Catlin, Robert M.	1,272,377	July 16, 1918	W
Cazin, Francis F. M.	400,634	Apr. 2, 1889	F
Cazin, F. M. F.	400,633	Apr. 2, 1889	V, G
Chamberlain, H. P.	1,221,790	Apr. 3, 1917	B
Chemin, Jean C. O.	297,766	Apr. 29, 1884	F, D
Cheney, Samuel.	230,239	July 20, 1880	F 2
Cherry, Cummings.	15,642	Sept. 2, 1856	A
Cherry, C.	15,643	Sept. 2, 1856	W
Cherry, L. B.	1,229,886	June 12, 1917	B, P
Chesebrough, Robt. A.	127,568	June 4, 1872	M
Chesebrough, Robt. A.	237,484	Feb. 8, 1881	M
Chesebrough, R. A.	49,502	Aug. 22, 1865	G, S
Chesebrough, R. A.	48,367	June 27, 1865	S
Chesebrough, R. A.	51,557	Dec. 19, 1865	S
Chesebrough, R. A.	51,558	Dec. 19, 1865	S
Chesebrough, R. A.	542,704	Aug. 21, 1894	F 2, II
Chevrier, Gervais.	106,915	Aug. 30, 1870	I
Childs, Samuel.	11,059	June 13, 1854	F 1, 2, I
Clarke, Edward.	232,685	Sept. 28, 1880	I
Clark, Edward M.	1,119,496	Dec. 1, 1914	B
Clark, E. M.	1,129,034	Feb. 16, 1915	B
Clark, E. M.	1,132,163	Mar. 16, 1915	B
Clark, C. E.	1,147,608	July 20, 1915	K 1
Clark, Frank W.	547,332	Oct. 1, 1895	F 3, 4
Clark, R. C. & Beecher, W. F.	275,589	Apr. 10, 1883	F 1, 4
Clark, R. C. & Warren, M. H.	298,825	May 20, 1884	F
Clark, R. C. & Warren, M. H.	318,698	May 26, 1885	F
Clark, S. G.	34,816	Apr. 1, 1862	G, F 2, II
Clifford, Victor	1,266,407	May 14, 1918	H
Coast, John W., Jr.	1,250,798	Dec. 18, 1917	B
Coast, J. W., Jr.	1,250,800	Dec. 18, 1917	B
Coast, J. W., Jr.	1,250,801	Dec. 18, 1917	B

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Name	Number	Date	Class
Coast, J. W., Jr.	1,252,401	Jan. 8, 1918	B
Coast, J. W., Jr.	1,253,000	Jan. 8, 1918	B
Coast, J. W., Jr.	1,258,190	Mar. 5, 1918	B
Coast, J. W., Jr.	1,252,999	Jan. 8, 1918	B
Coast, J. W., Jr.	1,291,414	Jan. 14, 1919	B
Coast, J. W., Jr.	1,307,724	June 24, 1919	S
Coast, John W., Jr.	1,250,799	Dec. 18, 1917	B
Coast, John W., Jr.	1,258,191	Mar. 5, 1918	B
Cobb, J. O.	1,201,558	Oct. 17, 1916	A
Cobb, E. B.	1,300,816	Apr. 15, 1919	D
Cochran, A.	1,296,367	Mar. 4, 1919	B
Cole, Jas., Jr.	128,169	Sept. 12, 1876	F 2, 4, II
Coleman, John T.	19,406	May 29, 1877	F
Colin, Theodore F.	607,017	July 12, 1898	V, D 1
Colin, T. F.	723,368	Mar. 24, 1903	V, D
Colin, T. F.	744,720	Nov. 24, 1903	V, D
Colin, T. F.	685,907	Nov. 5, 1901	V, D
Collins, Jacob	1,029,439	June 4, 1912	A
Collins, John F.	59,334	Oct. 30, 1866	F 4, I
Collins, Jos. G.	32,557	June 18, 1861	S
Connelly, Martin	240,093	Apr. 12, 1881	D 1, V
Connelly, Martin	240,094	Apr. 12, 1881	D 1, V
Cook & Price	1,190,633	July 11, 1916	E 3
Cooper, A. S.	67,226	Jan. 3, 1899	E 2, 3
Corfield, Wm.	54,061	Apr. 17, 1866	M
Corfield, Wm.	54,060	Apr. 17, 1866	M
Cornell, Sidney	1,202,969	Oct. 31, 1916	F 2
Cosden, J. S.	981,176	Jan. 19, 1911	F 2, II
Cosden, J. S. & Coast, J. W., Jr.	258,196	Mar. 5, 1918	B
Cosden & Coast	1,261,215	Apr. 2, 1918	B
Cottrell & Wright	987,117	Mar. 21, 1911	P
Cottrell & Speed	987,115	Mar. 21, 1911	P, A
Cottrell & Speed	987,116	Mar. 21, 1911	P
Cottrell, F. G.	987,114	Mar. 21, 1911	P
Courtois, F. A.	788,250	Apr. 25, 1905	N
Cowan, Wm. P.	558,358	Apr. 14, 1896	C
Crane, Frederick D.	1,223,153	Apr. 17, 1917	M, D
Crane, Gerard	231,280	Aug. 17, 1880	E 1
Crane, Adolphus G.	1,276,879	Aug. 27, 1918	F 1
Crawford, Benjamin	113,023	Mar. 28, 1871	B
Crocker, Saml. H.	120,463	July 16, 1872	B
Cronemeyer, A. H.	718,318	Jan. 13, 1903	V
Cronenberger, W. M.	1,152,399	Sept. 7, 1915	W
Cronin, C. J.	150,465	May 5, 1874	F
Cross, James P.	57,095	Aug. 14, 1866	M
Cross, Roy	1,255,138	Feb. 5, 1918	F 1, 2
Cross, Walter M.	1,203,312	Oct. 3, 1916	F
Culmer, Geo. & Geo. C. K.	635,429	Oct. 24, 1899	F
Culmer, Geo. & Geo. C. K.	635,430	Oct. 24, 1899	W
Culmer, J. W.	217,995	July 29, 1879	G
Cunningham, Christopher	158,042	Dec. 22, 1874	C
Danckwardt, P.	1,141,529	June 1, 1915	J, F 1, II
Daul, John	213,395	Mar. 18, 1879	F 2
Daul, Louis	258,284	May 23, 1882	F 2
Davidson, J. G. & Ford, R. W.	1,228,042	June 5, 1917	P
Davidson, Samuel	1,238,644	Aug. 28, 1917	J, K 2
Davis, John T.	671,078	Apr. 2, 1901	F 1, II
Davis, John T.	1,159,186	Nov. 2, 1915	F 2, II
Davis, Samuel	65,884	June 18, 1867	S
Day, David T.	826,089	July 17, 1906	A, V
Day, D. T.	1,004,632	Oct. 3, 1911	B
Day, D. T.	1,221,698	Apr. 3, 1917	B, D
Day, D. T.	826,089	July 17, 1906	V, D
Day, D. T.	1,280,178	Oct. 1, 1918	W
Day, Roland B.	1,280,179	Oct. 1, 1918	B
Dayton, W. C.	1,174,971	Mar. 14, 1916	K 1
Dayton, W. C.	1,174,970	Mar. 14, 1916	K 1
Dean, Richard	290,866	Dec. 25, 1883	F 2, II
Dean, Richard	305,056	Sept. 16, 1884	F 1, 2, II
Dean, Richard	310,497	Jan. 6, 1885	F

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Name	Number	Date	Class
Dean, R.	314,368	Mar. 24, 1885	F 1, 2, 3, II
Dean, R.	342,500	May 25, 1886	F 2, II
Dehnst, Julius	1,112,602	Oct. 6, 1914	V, D
De Smedt, Edw. J.	236,995	Jan. 25, 1881	E 1, 2
De Smedt, E. J.	237,662	Feb. 8, 1881	E 1, 2
Devericks, F. C.	1,260,970	Mar. 26, 1918	J. K 2
Dewar, J. & Redwood, B.	419,931	Jan. 21, 1890	B
Dewar & Redwood	426,173	Apr. 22, 1890	B
Dewitt, Henry C.	63,299	Mar. 26, 1867	M
Ditmar, Peter	246,096	Aug. 23, 1881	M
Devine, S. R. & Seely, C. A.	55,071	May 29, 1866	F 2
Dickey, Julius C.	166,349	Aug. 3, 1875	F 1
Diehl, H. A.	469,777	Mar. 1, 1892	E 2, 3
Deiterichs, E. F.	253,990	Feb. 21, 1882	F 1, 2
Divine, R. E.	1,303,779	May 13, 1919	I
Divine, R. E.	1,303,662	Apr. 22, 1919	I
Divine, R. E.	1,303,663	Apr. 22, 1919	I
Doe, Wm.	174,789	Mar. 14, 1876	S
Dow, Allan W.	688,073	Dec. 3, 1901	E 1, 2, B
Downard, J. S. & Roloson, B. A.	722,500	Mar. 10, 1903	E 2
Downer, Wm. P.	44,519	Oct. 4, 1864	D 1
Drake, Thos.	471,863	Mar. 29, 1892	L
Draper, Henry V. P.	238,867	Mar. 15, 1881	G, D
Drayton, Thos.	11,239	July 4, 1854	D
Dubbs, Henry	161,672	Apr. 6, 1875	D, S
Dubbs, Jesse A.	470,911	Mar. 15, 1892	V
Dubbs, J. A.	646,639	Apr. 3, 1900	F 2, 4
Dubbs, J. A.	1,002,570	Sept. 5, 1911	A, F
Dubbs, J. A.	1,100,717	June 23, 1914	B
Dubbs, J. A.	1,057,227	Mar. 25, 1913	E 2
Dubbs, J. A.	694,621	Mar. 4, 1902	F 4, II
Dubbs, J. A.	694,622	Mar. 4, 1902	F 4
Dubbs, J. A.	407,182	July 16, 1889	V, D
Dubbs, J. A.	1,123,502	Jan. 5, 1915	A
Dubbs, J. A.	1,135,506	Apr. 13, 1915	E 2, B
Dubbs, C. P.	1,231,509	June 26, 1917	B
Dubbs, C. P.	1,231,509	June 26, 1917	B
Dubler, John B.	251,770	Jan. 3, 1882	F
Dubler, J. B.	283,471	Aug. 21, 1883	F 1, II
Dubreuil, A.	48,265	June 20, 1865	F 2
Duffus, G. H. S.	46,088	Jan. 31, 1865	F, S
Duffus, G. H. S.	46,089	Jan. 31, 1865	F, S
Duffus, G. H. S.	46,090	Jan. 31, 1865	F, S
Dundas, R. C.	1,056,980	Mar. 25, 1913	E 2, B
Dundas, R. C.	1,120,039	Dec. 8, 1914	F 1, II
Dundas, R. C.	1,257,199	Feb. 19, 1918	B
Dunham, F. H.	1,003,040	Sept. 12, 1911	E
Dunham, F. H.	1,013,283	Jan. 2, 1912	E 2
Dunkle, Allen H.	530,300	Dec. 4, 1894	U
Dunscomb, Edward	62,739	Mar. 12, 1867	S
Dupias, A. C. G. & Fell, W. S.	749,368	Jan. 12, 1904	F, S
Durant, C. W. & Griffith, J.	132,263	Oct. 15, 1872	U
Dvorkovitz, Paul	546,697	Sept. 24, 1895	F 2
Dyar, N. A. & Augustus, J. F.	25,362	Sept. 6, 1859	M
Dyer, E. I.	1,207,381	Dec. 5, 1916	A
Dyer, E. I.	1,220,504	Mar. 27, 1917	A
Dyer, E. I. & Heise, A. R.	1,242,784	Oct. 9, 1917	A
Dyer, Frank L.	579,360	Mar. 23, 1897	F 2, 5
Dyer, Walter	1,256,535	Feb. 19, 1918	D
Dyer, Walter & W. E.	1,256,536	Feb. 19, 1918	D
Earle, G. W.	1,221,038	Apr. 3, 1917	H
Eaton, Richard	110,638	Jan. 3, 1871	O
Edeleanu, Lazar	911,553	Feb. 2, 1909	D
Edgerton, Henry H.	159,655	Feb. 9, 1875	K 1
Edwards, E. A.	439,745	Nov. 4, 1890	F 2, 4, II
Edwards, Jos. B.	100,874	Mar. 15, 1870	F 2
Edwards, Jos. B.	1,277,884	Sept. 3, 1918	B
Eggleston, J. E.	1,018,040	Feb. 20, 1912	F, V
Eldred, B. E. & Mersereau, G.	1,234,886	July 31, 1917	B

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Name	Number	Date	Class
Elliott, W. S.	1,242,667	Oct. 9, 1917	A, D
Ellis, Carleton	1,089,359	Mar. 3, 1914	O
Ellis, Carleton	1,191,880	July 18, 1916	D, L
Ellis, C.	1,216,971	Feb. 20, 1917	B
Ellis, C.	1,249,278	Dec. 4, 1917	J, B
Ellis, C.	1,295,825	Feb. 25, 1919	B
Ellis, Jno. & Kattell, E. C.	63,789	Apr. 16, 1867	F 2, II
Ellis & Kattell	68,860	Sept. 17, 1867	F 2, II
Ellithorp, S. B.	52,277	Jan. 30, 1866	U
Emory, F. F.	1,148,834	Aug. 3, 1915	S
Engle, Jacob P.	481,391	Aug. 23, 1892	A
Engle, J. P.	481,392	Aug. 23, 1892	A
Erickson, Emil T.	1,281,320	Oct. 15, 1918	W
Erwin, J. B. & O. R.	1,085,805	Feb. 3, 1914	H
Eva, Gray & Christy	1,100,126	June 16, 1914	O
Evans, Edward	1,257,829	Feb. 26, 1918	V
Everest, H. B.	212,914	Mar. 4, 1879	F
Everest, H. B.	68,426	Sept. 3, 1867	F 2, 5, II
Ewing, Chas. R.	1,083,998	Jan. 13, 1914	S
Ewing, M. P.	56,852	July 31, 1866	F 2, 5, II
Ewing, M. P. & Everest, H. B.	58,021	Sept. 11, 1866	F 2, 5, II
Fagan, John G.	1,148,763	Aug. 3, 1915	H
Fairchild, J. H.	53,528	Mar. 27, 1866	U
Fales, Levi S.	49,740	Sept. 5, 1865	S
Fales, L. S.	52,151	Jan. 23, 1866	F, U
Fales, L. S.	49,739	Sept. 5, 1865	F 4, I
Fales, L. S.	97,182	Nov. 23, 1869	I
Farrar, Alonzo	96,097	Oct. 26, 1869	D
Farrar, A.	100,876	Mar. 15, 1870	I
Faucett, H. W. & McGowan, T.	133,426	Nov. 26, 1872	S, F
Faucett & McGowan	133,425	Nov. 26, 1872	S, D
Faucett & McGowan	117,873	Aug. 8, 1871	U
Fazi, Romolo de	1,108,351	Aug. 25, 1914	M
Felizat, Louis	1,070,435	Aug. 19, 1913	D
Felton, D. F.	1,179,296	Apr. 11, 1916	K 1
Farrar, F. F. & Gill, F. P.	206,309	July 23, 1878	I
Fichet, L. V.	53,964	Apr. 17, 1866	F 2, II
Field, John K.	408,472	Aug. 6, 1889	D 1
Fleming, J. C.	956,065	Apr. 26, 1910	S, A
Fleury, Huot	50,571	Oct. 24, 1865	F 5, D
Flowers, Geo. W., Happersett, J. C. & Happersett, D. W.	74,756	Feb. 25, 1868	M
Fordried, John	54,267	Apr. 24, 1866	W, D 1
Forrest, Chas. N.	1,163,593	Dec. 7, 1915	E 1, 3
Forward, C. B.	1,189,083	June 27, 1916	B, J
Forward, C. B.	11,181,301	May 2, 1916	F 2, II
Forward, C. B.	1,202,823	Oct. 31, 1916	B
Forward, C. B.	998,569	July 18, 1911	E 2, B
Forward, C. B.	1,100,966	June 23, 1914	B
Forward, C. B.	1,088,693	Mar. 3, 1914	B
Forward, C. B.	1,088,692	Mar. 3, 1914	E 2, B
Forward, C. B.	1,247,808	Nov. 27, 1917	U
Forward, C. B.	1,255,149	Feb. 5, 1918	B
Forward, C. B.	1,274,405	Aug. 6, 1918	B
Forward, C. B.	1,299,449	Apr. 8, 1919	F
Forward, C. B. & Davidson, J. M.	611,620	Oct. 4, 1898	E 2, 3, D 1
Foubert, Andre	71,156	Nov. 19, 1867	F 2
Foubert, Andre	118,602	Aug. 29, 1871	F
Foubert, Andre	60,166	Dec. 4, 1866	F 1
Fowler, David W.	75,147	Mar. 3, 1868	M
Franke, A. H.	1,142,512	June 8, 1915	A
Frasch, Hans A.	488,628	Dec. 27, 1892	I
Frasch, Hans A.	640,292	Jan. 2, 1900	F 2, II
Frasch, Hans A.	525,811	Sept. 11, 1894	D 1
Frasch, Hans A.	581,546	Apr. 27, 1897	E 2, 3
Frasch, Hans A.	1,212,620	Jan. 16, 1917	B
Frasch, Herman	845,735	Feb. 26, 1907	F 2, II
Frasch, Herman	968,760	Aug. 30, 1910	F 1
Frasch, Herman	487,216	Nov. 29, 1892	V

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Name	Number	Date	Class
Frasch, Herman	564,920	July 28, 1896	V
Frasch, Herman	490,144	Jan. 17, 1893	V
Frasch, Herman	553,191	Jan. 14, 1896	S
Frasch, Herman	561,216	June 2, 1896	D 1
Frasch, Herman	564,921	July 28, 1896	V
Frasch, Herman	448,480	Mar. 17, 1891	V
Frasch, Herman	378,246	Feb. 21, 1888	V, D
Frasch, Herman	951,729	Mar. 8, 1910	G, D
Frasch, Herman	951,272	Mar. 8, 1910	G, D
Frasch, Herman	622,799	Apr. 11, 1899	V
Frasch, Herman	190,483	May 8, 1877	F 2, 4
Frasch, Herman	630,496	Aug. 8, 1899	V
Frasch, Herman	500,252	June 27, 1893	V
Frasch, Herman	572,676	Dec. 8, 1896	V, D
Frasch, Herman	321,420	Aug. 24, 1880	U
Frasch, Herman	205,792	Aug. 3, 1878	F
Frasch, Herman	649,047	May 8, 1900	O, V
Frasch, Herman	340,499	Apr. 20, 1886	F
Frasch, Herman	487,119	Nov. 29, 1892	V
Frasch, Herman	281,045	July 10, 1883	F 2, 3
Frasch, Herman	564,922	July 28, 1896	V
Frasch, Herman	564,923	July 28, 1896	V
Frasch, Herman	564,924	July 28, 1896	V, F
Frasch, Herman	649,048	May 8, 1900	V, D
Frasch, Herman	542,849	July 16, 1895	V, D 1
Frasch, Herman	543,619	July 30, 1895	V
Fraser, William M.	1,259,223	Mar. 12, 1918	E 1, 2
Fraser, Wm. M.	1,258,103	Mar. 5, 1918	E 1, 2
Frederici, C. F.	48,672	July 11, 1865	F
Freel, John	504,917	Sept. 12, 1893	S, F
Gaggin, Richard	118,359	Aug. 22, 1871	D 2, V
Gallsworthy, Benjamin	1,234,327	July 24, 1917	F 2, II
Galloupe, J. H.	1,283,723	Nov. 5, 1918	W
Gardner, J. & Harris, J. F.	442,802	Dec. 15, 1890	V, F
Garner, J. B. & Clayton, H. D.	1,262,769	Apr. 16, 1918	L
Garner, J. B.	1,299,455	Apr. 8, 1919	J, K
Garrity, W. F. & Jarvis, A.	1,190,538	July 11, 1916	O, A
Gravey, Benjamin	29,218	July 17, 1860	G
Gathmann, Louis	768,796	Aug. 30, 1904	F 1, 5
Gathmann, Louis	755,760	Mar. 29, 1904	F
Gay, Cassius M.	1,179,001	Apr. 11, 1916	J
Gearing, C. M.	212,084	Feb. 4, 1879	F 1, II
Gellen, A.	1,063,025	May 27, 1813	I
Gengembre, H. P.	52,283	Jan. 30, 1866	A
Gengembre, H. P.	52,284	Jan. 30, 1866	A
Gengembre, H. P.	24,454	June 21, 1859	G
Gengembre, H. P.	25,109	Aug. 16, 1859	G, B
Gengembre, H. P.	27,542	Mar. 20, 1860	G, W
Gengembre, H. P.	33,699	Nov. 12, 1861	G
Gerbeth, F. L. de	81,071	Aug. 18, 1867	L, P
Gesner, Abraham	11,205	June 27, 1854	G
Gesner, A.	11,203	June 27, 1854	G
Gesner, A.	11,204	June 27, 1854	G
Gibbons, Samuel	87,485	Mar. 2, 1869	O
Gibbons, S.	87,658	Mar. 9, 1869	F
Gibbons, S.	85,810	Jan. 12, 1869	F 2, II
Gibbons, S.	68,974	Sept. 17, 1867	F 1, 2, II
Gillespie, Jas.	23,362	Mar. 29, 1859	G, F
Gillons, G. H.	1,084,080	Jan. 13, 1914	F 1, II
Goldwater, Henry	366,720	July 19, 1887	F 1, 2, II
Goldwater, Henry	432,525	July 22, 1890	S
Goodaire, Wm. & Stead, Geo.	101,003	Mar. 22, 1870	I
Gordon, Thos.	451,724	May 5, 1891	D
Govers, F. X.	1,297,833	Mar. 18, 1919	W
Gracie, John	114,802	May 16, 1871	F 4
Gracie, John	114,803	May 16, 1871	F
Gracie, John	117,405	July 25, 1871	F
Gracie, John	117,406	July 25, 1871	F 1, I
Gracie, John	99,081	Jan. 25, 1870	F 1, II
Grady, Chas. F.	556,412	Mar. 17, 1896	F 2, II

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Name	Number	Date	Class
Graham, C. B.	732,937	July 7, 1903	D 1
Grannis, C. W.	36,403	Sept. 9, 1862	U, G
Grant, Jas. B.	57,311	Aug. 21, 1866	F
Grant, J. B. & Mason, A.	339,545	Apr. 6, 1886	F 1, 2, 5, II
Grant & Mason	339,546	Apr. 6, 1886	F 2, 5. II
Gray, A. McD.	653,235	July 10, 1900	C
Gray, Daniel T.	250,524	Dec. 6, 1881	C
Gray, D. T.	248,735	Oct. 25, 1881	C
Gray, D. T.	281,491	July 17, 1883	C, S
Gray, E. B.	1,005,425	Oct. 10, 1911	I
Gray, G. W.	1,193,540	Aug. 8, 191[illegible]	B, J
Grant & Mason	339,545	Apr. 6, 1886	A
Grant, H. F.	1,303,292	May 13, 1919	O
Gray, G. W.	1,193,541	Aug. 8, 1916	B
Gray, J. L.	923,429	June 1, 1909	I
Gray, J. L.	923,428	June 1, 1909	I
Gray, J. L.	1,192,889	Aug. 1, 1916	F
Gray, J. L.	923,427	June 1, 1909	I
Gray T. T.	1,158,205	Oct. 26, 1915	P
Gregory, Ralph	1,271,311	July 2, 1918	S
Greene, H. J.	1,252,000	Jan. 1, 1918	K 1
Green, Joel	46,794	Mar. 14, 1865	K 2
Greenstreet, Chas. J.	1,110,924	Oct. 26, 1915	B
Greenstreet, Chas. J.	1,110,923	Sept. 15, 1914	B
Greenstreet, C. J.	1,110,925	Sept. 15, 1914	B
Greenstreet, C. J.	1,166,982	Sept. 15, 1914	B
Greenstreet, C. J.	1,299,172	Apr. 1, 1919	B
Grieg, A. & Smith, Jas.	42,121	Mar. 29, 1864	K 1
Griffin, Jonathan	23,167	Mar. 8, 1869	M
Groble, J. C.	1,283,502	Nov. 5, 1918	K
Grogan, Henry	94,409	Aug. 31, 1869	F 2
Grogan, H. & Lape, G. T.	89,988	May 11, 1869	F 2, 5, II
Grousilliers, Hector de	378,774	Feb. 28, 1888	I
Guillaume, Emile	996,081	June 27, 1911	B
Gulick, W. R.	1,187,061	June 13, 1916	M
Gumpoldt, Emil	616,838	Dec. 27, 1898	M
Gesner, Abraham	12,612	Mar. 27, 1855	G
Hadley, B. E.	1,300,230	Apr. 8, 1919	S
Hague, S. L.	775,448	Nov. 22. 1904	W, S
Hague, S. L.	759,988	May 17, 1904	W, S
Hall, C. H.	86,535	Feb. 2, 1869	F 2
Hall, C. H.	55,855	June 26, 1866	F 1, 2, II
Hall, C. H. & Ellis, John	58,813	Oct. 16, 1866	F 1, II
Hall, T. G.	372,672	Nov. 8, 1887	V
Hall, Wm. A.	1,175,909	Mar. 14, 1916	B
Hall, Wm. A.	1,105,772	Aug. 4, 1914	B, K 1
Hall, Wm. A.	1,194,289	Aug. 8, 1916	B
Hall, Wm. A.	1,239,099	Sept. 4, 1917	B
Hall, Wm. A.	1,175,910	Mar. 14, 1916	B, K 1
Hall, Wm. A.	1,247,671	Nov. 27, 1917	B
Hall, Wm. A.	1,242,795	Oct. 9, 1917	B
Hall, Wm. A.	1,242,796	Oct. 9, 1917	B
Hall, Wm. A.	1,239,100	Sept. 14, 1917	B
Hall, Wm. A.	1,261,930	Apr. 9, 1918	B
Hall, Wm. A.	1,242,746	Oct. 9, 1917	B
Hall, Wm. A.	1,242,795	Oct. 9, 1917	B
Hall, Wm. A.	1,285,136	Nov. 19, 1918	B
Hall, Wm. C.	266,990	Nov. 7, 1882	F 2
Hamilton, T. S.	1,018,871	Feb. 27, 1912	A
Halvorson, Halvor	305,182	Sept. 16, 1884	S
Halvorson, H.	305,180	Sept. 16, 1884	F
Hand, Harry W.	596,874	Jan. 4, 1898	U, S
Handy, Jas. O.	1,281,354	Oct. 15, 1918	O
Handy, Jas. O.	1,084,738	Oct. 15, 1918	O
Hansen, Julius	1,281,355	Jan. 20, 1914	C
Hardy, C. A.	51,042	Nov. 21, 1865	F
Hardy, C. A.	40,168	Oct. 6, 1863	F 2, 4
Hardy, C. A.	46,899	Mar. 21, 1865	F
Harris, Ford W.	1,281,952	Oct. 15, 1918	A, P

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Name	Number	Date	Class
Harris, John	1,283,508	Nov. 5, 1918	K 2
Harris, Milo	170,730	Dec. 7, 1875	U
Hart, Thos. M.	1,252,433	Jan. 8, 1918	A, E 2, 3
Hartshorn, H. M.	91,843	June 29, 1869	N
Hastings, D. & Brink, A. W.	867,505	Oct. 1, 1907	K 2, J
Hatch, N. B.	22,798	Feb. 1, 1859	G
Hawes, Benj. N.	444,833	Jan. 20, 1891	V
Hazlett, R. W. & Hobbs, J. H.	24,211	May 31, 1859	G, S
Hebard, Benj. F.	31,457	Feb. 19, 1861	M
Heckenbleikner & Gilchrist	1,310,078	July 15, 1919	I
Helbing, H. & Passmire, F. W.	666,010	Jan. 15, 1901	D 1
Hempel, H.	621,338	Mar. 21, 1899	M
Hempel, H.	621,411	Mar. 21, 1899	M
Henderson, Geo. A.	1,266,261	May 14, 1918	E 1
Henderson, N. M.	490,199	Jan. 17, 1893	C
Henderson, N. M.	340,878	Apr. 27, 1886	F
Hennebutte, H.	1,165,878	Dec. 28, 1915	F
Hennebutte, H.	1,165,877	Dec. 28, 1915	F 4, I
Hense, Rudolf	1,073,233	Sept. 16, 1913	M
Herber, Samuel M.	1,111,580	Sept. 22, 1914	F, D 1
Herber, S. M.	1,183,457	May 16, 1916	F 2, 3, D
Hibbert, Harold	1,270,759	June 25, 1918	B, K 2
Higbie, M. S. & Dougherty, A.	387,358	Aug. 7, 1888	C, E, 1
Higbie, M. S. & Dougherty, A.	387,357	Aug. 7, 1888	C, E, 1, 3
Higgins, Chas. S.	309,718	Dec. 23, 1884	N
Higham, A. D.	54,157	Apr. 24, 1866	F
Hill, R. L.	1,269,439	June 11, 1918	B
Hill, S. & Thumm, C. F.	101,364	Mar. 29, 1870	F 1, II
Hill, S. & Thumm, C. F.	101,365	Mar. 29, 1870	F 1, II
Hill, S. & Thumm, C. F.	102,819	May 10, 1870	F 1, II
Hill, S. & Thumm, C. F.	114,293	May 2, 1871	F 1, 3, II
Hirshberg, Leon	1,042,915	Oct. 29, 1912	D
Hirt, Leon E.	1,222,402	Apr. 10, 1917	B, P
Hirt, L. E.	1,250,879	Dec. 18, 1917	B, P
Hirt, L. E.	1,264,796	Apr. 30, 1918	K, 3
Holmes, F. W. & Blasdell, E.	1,055,747	Mar. 11, 1913	B
Hodkinson, M	26,326	Nov. 29, 1859	G, W
Hofferberth, John	105,683	July 26, 1870	F 1, I
Hoffman, Bernhard	641,962	Jan. 23, 1900	M
Hoffman, Ross J.	405,738	June 25, 1889	S
Holmes, Jos. E.	23,427	Mar. 29, 1859	G, W
Holmes, Jos. E.	1,241,979	Oct. 2, 1917	B, J
Holmes, J. E.	24,212	May 31, 1859	W
Hood, J. J. & Salamon, A. G.	962,840	June 28, 1910	D 2
Hopkins, A. S.	1,199,463	Sept. 26, 1916	B
Hopkins, A. S.	1,199,464	Sept. 26, 1916	B
Horner, E. N.	22,727	Jan. 25, 1859	W, D
Houlker, Christopher	110,364	Dec. 20, 1870	O
Howard, F. A.	1,284,687	Nov. 12, 1918	F
Howarth, John	42,772	May 17, 1864	W, F
Howe, Ephriam	7,667	Sept. 24, 1850	M
Howell, ——	1,294,909	Feb. 18, 1919	S
Howell, C. G.	66,841	July 16, 1867	F 1, 2
Howell, H. F.	216,518	June 17, 1879	L
Hudson, Chas. R.	681,170	Aug. 20, 1901	A
Hudson, Samuel.	123,907	Feb. 20, 1872	G
Huglo, Victor.	953,952	Apr. 5, 1910	B
Hout, F. & Rogers, John	71,619	Nov. 15, 1867	F 4
Hout, F. & Rogers, John	63,051	Sept. 19, 1866	S
Humason, G. A.	1,291,899	Jan. 21, 1919	S
Humphreys, R. E.	1,122,002	Dec. 22, 1914	B, S
Humphreys, R. E.	1,122,003	Dec. 22, 1914	B
Humphreys, R. E.	1,119,700	Dec. 1, 1914	B
Humphreys, R. E.	1,286,179	Nov. 26, 1918	I
Huntington, John.	62,750	Mar. 12, 1867	F
Huston, John B.	297,603	Apr. 29, 1884	S
Huston, John B.	486,406	Nov. 15, 1892	V
Hyde, Burrows.	281,999	July 24, 1883	T
Hall, Wm. A.	1,242,746	Oct. 9, 1917	B

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Name	Number	Date	Class
Hall, Wm. A.	1,242,795	Oct. 9, 1917	B
Holmes, Fletcher B.	1,276,219	Aug. 20, 1918	D
Hussey, John S.	1,277,935	Sept. 3, 1918	C
Ihart, J. P.	654,258	July 24, 1900	A
Ilges, T. W.	968,478	Aug. 23, 1910	F 2, II
Isom, Edward W.	1,285,200	Nov. 19, 1918	B
Jaeger, W. G. W.	24,217	May 31, 1859	W
Jaeger, W. G. W.	24,561	June 28, 1859	W, S
Jaeger, W. G. W.	54,358	Apr. 16, 1866	F 1, 2, II
James, C. M.	86,232	Jan. 26, 1869	F 1, 2, II
Jann, John.	52,574	Feb. 13, 1866	M
Jann, John.	57,727	Sept. 4, 1866	M
Jenkins, U. S.	1,226,526	May 15, 1917	J, B
Jennings, Isaiah.	1,453	Dec. 31, 1839	M
Jenney, W. P.	190,762	May 15, 1877	I
Jenney, W. P.	178,061	May 30, 1876	I
Jenney, W. P.	178,154	May 30, 1876	I, T
Jensen, J. O.	1,268,721	June 4, 1918	A
Johnson, John.	54,917	May 22, 1866	S
Johnson & Snodgrass	1,283,202	Oct. 29, 1918	S
Johnston, Jas. J.	117,425	July 25, 1871	F
Johnston, Jas. J.	117,426	July 25, 1871	A
Johnston, Jas. J.	48,285	June 20, 1865	F 4, 5
Johnston, Jas. J.	31,982	Apr. 9, 1861	S
Johnston, Jas. J.	50,935	Nov. 14, 1865	F 2
Johnston, Jas. J.	91,448	June 15, 1869	F 2, II
Jones, Philip.	1,255,018	Jan. 29, 1918	K 2, S
Jones, E. C. & Jones, L. B.	1,089,926	Mar. 10, 1914	K 1, 2
Jones & Jones	1,157,225	Oct. 19, 1915	K 1
Jones, R. G.	1,166,375	Dec. 28, 1915	F 2, II
Jones, R. G.	1,005,977	Oct. 17, 1911	A
Jordery, Chas. A.	126,552	May 7, 1872	M
Just, John A.	658,988	Oct. 2, 1900	M
Kasson, H. R. & Saxton, S. S.	998,691	Apr. 7, 1914	E 1, 2
Kattell, E. C.	222,408	Dec. 9, 1879	F 2, 4
Kaysar, Adolf.	508,479	Nov. 14, 1893	D 1, V
Kaysar, A.	640,918	Jan. 9, 1900	V, D 1
Keen, Morris L.	25,552	Sept. 20, 1859	F 1
Kelley, E. G.	67,988	Aug. 20, 1867	F 1, II
Kelley, E. G. & Tait, A. H.	32,568	June 19, 1861	F 1, 2, II
Kelley, E. G.	84,195	Nov. 17, 1868	F 1, II
Kells, Edw.	298,210	May 6, 1884	F
Kells, Edw.	374,838	Dec. 13, 1887	F 1, I
Kelsey, S. E.	1,092,366	Apr. 7, 1914	B
Kelsey, S. E.	1,302,669	May 6, 1919	S
Kendall, Edw. D.	413,187	Oct. 22, 1889	D
Kendall, Edw. D.	359,357	Mar. 15, 1887	D 1
Kendall, Edw. D.	284,437	Sept. 4, 1883	D, M
Kendall, Edw. D.	451,660	May 5, 1891	D 1, 2
Kendall, Edw. D.	1,192,529	July 25, 1916	K 2, J
Kendall, Edw. D.	1,154,517	Sept. 21, 1915	D 1, S
Kendall, Edw. D.	1,154,516	Sept. 21, 1915	D 1
Kennedy, D. McD.	370,950	Oct. 4, 1887	V
Kerr, A. N.	1,199,903	Oct. 3, 1916	J
Keyt, M. H.	1,262,808	Apr. 16, 1918	D
Kipper, H. B.	1,253,048	Jan. 8, 1918	D 1
Kirchhoffer, G. W.	32,373	May 21, 1861	G, W
Kirk, Arthur.	78,878	June 16, 1868	F 1, II
Kirk, J. L.	215,756	May 27, 1879	F 1, II
Kirk, Solomon W.	267,752	Nov. 21, 1882	C
Kirschbraun, L.	1,194,750	Oct. 3, 1916	E 1, 2
Kitchen, J. M. W.	1,008,273	Aug. 15, 1916	F 1, 2, II
Klein, John S.	306,837	Oct. 21, 1884	S
Kline, Geo. H.	353,362	Nov. 30, 1886	F 1, II, S
Klosterman, Robt.	152,650	June 30, 1874	F
Knottenbelt, H. W.	1,194,033	Aug. 8, 1916	W
Knottenbelt, H. W.	1,277,605	Sept. 3, 1918	D 1
Koehler, Herman.	507,441	Oct. 24, 1893	V
Koehler, W. C. & Link, L.	1,084,016	Jan. 13, 1914	O

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Name	Number	Date	Class
Koppers, H.	1,098,734	June 2, 1914	F 2, II
Kreiser, J. M.	384,768	June 19, 1888	S
Kreiser, J. M.	366,487	July 12, 1887	F
Kreusler, A.	50,368	Oct. 10, 1865	F
Lacy, B. S.	1,263,906	Apr. 23, 1918	L
ckmen, A.	1,171,524	Feb. 15, 1916	F 2, II
ng, John.	471,291	Mar. 22, 1892	B
ing, John.	488,767	Dec. 27, 1892	B
aird, Robt. H.	507,230	Oct. 24, 1893	F 2, II
aird, Robt. H.	498,518	May 30, 1893	F
aird, R. E. & Raney, Jos. H.	1,116,299	Nov. 3, 1914	A, P
aird & Raney	1,142,761	June 8, 1915	A, P
ird & Raney	1,142,760	June 8, 1915	A, P
ird & Raney	1,142,759	June 8, 1915	A, P
Lamb, D. M.	183,401	Oct. 17, 1876	D 1
Lambe, Frederick.	102,135	Apr. 19, 1870	C
Lambert, Chas. G.	1,245,930	Nov. 6, 1917	B
Lamplough, F.	1,229,098	June 5, 1917	B
Landes, Wm.	1,199,909	Oct. 3, 1916	B
Landsberg, L.	1,211,721	Jan. 9, 1917	I
Lane, Edw.	172,131	Jan. 11, 1876	F 1, II
Lang, J. S.	954,575	Apr. 12, 1910	B
Lapham, Allen.	59,317	Oct. 30, 1866	F
app, C. E.	1,266,281	May 14, 1918	B
Lasher, D. F.	1,075,481	Oct. 14, 1913	D 1
Lee, A. K.	162,394	Apr. 20, 1875	E 1
Leete, H. C.	1,288,934	Dec. 24, 1918	D
eman, Wm. T.	727,391	May 5, 1903	U
ennard, F.	459,123	Sept. 8, 1891	F 2, II
Lennard, F.	499,557	June 13, 1893	F 2
Lennard, F.	659,076	Oct. 2, 1900	T
Lepley, Clyde E.	1,261,410	Apr. 2, 1918	F
Leslie, E. H.	1,310,164	July 15, 1919	S
Lessing, Rudolf.	1,281,597	Oct. 15, 1918	K 2
etchford, R. M. & Nation, W.	133,042	Nov. 12, 1872	C
evy, E. D. & Jacobs, H. W.	1,251,978	Jan. 1, 1918	Q
Lewis, Sylvester.	35,527	June 10, 1862	M
ewis, S.	42,671	May 10, 1864	V
ewis, S.	43,156	June 14, 1864	M
indenberg, G. & Scott, W. B.	1,220,651	Mar. 27, 1917	K 2, B
Lindsey, Wm. J.	1,256,340	Feb. 12, 1918	K 1
Linn, S. S.	1,284,117	Nov. 5, 1918	M
Livesay, Jas. & Kidd, Jas.	258,778	May 30, 1882	F
Livingston, Julius I.	239,260	Mar. 22, 1881	T
Livingston, Max.	237,560	Feb. 8, 1881	F
Livingston, Max.	728,257	May 19, 1903	F II
Lockhart, Chas. & Gracie, J.	40,632	Nov. 17, 1863	F
Lockhart & Gracie	80,294	July 28, 1868	F
Loew, Oscar.	101,284	Mar. 29, 1870	D 1
Lofhjelm, Karl.	546,018	Sept. 10, 1895	F
Loftus, Robt. G.	113,782	Apr. 18, 1871	D 1
Loftus, Robt. G.	81,654	Sept. 1, 1868	K 2
Loftus, Robt. G.	43,157	June 14, 1864	I
Long, F. R.	1,256,146	Feb. 12, 1918	S
Loomis, C. C.	1,280,612	Oct. 1, 1918	L
Loomis, Wells, Hitchcock & Stryker.	66,364	July 2, 1867	M
Looney, John J.	139,009	May 20, 1873	D 1
Lorch, H. D.	1,264,668	Apr. 30, 1918	F 2, 5
Lossen, Clemens.	537,121	Apr. 9, 1895	V
Low, Frank S.	1,192,653	July 25, 1916	J, B
Lowe, W. P. & Bilfinger, C. W.	556,155	Mar. 10, 1896	B
Lucas, Owen D.	1,168,404	Jan. 18, 1916	B
Lucas, Owen D.	1,183,091	May 16, 1916	B
Lugo, Orazio.	51,843	Jan. 2, 1866	F 3
Lugo, Orazio.	60,757	Jan. 1, 1867	V, D 1
Lugo, Orazio.	58,113	Sept. 18, 1866	F 3, 4, I
Lugo, O. & Schrader, T. O. L.	60,396	Dec. 11, 1866	F 3, 4, I
Lupton, George.	110,054	Dec. 13, 1870	D
Lutz, H. E.	240,914	May 3, 1881	F 1, II

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Name	Number	Date	Class
Maag, G. C.	1,142,525	June 8, 1915	B
McAfee, Almer M.	1,277,092	Aug. 27, 1918	C
McAfee, A. M.	1,099,096	June 2, 1914	B
McAfee, A. M.	1,127,465	Feb. 9, 1915	B
McAfee, A. M.	1,144,304	June 22, 1915	B
McAfee, A. M.	1,202,081	Oct. 24, 1916	B
McAfee, A. M	1,277,329	Aug. 27, 1918	D
McAfee, A. M	1,277,328	Aug. 27, 1918	D
McAfee, A. M.	1,235,523	July 31, 1917	B
McArthur, D. R.	1,119,974	Dec. 8, 1914	B
McCaig, D. C.	1,255,449	Feb. 5, 1918	S
McCarty, F.	91,953	June 29, 1869	F 2, II
McCarty, Wm. F. M.	1,274,912	Aug. 6, 1918	B
McCarty, W. F. M.	1,274,913	Aug. 6, 1918	B
McCue, J. & W. B.	21,143	Aug. 10, 1858	W
McElroy, Karl P.	1,259,757	Mar. 19, 1918	K 2, B
McElroy, Karl P.	1,259,758	Mar. 19, 1918	K 2
McGowan, Thompson.	492,421	Feb. 28, 1893	F
McGowan, T.	454,061	June 16, 1891	F
McGowan, T.	443,328	Dec. 23, 1890	F
McGowan, T.	658,857	Oct. 2, 1900	V
McGowan, T.	257,961	May 16, 1882	F 3, D 1
McGowan, T.	431,386	July 1, 1890	F
McGowan, T.	166,285	Aug. 3, 1875	F 2
McGowan, T.	492,419	Feb. 28, 1893	S
McGowan & Van Syckel, S.	154,700	Sept. 1, 1874	S
McGowan & Van Syckel.	156,229	Oct. 27, 1874	F 1
McHenry, C. D.	1,154,869	Sept. 28, 1915	B, K 1
McKee, Ralph H.	1,244,444	Oct. 23, 1917	L
McKibben, C. W.	1,299,589	Apr. 8, 1919	A
McKibben C. W.	1,299,590	Apr. 8, 1919	A
McKissack, R. I.	1,113,029	Oct. 6, 1914	K 1
McManus, H.	305,097	Sept. 16, 1884	I
McMillan, F. M.	215,471	May 20, 1879	C
Macalpine, Thos.	655,500	Aug. 7, 1900	D 1, 2
Macalpine, Thos.	686,663	Nov. 12, 1901	D 1, 2
Macalpine, Thos.	664,813	Dec. 25, 1900	F 2, 5, I
Macalpine, Thos.	741,517	Oct. 13, 1903	D
Maitland, H. T.	1,188,961	June 27, 1916	O, D
Maitland, H. T.	1,272,979	July 16, 1918	D 1
Mann, F. W.	619,593	Feb. 14, 1899	B
Mann & Chappell, M. L.	1,163,025	Dec. 7, 1915	D
Mann & Chappell.	1,183,094	May 16, 1916	L
Mann & Chappell.	1,214,204	Jan. 30, 1917	B
Mann & Chappell.	1,249,444	Dec. 11, 1917	B
Mann & Chappell.	1,257,906	Feb. 26, 1918	B
Mann, Stephen S.	204,235	May 28, 1878	N
Mann, Stephen S.	152,855	July 7, 1874	N
Mansfield, David.	55,880	June 26, 1866	M
Marrin, Thos.	211,762	Jan. 28, 1879	C
Marrin, Thos.	243,930	July 5, 1881	F
Martin, J. N.	254,990	Mar. 14, 1882	F
Martini, Dan.	892,378	June 30, 1908	B, P
Mason, Allan.	444,203	Jan. 6, 1891	F 1, 2, II
Mason, Allan.	444,202	Jan. 6, 1891	F 1, 2, II
Mason, F. B.	1,294,136	Feb. 11, 1919	M
Mathieu, Jean A.	374,077	Nov. 29, 1887	F 2, 5, II
Mavbury, Wm.	737,756	Sept. 1, 1903	F 1, 2, II
Meeds, Wilber R.	266,859	Oct. 31, 1882	M
Meeds, W. R.	250,830	Dec. 13, 1881	M
Meigher, Jas. D.	224,301	Feb. 10, 1880	F 1, 4, II
Mellen, G. H. & Hazelton, J. C.	57,749	Sept. 4, 1866	M
Mengel, Chas. C.	116,852	July 11, 1871	F
Mengel, C. C.	465,703	Dec. 22, 1891	F 1, 3
Mengel, C. C.	452,578	May 19, 1891	F 3, V
Meredith, S.	13,358	July 31, 1855	W
Merrick, Thos. E.	91,654	June 22, 1869	O, D
Merriam, E. S.	1,304,587	May 27, 1919	J-K
Merriam, J. B.	61,946	Feb. 12, 1867	C

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Name	Number	Date	Class
Merrill, Francis B.	761,315	May 31, 1904	F
Merrill, Joshua.	33,955	Dec. 17, 1861	S
Merrill, Joshua.	32,951	July 30, 1861	S
Merrill, Joshua.	32,706	July 2, 1861	S
Merrill, Joshua.	32,704	July 2, 1861	D 1
Miller, J. R.	1,312,265	Aug. 5, 1919	B
Merrill, Joshua.	32,705	July 2, 1861	D 1
Merrill, Joshua.	90,284	May 18, 1869	F 1, 2
Merrill, Joshua.	43,325	June 28, 1864	D 1
Merrill, Willis C.	1,252,376	Jan. 1, 1918	E 3
Mertz, Josef.	339,201	Apr. 6, 1886	F 2, II
Mesereau, G.	1,282,906	Oct. 29, 1918	K
Mesereau, G.	1,308,802	July 8, 1919	K
Meucci, Antonio.	36,419	Sept. 9, 1862	D 1
Midgely, T., Jr.	1,296,832	Mar. 11, 1919	M
Mijs, Jan.	1,178,532	Apr. 11, 1916	C
Miles, George.	205,407	June 25, 1878	F, S
Miles, George W.	1,168,534	Jan. 18, 1916	C
Miller, Jas.	77,070	Apr. 21, 1868	F 5, II
Millochau, Adolph.	38,641	May 19, 1863	D 1
Millochau, A.	37,918	Mar. 17, 1863	D 1
Millochau, A.	53,167	Mar. 13, 1866	F 1
Millochau, A.	46,923	Mar. 21, 1865	F 1
Millochau, A.	41,085	Jan. 5, 1864	D 1
Millochau, A.	49,777	Sept. 5, 1865	N
Mills, E. N.	1,007,788	Nov. 7, 1911	Q
Millspaugh, Pethuel.	127,259	May 28, 1872	N
Mims, John C.	713,475	Nov. 11, 1902	D 1, E 3
Minshall, F. W.	514,876	Nov. 26, 1889	F 2, 3, V
Mitchell, Willis.	1,141,072	May 25, 1915	K 1
Montague, H. E.	1,227,551	May 22, 1917	B
Mooney, L.	1,174,888	Mar. 7, 1916	R
Moore, E. A.	786,828	Apr. 11, 1905	A
Moore, George H.	586,520	July 13, 1897	V, D 1
Moore, E. S. & Thomas, H. H.	1,281,808	Oct. 15, 1918	S
Moore, J. B.	1,130,318	Mar. 2, 1915	B
Morehouse, C. L.	55,426	June 5, 1866	D 1, C
Morehouse, C. L.	174,921	Mar. 21, 1876	G
Morfit, Clarence.	66,243	July 2, 1867	U
Morris, W. L.	1,137,075	Apr. 27, 1915	C
Morris, W. L.	1,305,735	June 3, 1919	O
Mott, Leander M.	54,192	Apr. 24, 1866	O
Mowbray, George M.	25,575	Sept. 27, 1859	F 1, 4, II
Munson, A. L.	440,830	Nov. 18, 1890	D
Murray, Thos. E.	1,273,523	July 23, 1918	S
Murray, T. E. and Ricketts, E. B.	1,293,866	Feb. 11, 1919	F
Mueller, C. L. E.	1,297,388	Mar. 18, 1919	M
Murray, T. E.	1,302,200	Apr. 29, 1919	S
Myers, Geo. W.	147,783	Feb. 24, 1874	K 2, S
Navin, F.	1,312,266	Aug. 5, 1919	W
Neahous, Herman.	242,554	June 7, 1881	C
Neal, Stephens.	1,036,306	Aug. 20, 1912	F 2
Neilson, Albert.	239,618	Apr. 5, 1881	F
Newall, Robert.	53,656	Apr. 3, 1866	V, D
Newsome, Thos. J.	405,047	June 11, 1889	A
Nichols, H. M.	1,302,832	May 6, 1919	S
Nicholson, John.	22,973	Feb. 15, 1859	W
Nicolai, J. H. & W. F.	224,037	Feb. 3, 1880	G, S
Nicolai, Pierre.	225,635	Mar. 16, 1880	F 2
Nikiforoff, A.	755,309	Mar. 22, 1904	B
Noad, James.	971,468	Sept. 27, 1910	B
Noad, Jas.	985,053	Feb. 21, 1911	B, W
Nordenson, Carl O.	1,218,575	Mar. 6, 1917	K 1
Norton, J. W. & Rouse, F. H.	313,514	Mar. 10, 1885	S
Norton & Rouse	336,941	Mar. 2, 1886	F 2, 4, D 1
Noteman, Alonzo.	512,894	Jan. 16, 1894	D
Noyes, John E.	82,151	Sept. 15, 1868	G, M
Ogilvy, David J.	1,268,142	June 4. 1918	W
O'Hara, Jas.	22,573	Jan. 11, 1859	K 3

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Name	Number	Date	Class
Olsen, Geo. E.	1,199,491	Sept. 26, 1916	J, A
O'Neall, J. M.	754,687	Mar. 15, 1904	F 1, 2, II
Opl, Karl.	1,128,494	Feb. 16, 1915	C
Paine, Henry H.	9,119	July 13, 1852	M
Palmer, Chas. S.	1,187,380	June 13, 1916	B
Palmer, Chas. S.	1,268,763	June 4, 1918	K 1
Palmer, Chas. S.	1,313,009	Aug. 12, 1919	B
Parker, J. H.	958,820	May 24, 1910	B
Parker, R. B.	1,252,481	Jan. 8, 1918	K 2
Parker, W. C.	169,189	Oct. 26, 1875	O
Parker, W. M.	1,226,990	May 22, 1917	B
Parsons, Chas. C.	88,978	Apr. 13, 1869	F 2, 5
Parsons, C. Chauncey	93,739	Aug. 17, 1869	C
Parsons, H. E.	214,946	Apr. 29, 1879	F, K 2
Pease, Francis S.	226,187	Apr. 6, 1880	N
Pemberton, Henry.	24,952	Aug. 2, 1859	W, I
Penissat, Andre.	204,244	May 28, 1878	I
Perkins, A. H.	36,632	Oct. 7, 1862	T
Perkins, George H.	399,073	Mar. 5, 1889	F
Perkins, Geo. H.	240,923	May 3, 1881	S
Perkins, J. & Burnet, Wm. H.	47,125	Apr. 4, 1865	F 2, II
Perkins, W. D.	731,943	June 23, 1903	F 1, 2, II
Perrier, Odilon.	544,516	Aug. 13, 1895	F 1, 2, II
Perrine, Robt. M.	419,347	Jan. 14, 1890	V, D
Peterson, F. P.	1,031,664	July 2, 1912	J, K 2
Petroff, Grigori.	1,087,888	Feb. 17, 1914	I
Petroff, G.	1,233,700	July 17, 1917	D 1
Petty, T. K. & Warden, W. G.	37,263	Dec. 23, 1862	S
Peuchen, S. C.	531,560	Dec. 25, 1894	P
Pfeifer, F.	1,296,115	Mar. 4, 1919	K
Pfeifer, F.	1,296,116	Mar. 4, 1919	K
Philip, A.	1,286,091	Nov. 26, 1918	Q
Phillipps, Joseph.	98,883	Jan. 18, 1870	G, M
Pictet, Raoul P.	1,228,818	June 5, 1917	B
Pielsticker, Carl M.	186,951	Feb. 6, 1877	D 1
Pielsticker, Carl M.	477,153	June 14, 1892	F 2, II
Pijzel, Daniel.	1,070,730	Aug. 19, 1913	C
Pinckney, T. De Witt	221,421	Nov. 11, 1879	N
Pinkham, C. W.	34,772	Mar. 25, 1862	M, G
Pine, J. A. W. & Ruggles, Wm. B.	1,057,667	Apr. 1, 1913	E 3
Pitt, Wm. H.	379,492	Mar. 13, 1888	F, V
Pitt, Wm. H.	411,394	Sept. 17, 1889	F, V
Place, Chas. T.	243,080	June 21, 1881	F
Poisat, A. M. & Knab, D. C.	7,124	Feb. 26, 1850	F 2, II
Pollak, R. R.	1,254,271	Jan. 22, 1918	A
Ponton, John.	165,612	July 13, 1875	N
Porges, P, & Neumann, R.	1,017,587	Feb. 13, 1912	C
Porter, Alonzo W.	146,778	Jan. 27, 1874	G
Poterie, George.	453,386	June 2, 1891	W
Pray, Lyman.	61,098	Jan. 8, 1867	S, F
Prentiss, E. F. & Robertson, R. A.	48,435	June 27, 1865	U
Prentiss & Robertson	41,858	Mar. 8, 1864	F 2, II
Price, C. P.	1,273,091	July 16, 1918	F 2, 4
Price, Walter B.	548,391	Oct. 22, 1895	D 1
Price, W. B.	522,628	June 26, 1894	G, D 1
Prichard, Geo. I.	1,264,435	Apr. 30, 1918	F 2, II
Prichard, G. L.	1,290,345	Jan. 7, 1919	I
Propfe, H.	478,265	July 5, 1892	F 1, II
Prutzman, Paul W.	1,238,331	Aug. 28, 1917	A
Puning, Franz.	1,176,094	Mar. 21, 1916	K 2, S
Pyzel, Daniel.	1,040,408	Oct. 8, 1912	C
Pyzel, Daniel.	1,276,690	Aug. 20, 1918	S
Quinn, Abraham.	31,998	Apr. 9, 1861	F
Quinn, A.	36,481	Sept. 16, 1862	F
Rand, Alonzo C.	62,362	Feb. 26, 1867	S
Rave, Chas.	425,905	Apr. 15, 1890	I, P
Reese, Jacob.	38,602	May 19, 1863	S
Reese, Jacob.	150,614	May 5, 1874	S
Reeves, S. H.	1,302,090	Apr. 29, 1919	T

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Name	Number	Date	Class
Reeves, W. P.	1,283,559	Nov. 5, 1918	S
Reilly, P. C.	1,310,164	July 15, 1919	F, S
Rensink, G. C.	1,134,419	Apr. 6, 1915	A
Requa, Chas. W.	77,094	Apr. 21, 1868	F 1, 2, I
Restieux, Thos.	63,749	Apr. 9, 1867	V, D 1
Reynolds, F. R.	1,119,453	Dec. 1, 1914	F 2
Rice, L. M. & Adams, S. E.	90,392	May 25, 1869	S
Richardson, Clifford.	551,294	Dec. 10, 1895	E 3, A
Richardson, Wm. D.	1,257,397	Feb. 26, 1918	P
Richardson, John E.	65,275	May 28, 1867	C
Richter, Felix.	1,098,763	June 2, 1914	D
Richter, Felix.	1,098,764	June 2, 1914	D
Rites, F. M.	1,167,021	Jan. 4, 1916	K 1, B
Rites, F. M.	1,144,788	June 29, 1915	K 1, B
Rites, F. M.	1,144,789	June 29, 1915	K 1, B
Roake, John S.	700,373	May 20, 1902	D 1
Roberts, A. E. & Emery, A. L.	1,016,958	Feb. 13, 1912	Q
Robertson, J. H.	1,238,339	Aug. 28, 1917	B, P
Robinson, C. I.	1,014,520	Jan. 9, 1912	I
Robinson, C. I.	1,018,374	Feb. 20, 1912	F 1
Robinson, C. I.	968,692	Aug. 30, 1910	D 1
Robinson, C. I.	910,584	Jan. 26, 1909	V, D
Robinson, J. C.	218,901	Aug. 26, 1879	F 2, II
Rodman, Hugh.	1,209,336	Dec. 19, 1916	B
Rogers, Davenport.	211,055	Dec. 17, 1878	F 2, 4, II
Rogers, D.	284,331	Sept. 4, 1883	F
Rogers, F. M.	1,299,385	Apr. 1, 1919	A
Rogers, Henry H.	120,539	Oct. 31, 1871	F
Rogers, John.	50,276	Oct. 3, 1865	F
Rogers, Lebbeus H.	1,269,747	June 18, 1918	W
Rogers, F. M. & Cooke, T. S.	1,122,220	Dec. 22, 1914	J
Rogers, M. C.	1,148,990	Aug. 3, 1915	S
Rogers, Wm. B.	60,559	Dec. 18, 1866	M
Roots, James.	340,522	Apr. 20, 1886	M, G
Rose, H. C.	182,775	Oct. 3, 1876	F 1, 2, II
Rose, James R.	1,252,033	Jan. 1, 1918	B, K 1
Rosen, Jean.	1,165,909	Dec. 28, 1915	O
Rosen, Jean.	1,162,654	Nov. 30, 1915	B
Ross, S. J. & Schofield, H.	1,204,492	Nov. 14, 1916	B
Roth, P. & Venturino, M. E.	1,208,378	Dec. 12, 1916	B
Roth & Venturino	1,208,214	Dec. 12, 1916	B
Roth & Venturino	1,208,378	Dec. 12, 1916	B
Rowlands, P. O.	1,252,955	Jan. 8, 1918	S
Rowsell, John.	299,167	May 27, 1884	D 1
Ryder, Henry.	142,515	Sept. 2, 1873	F, S
Ryder, Watson.	214,199	Apr. 8, 1879	F 1, II
Ryder, W. & Qualey, J. A.	739,957	Sept. 22, 1903	F
Rosenbaum, R. R.	1,278,023	Sept. 3, 1918	C, E 2
Ruff, F. C.	1,263,289	Apr. 16, 1918	D 1
Sabatier, P. & Mailhe, A.	1,124,333	Jan. 12, 1915	B, P
Sabatier, P. & Mailhe, A.	1,152,765	Sept. 7, 1915	B
Salathe, Frederick.	452,764	May 19, 1891	T
Salathe, F.	564,341	July 21, 1896	T
Sampson, C. E. & Woods, W.	1,177,816	Apr. 4, 1916	B
Sangster, W. H.	54,414	May 1, 1866	S, D
Sangster, W. H. & Spencer, T. C.	56,276	July 10, 1866	F
Sargent, Thos. D.	20,587	June 15, 1858	W
Savage, Wallace.	1,279,918	Sept. 24, 1918	E 1
Sawyer, G. T., Howland, W., Jr., & Hatch, T. C.	33,905	Dec. 10, 1861	S
Saybolt, Geo M.	565,039	Aug. 4, 1896	D 1
Saybolt, G. M.	565,040	Aug. 4, 1896	D 1
Saybolt, G. M.	989,827	Apr. 18, 1911	J, K 2
Saybolt, G. M.	218,066	July 29, 1879	N
Saybolt, G. M.	245,568	Aug. 9, 1881	N
Schalk, Emil.	146,405	Jan. 13, 1874	D
Schalk, Emil.	133,598	Dec. 3, 1872	D, S
Schesch, H. A.	54,218	Apr. 24, 1866	F
Scheuffgen, Robert.	1,118,952	Dec. 1, 1914	H

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Name	Number	Date	Class
Schildhaus, G. & Condrea, C.	956,184	Apr. 26, 1910	I
Schill, E.	1,100,260	June 16, 1914	F, K 2
Schill, E.	1,142,275	June 8, 1915	J, K 2
Schiller, Max.	580,652	Apr. 13, 1897	V
Schmidt, A. T.	164,694	June 22, 1875	D
Schmidt, W. A. and Wolcott, E. R.	1,308,161	June 24, 1919	B
Schubert, Julius.	156,600	Nov. 3, 1874	A
Schwartz, Stephen.	1,247,883	Nov. 27, 1917	B
Scott, John B.	58,180	Sept. 18, 1866	M
Seeger, Robert.	1,259,786	Mar. 19, 1918	B
Seely, E. D.	57,390	Aug. 21, 1866	M
Seely, C. A.	87,207	Feb. 23, 1869	F
Seibert, F. M. and Brady, J. D.	1,290,369	Jan. 7, 1919	A
Seidenschur, F. & Dehnst, J.	1,162,729	Nov. 30, 1915	B
Seigle, A.	567,751	Sept. 15, 1896	F 1, II
Seigle, A.	567,752	Sept. 15, 1896	F
Sellers, H. L. & Conyngton, H. R.	549,399	Nov. 5, 1895	E 3
Setzler, H. B.	1,292,966	Jan. 28, 1919	B
Sewell, B. F. Brooke	781,045	Jan. 31, 1905	F
Sexton, Wm. A.	1,248,730	Dec. 4, 1917	A
Seymour, M. J.	306,965	Oct. 21, 1884	A
Shapter, J. S.	61,474	Jan. 22, 1867	F 1, 2, 5
Shaw, F. D.	1,098,412	June 2, 1914	K 1
Shaw, G. E.	61,572	Jan. 29, 1867	N
Shaw, G. E.	56,107	July 3, 1866	N
Sheets, Earl H.	1,273,191	July 23, 1918	K 2, J
Sherman, L. O.	968,088	Aug. 23, 1910	B
Sherman, L. O.	1,260,584	Mar. 26, 1918	B, J
Sherman, L. O.	1,288,711	Dec. 24, 1918	B
Shiner, O. J.	1,099,622	June 9, 1914	D 1
Shively, Martin.	613,728	Mar. 11, 1919	S
Shreves, F. G.	1,297,022	Nov. 8, 1898	A
Shroder, Richard.	16,255	Dec. 16, 1856	W
Slater, Wm. A.	1,263,950	Apr. 23, 1918	I
Skidmore, C. J. and Coventry, P. F.	1,302,094	Apr. 29, 1919	O
Slemmer, Henry T.	52,897	Feb. 27, 1866	O
Sloane, W. M.	109,772	Nov. 29, 1870	A
Sloane, W. M. & Potter, R. M.	223,549	Jan. 13, 1880	C
Sloane, W. M. & Bell, Wm.	235,057	Nov. 30, 1880	C
Slocum, F. L. and Stutz, C. C.	1,304,211	May 20, 1919	B
Slocum, F. L. and Stutz, C. C.	1,304,212	May 30, 1919	B
Small, H. J. & Stillman, H.	595,788	Dec. 21, 1897	D 1, F 2
Smedley, J. D.	37,709	Feb. 17, 1863	S
Smith, A. D.	1,239,423	Sept. 4, 1917	J, B
Smith, C. A.	558,747	Apr. 21, 1896	V, D
Smith, H. C.	300,811	June 24, 1884	F II
Smith, Hamilton L.	60,585	Dec. 18, 1866	S
Smith, H. L.	60,076	Nov. 27, 1866	F 2, 4, I
Smith, H. J. & Jones, W.	35,184	May 6, 1852	N
Smith, Rollin H.	306,653	Oct. 14, 1884	C
Smith, Wm.	23,119	Apr. 19, 1850	G, S
Smith, Wm. A.	596,437	Dec. 28, 1897	V
Smothers, H. F. & Norquist, E. E.	1,263,337	May 14, 1918	Q
Snee, J. A.	1,165,568	Dec. 28, 1915	K 2
Snelling, W. O.	1,056,845	Mar. 25, 1913	J, K 2, B
Snelling, W. O.	1,186,855	June 13, 1916	F 1
Snelling, W. O.	1,215,732	Feb. 13, 1917	V
Snow, Wm. B.	130,668	Aug. 20, 1872	S
Snow, Wm. B.	137,496	Apr. 1, 1873	S
Soderlund and Boberg	1,252,962	Jan. 18, 1918	F 2
Sommer, Adolph.	525,969	Sept. 11, 1894	V
Sommer, A.	523,716	July 31, 1894	V
Southey, A. W.	1,120,857	Dec. 15, 1914	K 1
Spangle, George W.	58,905	Oct. 16, 1866	D
Spears, Wm.	107,734	Sept. 27, 1870	F, G
Spier, Robert & Mather, J.	168,060	Sept. 21, 1875	U
Speller, F. N.	774,341	Nov. 8, 1904	N
Squires, Frederick.	1,249,232	Dec. 4, 1917	J, K 2
Squire, F. B.	197,197	Nov. 13, 1877	N

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Name	Number	Date	Class
Stafford, Jas. R.	10,813	Apr. 25, 1854	U
Starke, Eric A.	597,920	Jan. 25, 1898	D 1
Starke, E. A.	781,240	Jan. 31, 1905	E 3, B
Stanley, A. M.	1,177,904	Apr. 4, 1916	K 1
Starke, E. A.	913,780	Mar. 2, 1909	D, F 2
Starke, E. A.	1,109,187	Sept. 1, 1914	D 1
Stearns, H. A.	103,385	May 24, 1870	F 2, II
Steenbergh, B. van	1,124,364	Jan. 12, 1915	K 1, B
Steinschneider, ——	1,302,988	May 6, 1919	S
Steinschneider, Leo.	981,953	Jan. 17, 1911	F 5
Steinschneider, Leo.	1,192,581	July 25, 1916	F 5
Stelwagon, W. H.	503,996	Aug. 29, 1893	S
Stevens, Levi.	363,432	May 24, 1887	F 2
Stevens, Levi.	414,601	Nov. 5. 1889	B
Stevens, Wm. H.	1,165,462	Dec. 28, 1915	M
Stewart, John L.	24,587	June 28, 1850	W
Stewart, J. L.	162,965	May 4, 1875	F 2, II
Stewart, J. L. & Logan, J. P.	113,811	Apr. 18, 1871	F
Stewart, J. L. & Dubler, J. B.	136,557	Mar. 4, 1873	S
Stewart, Lyman.	1,163,570	Dec. 7, 1915	B
Still, Carl.	1,080,177	Dec. 2, 1913	S
Stombs, D. S. & Brace, J.	27,842	Apr. 10, 1860	G
Stone, C. W.	1,070,555	Aug. 19, 1913	A
Stott, Chas.	68,257	Aug. 19, 1867	F 1, 2
Strache, H. & Porges, P.	1,205,578	Nov. 21, 1916	B
Strain, E. W.	311,543	Feb. 3, 1883	F 1, 2, II
Street, G. E. J.	70,715	Mar. 11, 1902	M
Stringfellow, John H. W.	454,777	June 23, 1891	D
Stuber, John, Stuber, Jacob & Mager, John W.	123,741	Feb. 13, 1872	F 1, 2, II
Suckert, Julius J.	534,295	Feb. 19, 1895	V
Suhr, C. L.	1,122,169	Dec. 22, 1914	F 2, II
Swan, O. C.	1,250,526	Dec. 18, 1917	A
Swan, O. C.	1,283,945	Nov. 12, 1918	S
Swaton, J. A.	1,260,731	Mar. 26, 1918	B
Sylvester, F.	68,669	Sept. 10, 1867	A
Symmes, H. K.	26,000	Nov. 1, 1859	G
Symonds, D.	65,136	May 28, 1867	V
Symonds, D.	65,137	May 28, 1867	V
Tagliabue, Chas. J.	265,462	Oct. 3, 1882	F 1, 2, 3, 4, II
Tagliabue, Chas. J.	254,176	Feb. 28, 1882	F 1, 2, II
Tagliabue, Giuseppe.	36,826	Oct. 28, 1862	N
Tagliabue, Chas. J.	1,263,145	Apr. 16, 1918	N
Tagliabue, Giuseppe.	38,427	May 5, 1863	N
Tagliabue, John.	36,488	Sept. 16, 1862	N
Tait, A. H.	96,997	Nov. 16, 1869	S
Tait, E. W.	1,069,908	Aug. 12, 1913	J, K 2
Tait, G. M. S.	1,128,549	Feb. 16, 1915	K 1, B
Tait, A. H. & Avis, J. W.	53,359	Mar. 20, 1866	F 2, 3, II
Tait & Avis.	63,115	Mar. 19, 1867	F 1
Tait & Avis.	135,673	Feb. 11, 1873	F 2, II
Tatro, Jos. A.	99,728	Feb. 8, 1870	D 1
Tatro, Jos. A.	106,233	Aug. 9, 1870	D 1
Taveau, Rene de M.	1,271,387	July 2, 1918	I, E 1
Taylor, H. K. & Graham, D. M.	54,978	May 22, 1866	D 1
Taylor & Graham	59,751	Nov. 20, 1866	D 1
Tempere, Albert J.	557,291	Mar. 31, 1896	V, D
Testelin, A. & Rehard, G.	1,138,260	May 4, 1915	B
Theisen, Eduard.	552,456	Dec. 31, 1895	F
Theisen, Eduard.	552,455	Dec. 31, 1895	F
Thiele, Felix C.	683,354	Sept. 24, 1901	D 1
Thiele, Felix Carl	1,254,866	Jan. 29, 1918	L
Thirault, A.	61,120	Jan. 8, 1867	F 4, II
Thirault, A.	41,871	Mar. 8, 1864	
Thirault, A.	63,963	Apr. 16, 1867	F 2
Thomas, John J.	178,889	June 20, 1876	S
Thomas, Joshua.	282,239	July 31, 1883	F II
Thomas, Joshua.	314,490	Mar. 24, 1885	F 2
Thomas, Richard.	781,854	Feb. 7, 1905	S
Thompson, W. P.	1,160,670	Nov. 16, 1915	B

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Name	Number	Date	Class
Thumm, Chas. F.	389,988	Sept. 25, 1888	F 2, 4
Thursby, John.	3,067	May 2, 1843	M
Tiemann, Julius H.	321,465	July 7, 1885	D 1
Tiemann, J. H.	330,637	Nov. 17, 1885	D 1
Tienen, W. O. Th. van	1,000,646	Aug. 15, 1911	I
Timmons, J. R.	1,105,383	July 28, 1914	F 1, II
Timmons & Swain, O.	1,179,243	Apr. 11, 1916	F 1
Tilton, Ole.	204,943	Nov. 12, 1878	F 2, 4
Timmons, J. R.	1,279,611	Sept. 24, 1918	A
Tokheim, J. J.	1,248,951	Dec. 4, 1917	A
Toppan, Chas.	498,588	May 30, 1893	D
Travers, W. J.	1,004,219	Sept. 26, 1911	A
Trewby, G. C. & Fenner, H. W.	252,981	Jan. 31, 1882	F 2
Trumble, Milton J.	996,736	July 4, 1911	S, F
Trumble, M. J.	1,002,474	Sept. 5, 1911	F 1, II
Trumble, M. J.	1,070,361	Aug. 12, 1913	F 2, II
Trumble, M. J.	1,182,601	May 9, 1916	E 2, F 2, II
Trumble, M. J.	1,250,052	Dec. 11, 1917	F, S
Trumble, M. J.	1,259,171	Mar. 12, 1918	F 2, A
Trumble, M. J.	1,260,598	Mar. 26, 1918	F
Trumble, M. J.	1,262,875	Apr. 16, 1918	F
Trumble, M. J.	1,269,134	June 11, 1918	K 2, S
Turner, C. W.	1,046,683	Dec. 10, 1912	B
Turner, C. W.	1,151,422	Aug. 24, 1915	B
Turner, R. D.	194,275	Aug. 14, 1877	A, V
Thompson, N. W.	1,298,602	Mar. 25, 1919	S
Trumble, M. J.	1,304,125	May 20, 1919	B
Trumble, M. J.	1,304,124	May 20, 1919	A
Trumble, M. J.	1,281,884	Oct. 15, 1918	B
Turner, R. D.	154,430	Aug. 25, 1874	A
Turner, R. D.	156,899	Nov. 17, 1874	S, F
Tweddle, Herbert W. C.	120,349	Oct. 24, 1871	D
Tweddle, H. W. C.	189,401	Apr. 10, 1877	T
Tweddle, H. W. C.	189,402	Apr. 10, 1877	T
Tweddle, H. W. C.	45,363	Dec. 6, 1864	K 2
Tweddle, H. W. C.	72,125	Dec. 10, 1867	F 2, 5, II
Tweddle, H. W. C.	72,126	Dec. 10, 1867	F 2, 5, II
Tweddle, H. W. C.	34,324	Feb. 4, 1862	G, F 2, 5, II
Tyler, Chas. N.	38,015	Mar. 24, 1863	M
Ujhely, Heinrich.	289,788	Dec. 4, 1883	D
Ujhely, H. & Buerle, C.	131,137	Sept. 3, 1872	C
Upham, Richard D.	512,494	Jan. 9, 1894	E 3
Van Devort, C. & Van Fleet, C.	168,542	Oct. 5, 1875	F 2
Van Dyke, J. & Irish, Wm.	1,095,438	May 5, 1914	B
Van Dyke & Irish.	1,073,548	Sept. 16, 1913	B
Van Dyke & Irish.	1,143,466	June 15, 1915	B
Van Dyke & Irish.	1,130,862	Mar. 9, 1915	B
Van Vliet, L. & O'Neil, F.	1,094,762	Apr. 28, 1914	K 1
Vander Weyde, Peter H.	104,798	June 28, 1870	N
Vander Weyde, P. H.	61,125	Jan. 8, 1867	A
Vander Weyde, P. H.	58,005	Sept. 11, 1866	F 2, 4, 5, II
Vander Weyde, P. H.	58,512	Oct. 2, 1866	F
Vander Weyde, P. H.	53,062	Mar. 6. 1866	F
Van Syckel, Samuel.	191,203	May 22, 1877	F, II
Van Syckel, S.	140,801	July 15, 1873	F 2
Van Syckel, S.	152,440	June 23, 1874	F, II
Van Syckel, S.	126,503	May 7, 1872	S
Van Syckel, S.	154,772	Sept. 8, 1874	F, II
Van Syckel, S.	154,771	Sept. 8, 1874	U
Van Syckel, S.	143,945	Oct. 21, 1873	K 2
Van Syckel, S.	110,516	Dec. 27, 1870	F 2, I
Van Syckel, S.	191,204	May 22, 1877	F, II
Van Tine, Henry C.	60,290	Dec. 4, 1866	D
Van Wyck, C. I.	27,603	Mar. 20, 1860	W
Van Wyck, William.	65,313	May 28, 1867	S
Vaughan, Aaron C.	53,709	Apr. 3, 1866	G
Vaughan, John Ives.	49,689	Aug. 29, 1865	F 1, 2, II
Von Boyen, Edgar.	689,381	Dec. 24, 1901	C
Von Boyen, Edgar.	690,693	Jan. 7, 1902	C
Vuilleumier, Rudolph.	1,038,691	Sept. 17, 1912	K 1, B

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Name	Number	Date	Class
Von Groeling, A. F. G. P. J.	1,295,088	Feb. 18, 1919	B
Waddell, Alexander.	1,249,864	Dec. 11, 1917	K 1
Waitz, J. W.	1,105,727	Aug. 4, 1914	J, K 2
Walker, Henry V.	972,953	Oct. 18, 1910	D 1
Walker, H. V.	955,372	Apr. 19, 1910	V
Walker, W. E.	1,307,280	June 17, 1919	L, K
Wallace, Geo. W.	1,283,000	Oct. 29, 1918	W
Wallace, John Stewart.	716,132	Dec. 16, 1902	D
Warden, Henry.	266,929	Oct. 31, 1882	C
Warden, Wm. G.	240,937	May 3, 1881	S
Warden, Wm. G.	250,936	May 3, 1881	S, D
Warden, Wm. G.	110,806	Jan. 3, 1871	F 1, II
Warden, Wm. G.	112,751	Mar. 14, 1871	F 1
Warfield, R. N.	40,068	Sept. 22, 1863	V
Waring, Richard S.	284,098	Aug. 28, 1883	T
Waring, Wilson.	643,578	Feb. 13, 1900	I
Warren, Cyrus M.	248,074	Oct. 11, 1881	T
Warren, Cyrus M.	47,235	Apr. 11, 1865	U
Warren, John.	97,998	Dec. 14, 1869	F
Warren, John.	102,186	Apr. 19, 1870	S
Warren, John W.	705,168	July 22, 1902	V
Warren, John W.	666,446	Jan. 22, 1901	V
Warren, M. H.	1,110,361	Sept. 15, 1914	B
Warth, C. H.	1,131,880	Mar. 16, 1915	F 2, II, G
Washburn, C. H.	1,138,266	May 4, 1915	B
Weisenberger, P.	54,984	May 22, 1866	D 1
Weiser, Josef.	1,127,951	Feb. 9, 1915	S
Wellman, F. E.	1,275,337	Aug. 13, 1918	B
Wells, A. A.	1,232,454	July 3, 1917	B
Wells, A. A.	1,187,874	June 20, 1916	B
Wells, A. A.	1,248,225	Nov. 27, 1917	B, J
Wells, Willet C. & Wells, F. E.	877,620	Jan. 28, 1908	F 1, 3, II
Wells, W. C. & F. E.	1,296,244	Mar. 4, 1919	F
Welles, Wm. C.	61,291	Jan. 15, 1867	S
Wellman, F. E.	1,245,291	Nov. 6, 1917	B, S
Welsh, M. J.	1,159,450	Nov. 9, 1915	C
Wemple, H. R.	1,262,886	Apr. 16, 1918	K 1
Wendtland, August.	618,307	Jan. 24, 1899	C
Weston, Elijah.	219,546	Sept. 9, 1879	S
Wetmore, I. W.	39,978	Sept. 15, 1863	U
Wheeler, Norman W.	52,477	Feb. 6, 1866	S
Whitall, Frank M.	768,101	Aug. 24, 1904	T
Whitall, Samuel R.	734,482	July 21, 1903	T
White, Carter.	1,226,041	May 15, 1917	B
Whiting, Jas. R.	622,936	Apr. 11, 1890	S
Whiting, J. R. & Lawrence, W. A.	583,779	June 1, 1897	V
Whitmore, Samuel W.	1,125,422	Jan. 19, 1915	F 1, II
Wiegand, S. Lloyd.	39,607	Aug. 18, 1863	F 2
Wiegand, S. Lloyd.	62,583	Mar. 5, 1867	C
Wiggins, Isaac B.	63,777	Apr. 9, 1867	M
Wilber, William.	23,210	Mar. 8, 1859	M
Wilcox, L. N.	49,020	July 25, 1865	F
Wilkinson, Asa W.	145,707	Dec. 19, 1873	F 3
Wilkinson, Walter S.	512,348	Jan. 9, 1894	E 3
Wilkinson, Walter S.	597,892	Jan. 25, 1898	E 3
Willard, Franklin W.	26,739	Jan. 3, 1880	G, S
Willard, Franklin W.	27,503	Mar. 13, 1860	F
Willard, Franklin W.	27,327	Feb. 28, 1860	G, S
Williams, R. A. & Bragg, J.	304,390	Sept. 22, 1884	S
Willis, Geo. M.	918,628	Apr. 20, 1909	E 3
Wilson, R. J.	379,090	Mar. 6, 1888	F 4
Wingett, John N.	1,229,189	June 5, 1917	P
Wintz, Jas. P.	807,983	Dec. 19, 1905	D
Wirkner, George von.	783,916	Feb. 28, 1905	D 1
Wolff, Albert.	1,240,523	Sept. 28, 1917	D
Wolf, Hermann.	604,280	May 17, 1898	D 1
Wolf, Linus.	1,265,573	May 7, 1918	K 1
Wohle, Salo.	1,081,801	Dec. 16, 1913	D 1
Wynne, Edward W.	901,411	Oct. 20, 1908	D

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Name	Number	Date	Class
Wallace, Geo. W.	1,283,001	Oct. 29, 1918	F, W
Wells, Raymond.	1,267,611	May 28, 1918	A
Wright, E. H. & Atwood, E. H.	1,278,280	Sept. 10, 1918	F
Whitman, J. C.	1,312,375	Aug. 5, 1919	O, S
Yaryan, Homer T.	300,185	June 10, 1884	F 2, 5, II
Young, Jas.	127,446	June 4, 1872	D 1
Young, W. H.	62,798	Mar. 12, 1867	O
Zerning, Hermann.	1,183,266	May 16, 1916	J, K 2, B
Zimmerling, August F.	313,795	Mar. 10, 1885	M

BOOKS ON PETROLEUM, ASPHALT AND NATURAL GAS

Abady—Gas Analyst's Manual	$ 6.50
Abraham—Asphalts and Allied Substances	5.00
Aisinmann—Taschenbuch fur die Mineralol-Industrie. 8vo. Berlin, 1896	
Allen—Modern Power Gas Producer	2.50
Archbutt and Deeley—Lubrication and Lubricants. 8vo. London, 1912	
Bacon and Hamor—The American Petroleum Industry	10.00
Baker—Roads and Pavements	5.00
Battle—Lubricating Engineer's Handbook	4.00
Berlinerblau—Das Erdwachs, Ozokerit and Cerestin. 8vo. Brunswick, 1917	
Booth—Liquid Fuel	3.00
Boorman—Asphalts: Their Sources and Utilizations	2.60
Brannt—Petroleum: Its History, Origin, Occurrence, Production, Physical and Chemical Constitution, Technology, Examination and Uses. Philadelphia and London, 1895	
Butler—Oil Fuel: Its Supply, Composition and Application	2.25
Campbell—Petroleum Refining	8.50
Clowes and Redwood—The Detenticn and Measurement of Inflammable Gas and Vapor in the Air. 8vo. London, 1916	
Cooper-Key—Storage of Petroleum Spirit. London, 1914	
Coste—Calorific Power of Gas	2.00
Craig—Oil Finding	2.40
Crew—A Practical Treatise on Petroleum. 8vo. Philadelphia, 1887	
Danby—Natural Rock Asphalts and Bitumens	2.50
Delano—Twenty Years' Practical Experience of Natural Asphalt and Mineral Bitumen. 8vo. London and New York, 1893	
Dennis—Gas Analysis	2.10
Deutsch (De la Meurthe)—Le Petrole et ses Applications. Paris, N. D.	
Dowson and Larter—Producer Gas	3.00
Dunn—Industrial Uses of Fuel Gas	3.00
Franzen—Exercises in Gas Analysis	1.00
Frost—The Art of Roadmaking	3.00
Gas Chemist's Handbook	3.50
Gibbings—Oil Fuel Equipment for Locomotives and Principles of Application	2.50
Gill—Short Handbook of Oil Analysis	2.50
Gregorius—Mineral Waxes: Preparation and Uses	2.50
Hager—Practical Oil Geology	2.50
Hempel—Methods of Gas Analysis	2.25
Hicks—Laboratory Book of Mineral Oil Testing	1.00
Hofer—Das Erdol (Petroleum) und Seine Verwandten. Brunswick, 1888	
Holde-Mueller—Examination of Hydrocarbon Oils	5.00
Hubbard—Dust Preventives and Road Binders	3.00
Jaccard—Le Petrole, L'Ashphalte, et le Bitume au Point de vue Geologique. Paris, 1895	
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