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REPORT OF INVESTIGATIONS

UNITED STATES DEPARTMENT OF THE INTERIOR - BUREAU OF MINES

SURVEY OF CRUDE OIL IN STORAGE, 1936-1937[1/]

By Petroleum Economics Division and Petroleum and Natural Gas Division,

Bureau of Mines

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1/ The Bureau of Mines will welcome reprinting of this paper, provided the following footnote acknowledgment is used: "Reprinted from Bureau of Mines Report of Investigations 3417."

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INTRODUCTION

Early in 1936 the Interstate Oil Compact Commission and other groups interested in forecasts of demand for petroleum requested the Bureau of Mines to make a physical inventory of crude-oil stocks in the United States. Accordingly, the 74th Congress appropriated funds for conducting such a survey during the fiscal year ended June 30, 1937. In the discussions and hearings[2/] relative to the need for the survey, the opinion was expressed that crude oil held in storage for long periods had lost so much of its gasoline content that the economic significance of total stocks should be discounted materially. Therefore, a primary objective of the survey was to

2/ Hearings before Subcommittee of House Committee on Appropriations in charge of Interior Department Appropriation Bill for 1937, 74th Cong., 2nd sess., pp. 1186-92.

make a physical inventory of the crude oil held in storage above ground and to determine the quantities and characteristics of the light fractions contained in the various stocks.

The work was initiated July 1, 1936, covering stocks as of June 30, 1936. Data were collected during the ensuing fiscal year ended June 30, 1937, and the findings were published by the Bureau of Mines in a preliminary report3/, which was read on July 12, 1937, at a meeting of the Interstate Oil Compact Commission in Santa Fe, N. Mex. The present report presents a more complete analysis of the results of the survey and includes data that have been assembled since the preliminary report was prepared. It also includes appendices presenting data collected in the course of the survey relative to storage tanks, pipe lines, and characteristics of oils that were enroute to markets in pipe-line systems in 1937.

ACKNOWLEDGMENTS

This survey of crude-oil stocks, including the preparation of both reports, was a joint project of the Petroleum and Natural Gas Division, headed by R. A. Cattell, and the Petroleum Economics Division, headed by A. G. White. In general, the collection and analysis of samples to determine the characteristics of the various stocks of oil was handled by the Petroleum and Natural Gas Division, and the statistical and economic work was done by the Petroleum Economics Division.

The samples were collected by members of the Bartlesville, Laramie, and Amarillo stations and the Dallas and San Francisco offices of the Petroleum and Natural Gas Division. The analytical work was done at the Bartlesville station under the general direction of N. A. C. Smith, supervising engineer, and Ludwig Schmidt, senior petroleum engineer, and under the immediate supervision of J. W. Horne and E. C. Lane. Assisting in the work at Bartlesville were E. L. Garton, Lloyd Christianson, and a number of other members of the staffs of the Bartlesville and Laramie stations.

The statistical and economic work was done in Washington by A. G. White and G. R. Hopkins, in Bartlesville by F. S. Lott and Tell T. White, and in San Francisco by E. T. Knudsen, all of the Petroleum Economics Division.

The sampling, analytical, and statistical work involved in the survey was of considerable magnitude and was accomplished only through the wholehearted cooperation of the entire petroleum industry and assistance of various State officials.

3/ A Preliminary Report of the Survey of Crude Oil in Storage, 1936-1937: Supplement to Monthly Petroleum Statement No. 159, Bureau of Mines, July 13, 1937, 18 pp.

METHOD OF CONDUCTING SURVEY

Briefly, the survey involved four steps: Collection of detailed statistics showing quantities, locations, and other pertinent data concerning oils in storage and in transit; sampling of representative stocks; analysis of these samples; and evaluation of the facts.

Statistical Reports

Although the Bureau of Mines for years has obtained monthly data concerning stocks of crude petroleum, by States and districts of origin and by States of location, these figures were not in detail compatible with the objectives of the present survey. Therefore, it was necessary to prepare special forms, designated generally as CP forms, embracing items such as size, location, and contents of each tank used in the storage of crude petroleum. Supplementary questions as to the shells and roofs of the tanks were included in these forms.

The CP forms were sent only to companies holding 100,000 barrels or more of refinable crude oil, as indicated by monthly reports sent to the Bureau, because stocks of such companies are at least 95 percent of the total. Lease stocks were disregarded, as they amount to only about 3 percent of the total and it would have been impossible with the funds and time available to make an adequate survey of the thousands of small tanks used at the wells.

Sampling

The information supplied on the CP forms was used in designating the tanks to be sampled. Many tank farms, especially those used in the storage of the older oil, contained only one type of petroleum, all having been produced at about the same time. In such instances it was generally found that a sample from one tank was representative of the crude oil in several tanks. Tanks containing inconsequential amounts of oil also were eliminated in the sampling program. In all, about 1,500 samples were collected, or about one sample for every 10 tanks.

The controlling factors in the sampling program were age, location, origin, and quantity of the oil. In some instances stocks of recently produced oil reported to be on hand June 30, 1936, had been moved by the time of sampling, so samples of current oil from the same source were substituted for the original oil.

A sample was obtained by lowering a half-gallon container in a special holder to a point midway between the top of the oil and the level of B. S. (basic sediment) and water in the tank. Experience of the Petroleum and Natural Gas Division in its studies of evaporation losses has shown that such a sample is closely representative of the merchantable oil. After a sample container was filled, it was sealed and shipped to the laboratory of the Bureau's Petroleum Experiment Station, Bartlesville, Okla., for analysis.

All samples were taken by members of the staff of the Bureau of Mines with a company representative usually present. Field representatives of the companies helped materially by supplying data supplementary to those previously obtained on the CP forms.

Analytical Work

The Bureau of Mines Hempel method of distillation, described by Dean and others[4/], was used in analyzing the samples. This method is based on a carefully controlled laboratory distillation and includes a summary of data concerning the distilled fractions.

As the information required in this survey related primarily to the lighter fractions in the crude oil, the analysis of all but a few samples was carried only through "distillation at atmospheric pressure." Ordinarily, 527° F. (275° C.) is the highest vapor temperature reached in this distillation; however, for purposes of the survey, an additional cut was made to determine the fraction distilling between 527° and 572° F. (275° and 300° C.). In some crude petroleums this fraction "cracks" during a distillation at atmospheric pressure. All distillations were watched closely and any "cracking" was recorded.

In addition to the data from the distillations, the gravity and carbon residue of each sample and the amount and gravity of the residue remaining in the flask after the distillation was completed were determined. In the laboratory, 60 analytical tests and observations were made on each crude-oil sample, or 90,000 determinations for the 1,500 samples collected. A report of a typical laboratory analysis is shown in table 1.

QUANTITATIVE DISCUSSION OF CRUDE-OIL STOCKS

Net Stocks

The crude-oil stocks studied in the survey may be defined as net, refinable stocks; the term "net" generally refers to gross stocks minus basic sediment (B.S.) and water, and the term "refinable" designates total net crude-oil stocks minus the stocks of the heaviest grades not ordinarily refined. Strictly speaking, net stocks are stocks corrected for expansion or contraction to the standard temperature of 60° F.; however, most companies do not make these rather arduous adjustments more than once or twice a year, hence most of the Bureau's figures are uncorrected for temperature.

The definition of net stocks as given above excludes from consideration approximately 30 million barrels of B. S. and water as well as about 65 million barrels of heavy crude oil and fuel oil stored in California. Stocks of crude oil of foreign origin, normally amounting to several million barrels, were included, as virtually all such imports are refined in satisfying a small part of the domestic demand for products.

4/ Dean, E. W., Hill, H. H., Smith, N. A. C., and Jacobs, W. A., The Analytical Distillation of Petroleum and Its Products: Bull. 207, Bureau of Mines, 1922, pp. 4-35.

TABLE 1. - Typical laboratory analysis of crude-petroleum samples for survey of crude oil in storage

GENERAL CHARACTERISTICS

Sample 1664.
Field of origin, mixture, western Kansas fields.
Specific gravity, 0.818.

Amount represented by sample, 70,965 bbls.
Year stored, 1936.
A.P.I. gravity, 41.5°.

Distillation, Bureau of Mines Hempel method.

Distillation at atmospheric pressure. Barometer, 750 mm. First drop, 23°C. (73°F.)

Temperature, °C.	Percent cut	Sum, percent	Sp.gr. of cut	°A.P.I. of cut	Temperature, °F.
Up to 50	5.5	5.5	0.633	92.0	Up to 122
50 - 75	3.3	8.8	.672	79.1	122 - 167
75 - 100	5.9	14.7	.707	68.6	167 - 212
100 - 125	7.7	22.4	.734	61.3	212 - 257
125 - 150	6.1	28.5	.753	56.4	257 - 302
150 - 175	4.8	33.3	.776	50.8	302 - 347
175 - 200	6.0	39.3	.787	48.3	347 - 392
200 - 225	5.0	44.3	.803	44.7	392 - 437
225 - 250	5.4	49.7	.816	41.9	437 - 482
250 - 275	4.0	53.7	.829	39.2	482 - 527
275 - 300	7.5	61.2	.839	37.2	527 - 572

Carbon residue of residuum 6.0 percent. Carbon residue of crude 2.2 percent.

APPROXIMATE SUMMARY

	Percent	Sp.gr.	°A.P.I.
Distillate recovered below 100°C. or 212°F.	14.7	0.671	79.4
Distillate recovered below 200°C. or 392°F.	39.3	.726	63.4
Distillate recovered below 225°C. or 437°F.	44.3	.735	61.0
Distillate recovered between 225°C. and 300°C. (437°F. - 572°F.)	16.9	.829	39.2
Residuum	36.4	.925	21.5
Distillation loss	2.4	---	---

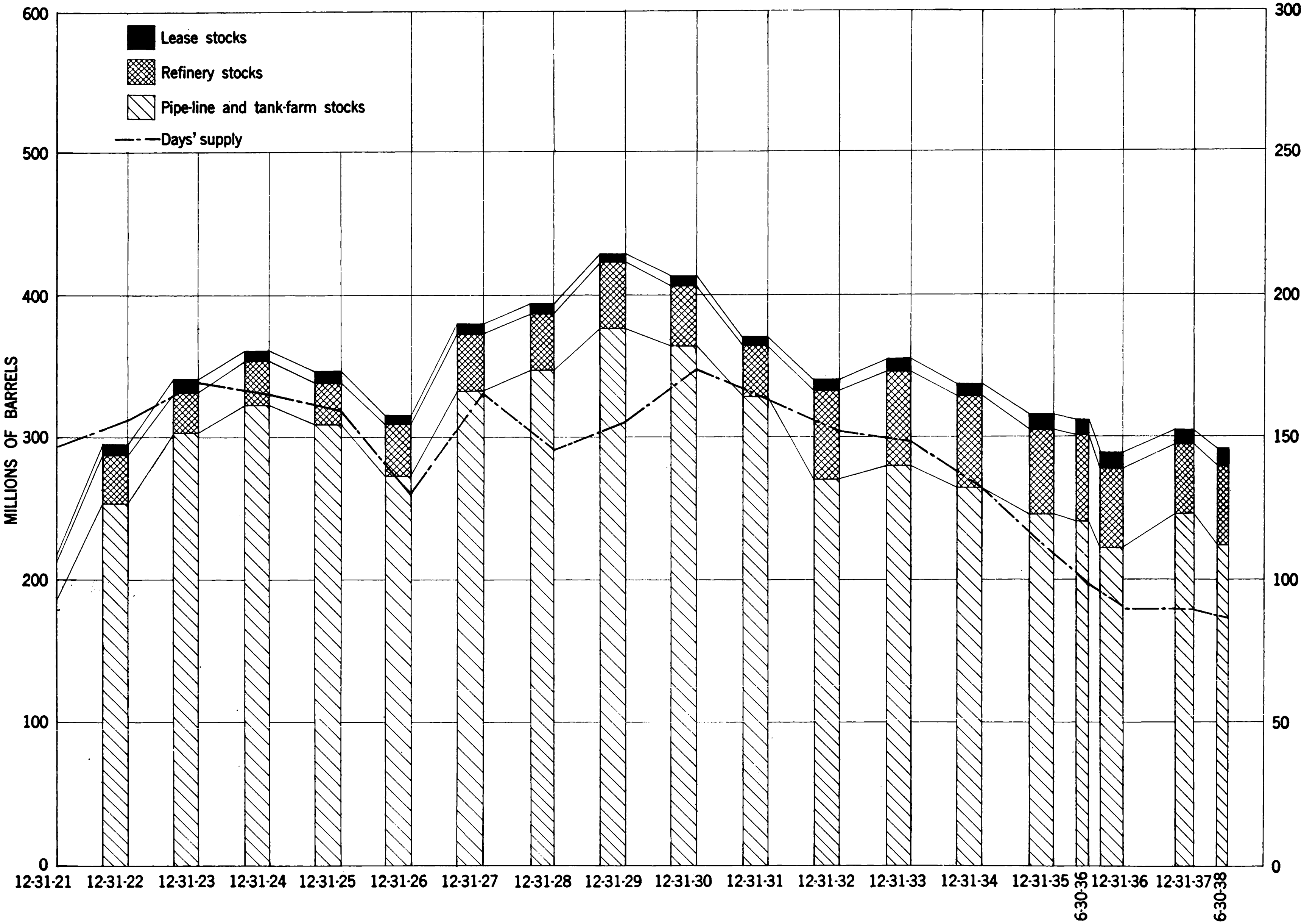

Figure 1.—Crude-oil stocks by principal types and days' supply, Dec. 31, 1921, to June 30, 1938.

Trend in Total Stocks

As shown in table 2 and figure 1, total net stocks of refinable crude oil in the UnitedStates over the past 15 years have fluctuated considerably, with a high of about 434 million barrels in the latter part of 1929 and a low of about 287 million barrels on January 31, 1937.

The decline from the high to the low point is indicated as 147 million barrels; actually, the net withdrawal was about 148 million barrels, as the positive revisions due to "change of base" exceed the negative revisions by about 1 million barrels.

Although, as previously noted, recent reports of crude-oil stocks to the Bureau of Mines cover only net, refinable oil, that was not always the case. For example, stocks of heavy crude in California and imported topped crude were included in the earlier years. On the other hand, additional stocks were "discovered" occasionally or were transferred to crude-oil stocks from other categories. These unavoidable changes in definition have been handled by showing two figures for December 31, one comparing with preceding data, and the other with succeeding data. (See table 2.) These changes of base permit the calculation of yearly additions or withdrawals but do not allow direct comparisons of totals for all the years.

In general, the major upward movements of crude-oil stocks in the last 15 years have occurred in periods marked by numerous discoveries of large fields, specifically the periods 1922 to 1924 and 1926 to 1929. Proration, which received its first major impetus in the Seminole era, has tended to prevent radical increases in crude-oil stocks, although several breakdowns of curtailment in the East Texas field were followed by material additions.

An analysis of the monthly stock figures for the period from the beginning of 1922 to June 30, 1938 (table 2) shows that stocks have increased 96 times and declined 102 times. As the total has shown a material net increase of 120 million barrels in the 16-1/2-year interval, it is evident that the average monthly increase has exceeded the average monthly withdrawal. The seasonal factor in crude-oil stock levels is much less evident than in gasoline stocks, but a frequency table of monthly changes shows that in February, March, April, and May stocks usually increase and in July, August, September, and October they decline. These movements are largely a result of variations in crude-oil runs to stills, which, in turn, are influenced by gasoline demand.

Stocks, by location

Although stocks of crude petroleum at refineries have been reported by districts of origin and location for a number of years, data showing the total crude stocks stored in individual States have been available only since the beginning of the code period late in 1933. Such data for various dates are shown in tables 3 and 4.

TABLE 2. – Stocks of crude petroleum at end of each month, Dec. 31, 1921, to June 30, 1938
(thousands of barrels)

	Jan.	Feb.	March	April	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.
1921	-	-	-	-	-	-	-	-	-	-	-	217,324
1922 1/	228,411	241,102	258,836	274,934	289,069	298,765	303,731	304,066	304,975	305,717	305,931	306,811
												2/295,708
1923 3/	296,660	297,488	304,811	310,395	319,800	331,105	342,203	350,746	356,739	367,071	375,630	376,615
												2/340,637
1924..	341,611	346,924	349,377	355,449	359,753	363,518	367,954	372,740	373,747	372,262	368,011	361,655
1925..	361,252	361,032	360,337	361,091	364,594	362,730	359,550	352,695	351,932	349,951	349,095	343,820
												2/345,863
1926..	343,244	341,079	339,315	4/332,059	328,252	323,259	318,817	316,564	314,802	314,017	313,244	315,029
1927..	316,253	322,003	326,711	334,319	340,183	348,474	355,908	363,148	369,111	374,606	379,016	379,660
1928..	387,375	391,371	396,302	398,060	398,602	397,704	394,635	393,877	390,367	391,324	390,754	391,869
												2/392,629
1929..	398,534	406,037	411,734	415,033	416,761	419,232	424,296	430,537	433,425	433,501	428,388	428,445
1930..	427,739	431,357	430,662	429,933	427,958	425,503	425,767	422,622	417,195	416,206	413,768	408,809
												2/411,882
1931..	409,227	405,199	401,515	400,439	398,972	397,304	395,195	381,356	370,822	367,171	368,585	370,919
												2/370,194
1932..	368,302	368,353	371,050	370,981	369,072	363,696	358,308	354,846	354,104	351,893	348,432	339,715
												2/339,875
1933..	337,483	337,107	344,253	339,140	348,103	352,756	355,263	359,945	359,904	356,849	355,199	355,312
												2/354,223
1934..	353,642	351,641	354,067	354,350	355,883	357,451	355,525	351,092	349,407	346,800	341,403	337,254
1935..	338,199	337,349	339,179	339,823	338,619	334,841	329,459	325,106	320,880	317,955	315,779	314,855
1936..	313,330	311,078	313,448	315,626	315,434	311,311	306,680	302,057	296,018	292,641	289,378	288,579
												2/288,184
1937..	286,759	289,972	297,496	304,161	308,209	308,788	308,666	310,923	309,742	308,472	305,747	306,084
												2/305,091
1938..	306,195	306,349	309,403	307,297	298,983	292,634						

1/ Includes heavy crude in California and topped foreign crude held by importers. 2/ To compare with subsequent years. 3/ Includes heavy crude in California. 4/ Fire loss in California, 4,600,000 barrels.

TABLE 3. - Stocks of crude petroleum, 1933-37, by States of location
(thousands of barrels)

	Dec. 31, 1933	Dec. 31, 1934	Dec. 31, 1935	June 30, 1936	Dec. 31, 1936	Dec. 31, 1937
Arkansas	5,663	3,924	4,314	4,143	3,564	2,541
California	35,879	37,529	38,944	37,856	34,189	30,407
Colorado	317	439	485	450	457	519
Georgia 1/	596	713	706	655	378	562
Illinois	11,952	11,719	11,630	10,750	11,260	10,913
Indiana	3,445	3,122	2,654	2,115	2,447	2,962
Kansas	14,921	13,350	12,171	11,020	8,233	10,715
Kentucky 2/	1,161	1,035	801	1,031	823	953
Louisiana 3/	12,596	11,181	9,204	10,650	10,626	11,848
Maryland	1,123	1,144	1,124	751	1,111	1,320
Massachusetts 4/	1,152	1,078	762	1,073	1,088	1,000
Michigan	1,090	810	744	1,044	766	787
Missouri	5/ 3,480	5/ 3,351	5/ 3,454	5/ 3,662	6/ 3,815	6/ 4,475
Montana	623	1,075	1,127	1,311	1,028	1,430
New Jersey	5,250	5,676	6,051	6,066	5,264	6,294
New Mexico	437	536	669	789	829	1,114
New York	2,007	1,206	1,403	1,294	1,171	1,150
Ohio	8,885	8,079	7,378	7,200	7,040	8,057
Oklahoma	84,029	82,614	70,715	67,006	62,258	70,823
Pennsylvania ..	5,888	6,533	6,070	7,081	7,036	6,544
Texas	124,320	113,001	106,341	107,902	98,488	107,388
Utah	270	282	194	138	113	136
West Virginia .	2,420	2,124	1,988	1,876	1,954	2,151
Wyoming 7/	26,719	26,733	25,926	25,448	24,641	21,995
Total	354,223	337,254	8/ 314,855	311,311	288,579	306,084

1/ Includes Delaware, South Carolina and Virginia.
2/ Includes Tennessee.
3/ Includes Alabama.
4/ Includes Rhode Island.
5/ Includes Iowa.
6/ Includes Iowa and Pipe-line stocks in Nebraska.
7/ Includes refinery stocks in Nebraska and South Dakota.
8/ New basis for Jan. 1, 1936, is 314,631,000 barrels.

TABLE 4. - Stocks of crude petroleum, by States of location, June 30, 1936 and 1937
(thousands of barrels)

	At refineries		At tank farms and in pipe lines		On leases		Total	
	1936	1937	1936	1937	1936	1937	1936	1937
Arkansas	706	737	3,162	1,695	275	245	4,143	2,677
California	7,984	8,451	26,992	21,508	2,880	2,771	37,856	32,730
Colorado	369	387	51	53	30	40	450	480
Georgia 1/.......	655	369	--	--	--	--	655	369
Illinois	985	1,363	9,665	9,686	100	110	10,750	11,159
Indiana	722	1,375	1,385	1,668	8	8	2,115	3,051
Kansas	2,118	2,512	8,362	8,948	540	585	11,020	12,045
Kentucky 2/......	615	525	376	473	40	45	1,031	1,043
Louisiana	3/ 3,690	3/4,471	6,335	7,492	625	530	10,650	12,493
Maryland	751	1,325	--	--	--	--	751	1,325
Massachusetts 4/.	1,073	1,288	--	--	--	--	1,073	1,288
Michigan	166	248	768	841	110	100	1,044	1,189
Missouri	144	341	5/ 3,518	5/ 4,029	--	--	3,662	4,370
Montana	281	337	875	853	155	170	1,311	1,360
New Jersey	5,697	7,108	369	191	--	--	6,066	7,299
New Mexico	18	27	341	488	430	535	789	1,050
New York	1,163	1,045	113	133	18	18	1,294	1,196
Ohio	546	1,098	6,579	6,621	75	75	7,200	7,794
Oklahoma	2,400	2,075	62,676	64,160	1,930	2,020	67,006	68,255
Pennsylvania	4,614	5,016	2,367	1,854	100	100	7,081	6,970
Texas	15,329	15,184	89,628	87,211	2,945	2,850	107,902	105,245
Utah	138	105	--	--	--	--	138	105
West Virginia ...	36	40	1,690	1,838	150	145	1,876	2,023
Wyoming	6/ 1,412	6/1,239	23,666	21,638	370	395	25,448	23,272
United States total	51,612	56,666	248,918	241,380	10,781	10,742	311,311	308,788

1/ Includes Delaware, South Carolina, and Virginia. 2/ Includes Tennessee. 3/ Includes Alabama.
4/ Includes Rhode Island. 5/ Includes Iowa and Nebraska. 6/ Includes Nebraska and South Dakota.

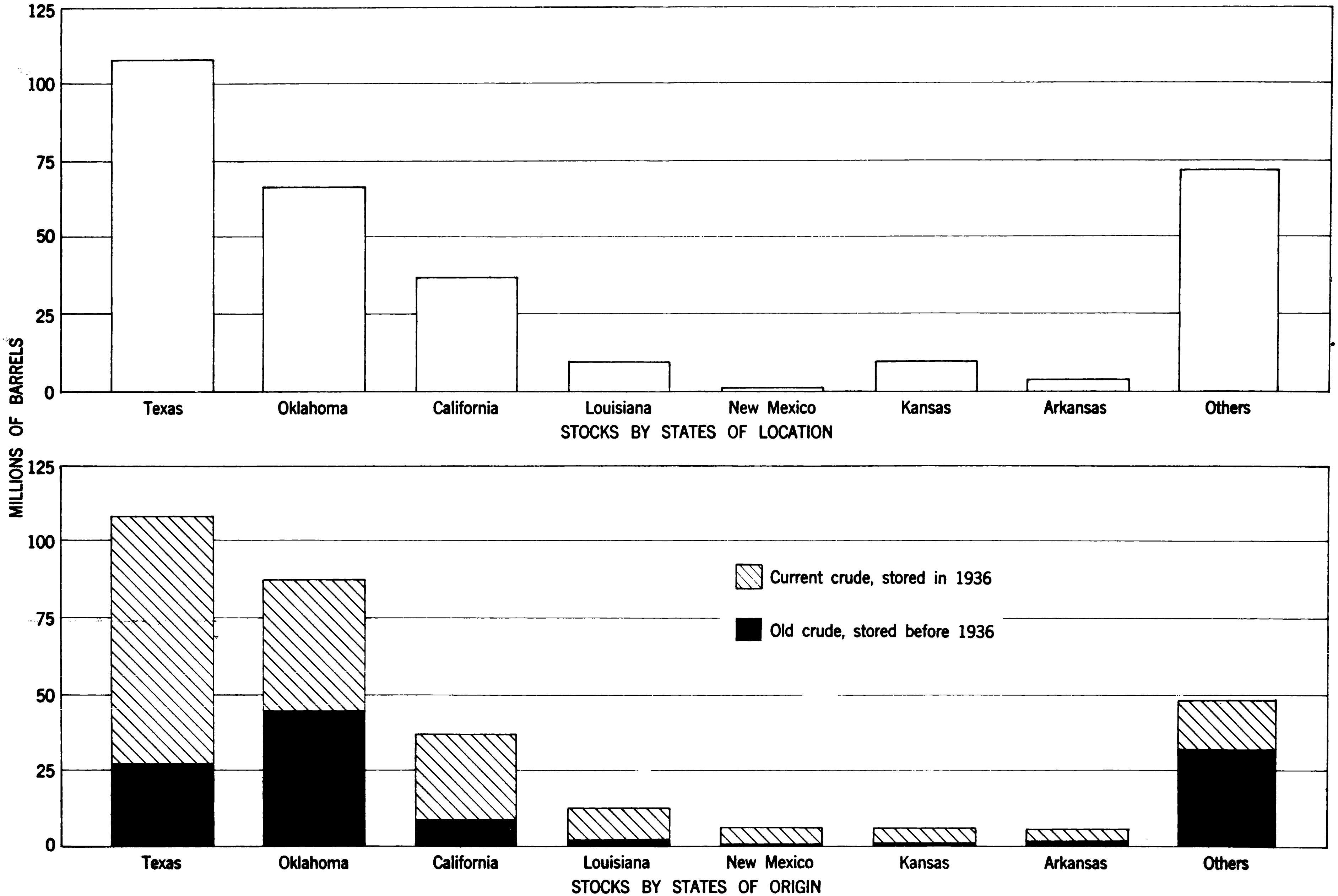

Figure 2.—Crude-oil stocks by States of location and origin, June 30, 1936.

An analysis of table 3 indicates that no important producing State has changed its relative position with regard to the amount of crude oil stored within it. The oil stored in Texas was 35.1 percent of the total at the close of both 1933 and 1937. Oil in storage in Oklahoma fell from 23.7 percent to 23.1 percent of the total in the same period, and California's stock fell from 10.1 to 9.9 percent. There is no direct relationship between the rank of the States in production and that in crude stocks held. In December 1937 Texas had 38.9 percent of the Nation's production and 35.1 percent of the stocks, ranking first in both; but Oklahoma, ranking third in production with 16.6 percent of the total, stood second in stocks, holding 23.1 percent of the oil stored in the Nation; and California, ranking second in production with 20.5 percent, was third in stocks with only 9.9 percent. Wyoming and Illinois were the outstanding examples of States with stocks that were large in proportion to their production.

Table 4, which is included principally to show the changes in the major categories of stocks by States between 1936 and 1937, reveals an increase in refinery stocks balanced by a decline in tank-farm stocks. The effective dates, June 30, 1936, and June 30, 1937, were chosen because total stocks were approximately the same at both times and because the seasonal factor, although vague, was thereby eliminated. Most of the gain in refinery stocks took place at large refineries in Illinois, Indiana, New Jersey, and Pennsylvania. In California, refinery stocks increased although tank-farm stocks were liquidated materially. Tank-farm stocks also were depleted in Arkansas, Texas, and Wyoming, but were increased in Oklahoma. Lease stocks showed relatively little change in the 12 months ended June 30, 1937.

Stocks, by Origin

Although statistics showing total crude-oil stocks by districts of origin (Appalachian, Mid-Continent, etc.) run back about 25 years, the breakdown by States of origin has been available only since the latter part of 1934. These data, for various dates, are given in table 5.

Figure 2 indicates that on June 30, 1936, the quantity of Texas crude oil stored outside that State was about equal to the quantity of oil from other States stored in Texas; and comparisons of data in tables 3 and 5 show that similar relations held on December 31, 1936, and December 31, 1937. On the other hand, the quantity of oil of Oklahoma origin included in the Nation's stocks consistently has exceeded the quantity of oil stored in Oklahoma. For example, on December 31, 1937, 29.6 percent of the Nation's stock was oil of Oklahoma origin, whereas only 23.1 percent was stored in that State. All but a few thousand barrels of California oil is stored within that State. Louisiana, Kansas, and New Mexico, which have increased production rapidly in recent years, have increased their share of stocks based on States of origin.

TABLE 5. - Stocks of crude petroleum, 1934-37, by States of origin
(thousands of barrels)

	Dec. 31, 1934	Dec. 31, 1935	June 30, 1936	Dec. 31, 1936	Dec. 31, 1937
Arkansas	6,380	5,916	5,063	4,772	3,706
California ...	37,529	38,944	37,856	34,189	30,452
Colorado	504	403	379	486	490
Illinois	11,533	11,052	10,268	9,729	9,851
Indiana	49	44	47	46	63
Kansas	5,108	5,165	5,766	5,600	6,478
Kentucky	1,049	764	999	819	909
Louisiana	8,833	8,908	12,292	12,472	12,953
Michigan	800	895	1,105	809	1,129
Montana	1,074	1,108	1,306	993	1,404
New Mexico ...	4,807	5,533	6,154	7,596	10,178
New York	446	438	349	390	427
Ohio	1,047	1,120	1,066	956	896
Oklahoma	108,037	94,350	87,852	80,989	90,509
Pennsylvania .	2,531	2,315	2,369	2,275	2,545
Texas	114,918	106,203	108,546	97,325	105,691
West Virginia.	1,909	1,752	1,665	1,783	1,874
Wyoming	26,909	26,200	25,652	25,233	23,034
Foreign	3,791	3,745	2,577	2,117	3,495
Total ...	337,254	1/ 314,855	311,311	288,579	306,084

1/ New basis for Jan. 1, 1936, is 314,631,000 barrels.

Stocks, by Age Groups

When the results of the survey were analyzed, the stocks were divided into four age groups: (1) current stocks, or oil stored in 1936; (2) stocks stored from 1931 to 1935, or the East Texas era; (3) stocks stored in the period from 1925 to 1930, marked by the discovery of Seminole, Oklahoma City, and other prolific districts; and (4) stocks stored before 1925, when virtually no curtailment was practiced and when the discovery of a large field like Salt Creek was followed inevitably by a build-up of stocks.

Table 6, in which stocks of the different age groups are segregated by States of origin, shows that on June 30, 1936, current stocks were 193.8 million barrels, or 62 percent of all oil in storage. The next largest age group consisted of 50.8 million barrels of oil stored from 1931 to 1935, these stocks comprising 16 percent of the total. Primarily because one large accumulation of oil stored before 1925 had not been liquidated extensively, total stocks in that age group exceeded the total in the next oldest group, representing oil stored in the period 1925 to 1930. The weighted average age of all the stocks on June 30, 1936, was about 3 years.

Table 7 shows the stocks on June 30, 1936, by States of origin, divided into two age groups - oils stored in 1936 and oils stored before that year. These stocks are expressed in thousands of barrels and in days' supply, based on the average daily demand in July 1936.

TABLE 6. - Stocks of crude petroleum, June 30, 1936, by age groups, by States of origin (millions of barrels)

State of origin	Stored before 1925	Stored 1925-30	Stored 1931-35	Stored 1936	Total
California	-	2.4	7.0	28.5	37.9
Texas	1.1	10.7	15.6	81.1	108.5
Oklahoma	14.6	9.8	19.9	43.5	87.8
Louisiana	1.4	-	.1	10.8	12.3
New Mexico	-	-	.4	5.7	6.1
Kansas	-	.1	.5	5.2	5.8
Arkansas	.6	.4	.4	3.7	5.1
Other States	21.3	4.3	6.9	12.7	45.2
Foreign	-	-	-	2.6	2.6
Total	39.0	27.7	50.8	193.8	311.3

TABLE 7. - Stocks and days' supply of crude petroleum, June 30, 1936, by age groups, by States of origin

State of origin	Stocks, June 30, 1936 (thousands of barrels)			Daily average demand, July 1936 (thousands of barrels)	Days' supply, June 30, 1936		
	Old crude stored before 1936	Current crude stored in 1936	Total		Old crude stored before 1936	Current crude stored in 1936	Total
California	9,400	28,456	37,856	572.1	16.5	49.7	66.2
Texas	27,390	81,156	108,546	1,155.4	23.7	70.2	93.9
Oklahoma	44,363	43,489	87,852	650.3	68.2	66.9	135.1
Louisiana	1,483	10,809	12,292	236.5	6.3	45.7	52.0
New Mexico	408	5,746	6,154	65.0	6.3	88.4	94.7
Kansas	629	5,137	5,766	161.4	3.9	31.8	35.7
Arkansas	1,374	3,689	5,063	23.8	57.7	155.0	212.7
Other States ..	32,533	12,672	45,205	222.9	146.0	56.8	202.8
Foreign	-	2,577	2,577	85.9	-	30.0	30.0
Total	117,580	193,731	311,311	3,173.3	37.1	61.0	98.1

QUALITATIVE DISCUSSION OF CRUDE-OIL STOCKS

Interpretation of Laboratory Analyses

Because of the complexity of the hydrocarbons in the various types of crude petroleum, it is not possible to select arbitrarily any given fraction of a Hempel analysis and state that it is a true measure of the commercial gasoline obtainable from a crude oil. However, the characteristics of the various fractions indicate the portion of the crude oil that may be used in the manufacture of modern commercial gasoline without cracking, as well as the fractions most suitable for the manufacture of naphthas, kerosene, cracking stocks, lubricating oils, fuel oils, and other products.

Commercial standards require that gasoline have certain characteristics, the most important of which are octane number, vapor pressure, volatility, and sulphur content. These characteristics are varied seasonally and geographically by the refiners according to climatic conditions. Minor requirements include gum stability, odor, noncorrosiveness, and doctor test. It is obvious that no single property of the crude oil can control all these characteristics in gasolines made from a variety of oils. Consequently, it is not possible to select a fraction and say that it represents even a close approximation of the "straight-run" gasoline that may be produced from the various grades of crude oils studied in this survey.

In the great majority of crude oils the fraction distilling below 392° F. (200° C.) merely represents a portion of the crude oil having certain characteristics of volatility. This fraction, if distilled from some crude oils, might be used without additional processing as third-grade gasoline, but the same fraction from other crude oils would not meet the specifications of a complete motor fuel. In general, the analyses show that few of the 1,500 crude oils sampled in this survey would yield "straight-run" products that could be sold on the open market as regular-grade gasoline without treatment or blending. Distillates recovered from most of the oils would require chemical treatment and the addition of natural gasoline or tetra-ethyl lead, or both, to meet the requirements for regular-grade gasoline. However, the percentage of distillate recovered below 392° F. (200° C.) may be selected as the closest approach to the percentage of "straight-run" gasoline commercially recoverable from the average crude oil that can be obtained by a convenient and generally recognized method of laboratory distillation. As pointed out by Smith[5], this fraction approximates the amount of material in the crude oil having a maximum boiling point of about 215° C. (419° F.).

5/ Smith, N. A. C., The Interpretation of Crude-Oil Analyses: Report of Investigations 2806, Bureau of Mines, 1927, pp. 6 and 11.

Distillate Content of Stored Oil

Table 8 segregates data concerning the crude oils in storage on June 30, 1936, according to the States in which the oil was stored and by age groups. The table also lists the cumulative percentages, quantities, and gravities of the distillate fractions recoverable below 212° F. (100° C.) and below 392° F. (200° C.) from the various stocks, as indicated by analyses of representative samples. The distillation loss is listed separately because there are differences of opinion among refiners as to the actual recovery in commercial practice of the part of a crude oil that is lost during laboratory distillation.

The weighted-average indicated yield of the fractions distilling below 392° F. (200° C.) was 26.1 percent for the samples representing the 311 million barrels of crude oil in storage June 30, 1936. For the samples representing the 194 million barrels of current oil (stored in the first half of 1936) the fractions distilling below 392° F. comprised 26.8 percent of the crude oil.

For Texas stocks, the group comprising oil stored prior to 1925 shows a decidedly larger amount of distillate recoverable below 392° F. (200° C.) than the other age groups. This is attributed to the fact that most of the oil stored during this earliest period was light oil from the Mexia field. Likewise, the 34.5 percent of distillate recoverable below 392° F. (200° C.) from the Oklahoma oil stored between 1925 and 1930 is high, principally because most of this oil was Seminole crude containing a relatively large proportion of light fractions. As this light Oklahoma oil comprised about 40 percent of all the Nation's stock that had been accumulated from 1925 to 1930, the average distillate content of the total oil stored in that period (27.1 percent) was higher than the average for the total stored in any of the other three periods.

Excluding exceptions of the kind mentioned above, which may be explained by characteristics of the oil when placed in storage, table 8 shows that for the various geographical classifications the fractions recoverable below 212° F. (100° C.) and 392° F. (200° C.) are larger in volume (in relation to the volume of the crude oil) and lighter in gravity for each succeeding period of storage.

Field Depletion and Evaporation Losses

In considering the amounts and gravities of distillate recoverable below 392° F. (200° C.) from the oil in storage on June 30, 1936, by age groups and States, as indicated in table 8, account should be taken of two important factors: (1) The changes in characteristics of oil during production as the fields are depleted, and (2) losses by evaporation in storage.

TABLE 8. - Distillate recoverable from crude petroleum in storage on June 30, 1936

State in which stocks were stored	Time of initial storage	Crude oil: Net stocks, in millions of barrels	Crude oil: °A.P.I.	Distillation loss, percent	Distillate recoverable[1/] Below 212°F. (100°C.): Millions of barrels	Below 212°F. (100°C.): Percent	Below 212°F. (100°C.): °A.P.I.	Below 392°F. (200°C.): Millions of barrels	Below 392°F. (200°C.): Percent	Below 392°F. (200°C.): °A.P.I.
California	Prior to 1925	None	-	-	-	-	-	-	-	-
	1925-30	2.4	14.5	0.3	-	None	-	0.185	8.0	39.8
	1931-35	7.0	22.5	1.7	0.224	3.2	62.6	1.127	16.1	51.1
	1936	28.5	26.6	1.9	1.622	5.7	67.0	6.498	22.8	52.7
		37.9	25.0	1.8	1.846	4.9	66.4	7.810	20.6	52.3
Texas	Prior to 1925	0.9	35.8	1.3	0.057	6.3	70.6	0.260	28.9	54.1
	1925-30	9.6	30.6	.9	.478	5.0	72.1	2.348	24.5	56.9
	1931-35	17.0	33.0	1.3	1.198	7.0	73.3	4.450	26.2	58.7
	1936	80.4	31.9	1.9	6.100	7.6	75.7	20.880	26.0	57.8
		107.9	31.9	1.7	7.833	7.3	75.1	27.938	25.9	57.8
Oklahoma	Prior to 1925	11.3	32.1	0.8	0.463	4.1	69.2	2.629	23.3	54.2
	1925-30	10.7	38.0	.8	1.123	10.5	76.3	3.686	34.5	60.3
	1931-35	17.2	35.8	1.1	1.546	9.0	75.1	5.123	29.8	58.8
	1936	27.8	37.6	1.6	2.367	8.5	74.8	8.407	30.2	59.1
		67.0	36.2	1.2	5.499	8.2	74.8	19.845	29.6	58.8
Louisiana	Prior to 1925	1.4	30.6	0.8	0.004	0.3	70.6	0.218	15.6	51.8
	1925-30	None	-	-	-	-	-	-	-	-
	1931-35	0.3	20.8	0.7	.004	1.3	71.2	.041	13.6	56.7
	1936	8.9	34.2	1.6	.466	5.2	73.9	2.303	25.9	58.7
		10.6	33.2	1.5	.474	4.5	73.9	2.562	24.2	58.1
New Mexico	Prior to 1925	None	-	-	-	-	-	-	-	-
	1925-30	None	-	-	-	-	-	-	-	-
	1931-35	None	-	-	-	-	-	-	-	-
	1936	0.8	44.3	1.1	0.136	17.0	80.0	0.309	38.6	61.7
		.8	44.3	1.1	.136	17.0	80.0	.309	38.6	61.7

1/ Not including distillation loss.

TABLE 8. - Distillate recoverable from crude petroleum in storage on June 30, 1936 (Continued)

State in which stocks were stored	Time of initial storage	Crude oil: Net stocks, in millions of barrels	Crude oil: °A.P.I.	Distillation loss, percent	Distillate recoverable[1/] Below 212°F.(100°C.): Millions of barrels	Percent	°A.P.I.	Below 392°F.(200°C.): Millions of barrels	Percent	°A.P.I.
Kansas	Prior to 1925	2.9	32.3	0.7	0.040	1.4	67.5	0.616	21.2	52.6
	1925-30	.1	35.4	1.2	.004	4.1	71.8	.028	27.8	57.5
	1931-35	1.9	35.6	1.7	.112	5.8	73.6	.574	30.2	59.2
	1936	6.1	37.4	1.9	.594	9.7	75.4	2.082	34.1	59.0
		11.0	35.8	1.5	.750	6.8	74.8	3.300	30.0	57.8
Arkansas	Prior to 1925	0.3	19.4	0.3	-	None	-	0.025	8.4	45.3
	1925-30	.7	19.8	.4	0.003	0.4	69.5	.062	8.9	45.5
	1931-35	.4	22.5	.6	.009	2.5	73.6	.057	14.2	54.1
	1936	2.7	16.8	.7	.121	4.4	70.9	.502	18.6	54.8
		4.1	18.1	.6	.133	3.2	71.2	.646	15.8	53.5
Other States	Prior to 1925	22.2	32.5	0.4	0.797	3.6	67.2	4.961	22.3	54.9
	1925-30	4.2	37.0	.7	.267	6.3	70.6	1.204	28.7	58.7
	1931-35	7.0	35.0	.6	.420	6.0	65.3	1.869	26.7	55.4
	1936	38.6	36.2	1.2	3.018	7.8	74.2	10.954	28.4	57.7
		72.0	35.0	.9	4.502	6.3	71.8	18.988	26.4	56.7
United States	Prior to 1925	39.0	32.2	0.6	1.361	3.5	68.1	8.709	22.3	54.4
	1925-30	27.7	32.4	.8	1.875	6.8	74.4	7.513	27.1	58.2
	1931-35	50.8	32.6	1.2	3.513	6.9	72.4	13.241	26.1	57.6
	1936	193.8	32.8	1.7	14.424	7.4	74.1	51.935	26.8	57.4
		311.3	32.7	1.4	21.173	6.8	73.6	81.398	26.1	57.2

1/ Not including distillation loss.

Effects of Field Depletion on Characteristics of Oil Produced

Usually the oil produced from a certain horizon or formation becomes heavier as the field is depleted. Oil can be distilled by lowering its pressure as well as by raising its temperature; therefore, as the pressure in a producing horizon is decreased, a partial distillation takes place and the lighter fractions tend to move toward the producing well more rapidly than the heavier fractions. Thus, the oil produced from the well tends to be lighter than the oil remaining in the sand. This tendency is increased by the movement of natural gas associated with the oil, which carries the lighter fractions toward the well. With the reduction in the formation pressure, there is a decrease in the percentage of lighter fractions contained in the produced oil. This tendency of the oil from a field to become heavier is more marked during the period of flush production than during the later life of the field.

The effect of field depletion on the properties of crude oil is shown in table 9, which compares general characteristics and distillate contents of oils produced from certain wells in the Seminole and Oklahoma City fields when they were first placed in operation and at the latter part of 1937. Each well has produced continuously from the formation listed in the table.

Comparison of the data for the two periods, initial and present, for the seven wells shows that in general the crude oil and its distillate fraction below 200° C. (392° F.) became heavier, the amount of light ends decreased, the temperature of the first drop became higher, and the carbon residue of the crude oil increased as the well became older.

Effects of Evaporation Losses on Stored Oil

When oil is stored, especially in old-type tanks, it loses light fractions by evaporation. The loss is largely of the fractions recoverable below 212° F. (100° C.) and therefore is greater for oils having a high percentage of light distillate than for heavier oils deficient in easily volatile material. This deterioration is greater during the early part of the storage period than during the latter part. The loss by evaporation decreases both the quantity and quality of straight-run gasoline but has no marked effect on gasoline that can be recovered by cracking the residue from which the straight-run distillate has been removed; nor does it seriously handicap the manufacture of other products, such as heating oils and lubricants.

The regular monthly reports of crude-oil stocks to the Bureau of Mines covering several large tank farms of static storage have shown evaporation losses for the first year from about 1/2 percent of the volume to as high as 5 percent. The monthly losses diminished rapidly in each instance, being virtually nothing at the end of 15 years. The crude oil in these tank farms was stored from 1922 to 1928, virtually all in tanks with steel shells and sheet-metal roofs. Losses in modern tanks with devices such as floating roofs and vapor-tight hatches would be much less, and the trend over a period of years would be considerably flatter than in the case of the storage cited above.

TABLE 9. - Analyses of old and new crude oils produced from identical wells and formations

Well	Field of origin	Producing formation	Year collected and analyzed	Characteristics of crude oil: Gravity, °A.P.I.	Temperature of first drop, °C.	Temperature of first drop, °F.	Carbon residue, percent
1	Little River, Okla.	Wilcox	1928	40.9	26	79	1.3
1	do.	do.	1937	40.2	28	82	1.7
2	Bowlegs, Okla.	Hunton	1928	40.6	26	79	.8
2	do.	do.	1937	37.8	38	100	1.1
3	St. Louis, Okla.	Simpson	1929	41.5	26	79	1.7
3	do.	do.	1937	37.4	32	90	2.1
4	Earlsboro, Okla.	Earlsboro	1927	40.2	32	90	1.2
4	do.	do.	1937	38.0	30	86	1.6
5	Oklahoma City, Okla.	Wilcox	1932	40.0	27	81	.8
5	do.	do.	1937	39.0	29	84	1.2
6	Oklahoma City, Okla.	Johnson	1930	45.2	27	81	.8
6	do.	do.	1937	40.2	30	86	1.1
7	Oklahoma City, Okla.	First Oolitic	1932	41.7	27	81	1.5
7	do.	do.	1937	39.8	30	86	2.2

Distillation at atmospheric pressure

Well	Fraction up to 50° C. (up to 122°F.)		Fraction 50° to 75°C. (122° - 167°F.)		Fraction 75°C. to 100°C. (167° - 212°F.)		Distillate recovered below 100°C. (below 212°F.)		Distillate recovered below 200°C. (below 392°F.)	
	Percent	°A.P.I.	Percent	°A.P.I.	Percent	°A.P.I.	Percent	°A.P.I.	Percent	°A.P.I.
1	4.1	85.5	4.8	82.6	5.6	70.4	14.5	78.4	36.9	63.7
1	3.8	90.3	3.4	84.2	5.8	70.4	13.0	79.4	35.7	63.7
2	.9	-	2.9	83.9	5.7	70.6	9.5	75.7	34.0	61.3
2	-	-	-	-	3.0	76.0	3.0	76.0	27.2	58.4
3	4.7	83.6	4.1	81.0	5.6	68.6	14.4	76.9	37.0	62.3
3	-	-	3.6	83.9	4.2	69.5	7.8	76.0	32.6	59.2
4	2.9	89.3	4.1	81.9	6.2	70.1	13.2	77.8	37.9	62.6
4	-	-	2.8	84.2	3.0	72.4	5.8	77.8	30.4	60.0
5	2.3	-	2.8	81.0	4.9	71.8	10.0	76.3	30.2	62.3
5	-	-	4.3	86.2	3.7	71.5	8.0	79.1	28.1	61.8
6	4.5	88.6	6.8	81.3	9.5	70.4	20.8	77.5	46.4	65.6
6	2.8	87.2	2.2	85.9	3.8	71.2	8.8	79.7	31.0	61.3
7	3.1	84.2	4.0	81.6	5.9	86.9	13.0	76.3	35.5	62.3
7	2.7	87.2	2.5	84.2	4.0	70.4	9.2	78.8	30.1	61.8

An increase in the temperature of the surface of a liquid increases the vapor pressure and increases the rate at which the liquid vaporizes; consequently, evaporation losses show a distinct seasonal variation. For example, a 55,000-barrel tank containing 50,000 barrels might lose 1,250 barrels the first year, of which the loss in January might be only 50 barrels, and that in July 200 barrels. However, such losses may be masked completely by expansion and contraction of the oil due to temperature changes. As an average, in a majority of States the temperatures at the beginning of most months are about 10° F. higher or lower than at the close. This means that if 40-gravity oil were stored in the 55,000-barrel tank mentioned above, the volume would expand about 235 barrels monthly because of rises in temperature in the spring and contract a like amount in the fall. As these monthly expansions and contractions are greater than the evaporation losses, it is apparent that uncorrected readings of stocks will give overages for about four months, generally March, April, May and June. Most companies correct their storage for temperature (to 60° F.) twice a year, June 30 and December 31; this procedure affects their shortages or overages for June and December appreciably.

An extreme example of the loss of lighter fractions that may take place in storage over a long period is afforded by a comparison of an analysis of a sample of Glenn Pool, Okla., oil placed in storage in 1916 and sampled in 1937, with an analysis of a fresh sample of Glenn Pool oil taken and analyzed in 1921. The 1921 sample probably contained a somewhat smaller proportion of light fractions than the oil produced from the pool in 1916. Table 10 gives significant data from these analyses, which show there has been a marked loss in both the quantity and quality of the stock for gasoline production recoverable by "straight-run" distillation from this stored Glenn Pool oil. With samples of equal volume, the fraction recovered below 392° F. (200° C.) from the sample of stored oil was 42 percent smaller in volume and heavier by 5.4° A.P.I. than the corresponding fraction from the sample of fresh oil analyzed in 1921.

TABLE 10. - Comparative data from analyses of Glenn Pool samples

		Sample of oil produced and analyzed in 1921	Sample of oil stored in 1916 and analyzed in 1937
Total fraction up to 212° F.	Percent.........	5.0	0.0
(100° C.)	°A.P.I. gravity..	66.4	-
Fraction, 212° to 257° F.	Percent.........	4.3	0.0
(100° to 125° C.)	°A.P.I. gravity..	57.9	-
Fraction, 257° to 302° F.	Percent.........	5.1	1.5
(125° to 150° C.)	°A.P.I. gravity..	53.7	53.5
Total fraction up to 392° F.	Percent.........	24.8	14.4
(200° C.)	°A.P.I. gravity..	54.2	48.8

Comparisons of Changes in Oils Due to Field Depletion and Evaporation Losses

Table 11 compares characteristics of oil from flush production, from present production, and from tanks in which oil was stored at the time of flush production, for two fields. These data show changes in the characteristics of the oil due to field depletion and those due to evaporation losses.

Figure 3 is based on the data for samples 1, 2, and 3 (table 11) of oil from a field in the southern part of the Mid-Continent. The curves designated by circles were plotted from the analysis of sample 1, which was of fresh oil taken from a well in that field and analyzed in 1929; those designated by triangles represent data from the analysis of sample 2 taken from the same well in 1937; and those designated by squares were plotted from the analysis of sample 3, taken and analyzed in 1937, of oil produced from that field and placed in storage in 1927. The storage tank was of 55,000-barrel capacity, and had a steel shell painted black and a wood roof covered with sheet metal painted a light color. It was typical of the oldest types of storage tanks sampled in the survey.

A comparison of data in table 11 indicates that due to evaporation, the distillate recoverable below 212° F. (100° C.) from the stored oil (sample 3) was only 56.2 percent of that recoverable from an equal volume of the original oil (sample 1); and the distillate recoverable below 392° F. (200° C.) from the stored oil was 91.1 percent of that recoverable from an equal volume of the original oil. The tank was some distance from the field, and part of the loss by evaporation occurred in transportation.

In spite of the loss by evaporation, the oil from the storage tank contained a larger proportion of light fractions than did oil produced from the field in 1937, as the distillate recovered below 212° F. (100° C.) from the stored oil (sample 3) was 103.8 percent of that recovered from sample 2 taken from the well in 1937, and the distillate recovered below 392° F. (200° C.) from sample 3 was 103.4 percent of that recovered from sample 2. This indicates that under some conditions, and during the same interval of time, depletion may cause greater changes in the oil produced from a field than evaporation causes in oil stored from that field.

Figure 4, based on analyses of samples 4, 5, and 6 (table 11) represents oil from a northern field. Sample 4 (curves indicated by circles) was taken from a well and analyzed in 1924 and closely approximates the character of oil run to storage in that year. Sample 6 (curves indicated by squares) was taken in 1937 from the oil stored in 1924. The tank was of 80,000-barrel capacity, all-steel construction, and equipped with vent lines and vapor-tight gage hatches. Comparison of the data for these two samples indicates that in a storage period of 13 years evaporation reduced the distillate recoverable from a unit volume of the stored oil to about 83.3 percent of that recoverable from a like volume of the original oil and reduced the distillate recoverable below 392° F. (200° C.) to about 97.6 percent of the original quantity. It may also be noted from the curves of

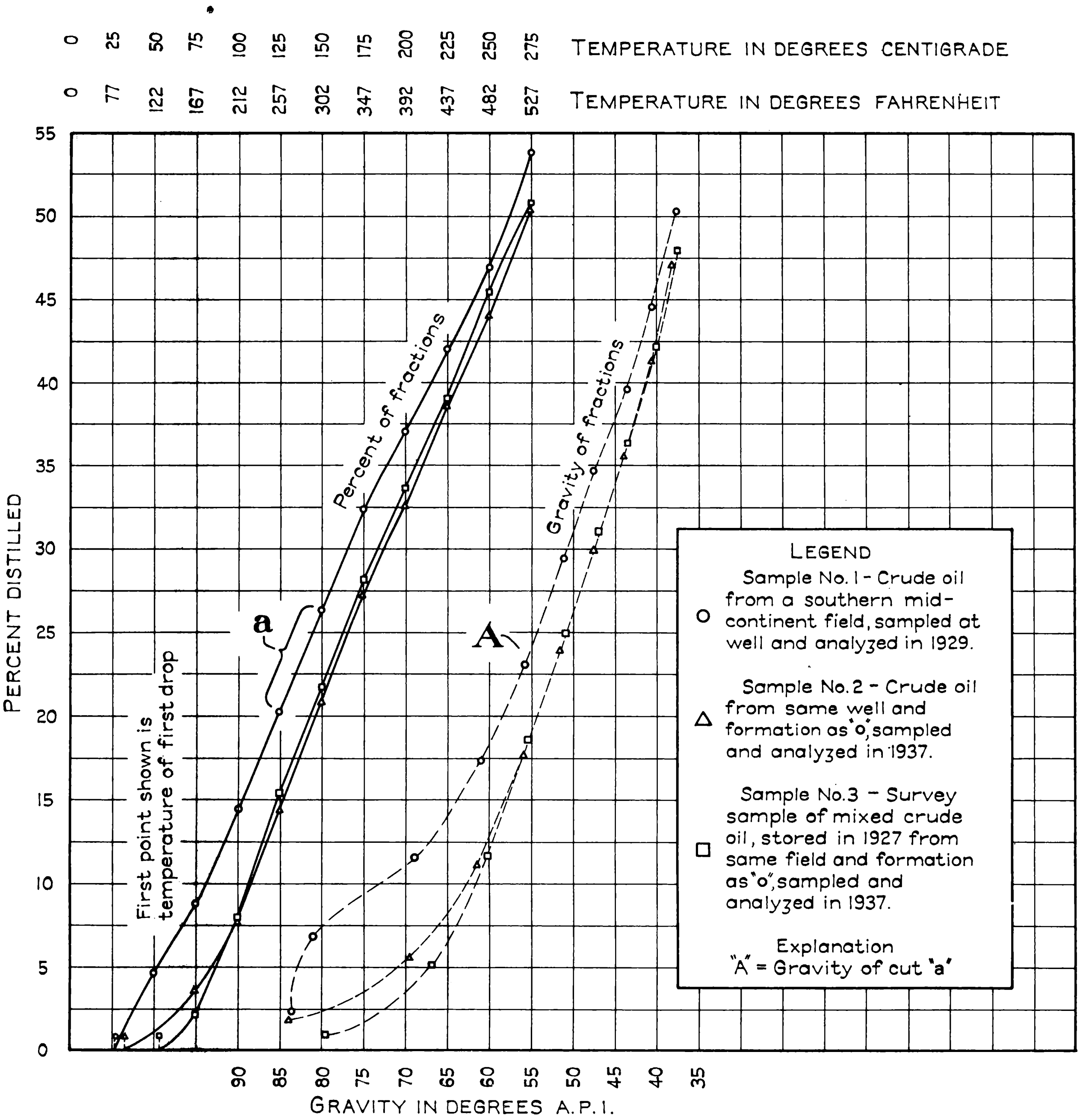

FIGURE 3. – COMPARATIVE CURVES SHOWING PERCENT AND GRAVITY DATA OF DISTILLATE FRACTIONS OF SAMPLES 1, 2, AND 3 IN TABLE II.

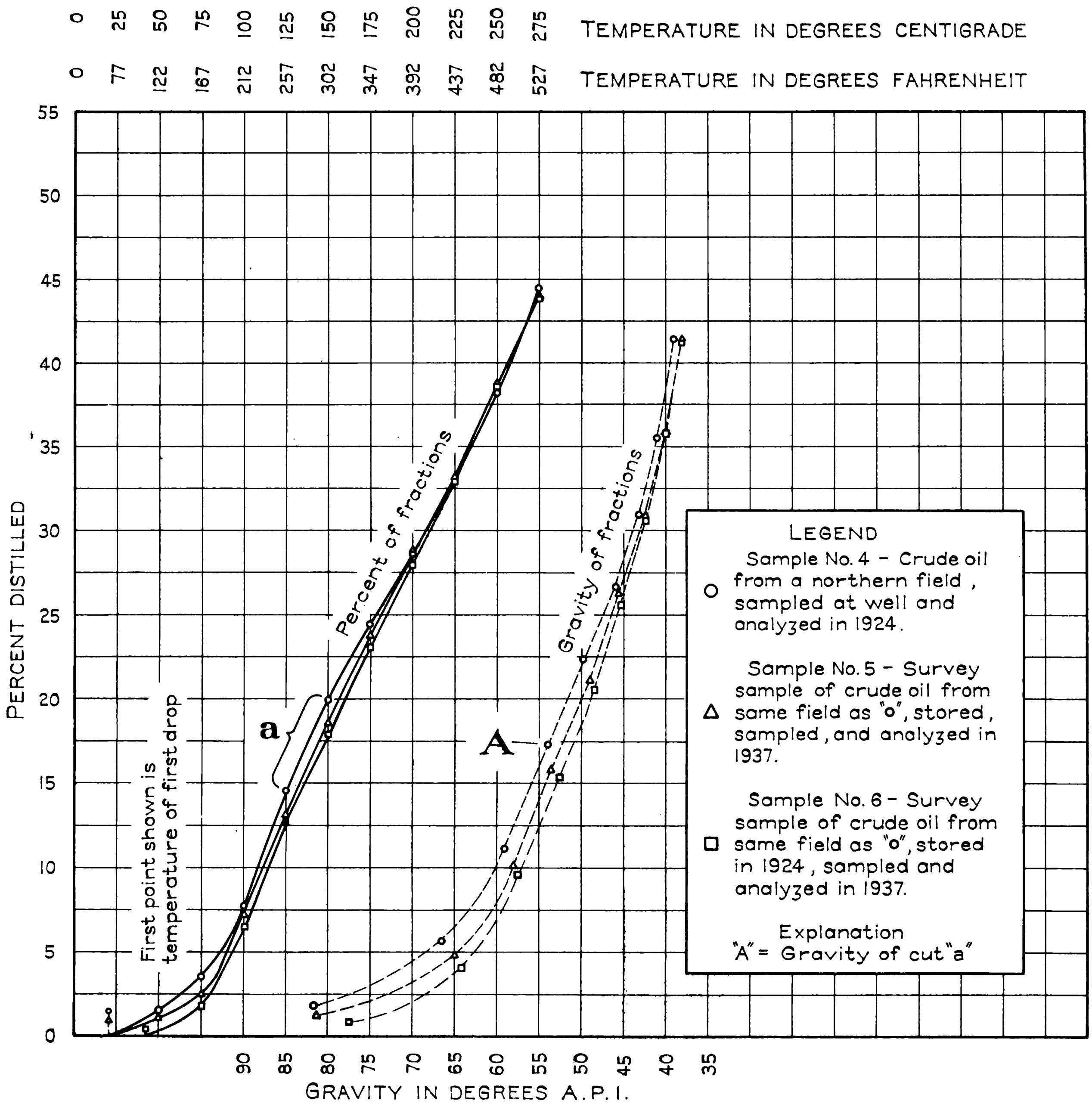

FIGURE 4.- COMPARATIVE CURVES SHOWING PERCENT AND GRAVITY DATA OF DISTILLATE FRACTIONS OF SAMPLES 4, 5, AND 6 IN TABLE II.

figure 4 that, in general, the lighter fractions of the oil produced and stored in 1937 (sample 5) were smaller in volume and heavier in gravity than the corresponding fractions from the oil produced and analyzed in 1924; but it seems likely that the difference between the two samples is somewhat greater than it would have been if sample 5 had been taken directly from the well, because the oil represented by this sample must have suffered some loss by evaporation in transportation to the tank and during the short period of storage.

The loss by evaporation from the oil produced in the northern field (fig. 4) was less than that from the southern Mid-Continent oil (fig. 3), because the northern oil originally contained a smaller proportion of the more volatile constituents, the tank in which it was stored was of larger capacity and superior construction, and the climate was cooler. The influence of these factors on evaporation losses has been discussed by Schmidt.[6]

Comparison of the data for samples 5 and 6 (table 11) and examination of the corresponding curves designated by triangles and squares in figure 4, indicate that in this northern field the change in the characteristics of the oil from the well as a result of depletion was less than the change in the stored oil due to evaporation. The relative changes in oil due to evaporation and field depletion depend on many factors, so no uniform relation is to be expected.

The data presented in table 11 and figures 3 and 4 show that comparison of an analysis of oil that has been in storage for a considerable period with an analysis of current production from the same source (field or well) will not give a true indication of the evaporation loss. To obtain a correct measure of the loss it is necessary to compare an analysis of the stored oil with an analysis of that oil at the time it was placed in storage.

Compensating Effects of Initial Quality and Evaporation Losses on Characteristics of Oil Stocks

Many stored oils sampled in this survey had lost considerable quantities of light fractions by evaporation, the amounts depending upon the characteristics of the original oil, the length of the storage period, the type of tank in which the oil was stored, and various other influencing factors. However, much of the oil that had been in storage for long periods compared more favorably with current production than might be expected from a consideration of evaporation losses alone.

6/ Schmidt, Ludwig, Applied Methods and Equipment for Reducing Evaporation Losses of Petroleum and Gasoline: Bull. 379, Bureau of Mines, 1934, 160 pp.

TABLE 11. - Analyses of crude-oil samples showing effects of field depletion and evaporation loss on characteristics of oils

Sample	Origin of samples				Characteristics of crude oil			
	Field of origin	Type of sample	Year of initial storage	Year collected and analyzed	Gravity °A.P.I.	Temperature of first drop °C.	Temperature of first drop °F.	Carbon residue, percent
1	Southern Mid-Continent	Well	-	1929	41.5	26	79	1.7
2	do.	Well	-	1937	37.4	32	90	2.1
3	do.	Storage	1927	1937	36.2	54	129	1.7
4	Northern Field	Well	-	1924	37.8	21	70	-
5	do.	Storage	1937	1937	36.0	22	72	1.7
6	do.	Storage	1924	1937	35.6	39	102	1.8

Distillation at atmospheric pressure

Sample	Fraction up to 50°C. (up to 122°F.)		Fraction 50° to 75°C. (122° to 167°F.)		Fraction 75° to 100°C. (167° to 212°F.)		Fraction 100° to 125°C. (212° to 257°F.)	
	Percent	°A.P.I.	Percent	°A.P.I.	Percent	°A.P.I.	Percent	°A.P.I.
1	4.7	83.6	4.1	81.0	5.6	68.6	5.8	61.0
2	-	-	3.6	83.9	4.2	69.5	6.5	61.5
3	-	-	2.1	79.7	6.0	67.0	7.3	60.2
4	1.5	-	2.1	81.6	4.2	66.4	6.8	59.2
5	1.1	-	1.4	81.3	4.7	64.8	6.0	58.2
6	-	-	1.8	77.5	4.7	64.2	6.1	57.4

Distillation at atmospheric pressure (Cont'd)

Sample	Fraction 125° to 150°C. (257° to 302°F.)		Fraction 150° to 175°C. (302° to 347°F.)		Fraction 175° to 200°C. (347° to 392°F.)		Fraction 200° to 225°C. (392° to 437°F.)	
	Percent	°A.P.I.	Percent	°A.P.I.	Percent	°A.P.I.	Percent	°A.P.I.
1	6.1	55.9	5.9	51.1	4.8	47.2	5.0	43.6
2	6.6	55.9	6.3	51.6	5.4	47.6	6.0	44.1
3	6.3	55.4	6.4	50.9	5.6	46.9	5.4	43.4
4	5.3	54.0	4.5	49.7	4.3	45.8	4.4	43.2
5	5.4	53.5	5.2	49.0	5.0	45.4	4.4	42.6
6	5.3	52.7	5.2	48.5	4.9	45.4	5.0	42.3

Distillation at atmospheric pressure (Cont'd)

Sample	Fraction 225° to 250°C. (437° to 482°F.)		Fraction 250° to 275°C. (482° to 527°F.)		Distillate below 100°C. (below 212°F.)		Distillate below 200°C. (below 392°F.)	
	Percent	°A.P.I.	Percent	°A.P.I.	Percent	°A.P.I.	Percent	°A.P.I.
1	4.9	40.6	7.0	37.6	14.4	76.9	37.0	62.3
2	5.4	40.6	6.3	38.2	7.8	76.0	32.6	59.2
3	6.3	40.0	5.5	37.6	8.1	70.1	33.7	57.4
4	5.1	41.1	6.3	38.8	7.8	73.3	28.7	57.9
5	5.4	40.0	5.5	38.0	7.2	70.1	28.8	55.9
6	5.5	40.0	5.5	38.0	6.5	67.8	28.0	54.9

As shown by the totals for theUnited States in table 8, the distillate recoverable below 392° F. (200° C.) from the 39 million barrels stored before 1925 represented 22.3 percent of the crude oil and had an average gravity of 54.4° A.P.I. This compares unfavorably with distillates totaling 26.8 percent of the crude oil and having a gravity of 57.4° A.P.I., recoverable from the 193.8 million barrels stored in 1936. On the other hand, the 27.1 percent of distillate recoverable below 392° F. (200° C.) from the 27.7 million barrels stored from 1925 to 1930 represented 0.3 percent more of the crude oil and was lighter in gravity by 0.8° A.P.I. than the distillate recoverable at the same temperature from the oil stored in 1936; also, the oils stored from 1931 to 1935 had only a little lower distillate content and a slightly lighter gravity of distillate than the 1936 oils.

In part, this favorable showing of the oils stored from 1925 to 1935 reflects improvement in equipment and practices for preventing losses by evaporation and the care operators have taken to guard against them. However, it is evident that there must have been factors that tended to compensate for, as well as to reduce, losses by evaporation.

Undoubtedly one of the most important of these compensating factors was the high content of lighter hydrocarbons in the flush-production oil from the Seminole, Oklahoma City, and East Texas fields run to storage from 1925 to 1935. In general, much of the oil that has been run to storage in large quantities in periods of stock accumulation and held for several years has been surplus oil from fields of flush production. Considering that the proportion of light fractions in an oil is highest when the field is new, on the average the oil run to long-time storage probably has been lighter than the oil consumed currently. Thus, it is apparent that the favorable showing now made by the 1925 to 1935 oils, which must have suffered a considerable loss by evaporation, is due in large measure to a high average content of light fractions in these oils when they were placed in storage.

Another factor that has had some influence is the practice of "topping out." Often when there has been a shrinkage of the gross fluid in a tank, due to evaporation losses and the withdrawal of water and basic sediment that has settled to the bottom, the operator fills the available space with new oil. Usually the age reported for the oil in a tank is computed from the year in which it first was filled, even though the older crude has been "topped out" with a more current stock. Thus, the average age of some of the oil may be less than is indicated by the reports.

DISTILLATE CONTENTS OF SAMPLES AND REFINERY YIELDS OF GASOLINE

As indicated in the discussion of the interpretation of laboratory analyses, the yield of distillate (up to 392° F.) by the Hempel method is at best only an indication of the portion of the crude oil useful for manufacture of "straight-run" gasoline. Before the widespread use of cracking processes and the more recent increase in combination units, laboratory distillation was more indicative of gasoline yield than at present.

According to table 8, the distillate recoverable below 392° F. (200° C.) from the crude-oil stocks, including the old oil that had been in storage for many years, was 26.1 percent of the volume of the oil. On the other hand, the actual yield of straight-run gasoline from the crude oil refined during the period when these analyses were being made, based on the average of reports made by refiners to the Bureau of Mines, was not quite 22 percent. The difference of 4 or more percent in yields might at first glance seem to be due to a higher proportion of low-yield crude oils of foreign origin in the runs than in the stocks. However, it can be shown that this factor could be responsible for not more than 0.2 percent of the difference in yields. The most likely explanation is that in actual practice refiners are not "cutting as deeply" into the crude oil for straight-run gasoline as the Hempel distillation below 392° F. (200° C.) "cuts into" a sample. In other words, in present refinery practice some material at the heavier end of light fractions, which formerly was recovered in straight-run distillation, now is left in the cracking stock. Thus, the yield of gasoline by cracking has increased at the expense of the straight-run yield. As evidence of this, the yield from cracking increased from 14.6 percent of the crude oil in 1929 to 21.5 percent in 1935 and 22.4 percent in 1936, whereas the yield of straight-run gasoline declined from 24.8 percent in 1929 to 22.7 percent in 1935 and 21.7 percent in 1936.

No tests of the cracking possibilities of crude-oil stocks were made in this survey. The major portion of the stocks is held by companies that operate cracking units, so that when the oil eventually is processed the gasoline yield will be considerably more than the 26.1 percent of light distillate (below 392° F.) recovered from the samples. Just how much higher is a matter of conjecture, but, considering that the few large companies holding most of the older stocks crack much more extensively than the average, it is reasonable to suppose that the eventual gasoline yield from the oil in storage on June 30, 1936, will exceed 44.1 percent, which was the actual average for all crude oil refined in the United States in 1936.

As has been stated, the oils surveyed did not include stocks of heavy crude and fuel oil (including mixtures of the two) in California. In the Bureau's statistics these oils were transferred to fuel-oil stocks several years ago. However, much of this oil is suitable for use as cracking stock, particularly the heavy crude unmixed with residual fuel oil. To develop this point, the California companies were asked to supply a breakdown of their heavy crude and fuel-oil stocks for June 30, 1936, and March 31, 1937. Beginning January 1, 1938, the California companies began to segregate unmixed heavy crude stocks as a regular feature of their monthly reports. This breakdown on pertinent dates was as follows, in thousands of barrels:

	June 30, 1936	Mar. 31, 1937	Dec. 31, 1937	June 30, 1938
Unmixed heavy crude..	13,717	12,610	14,505	17,425
Mixtures of heavy crude and residual fuel oil..........	50,000	49,500	54,144	65,408
	63,717	62,110	68,649	82,833

The average yield of gasoline from heavy crude and fuel oil charged to cracking stills in California is about 35 percent, but it would be misleading to apply this percentage to all the stocks listed above because most of them undoubtedly will be sold eventually as fuel oil without further refining. Nevertheless, if one is investigating various stocks in the light of possible gasoline production, the California stocks of heavy crude and fuel oil potentially are much more important than stocks of heavy fuel oil east of California.

WORKING STOCKS AND RESERVE STOCKS

Two of the primary objectives of this study were the qualitative evaluation of crude-oil stocks as an element in supply and the quantitative determination of desirable levels for crude-oil stocks. The attainment of both objectives was of interest to the industry generally, but particularly to those directly concerned with conservation and proration. Obviously, if the stored oil had lost most of its light fractions through evaporation, it was no longer an important factor in the available supply of crude oil for refining and withdrawals from the older stocks could be virtually ignored in setting allowables. Likewise, the determination of desirable economic stock levels for crude oil was of interest to State officials and others concerned with regulatory matters, as this would assist in determining reasonable withdrawals from or additions to stocks.

The qualitative discussion has shown that because the original volatility of much of the older oil was superior to that of the average current production, and because much of it was stored in "vapor-tight" tanks, the older stocks, totaling about 117 million barrels on June 30, 1936, were not greatly inferior, from the standpoint of potential gasoline, to the stocks stored in the first six months of 1936. This means that in allocating production to demand it would be inadvisable to discount stock withdrawals of old oil. On the other hand, the fact that the quality of the stored oil exceeded expectations should not be used as an excuse to increase stocks, as there will always be evaporation from oil stored above ground. In other words, the efficiency of tanks in the storage of oil never can be raised to that of the original reservoirs. The change in character of the oil produced from a well with passage of time is a result of depletion caused by production. It does not occur if the oil is not produced.

The determination of desirable levels for stocks of crude oil is a difficult and vexing problem. It is much easier to arrive at reasonable economic levels of gasoline stocks because the seasonal trends of gasoline demand are more or less definite and the price fluctuations give indications as to whether the amounts on hand are too large or too small. On the other hand, in modern statistical times, crude-oil stocks have always exceeded the minimum working-stock level and prices have reacted more to withdrawals or other factors, such as discovery rates, shut-in production, and underground stocks, than to the quantity of oil stored above ground.

Past Determinations of Working Stocks

In the code period, when stock withdrawals were made on consent of the Administrator, the Federal Agency found it desirable to establish an "objective" for crude-oil stocks of 200 million barrels. The theoretical attainment of this level was dated several years in advance and the actual fluctuations in stocks were checked against the desired monthly changes. Since this rough "objective" was established, demand has increased materially, and if the same computations were made today they would give a much larger figure.

On January 31, 1937, total stocks of refinable crude oil reached 286,759,000 barrels after 9 months of continued decline. At that time a number of refiners complained that their stocks were too low, which indicated to some observers that the total was approaching the economic minimum. Although the experience of reaching that point (286,759,000 barrels) was a valuable contribution to the meager fund of knowledge on the subject, the complaints referred to can be discounted largely because a considerable proportion were from refiners who in the aggregate have never held much stock, and many of the others arose from considerations related to prices or allowables.

In a paper presented at the annual meeting of the American Institute of Mining and Metallurgical Engineers in February 1937, Van Covern7/ of the American Petroleum Institute placed the minimum economic level between 250 and 275 million barrels. Of the two, Van Covern stated that the latter "properly and equitably distributed by grades, location, and companies would more nearly represent economically desirable levels and permit convenient and proper operation."

Except for the "objective" under the code and Van Covern's study, very little has been done nationally toward determining the proper economic levels for crude-oil stocks. In this survey, the views of a number of companies on their own situations were received, but unfortunately the stocks of these were small in the aggregate.

Determination Based on Days' Supply

In the simplest of operating conditions - for example, in the operation of a single pipe line or a small refinery - it generally is possible

7/ Van Covern, Fred, Status and Outlook of Petroleum - Supply, Demand, and Stocks: Petroleum Development and Technology 1937, Amer. Inst. Min. and Met. Eng., New York, 1937, p. 222.

to estimate desirable stock levels by multiplying the daily average throughput by the number of days it would take to correct the worst possible disruption in supply. However, the industry as a whole will never experience a complete breakdown of supply; and, if it could, there would be no way of computing the number of days necessary for reconstruction. However, once having established and reached a desirable stock level, the number of days' supply represented is valuable as a guide to future levels, provided a reasonable balance is maintained between supply and demand.

Figure 1 throws additional light on days' supply of crude oil; for example, it shows that the stock on hand at the end of June 1938 (292,634,000 barrels) was the lowest, in terms of days' supply, recorded since stocks first began to accumulate in quantity. It is interesting to note that the curve of days' supply declined in 1937 although stocks increased. This was the result of a gain in demand that was relatively greater than the increase in stocks.

Determination Based on Age

In table 6 stocks of June 30, 1936, are divided into four age groups as follows: Stored before 1925, 39 million barrels; stored 1925 to 1930, 27.7 million barrels; stored 1931 to 1935, 50.8 million barrels; stored in 1936, 193.8 million barrels. Obviously, the oil in the two older groups, nearly all of which is stored in large tank farms, can have little relation to working stocks. The same reasoning might be applied to the group stored from 1931 to 1935, although much of this probably is classed as contingent reserves. On this basis the minimum economic level would range from about 200 million barrels, the current oil, to about 250 million barrels, the sum of the two younger groups.

Determination Based on Age and Location

Although the chief criterion for determining the relationship of the older stocks to contingent reserves is the age of the oil, a certain degree of refinement is attainable when location also is considered. To evaluate the location factor, the stocks held by various companies on June 30, 1936, (exclusive of lease stocks and pipe-line fill) were plotted on a large-scale map. An analysis then was made of the older stocks on the general theory that if the storage locations were several hundred miles from the principal refineries (or terminals) of the respective companies, the oil involved could have little relationship either to working stocks or contingent reserves. The results of this analysis of stocks by location are shown in table 12, in which the terms "near" and "far" are used to designate the two classes into which stocks were segregated according to the distances to their respective refining centers.

Table 12 indicates that on June 30, 1936, nearly 100 million barrels (96,900,000) of older stocks could have been liquidated without any serious effect on the availability of oil for refining. This leaves about 215 million barrels (214,400,000) in the "near" classification, made up of the 105 million barrels of minimum working stocks (discussed later) plus 110 million barrels of contingent reserves.

TABLE 12. - Stocks of crude petroleum, June 30, 1936, by age groups, by location (millions of barrels)

State of location	Stored before 1925		Stored 1925-1930		Stored 1931-1935		Stored in 1936	Totals		
	Near[1]	Far[1]	Near[1]	Far[1]	Near[1]	Far[1]	Near[1]	Near[1]	Far[1]	State
California...	-	-	-	2.4	-	7.0	28.5	28.5	9.4	37.9
Texas........	0.2	0.7	2.9	6.7	5.4	11.6	80.4	88.9	19.0	107.9
Oklahoma.....	.5	10.8	.5	10.2	7.6	9.6	27.8	36.4	30.6	67.0
Louisiana....	-	1.4	-	-	.2	.1	8.9	9.1	1.5	10.6
Kansas.......	.6	2.3	.1	-	.7	1.2	6.1	7.5	3.5	11.0
Arkansas.....	-	.3	.1	.6	-	.4	2.7	2.8	1.3	4.1
Other States.	.3	21.9	.6	3.6	.9	6.1	39.4	41.2	31.6	72.8
Total...	1.6	37.4	4.2	23.5	14.8	36.0	193.8	214.4	96.9	311.3

1/ The terms "near" and "far" designate relative distances from refineries or terminals of the companies owning the stocks.

A breakdown of the 100-million-barrel "excess" by States shows that the largest items are in Oklahoma, Wyoming, Texas, and Illinois. However, the 30.6 million barrel excess in Oklahoma does not necessarily mean there was that much Oklahoma oil in storage above possible requirements, because the oil stored in Oklahoma (67 million barrels) included some oil that originated in other States.

In October 1937 stocks in California reached a low of 30 million barrels, which was not far above the "economic minimum" of 28.5 million barrels indicated for that State by the "near" classification of table 12. Arkansas stocks were reduced in July 1937 to 2.6 million barrels, which is lower than the minimum of 2.8 million barrels suggested by the "near" classification. This indicates chiefly that too much current stock had been on hand.

Determination Based on Types

As shown in table 13, stocks may be segregated into six types, based on location. The first type listed, lease stocks, amounting to about 11 million barrels, represents current production and is definitely a part of working stocks. Likewise, the crude oil in pipe lines, amounting to about 21 million barrels, is a part of working stocks. Because lease stocks and pipe-line stocks fluctuate but little, they often are classed as "fixed unavailable" stocks. The status of the 29 million barrels held by pipe-line companies in tanks is not as clear because it includes considerable old oil. However, about 12 million barrels of this may be considered as minimum working stocks along the main lines, leaving possibly 10 million barrels as working stocks at the terminals and 7 million barrels in tanks as contingent reserves. Stocks on refinery grounds, amounting to about 47 million barrels, of which all but about 3 million barrels was current stocks, may all be considered as working stocks for almost immediate consumption. Likewise, the 4 million barrels estimated to be in transit to refineries, mostly in tankers bound to the Atlantic seaboard from the Gulf, is definitely a part of working stocks.

The summation of these data gives 105 million barrels as minimum working stocks, or the total of the oil that does not remain in one place for more than a few days. There remains 206 million barrels, the relationship of which to working stocks is difficult to determine. Some is near the refineries and probably is as much a part of working stocks as oil stored on refinery grounds. Beyond such tank-farm stocks lies an indeterminate quantity of contingent reserves. Such stocks represent mainly the net safety factor of the companies as insurance against declines in production.

Although the minimum working-stock level moves upward in a more or less definite relationship to the growth in demand, the quantity of contingent reserves fluctuates in accordance with potentials or shut-in production. The larger the shut-in production or available stock underground, the less the need for stocks above ground. If all the activities were merged under a single operating unit not more than 105 million barrels, the estimate of minimum working stocks, would have been absolutely necessary above ground on June 30, 1936. However, with control divided as it is, it may be considered necessary to have at least 100 million barrels of contingent reserves above ground in addition to the 105 million barrels of true working stocks.

TABLE 13. - Stocks and days' supply of crude petroleum, June 30, 1936, by types of storage

Type of storage	Net stocks, June 30, 1936 (millions of barrels)	Days' supply 1/
Lease	11	4
Pipe line:		
In lines	21	7
In tanks	29	9
Refinery:		
At plants	47	15
In transit	4	1
Tank farm	199	62
United States Total	311	98

1/ Based on average daily demand of 3.2 million barrels for July 1936.

RECENT TRENDS IN STOCKS

Crude-Oil Stocks

Between June 30, 1936, and January 31, 1937, stocks declined from 311,311,000 barrels to 286,759,000 barrels. The net withdrawal of about 25 million barrels was principally a liquidation of the older stocks accumulated prior to January 1, 1936. Between January 31 and December 31, 1937, stocks showed a net increase of about 19 million barrels. This was all current production; in fact, the increase in stocks of current oil in that 11-months period was about 30 million barrels, because it is estimated that withdrawals from older stocks, mainly the group stored before 1925, were 11 million barrels. Thus, on December 31, 1937, there were about 216 million barrels of oil that had been placed in storage since January 1, 1936, and about 90 million barrels of the older oil. As the increase in the youngest group was mainly attributable to companies not holding much old oil - the companies withdrawing the 11 million barrels of old oil in the 11 months of 1937 adding only about 5 million barrels of current stocks - it follows that there has been a trend toward a more equitable distribution of stocks between companies and that the economic minimum for stocks is increasing within the limits previously indicated, namely 200 million and 250 million barrels.

Stocks of Products

In determining economic levels for crude-oil stocks, consideration should be given to the comparative levels for products; for example, it

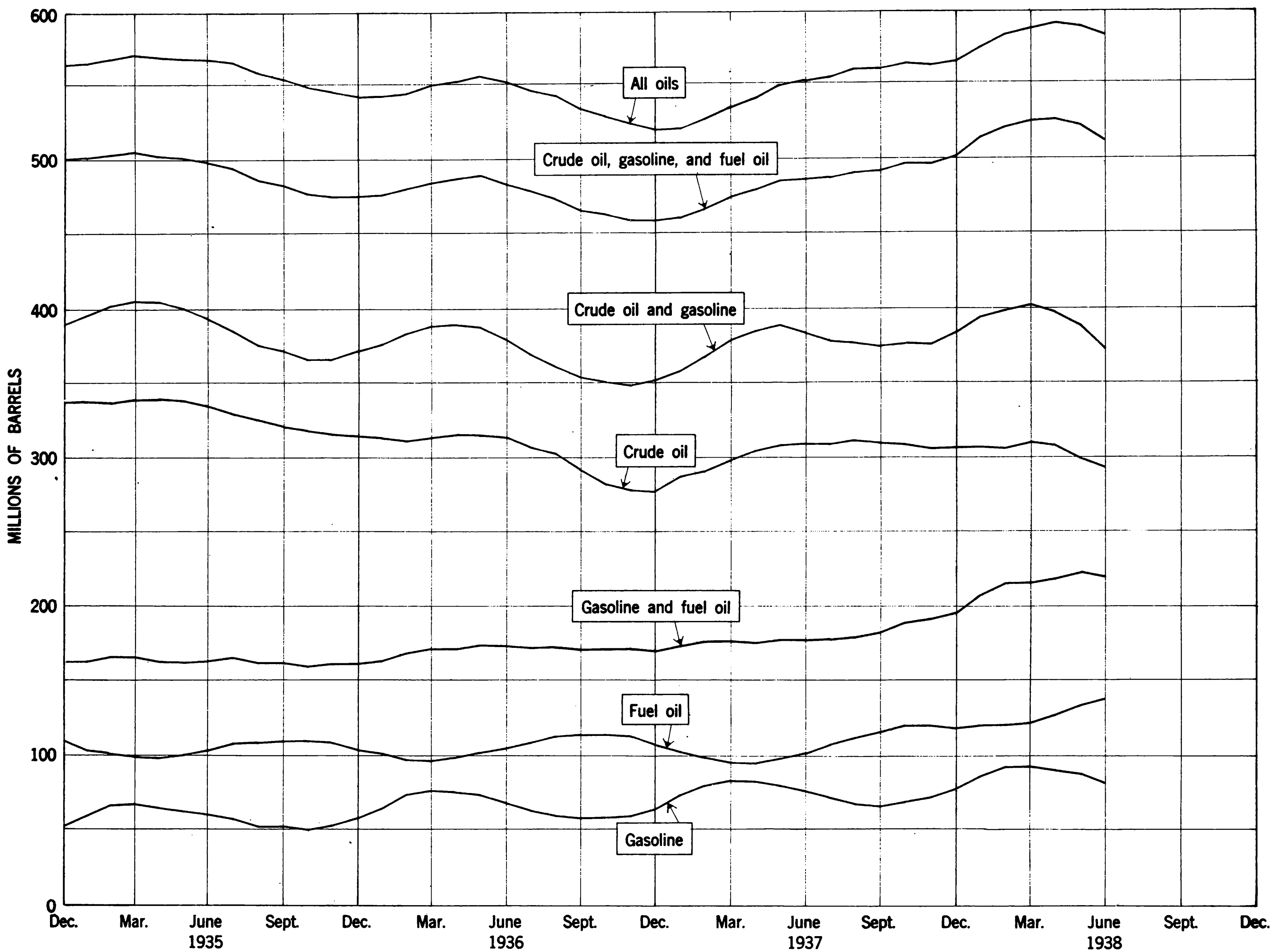

Figure 5.—Trends in stocks of crude oil, gasoline, fuel oil, and all oils, 1935–38.

would be generally unsound to convert excess crude stocks into surplus gasoline and fuel-oil stocks. It is therefore advisable to note the trends in stocks of the principal refined products, as shown graphically in figure 5, with particular reference to stocks of all oils.

In general, the only important products showing distinct seasonal trends in stocks are gasoline and fuel oil. As shown in figure 5, the seasonals for these are almost diametrically opposed; hence, the total for the two is virtually a straight line that trends upward because of the steady over-all increase in gasoline stocks. As stocks of all other refined products as a group show little change, it follows that the trend in stocks of all oils coincides largely with the trend in crude-oil stocks. In terms of days' supply, stocks of all oils generally have declined in recent years, although the trend changed abruptly in the latter part of 1937.

SUMMARY OF RESULTS OF SURVEY

The results of sampling and analysis indicate that the average quality of stored oil closely approximates that of the average current production. The reason is that a large part of the older crude oil in storage was flush production from fields that produced high-grade oil. The original superior quality of these oils has offset the deterioration from evaporation losses, and progressive improvement in storage-tank construction has reduced the rate of such losses materially in recent years.

The growth in demand for heating oils and Diesel oil has been greater, relatively, than the rate of increase in gasoline demand. However, as the age of the crude oil generally has little effect on fuel-oil yields, the older stored oils may be used to produce heating oils and Diesel oil and thus release current production for the manufacture of gasoline. In other words, the oil now in storage can meet the combined demand for gasoline and light fuel oil almost as well as an equal volume of the average oil from current production.

Total stocks of crude oil may be subdivided into three economic groups: (1) minimum working stocks, (2) contingent reserves, and (3) unnecessary accumulations of stocks during periods of over-production.

At the time of the survey, the minimum working stocks of crude oil required for operation of the industry were approximately 105 million barrels, as follows:

1. About 11 million barrels of crude oil representing accumulations on leases to maintain an adequate supply for delivery to gathering lines.

2. About 43 million barrels of the 50 million barrels held by pipe-line companies, divided into -

(a) The 21 million barrels actually contained in gathering and trunk pipe lines.

(b) About 12 million barrels contained in minimum working tanks for main trunk-line operations.

(c) About 10 million barrels of essential terminal storage out of the 17 million barrels of tank storage at gathering-line terminals, main-line transshipment points, and main-line terminals.

3. An average of about 4 million barrels in transit to domestic refineries by barge or tank ship.

4. Approximately 47 million barrels at refineries, representing a minimum safety factor of about two weeks' supply.

Considering the characteristics of petroleum operations and the organization of the industry, probably it is necessary to have at least 100 million barrels of contingent reserves above ground, in addition to the 105 million barrels of true working stocks, to meet all of the industry's varied needs.

Total stocks of over 311 million barrels of refinable crude oil on June 30, 1936, included approximately 51 million barrels of crude oil stored from 1931 to 1935, 28 million barrels stored from 1925 to 1930, and 39 million barrels stored before 1925. The stocks, totaling 67 million barrels, stored before 1931 primarily represented old reserves in the hands of a few companies and obviously had little or no relation to current working requirements except when in an active state of liquidation. These stocks represented accumulations from excess production in the past of a kind the present program of oil conservation is attempting to avoid.

Apparently at the time of the survey, the requirements for minimum working stocks and contingent reserves could be met from the current stocks of 194 million barrels and an indeterminate part of the next older group containing 51 million barrels.

Although this survey indicates that a minimum of stocks ranging from 200 million to 250 million barrels is needed, no exact level of desirable crude-oil stocks can be fixed without a detailed analysis of individual company positions and policy and without more accurate information than is now available concerning potential reserves and the extent to which a program of underground storage has replaced above-ground storage. Without such information, a considerable factor of safety in stocks undoubtedly is necessary in an industry in which production and demand are subject to such rapid change.

APPENDIX 1. - CRUDE-OIL TANKS

Capacity and Number

The total capacity of storage tanks for crude petroleum on June 30, 1936, (table 14) was 583,478,000 barrels, exclusive of tanks for producers' (lease) stocks and of tanks used in California for storage of heavy crude and fuel oil. This represents a decline of 6 percent from the total of 620,505,000 barrels in the United States on May 1, 1931. The total number of crude-oil tanks declined in the same period from 16,342 to 15,094, or about 8 percent.

Total stocks of crude petroleum, less lease stocks, decreased from 394 million to 301 million barrels in the interval between May 1, 1931, and June 30, 1936. As this decline is more than double the decline in tankage capacity, it follows that the amount of unused tank capacity increased materially. The total of empty storage capacity on June 30, 1936, is estimated at 260 million barrels, contrasted with 187 million barrels on May 1, 1931, an increase of 39 percent. These figures were obtained after adjustments were made for the cubic capacity of the pipe lines and amounts of B. S. and water contained in the tanks.

Method of Classification

Tanks have been classified by location - at tank farms, refineries, and pipe-line stations - and segregated by States as far as practicable. Producers' (lease) tanks have not been included. In the 1931 survey of tanks no attempt was made to separate storage at pipe-line stations from tank-farm storage; hence, table 14, giving comparable data for 1931 and 1936, shows combined figures for storage at tank farms and pipe-line stations. Table 15, for June 30, 1936, only, shows data for both these classes.

Changes in Capacity, by States

The decline in total capacity of tanks for crude petroleum has been general throughout the Nation in the five-year period, as all of the more important oil States, except Pennsylvania, contributed to it. The largest reductions occurred in Oklahoma, Texas, and California, in the order named. The greatest percentage decline (about 33 percent) was in Arkansas, where total storage capacity was 15,660,000 barrels on May 1, 1931, and only 10,411,000 barrels on June 30, 1936. This reflects principally the deflation in storage of large amounts of Smackover heavy oil that had been accumulated during the flush era (1923-1925) of that district. The shrinkage in Arkansas was entirely in the tank-farm and pipe-line station categories; refinery storage showed an increase of over 100 percent, or almost 900,000 barrels.

TABLE 14. - Number and capacity of storage tanks for crude petroleum, May 1, 1931, and June 30, 1936, by States
(thousands of barrels)

	At tank farms and pipe-line stations				At refineries				Total			
	May 1, 1931		June 30, 1936		May 1, 1931		June 30, 1936		May 1, 1931		June 30, 1936	
	No.	Capacity	No.	Capacity	No.	Capacity	No.	Capacity	No.	Capacity	No.	Capacity
Arkansas..	288	14,924	199	8,782	33	736	50	1,629	321	15,660	249	10,411
California	2,258	1/46,766	1,105	44,892	746	1/17,687	301	13,712	3,004	1/64,453	1,406	58,604
Kansas....	716	22,887	604	17,932	103	3,213	98	4,436	819	26,100	702	22,368
Louisiana.	371	17,852	358	15,317	212	10,967	194	10,122	583	28,819	552	25,439
New Mexico	57	1,232	54	1,229	5	5	5	5	62	1,237	59	1,234
Oklahoma..	3,193	153,446	2,806	134,075	178	5,976	133	5,709	3,371	159,422	2,939	139,784
Texas.....	3,737	195,636	3,567	173,563	452	17,449	586	28,474	4,189	213,085	4,153	202,037
Indiana, Illinois and Kentucky.	565	16,935	577	16,261	121	5,545	111	5,701	686	22,480	688	21,962
Colorado, Montana, Utah and Wyoming..	579	33,677	499	29,845	85	2,291	103	3,624	664	35,968	602	33,469
Other States...	1,935	32,663	1,832	30,456	708	20,618	717	23,227	2,643	53,281	2,549	53,683
Undistributed.....	—	—	410	6,862	—	—	785	7,625	—	—	1,195	14,487
United States Total.	13,699	536,018	12,011	479,214	2,643	84,487	3,083	104,264	16,342	620,505	15,094	583,478

1/ Revised to exclude capacity of tankage for heavy crude and fuel oil.

TABLE 15. - Capacity and types of storage tanks for crude petroleum and net stocks, June 30, 1936, by States
(thousands of barrels)

Location	Steel shells						Wood shells		Earthen tanks		Concrete tanks		Total		Net stocks in tanks
	Steel roofs		Wood roofs		Other type roofs										
	No.	Capacity	No.	Capacity	No.	Capacity	No.	Capacity	No.	Capacity	No.	Capacity	No.	Capacity	
At tank farms:															
Arkansas	59	1,234	19	990	101	6,195	--	--	--	--	--	--	179	8,419	2,778
California	586	25,645	188	8,230	27	2,115	--	--	--	--	--	--	801	35,990	24,317
Kansas	101	2,934	281	10,517	21	1,012	--	--	--	--	--	--	403	14,463	5,579
Louisiana	151	7,217	38	1,610	93	4,535	15	12	--	--	--	--	297	13,374	3,853
New Mexico	27	658	3	145	3	165	--	--	--	--	--	--	33	968	118
Oklahoma	1,081	66,959	841	37,948	297	16,515	--	--	--	--	--	--	2,219	121,422	51,485
Texas	1,639	92,104	442	25,220	694	39,616	--	--	4	530	2	2,111	2,781	159,581	72,895
Ind., Ill., & Ky.	61	2,282	278	9,762	--	--	52	25	--	--	--	--	391	12,069	7,325
Colo., Mont., Utah, and Wyo.	439	28,393	17	737	--	--	--	--	--	--	--	--	456	29,130	23,689
Other States	456	13,214	338	8,803	--	--	2	1	--	--	--	--	796	22,018	6,563
Undistributed	100	2,500	100	2,000	60	1,200	5	2	--	--	--	--	265	5,702	--
U. S. Total	4,700	243,140	2,545	105,962	1,296	71,353	74	40	4	530	2	2,111	8,621	423,136	198,602
At refineries:															
Arkansas	29	501	21	1,128	--	--	--	--	--	--	--	--	50	1,629	706
California	282	12,300	4	137	15	1,275	--	--	--	--	--	--	301	13,712	7,984
Kansas	96	4,276	--	--	2	160	--	--	--	--	--	--	98	4,436	2,118
Louisiana	83	4,892	111	5,230	--	--	--	--	--	--	--	--	194	10,122	1/3,690
Oklahoma	124	5,214	8	440	1	55	--	--	--	--	--	--	133	5,709	2,400
Texas	526	25,445	27	1,182	33	1,847	--	--	--	--	--	--	586	28,474	15,329
Ind., Ill., and Ky.	90	4,443	4	220	17	1,038	--	--	--	--	--	--	111	5,701	2,322
Colo., Mont., N.Mex. Utah, and Wyo.	108	3,629	--	--	--	--	--	--	--	--	--	--	108	3,629	2,218
Other States	666	21,332	23	570	18	894	5	7	--	--	5	424	717	23,227	14,845
Undistributed	650	6,500	100	1,000	10	100	25	25	--	--	--	--	785	7,625	--
U. S. Total	2,654	88,532	298	9,907	96	5,369	30	32	--	--	5	424	3,083	104,264	2/51,612

1/ Includes Alabama.
2/ Includes stocks in transit.

Table 15. - Capacity and types of storage tanks for crude petroleum. and net stocks, June 30, 1936, by States - Cont'd

(Thousands of barrels)

Location	Steel shells						Wood shells		Earthen tanks		Concrete tanks		Total		Net stocks in tanks	Pipe-line fill
	Steel roofs		Wood roofs		Other type roofs											
	No.	Capacity	No.	Capacity	No.	Capacity	No.	Capacity	No.	Capacity	No.	Capacity	No.	Capacity		
At pipe-line stations:																
Arkansas	20	363	-	-	-	-	-	-	-	-	-	-	20	363	138	246
California	187	3,562	97	4,054	20	1,286	-	-	-	-	-	-	304	8,902	1,760	915
Kansas	124	1,464	75	1,935	2	20	-	-	-	-	-	-	201	3,469	1,334	1,449
Louisiana	59	1,883	2	60	-	-	-	-	-	-	-	-	61	1,943	1,699	783
Oklahoma	463	8,355	110	3,753	14	545	-	-	-	-	-	-	587	12,653	7,706	3,485
Texas	740	12,433	12	556	30	988	4	5	-	-	-	-	786	13,982	8,298	8,435
Ind., Ill., & Ky.	143	2,792	43	1,400	-	-	-	-	-	-	-	-	186	4,192	2,081	2,020
Colo., Mont., N. Mex. Utah, and Wyo..	63	939	1	37	-	-	-	-	-	-	-	-	64	976	748	378
Other States ...	623	6,627	116	1,580	2	75	295	156	-	-	-	-	1,036	8,438	5,019	3,822
Undistributed ..	100	750	20	300	5	100	20	10	-	-	-		145	1,160	-	-
U. S. Total ...	2,522	39,168	476	13,725	73	3,014	319	171	-	-	-	-	3,390	56,078	28,783	21,533
															Total net stocks in tanks	Total net stocks including pipe-line fill
Total storage capacity, exclusive of lease:																
Arkansas	108	2,098	40	2,118	101	6,195	-	-	-	-	-	-	249	10,411	3,622	3,868
California	1,055	41,507	289	12,421	62	4,676	-	-	-	-	-	-	1,406	58,604	34,061	34,976
Kansas	321	8,674	356	12,502	25	1,192	-	-	-	-	-	-	702	22,368	9,031	10,480
Louisiana	293	13,992	151	6,900	93	4,535	15	12	-	-	-	-	552	25,439	1/9,242	1/10,025
New Mexico	53	924	3	145	3	165	-	-	-	-	-	-	59	1,234	244	359
Oklahoma	1,668	80,528	959	42,141	312	17,115	-	-	-	-	-	-	2,939	139,784	61,591	65,076
Texas	2,905	129,982	481	26,958	757	42,451	4	5	4	530	2	2,111	4,153	202,037	96,522	104,957
Ind., Ill., & Ky.	294	9,517	325	11,382	17	1,038	52	25	-	-	-	-	688	21,962	11,728	13,748
Colo., Mont., Utah, and Wyo..	584	32,695	18	774	-	-	-	-	-	-	-	-	602	33,469	26,529	26,792
Other States ...	1,745	41,173	477	10,953	20	969	302	164	-	-	5	424	2,549	53,683	26,427	30,249
Undistributed ..	850	9,750	220	3,300	75	1,400	50	37	-	-	-	-	1,195	14,487	-	-
U. S. Total ...	9,876	370,840	3,319	129,594	1,465	79,736	423	243	4	530	7	2,535	15,094	583,478	278,997	300,530

Tankage at Pipe-Line Stations

Total capacity for crude petroleum at pipe-line stations on June 30, 1936, was 56,078,000 barrels, or almost 10 percent of the national total. Tanks at pipe-line stations numbered 3,390; these had an average capacity of 16,542 barrels, contrasted with an average of 38,656 barrels for all crude-oil storage tanks. The three most important oil States - Texas, California, and Oklahoma - had 35,537,000 barrels (63 percent) of the total storage at pipe-line stations. Pump-station capacity, particularly at junction points, is sometimes rather large, exceeding requirements for strictly pumping operations and line-break emergencies. In such cases the stations give flexibility to pipe-line systems by serving as gathering depots for temporary accumulations of oil to be pumped into the main line as required.

Tankage at Tank Farms

On June 30, 1936, tank farms had a total of 8,621 tanks whose capacity was 423,136,000 barrels, or 73 percent of the total. The average capacity of these tanks was 49,082 barrels. The report for May 1, 1931, did not show separate tank-farm data, but it is reasonable to assume that nearly all of the reduction in storage capacity was at tank farms. In view of the increased volume of oil being handled by pipe lines in 1936 as compared with 1931, a material reduction in pipe-line tankage seems illogical. The combined total capacity of tank farms and pipe-line stations on June 30, 1936, was 479,214,000 barrels, compared with 536,018,000 barrels on May 1, 1931, a reduction of 56,804,000 barrels or 11 percent. Texas and Oklahoma, with 38 and 29 percent, respectively, of the total tank-farm capacity in the United States, were far ahead of the other States. California was third in tank-farm capacity with 9 percent of the total.

A substantial part of the storage capacity that has disappeared from Oklahoma, Kansas, and Texas since 1931 is accounted for by the demolition of a large number of old surplus tanks, particularly during 1935 and 1936, when there was a boom in the market for scrap steel. Advantage was taken of the unusually high prices that prevailed in those years (and that still prevail) to dispose of a large tonnage of steel plates and accessory material.

Tankage at Refineries

Contrary to the general trend, the capacity of crude-oil tankage at refineries was expanded 23 percent between May 1, 1931, and June 30, 1936, or from 84,487,000 barrels to 104,264,000 barrels, and the number of tanks was increased from 2,643 to 3,083. The average tank size in 1936 was 33,819 barrels - about twice that of pipe-line-station tanks and two-thirds that of farm tanks.

More than half of the added capacity at refineries was in Texas, which showed an increase of 63 percent (11,025,000 barrels), reflecting the remarkable growth in refining within the State, particularly on the Gulf coast. Substantial increases, on a percentage basis, were recorded in

Kansas, Arkansas, and the Rocky Mountain group of States, amounting in the aggregate to 3,449,000 barrels. Changes in other States were small, a moderate increase being evident in most of them. The most notable exception was California, which showed a reduction of 3,975,000 barrels, or 22 percent.

Tankage by Types of Shells

The survey of June 30, 1936, shows that tanks with steel shells or walls have displaced all but negligible remnants of other types for the storage of refinable crude petroleum. Of the total capacity on that date, 580,170,000 barrels, or 99-1/2 percent, were of steel, and only 3,308,000 barrels, or 1/2 percent, were wood, concrete, and earthen types of tanks.

The principal reason for the paramount position of tanks with steel shells is that they alone possess to a relatively high degree the combined qualities of low initial and maintenance costs, mobility, and low evaporation losses. Tanks with wood shells have never been used extensively except in the Appalachian district or for the storage of small amounts of corrosive crude oils elsewhere. On June 30, 1936, 423 wood tanks were in service, but their total capacity was only 243,000 barrels. Concrete tanks have been erected principally for the storage of heavy crude (and/or fuel oil) in California. However, as such stocks are classed with fuel oil and not as crude, the number and capacity of these tanks are not included in this report. The only concrete tanks included are seven east of California having a total capacity of 2,535,000 barrels, probably used to store corrosive oils. Earthen tanks were constructed in Arkansas, Texas, California, and elsewhere for the temporary storage of flush production, generally heavy oils. This wasteful practice was terminated by the extension of pipe lines and by the general adoption of proration; hence, only four earthen tanks, with a capacity of 530,000 barrels, were reported for June 30, 1936.

Types of Roofs

In this survey, as in that for May 1, 1931, data were obtained concerning the types of roofs on tanks with steel shells. This information, for both periods, is given in table 16.

The salient feature of table 16 is the increase in relative importance of steel tanks with "other types" of roofs at the expense of the conventional roofs of steel and wood. The number of "other-type" roofs increased from 594 on May 1, 1931, to 1,465 on June 30, 1936; the capacity of tanks with such roofs increased from 30,549,000 barrels to 79,736,000 barrels, or 161 percent. On the other hand, the number of tanks with steel roofs declined by about 2,000 (11,857 to 9,876) and their capacity declined from 408,391,000 to 370,840,000 barrels, or 9 percent. The number of steel tanks with wood roofs declined by about 700 (4,028 to 3,319) and their capacity decreased from 180,026,000 to 129,574,000 barrels, or 28 percent. Steel tanks with all-steel roofs accounted for nearly two-thirds of the total capacity on June 30, 1936, but the development of special roofs to reduce evaporation losses is lowering this proportion rapidly.

TABLE 16. - Types of roofs on tanks with steel shells used in storing crude petroleum in the United States, May 1, 1931, and June 30, 1936 (capacity data in thousands of barrels)

Type of roof	At tank farms and pipe-line stations				At refineries				Total			
	May 1, 1931		June 30, 1936		May 1, 1931		June 30, 1936		May 1, 1931		June 30, 1936	
	Number	Capacity	Number	Capacity	Number	Capacity	Number	Capacity	Number	Capacity	Number	Capacity
Steel..	9,210	332,358	7,222	282,308	2,647	76,033	2,654	88,532	11,857	408,391	9,876	370,840
Wood...	3,606	163,533	3,021	119,687	422	16,493	298	9,907	4,028	180,026	3,319	129,594
Other types.	543	29,026	1,369	74,367	51	1,523	96	5,369	594	30,549	1,465	79,736
Total..	13,359	524,917	11,612	476,362	3,120	94,049	3,048	103,808	16,479	618,966	14,660	580,170

The great majority of "other-type" roofs are composed of various heat-insulating materials, usually applied in combination with wood and/or sheet metal. Floating-type roofs are used advantageously on active "working" tanks in which the surface of the contained oil fluctuates more or less continuously as oil is pumped in or withdrawn. Most tanks now used for storage of refinable crude oils are constructed to reduce losses by evaporation, by making them vapor-tight and equipping them with devices to minimize "breathing", or the emission of vapors emanating from the oil and intake of air as a result of temperature changes.

APPENDIX 2. - CRUDE-OIL PIPE LINES

Total Mileage

The total length of crude-petroleum pipe lines in the United States on June 30, 1936, was 110,580 miles, of which 57,820 miles were trunk lines and 52,760 miles were gathering lines (see table 17). A slight decrease in mileage of both trunk and gathering lines took place after May 1, 1931, when a similar survey showed that there were 58,020 miles of trunk lines and 53,640 miles of gathering lines, or a total of 111,660 miles of pipe used in moving crude petroleum. In the 5-year period preceding May 1, 1931, the ratio of trunk-line mileage to total mileage increased from 49 to 52 percent, with a corresponding decrease in gathering-line mileage from 51 to 48 percent. The present survey indicates that these percentages for trunk and gathering lines have remained virtually constant since May 1, 1931, at 52 and 48, respectively.

Diameters of Pipe Lines

The tendency to use relatively more pipe of the larger sizes for transportation of crude oil has been evident for a number of years. The average diameter of trunk lines, as calculated from total length and cubic content, increased from 8 inches in 1931 to 8.3 inches in 1936. Table 18 indicates that in the 5-year interval the total mileage of all pipe of 8-inch and larger diameter increased, whereas that of 6-inch and all smaller sizes decreased. Almost half of all trunk-line mileage is of 8-inch pipe. In gathering lines, however, the average diameter (which was 3.7 inches in 1926) was 3.9 inches in both 1931 and 1936, because increases in amounts of 4-inch and 6-inch pipe were offset by decreases in 2-inch, 3-inch, and "above 6-inch." Two-inch pipe is employed most widely in gathering lines, but present trends indicate the increasing importance of 4- and 6-inch pipe.

Tonnage of Pipe Lines

On June 30, 1936, the weight of steel in pipe lines in use to transport crude petroleum was 5,684,000 short tons, 4 percent more than on May 1, 1931, when 5,460,000 short tons were in use. Of the 1936 total, 4,390,000 short tons (77 percent) were in trunk lines and 1,294,000 short tons (23 percent) were in gathering lines. These figures cover the pipe only, excluding fittings, machinery, and other necessary equipment.

TABLE 17. - Mileage of crude-oil pipe-line in the United States, June 30, 1936, and May 1, 1931, by States

	June 30, 1936					May 1, 1931		
	Trunk lines	Gathering lines	Total miles	Pipe-line fill (thousands of barrels) Calculated	Pipe-line fill (thousands of barrels) Actual	Trunk lines	Gathering lines	Total miles
Arkansas	650	650	1,300	268	246	820	840	1,660
California ...	2,680	1,770	4,450	1,329	915	3,780	1,820	5,600
Colorado	20	100	120	10	8	20	90	110
Illinois	3,110	940	4,050	1,411	1,286	3,020	1,140	4,160
Indiana	1,980	280	2,260	764	663	1,980	410	2,390
Iowa	100	-	100	55	51	98	-	98
Kansas	3,770	3,910	7,680	1,604	1,449	3,440	3,500	6,940
Kentucky	430	1,340	1,770	96	71	540	1,700	2,240
Louisiana	2,200	1,100	3,300	850	783	1,890	900	2,790
Maryland	-	-	-	-	-	33	-	33
Michigan	490	250	740	132	111	325	160	485
Missouri	4,180	-	4,180	1,948	1,826	4,170	-	4,170
Montana	100	350	450	43	34	60	215	275
Nebraska	390	-	390	255	(1/)	404	-	404
New Jersey ...	180	-	180	39	38	190	-	190
New Mexico ...	300	450	750	128	115	150	350	500
New York	200	550	750	40	28	210	610	820
Ohio	2,360	5,620	7,980	960	780	2,580	5,780	8,360
Oklahoma	10,170	11,510	21,680	3,867	3,485	10,990	13,510	24,500
Pennsylvania .	3,470	5,810	9,280	835	695	3,510	6,540	10,050
Tennessee	-	10	10	-	-	-	15	15
Texas	20,290	12,600	32,890	9,290	8,435	18,880	10,460	29,340
West Virginia.	260	4,820	5,080	328	293	320	4,910	5,230
Wyoming	490	700	1,190	288	221	610	690	1,300
U. S. Total.	57,820	52,760	110,580	24,540	21,533	58,020	53,640	111,660

1/ The only line in Nebraska was used for gas temporarily and refilled with crude oil late in 1936.

TABLE 18. - Mileage and tonnage of crude-oil pipe lines in the United States, May 1, 1931, and June 30, 1936, by sizes

Size (I.D.)1/	Trunk lines				Gathering lines				Total			
	Miles		Short tons (1,000's)		Miles		Short tons (1,000's)		Miles		Short tons (1,000's)	
	May 1, 1931	June 30, 1936	May 1, 1931	June 30, 1936	May 1, 1931	June 30, 1936	May 1, 1931	June 30, 1936	May 1, 1931	June 30, 1936	May 1, 1931	June 30, 1936
2 inch.......	—	—	—		21,450	19,620	204	187	21,450	19,620	204	187
3 inch.......	—	—	—		9,970	9,220	198	183	9,970	9,220	198	183
Below 4 inch.	3,070	1,270	57	24	—	—	—	—	3,070	1,270	57	24
4 inch.......	4,520	3,990	127	112	11,890	13,550	335	381	16,410	17,540	462	493
6 inch.......	11,140	10,460	552	518	7,360	7,680	364	380	18,500	18,140	916	898
Above 6 inch.	—	—	—	—	2,970	2,690	180	163	2,970	2,690	180	163
8 inch.......	26,290	27,060	1,956	2,013	—	—	—	—	26,290	27,060	1,956	2,013
10 inch......	8,270	9,450	875	1,000	—	—	—	—	8,270	9,450	875	1,000
12 inch......	4,700	5,510	608	713	—	—	—	—	4,700	5,510	608	713
Above 12 inch	30	80	4	10	—	—	—	—	30	80	4	10
Total........	58,020	57,820	4,179	4,390	53,640	52,760	1,281	1,294	111,660	110,580	5,460	5,684

1/ Data for odd sizes are included in the next lower size listed.

Pipe-Line Developments, by States

As might be expected, the principal growth in the crude-oil pipe-line system has taken place in areas where a considerable increase in oil production has occurred during the last 5 or 6 years. Texas, with a net increase of over 3,500 miles of crude-oil lines, exceeds all other areas in this respect. As an indication of the phenomenal rise in oil activity in that State, it is interesting to note that from 1931 to 1936 production in Texas increased 29 percent and crude-oil runs to stills 38 percent. The refinery expansion was concentrated largely on the Gulf coast, but the increase in production was rather generally distributed and additional facilities for transportation to tidewater were required. Other States in which pipe-line mileage increased were Kansas, Louisiana, Michigan, New Mexico, and Montana, in the order named. A material increase in development work has taken place in each of these States in recent years.

The greatest shrinkage in pipe-line mileage took place in Oklahoma, where there was a net reduction of 820 miles of trunk lines and 2,000 miles of gathering lines. The pipe-line systems of several large companies in Oklahoma have been reorganized extensively since 1931, which involved abandonment of many old lines that had outlived their usefulness and the laying of lines in new locations. These adjustments reflect changes that have taken place over a period of years in the producing fields and in the market demand for Oklahoma oil. The recent tendency to ship increasing proportions of Oklahoma oil to markets in the north and east has reduced substantially the need for pipe-line capacity to handle a southward movement into Texas and Louisiana.

The important reduction in California mileage (1,100 miles of trunk line) is substantially accounted for by a change in the routing of crude to some refineries in the San Francisco area. Considerable trunk-line mileage was salvaged when it was found to be more advantageous to ship oil north from some of the southern fields by ocean tanker than through the old pipe lines.

A few minor crude-oil lines were salvaged in Wyoming and in all of the eastern producing States. These changes doubtless indicate the gradual adjustment of pipe-line systems to requirements in old, settled fields where declining volumes of production dictate consolidation and abandonment of some lines in order to utilize the remaining pipe-line capacity more efficiently. These changes also are influenced strongly by such factors as the prices of oil and of scrap metal and labor costs.

General Economic and Technical Developments

Modern practices in oil-pipe-line construction and operation have brought about a marked increase in efficiency under the economic pressure of increasing labor and material costs and reduced rates. The carrying capacity of many of the older lines has been increased 40 percent or more by reconditioning old equipment and installing new pumping equipment. The use of high-speed centrifugal pumps in place of the reciprocating type has become almost universal on new installations. Motive power is supplied by compact, multicylinder Diesel or gas engines or by electric motors. Steam turbines are the prime movers in some recently built trunk-line stations. Seamless pipe of high-tensile steel, with welded joints, is now generally used in oil trunk lines and permit operating pressures of 700 to 1,000 pounds per square inch. Heating heavy oils and blending them with light crudes and natural gasoline are common practices designed to increase the carrying capacity of pipe lines.

In recent years emphasis has been placed upon reduction to a minimum of necessary shut-down time in pipe-line operations due to failure of pumping equipment, line breaks, and other causes. Improved engineering design and systematic training of personnel in the refinements of operating practice have accomplished much in this direction.

The use of larger pipe in trunk-line construction, previously mentioned, is encouraged by the relationship of operating costs to initial investment. When it can be anticipated that the useful life of a proposed trunk line of given capacity will be perhaps 20 years or more, it is often advantageous to increase the initial investment above a necessary minimum in order to reduce the annual cost of operating the line. For example, an 8-inch line with pump stations at 40-mile intervals might be adequate to handle 20,000 barrels of oil per day. A 10- or 12-inch line would cost more but could carry this volume with a much smaller number of stations and consequently a lower payroll and maintenance expense. Another consideration that favors the large line is its superior adaptability for handling greater volumes of oil, if this becomes necessary.

The problem of corrosion in buried pipe lines has been the subject of extensive research and experimentation during recent years. Many substances have been developed for use as a protective coating for pipe. They may be applied either in the factory or in the field. Significant developments are the growing use of portable machines that displace manual labor in the field to clean and coat pipe, and the tendency under favorable conditions to do much of this work in temporary field shops conveniently situated, rather than along the right of way.

Cathodic protection of pipe lines, in which low-voltage electric currents are used to combat the effects of electrolysis, is emerging from the experimental stage of development and entering a rather broad field of practical application. Several hundred miles of pipe line have been protected by this means against the highly corrosive effects of acid soils in areas of the Gulf coast and California. Usually the pipe lines protected by the cathodic method are made of coated pipe, but in some instances no protection other than the electric current has been provided.

APPENDIX 3. - ANALYSES OF OILS FROM PIPE-LINE SYSTEMS

Crude-oil pipe lines in the United States held stocks totaling about 21 million barrels on June 30, 1936 (table 17). The oil transported in most of the large lines is from several fields and States, so it is not a uniform mixture and varies in characteristics from time to time.

Analyses of 19 samples of oils that were in pipe lines enroute to market in 1937 are shown in table 19. The samples numbered 1 to 12 are from pipe lines transporting oil from a general area or a number of small fields; those numbered 13 to 19 are from pipe lines each of which transports oil from one field only.

The chemical and physical properties shown in table 19 are indicative, in a general way, of types of petroleum that were being marketed in 1937 and of the wide range in properties of the various oils. Omitting the Smackover, Ark., oil (sample 17), which is considerably heavier than the others, the samples range in gravity from 45.2° A.P.I. for the mixed Appalachian oil (sample 3) to 25.6° A.P.I. for the Midway, Calif., oil (sample 18); in viscosity at 100° F., from 36 seconds Saybolt for the East Texas oil (sample 10) to 75 seconds for the Midway oil; in sulphur content, from less than 0.1 percent for oils of the Appalachian districts (samples 1, 2, 3, and 13) to 1.32 percent for the Hobbs, N. M., oil (sample 16); in first drop temperature, from 82° F. for the East Texas oil (sample 10) to 165° F. for the Midway oil; in distillate recovery below 392° F. (200° C.), of 40 percent with gravity of 64.2° A.P.I. for the Burrton, Kans., oil (sample 19) to 21.2 percent with gravity of 50.1° A.P.I. for the Midway oil; and in total distillate recovery (atmospheric and reduced pressure), from 79.2 percent for the mixed Rodessa, La., oil (sample 11) to 66.2 percent for the Midway oil.

Table 19.-Analyses of "Pipeline-Run" Crude Oils Enroute to Market

Sample No.	Fields of Origin	Characteristics of Crude					
		Color	°A.P.I.	Viscosity at 77°F. 1/	Viscosity at 100° F. 1/	Sulphur percent	Carbon residue in crude
1	Mixed Pennsylvania	gr.	44.3	42	40	0.1-	0.5
2	" West Virginia	gr.	43.8	43	40	0.1-	0.5
3	" Appalachian	gr.	45.2	40	38	0.1-	0.5
4	" Mid-Continent	Br.-bl.	38.0	46	42	0.31	2.1
5	" " "	Gr.-bl.	38.0	48	43	0.33	1.9
6	" " "	Br.-bl.	38.2	48	43	0.32	2.2
7.	" " "	Br.-bl.	38.2	47	43	0.28	1.8
8	" Western Kansas	Br.-bl.	40.4	47	44	0.37	2.8
9	" Oklahoma	Gr.-bl.	37.6	49	44	0.35	1.9
10	" East Texas	Gr.-bl.	39.4	40	36	0.26	2.4
11	" Rodessa, La.	Dk.-Gr.	41.9	43	38	0.29	1.0
12	" Texas Panhandle	Gr.-bl.	42.8	44	41	0.38	1.5
13	West Virginia	Dk.-gr.	43.6	42	39	0.1-	0.4
14	Lima, Ohio	Dk.-gr.	36.4	56	47	0.56	1.3
15	Oklahoma City, Okla.	Dk.-gr.	37.8	52	45	0.17	1.3
16	Hobbs, N. M.	Gr.-bl.	33.0	55 2/	47 2/	1.32	2.5
17	Smackover, Ark.	Br.-bl.	20.5	270 2/	160 2/	2.30	7.6
18	Midway (light), Calif.	Br.-bl.	25.6	110	75	0.65	4.1
19	Burrton, Kan.	Br.-bl.	42.1	42	39	0.36	2.5

1/ Viscosity is given in Saybolt seconds.
2/ Temperatures used were 100°F. and 130°F., instead of 77°F. and 100°F., respectively.

Sample No.	Distillation at atmospheric pressure									
	Temperature		Fraction up to 50°C. (122°F.)		Fraction, 50° to 75°C. (122 to 167°F.)		Fraction, 75° to 100°C. (167° to 212° F.)		Fraction, 100° to 125°C. (212° to 257°F.)	
	First drop °C.	First drop °F.	Percent	°A.P.I.	Percent	°A.P.I.	Percent	°A.P.I.	Percent	°A.P.I.
1	31	88	3.0	89.9	3.1	84.2	5.3	70.9	6.7	62.6
2	32	90	-	-	3.2	86.2	4.2	73.0	6.6	64.2
3	30	86	2.5	88.9	3.3	85.9	5.5	70.9	7.9	62.6
4	33	91	2.3	87.9	2.6	83.2	3.9	70.1	5.9	62.3
5	36	97	2.1	-	2.1	84.2	4.1	70.6	5.7	62.1
6	36	97	-	-	4.6	82.9	4.5	69.5	5.7	61.5
7	34	93	2.3	86.9	2.0	81.9	4.2	69.5	5.8	61.5
8	36	97	-	-	3.7	82.6	5.5	71.2	7.4	62.9
9	34	93	2.0	87.2	2.6	82.6	4.5	69.5	5.9	61.5
10	28	82	6.0	88.6	2.6	74.8	5.4	69.8	6.4	58.4
11	38	100	-	-	3.1	82.6	4.3	70.1	5.8	63.9
12	33	91	3.5	89.6	3.8	81.3	6.9	67.5	8.1	60.5
13	37	99	0.6	-	1.8	83.9	4.1	73.6	6.4	65.0
14	61	142	-	-	-	-	3.0	73.3	4.7	63.7
15	33	91	-	-	2.6	84.5	3.6	71.2	5.3	62.1
16	36	97	-	-	4.8	85.2	4.2	69.5	5.4	60.8
17	73	163	-	-	-	-	2.6	57.2	0.7	-
18	74	165	-	-	-	-	1.8	67.2	4.9	56.4
19	33	91	4.4	89.9	4.6	82.6	6.3	69.8	7.5	62.6

Table 19.-Analyses of "Pipeline-Run" Crude Oils Enroute to Market (Continued)

Sample No.	Distillation at atmospheric pressure (continued)							
	Fraction, 125° to 150°C. (257° to 302°F.)		Fraction, 150° to 175°C. (302° to 347°F.)		Fraction, 175° to 200°C. (347° to 392°F.)		Fraction, 200° to 225°C. (392° to 437°F.)	
	Percent	°A.P.I.	Percent	°A.P.I.	Percent	°A.P.I.	Percent	°A.P.I.
1	6.4	57.7	6.5	53.5	4.3	50.6	5.1	48.1
2	6.6	59.2	6.4	55.2	5.6	52.0	5.5	49.5
3	6.7	57.7	5.7	53.7	5.8	50.9	4.6	48.3
4	5.9	56.7	5.7	52.3	5.1	48.1	5.4	44.5
5	5.6	56.7	5.4	52.0	4.8	48.3	5.1	44.9
6	5.6	56.4	5.4	52.0	5.0	48.1	5.4	44.7
7	5.6	55.9	5.1	51.6	4.5	48.3	5.4	45.4
8	6.2	57.9	5.8	53.0	5.3	49.0	5.5	44.9
9	5.5	56.4	5.3	51.6	4.9	48.1	5.6	44.7
10	6.0	54.7	4.4	49.5	5.0	45.4	4.3	41.9
11	6.2	59.7	6.0	55.2	6.3	52.3	5.3	49.2
12	5.6	55.7	5.1	52.0	4.3	48.5	4.5	45.6
13	6.7	59.7	6.6	55.9	6.1	52.7	6.2	49.7
14	5.0	58.9	5.4	53.7	5.6	49.9	5.8	46.9
15	5.1	56.4	4.9	52.0	5.0	48.8	5.1	45.6
16	5.2	55.2	5.4	50.4	4.7	44.9	4.9	41.5
17	0.6	54.4	3.2	44.7	2.0	41.1	3.7	37.4
18	5.5	50.9	4.5	45.8	4.5	41.3	5.2	37.6
19	6.5	57.2	5.8	52.5	4.9	48.5	4.9	44.7

Sample No.	Distillation at atmospheric pressure (continued)				Distillation at reduced pressure (40mm.)			
	Fraction, 225° to 250° C. (437° to 482°F.)		Fraction, 250° to 275°C. (482° to 527°F.)		Fraction, up to 200°C. (392°F.)			
	Percent	°A.P.I.	Percent	°A.P.I.	Percent	°A.P.I.	Viscosity (Saybolt seconds)	Cloud point °F.
1	5.3	45.6	6.3	43.0	3.5	39.0	40	20
2	5.5	47.2	7.6	44.1	3.8	39.6	41	15
3	5.3	45.8	6.6	43.0	4.3	38.8	40	20
4	5.8	41.7	6.7	38.8	4.3	35.6	40	10
5	5.3	41.9	6.9	39.2	4.8	36.2	40	10
6	5.9	41.5	6.7	38.8	4.0	36.0	40	15
7	5.8	42.1	7.0	39.2	3.6	36.0	41	15
8	5.4	41.9	6.9	39.4	4.5	36.2	40	10
9	5.6	41.3	6.2	38.8	4.6	35.4	41	15
10	4.7	39.6	5.9	37.4	4.1	34.8	40	20
11	6.4	46.3	7.9	43.2	4.4	39.2	40	15
12	4.3	42.8	6.3	40.0	2.0	37.4	40	20
13	5.9	47.2	7.7	43.8	4.0	39.8	40	15
14	6.6	43.8	8.3	40.6	3.9	37.4	40	20
15	5.3	42.3	6.9	39.4	3.9	36.6	40	15
16	5.5	38.0	7.2	34.0	3.6	29.5	42	5-
17	3.9	35.0	6.8	31.7	2.2	27.7	43	5-
18	6.3	34.4	7.5	31.1	4.6	27.9	43	5-
19	5.3	41.7	6.5	39.2	2.5	36.4	40	15

Table 19.-Analyses of "Pipeline-Run" Crude Oils Enroute to Market (Continued)

Sample No.	Distillation at reduced pressure (40mm.) (continued)											
	Fraction, 200° to 225°C. (392° to 437°F.)				Fraction, 225° to 250°C. (437° to 482°F.)				Fraction, 250° to 275°C. (482° to 527°F.)			
	Percent	°A.P.I.	Viscosity (Saybolt seconds)	Cloud point °F.	Percent	°A.P.I.	Viscosity (Saybolt seconds)	Cloud point °F.	Percent	°A.P.I.	Viscosity (Saybolt seconds)	Cloud point °F.
1	5.2	37.4	45	35	5.5	36.0	56	55	4.3	34.2	75	70
2	6.4	38.4	45	35	5.5	36.6	57	55	4.9	35.2	74	75
3	5.0	37.6	46	35	4.9	35.8	56	55	5.1	34.4	80	70
4	5.7	34.4	46	25	5.1	31.9	58	45	4.7	29.7	85	60
5	5.7	34.2	46	30	5.1	31.9	57	50	4.7	30.0	85	65
6	5.5	34.4	45	30	5.1	31.9	57	50	4.5	29.7	83	65
7	5.9	35.0	45	30	5.7	32.3	57	45	5.3	30.4	85	65
8	5.5	34.4	46	30	4.2	31.7	58	50	4.5	29.5	83	65
9	4.6	34.0	47	35	5.1	31.9	58	50	5.9	29.9	87	70
10	4.9	33.8	46	40	4.4	31.5	58	55	4.3	29.7	81	75
11	6.3	37.8	45	35	5.8	35.8	53	55	5.2	33.6	70	70
12	4.5	36.6	44	35	4.7	35.4	52	55	4.4	33.6	72	75
13	6.3	38.6	45	35	5.4	37.0	55	55	5.0	35.6	72	75
14	6.4	36.2	45	35	5.8	33.6	55	55	5.3	31.0	80	70
15	6.2	35.2	46	30	6.5	32.8	57	50	5.7	31.0	81	70
16	5.0	27.3	49	5-	5.1	25.2	68	5-	5.0	23.1	110	10
17	5.7	26.1	49	5-	6.4	23.5	68	5-	5.4	21.5	105	5-
18	5.3	25.7	53	5-	4.8	23.3	77	5-	4.9	21.0	160	5-
19	5.2	34.6	45	35	4.3	32.3	56	55	3.8	29.7	80	70

Sample No.	Distillation at reduced pressure (40mm.) (continued)				Summary					
	Fraction, 275° to 300°C. (527° to 572°F.)				Distillate recovered at atmospheric pressure				Kerosene distillate	
					Up to 100°C. (212°F.)		Up to 200°C. (392°F.)		200° to 275°C. (392 to 527°F.) at ats. pressure	
	Percent	°A.P.I.	Viscosity (Saybolt seconds)	Cloud point °F.	Percent	°A.P.I.	Percent	°A.P.I.	Percent	°A.P.I.
1	5.3	32.7	115	85	11.4	79.1	35.3	63.4	16.7	45.4
2	6.5	33.2	120	90	7.4	78.4	32.6	62.1	18.6	46.5
3	5.8	32.5	130	85	11.3	79.1	37.4	62.9	16.5	45.4
4	5.5	27.3	145	80	8.8	78.4	31.4	61.0	11.2	43.0
5	6.4	28.0	150	80	8.3	77.2	29.8	60.8	10.4	43.4
6	5.9	27.7	150	80	9.1	76.0	30.8	60.5	11.3	43.0
7	5.9	28.8	140	85	8.5	76.9	29.5	60.5	11.2	43.6
8	4.7	27.7	150	80	9.2	75.7	33.9	61.0	10.9	43.4
9	4.9	27.7	150	85	9.1	76.9	30.7	60.8	11.2	43.0
10	5.0	28.0	140	95	14.0	78.4	35.8	61.8	9.0	40.6
11	6.2	31.7	105	85	7.4	75.1	31.7	61.3	19.6	45.2
12	5.1	32.5	100	95	14.2	76.3	37.3	62.6	15.1	42.3
13	5.6	33.8	105	90	6.5	77.2	32.3	61.8	19.8	46.7
14	6.3	29.5	120	85	3.0	73.3	23.7	58.2	20.7	43.4
15	6.5	29.3	135	85	6.2	76.6	26.5	59.5	10.4	43.8
16	6.0	22.3	230	25	9.0	77.5	29.7	59.7	4.9	41.5
17	6.6	20.7	200	5-	2.6	57.2	9.1	48.5	-	-
18	6.4	19.4	400+	5-	1.8	67.2	21.2	50.1	-	-
19	5.2	27.5	150	85	15.3	79.1	40.0	64.2	10.2	43.2

Table 19.-Analyses of "Pipeline-Run" Crude Oils Enroute to Market (Continued)

Sample No.	Summary (continued) Gas oil Percent	Gas oil °A.P.I.	Nonviscous lubricating distillate Percent	Nonviscous lubricating distillate °A.P.I.	Medium lubricating distillate Percent	Medium lubricating distillate °A.P.I.	Viscous lubricating distillate Percent	Viscous lubricating distillate °A.P.I.
1	8.6	38.2	10.8	36.8 to 33.2	4.4	33.2 to 31.9	None	-
2	9.6	38.8	11.8	37.6 to 34.0	5.7	34.0 to 32.1	"	-
3	8.8	38.0	10.2	36.8 to 33.6	6.1	33.6 to 31.5	"	-
4	15.7	36.6	9.8	33.6 to 29.1	6.5	29.1 to 26.1	"	-
5	16.6	36.8	9.5	33.2 to 29.7	7.5	29.7 to 27.0	"	-
6	15.7	36.6	9.2	33.4 to 29.1	6.8	29.1 to 26.6	"	-
7	16.1	36.8	10.3	33.8 to 30.0	7.0	30.0 to 28.0	"	-
8	15.8	37.0	8.7	33.6 to 29.1	5.8	29.1 to 26.8	"	-
9	14.5	36.6	10.1	33.4 to 29.5	6.7	29.5 to 26.8	"	-
10	13.9	36.0	9.0	33.0 to 29.1	5.6	29.1 to 29.3	"	-
11	11.4	38.2	12.6	36.6 to 32.1	3.9	32.1 to 30.8	"	-
12	7.2	36.6	11.0	35.8 to 32.5	2.5	32.5 to 31.9	"	-
13	10.2	39.0	12.5	37.8 to 34.0	3.6	34.0 to 32.8	"	-
14	10.2	36.4	11.4	35.0 to 30.2	6.1	30.2 to 28.8	"	-
15	16.3	37.4	12.2	34.4 to 30.4	7.2	30.4 to 28.4	"	-
16	19.2	33.2	8.5	27.1 to 23.7	5.4	23.7 to 22.5	4.3	22.5 to 21.8
17	19.9	32.1	10.7	25.9 to 21.8	6.8	21.8 to 20.7	3.3	20.7 to 20.2
18	24.8	32.5	7.9	26.4 to 22.6	4.4	22.6 to 20.7	7.9	20.7 to 18.6
19	13.8	37.0	7.9	33.6 to 29.1	5.8	29.1 to 26.3	None	-

Sample No.	Summary (continued) Total distillate Percent	Residuum Percent	Residuum °A.P.I.	Carbon residue of residuum Percent
1	75.8	22.5	26.4	2.4
2	78.3	20.5	26.8	2.2
3	79.0	18.8	25.9	2.6
4	74.6	24.1	17.3	8.8
5	73.8	24.8	18.7	7.7
6	73.8	24.4	17.3	9.0
7	74.1	24.0	19.0	7.7
8	75.1	23.2	15.6	12.1
9	73.2	25.6	17.9	7.6
10	73.4	24.6	16.0	9.6
11	79.2	19.3	17.3	5.3
12	73.1	24.2	21.6	6.1
13	78.4	21.4	27.0	1.9
14	72.1	27.0	20.5	4.8
15	72.6	26.7	21.6	4.8
16	72.0	26.9	16.5	9.4
17	49.8	48.8	11.7	15.6
18	66.2	32.9	11.9	12.5
19	77.7	20.1	15.1	12.5