PROVISIONAL INTELLIGENCE REPORT

OUTPUT OF REFINED PETROLEUM PRODUCTS IN THE USSR

CIA/RR PR-135
8 March 1956

CENTRAL INTELLIGENCE AGENCY

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Figure 1

Product Yield Pattern in Soviet Crude Oil Refining, 1930-54

(Gross product yield percentage trend lines)

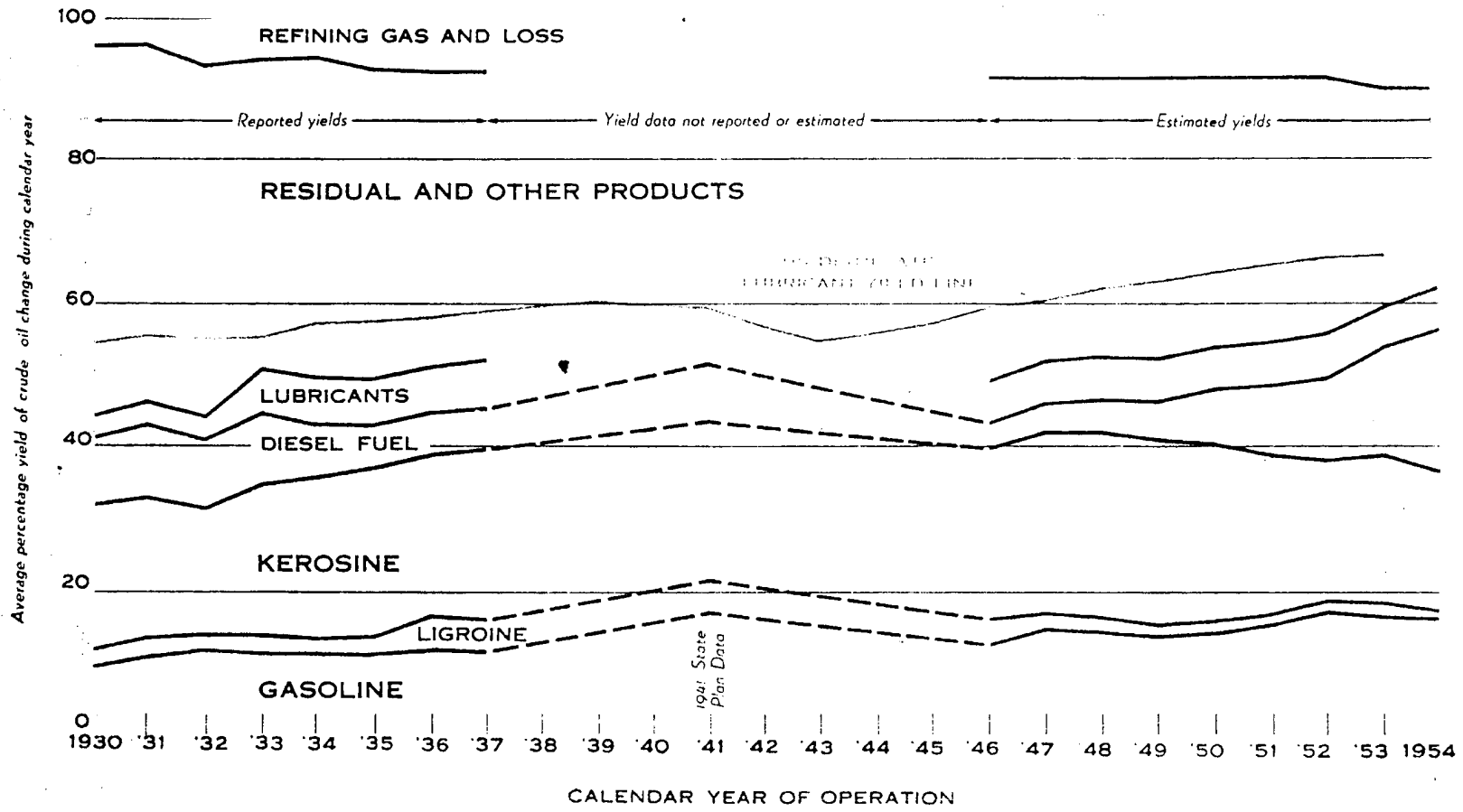

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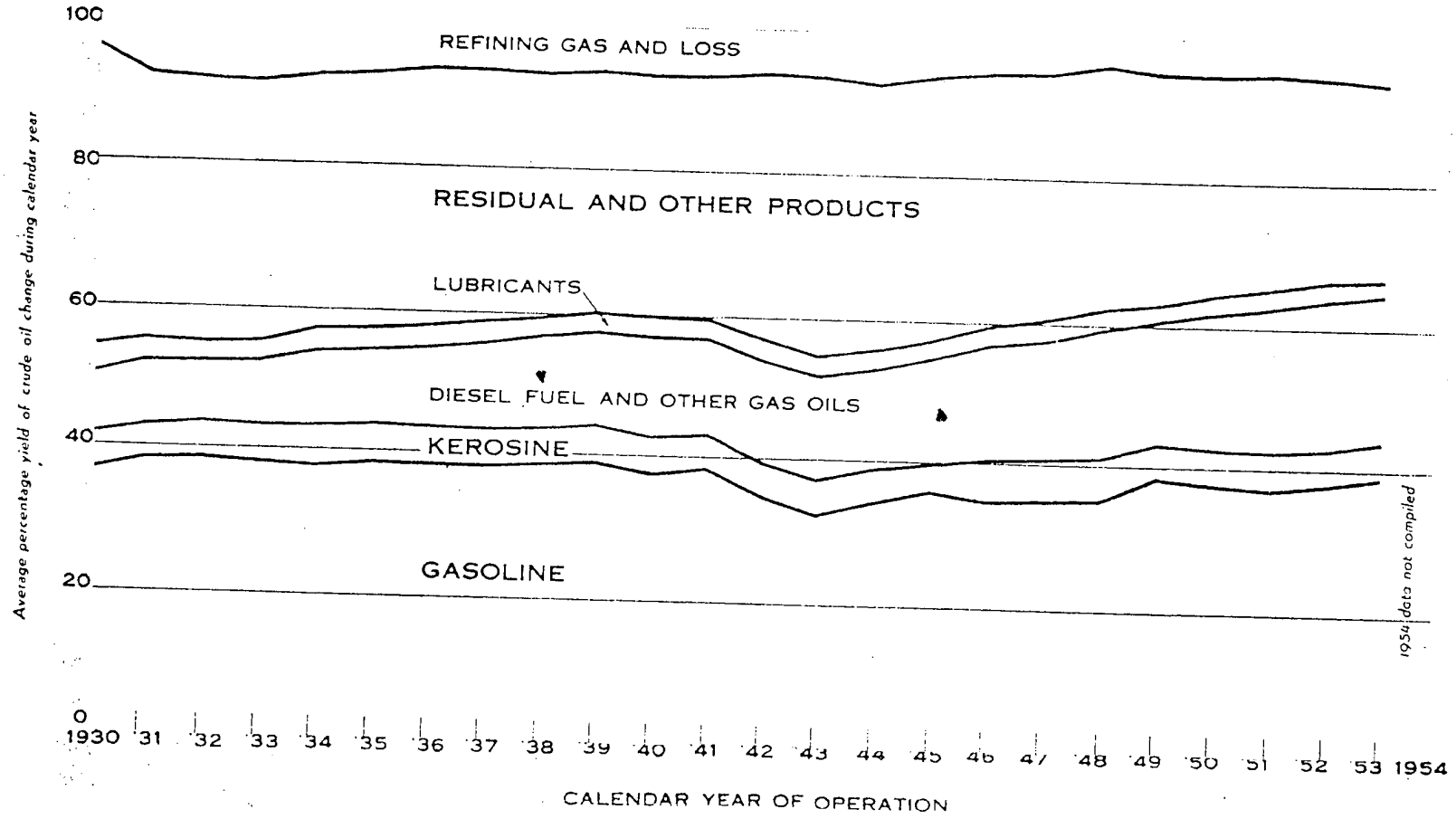
Figure 2

Product Yield Pattern in US Crude Oil Refining, 1930-54

(Gross product yield percentage trend lines)



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CIA/RR PR-135

(ORR Project 25.471)

NOTICE

The data and conclusions contained in this report do not necessarily represent the final position of ORR and should be regarded as provisional only and subject to revision. Comments and data which may be available to the user are solicited.

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FOREWORD

The purpose of this report is twofold: to develop a methodology by which the output of each of the major petroleum products in the USSR can be calculated and to apply that methodology to the available relevant information in order to derive estimates of Soviet output of petroleum products during the 1946-54 period.

The methodology is designed to correlate all available information pertinent to the output of petroleum products in the USSR: data on the Soviet supply of crude oil, synthetic oils, and natural gas liquids; official Soviet announcements of annual growth rates of the output of specific petroleum products; and data on the demand for petroleum products in the USSR.

Any evaluation of the estimates derived in this report must consider the fact that the basic data used are subject to rather wide ranges of error. In particular, current estimates of Soviet production of crude oil, synthetic oils, and natural gas liquids and current data on the demand for petroleum products in the USSR are approximations and must be recognized as such. Although the estimates developed in this report appear to correlate more closely with all available relevant information on the subject than do any known corresponding estimates, they are affected by the infirmities of the basic data.

These infirmities are apparent throughout the report, particularly in those areas where it has been necessary to derive estimates by the use of technical analogues or judgment appraisals. The need for more complete and accurate basic data is evident, and this report attempts to focus attention on that need. The methodology developed in this report will permit the derivation of firmer estimates as more factual evidence becomes available.

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OUTPUT OF REFINED PETROLEUM PRODUCTS IN THE USSR*

Summary

The annual output of refined petroleum products** in the USSR during the postwar period increased from 19 million metric tons*** in 1946**** to about 50 million tons in 1954. The Soviet output in 1953 is estimated to have been 45.7 million tons, equal to about 13 percent of the 1953 US output of 347 million tons. The prewar annual output in the USSR ranged from 8.5 million tons in fiscal year 1927-28 to 24.5 million tons in 1937. Available information on the 1938-45 period is inadequate to provide realistic estimates of output during those years.

There has been a significant change in the postwar pattern of petroleum product yields in the USSR. This change is shown below in the tabulation, which gives product yields for 1946 and 1954 by principal product categories. The kerosine category includes both kerosine and equivalent end-use products. Ligroine is a special Soviet tractor fuel, the production of which as a separate product probably was discontinued in 1954.

Type of Product	Annual Yield (Million Metric Tons) 1946	1954	Ratio of 1954 Yield to 1946 Yield
Gasoline and ligroine	3.4	10.1	3.0
Kerosine	4.9	12.0	2.4
Diesel fuel	0.7	10.0	14.3
Lubricants	1.2	3.0	2.5
Residuals and other	8.8	14.6	1.7
Total	19.0	49.7	2.6

* The estimates and conclusions contained in this report represent the best judgment of ORR as of 1 January 1956.

** For the purposes of this report, a petroleum product is one consumed or prepared for consumption as an end product, as distinguished from

This postwar pattern change is chiefly a reflection of the product percentage yields* derived from the refining of crude oil. In the USSR and the US alike, petroleum product yields are, for the most part, derived by that process. The significance of the change in the Soviet yield pattern is indicated by a comparison of the estimated Soviet percentage yields with those of the US. This comparison is shown below in tabular form. In the USSR the gas oil products are diesel fuels only; in the US the gas oil products consist of distillate fuel oil and lesser quantities of diesel fuel. Ligroine has not been derived as a product in the US.

	Yields as Percentages of Crude Oil Refining Charge				
	USSR			US	
Type of Product	1946	1953	1954	1946	1953
Gasoline and ligroine	16.2	18.1	16.7	34.3	38.8
Kerosine and gas oil products	27.0	35.5	39.3	22.3	25.6
Lubricants	6.1	6.1	6.1	2.8	2.2
Total principal distillates and lubricants	49.3	59.7	62.1	59.4	66.6
Residuals and other	41.7	30.1	27.7	34.6	27.0
Total	91.0	89.8	89.8	94.0	93.6

a raw source material from which other petroleum stocks are derived. Although the product is usually refined (processed) it is sometimes unrefined and may be semirefined. A petroleum stock is said to be crude if it has not been subjected to refining, and it is sometimes said to be crude even though it has been refined, if it serves as a raw source material for derivation of other petroleum stock.

*** Tonnages are given in metric tons throughout this report.

**** The annual operations are those which occurred in calendar-year periods, except for the fiscal operations in the USSR before 1930.

* In this report, all percentages are given on a weight basis and, unless otherwise noted, are given as annual averages.

As of 1954, Soviet crude oil refining percentage yields of the principal distillates plus lubricants appear to be approaching those of the US. Within that category, however, the Soviet percentage yields indicate definite emphasis on the intermediate distillates (kerosine and diesel fuel). This emphasis reflects not only the priority position given diesel fuel in the USSR during the postwar period but also the growth in the production of jet fuels, which are included in the kerosine yields. In the US, of course, gasoline has always been the priority petroleum product. As the Soviet percentage yields of the intermediate distillates have increased, there has been a decrease in the percentage yields of residuals and other products. In that category, too, the Soviet yields are now approaching US levels.

Estimates of the output of refined petroleum products in the USSR during the 1946-54 period do not provide a base for significant conclusions about Soviet capabilities, vulnerabilities, and intentions. What these estimates reveal about the over-all petroleum economy of the USSR seems to indicate that the Soviet petroleum industry is geared to meet the demands of the current cold-war period.

I. Introduction.

A. Terminology and Technology.

Petroleum product yields in the USSR are primarily developed as indigenous gross yields of nongaseous products. The generalized terms petroleum products and product yields are used in this report to imply certain qualifications which are fundamental in any statistical analysis of petroleum product yields.

With reference to the physical state of the product as ordinarily handled, natural gas and residue process gas are the only significant gaseous petroleum products within the broad intelligence meaning. 1/* Natural gas, a stock** of major commercial importance,

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* For serially numbered source references, see Appendix E.

** The term stock is applied in this report in the generalized meaning of material and does not refer to inventories.

is not considered in this report. Residue process gas is generally burned as fuel gas in the processing plant within which the gas is produced. Residue process gas is chiefly represented by crude oil refinery still gas 2/ in the USSR, and refinery still gas is generally shown in this report as an unspecified portion of "refinery gas and loss" in the refinery balances.

For the purpose of this report the generalized term petroleum product includes not only the extremely important liquid petroleum fuels and lubricating oils of common occurrence but also the relatively smaller quantities of other liquid products (solvent distillates and specialty tars, for instance) and relatively smaller quantities of solid products such as petroleum coke, petroleum wax, asphalt, and lubricating greases. 3/

The product yields are indigenous in that they are all derived from crude source stocks (natural and synthetic) by processing operations within Soviet plants. The product yields are gross; they are the totals which include all of the stocks finally involved in the ultimate dispositions, as follows: (1) relatively minor quantities of nongaseous products consumed in the product processing operations; (2) relatively minor quantities of material loss and waste in handling and storage, comprising "distribution losses" in the stock balances of the report; and (3) the remaining stocks finally available for exports, storage reserves, and useful indigenous consumption external to the processing of the product.

Net product yields are the gross yields less the nongaseous products consumed in product processing. In the USSR the principal consumption of this kind is represented by residual fuel oil burned in the crude oil refineries. In the Soviet crude oil refineries the principal fuel consumption probably is of refinery still gas, residual fuel oil, and natural gas. Also burned to furnish the necessary energy input for these refineries -- chiefly as additional fuels fired in the refinery boiler and power plants -- there may be smaller quantities of other petroleum fuels such as petroleum coke and of nonpetroleum fuels such as coal and lignite.

Net availability product yields are the net product yields less the distribution losses. This net availability is important because it includes the potential for the end-use consumption external to the product processing.

Indigenous gross yields represent the actual achievements in production. Net yields and net availability yields depend on practices in processing and distribution. Indigenous gross yields comprise the petroleum product yields reported in the national annual statistics of the US, of most other Free World countries, and -- in the prewar period -- of the USSR. It is almost certain that indigenous gross yields are compared in the annual Soviet product-yield ratios, which are officially reported in the postwar period. These reported ratios constitute the principal Soviet source data now available for checking the estimates of postwar yields.

Natural petroleum 4/ has furnished the principal source stocks from which petroleum products were derived in Soviet processing plants. During the postwar period in the USSR, however, relatively small quantities of the nongaseous products have been derived from synthetic petroleum. 5/ These so-called synthetic oil products 6/ probably will have a more important status in the future. Historically, in the USSR as elsewhere, crude oil (that is, natural crude oil as distinguished from synthetic crude oil) 7/ has been and continues to be the principal natural petroleum crude source stock. In the US and certain other Free World countries, nevertheless, considerable and increasing quantities of the nongaseous products are derived as natural gas liquids extracted from wet crude natural gas. 8/ Prewar official statistics of the USSR record yields of the natural gasoline type 9/ of natural gas liquids. At present it is unwarranted to ignore the increasing postwar potential for the yield of natural gas liquids in the USSR. 10/

Estimated yields of nongaseous petroleum products in the USSR, by type of product, in 1953 are shown in Table 1.*

B. Survey of the Problem.

The primary objective of this report is to develop a material balance technique for estimating the postwar yields of petroleum products in the USSR. The estimated yields and the methodology are subject to special qualifications as outlined below.**

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* Table 1 follows on p. 6.

** Sections IV and V provide a more complete summary of these features. The present introductory discussion is directed toward a preliminary analysis of the intelligence significance, and for this purpose the Introduction necessarily involves some of the description and

Table 1

Estimated Indigenous Gross Yields of Nongaseous Petroleum Products in the USSR, by Type of Product
1953

Type of Product	Estimated Yield a/ (Million Metric Tons)	Percent of Total
Products from crude oil refining	41.7	92.2
Natural gas liquids	3.1	6.8
Synthetic oil products	0.5	1.0
Total finished products	45.3	100.0

a. These yields are shown in more detail in Table 5, p. 24, below.

The estimates of Soviet postwar product yields derived in this report are compatible with other intelligence estimates to the extent that those estimates serve to quantify ultimate source materials for the derived products and to indicate the ultimate disposition of those products. As a matter of verbal convenience, these values for the ultimate source materials and dispositions may be defined as the product-yield parameters.

The estimates of postwar product yields in the USSR also conform to the available official link relatives. As described more completely later in this report, a petroleum-product link relative is a ratio relating one annual yield of the product to the corresponding yield in a previous year.

explanations which are also included later in the text. Sections IV and V are developed so that cross reference to this introductory discussion is not necessary for an understanding of the essentials.

The methodology developed provides a reasonably complete system for estimating postwar yield values for the major categories of products, thus accounting also for the principal types of processing. In addition, the technique is developed in a generalized form for more or less rapid and methodical application to possible revised values of the product-yield parameters, which are constituted by the values for source materials and dispositions as stated above.

The estimates of postwar product yields in this report therefore reflect all errors which may be involved in the estimates of such parameters. The related methodology has specific limitations and is based on the premise that the parametric values are independently established. The methodology in itself actually serves to develop original yield estimates only for the products from crude oil refining.* For complete application to a given annual operation, the methodology requires independently derived values for basic parameters as follows: indigenous production of crude oil, indigenous yield of petroleum products other than by crude oil refining -- and with respect to all types of nongaseous petroleum stocks -- indigenous consumption and international trade data.

Incidental dispositions of petroleum stocks, although parametric, are not considered as basic parameters. The minor dispositions consist of storage increments and the various physical material losses which normally occur in the petroleum industry. In general, the postwar incidental dispositions cannot be quantified on the basis of direct data available for the USSR. Although the typical annual quantities of such dispositions are not relatively large enough to be controlling, the values usually have a significant total and have significant cumulative effect when use is made of the reported official link relatives.

In formulating the postwar Soviet yields in this report, the incidental losses and storage increments are quantified. This is done by the use of estimating factors which are developed in the methodology. The factors are specifically derived by supplementary considerations or assumptions and are considered to be accurate enough for the purpose.

The methodology is generally applicable to revised estimates of the basic parameters when and if new data with a smaller range of probable error become available. Assuming that the estimated basic

* As already noted, however, crude oil refining furnishes more than 90 percent of all indigenous petroleum products in the USSR.

parameters are not self-evidently contradictory in terms of over-all quantities, the methodology serves for a detailed check of the compatibility of the estimates of source materials with the estimates of dispositions. The methodology may be applied to derive an apparent yield pattern of crude oil refining products where the products are expressed in terms of percentages of their total. Such a pattern is subject to technical analysis from the point of view of reasonableness.

Although there is much flexibility in practicable crude oil refining operations, even when the quality of the crude oil and the refining facilities are established, there are certain comprehensive limits imposed on the plausible over-all product-yield pattern. Although the range of practicable yield percentages may be quite wide for a given product category, the range for reasonable practice is nevertheless within determinable limits, and the corollary of an increased yield percentage in one specific category is usually a decreased yield percentage in another specific category.*

Because of the wide practicable variations in the yield pattern of refined petroleum products, no theoretical pattern can be satisfactorily evolved for the yields actually attained in a national crude oil refining complex, specifically when the available data are confined to the quantity and quality of crude oil and the installed refining facilities. For postwar refining of crude oil in the USSR, the known fragmentary data are here considered inadequate for direct estimates of the actual yields of crude oil refining products, and the estimates of the basic parameters appear to provide the only adequate framework for realistic estimates of such yields. The methodology of this report leads to a solution of the problem. The final form of the national product-yield pattern is derived from the national product-demand pattern. The demand pattern itself is developed from the estimates of the trade balances and the ultimate dispositions.

The methodology of this report thus may be used to correlate a comprehensive and internally consistent series of intelligence estimates, covering the entire field of the postwar Soviet yields and dispositions of nongaseous petroleum stock. In this series the coverage ranges from production through processing to ultimate consumption. Also covered are the stock trade balances and the attendant dispositions in losses and storage increments.

* These facts are important even though the technical nature of the matter precludes more detailed discussion in this report.

This report shows the application of the methodology to the parametric data which are currently available. The postwar yields of petroleum products in the USSR are thus calculated by major categories. The categories are quantified as annual yields from 1946 through 1954, conforming to the link-relative ratios which have been officially published by the Soviet government.* The published product link relatives form chains of percentage values, each relating to an unrevealed 1946 yield as the base. The applied methodology indirectly develops the basic 1946 yields so that they are consistent with a considerable variety of other available data. As indicated above, and as analyzed in more detail in later sections of the report, this consistency is not provided by use of the available fragmentary data for direct estimates of the 1946 yields.

The required parametric data and three individual link relatives are not at present available for complete application of the generalized methodology to the postwar years. For the estimates of 1946-54 yields, certain supplementary assumptions were applied in addition to the supplementary assumptions which are involved in the estimating factors. Although the pertinent details of these features are covered in subsequent sections of this report, specific mention is made of the fact that independent estimates are not presently available for the annual indigenous civil consumption of the "residual and other products" category. For the over-all sequence of postwar years, moreover, the basic parametric data are not completely available for the consumption of products by the armed forces and for international trade in the products.

By use of the available parameters, the reported link relatives, and the supplementary assumptions of the methodology, the postwar yields of "residuals and other products" result as differences (or remainders) in the material balances. All required basic parameters are available at the present time for 1953 only. For 1951 and 1952, however, the only missing parameters are also of a type that can be separately equated to a material balance remainder, provided that the supplementary assumptions are correct. For 1946 through 1950 and for 1954 the methodology of this report cannot be applied for over-all material balances.

* The derived postwar product yield patterns also conform to technical practicability.

Because the influence of the probable ranges of error in the estimated parameters would prevail even with all parameters available so that no supplementary assumptions would be required, the absolute product yields thus derived must depend on other correlations for independent evidence of validity. The 1946-54 yield series in this report is further influenced by a number of irregularities caused by the current unavailability of certain individual parameters. The 1946 yields in this series, however, may be correlated favorably with the known prewar trends in product yields in the USSR and with certain independent estimates.

In view of the over-all evidence, a probable range of error well within plus or minus 10 percent is believed to be applicable for the absolute postwar yield values derived for gasoline, ligroine, the kerosine category, diesel fuel, and lubricants. This range compares with a probable range of error of up to plus or minus 25 percent as established on a technical basis, even if possible errors are discounted in crude oil availability when fragmentary data are used for direct estimates of the product yields. In this report the remainder yields of "residual and other products" have a probable range of error almost directly proportional to that in the estimated crude oil availabilities.

In the application of the methodology, an estimating factor is used to establish the year-end storage stock value for crude oil and each separate product, generally quantifying this stock as 12.5 percent of the respective preceding annual gross yield. This storage reserve approximates 45 days of supply to meet average demand, which is calculated on the basis of the preceding annual gross yield. Because there are no known firm data revealing numerical values or ratios for the actual Soviet storage stock quantities, the storage factor is based on analogy with US practice. The 45-day reserve supply is considered an average for operational reserves, providing ballast for seasonal variations, plant shutdowns, and the like.

The reserve supply is by no means a fixed factor, even though it reflects the average conditions which prevail in the US petroleum industry. It is generally true, however, that with less than 15 days of average operational reserve, serious disruptions would be very probable in the normal stock flows and over-all operations. More than 60 days of average operational reserve would not be necessary except under abnormal conditions.

With no general quantitative distinctions possible except when extreme ratios are considered, the operational reserves may be qualitatively distinguished from stockpiles. Stockpiles in this sense are those stocks which are handled primarily as reserves for extraneous emergency use. Stockpiles as thus defined would logically consist chiefly of distillate products.

Considering that the 45-day reserve supply represents operational reserves only and that estimates of postwar yields of distillate products in the USSR have favorable correlations with estimated parameters, with technical considerations, with prewar product-yield trends, and even with certain independent estimates which provide a degree of realism in the absolute values, it is probable that excess distillate yields are not available for the stockpiling purposes.

In the USSR the petroleum storage stocks consist of state reserves and working reserves. Although there are available some inconclusive data on Soviet capacity for petroleum storage, no firm quantitative data are available in regard to the totals of the storage stock, and it is possible that the state reserves plus the so-called working reserves actually comprise what should be called operational reserves. Depending on unknown data which relate to intentions and the actual storage stock quantities, it is also possible that the state reserves comprise true stockpiles. It is known only that the state reserves are subject to special government control in regard to the quality, handling, and unrevealed minimum quantities.

II. Product Yields, 1927-37.

The earliest complete and "official" national statistics on petroleum product yields and crude oil refining in the USSR appear to be those published for the fiscal year* 1927-28. 11/ Prewar Soviet publications include partial statistics of the same nature relative to either Russia or the USSR in certain earlier years -- 1913, for example 12/ -- and include earlier annual data on indigenous consumption of gasoline, ligroine, and kerosine -- 1913 and fiscal year 1925-26, for example. 13/

* The fiscal year extended from October through September. In 1930 -- and in 1929, in some instances -- the calendar-year basis was adopted.

The "official" statistical record of data on annual petroleum product yields and crude oil refining in the USSR is effectively complete for fiscal 1927-28 and 1928-29 and for the years from 1930 through 1934, and nearly complete but preliminary equivalent statistics are included for 1935. 14/ Statistics for 1930 which are generally compatible with those in this record may be developed by engineering analysis of the yield data reported in another Soviet publication, and the corresponding 1929 calendar-year statistics may be similarly developed from the same source. 15/ Another Soviet publication shows the 1932 and 1935 yield data in less detail; these yields are also generally compatible with the data developed in the "official" record. The same publication gives corresponding yield statistics for 1936 and shows for annual indigenous consumption of certain distillate products* during 1932 and 1936 data which are compatible with the yields. 16/ Indigenous consumption data on the same distillate products were reported early in 1937 as a forecast for 1937 -- apparently on an authoritative basis with respect to state plans. 17/

A complete sequence of annual petroleum product yields in the USSR has been published, covering the fiscal years 1927-28 and 1928-29 and the calendar years from 1930 through 1937. 18/ This sequence recapitulates the official statistical record through 1934, and for subsequent years is a correlation and projection of the pertinent yield data published by the Soviet press. Hence the published sequence may be considered sufficiently authoritative for intelligence purposes. An independent intelligence estimate is also available as a source reference. This reference shows Soviet yields** of petroleum products in 1936 which are compatible with those given in the published sequence. 19/

Reported yields of petroleum products in the USSR in 1927-28, 1932, 1936, and 1937 are shown in Table 2.*** The fiscal year 1927-28 and the calendar year 1932 are selected because they were the first and last years of the First Five Year Plan. The calendar years 1936 and 1937 are selected because they were the last two years of the authoritative sequence and of the Second Five Year Plan. The 1936 yields are somewhat more firmly substantiated by Soviet press data than are the 1937 yields.

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* Gasoline, ligroine, and kerosine.

** For a comparative summary of the data in the various sources cited, see Appendix A, Table 13, p. 49, below.

*** Table 2 follows on p. 13.

Table 2

Reported Yields of Petroleum Products in the USSR a/*
1927-28, 1932, 1936, and 1937

Thousand Metric Tons

	Fiscal Year	Calendar Year		
	1927-28	1932	1936	1937
Crude oil refining				
Straight-run gasoline	732	1,771	1,214	1,250
Thermal cracked gasoline	0	593	1,732	1,760
Total refined gasoline	732	2,364	2,946	3,010
Ligroine	130	422 b/	1,190	1,295
Kerosine	1,912	3,560	5,433	6,132
Diesel fuel	746	1,889	1,514	1,598
Lubricants	346	698 b/	1,554	1,701
Residual and other products	4,576	9,806	10,139	10,584
Total nongaseous products	8,442	18,739	22,776	24,320
Refining gas and loss	440	1,476	1,998	2,128
Crude oil refinery charge	8,882	20,215	24,774	26,448
Crude oil exports	2,590	526	167	69
Other crude oil disposition c/		672	2,949	1,984
Total crude oil production	11,472	21,413	27,890	28,501
Nongaseous products				
Natural gasoline	24	96	116	136
Crude oil refining gasoline	732	2,364	2,946	3,010
Total gasoline	756	2,460 b/	3,062	3,146
Other crude oil refining products	7,710	16,375	19,830	21,310
Total products	8,466	18,835	22,892	24,456

* Footnotes for Table 2 follow on p. 14.

Table 2

Reported Yields of Petroleum Products in the USSR a/
1927-28, 1932, 1936, and 1937
(Continued)

Thousand Metric Tons

	Fiscal Year	Calendar Year		
	1927-28	1932	1936	1937
Refining gas and loss				
Dry refinery gas	6	234	579	635
Waste and other stock	434	1,242	1,419	1,493
Total	440	1,476	1,998	2,128

a. Product-yield figures refer to indigenous gross product yields. As shown here, the product category yield totals are developed principally from the source report data by applying technical information and judgment in order to combine the separately reported yield values for the individual products. 20/ Appendix A provides further summary data for more direct correlation with the separately reported yields. 21/
b. The Second Five Year Plan quotes for 1932 the following yield values (in thousands of metric tons) which are the same as the rounded figures shown here: 2,459 for total gasoline, 422 for ligroine, 680 for lubricating oil (the yield of 698 for lubricants includes a value of 18 for greases in the table). This Plan, 22/ also shows the following 1932 yields which do not seem to be on the same basis as the later Soviet source 23/: 4,203 for kerosine, 1,250 for "motor oil," 8,530 for mazut.
c. This obviously consisted of "crude oil storage increment," "crude oil use as residual product," and "crude oil loss." The latter two "crude oil dispositions" are indicated to have been considerable in the USSR during the prewar period. The principal "residual product" use of unrefined crude oil is identified as fuel oil burned under boilers. 24/

Included in Appendix A is a more comprehensive summary for the USSR in the prewar period, showing the currently available numerical data on petroleum product yields and crude oil refining.

III. Product Yields, 1938-45.

There appear to be no published Soviet source data which disclose quantitative values for Soviet yields of petroleum products obtained after 1937.

The only available significant published or unpublished Soviet source data which relate to the 1938-45 yields are in a captured Soviet State Plan for 1941. 25/ Because of World War II, the captured 1941 State Plan was not applied in practice. The 1941 State Plan for the output of petroleum products in the USSR is shown in Table 3.*

In the prewar Soviet Five Year Plans, unrealistic goals sometimes were set. The goal for indigenous production of crude oil was set at 44.3 million tons in 1937, the last year of the Second Five Year Plan, 26/ and at 49.5 million tons in 1942, the year that was to terminate the Third Five Year Plan. World War II prevented fulfillment of the Third Five Year Plan, 27/ of course. The actual indigenous production of crude oil in the USSR in 1937 is estimated to have been only 28.5 million tons. 28/

In the Soviet Annual State Plans generally, however, and particularly in the postwar Five Year State Plans, apparent results have indicated reasonable accounting for Soviet capabilities. 29/ Hence the captured 1941 Plan may be assumed to be reasonably indicative of the yield pattern of petroleum products in 1940, the year before the USSR was invaded by Nazi forces.

An estimate of the Soviet yields from crude oil refining in 1939 30/ shows results that conform reasonably well with what might be inferred from the 1941 Plan.** Another source gives an estimate of 6 million tons for the yield of gasoline obtained by crude oil refining in the USSR in 1940, 31/ but this yield considerably exceeds any yield indicated by the 1941 Plan. A US statistical handbook 32/ gives estimates of the total 1938 yields of petroleum products in the USSR. These estimated 1938

* Table 3 follows on p. 16.
** See Appendix A, Table 11, p. 43, below.

Table 3

1941 State Plan for the Output of Petroleum Products in the USSR a/

	Quantity (Thousand Metric Tons)	Refinery Charge (Percent of Total)	Crude Oil Production (Percent of Total)
Crude oil refining			
Straight-run gasoline	2,032	6.3	
Thermal cracked gasoline b/	3,482	10.7	
Total refined gasoline	5,514	17.0	
Ligroine	1,418	4.4	
Kerosine	7,119	21.9	
Diesel fuel c/	2,600	8.0	
Residual fuel oil d/	10,044	30.9	
Lubricants, miscellaneous products, refining gas and loss e/	5,762	17.8	
Total crude oil refinery charge	32,457	100.0	93.8
Other indigenous crude oil disposition e/	2,145		6.2
Total crude oil production	34,602		100.0

a. 33/ Product-yield figures refer to indigenous gross product yields.
b. 30.4 percent of the Plan cracking charge value (in thousand metric tons) of 11,441. The thermal cracking yields in the USSR in 1938 were reported in the Soviet press to range from 26.4 percent to 33.9 percent of the cracking charge, mostly as annual averages in different refineries, 34/ although 26.4 percent is given as what appears to be the Soviet national average during the first 9 months of the year. 35/

Table 3

1941 State Plan for the Output of Petroleum Products in the USSR a/
(Continued)

c. Shown as Plan value (in thousand metric tons) of 1,100 for type diesel fuel plus a Plan value of 1,500 for motor (heavy diesel) fuel.
d. Shown as "fuel mazut" in the Plan.
e. A value derived here as a difference. The Plan does not account for the difference.

yields* correspond, within limits, with the 1937 pattern shown in Table 2,** and the estimates presumably were based on miscellaneous Soviet data.

For the 1938-45 period in the USSR the available information is considered inadequate for a correlated estimate of the annual yields of petroleum products.*** A reliable estimate of this sort would do much toward solving the problem of estimating the related postwar yields, but postwar yields can be estimated within reasonable limits of certainty by other methodologies.

IV. Product Yields, 1946-54.

Soviet data published early in 1948 36/ gave the ratios of the 1947 yields of certain petroleum stocks**** to the corresponding 1946 yields. Quantitative yields were not given. This publication of ratios was the first of four, the ones covering subsequent years following the same pattern as the first -- giving the ratio of each annual yield to its counterpart in the preceding year and not mentioning the quantitative yield of any product. It is significant that three annual ratios were omitted in the over-all published system of the series. These published ratios are representative of

* The estimated yields are summarized in Table 7, p. 29, below.
** P. 13, above.
*** Appendix A summarizes the more important Soviet petroleum product-yield data which are available for 1938-45. See also Table 7, p. 29, below.
**** Crude oil, gasoline, kerosine, and diesel fuel.

factors that are sometimes called link relatives. Effectively concealed in the general instance of such a chain of link relatives is the quantitative base yield in the most remote year to which the factors apply. The link relatives constitute the only significant Soviet source data applicable as an official check on estimates of postwar petroleum product yields. The link relatives for production of petroleum products in the USSR in 1947-54 are shown in Table 4.* The table footnotes outline the assumptions made to establish values for the three annual factors which were unreported.

In addition to the published link relatives for Soviet postwar petroleum product yields, there are also other data bearing on such yields. These data are often fragmentary and inconsistent, and they vary widely in usefulness. The intelligence problem is to evaluate the available data and to develop estimates of postwar petroleum product yields which can be reasonably well correlated with the following factors: (1) the official link relatives; (2) the most realistic estimates of the availability of the principal crude oil source stocks from which the products are derived; (3) the most realistic estimates of the actual concurrent consumption of the products, considering the export-import balances; and (4) the best information available on product-yield trends in the past.

If the 1946 product yields were quantified and the link relatives applied, other postwar annual Soviet yields could be calculated for gasoline, kerosine, and diesel fuel. Such calculations are sensitive, of course, to a variation in any one link-relative value. The link relatives are multiplied together in successive applications, and a variation in one link-relative value gives rise to a greater cumulative variation in the sequence. Hence the assumptions are very important in regard to the three unreported link relatives. By use of such assumptions as shown in Table 4,* the results may be considered to be reasonably valid only insofar as it is possible to check the results with other information, deductions, or inferences.

There are four distinct phases in a direct analytical approach to the problem of estimating the postwar Soviet annual petroleum product yields: (1) derivation of estimates for the 1946 yields; (2) application of the link relatives to derive the subsequent annual yields of gasoline, kerosine, and diesel fuel; (3) derivation of estimates for the other postwar annual yields of the products in

* Table 4 follows on p. 19.

Table 4

Link Relatives for Production of Petroleum Products in the USSR a/
1947-54

Year	Type of Product		
	Gasoline	Kerosine	Diesel Fuel
1947 b/	1.36	1.25	1.31
1948 c/	1.12	1.17	1.32 d/
1949 e/	1.10	1.17	1.32
1950 f/	1.17	1.08	1.58
1951 g/	1.20	1.03	1.45
1952 h/	1.26	1.00 d/	1.34
1953 i/	1.11	1.23	1.34 d/
1954 j/	1.09	1.05	1.44

a. Production refers to indigenous gross yields. Each value relates to production in the preceding year. All values are reported, unless otherwise indicated.

b. 37/

c. 38/

d. Assumed value. The assumption is that the missing value probably approximated the corresponding value reported in the previous year, the missing value being unity if the previous reported value was near unity. Arbitrary assignment of unity is often practiced in similar instances of missing link relatives, the assumption being that the USSR would not publish a link relative unless the factor exceeded unit value so as to be an index of favorable progress. On the other hand, it is also possible that certain link relatives may be deliberately concealed to break the sequence of factors available for foreign intelligence analysis. The conventional unit value is not here assigned to the missing "diesel fuel" link relatives, inasmuch as such a sudden decrease in the ratio would not be consistent with estimated civil

Table 4

Link Relatives for Production of Petroleum Products in the USSR a/
1947-54
(Continued)

consumption as elsewhere discussed in this report and would furthermore introduce unexplained depressions in the "diesel fuel" percentage trend line of Figure 1, following p. 36, below. Trial calculations were actually made, assuming both of the missing "diesel fuel" link relatives to have a value of one; serious internal inconsistencies resulted by use of these arbitrary unit values.

e. 39/
f. 40/
g. 41/
h. 42/
i. 43/
j. 44/

the other three principal categories (ligroine, lubricants, and residual and other products); and (4) development of an independent correlation to check the resulting estimated yields in a recent year, 1953, for example -- this would serve to check the assumptions applied in regard to the unreported link relatives.

The postwar petroleum product yields in the USSR have continued to be derived for the most part, by crude oil refining. Even with the annual crude oil charge to a national refining complex completely known, however, many independent data also must be known before any probable pattern* of the refinery product yields can be estimated. With a given average type of crude oil for processing and

* As used in this report, the term product pattern is specifically defined as the relationship determined by the percentages of different products, or of different categories of products, referred to the total of such products.

with a given over-all system of installed refining equipment which is completely defined from the technological point of view, the product-yield pattern of such a refinery complex can be varied practicably and efficiently within very wide limits.

The technique of analogy is of little practical use in estimating the probable product-yield pattern in such a refinery complex, even when the analogy is correlated with established technological principles. In the US and the USSR alike, for example, the major portions of the indigenously consumed products are derived by indigenous crude oil refining, and the major portions of products from indigenous crude oil refining are indigenously consumed. Yet, as shown in Table 8,* there was marked dissimilarity in the crude oil refining product-yield patterns in the years 1932 and 1937, and wide dissimilarity probably continued in the postwar period.**

The total annual product yields since 1932 in the US have ranged up to 10 or 11 times those in the USSR. In pattern as well as quantities, it is evident that the two countries differ in product consumption. The pattern difference does not arise from technological differences at the source of supply. A 1952 estimate, 45/ based on technological and engineering principles, developed a theoretical yield pattern for crude oil refining products for the USSR in 1950. This estimate applied the US yield pattern to the installed Soviet refining equipment and the average Soviet crude oil insofar as pertinent data were available. Although the resulting 1950 theoretical yield pattern for the USSR thus differed from that of the US only on the basis of technology, necessarily generalized, the pattern still differed widely from the most realistic estimates of the 1950 Soviet consumption of petroleum products in the civil and military sectors. 46/

A 1952 estimate developed values for Soviet yields of crude oil refining products in 1946*** applying certain assumptions including a limited correlation with the captured 1941 State Plan of the USSR. The reported link relatives were applied to the 1946 base yields by use of certain other assumptions, and estimates were derived for the annual Soviet yields of crude oil refining products through 1951. 47/ Here again the estimated annual Soviet yields are not compatible with the estimates of annual indigenous product consumption, 48/ but the

* P. 32, below.

** The comparison between the US and the Soviet product-yield patterns is also shown graphically in Figures 1 and 2, following p. 36, below.

*** See Appendix A, Table 14, p. 57, below.

estimated yields in 1950 49/ may be correlated in most respects with the theoretical yield pattern for 1950. 50/

An estimate of Soviet yields of crude oil refining products in 1949 51/ seems to be based on little more than speculation.

There appears to be a firmer basis for direct estimates of the postwar civil consumption of petroleum distillates and lubricants in the USSR* than there is for direct estimates of the indigenous gross yields of such products. Factors affecting the estimates of consumption of these products are not so variable as are most of the factors affecting estimates of the yields from crude oil refining. Substantial data are available for the extent and types of the civil operations which involve consumption of petroleum distillates and lubricants. Although the civil consumption of residual fuel oil and other residual products seems to be affected by too many uncertain factors to permit realistic direct quantitative estimates, an adequate estimate is available for the postwar civil consumption of petroleum distillates and lubricants. This estimate was derived independently -- without reference to estimates of indigenous gross yields. 52/

An adequate estimate is also available for the postwar annual production of crude oil in the USSR. The estimate is essentially within the limits indicated by official Soviet reports. The same estimate covers the probable postwar annual potential yields of natural gas liquids in the USSR. 53/

The most realistic approach to estimates of Soviet gross product yields in the postwar period appears to be one which is consistent with the estimates of crude oil production, the yields of natural gas liquids, and civil consumption. Independent estimates are available for the postwar annual gross yields of synthetic oil products in the USSR.** Assuming that estimates are also available for the annual consumptions of petroleum distillates and lubricants directly utilized by the Soviet armed forces and for the annual import-export balances in crude oil and petroleum products, the problem is essentially reduced to that of estimating the indigenous gross yields derived by crude oil refining.

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* For a discussion of civil consumption of lubricants, see Appendix B, 4, b.

** See Appendix B.

The method used here consists of deriving estimates for indigenous gross product yields in at least one postwar year so that indigenous net availability yields* are in balance with the total indigenous product consumption -- after accounting for storage increments and the import-export balances. Both the gross yields and the indigenous civil consumption of the "residual and other products" result by difference. The complete annual petroleum stock balance specifically involves the application of constant estimating factors which can be evaluated within a reasonable probability range for the following: (1) use of unrefined crude oil as a product; (2) crude oil handling loss; (3) crude oil storage increment; (4) refining gas and loss; (5) distribution losses in petroleum products; and (6) storage increments for the petroleum products. The complete stock balance is otherwise based entirely on the independently estimated quantities as outlined above.

For a direct estimate of all petroleum product yields in the USSR in a postwar year, available information is adequate only for 1953. For this year alone are there simultaneously available the realistic and independent estimates necessary to derive total indigenous consumption of the principal distillates and lubricants and the national import-export balances in crude oil and petroleum products. Soviet gross product yields for other postwar years are estimated by the use of the reported link relatives and the assumed constant estimating factors.**

The estimated yields of petroleum products in the USSR, by type of source, in 1946-54 are shown in Table 5.*** The estimated****

* This terminology is defined in the Introduction.

** For methodology, see Appendix B. Technical considerations show that the product-yield patterns derived for crude oil refining are reasonable and are in correlation with the available data on average crude oil quality and installed refining facilities in the USSR. These considerations cannot be summarized properly in a nontechnical report. The special feature in point is the increase in relative yields of diesel fuel as discussed in Part V.

*** Table 5 follows on p. 24.

**** Continued on p. 26.

Table 5

Estimated Yields of Petroleum Products in the USSR, by Type of Source a/*
1946-54

Million Metric Tons

Source	Year								
	1946	1947	1948	1949	1950	1951	1952	1953	1954
Crude oil refining									
Gasoline	2.6	3.5	3.9	4.3	5.0	5.9	7.2	7.7	8.1
Ligroine	0.7	0.6	0.6	0.5	0.5	0.6	0.7	0.7	0.3
Kerosine	4.8	5.9	6.9	8.0	8.5	8.6	8.0	9.6	9.6
Diesel fuel	0.7	1.0	1.3	1.7	2.7	3.8	5.2	6.9	10.0
Lubricants	1.2	1.5	1.7	1.9	2.1	2.4	2.6	2.8	3.0
Residual and other products	8.5	9.5	10.7	12.3	13.1	14.1	15.0	14.0	13.7
Total nongaseous products	18.5	22.0	25.1	28.7	31.9	35.4	38.7	41.7	44.7
Refining gas and loss	1.8	2.2	2.5	2.8	3.2	3.5	3.8	4.8	5.1
Total crude oil refinery charge	20.3	24.2	27.6	31.5	35.1	38.9	42.5	46.5	49.8
Crude oil use as residual product b/	0.2	0.3	0.3	0.3	0.4	0.4	0.5	0.5	0.5
Crude oil storage increment	0.3	0.5	0.4	0.5	0.5	0.5	0.5	0.5	0.5
Crude oil exports	0.0	0.0	0.0	0.0	0.2 c/	0.3 d/	0.5 d/	0.3 d/	0.6 e/
Crude oil loss	0.9	1.0	1.2	1.4	1.5	1.7	1.8	2.0	2.2
Total new crude oil supply	21.7	26.0	29.5	33.7	37.7	41.8	45.8	49.8	53.6
Crude oil imports	0.0	0.0	0.1 f/	0.1 f/	0.1 f/	0.2 g/	0.2 g/	0.2 g/	0.0
Total indigenous crude oil production h/	21.7	26.0	29.4	33.6	37.6	41.6	45.6	49.6	53.6

* Footnotes for Table 5 follow on p. 25.

Table 5

Estimated Yields of Petroleum Products in the USSR, by Type of Source a/
1946-54
(Continued)

Million Metric Tons

Source	Year								
	1946	1947	1948	1949	1950	1951	1952	1953	1954
Natural gas liquids b/									
Natural gasoline	0.08	0.12	0.16	0.24	0.32	0.48	0.84	1.24	1.60
Liquefied petroleum gases (LPG)	0.12	0.18	0.24	0.36	0.48	0.72	1.26	1.86	2.40
Total natural gas liquids	0.2	0.3	0.4	0.6	0.8	1.2	2.1	3.1	4.0
Nongaseous synthetic oil products									
Gasoline	0.051	0.054	0.058	0.061	0.064	0.072	0.081	0.089	0.096
Kerosine	0.010	0.010	0.010	0.010	0.010	0.010	0.010	0.010	0.010
Diesel fuel	0.005	0.006	0.007	0.009	0.010	0.014	0.017	0.020	0.023
Residual and other products	0.080	0.093	0.123	0.147	0.166	0.224	0.282	0.336	0.389
Total nongaseous synthetic oil products	0.146	0.163	0.198	0.227	0.250	0.320	0.390	0.455	0.518

a. For methodology, see Appendix B. Product-yield figures refer to indigenous gross product yields.
b. Assumed to be used mostly as fuel oil. In the total product summations shown in Table 6, p. 27, below, the values are included as "Residual and other products."
c. 54/
d. 55/
e. 56/
f. 57/
g. 58/
h. 59/

total yields of petroleum products in the USSR in 1946-54 are shown in Table 6.* The over-all check on the apparent reasonableness of the estimates is on the basis of the yields developed for 1946 and is as discussed below.

World War II damage to Soviet crude oil production and refining facilities was officially reported to have been repaired during the course of the Fourth Five Year Plan (1946-50). The rehabilitation probably was completed in the latter part of the period. 60/ It is probable, therefore, that Soviet refining facilities as of 1946 were not operating at the immediate prewar level of output, efficiency, and product pattern. An index to this prewar level is in the captured 1941 State Plan.** The actual 1946 operating level probably would more nearly approach that of an earlier prewar year such as 1937, the last year of the prewar "authoritative" sequence of yields.***

In considering the probable Soviet yields of petroleum products in 1946, it should be noted that US petroleum refining engineers and technologists were in the USSR as late as the fall of 1946. From 1942 to 1946 these representatives of US companies were concerned with the bilateral arrangements sometimes called the Houdry Lend-Lease Projects. The Houdry units were the earliest catalytic cracking facilities to be installed in the USSR. 61/

The Houdry projects terminated a sequence of events which began in 1929 wherein major crude oil refining facilities were supplied to the USSR by major US petroleum refinery engineering and construction companies. The US companies either installed the facilities or supervised the construction, and usually they had qualified technical representatives in the USSR at various times for considerable periods. Beginning in 1929, the US companies furnished and sometimes erected the earliest commercial thermal cracking units in the USSR. Winkler-Koch units were the earliest and the most common of the modern types to be furnished. In 1939-40, refining equipment furnished and installed by US companies consisted of the first catalytic refining facilities to be constructed in the USSR. These facilities were composed of units for catalytic polymerization and codimer hydrogenation. 62/

* Table 6 follows on p. 27.
** See Table 3, p. 16, above.
*** See Table 2, p. 13, above.

Table 6

Estimated Total Yields of Petroleum Products in the USSR a/
1946-54

Million Metric Tons

Type of Product	Year								
	1946	1947	1948	1949	1950	1951	1952	1953	1954
Gasoline	2.7	3.7	4.1	4.6	5.4	6.4	8.1	9.0	9.8
Ligroine	0.7	0.6	0.6	0.5	0.5	0.6	0.7	0.7	0.3
Kerosine and liquefied petroleum gases	4.9	6.1	7.2	8.4	9.0	9.3	9.3	11.5	12.0
Diesel fuel	0.7	1.0	1.3	1.7	2.7	3.8	5.2	6.9	10.0
Lubricants	1.2	1.5	1.7	1.9	2.1	2.4	2.6	2.8	3.0
Residual and other products b/	8.8	9.9	11.1	12.7	13.7	14.7	15.8	14.8	14.6
Total products b/	19.0	22.8	26.0	29.8	33.4	37.2	41.7	45.7	49.7

a. Figures are rounded summations of yields shown in Table 5, p. 24, above.
b. Crude oil used as a residual product is included here. It is not included in prewar figures (see Table 2, p. 13, above, and Appendix A), because of lack of data.

The 1938-46 period is of special importance in this report. It is probable that the US petroleum industry gathered much specific information about the refining operations and product yields in the USSR during that period. 63/

As noted in Section III of this report, the American Statistical Handbook gives estimates of indigenous gross petroleum product yields in the USSR for 1938 and 1946. These estimates assume the 1938 and 1946 annual product-yield patterns to be identical and presumably were derived on the basis of this assumption and data generally available in the petroleum industry. 64/

A comparison of estimates of total gross yields of petroleum products in the USSR in 1937, 1938, and 1946 is shown in Table 7.* Significant correspondence of data is indicated in Table 7 -- sometimes in product-yield patterns and sometimes in absolute-yield quantities.

V. Trends and Product-Yield Patterns.

Percentage** trends and yield patterns for Soviet crude oil refining operations are shown in Figure 1.*** Equivalent information for US crude oil refining operations, based on published petroleum statistics, is shown in Figure 2.*** The US distillate-lubricant yield line is reproduced in Figure 1 for comparison. A comparison of petroleum balances in the USSR and the US in 1932 and 1937 is shown in Table 8.**** A comparison of petroleum balances in the USSR and the US in 1946 and 1953 is shown in Table 9.*****

Gasoline has continued to be the most important type of petroleum stock in the US, and the refining operations are generally directed toward improved quality in an optimum yield of gasoline. The major emphasis in the USSR has been on kerosine yield, and, in the more recent postwar years, on diesel fuel. Differences in quality of the average crude oil in the two countries partially account for the difference in emphasis.

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* Table 7 follows on p. 29.

** The percentages correspond to quantitative data given in the appendixes.

*** Following p. 36.

**** Table 8 follows on p. 32.

***** Table 9 follows on p. 34.

Table 7

Comparison of Estimates of Total Gross Yields of Petroleum Products in the USSR a/
1937, 1938, and 1946

Type of Product	1937 c/ Yield (Million Metric Tons)	1937 c/ Percent	American "Statistical-Handbook" Estimates b/ 1938 Yield (Million Metric Tons)	1938 Percent	1946 Yield (Million Metric Tons)	1946 Percent	1946 d/ Yield (Million Metric Tons)	1946 d/ Percent
Gasoline e/	3.1	12.9	3.7	12.9	2.8	12.9	2.7	14.4
Kerosine	6.1	25.1	6.4	22.3	4.9	22.3	4.9 f/	25.6
Gas oils (diesel fuels)	1.6	6.5	1.4	4.8	1.1	4.8	0.7	3.9
Lubricating oils	1.7 g/	7.0	1.4	5.0	1.1	5.0	1.2 g/	6.5
Residual and other products	12.0 h/	48.5	15.6 i/	55.0	11.9 i/	55.0	9.5 h/	49.6
Total	24.5	100.0	28.5	100.0	21.8	100.0	19.0	100.0

a. The percentages given in this table are based on the quantities as originally developed in terms of thousands of metric tons. Product-yield figures refer to indigenous gross product yields.
b. 65/. Estimates are given by volume only. For volume-to-weight conversion factors, see Appendix A, Table 13, p. 49, below.
c. Estimates from Table 2, p. 13, above.
d. Estimates from Table 6, p. 27, above.
e. Including natural gasoline.
f. Including liquefied petroleum gas.
g. Total lubricants.
h. Including ligroine.
i. Presumably includes ligroine; no separate estimate is shown for that product.

In the USSR the indigenous crude oils are predominantly of the so-called naphthene base types, containing much asphalt base and even aromatic base stock. 66/ The Soviet crude oils contain little paraffin base stocks, but the indigenous US crude oils are mostly of paraffin base and mixed base. In nontechnical terms this means that average Soviet crude oils in comparison with US crude oils, contain a much smaller percentage of straight-run gasoline, although the average Soviet virgin gasoline would be good straight-run aviation gas base stock because of its content of naphthenes 67/; a probable equal percentage of potential straight-run kerosine, if this potential kerosine cut is taken as a product; and a larger percentage of virgin heavy gas oil which is above the usual diesel fuel boiling range, even assuming that such gas oil had quality suitable for diesel fuel use (naphthenic stock generally has low cetane rating).

In the Soviet crude oils the potential naphthenic virgin gas oils would comprise good catalytic cracking charge stock, giving large relative yields of high-quality gasolines with high-octane aviation gas base stock included. 68/ There is evidence to indicate, however, that catalytic cracking has no high priority status in the USSR, 69/ even though some new catalytic cracking plants, in addition to the World War II Houndry units, 70/ probably have been constructed in the USSR. Figure 1 shows that the trend has been to use cracking, probably thermal cracking in major part to derive a larger percentage of total diesel fuel with only a moderate increase in the yield of total gasoline (gasoline and ligroine). It is indicated that ligroine will no longer be obtained as a product after 1954. 71/

Figure 1 and the reported link relatives shown in Table 4* indicate a large and steady increase in the Soviet yields of total diesel fuel through 1954. Increased percentage yield in the gas oil products in the US is indicated in Figure 2. In the US the gas oil products consist of diesel fuel and distillate fuel oil for end use as such (see Tables 8 and 9**), but the relative proportion of diesel fuel has been increasing in the US -- from 14.9 percent of the gas oil products in 1937 to 28.1 percent in 1953.

Figure 1 shows that in the relative yield of principal distillates plus lubricants, the yield pattern for crude oil refining products in the USSR is approaching that of the US as of 1954. Figure 1 also shows

* P. 19, above.
** Pp. 32 and 34, respectively, below.

that there has been a corresponding relative decrease in the yield of "residual and other products" in the USSR. Residual fuel oil, or mazut, is considered to be a valuable product in the USSR, however, and the relative yield of that product probably will not be reduced beyond a minimum. 72/

This report is not primarily concerned with the yield of aviation engine fuels in the USSR; the aviation gasoline yield is included as an unspecified portion of total gasoline, and the jet fuel yield is included as an unspecified portion of total kerosine.

With specific consideration of aviation engine fuels excluded, the estimated postwar product yields are not particularly indicative of capabilities, vulnerabilities, and intentions. The physical vulnerabilities are those which are generally well established for petroleum industry operations. In the manufacture of petroleum products the USSR appears to have the capability to continue with the product-yield pattern as indicated in the estimates. As of 1954 the USSR is estimated to have approached what would be the practicable limit in the percentage yield of distillates plus lubricants. There is no indication that the USSR plans to place more emphasis on the relative yield of gasoline. The present emphasis on increased yield of diesel fuel probably will continue until a practicable optimum is attained. There is no indication of plans for extensive stockpiling of petroleum products in the USSR. The present pattern of product consumption appears to approximate the present pattern of product yields with only normal annual storage increments involved. Stockpiling of products probably would be centered in distillates, and large increases in such stockpiling are not indicated.

Table 8

Comparison of Petroleum Balances in the USSR and the US
1932 and 1937

	USSR a/*						US b/					
	1932			1937			1932			1937		
	Quantity (Thousand Metric Tons)	Refinery Charge (Percent)	New Supply (Percent)	Quantity (Thousand Metric Tons)	Refinery Charge (Percent)	New Supply (Percent)	Quantity (Thousand Metric Tons)	Refinery Charge (Percent)	New Supply (Percent)	Quantity (Thousand Metric Tons)	Refinery Charge (Percent)	New Supply (Percent)
Crude oil refining products												
Straight-run gasoline	1,771	8.8		1,250	4.7		22,777	20.6		29,333	18.4	
Conversion gasoline	593	2.9		1,760	6.7		19,924	18.0		31,259	19.6	
Ligroine	422	2.1		1,295	4.9		0	0		0	0	
Total gasoline and ligroine	2,786	13.8		4,305	16.3		42,701	38.6		60,592	38.0	
Kerosine	3,560	17.6		6,132	23.2		5,671	5.1		8,448	5.3	
Light fuel oil products	1,889	9.3		1,598	6.1		9,309	8.4		19,659	12.3	
Lubricants	698	3.5		1,701	6.4		3,177	2.9		5,002	3.1	
Residual and other products	9,806	48.5		10,584	40.0		40,437	36.6		55,343	34.7	
Total nongaseous products	18,739	92.7		24,320	92.0		101,295	91.6		149,044	93.4	
Refining gas and loss	1,476	7.3		2,128	8.0		9,240	8.4		10,483	6.6	
Crude oil refinery charge	20,215	100.0	94.4	26,448	100.0	92.8	110,535	100.0	98.8	159,527	100.0	90.6
Crude oil exports	526		2.5	69		0.2	3,693		3.3	9,064		5.1
Other crude oil disposition	672		3.1	1,984		7.0	-2,366		-2.1	7,545		4.3
New crude oil supply	21,413		100.0	28,501		100.0	111,862		100.0	176,136		100.0
Crude oil imports	0		0	0		0	6,023		5.4	3,706		2.1
Indigenous crude oil production	21,413		100.0	28,501		100.0	105,839		94.6	172,430		97.9
Natural gasoline yield	96			136			3,868			5,243		
Indigenous yield natural liquid hydrocarbons	21,509			28,637			109,707			177,673		
Gasoline (benzene) from coal carbonization	0			0			144			389		
Refined light fuel oil products												
Diesel fuel c/	1,889	9.3		1,598	6.1		d/	d/		2,935	1.8	
Distillate fuel oil e/	0	0		0	0		d/	d/		16,724	10.5	
Total	1,889	9.3		1,598	6.1		9,309	8.4		19,659	12.3	

* Footnotes for Table 8 follow on p. 33.

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Table 8

Comparison of Petroleum Balances in the USSR and the US
1932 and 1937
(Continued)

	USSR a/						US b/					
	1932			1937			1932			1937		
	Quantity (Thousand Metric Tons)	Refinery Charge (Percent)	New Supply (Percent)	Quantity (Thousand Metric Tons)	Refinery Charge (Percent)	New Supply (Percent)	Quantity (Thousand Metric Tons)	Refinery Charge (Percent)	New Supply (Percent)	Quantity (Thousand Metric Tons)	Refinery Charge (Percent)	New Supply (Percent)
Refined residual and other products												
Residual fuel oil	8,470	41.9		9,756	36.9		35,001	31.7		48,485	30.4	
Waxes	17	0.1		64	0.2		208	0.2		237	0.1	
Asphalt and gudron f/	799	3.9		466	1.8		2,245	2.0		3,794	2.4	
Other specialty products	520	2.6		298	1.1		2,983	2.7		2,828	1.8	
Total	9,806	48.5		10,584	40.0		40,437	36.6		55,343	34.7	
Refining gas and loss												
Dry refinery gas	234	1.2		635	2.4		4,676	4.3		7,341	4.6	
Waste and other stock	1,242	6.1		1,493	5.6		4,564	4.1		3,142	2.0	
Total	1,476	7.3		2,128	8.0		9,240	8.4		10,483	6.6	
Other crude oil disposition												
Storage increment	d/		d/	d/		d/	-4,109		-3.7	2,460		1.4
Loss and use as residual product	d/		d/	d/		d/	1,743		1.6	5,085		2.9
Total	672		3.1	1,984		7.0	-2,366		-2.1	7,545		4.3

a. Data taken from Table 2, p. 13, above. No synthetic oil products are known to have been produced in the USSR in prewar years. Petroleum product-yield figures refer to indigenous gross product yields.

b. These data are part of those derived by an analysis of US petroleum statistics. 73/ The analysis covers the US annual statistics beginning with 1918. The yields and percentages calculated are essentially as shown in this report. The calculations are primarily resolved from the US Bureau of Mines statistical series, which cover crude oil production, yields of natural gas liquids, crude oil refining, imports, exports, storage stocks, stock balances, and national consumption. For the productions of crude oil and natural gas liquids in recent years, American Petroleum Institute (API) and the American Gas Association (AGA) also carry a series of statistics which differ somewhat from those of the Bureau of Mines. The two series do not diverge significantly for total yields of natural liquid hydrocarbons, but internally the series differ considerably. For reasons of technical definition, the American Petroleum Institute and the American Gas Association series shows field condensate stock as natural gas liquids, whereas the Bureau of Mines series shows that stock as crude oil, the typical disposition of the material being in the aggregate liquid mixture physically handled as crude oil. Petroleum-product yield figures refer to indigenous gross product yields.

c. As shown in Table 2, p. 13, above, the yields of this product are the totals of the yields separately reported for "motor (heavy diesel) fuel" and "type diesel fuel" (light diesel fuel but not necessarily "high-speed" diesel fuel in quality); for gas oil products known as "solar oils"; and for a product specifically called "gas oil." 74/

d. The breakdown by types is not reported.

e. There is no available evidence that this product is derived as such for the inferred end use in the USSR.

f. Gudron is a Soviet product with yield values shown in Table 2, p. 13, above. The product is presumably a residue tar sometimes having lubricant grease quality. 75/

Table 9

Comparison of Petroleum Balances in the USSR and the US
1946 and 1953

	USSR a/*						US b/					
	1946			1953			1946			1953		
	Quantity (Thousand Metric Tons)	Refinery Charge (Percent)	New Supply (Percent)	Quantity (Thousand Metric Tons)	Refinery Charge (Percent)	New Supply (Percent)	Quantity (Thousand Metric Tons)	Refinery Charge (Percent)	New Supply (Percent)	Quantity (Thousand Metric Tons)	Refinery Charge (Percent)	New Supply (Percent)
Crude oil refining												
Gasoline	2.6	12.8		7.7	16.5		79.9	34.3		133.7	38.8	
Ligroine	0.7	3.4		0.7	1.6		0	0		0	0	
Total gasoline and ligroine	3.3	16.2		8.4	18.1		79.9	34.3		133.7	38.8	
Kerosine	4.8	23.4		9.6	20.6		13.5	5.8		16.8	4.9	
Light fuel oil products	0.7	3.6		6.9	14.9		38.6	16.5		71.3	20.7	
Lubricants	1.2	6.1		2.8	6.1		6.5	2.8		7.5	2.2	
Residual and other products	8.5	41.7		14.0	30.1		80.6	34.6		93.0	27.0	
Total nongaseous products	18.5	91.0		41.7	89.8		219.1	94.0		322.3	93.6	
Refining gas and loss	1.8	9.0		4.8	10.2		14.1	6.0		22.1	6.4	
Crude oil refinery charge	20.3	100.0	93.7	46.5	100.0	93.3	233.2	100.0	95.1	344.4	100.0	98.4
Crude oil exports	0		0	0.3		0.7	5.7		2.3	2.7		0.8
Other crude oil disposition	1.4		6.3	3.0		6.0	6.4		2.6	2.9		0.8
New crude oil supply	21.7		100.0	49.8		100.0	245.3		100.0	350.0		100.0
Crude oil imports	0		0	0.2		0.4	11.6		4.7	31.9		9.1
Indigenous crude oil production	21.7		100.0	49.6		99.6	233.7 c/		95.3	318.1 c/		90.9
Natural gas liquids yield	0.2			3.1			11.9			24.0 c/		
Indigenous yield natural liquid hydrocarbons	21.9			52.7			245.6 c/			342.1 c/		
Nongaseous synthetic oil products d/	0.15			0.46			0.29			0.05		
Refined light fuel oil products												
Diesel fuel e/	0.7	3.6		6.9	14.9		7.3	3.1		20.0	5.8	
Distillate fuel oil f/	0	0		0	0		31.3	13.4		51.3	14.9	
Total	0.7	3.6		6.9	14.9		38.6	16.5		71.3	20.7	

* Footnotes for Table 9 follow on p. 35.

Table 9

Comparison of Petroleum Balances in the USSR and the US
1946 and 1953
(Continued)

	USSR a/						US b/					
	1946			1953			1946			1953		
	Quantity (Thousand Metric Tons)	Refinery Charge (Percent)	New Supply (Percent)	Quantity (Thousand Metric Tons)	Refinery Charge (Percent)	New Supp (Percent)	Quantity (Thousand Metric Tons)	Refinery Charge (Percent)	New Supply (Percent)	Quantity (Thousand Metric Tons)	Refinery Charge (Percent)	New Supply (Percent)
Refined residual and other products												
Residual fuel oil	g/	g/		g/	g/		67.0	28.8		69.9	20.3	
Specialty products	g/	g/		g/	g/		13.6	5.8		23.1	6.7	
Total	8.5	41.7		14.0	30.1		80.6	34.6		93.0	27.0	
Refining gas and loss												
Dry refinery gas	g/	g/		g/	g/		10.1	4.3		11.7	3.4	
Waste and other stock	g/	g/		g/	g/		4.0	1.7		10.4	3.0	
Total	1.8	9.0		4.8	10.2		14.1	6.0		22.1	6.4	
Other crude oil disposition												
Use as residual product	0.2		1.0	0.5		1.0	h/		h/	h/	h/	
Loss	0.9		4.0	2.0		4.0	h/		h/	h/	h/	
Loss and use as residual products	1.1		5.0	2.5		5.0	5.5		2.2	2.3		0.6
Storage increment	0.3		1.0	0.5		1.0	0.9		0.4	0.6		0.2
Total	1.4		6.0	3.0		6.0	6.4		2.6	2.9		0.8

a. Data taken from Table 5, p. 24, above. The figures are rounded to the nearest 100,000 tons, but for convenience in the calculations, which are outlined in Appendix B, the numerical operations were with quantities expressed in thousand tons, and the percentages represent the ratios of quantities expressed as thousand tons. The percentages are not necessarily the ratios of the corresponding rounded figures shown in this table. Product-yield figures refer to indigenous gross product yields.
b. See Table 8, footnote b, p. 33, above.
c. The value is different but in the same range of magnitude when the basis is in the API-AGA series of statistics. 76/ (See Table 8, footnote b.) The 1953 natural gas liquids yield is not available in the US Bureau of Mines statistics, but the value that probably will appear as the US Bureau of Mines yield is here estimated, using the 1953 yield in the API-AGA statistics and ratios previously featured in the US Bureau of Mines and API-AGA series of statistics.

Table 9

Comparison of Petroleum Balances in the USSR and the US
1946 and 1953
(Continued)

d. Gasoline (benzene) from coal carbonization has been the only commercial synthetic oil product derived in the US. There has been, nevertheless, an intensive government-sponsored program of experimentation and semicommercial pilot plant operation, dealing with oil shale retorting, crude shale oil refining, and the catalytic hydrogenation processes (Bergius hydrogenation and Fischer-Tropsch synthesis) which are commercially applied in other countries to derive petroleum products from carbonaceous charge stock -- chiefly coal and lignite materials. In the USSR prior to 1955, as shown in Appendix B, the only evident synthetic oil product yields were derived by coal carbonization and oil shale processing.
e. In the USSR in the postwar period this product is assumed to consist of "type diesel fuel," "motor (heavy diesel) fuel," and product "solar oils."
f. There is no available evidence that this product is derived as such for the inferred end-use in the USSR.
g. The breakdown by types is not estimated.
h. The breakdown by types is not reported.

APPENDIX A

SUPPLEMENTARY DATA ON PETROLEUM PRODUCT YIELDS, 1927-46

1. Available Data.

As summarized in Section II, official Soviet reports provide a firm basis for the 1928-37 yields of petroleum products in the USSR. For the earlier part of this period the official reports are relatively complete. Since 1937, however, the reports have been rare and indeterminate, and conclusive information on product yields has been lacking in other available sources.

A condensed summary of information on yields of petroleum products for 1938 and later years is given in Sections III and IV. This information follows the usual pattern, becoming increasingly meager and more uncertain the later the year. From the quantitative point of view, Soviet reports of the yields in the later years appear to be restricted to fragments of two types. Although these fragments show no absolute quantities for the actual product yields derived in Soviet practice, each type has some degree of usefulness for deductions, inferences, and counterchecks. One type of fragment is contained in the captured 1941 Soviet State Plan,* probably applicable to the immediate prewar period. The other type consists of the link relatives** which have been published annually and which relate to the postwar period.

The data on yields of Soviet petroleum 77/ are especially equivocal for the World War II years, particularly so for petroleum product yields.*** As noted in Section III, available information is inadequate for an over-all correlated estimate of Soviet petroleum product yields from 1938 through 1945. Although reasonably realistic estimates of the yields may be derived for the earlier part of this period -- before the full impact of World War II on the USSR**** -- the uncertainty of the World War II yields makes a hypothetical 1938-45 correlation of little practical use.

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* See Table 3, p. 16, above.

** See Table 4, p. 19, above.

*** Estimates of the World War II production of Soviet indigenous crude oil are included in a recently published report. 78/

**** An estimate of the 1938 yields is shown in Table 7, p. 29, above, and estimates of the yields of 1939 crude oil refining are shown in Table 11, p. 43, below.

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**** An estimate of the 1938 yields is shown in Table 7, p. 29, above, and estimates of the yields of 1939 crude oil refining are shown in Table 11, p. 43, below.

Tables 10, 11, and 12* provide a summary of the yields of petroleum product in the USSR for fiscal year 1927-28 and the following calendar years through 1937. Tables 10 and 11 show the national yield patterns in major categories of products. These yield patterns are generally useful in estimating corresponding postwar yields. Table 12 completes the record, showing the direct correlation with the principal sources 79/ used as the basis of Tables 10, 11, and 12 and indicating the methodology employed to develop the totals for major categories of products in Tables 10 and 11.

Soviet reports other than those used as the basis of Tables 10, 11, and 12 are complete and specific enough to be important in estimating Soviet petroleum product yields from 1929 through 1937. These reports sometimes contain data which seem to contradict that shown in Tables 10, 11, and 12. Actually, the contradictions are more apparent than real. A correlation of the data provided by the various sources is shown in Table 13.** The table will serve a useful purpose if confusion should arise in the future because of apparent contradictions in the Soviet reports. Table 13 outlines not only the direct comparisons, but also the methodologies by which the major differences may be explained as a confounding of terms and as discrepancies in the reporting of the product categories.

Table 14*** provides a correlation of the data in Sections III and IV and shows the basis of certain generalized statements in the text.

2. National Yields and Political Areas.

The Soviet petroleum yields developed in this report include only the production within the political boundaries of the USSR in the given year. Relatively minor quantities of petroleum products were obtained, however, in the 1928-54 period from areas which were not within the USSR before the close of World War II -- Estonia (shale oil products) and the Carpathian Polish sector (crude oil refining products). The petroleum product yields in these areas are excluded from Soviet totals for the prewar and wartime periods.

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* Tables 10, 11, and 12 follow on pp. 40, 43, and 46, respectively, below.

** Table 13 follows on p. 49.

*** Table 14 follows on p. 57.

Data on the comparatively small yields of petroleum products obtained in the Carpathian Polish crude oil refineries before the area became a part of the USSR are not available. By virtue of its status as the principal contributor to the postwar Soviet yields of the shale-oil type of synthetic oil products, Estonia is of some importance. Estimates of the postwar synthetic oil product yields in the Estonian SSR are based, to some extent, on corresponding yields in prewar Estonia. A series of the prewar yields of petroleum products in Estonia is shown in Table 15.*

3. Volume-to-Weight Conversion Factors.

With the exception of certain source reports, 80/** all quantities given in this report are stated in sources in terms of weight. The volume-to-weight conversion factors applied to the volume data in the two reports mentioned are shown in Table 16.***

* Table 15 follows on p. 59.
** See Table 7, p. 29, above, and Table 18, p. 66, below.
*** Table 16 follows on p. 62.

Table 10

Reported Yields of Petroleum Products in the USSR a/
Fiscal Years 1927-28 and 1928-29 and Calendar Years 1930-32
(Continued)

	Fiscal Year				Calendar Year					
	1927-28		1928-29		1930		1931		1932	
	Quantity (Thousand Metric Tons)	Percent	Quantity (Thousand Metric Tons)	Percent	Quantity (Thousand Metric Tons)	Percent	Quantity (Thousand Metric Tons)	Percent	Quantity (Thousand Metric Tons)	Percent
Crude oil exports	2,590		310		294		382		526	
Other crude oil disposition c/	0		2,165		1,984		2,090		672	
Total indigenous crude oil production d/	11,472		13,509		18,451		22,392		21,413	
Nongaseous products										
Natural gasoline	24 e/		28 d/		55 d/		79 d/		96 d/	
Crude oil refining gasoline	732		1,062		1,599		2,135		2,364	
Total gasoline	756		1,090		1,654		2,214		2,460 b/	
Other crude oil refining products	7,710		9,641		13,826		16,887		16,375	
Total nongaseous products	8,466		10,731		15,480		19,101		18,835	
Refining gas and loss										
Dry refinery gas	6		14		54		137		234	
Waste and other stock	434		317		694		761		1,242	
Total refining gas and loss	440		331		748		898		1,476	

[P. 40 blank]

Table 10

Reported Yields of Petroleum Products in the USSR a/
Fiscal Years 1927-28 and 1928-29 and Calendar Years 1930-32
(Continued)

a. 81/ except as noted in the table. In this period, no output of synthetic oil products was indicated within the USSR as then constituted, and it is assumed that natural gasoline was the only type of natural gas liquid produced. The yields shown are indigenous and gross. See Tables 2 and 8, pp. 15 and 32, respectively, above.
b. The Second Five Year Plan quotes for 1932, the following yield values which are the same as the rounded figures shown here (in thousand tons): 2,459 for total gasoline, 422 for ligroine, 680 for lubricating oil (the yield of 698 for lubricants includes a value of 18 for greases in the table). This Plan 82/ also shows 1932 yields which do not seem to be on the same basis as the later Soviet source statistics, 83/ above (in thousand tons): 4,203 for kerosine, 1,250 for "motor oil" (?), 8,530 for mazut.
c. Although reported data do not include breakdowns for such dispositions in the USSR, this obviously consisted of crude oil storage increment, crude oil use as residual product, and crude oil loss. There is no available evidence of any prewar crude oil imports into the USSR.
d. 84/
e. 85/

Table 11

Reported Yields of Petroleum Products in the USSR a/*
1933-37

	Year									
	1933		1934		1935		1936 e/		1937 e/	
	Quantity (Thousand Metric Tons)	Percent	Quantity (Thousand Metric Tons)	Percent	Quantity (Thousand Metric Tons)	Percent	Quantity (Thousand Metric Tons)	Percent	Quantity (Thousand Metric Tons)	Percent
Crude oil refining										
Straight-run gasoline	1,401	7.6	1,411	7.0	1,248	5.8	1,214	4.9	1,250	4.7
Thermal cracked gasoline	681	3.7	834	4.1	1,132	5.3	1,732	7.0	1,760	6.7
Total refined gasoline	2,082	11.3	2,245	11.1	2,380	11.1	2,946	11.9	3,010	11.4
Ligroine	486	2.6	463	2.3	628	2.9	1,190	4.8	1,295	4.9
Kerosine	3,822	20.7	4,462	22.0	4,877	22.7	5,433	21.9	6,132	23.2
Diesel fuel	1,844	10.0	1,521	7.5	1,346	6.3	1,514	6.1	1,598	6.1
Lubricants	1,148	6.2	1,388	6.8	1,389	6.4	1,554	6.3	1,701	6.4
Residual and other products	7,938	43.0	8,995	44.3	9,188	42.7	10,139	40.9	10,584	40.0
Total nongaseous products	17,320	93.8	19,074	94.0	19,808	92.1	22,776	91.9	24,320	92.0
Refining gas and loss	1,136	6.2	1,226	6.0	1,707	7.9	1,998	8.1	2,128	8.0
Total crude oil refinery charge	18,456	100.0	20,300	100.0	21,515	100.0	24,774	100.0	26,448	100.0

* Footnotes for Table 11 follow on p. 45.

Table 11

Reported Yields of Petroleum Products in the USSR a/
1933-37
(Continued)

	Year									
	1933		1934		1935		1936 e/		1937 e/	
	Quantity (Thousand Metric Tons)	Percent	Quantity (Thousand Metric Tons)	Percent	Quantity (Thousand Metric Tons)	Percent	Quantity (Thousand Metric Tons)	Percent	Quantity (Thousand Metric Tons)	Percent
Crude oil exports	526		459		207		167 f/		69 f/	
Other crude oil disposition b/	2,507		3,456		3,516		2,949		1,984	
Total indigenous crude oil production	21,489 c/		24,218 c/		25,238 d/		27,890 d/		28,501 d/	
Nongaseous products										
Natural gasoline	87 c/		66 c/		87 d/		116 d/		136 d/	
Crude oil refining gasoline	2,082		2,245		2,380		2,946		3,010	
Total gasoline	2,169		2,311		2,467		3,062		3,146	
Other crude oil refining products	15,238		16,829		17,428		19,830		21,310	
Total nongaseous products	17,407		19,140		19,895		22,892		24,456	
Refining gas and loss										
Dry refinery gas	234		411		475		579		635	
Waste and other stock	902		815		1,232		1,419		1,493	
Total refining gas and loss	1,136		1,226		1,707		1,998		2,128	

Table 11

Reported Yields of Petroleum Products in the USSR a/
1933-37
(Continued)

a. 86/ except as noted in the table. In this period, no output of synthetic oil products was indicated within the USSR as then constituted, and it is assumed that natural gasoline was the only type of natural gas liquid produced. The yields shown are indigenous and gross. See Tables 2 and 8, pp. 13 and 32, respectively, above.
b. Although reported data do not include breakdowns for such dispositions in the USSR, this obviously consisted of crude oil storage increment, crude oil use as residual product, and crude oil loss. There is no available evidence of any prewar crude oil imports into the USSR.
c. 87/
d. 88/
e. 89/ except as noted in the column.
f. 90/

Table 12

Reported Yields of Petroleum Products in the USSR, by Product a/*
Fiscal Years 1927-28 and 1928-29 and Calendar Years 1930-37

Thousand Metric Tons

Product	Fiscal Year		Calendar Year							
	1927-28	1928-29	1930	1931	1932	1933	1934	1935	1936	1937
First grade	213.4	263.2	500.4	773.8	771.5	472.8	329.4	165.0	165.0	165.0
Second grade	518.6	796.8	1,059.4	955.4	999.5	928.6	1,081.4	1,083.4	1,048.9	1,085.3
Total straight-run gasoline	732.0	1,060.0	1,559.8	1,729.2	1,771.0	1,401.4	1,410.8	1,248.4	1,213.9	1,250.3
Naphtha	129.5	172.4	302.5	501.6	339.6	472.6	433.3	576.7	1,094.4	1,190.9
White spirit	0.3	.6	3.4	40.1	82.7	13.8	30.1	51.0	95.2	103.6
Total ligroine	129.8	173.0	305.9	541.7	422.3	486.4	463.4	627.7	1,189.6	1,294.5
Diesel fuel, motor fuel	187.4	1.4	64.2	102.2	30.9	165.3	436.2	364.9	398.4	414.2
Gas oil	221.9	351.9	656.4	891.9	714.7	866.1	584.3	480.5	524.3	545.0
Solar oil	66.4	76.0	91.5	63.8	96.7	163.8	159.9	160.0	178.2	185.3
Black solar oil, mixed solar oil	270.8	456.7	648.3	907.2	1,045.7	648.7	341.4	340.0	414.3	454.1
Total diesel fuel	746.5	886.3	1,460.4	1,965.1	1,888.0	1,843.9	1,521.8	1,345.4	1,515.2	1,598.6
Greases	0.0	0.0	0.0	1.0	1.9	1.4	0.9	18.8	22.9	25.1
Technical greases	14.6	20.5	13.5	12.1	16.1	14.0	14.7	25.6	31.2	34.2
Total greases	14.6	20.5	13.5	13.1	18.0	15.4	15.6	44.4	54.1	59.3
Special steam cylinder oils	14.3	18.0	22.7	18.9	32.0	15.7	25.3	18.6	16.5	17.7
Other cylinder oils	29.2	44.2	28.4	50.8	55.1	50.6	39.3	28.6	35.4	38.1
Total cylinder oils	43.5	62.2	51.1	69.7	87.1	66.3	64.6	47.2	51.9	55.8

* Footnotes for Table 12 follow on p. 48.

Table 12

Reported Yields of Petroleum Products in the USSR, by Product a/
Fiscal Years 1927-28 and 1928-29 and Calendar Years 1930-37
(Continued)

Thousand Metric Tons

Product	Fiscal Year		Calendar Year							
	1927-28	1928-29	1930	1931	1932	1933	1934	1935	1936	1937
Bright stock	0.0	0.0	0.0	0.0	2.3	26.9	31.3	28.1	30.0	30.0
Other engine oils	12.8	23.7	116.8	181.7	222.6	430.6	593.0	513.1	585.0	643.2
Total engine oils	12.8	23.7	116.8	181.7	224.9	457.5	624.3	541.2	615.0	673.2
Cylinder oils	43.5	62.2	51.1	69.7	87.1	66.3	64.6	47.2	51.9	55.8
Machine oils	226.1	236.[illegible]	242.1	284.5	215.0	435.4	460.0	430.6	474.1	518.9
Turbine oils	1.1	0.9	1.3	1.2	2.9	4.7	5.4	6.1	6.7	8.2
Motor oils	3.8	3.8	5.3	7.7	9.3	9.8	15.7	13.4	14.8	16.4
Transformer oils	3.7	5.5	13.0	13.7	19.3	28.2	25.1	27.5	30.3	32.8
Vaseline oils	10.9	12.0	11.5	11.7	8.7	6.4	9.6	5.5	6.1	6.6
Spindle oils	26.0	25.8	31.3	50.4	72.7	95.0	98.7	147.6	162.5	177.4
Nigrol	1.0	2.1	12.2	30.6	37.5	26.0	39.5	54.5	60.0	65.7
Other lubricating oils	2.2	2.2	2.8	1.3	2.6	4.1	29.2	71.4	78.6	87.0
Total lubricating oils	331.1	374.9	487.4	652.5	680.0	1,133.4	1,372.1	1,345.0	1,500.0	1,642.0
Total greases	14.6	20.5	13.5	13.1	18.0	15.4	15.6	44.4	54.1	59.3
Total lubricants	345.7	395.4	500.9	665.6	698.0	1,148.8	1,387.7	1,389.4	1,554.1	1,701.3
Petrolatum	0.0	0.0	0.0	0.0	0.0	15.8	4.4	9.9	12.1	13.2
Vaseline	0.6	1.2	1.1	1.3	0.7	0.2	2.6	3.4	4.1	4.5
Paraffin	0.0	6.2	8.5	11.6	15.3	18.7	30.8	33.3	40.5	44.4
Ceresine	0.0	0.0	0.0	0.2	0.6	1.5	1.8	1.2	1.4	1.6
Total waxes	0.6	7.4	9.6	13.1	16.6	36.2	39.6	47.8	58.1	63.7

Table 12

Reported Yields of Petroleum Products in the USSR, by Product a/
Fiscal Years 1927-28 and 1928-29 and Calendar Years 1930-37
(Continued)

Thousand Metric Tons

Product	Fiscal Year		Calendar Year							
	1927-28	1928-29	1930	1931	1932	1933	1934	1935	1936	1937
Asphalt	7.7	38.5	72.7	71.1	108.3	146.2	206.9	220.8	269.0	170.8
Gudron b/	386.2	413.9	501.2	600.1	690.2	958.1	18.1	127.9	155.9	294.9
Total asphalt and gudron	393.9	452.4	573.9	671.2	798.5	1,104.3	225.0	348.7	424.9	465.7
Polymers and bottoms	0.0	0.3	15.1	110.1	279.8	235.0	134.6	136.3	166.0	181.9
Black oil	85.2	93.7	118.1	92.7	216.6	37.1	40.7	54.1	65.9	72.3
Acid oil	0.0	0.0	0.0	6.0	11.7	17.2	26.0	25.8	31.4	34.4
Soap-lye crudes	0.0	0.0	0.0	16.0	9.9	3.6	4.5	4.3	5.2	5.7
Naphthenic acid stock	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.1	0.2	0.2
Contact oil	0.0	0.0	0.0	1.7	2.2	0.7	5.2	2.4	2.9	3.2
Total heavy specialty oils	85.2	94.0	133.2	226.5	520.2	293.6	211.1	223.0	271.6	297.7
Waxes	0.6	7.4	9.6	13.1	16.6	36.2	39.6	47.8	58.1	63.7
Asphalt and gudron	393.9	452.4	573.9	671.2	798.5	1,104.3	225.0	348.7	424.9	465.7
Residual fuel oils	4,095.9	5,315.4	7,610.9	8,942.0	8,469.5	6,503.5	8,519.4	8,568.3	9,384.1	9,755.5
Total residual and other products	4,575.6	5,869.2	8,327.6	9,852.8	9,804.8	7,937.6	8,995.1	9,187.8	10,138.7	10,582.6

a. The category yields in Tables 10 and 11 are generally the totals of separately rounded yield figures and may vary plus or minus 1 percent from the results if the totals of unrounded figures in Table 12 were rounded. (The basic data for Table 12 are from source 89/.) Product-yield figures refer to indigenous gross product yields.
b. Gudron presumably is a residue tar, sometimes having lubricant grease quality. 91/

Table 13

Correlation of Data on Output and Consumption of Petroleum Products Derived from Crude Oil Refining in the USSR a/*
Fiscal Year 1928-29 and Calendar Years 1929, 1930, 1932, and 1935-37

Thousand Metric Tons

	Data from Tables 10, 11, and 12					Data from Source A b/ c/		Data from Source B d/			Data from Source C e/
	1928-29	1930	1932	1935	1936	1929	1930	1932	1935	1936	1936
Gross refining product yields											
Straight-run gasoline	1,060.0	1,559.8				1,113.9	1,567.1				1,257
Thermal cracked gasoline	1.8	39.1				4.4	39.1				1,745
Total gasoline	1,061.8	1,598.9	2,364	2,380	2,946	1,118.3	1,606.2	2,459	2,436	3,054	3,002
Ligroine	173.0	305.9	422	628	1,190	186.9	300.4	422	624	1,139	1,207
Total ligroine and gasoline	1,234.8	1,904.8	2,786	3,008	4,136	1,305.2	1,906.6	2,881	3,060	4,193	4,209
Kerosine	2,316.8	3,231.0	3,560	4,877	5,433	2,501.8	3,230.4	3,560	4,939	5,597	5,410
Total naphtha distillates (kerosine, ligroine, gasoline)	3,551.6	5,135.8	6,346	7,885	9,569	3,807.0	5,137.0	6,441	7,999	9,790 f/	9,619
Other products, gas, and loss	7,482.4	11,036.7			15,205	7,979.6	11,226.6			15,021	15,381
Total refinery charge	11,034.0	16,172.5			24,774	11,786.6	16,363.6			24,811 f/	25,000
Crude oil refinery charge	11,034.0	16,172.5			24,774	11,659.3	16,196.0			24,811 f/	25,000
Refinery charge not crude oil	0	0			0	127.3 g/	167.6 g/			0	0
Transformer oils	5.5	13.0				7.6	13.0				
Automotive (engine) oils	23.7	116.8				22.5	116.7				
Other lubricating oils	345.7	357.6 h/				356.1	338.5				
Lubricating oils subtotal	0	0				386.2	468.2				

* Footnotes for Table 13 follow on p. 52.

Table 13

Correlation of Data on Output and Consumption of Petroleum Products Derived from Crude Oil Refining in the USSR a/
Fiscal Year 1928-29 and Calendar Years 1929, 1930, 1932, and 1935-37
(Continued)

Thousand Metric Tons

	Data from Tables 10, 11, and 12					Data from Source A b/ c/		Data from Source B d/			Data from Source C e/
	1928-29	1930	1932	1935	1936	1929	1930	1932	1935	1936	1936
Gross refining product yields (Continued)											
Special oils	0	0				18.2	19.2				
Total lubricating oils	374.9	487.4				404.4	487.4				
Solar oil	76.0	91.5				76.2	91.4				
Total "oils"	450.9	578.9				480.6	578.8				
Greases	20.5	13.5				{ 23.7	{ 14.6				
Vaseline	1.2	1.1									
Waxes	6.2	8.5				6.8	8.5				
Asphalt	38.5	72.7				43.0	72.7				
Other products, gas, and loss	10,516.7	15,497.8				11,232.5	15,689.0				
Total	11,034.0	16,172.5				11,786.6	16,363.6				
Natural gasoline	27.9	55.1				29.6	55.1				
Lubricating oil					1,500						1,207
Indigenous crude oil production					27,890					27,446 e/	27,342

Table 13

Correlation of Data on Output and Consumption of Petroleum Products Derived from Crude Oil Refining in the USSR a/
Fiscal Year 1928-29 and Calendar Years 1929, 1930, 1932, and 1935-37
(Continued)

Thousand Metric Tons

	Data from Tables 10, 11 and 12					Data from Source A b/ c/		Data from Source B d/			Data from Source C e/
	1928-29	1930	1932	1935	1936	1929	1930	1932	1935	1936	1936
								Data from Source B d/			Data from Source D i/
								1932		1936	1937
Indigenous consumption of products											
Gasoline											2,980
Ligroine											1,756
Total gasoline and ligroine								895		3,535	5,585
Kerosine								3,028		4,652	
Total naphtha distillates								3,923		8,187	
Exports of naphtha distillates								2,550 j/			
Total reported disposition of naphtha distillates								6,473			
Tractor kerosine								1,392		3,170	
Other kerosine								1,636		1,482	
"Oils" (lubricating oils)								784		1,083	

Table 13

Correlation of Data on Output and Consumption of Petroleum Products Derived from Crude Oil Refining in the USSR a/
Fiscal Year 1928-29 and Calendar Years 1929, 1930, 1932, and 1935-37
(Continued)

a. This table compares the data given in Tables 10, 11, and 12 with corresponding or related data from other significant source reports. The comparisons cover four such reports (A, B, C, D) which are considered especially important. This table includes a condensed summary of the data in those reports and recapitulates certain data from Tables 10, 11, and 12 in a manner to correspond with the product-yield breakdowns in the other sources (this table omits recapitulation of yield data which correlate with the source D, 1937 consumption values). Of the four other sources, A, B, and D are Soviet publications, and C is an intelligence estimate.

b. 92/. (Source A.) This report is of Soviet origin and has certain distinctive features. The report shows the 1929 and 1930 product yields in detail separately derived in each major crude oil refinery complex which then existed in the USSR. (As of 1930 the major part of the Soviet crude oil refining capacity was located at Baku while most of the remainder was located at Groznyy. The Soviet crude oil refining outputs of gasoline, kerosine, lubricating oils, and mazut /residual fuel oil/ are also officially reported by constituent Soviet Republics, covering selected years prior to 1935. 93/) The report contains some corruption in its statistical correlations by way of self-evident errors and inconsistencies. Various obvious but minor arithmetical errors which appear in an English translation 94/ of a portion of the report are corrected in the present table and in the related footnotes.

c. Because it was published as a monograph in the Soviet press, Source A presents a considerable problem. Source A apparently contradicts the values shown in the official Soviet report which is the primary source for the pre-1935 yield data shown in Tables 10, 11, and 12. For convenience in discussion, this primary source is here designated as Source Y (see source 11/).

In a study of that problem, however, it developed that the Source A values can be rendered compatible with the Source Y yields in a uniform fashion, as shown in the present table. The Source A values can be placed in this compatible status by means of adjustments which compensate for internal inconsistencies in the Source A. Some degree of validity is established for the adjustments by virtue of two considerations: first, the necessary adjustments apply to only two or three of the several distinct product category yields; second, the adjustments may be made so as to maintain subtotal material balances exactly as given in the Source A. The resulting analysis of the Source A values appears to bear incidental importance sufficient to warrant the brief summary which follows.

Source A presents statistical correlations in two forms, as summary tabulations and as supplementary textual developments. The internal inconsistencies and numerical errors are present in both the tabulations and textual developments. Total Soviet yields are given by product categories in a final tabulation; these totals are here designated by (T). The total national yields by product categories may also be developed by summation of the values shown for separate refinery complexes; these summation totals are here denoted by (S). After making corrections for numerical errors and preliminary adjustments to compensate for internal inconsistencies, the final internal statistical irregularities in this Source A may be resolved as differences between the (S) and (T) values which correspond for product-category yields. The analysis is then completed by making a choice between the (S) and (T) values and selecting the (S) or (T) value which is nearest to the corresponding yield value in Source Y. Additional adjustments are also made to maintain the Source A internal subtotal material balances according to either the (S) or (T) series of values.

These steps are explained more clearly, perhaps, by means of the tabulation of numerical material balances shown below, where (F) denotes the final adjusted yield value, developed either by selection or by algebraic summation. The selection is controlled by comparison of the calendar year 1930 yield totals in Sources A and Y; corresponding adjustments are applied to compare the yield totals for the calendar year 1929 in Source A with yield totals for fiscal year 1928-29 in Source Y.

Table 13

Correlation of Data on Output and Consumption of Petroleum Products Derived from Crude Oil Refining in the USSR a/
Fiscal Year 1928-29 and Calendar Years 1929, 1930, 1932, and 1935-37
(Continued)

			1930	1929
	(T)	Transformer oil	13.0	7.6
	(T)	Automotive (engine) oil	116.7	22.5
	(T)	Other "oils"	449.1	450.5
	(T)	Total "oils" I	578.8	480.6
	(T)	Straight-run gasoline	1,867.6	1,113.8
(S)	(T)	Cracked gasoline	39.1	4.4
	(T)	Total refined gasoline	1,906.7	1,118.2
	(T)	Ligroine	300.4	186.9
	(T)	Total ligroine plus gasoline	2,207.1	1,305.1
	(T)	Greases	14.6	23.7
	(T)	"Other" products I	515.6	127.7
	(T)	Total "oils" I	578.8	480.6
	(T)	Total I	3,316.1	1,937.1
	(T)	Remaining products plus losses I	13,047.5	9,849.5
(S)	(T)	Total refinery charge	16,363.6	11,786.6
	(S)	"Special" oils	19.2	18.2
	(S)	Solar oil	91.4	76.2
	(S)	Lubricating oils subtotal I	449.6	377.1
	(S)	Total "oils" II	560.2	471.5

Table 13

Correlation of Data on Output and Consumption of Petroleum Products Derived from Crude Oil Refining in the USSR a/
Fiscal Year 1928-29 and Calendar Years 1929, 1930, 1932, and 1935-37
(Continued)

				1930	1929
		(S)	Straight-run gasoline plus ligroine	1,867.5	1,300.8
	(S)	(T)	Cracked gasoline	39.1	4.4
		(S)	Total ligroine plus gasoline	1,906.6	1,305.2
		(S)	Greases	129.7	83.3
		(S)	"Other" products II	291.8	76.6
		(S)	Total "oils" II	560.2	471.5
		(S)	Total II	2,888.3	1,936.6
		(S)	Remaining products plus losses II	13,475.3	9,850.0
	(S)	(T)	Total refinery charge	16,363.6	11,786.6
	(F)	(S)	Straight-run gasoline plus ligroine	1,867.5	1,300.8
	(F)	(T)	Ligroine	300.4	186.9
		(F)	Straight-run gasoline	1,567.1	1,113.9
(F)	(S)	(T)	Cracked gasoline	39.1	4.4
		(F)	Total gasoline	1,606.2	1,118.3
	(F)	(T)	Ligroine	300.4	186.9
	(F)	(S)	Total ligroine plus gasoline	1,906.6	1,305.2

Table 13

Correlation of Data on Output and Consumption of Petroleum Products Derived from Crude Oil Refining in the USSR a/
Fiscal Year 1928-29 and Calendar Years 1929, 1930, 1932, and 1935-37
(Continued)

			1930	1929
(F)	(S)	"Special" oils	19.2	18.2
(F)	(S)	Solar oil	91.4	76.2
(F)		Lubricating oils subtotal II	468.2	386.2
(F)	(T)	Total "oils" I	578.8	480.6
(F)	(T)	Greases	14.6	23.7
(F)		"Other" products III	388.3	127.1
(F)	(S)	Ligroine plus gasoline	1,906.6	1,305.2
(F)	(S)	Total II	2,388.3	1,936.6
(F)	(T)	Transformer oil	13.0	7.6
(F)	(T)	Automotive (engine) oil	116.7	22.5
(F)		Other lubricating oils I	338.5	356.1
(F)				
(F)		Lubricating oils subtotal II	468.2	386.2
(F)	(S)	"Special" oils	19.2	18.2
(F)		Total lubricating oils	487.4	404.4
(F)		Other lubricating oils I	338.5	356.1
(F)	(S)	"Special" oils	19.2	18.2
(F)		Total other lubricating oils II	357.7	374.3

Table 13

Correlation of Data on Output and Consumption of Petroleum Products Derived from Crude Oil Refining in the USSR a/
Fiscal Year 1928-29 and Calendar Years 1929, 1930, 1932, and 1935-37
(Continued)

d. 25/. (Source B.)
e. 26/. (Source C.) These productions appear to be identified as net yields, but the "refinery consumption" presumably is confined for the most part to refinery still gas and residual fuel oil. For practical purposes, the net yields and gross yields from a processing plant may be considered to be identical except in the manufacture of residual fuel oil.
f. The values of 24,811,000 tons and 27,446,000 tons are here calculated on the basis of percentages quoted in Source B. Thus 9,790,000 tons is stated to be 39.5 percent of the crude oil refinery charge, and the latter is stated to be 90.4 percent of the indigenous crude oil production. Source B also notes that the Soviet crude oil refinery charge was 80 percent of the indigenous crude oil production in fiscal 1928-29, whereas that ratio is developed as 81.7 percent in Tables 10, 11, and 12.
g. Although these quantities are not directly identified in Source A and could have been recycle oil stock charged to processing, having origin in a storage reserve accumulated in previous annual operation, the text of Source A contains a cryptic reference to "nonpetroliferous" products in certain refineries.
h. Presumably includes the "special" oils separately reported in Source A. (See footnote c, above.)
i. 27/. (Source D.) The data were published early in 1937 as a forecast for 1937, apparently upon an official basis.
j. This quantity is based on the following percentages reported in Source B: (1) "Gasoline Exports" are stated to be 70 percent of the gross product yield -- 0.7 x 2,459,000 tons = 1,721,000 tons; (2) "Kerosine Exports" are stated to be 23.3 percent of the gross product yield -- 0.233 x 3,560,000 tons = 829,000 tons; (3) hence 1,721,000 tons + 829,000 tons = 2,550,000 tons.

Table 14

Estimated Yields of Crude Oil Refining Products in the USSR
Based on the Captured 1941 Soviet State Plan a/*
1939, 1941 Plan, and 1946

	1939		1941 Plan b/		1946 c/	
	Quantity (Thousand Metric Tons)	Percent	Quantity (Thousand Metric Tons)	Percent	Quantity (Thousand Metric Tons)	Percent
Straight-run gasoline	1,580	5.5	2,032	6.3	1,430	6.9
Thermal cracked gasoline	2,700 d/	9.4	3,482 e/	10.7	2,700 d/	12.9
Total refined gasoline	4,280	14.9	5,514	17.0	4,130	19.8
Ligroine	1,350	4.7	1,418	4.4	900	4.3
Kerosine	6,450	22.5	7,118	21.9	4,400	21.1
Diesel fuel			2,600	8.0	1,660	8.0
Lubricating oil	12,886	44.9	11,588	35.7	1,000	4.8
Residual and other products					6,100	29.2
Total net nongaseous products	24,966	87.0	28,238	87.0	18,190	87.1
Refinery consumption b/	3,734	13.0	4,219	13.0	2,700	12.9
Total crude oil refinery charge	28,700	100.0	32,457	100.0	20,890	100.0

* Footnotes for Table 14 follow on p. 58.

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Table 14

Estimated Yields of Crude Oil Refining Products in the USSR
Based on the Captured 1941 Soviet State Plan a/
1939, 1941 Plan, and 1946
(Continued)

	1939		1941 Plan b/		1946 c/	
	Quantity (Thousand Metric Tons)	Percent	Quantity (Thousand Metric Tons)	Percent	Quantity (Thousand Metric Tons)	Percent
Type diesel fuel			1,100	3.4	700	
Motor (heavy diesel fuel)			1,500	4.6	960	

a. 98/ (Source C in Table 10.) See Table 13, footnote e, p. 49, above.
b. See Table 3, p. 16, above, and Section III, p. 15, above.
c. These estimated 1946 yields developed in an Air Force Working Paper, are included here for comparison with the estimated yields of crude oil refining products in the present report (see Table 5, p. 24, above; Table 9, p. 34, above; and Table 31, p. 118, below). The two sets of estimated 1946 yields are derived by consistent and completely developed analyses and serve to illustrate the differences which result from the differences in the basic assumptions. The 1939 estimates in Table 14 appear to be as realistic as possible, in view of the limited intelligence available.
d. 30 percent of the thermal cracking charge value of 9,000 tons.
e. 30.434 percent of the thermal cracking charge value of 11,441,000 tons.

Table 15

Estimated Production of Synthetic Petroleum Products from Oil Shale in the Estonian SSR a/*
1921-44

Year	Crude Shale Oil Recovery c/ (Thousand Metric Tons)	Crude Shale Oil Recovery and Refining b/				
		Crude Shale Oil		Gasoline from Shale Oil Refining		
		Recovery (Thousand Metric Tons)	Percent of Retorted Oil Shale	Recovery (Thousand Metric Tons)	Percent	
					Crude Oil	Retorted Oil Shale
1921	0.1					
1922	0.3					
1923	0.4					
1924	0.3					
1925	3.1					
1926	5.8					
1927	4.3					
1928	11.9					
1929	10.8					
1930	10.0					
1931	17.1					
1932	36.6					
1933	37.6					
1934 d/	46.8	46.88	19.3	5.83	12.4	2.4
1935	47.3	47.27	18.8	6.22	13.2	2.5
1936 d/	63.4	63.46	18.5	7.74	12.2	2.3

* Footnotes for Table 15 follow on p. 60.

Table 15

Estimated Production of Synthetic Petroleum Products from Oil Shale in the Estonian SSR a/
1921-44
(Continued)

Year	Crude Shale Oil Recovery c/ (Thousand Metric Tons)	Crude Shale Oil Recovery and Refining b/				
		Crude Shale Oil		Gasoline from Shale Oil Refining		
		Recovery (Thousand Metric Tons)	Percent of Retorted Oil Shale	Recovery (Thousand Metric Tons)	Percent	
					Crude Oil	Retorted Oil Shale
1937 d/	111.7	111.89	18.7	14.40	12.9	2.4
1938 d/	140.2	139.64	18.2	15.16	10.9	2.0
1939 d/	180.1	178.89	18.5	22.62	12.6	2.3
1940	174.1					
1941 e/ f/	87.3					
1942	53.1					
1943	110.0					
1944 g/	78.6					

a. In this report, crude shale oil and total shale oil products are considered equivalent. Possible refining gas and loss in crude shale oil processing is considered negligible in view of the relatively small yields of crude shale oil. Product-yield figures refer to annual gross product yield.
b. 99/
c. 100/
d. Negligible differences are shown in the crude shale oil values reported. Some of the differences are evidently the result of rounding.

Table 15

Estimated Production of Synthetic Petroleum Products from Oil Shale in the Estonian SSR a/
1921-44
(Continued)

e. German exploitation during Nazi occupation began in July 1941 and continued until the Soviet forces expelled the Germans in 1944. German plans reportedly 101/ involved the following anticipated yields in crude shale oil refining:

Finished Product	Volume Percent of Crude Shale Oil Charge
Gasoline	12.0
Tractor fuel (kerosine)	4.0
Diesel fuel (middle oil)	27.0
Fuel oil (heating oil)	37.0
Bitumens	17.5
Refining gas and loss	2.5
Crude shale oil refinery charge	100.0

f. Includes 81,700 tons for the first half of the year before German occupation, and a value of 5,600 tons for the latter half of the year under German exploitation.
g. Yield data in this year after September 15 are missing.

Table 16

Volume-to-Weight Conversion Factors for Nongaseous Petroleum Stocks a/

Product	Barrels b/ per Metric Ton
Gasoline	8.5 c/ d/
Kerosine	7.7 c/ d/
Diesel fuels, other gas oils	7.5 c/ d/
Lubricating oils	7.1 c/ d/
Residual fuel oil	6.5 c/
Other petroleum products	7.3 c/
Residual and other products	7.1 d/
Crude oil charge	7.3 c/ d/

a. Basis: data in source 102/ correlated with other pertinent factors for particular applications.
b. Barrels of 42 US gallons.
c. Applied to the data from source 65/ in Table 7, p. 29, above.
d. Applied to the data from source 111/ in Table 18, p. 66, below.

APPENDIX B

METHODOLOGY FOR DERIVATION OF ESTIMATES OF SOVIET YIELDS OF PETROLEUM PRODUCTS 1946-54

1. General.

The introduction and text of this report give a general description of the methodology used. The text of this appendix summarizes the major features of the methodology, and simplified tables give the principal details. The footnotes to these tables outline the developments and applications of the methodology.

2. Available Parameters.

Tables 17 through 19* provide a record of the parametric values available for the years 1946-54. Table 17 shows the estimated indigenous consumption of petroleum products, and Table 18 shows the estimated international trade in crude oil and petroleum products by the USSR. Table 19 shows estimated indigenous yields of petroleum products not of crude-oil origin. (Estimated indigenous yields of petroleum products which are of crude oil origin are shown subsequently in Table 21.**)

3. Estimating Factors.

a. Handling Losses and Direct Use as Petroleum Products of Unrefined Crude Oil.

Before World War II, open Soviet sources provided some information on Soviet crude-oil handling losses and also on the Soviet practice of making direct use of crude oil and topped crude*** as

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* Tables 17, 18, and 19 follow on pp. 65, 66, and 68, respectively, below.

** P. 99, below.

*** Topped crude is the long residue or semirefined crude oil which remains when the lower boiling fractions, generally consisting of gasoline and kerosine, are removed by straight-run distillation.

petroleum products. Table 20* shows reported losses and fuel oil uses of crude oil in the USSR, 1935-37 and 1939-40.

In the past the USSR often used open-pit excavations for the storage of crude oil and nonvolatile petroleum products, chiefly fuel oils. 103/ Soviet sources criticize the use of such pits on the grounds of excessive evaporation losses and also on the grounds of seepage losses when the walls of the pits are not of impervious natural rock and are not lined or treated. Use of the pits is reported to be officially prohibited now except by grant of special permission. 104/

Only fragmentary and qualitative data, as outlined above, are available for the losses and direct petroleum-product uses of crude oil in the USSR. In the US these 2 types of crude oil dispositions together have ranged from about 0.6 percent to about 3.8 percent of total new supply.**

Estimating factors are arbitrarily applied to the postwar Soviet data as follows: 4 percent for crude oil handling losses and 1 percent for direct petroleum-product use of crude oil, the base on which these percentages are applied being the indigenous production of crude oil because the apparent values for imports of crude oil are relatively insignificant. Two principal assumptions are involved: (1) that Soviet handling is accompanied by considerable extraneous crude oil evaporation loss, whereas this sort of loss is effectively nil in US practice, and (2) that in order to obtain relatively higher yields of the more valuable refined petroleum products, the USSR has greatly reduced*** the percentage of unrefined crude oil used directly as petroleum products.****

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* Table 20 follows on p. 73.

** See Table 8, footnote b, p. 33, above, for the basis of the US data. The total new supply is the sum of indigenous crude oil production plus crude oil imports.

*** Compared with the reported prewar level (see Table 20, p. 73, below).

**** Continued on p. 77.

Table 17

Estimated Consumption of Petroleum Products in the USSR a/
1946-54

Thousand Metric Tons

Consumption and Years	Gasoline	Ligroine	Kerosine Category	Diesel Fuel	Lubricants	Distillates plus Lubricants	Residual and Other Products	Total Nongaseous Products	Aviation Gasoline b/	Motor Gasoline b/
Civil consumption c/										
1946	1,908	600 d/ e/	5,111 d/ f/	317 d/ g/	995	8,931				
1947	3,112	615	6,003	470	1,208	11,408				
1948	3,819	617	7,050	724	1,396	13,606				
1949	4,834	523	7,543	1,281	1,634	15,815				
1950	5,721	517	8,082	2,111	1,859	18,290				
1951	7,031	548	8,976	3,111	2,090	21,756				
1952	8,108	649	9,072	5,066	2,334	25,229				
1953	8,928	732	9,669	6,589	2,571	28,489				
1954	9,780	323	10,418	8,800	2,972	32,293				
Military consumption h/										
1953	1,928	0	1,540	747	173	4,388	423	4,811	599	1,329

a. The following values given in source 105/ are omitted: civil consumption of total nongaseous products, which had a basis in prior intelligence estimates that are here revised, and civil consumption of residual and other products, which resulted by difference.
b. Source 106/ shows no breakdown for Aviation Gasoline and Motor Gasoline.
c. 107/
d. These 3 values were shown as an aggregate of 6,028,000 in source 108/.
e. Arbitrary separate estimate approximating the corresponding given values for 1947 and 1948.
f. Based on an assumed relationship involving the corresponding given values for 1947 and 1948, thus: $\frac{5,111}{6,003} = \frac{6,003}{7,050}$
g. Residual resulting by difference.
h. 109/

Table 18

Estimated Petroleum Trade Data for International Trade in Crude Oil and Petroleum Products by the USSR a/*
1946-54

Thousand Metric Tons

Trade and Year	Gasoline	Kerosine	Diesel Fuel	Lubricating Oils	Residual and Other Products	Total Nongaseous Products	Crude Oil
Imports b/							
1946	1,384	445	632	84	829	3,374	0
1947	1,112	416	365	63	513	2,469	0
1948							115 c/
1949							100 c/
1950							120 c/
1951	1,870	440	800	35	525	3,670	170
1952	2,380	560	1,025	45	660	4,670	200
1953	2,504	588	1,071	62	662	4,887	200
1954							0
Exports							
1946							0
1947							0
1948							0
1949							0
1950							230 d/

* Footnotes for Table 18 follow on p. 67.

Table 18

Estimated Petroleum Trade Data for International Trade in Crude Oil and Petroleum Products by the USSR a/
1946-54
(Continued)

Thousand Metric Tons

Trade and Year	Gasoline	Kerosine	Diesel Fuel	Lubricating Oils	Residual and Other Products	Total Nongaseous Products	Crude Oil
Exports (Continued)							
1951	233	186	62	54	136	671	339
1952	299	306	125	62	121	913	494
1953	354	330	312	57	192	1,245	342
1954							618 e/

a. Data for the years 1951-53, are from source 110/. There is no available evidence that any crude oil was imported in 1946, 1947, or 1954, or exported in 1946-49. Data on imports of petroleum products are not available for 1948-50 and 1954. Data on exports of petroleum products are not available for 1946-50 and 1954.
b. Data on imports of petroleum products in 1946-47 are from source 111/ and are given by volume. See Appendix A, Table 16, for volume/weight conversion factors.
c. 112/
d. 113/
e. 114/

Table 19

Estimated Yields of Petroleum Products Not of Crude Oil Origin in the USSR a/
1946-54

Thousand Metric Tons

Year	Shale Oil Products b/				Coal-Carbonization Oil Products			Total Synthetic Oil Products c/				
	Gasoline d/	Diesel Fuel d/	Residual and Other Products d/	Total Nongaseous Products d/ e/ f/	Gasoline g/ h/	Kerosine g/ h/	Total Petroleum Products g/ h/ i/	Gasoline	Kerosine	Diesel Fuel	Residual and Other Products	Total Nongaseous Products
1946	11	5	80	96 j/ k/ l/ m/	40	10	50	51	10	5	80	146
1947	14	6	93	113 j/ k/ l/	40	10	50	54	10	6	93	163
1948	18	7	123	148 j/ k/	40	10	50	58	10	7	123	198
1949	21	9	147	177 j/ k/	40	10	50	61	10	9	147	227
1950	24	10	166	200 j/ n/	40	10	50	64	10	10	166	250
1951	32	14	224	270 o/ p/	40	10	50	72	10	14	224	320
1952	41	17	282	340 o/ p/	40	10	50	81	10	17	282	390
1953	49	20	336	405 k/ o/	40	10	50	89	10	20	336	455
1954	56	23	389	468 l/ o/ p/	40	10	50	96	10	23	389	518

	1946	1947	1948	1949	1950	1951	1952	1953	1954
Natural gasoline	80	120	160	240	320	480	840	1,240	1,600
Equivalent liquefied petroleum gases	120	180	240	360	480	720	1,260	1,860	2,400
Total natural gas liquids g/ r/ s/	200	300	400	600	800	1,200	2,100	3,100	4,000

a. Yield figures refer to indigenous gross yields of nongaseous products.
b. The Estonian SSR is the primary source of shale oil in the USSR. A small quantity is also obtained from the Slantsy plant in the Gdov region of Leningrad Oblast. It is estimated that the Slantsy plant began production in 1951 and was producing at an annual rate of 25,000 tons per year through 1953. In 1954 the annual output of shale oil in the Slantsy plant may have reached 50,000 tons, the estimated capacity of the plant. 115/ Although there are known deposits of oil shale in other areas of the USSR, there are no current data which reveal the derivation of shale oil from such deposits. The only known processing of oil shale in the USSR, other than those in the Estonian SSR and the Leningrad Oblast, is located at Kashperovka (53°02' N - 48°26' E) in Kuybyshev Oblast. Production of chemicals, tar, and silica bricks has been reported in this plant, but no yield of shale oil as such. Thus the Soviet output of shale oil is estimated to emanate entirely from the plants in the Estonian SSR and Leningrad Oblast. 116/
c. Before 1955 the only significant yields of Soviet synthetic oil are indicated to be from processing of shale oil and carbonization of coal. Although postwar construction of commercial hydrogenation plants (see footnote h, below) is reported, 117/ there is no evidence of significant yields before 1955.

Table 19

Estimated Yields of Petroleum Products Not of Crude-Oil Origin in the USSR a/
1946-54
(Continued)

d. The total nongaseous products (that is, the crude shale oils -- see footnote e, below) are estimated to have a percentage breakdown as follows. These percentages are based on Table 15 for gasoline and also on the fact that available intelligence indicates that gasoline and diesel fuel are the only significant distillates from shale oil refineries, and that these distillates are produced in the ratio of about 2 parts gasoline to 1 part diesel fuel.

Product Category	Percent of Total Nongaseous Shale Oil Products
Gasoline	12
Diesel fuel	5
Residual and other products	83
Total	100

e. Estimated as equivalent to crude shale oil (see Table 15, footnote a, p. 60, above). The indicated yields are estimated to be entirely from the Estonian SSR before 1951. The annual yield in the Slantsy plant is estimated as a value of 25 (25,000 tons) in 1951-53 and as a value of 50 (50,000 tons) in 1954. (See footnote a, above.)

f. These estimates generally differ from the more important earlier estimates. 118/

g. 119/

h. The total coal-carbonization products are estimated to have the percentage breakdown shown below. These percentages are arbitarily applied to develop the relatively small yields in the USSR and are derived by analogy based upon the estimated peak operations of Germany during World War II. Before effective destruction of the German facilities, Germany had developed the maximum potential rates ever attained anywhere for the industrial yield of synthetic petroleum products by coal carbonization as well as by the basic commercial hydrogenation processes (Bergius Hydrogenation and Fischer-Tropsch Synthesis -- both of these techniques being fundamentally of German origin). The basis of the percentage breakdown is also shown below, as represented in the equivalent annual yield rates estimated to have been attained in early 1944 in Germany:

Product Category	Percent of Total Petroleum Products (All Distillate-Type) Formed by Carbonization of Coal in the USSR
Gasoline	80
Kerosine	20
Total	100

Table 19

Estimated Yields of Petroleum Products Not of Crude Oil Origin in the USSR a/
1946-54
(Continued)

Product Category	Estimated Annual Yield Rates Attained in Commercial German Practice of Nongaseous Petroleum Products by Carbonization of Coal and Lignite			
	As of 1 January 1944 120/		As of Early 1944 121/	
	Quantity (Thousand Metric Tons)	Percent	Quantity (Thousand Metric Tons)	Percent
Gasoline	680	77.3	415	79.0
Kerosine and diesel fuel	200	22.7	110	21.0
Distillate-type petroleum products	880	100.0	525	100.0
Residual and other type petroleum products	1,000		800	
Total product	1,800		1,325	

i. Derived from the only coal-carbonization plants indicated to be producing petroleum stocks; this small total presumably consists of distillates only. The available intelligence generally indicates that there are only four small-capacity plants of the low-temperature type. 122/ Distillates generally are constituted by benzene for use as gasoline and by a light aromatic oil for use as kerosine or diesel fuel. Refining the tars derived by high- or low-temperature carbonization of coal or by the carbonization of lignite, however, may also yield heavy fuel oils and other products, which approximate crude oil-refining residual products in type (consisting mostly of hydrocarbon compounds). At present, however, it is assumed that distillates are the only petroleum products derived by carbonization of coal in the USSR.

j. From the Estonian SSR only.

k. Estimates for the contributions of the Estonian SSR approximate those derived by application of reported link relatives, taking the estimated 1950 yield as the base. These link relatives have been officially reported, with probable significance as follows:

1950 yield = 1.13 123/ x 1949 yield
1949 yield = 1.20 124/ x 1948 yield
1948 yield = 1.31 125/ x 1947 yield
1947 yield = 1.17 126/ x 1946 yield
1946 yield = 2.58 127/ x 1945 yield
1953 yield = 1.90 128/ x 1950 yield

Table 19

Estimated Yields of Petroleum Products Not of Crude-Oil Origin in the USSR a/
1946-54
(Continued)

Although not shown in this table, the 1945 yield of crude shale oil in the Estonian SSR is thus calculated to have been 96+2.58 = 37,000 tons.

l. Component figures have been forced to add to total figure.

m. A figure of 96 is correct if obtained directly through division of the 1950 figure by the product of the applicable link relatives. A figure of 97 would be obtained if each link relative were applied to the annual production estimates.

n. The estimated yield of crude shale oil in the USSR in 1950 (200,000 tons) is correlated with production of oil shale in the Estonian SSR as follows: (1) Yield of shale oil in 1950 in the Estonian SSR was reported to have been about 1.5 times the unidentified prewar annual yield in the same area, 129/ as cited in an unpublished manuscript. 130/ The 1950 production of oil shale in the Estonian SSR was similarly reported to have been 2.4 times the unidentified prewar production, 131/ as cited in the unpublished manuscript. 132/ The 1950 production of oil shale in the Estonian SSR was also officially reported to have been 1.8 times the 1940 production. 133/ (2) The values of prewar production of oil shale in the Estonian SSR are available with the production values for 1938-40 included, source 134/ and likewise the unpublished manuscript. 135/ In the unpublished manuscript 136/ the 1938 and 1939 production of oil shale in the Estonian SSR is given as 1.5 and 1.7 million tons respectively, and the 1940 production is given as 1.25 x 1.7 = 2.1 million tons, rounded to 2.0 million tons. The 1950 production of oil shale in the Estonian SSR is then calculated to be on the basis of the 1940 value, 1.8 x 2.0 = 3.6 million tons, which is the same as 2.4 times the 1938 value (2.4 x 1.5 = 3.6). The year 1938 is therefore assumed to be the prewar base for both production of oil shale and yield of crude shale oil. (3) The 1938 yield of crude shale oil in the Estonian SSR is reported to have been about 140,000 tons (see Table 15, p. 59, above), and the 1950 yield is estimated to have been 1.5 x 140,000 = 210,000 tons, rounded to 200,000 tons.

o. Total of the yield from the Estonian SSR plus the estimated yield from the Slantsy plant (see footnote e, above).

p. Estimates for the contributions of the Estonian SSR are based upon the application of arbitrarily assumed link relatives. These link relatives, however, generally reflect the trends indicated in available data 137/ and are as follows:

1951 yield = 1.225 x 1950 yield
1952 yield = 1.285 x 1951 yield
1954 yield = 1.10 x 1953 yield

q. 138/ These estimates are included to indicate potential yields which cannot logically be discounted. Soviet sources indicate knowledge of and concern with such potentials and infer that some yields may actually be obtained, although no quantitative data are provided.

r. The potential yield of natural gas liquids in the USSR is estimated to be 40 percent natural gasoline and 60 percent equivalent liquefied petroleum gases. This percentage breakdown is based on analogy with US data (modified by technical considerations discussed in footnote s) and on the arbitrary assumption that the USSR has been able to decrease the relative proportion of gasoline in equivalent liquefied petroleum gases from about one-half in 1946 to about one-third in 1954.

Over the 12-year period 1941-52 the average yield of natural gas liquids in the US consisted of about 71 percent natural gasoline and 29 percent liquefied petroleum gases (see Table 8, footnote b, p. 33, above and Table 9, p. 34, above), where the various terms are applicable in the technical sense. The corresponding US ratios in 1953 were about 61 percent and 39 percent, respectively. If the Soviet natural gas liquids in 1946 consisted of 70 percent natural gasoline and 30 percent liquefied petroleum gases, in the technical sense, with Soviet equivalent liquefied petroleum gases containing 50 percent natural gasoline, the Soviet equivalent liquefied petroleum gases would constitute (30 + 0.5 = 60) percent of the total natural gas liquids. In the same way, if Soviet natural gas liquids in 1953-54 consisted of 60 percent natural gasoline and 40 percent liquefied petroleum gases, in the technical sense, with Soviet equivalent

Table 19

Estimated Yields of Petroleum Products Not of Crude-Oil Origin in the USSR a/
1946-54
(Continued)

liquefied petroleum gases containing about one-third natural gasoline, the Soviet equivalent liquefied petroleum gases would constitute (40 + 2/3 = 60) percent of the total natural gas liquids.

s. It is assumed that the liquefied petroleum gases are mostly consumed as fuel for domestic ranges, space heating, and illumination. For estimating purposes and material balances, the product is classified in the kerosine and equivalent products category. The equivalent liquefied petroleum gases are estimated actually to consist of products that would be technically classified as natural gasoline and liquefied petroleum gases. For various reasons the assumed total Soviet yield of natural gasoline in the technical sense is considered to be in excess of what could be absorbed in gasoline blends. Excess natural gasoline is therefore assumed to be used in quantities along with liquefied petroleum gases in the technical meaning, serving as fuel for stoves and lamps, the fuels for which have been historically constituted by kerosine. While actual practice, active interest, and realistic plans are reported in the Soviet press 139/ with respect to the indigenous utilization of liquefied petroleum gases, pertinent quantitative intelligence appears to be unavailable.

The reasons for the excess supply of natural gasoline are technical, but are basically as follows: The USSR is estimated to have relatively limited refining facilities for alkylation and other types of polymerization. 140/ These polymerization processes are reversion techniques which normally serve to convert volatile or low boiling liquid hydrocarbons into less volatile or higher boiling liquids. The cracking operations produce the volatile liquids along with dry refinery gas, and efficient refining operation requires that the volatile liquids be utilized, generally as liquefied petroleum gases, or as charge stock to the reversion processes, or as blend stocks in the plant yields of gasoline. Soviet plant gasolines probably contain larger proportions of the low boiling liquids than do US plant gasolines. Hence, because of vapor pressure limits, smaller quantities of natural gasoline would be permissible in the final gasoline blends. Further restriction is inferred in this respect, inasmuch as the Soviet yield of gasoline blend is a relatively low percentage of total product.

Table 20

Reported Losses and Fuel Oil Uses of Crude Oil in the USSR
1935-37 and 1939-40

	Indigenous Production of Crude Oil a/* (Thousand Metric Tons)	Loss or Use Fraction (Thousand Metric Tons)	Loss or Use Fraction (Percent of Indigenous Production of Crude Oil)
1935			
Indigenous production of crude oil	25,238		100.0
Unrefined crude oil burned as fuel oil b/		1,500 c/	5.9
Topped crude oil burned as fuel oil b/		8,000 d/	31.7
1936			
Indigenous production of crude oil	27,890		100.0
Physical losses of unrefined crude oil b/			
Handling in production e/			
Low-boiling fractions		530 f/	1.9
High-boiling fractions		60	0.2
Total		590 g/	2.2

* Footnotes for Table 20 follow on p. 75.

Table 20

Reported Losses and Fuel Oil Uses of Crude Oil in the USSR
1935-37 and 1939-40
(Continued)

	Indigenous Production of Crude Oil a/* (Thousand Metric Tons)	Loss or Use Fraction (Thousand Metric Tons)	Loss or Use Fraction (Percent of Indigenous Production of Crude Oil)
1936 (Continued)			
Handling in refining h/			
Low-boiling fractions		495 i/	1.8
High-boiling fractions		660	2.4
Total		1,155	4.2
Unrefined crude oil burned as fuel oil b/		1,600 g/	5.7
Topped crude oil burned as fuel oil b/		8,700 j/	31.2
1937			
Indigenous production of crude oil	28,501		100.0
Unrefined crude oil burned as fuel oil k/			
General industry use		800	2.8
Petroleum industry use		700	2.5
Total industry use		1,500	5.3

Table 20

Reported Losses and Fuel Oil Uses of Crude Oil in the USSR
1935-37 and 1939-40
(Continued)

	Indigenous Production of Crude Oil a/ (Thousand Metric Tons)	Loss or Use Fraction (Thousand Metric Tons)	Loss or Use Fraction (Percent of Indigenous Production of Crude Oil)
1939			
Indigenous production of crude oil	30,417		100.0
Unrefined crude oil burned as fuel oil 1/		500	1.6
1940			
Indigenous production of crude oil	30,661		100.0
Unrefined crude oil burned as fuel oil 1/		500	1.6
Topped crude oil burned as fuel oil		1,000	3.3

a. 141/ See Table 2, p. 13, above, and Table 11, p. 43, above.
b. 142/
c. This quantity presumably is included in the total of 3,516,000 shown for other crude oil disposition in Table 11.
d. This quantity presumably is included in the total of 9,188,000 shown for the crude-oil refining yield of residual and other products in Table 11. Because of the large percentage yield in such total, the total is obviously composed largely of the semirefined crude oil.

Table 20

Reported Losses and Fuel Oil Uses of Crude Oil in the USSR
1935-37 and 1939-40
(Continued)

e. 143/ Inferred in the source to be extraneous and largely due to evaporation and needless waste. Apparently does not include the operational losses in crude oil storage, field treating, and other normal handling. The source states that the evaporation loss is one cause of low percentage yields of straight-run gasoline in refining.

f. 144/ The source states that this loss was about 38.8 percent of the concurrent yield of straight-run gasoline, although the source does not directly quantify the straight-run gasoline yield. According to the source, the inferred yield is thus 530 ÷ 0.388 = 1,366, compared with the yield value shown as 1,214 in Table 11.

g. This quantity is presumably included in the total of 2,949,000 shown for other crude oil disposition in Table 11.

h. 145/ Probably includes the physical losses incurred in the handling of refined products as well as crude oil. This status is somewhat ambiguously developed in the source. These losses are not presently considered to be a part of crude-oil-handling losses, since they appear to be partly refining gas and loss and partly product distribution losses.

i. 146/ As shown in the source, this is equivalent to about 16.2 percent of the concurrent total gasoline yield value of 3,054,000 which is also shown in the source (see Table 13, p. 49, above). Table 11 indicates a total gasoline yield value of 2,946,000 (see Tables 2, 11, and 13).

j. This quantity is presumably included in the total of 10,139,000 shown for the crude-oil-refining yield of residual and other products in Table 11. The other comments in footnote d, above, are applicable.

k. The total value of 1,500 is quoted in one source, 147/ whereas the value of 800 is quoted in another source with inference that the use was in general industry exclusive of the petroleum industry itself. 148/ The use breakdown is therefore assumed as shown. 149/ The value of 1,500 presumably is included in the total of 1,984 shown for other crude oil disposition in Table 11.

l. 150/ The use as reported is inferred to have been in the petroleum industry only. The source complains that about a third of the average material thus burned was potential gasoline recoverable by refining.

b. Refining Gas and Loss.

The derivation of an estimating factor for refining gas and loss is somewhat complicated. Tables 10 and 11* give the prewar percentages of the crude oil refinery charge accounted for by refining gas and loss. These percentages are shown to vary from 3 percent of the crude oil refinery charge in 1928-29 to about 8 percent in 1935-37. The percentage of refining gas and loss tends to increase with the relative increase in cracking operations -- a normal trend because cracking operations are usually the source of most the production of refinery gas -- and the production of refinery gas increased in the prewar period with relative increase in cracking. Dry refinery gas increased from less than 0.1 percent of the crude oil refinery charge in 1927-28 to about 2.4 percent in 1937 (see Tables 10 and 11*).

The relative increase in cracking operations continued. This is indicated by comparison of the data in Tables 10 and 11 with the 1941 State Plan (Tables 3 and 14**) and by further comparison of the same data with various other estimates. 151/

Hence larger postwar than prewar percentages of dry refinery gas, and consequently larger percentages of refining gas and loss, would be normal. Another reason for a large percentage of refinery gas is that the USSR has limited capacity for polymerization reversions (see Table 19, footnote s ***). Conversion refining**** of the polymerization reversion type serves in part to form liquid petroleum products from the heaviest or least volatile components which otherwise would remain in the refinery gas. Another reason for the larger percentage of refinery gas and loss is that the USSR does have some capacity for catalytic cracking.***** Catalytic cracking tends to produce a greater carbon deposit than do the thermal cracking processes, which are generally used in the USSR. (Carbon or coke is

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* Pp. 40 and 43, respectively, above.

** Pp. 16 and 57, respectively, above.

*** P. 71, above.

**** Conversion refining consists of those petroleum-refining operations which cause chemical change in the principal constituents. In addition to the reversion type of process already mentioned, conversion refining includes the processes which come within the general meaning of cracking and reforming.

***** See V, p. 28, above.

deposited upon the catalyst or other media present in the zone of reaction, and a carbon deposit thus developed is not normally recovered for output of petroleum products.)

It is also probable that the Soviet refining practice has become more efficient and has thus reduced the prewar percentage of miscellaneous refining losses exclusive of those due to the refinery gas. Before World War II the miscellaneous refining losses varied from less than 3 percent of the crude oil refinery charge in 1928-29 to more than 6 percent in 1932 (see Tables 10 and 11*). In the US,** where an extensive practice of catalytic cracking together with the alkylation/polymerization reversions was featured in the latter part of the period 1931-53, the following percentages of the crude oil refinery charge have prevailed:

	Percentage Range	
	1931 - 1945	1946 - 1953
Dry refinery gas	3.7 to 5.2	3.3 to 4.3
Other refining losses	1.5 to 4.3	1.3 to 2.7
Refining gas and loss	6.5 to 8.8	2.7 to 6.4

For determining postwar refining gas and loss in the USSR before 1953, the estimating factor is presently assumed to be 9 percent of the crude oil refinery charge. In order to account for the increased cracking which is indicated by increased relative yields of distillates (see Figure 1***), this estimating factor is increased to 10.2 percent after 1952. The 9-percent estimating factor has a somewhat involved technical derivation. 152/ Although the derivation was correlated with certain assumptions which now are not believed to be realistic, especially those referring to the hypothetical objectives to be obtained by use of the Soviet cracking facilities, the applied variations would have little effect upon the estimating factor for refining gas and loss.

* Pp. 40 and 43, above.
** The development of the US data is as indicated in Table 8, footnote b, p. 33, above.
*** Following p. 36.

c. Consumption of Nongaseous Petroleum Products in Processing.

In this report the consumption of nongaseous petroleum products in processing is considered to be restricted to the consumption of residual fuel oil in crude oil refining (see I, above, and also Table 13, footnote e*). The fragmentary available data on such consumption in the USSR are of little value for estimating purposes. In 1936, for instance, some of the largest Soviet refineries reportedly consumed a quantity of fuel oil equivalent to about 11 percent of the crude oil refinery charge. 153/ Soviet stock wastes, particularly the needless or wasteful consumption of residual fuel oil (mazut), were severely criticized recently in the Soviet press. 154/ As will be shown below, the estimating factor for this consumption is only of incidental use in the present methodology. The factor itself is derived by analogy with US data.**

In the US crude oil refinery complex the general pattern of fuel consumption in processing is as follows:

(1) Sources of net heat and mechanical energy input

(a) Purchased electrical power
(b) Purchased steam
(c) Combustion of fuels

(2) Types of fuels burned

(a) Coal (in power plants)
(b) Petroleum derivatives

Natural gas
Crude oil charge derivatives

(3) Crude oil charge derivatives as fuels

(a) Refining gas and loss materials

Acid sludge oil
Dry refinery gas

* Pp. 3 and 56, respectively, above.
** See Table 8, footnote b, p. 33, above, for the basis of the US data.

(b) Nongaseous petroleum products

Petroleum coke (in power plants)
Residual fuel oil

It is probable that a similar general pattern, with modification, is also applicable to the Soviet crude oil refinery operations. It is evident that with one exception the type of the consumed fuel is almost entirely dependent upon choice. The one exception is that for greater practicability of operation and equipment design, the fuels probably are restricted to fluid* types when the fuels are directly fired to heat the petroleum stock. The fuels for direct heating of petroleum stock are fired in various furnaces or fireboxes, including the furnaces in tubestill heaters and the fireboxes under the old-fashioned pot stills. It is possible that pot stills are retained in limited use in the USSR.

Even when the general type of processing and the actual end products are known, moreover, there is no technical basis for a realistic estimate of the total net energy input itself, the principal reasons being as follows: The requirement of net input of heat and mechanical energy from the above-mentioned sources is determined to some extent by the efficiency of design and operation. The total input of energy for the specified end results is the sum of this net requirement plus recovered heat. Proper design and operation, for example, may reduce the net requirement (1) by elimination of needless intermediate processes which use part of the total energy input, (2) by use of insulation and a variety of devices to eliminate needless loss of heat, and (3) by use of heat exchange to recover from hot material heat which would otherwise be wasted, such as the heat liberated when the carbon deposit is burned to remove it from catalyst material.

The composite fuels and equivalent fuel data for the US (based on recorded statistics and computed in this report, taking into account the respective heating values and physical densities of the fuels, are as follows):

* In this report the term fluid is used in the broad sense to include both gases and liquids.

	Range (Percentage of Crude Oil Refinery Charge)
For total net energy input	
Dry refinery gas available	3.3 to 5.2
Balance as residual fuel oil*	4.8 to 8.5
Combination of above**	9.5 to 12.1
Actual fuels burned	
Coal	0.2 to 1.1
Natural gas	1.3 to 3.8
Acid sludge oil	0.1 to 0.8
Dry refinery gas	3.3 to 5.2
Petroleum coke	0.02 to 0.5
Residual fuel oil	1.9 to 5.8
Combination of above**	9.7 to 12.4

In this report the postwar Soviet refinery consumption of residual fuel oil is assumed to be 3 percent of the crude oil refinery charge. The estimating factor is intermediate within the range for US practice, and is considered to be adequate for the incidental use which the factor has in the methodology. It is assumed that the Soviet crude oil refineries obtain from various other sources the remaining net requirement of heat and mechanical energy input. In addition to dry refinery gas and residual fuel oil, the principal other fuel, apparently available in sufficient quantities for significant use in Soviet refineries, is probably natural gas. 155/

d. Losses in Distribution of Petroleum Products.

The estimating factor for the Soviet losses in distribution of petroleum products is here assumed to be 2 percent of the net product

* Calculated to have a heating value equivalent to that of all fuels burned, with the exception of dry refinery gas; also calculated to account for the relatively small heat equivalents in purchased steam and electricity.

** The two sets of combined percentages do not necessarily correspond in any given year, owing to the purchased steam and electricity and the differences in heating values per unit weight of the different fuels.

yields.* This estimating factor is based upon general experience and company data in US practice and is correlated where possible with Soviet data. This establishes the general order of magnitude which, in the absence of more realistic data, is considered adequate. Various Soviet reports deal with phases of the subject, but the information provided is generally qualitative and not numerically resolvable except, sometimes, to infer limits on a national basis. A brief review of a selection of the Soviet data is as follows:

Actual loss percentages have been published in the Soviet press, but the data are identified ambiguously and apparently refer to a combination of handling losses in production and refining of crude oil and in distribution of petroleum products. The reports seem to infer that the losses consist of the extraneous or needless types of losses. The data on losses, moreover, seem to apply only to the "eastern" areas of the USSR (presumably the USSR exclusive of the Caucasus and the Ukraine). The loss percentages presumably refer to the crude oil refinery charge as a base and are reported as follows: 4.7 percent in 1940, 156/ 6.5 percent in 1941, 157/ 5.3 percent in 1942, 4.7 percent in 1943, 4.5 percent in 1944, 4.4 percent in 1953, and 4.2 percent in 1946. 158/

In 1938 the transportation type of petroleum-product distribution losses were stated to have been 1.7 percent of the petroleum products shipped during the summer season in railroad tank cars. 159/ Plans and exhortations for improvements and also records of actual improvements are indicated in a number of Soviet sources dealing with product distribution losses and further with the techniques and equipment for the handling and storage of the products. The Soviet source reports of this type may be variously classified as economic, technological, and engineering studies. 160/

Soviet sources also deal with the elimination of waste and the efficiency in the handling, storage, distribution, utilization, and consumption of petroleum products, referring in particular to lubricants and to liquid fuels for engines. Among such reports there are

* Net petroleum product yields and gross petroleum product yields are considered identical in this report except in the case of "residual and other products" derived by crude oil refining. See I, A, p. 3, above; Table 10, footnote c, p. 42, above; and this appendix, 3, c, p. 79, above.

those which provide extensive treatment of technological features; some of these refer specifically to the utilization in tractors and in all types of agricultural machinery, 161/ while others relate directly to machine tractor stations and state farms. 162/ Technical norms giving the maximum allowable loss percentages (referred to the stocks handled) were recently formalized. 163/

e. Storage Increments.

The introduction* of this report discusses briefly the estimating factor applied for year-end storage reserves in the USSR. For crude oil and for each category of petroleum products, the postwar year-end storage reserve is, with certain exceptions, assumed to be 12.5 percent of the respective gross yields for the preceding year. The exceptions refer to the initial, or 1945, year-end storage reserves of petroleum products. It is probable that the year-end storage reserves for 1945 were at a low level since this status immediately followed World War II -- a period of heavy consumption requirements while refining operations were generally disrupted. Year-end storage reserves for 1945 are calculated as percentages of the respective gross yields derived in 1946. For estimating purposes the 1945 year-end storage reserve for the kerosine category** is assumed to have been 10 percent of the 1946 gross yield and for all other categories of products, 2.5 percent of the respective 1946 gross yield.

The 12.5 percent factor*** approximates 45 days of reserve supply and is based upon analogy with US data. The 45 days of reserve supply is considered to be the minimum for refined petroleum products in US practice. 164/ General statistics show that -- as a percentage of the preceding total annual new supply of crude oil in the US, with more than 90 percent of this total new supply being, in each year of the period, the annual indigenous crude oil production -- the year-end crude oil storage reserve in the years 1944-53, ranged from 10.7 percent to 13.2 percent.**** The 12.5-percent factor is assumed for crude oil in the USSR, corresponding to the similar factor applied for petroleum products.

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* P. 3, above.

** Hereafter in Appendix B equivalent liquefied petroleum gases are included in the term kerosine when kerosine is used to mean kerosine category, or, more specifically, kerosine and equivalent products. See the Summary, the first tabulation, p. 1, above; Tables 6 and 7, pp. 27 and 29, respectively, above; and Table 19, footnote q, p. 71, above.

*** See I, B, p. 5, above.

**** See Table 8, footnote b, p. 33, above, for the basis of the US data.

4. Calculation of Estimates of Postwar Product Yields.

a. Formulation of the Numerical Calculations.

Appendix B, Section 5, presents the complete formulations for the material balances of the methodology.* The balances involve numerous separate quantities, and the use of literal symbols thus seems the only satisfactory means for developing the relationships. The formulations are all resolved as simplified algebraic equations. Although intermediate algebraic relationships are recorded so as to provide a pattern for reference should the methodology be applied to revised parametric data in the future, the actual calculations may be made with combined equations, thus deriving the final numerical results directly, without showing intermediate relationships.

The formulated material balances depend upon a variety of supplementary assumptions. The supplementary assumptions are applied chiefly to derive hypothetical constants for estimating. The assumptions serve to bridge the gaps in intelligence. The methodology otherwise serves merely to express the self-evident equalities of total availabilities and total dispositions as outlined below:

(1) Availabilities of Crude Oil.**

(a) Indigenous production
(b) Imports

(2) Disposition of Crude Oil.

(a) Handling losses
(b) Direct product use
(c) Storage increment
(d) Exports
(e) Indigenous refinery charge, disposition as follows:

Indigenous refinery gas and loss
Indigenous gross yields of crude oil refining products

* These formulations are mathematical expressions of the balance relationships which are described generally in I, B, p. 5, above, and further in IV, p. 17, above.

** The total availability constitutes the total new supply.

(3) Availabilities of Petroleum Products.*

(a) Crude oil in direct petroleum product use
(b) Indigenous gross yields of:

Natural gas liquids
Synthetic petroleum products
Crude oil refining products

(c) Petroleum product imports

(4) Dispositions of Petroleum Products.

(a) Distribution losses
(b) Storage increment
(c) Exports
(d) Indigenous consumption in:

Civil sector
Military sector

b. Tabular Summaries of Calculated Balances.

Tables 21 through 31** record the numerical details of the final results derived by applying the methodology so as to develop estimated values where these values apply in turn to the postwar yields of crude oil and petroleum products in the USSR. Each table is developed in the form of a sequence of subbalances showing the relationships which are implied by the following general terms: gross yields, net product yields, product net availability yields, and total new supply (total availability).

The tables are thus very detailed in order to provide patterns for possible future applications of the methodology to revised parameters. The blank spaces illustrate the gaps in intelligence. The details of these tables, therefore, include numerous intermediate values which would not need to be calculated if the methodology were applied to derive the final over-all yield estimates directly.

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* The total availability constitutes the total new supply.
** Tables 21 through 31 follow on pp. 99 through 116, below.

It is noted that the estimates of civil consumption of lubricants are only tentative. In the source, 165/ which provides the values of the civil consumption parameters (see Table 17*) the quantities for lubricants are based essentially upon the quantities for the residual and other products category, whereas that source's estimates for the residual and other products category are discounted in the present report (see Table 17,* footnote a). That source's estimate for lubricants in 1953 would not be much influenced by the present methodology, however, and this 1953 value is considered a realistic parameter. The further assumption that the yield of lubricants is a constant percentage of the crude oil refinery charge** is considered sufficiently realistic for estimating purposes. The basis for the assumed constant percentage is shown in Figure 1*** for prewar Soviet yields and in Figure 2**** for US yields.

The reported link relatives are considered directly applicable to the calculated gross petroleum product yields. Although the link relatives are cryptically recorded without further explanation in the Soviet press, and thus may be given various interpretations, only the gross yields would be logically adaptable to consistent measurement for the purpose of providing an index of annual achievements.

Table 21 shows the estimated data for crude oil, and Tables 22 through 29***** provide the numerical details for petroleum products. Table 30† summarizes the data for all nongaseous petroleum stock in the USSR, resulting by combination of the values of Tables 21 through 29. Table 31†† summarizes the estimated postwar crude oil refining operations in the USSR and develops the percentages which are shown graphically in Figure 1.***

c. Example of Numerical Calculations.

The detailed pattern of the numerical calculations is illustrated by the following example which is developed for crude oil and total gasoline. The algebraic symbols and equations are established by cross reference to Appendix B, Section 5.

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* P. 65, above.
** See Appendix B, Section 5, equation 43, p. 95, below.
*** Following p. 36.
**** Following p. 36.
***** Tables 21 through 29 follow on pp. 99 through 114, below.
† Table 30 follows on p. 116.
†† Table 31 follows on p. 118.

(1) Crude Oil in 1952*

a_7 = Indigenous production
= 45,600 (Table 21, p. 99, below)

(2) Crude Oil in 1953*

a_8 = Indigenous production
= 49,600 (Table 21, p. 99, below)

b_8 = Handling losses
= 0.04 a_8 (Equation 19)
= (0.04) (49,600) = 1,984

c_8 = Direct product use
= 0.01 a_8 (Equation 20)
= (0.01) (49,600) = 496

e_8 = Storage increment
= 0.125 (a_8 - a_7) (Equation 22)
= 0.125 (49,600 - 45,600) = 500

f_8 = Imports
= 200 (Table 18, p. 66, above)

g_8 = Exports
= 342 (Table 18, p. 66, above)

m_8 = Crude oil refinery charge
= a_8 - b_8 - c_8 - e_8 + f_8 - g_8 (Equation 4)
= 49,600 - 1,984 - 496 - 500 + 200 - 342
= 46,478

(3) Gasoline in 1953*

F_{8G} = Imports
= 2,504 (Table 18, p. 66, above)

G_{8G} = Exports
= 354 (Table 18, p. 66, above)

* All figures in this tabulation are given in terms of thousand metric tons annually.

H_{8G} = Civil consumption
= 8,928 (Table 17, p. 65, above)

J_{8G} = Military consumption
= 1,928 (Table 17, p. 65, above)

K_{8G} = Link relative
= 1.11 (Table 17, p. 65, above)

A_{8G} = Indigenous gross yield

$$= \frac{G_{8G} - F_{8G} + H_{8G} + J_{8G}}{0.98 - 0.125 \frac{K_{8G} - 1}{K_{8G}}} \text{ (Equation 52)}$$

$$= \frac{354 - 2,504 + 8,928 + 1,928}{0.98 - 0.125 \frac{1.11 - 1}{1.11}}$$

$$= \frac{8,706}{0.98 - 0.0124} = \frac{8,706}{0.9676} = 8,998$$

$= K_{8G} A_{7G}$ (Equation 7) (Equation 40)
$= 1.11 A_{7G}$

A_{7G} = Indigenous gross yield in 1952
$= \frac{8,998}{1.11} \cong 8,107$ (balance value)*

N_{8G} = Indigenous net yield
= A_{8G} (Equation 18)
= 8,998

B_{8G} = Distribution losses
= 0.02 N_{8G} (Equation 23)
= (0.02) (8,998) = 180

C_{8G} = Refinery product consumption
= 0 (Equation 14)

* Balance values are those values that resulted from use of composite equations and rounded values, arithmetical balances being forced in the over-all series of postwar years.

E_{8G} = Storage increment
= 0.125 (A_{8G} - A_{7G}) (Equation 26)
= (0.125) (8,998 - 8,107)
= (0.125) (891) ≅ 112 (balance value)

A_{8G} = B_{8G} + E_{8G} - F_{8G} + G_{8G} + H_{8G} + J_{8G} (Equation 6)
= 180 + 112 - 2,504 + 354 + 8,928 + 1,928
= 8,998 (Q.E.D.)

A''_{8G} = Indigenous gross yield of synthetic gasoline
= 89 (Table 19, p. 68, above)

A'''_{8G} = Indigenous gross yield of natural gasoline
= 1,240 (Table 19, p. 68, above)

A_{8G} = A'_{8G} + A''_{8G} + A'''_{8G} (Equation 16)
8,998 = A_{8G} + 89 + 1,240

A'_{8G} = Indigenous gross yield of crude oil refining gasoline
= 8,998 - 89 - 1,240 = 7,669

5. Outline of Numerical Calculations.

a. Definition of Literal Symbols.

(1) Crude Oil.

a = Indigenous production.

b = Handling losses.

c = Use as unrefined product (residual and other).

d = Year-end storage reserve.

e = Storage increment.

f = Imports.

g = Exports.

m = Crude oil refinery charge.

(2) Each Nongaseous Product.

A = Gross yield.*

B = Distribution losses.

C = Refinery product consumption (residual and other).

D = Year-end storage reserve

E = Storage increment.

F = Imports.

G = Exports.

H = Civil consumption including C -- refinery product consumption.

J = Military consumption.

K = Link relative.

N = Net yield.*

(3) Subscripts.

G = Gasoline.

L = Ligroine.

K = Kerosine and equivalent end-use products.

D = Diesel fuel.

B = Lubricants.

R = Residual and other products.

T = Total nongaseous products.

* As defined on p. 4, above.

Q = Any nongaseous product.

P = Gasoline, kerosine category, or diesel fuel.

S = Any nongaseous product except R -- Residual and other products.

W = Any nongaseous product except kerosine category.

r = denotes correlated annual data for a given year. r = 0 for 1945; r = 1 for 1946; ... r = 9 for 1954.

(4) Superscripts.*

' = for crude-oil refining petroleum products.
" = for synthetic-oil petroleum product.
''' = for natural gas liquids.

(5) Other.

Z = Crude oil refining gas and loss.

Equations

$$Y_{rQ} = (K_{rQ})\,(K_{(r-1)Q})\,(K_{(r-2)Q}) \cdots (K_{2Q}) \qquad (1)$$

$$Y_{(r-1)Q} = (K_{(r-1)Q})\,(K_{(r-2)Q}) \cdots (K_{2Q}) = Y_{rQ}/K_{rQ} \qquad (2)$$

$$Y_{rQ} - Y_{(r-1)Q} = (K_{rQ} - 1)\,Y_{(r-1)Q} \qquad (3)$$

b. Data Given for Application.

a_r.

f_r, if $r \geq 1$.

g_r, if $r \geq 1$.

K_{rP}, if $r \geq 2$.

H_{rS}, if $r \geq 2$.

* No superscript is used for total from all sources.

J_{8Q}.

Equations

F_{rQ}, where r = 1, 2, 6, 7, 8.

G_{rQ}, where r = 6, 7, 8.

$J_{rL} = 0$; $F_{rL} = 0$; $G_{rL} = 0$; $A''_{rL} = 0$; $A'''_{rL} = 0$; $A_{rL} = A'_{rL}$. (1a)

$A''_{rB} = 0$; $A'''_{rB} = 0$; $A_{rB} = A'_{rB}$. (2a)

$A'''_{rD} = 0$; $A'''_{rR} = 0$. (3a)

A''_{rQ}.

A'''_{rQ}.

c. Material Balances by Definition.

Crude oil:

$$m_r = a_r - b_r - c_r - e_r + f_r - g_r. \quad (4)$$

$$e_r = d_r - d_{(r-1)} \quad (5)$$

Any nongaseous product:

$$A_{rQ} = B_{rQ} + E_{rQ} - F_{rQ} + G_{rQ} + H_{rQ} + J_{rQ} \quad (6)$$

$$= K_{rQ} A_{(r-1)Q} = Y_{rQ} A_{1Q} \quad (7)$$

$$E_{rQ} = D_{rQ} - D_{(r-1)Q} \quad (8)$$

Total nongaseous products:

$$A_{rT} = A'_{rT} + A''_{rT} + A'''_{rT} + c_r \quad (9)$$

Total crude oil refining nongaseous products:

$$A'_{rT} = A'_{rG} + A'_{rL} + A'_{rD} + A'_{rK} + A'_{rR} + A'_{rB} \quad (10)$$

$$= m_r - Z_r \quad (11)$$

Gross and net product yields:

$$N_{rQ} = A_{rQ} - C_{rQ} \tag{12}$$

d. Material Balances by Assumption.

$$C_{rT} = C_{rR} \tag{13}$$

$$C_{rS} = 0 \tag{14}$$

$$A_{rR} = A'_{rR} + A''_{rR} + c_r \tag{15}$$

$$A_{rS} = A'_{rS} + A''_{rS} + A'''_{rS} \tag{16}$$

$$N_{rR} = A_{rR} - C_{rR} \tag{17}$$

$$N_{rS} = A_{rS} \tag{18}$$

e. Estimating Factors Assumed.

$$b_r = 0.04\ a_r \tag{19}$$

$$c_r = 0.01\ a_r \tag{20}$$

$$d_r = 0.125\ a_r, \tag{21}$$

$$e_r = 0.125\ \left[a_r - a_{(r-1)}\right] \tag{22}$$

$$B_{rQ} = 0.02\ N_{rQ} \tag{23}$$

$$C_{rT} = 0.03\ m_r = C_{rR} \tag{24}$$

$$D_{rQ} = 0.125\ A_{rQ}, \text{ if } r \geq 1, \tag{25}$$

$$E_{rQ} = 0.125\ \left[A_{rQ} - A_{(r-1)Q}\right], \text{ if } r \geq 2 \tag{26}$$

$$D_{0W} = 0.025\ A_{1W}, \tag{27}$$

$$E_{1W} = 0.1 A_{1W} \tag{28}$$

$$D_{OK} = 0.1\ A_{1K}, \tag{29}$$

$$E_{1K} = 0.025\ A_{1K} \tag{30}$$

$$Z_r = 0.09\ m_r, \text{ if } r \leq 7 \tag{31}$$

$$Z_r = 0.102\ m_r, \text{ if } r \geq 8 \tag{32}$$

f. Formulations.*

(1) Gasoline, Kerosine Category, Diesel Fuel.

$$A_{rP} = Y_{rP}A_{1P} \text{ (from Equation 7)} \tag{33}$$

$$A_{(r-1)P} = Y_{(r-1)P}\ A_{1P} \text{ (from Equation 7)} \tag{34}$$

$$A_{rP} - A_{(r-1)P} = (Y_{rP} - Y_{(r-1)P})\ A_{1P}$$
$$= (K_{rP} - 1)\ Y_{(r-1)P}A_{1P} \text{ (from Equation 3)} \tag{35}$$

$$E_{rP} = 0.125\ (A_{rP} - A_{(r-1)P}) \text{ (from Equation 26)}$$
$$= 0.125\ (K_{rP} - 1)\ Y_{(r-1)P}A_{1P} \tag{36}$$

$$B_{rP} = 0.02\ A_{rP} = 0.02\ Y_{rP}A_{1P} \text{ (from Equations 18, 23, and 33)} \tag{37}$$

From Equations 2, 6, 33, 36, and 37:

$$A_{rP} = Y_{rP}A_{1P} = B_{rP} + E_{rP} - F_{rP} + G_{rP} + H_{rP} + J_{rP}$$
$$= \left[0.02\ Y_{rP} + 0.125\ (K_{rP} - 1)\ Y_{(r-1)_P}\right] A_{1P} - F_{rP}$$
$$+ G_{rP} + H_{rP} + J_{rP}$$
$$\left[Y_{rP} - 0.02\ Y_{rP} - 0.125\ (K_{rP} - 1)\ Y_{(r-1)P}\right] A_{1P}$$
$$= \left[0.98\ K_{rP}\ Y_{(r-1)P} - 0.125\ (K_{rP} - 1)\ Y_{(r-1)P}\right] A_{1P},$$
$$= (0.125 + 0.855\ K_{rP})\ Y_{(r-1)P}\ A_{1P},$$
$$= G_{rP} - F_{rP} + H_{rP} + J_{rP}$$

* $r \geq 2$, except as otherwise noted.

$$A_{rP} = \frac{G_{rP} - F_{rP} + H_{rP} + J_{rP}}{(0.125 + 0.855\ K_{rP})\ Y_{(r-1)\ P}} \tag{38}$$

From Equations 7 and 38:

$$A_{1P} = \frac{G_{8P} - F_{8P} + H_{8P} + J_{8P}}{(0.125 + 0.855\ K_{8P})\ (K_{7P}K_{6P}K_{5P}K_{4P}K_{3P}K_{2P})} \tag{39}$$

$$A_{rP} = K_{rP}A_{(r-1)P} \tag{40}$$

(2) Ligroine.

From Equations 1a, 18, 23, and 28:

$$A_{rL} = B_{rL} + E_{rL} + H_{rL}$$

$$= 0.02\ A_{rL} + 0.125\ (A_{rL} - A_{(r-1)L}) + H_{rL}$$

$$= 0.855\ A_{rL} = H_{rL} - 0.125A_{(r-1)L}$$

$$A_{rL} = \frac{H_{rL} - 0.125A_{(r-1)L}}{0.855} \tag{41}$$

$$A_{IL} = B_{IL} + E_{IL} + H_{IL} = 0.02\ A_{IL} + 0.1\ A_{IL} + H_{IL}$$

$$0.88A_{IL} = H_{IL}$$

$$A_{IL} = \frac{H_{IL}}{0.88} \tag{42}$$

(3) Lubricants.

Assumption:

$$\frac{A_{rB}}{m_r} = \frac{A_{(r-1)B}}{m_{(r-1)}} \tag{43}$$

From Equations 6, 18, 23, 26, and 43:

$$E_{rB} = 0.125\ (A_{rB} - A_{(r-1)B})$$

$$= 0.125 \left(A_{rB} - A_{rB} \frac{m_{(r-1)}}{m_r} \right)$$

$$= 0.125 \left(\frac{m_r - m_{(r-1)}}{m_r} \right) A_{rB} \qquad (44)$$

$$A_{rB} = B_{rB} + E_{rB} - F_{rB} + G_{rB} + H_{rB} + J_{rB}$$

$$= 0.02A_{rB} + 0.125 \left[\frac{m_r - m_{(r-1)}}{m_r} \right] A_{rB} - F_{rB} + G_{rB} + H_{rB} + J_{rB}$$

$$G_{rB} - F_{rB} + H_{rB} + J_{rB} = \left[0.98 - 0.125 \frac{m_r - m_{(r-1)}}{m_r} \right] A_{rB}$$

$$A_{rB} = \left[\frac{G_{rB} - F_{rB} + H_{rB} + J_{rB}}{0.855\ m_r + 0.125\ m_{(r-1)}} \right] m_r \qquad (45)$$

$$A_{8B} = \left[\frac{G_{8B} - F_{8B} + H_{8B} + J_{8B}}{0.855\ m_8 + 0.125\ m_7} \right] m_8 \qquad (46)$$

$$A_{rB} = \frac{A_{(r-1)B} m_r}{m_{(r-1)}} \qquad (47)$$

$$A_{(r-1)B} = \frac{A_{rB} m_{(r-1)}}{m_r} \qquad (48)$$

(4) Residual and Other Products.

From Equations 10, 11, and 15:

$$A_{rR} = m_r - A'_{rG} - A'_{rL} - A'_{rD} - A'_{rK} - Z_r + A_{rR} + c_r \qquad (49)$$

(5) Summary of Formulations.

From Equations 4, 19, 20, and 22:

m_r, b_r, c_r, e_r;

Given: a_r, f_r, g_r

From Equations 39 and 40:

A_{1G}, A_{1K}, A_{1D}, A_{rG}, A_{rK}, A_{rD};

Given: F_{8P}, G_{8P}, H_{8P}, J_{8P}, K_{rP}

From Equations 41 and 42

A_{IL}, A_{rL};

Given: H_{rL}

From Equations 46, 47, and 48:

A_{8B}, A_{rB} or $A_{(r-1)B}$;

Given: F_{8B}, G_{8B}, H_{8B}, J_{8B}

From Equations 15, 31, 32, and 49:

A_{rR}, A'_{rR}, Z_r

Given: A''_{rR}

From Equations 2a, 3a, and 16; check 10 and 11:

A_{rG}, A_{rL}, A_{rK}, A_{rD}, A_{rB};

Given: A''_{rS}, A'''_{rS}

(6) Gasoline, Kerosine Category, Diesel Fuel (Alternate Formulations).

From Equations 6, 7, and 26:

$$A_{rP} = K_{rP} A_{(r-1)P} \qquad (40)$$

$$A_{(r-1)P} = \frac{A_{rP}}{K_{rP}} \tag{50}$$

$$A_{rP} - A_{(r-1)P} = \frac{K_{rP} - 1}{K_{rP}} (A_{rP})$$

$$B_{rP} = 0.02\ A_{rP} \tag{37}$$

$$A_{rP} = B_{rP} + E_{rP} - F_{rP} + G_{rP} + H_{rP} + J_{rP}$$

$$= \left(0.02 + \frac{K_{rp} - 1}{K_{rP}}\right) A_{rP} - F_{rP} + G_{rP} + H_{rP} + J_{rP}$$

$$\left(0.98 - \frac{K_{rP} - 1}{K_{rP}}\right) A_{rP} = G_{rP} - F_{rP} + H_{rP} + J_{rP}$$

$$A_{rP} = \frac{G_{rp} - F_{rp} + H_{rp} + J_{rp}}{0.98 - 0.125 \frac{K_{rp} - 1}{K_{rP}}} \tag{51}$$

$$A_{rP} = \frac{G_{8P} - F_{8P} + H_{8P} + J_{8P}}{0.98 - 0.125 \frac{K_{8P} - 1}{K_{8P}}} \tag{52}$$

Table 21

Estimated Balances of Crude Oil in the USSR a/*
1945-54

Thousand Metric Tons

	1945	1946	1947	1948	1949	1950	1951	1952	1953	1954
Indigenous production b/	19,400	21,700	26,000	29,400	33,600	37,600	41,600	45,600	49,600	53,600
Crude oil handling losses		868	1,040	1,176	1,344	1,504	1,664	1,824	1,984	2,144
Balance I (indigenous production)		20,832	24,960	28,224	32,256	36,096	39,936	43,776	47,616	51,456
Storage increment		288	537	425	525	500	500	500	500	500
Balance II (indigenous production)		20,544	24,423	27,799	31,731	35,596	39,436	43,276	47,116	50,956
Crude oil use as residual product		217	260	294	336	376	416	456	496	536
Balance III (indigenous production)		20,327	24,163	27,505	31,395	35,220	39,020	42,820	46,620	50,420
Exports c/		0	0	0	0	-230	-339	-494	-342	-618
Imports		0	0	115	100	120	170	200	200	0
Refinery crude oil charge		20,327	24,163	27,620	31,495	35,110	38,851	42,526	46,478	49,802
Crude oil use as a residual product		217	260	294	336	376	416	456	496	536
Indigenous consumption		20,544	24,423	27,914	31,831	35,486	39,267	42,982	46,974	50,338
Storage increment		288	537	425	525	500	500	500	500	500
Exports		0	0	0	0	230	339	494	342	618
Total utilization of new supply		20,832	24,960	28,339	32,356	36,216	40,106	43,976	47,816	51,456

* Footnotes for Table 21 follow on p. 100.

Table 21

Estimated Balances of Crude Oil in the USSR a/
1945-54
(Continued)

Thousand Metric Tons

	1945	1946	1947	1948	1949	1950	1951	1952	1953	1954
Crude oil handling losses		868	1,040	1,176	1,334	1,504	1,664	1,824	1,984	2,144
Total new supply		21,700	26,000	29,515	33,700	37,720	41,770	45,800	49,800	53,600
Imports		0	0	115	100	120	170	200	200	0
Indigenous production		21,700	26,000	29,400	33,600	37,600	41,600	45,600	49,600	53,600
Year-end storage reserve	2,425	2,713	3,250	3,675	4,200	4,700	5,200	5,700	6,200	6,700

a. Data are based on Appendix B, Section 5, p. 89, above; and Table 18, p. 66, above. Blank spaces indicate that values are not completely available.
b. 166/
c. Algebraically negative in this balance.

Table 22

Estimated Balances of Gasoline in the USSR a/*
1945-54

Thousand Metric Tons

	1945	1946	1947	1948	1949	1950	1951	1952	1953	1954
Product from crude oil refining		2,604	3,546	3,948	4,282	4,978	5,882	7,186	7,669	8,112
Product from synthetic petroleum		51	54	58	61	64	72	81	89	96
Product from natural gas liquids		80	120	160	240	320	480	840	1,240	1,600
Product yield (gross = net)		2,735	3,720	4,166	4,583	5,362	6,434	8,107	8,998	9,808
Distribution losses		55	74	83	92	107	129	162	180	196
Net availability yield		2,680	3,646	4,083	4,491	5,255	6,305	7,945	8,818	9,612
Storage increment		274	123	56	52	97	134	209	112	101
Balance I (indigenous yield)		2,406	3,523	4,027	4,439	5,158	6,171	7,736	8,706	9,511
Civil consumption		1,903	3,112	3,819	4,834	5,721	7,031	6,108	8,928	9,780
Balance II (indigenous yield)		498	411	208	-395	-563	-860	-372	-222	-269
Military consumption							777 b/	1,709 b/	1,928	
Balance III (indigenous yield)							-1,637	-2,081	-2,150	
Exports c/							-233	-299	-354	
Imports		1,384	1,112				1,870	2,380	2,504	
Balance IV							0	0	0	
Total consumption							7,808 b/	9,817 b/	10,856	

* Footnotes for Table 22 follow on p. 102.

Table 22

Estimated Balances of Gasoline in the USSR a/
1945-54
(Continued)

Thousand Metric Tons

	1945	1946	1947	1948	1949	1950	1951	1952	1953	1954
Storage increment							134	209	112	
Exports							233	299	354	
Total utilization of new supply							8,175	10,325	11,322	
Distribution losses							129	162	180	
Total new supply							8,304	10,487	11,502	
Imports							1,870	2,380	2,504	
Product yield (gross = net)							6,434	8,107	8,998	
Year-end storage reserve	68	342	465	521	573	670	804	1,013	1,125	1,226

a. Data are based on Appendix B, Section 5, p. 89, above; Tables 17, 18, and 19, pp. 65, 66, and 68, respectively, above. Blank spaces indicate that values are not completely available.
b. These quantities not independently estimated but are inserted as calculated values, thus developing complete hypothetical material balances for the years for which the component quantities are otherwise all available.
c. Algebraically negative in this balance.

Table 23

Estimated Balances of Ligroine in the USSR a/
1945-54

Thousand Metric Tons

	1945	1946	1947	1948	1949	1950	1951	1952	1953	1954
Yield from crude oil refining (gross = net)		682	620	632	519	529	564	676	757	233
Distribution losses		14	13	13	10	11	11	13	15	5
Net availability yield		668	607	619	509	518	553	663	742	228
Storage increment		68	-8	2	-14	1	5	14	10	-95
Balance I (indigenous yield)		600	615	617	523	517	548	649	732	323
Civil consumption		600	615	617	523	517	548	649	732	323
Balance II (indigenous yield)		0	0	0	0	0	0	0	0	0
Total consumption		600	615	617	523	517	548	649	732	323
Storage increment		68	-8	2	-14	1	5	14	10	-95
Total new supply		668	607	619	509	518	553	663	742	228
Distribution losses		14	13	13	10	11	11	13	15	5
Yield from crude oil refining (gross = net)		682	620	632	519	529	564	676	757	233
Year-end storage reserve	17	85	77	79	65	66	71	85	95	0

a. These data are based on Appendix B, Section 5, p. 89, above, and Table 17, p. 65, above. Blank spaces indicate that values are not completely available.

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Table 24

Estimated Balances of Kerosine Products in the USSR a/*
1945-54

Thousand Metric Tons

	1945	1946	1947	1948	1949	1950	1951	1952	1953	1954
Product from crude oil refining		4,760	5,922	6,901	7,997	8,546	8,577	8,037	9,578	9,610
Product from synthetic petroleum		10	10	10	10	10	10	10	10	10
Product from natural gas liquids b/		120	180	240	360	480	720	1,260	1,860	2,400
Product yield (gross = net)		4,890	6,112	7,151	8,367	9,036	9,307	9,307	11,448	12,020
Distribution losses		98	122	143	167	181	186	186	229	240
Net availability yield		4,792	5,990	7,008	8,200	8,855	9,121	9,121	11,219	11,780
Storage increment		122	153	130	152	84	33	0	268	72
Balance I (indigenous yield)		4,670	5,837	6,878	8,048	8,771	9,088	9,121	10,951	11,708
Civil consumption		5,111	6,003	7,050	7,543	8,082	8,976	9,072	9,669	10,418
Balance II (indigenous yield)		-441	-166	-172	505	689	112	49	1,282	1,290
Military consumption							366 c/	303 c/	1,540	
Balance III (indigenous yield)							-254	-254	-258	
Exports d/							-186	-306	-330	
Imports		445	416				440	560	588	
Balance IV							0	0	0	
Total consumption							9,342 c/	9,375 c/	11,209	

* Footnotes for Table 24 follow on p. 105.

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Table 24

Estimated Balances of Kerosine Products in the USSR a/
1945-54
(Continued)

Thousand Metric Tons

	1945	1946	1947	1948	1949	1950	1951	1952	1953	1954
Storage increment							33	0	268	
Exports							186	306	330	
Total utilization of new supply							9,561	9,681	11,807	
Distribution losses							186	186	229	
Total new supply							9,747	9,867	12,036	
Imports							440	560	588	
Product yield (gross = net)							9,307	9,307	11,448	
Year-end storage reserve	489	611	764	894	1,046	1,130	1,163	1,163	1,431	1,503

a. Data are based on Appendix B, Section 5, p. 89, above, and Tables 17, 18, and 19, pp. 65, 66, and 68, respectively, above. Blank spaces indicate that values are not completely available.
b. Liquefied petroleum gases.
c. Quantities not independently estimated but here inserted as calculated values, thus developing complete hypothetical material balances for the years for which the component quantities are otherwise all available.
d. Algebraically negative in this balance.

Table 25

Estimated Balances of Diesel Fuel in the USSR a/*
1945-54

Thousand Metric Tons

	1945	1946	1947	1948	1949	1950	1951	1952	1953	1954
Product from crude oil refining		734	962	1,271	1,678	2,655	3,850	5,160	6,916	9,965
Product from synthetic petroleum		5	6	7	9	10	14	17	20	23
Product yield (gross = net)		739	968	1,278	1,687	2,665	3,864	5,177	6,936	9,988
Distribution losses		15	19	26	34	53	77	104	139	200
Net availability yield		724	949	1,252	1,653	2,612	3,787	5,073	6,797	9,788
Storage increment		74	29	39	51	122	150	164	220	382
Balance I (indigenous yield)		650	920	1,213	1,602	2,490	3,637	4,909	6,577	9,406
Civil consumption		317	470	724	1,281	2,111	3,111	5,066	6,589	8,800
Balance II (indigenous yield)		333	450	489	321	379	526	-157	-12	606
Military consumption							1,264 b/	743 b/	747	
Balance III (indigenous yield)							-738	-900	-759	
Exports c/							62	125	-312	
Imports		632	365				800	1,025	1,071	
Balance IV							0	0	0	
Total consumption							4,375 b/	5,809 b/	7,336	

* Footnotes for Table 25 follow on p. 107.

Table 25

Estimated Balances of Diesel Fuel in the USSR a/
1945-54
(Continued)

Thousand Metric Tons

	1945	1946	1947	1948	1949	1950	1951	1952	1953	1954
Storage increment							150	164	220	
Exports							62	125	312	
Total utilization of new supply							4,587	6,098	7,868	
Distribution losses							77	104	139	
Total new supply							4,664	6,202	8,007	
Imports							800	1,025	1,071	
Product yield (gross = net)							3,864	5,177	6,936	
Year-end storage reserve	18	92	121	160	211	333	483	647	867	1,249

a. Data are based on Appendix B, Section 5, p. 89, above, and Tables 17, 18, and 19, pp. 65, 66, and 68, respectively, above. Blank spaces indicate that values are not completely available.
b. Quantities not independently estimated but here inserted as calculated values, thus developing complete hypothetical material balances for the years for which the component quantities are otherwise all available.
c. Algebraically negative in this balance.

Table 26

Estimated Balances of Lubricants in the USSR a/*
1945-54

Thousand Metric Tons

	1945	1946	1947	1948	1949	1950	1951	1952	1953	1954
Yield from crude oil refining (gross = net)		1,236	1,469	1,679	1,915	2,135	2,362	2,586	2,826	3,028
Distribution losses		25	29	34	38	43	47	52	57	61
Net availability yield		1,211	1,440	1,645	1,877	2,092	2,315	2,534	2,769	2,967
Storage increment		124	29	26	29	28	28	28	30	25
Balance I (indigenous yield)		1,087	1,411	1,619	1,848	2,064	2,287	2,506	2,739	2,942
Civil consumption		995	1,208	1,396	1,634	1,859	2,090	2,334	2,571	2,972
Balance II (indigenous yield)		92	203	223	214	205	197	172	168	-30
Military consumption							178 b/	155 b/	173	
Balance III (indigenous yield)							19	17	-5	
Exports c/							-54	-62	-57	
Imports		84	63				35	45	62	
Balance IV							0	0	0	
Total consumption							2,268 b/	2,489 b/	2,744	
Storage increment							28	28	30	
Exports							54	62	57	
Total utilization of new supply							2,350	2,579	2,831	

* Footnotes for Table 26 follow on p. 109.

Table 26

Estimated Balances of Lubricants in the USSR a/
1945-54
(Continued)

Thousand Metric Tons

	1945	1946	1947	1948	1949	1950	1951	1952	1953	1954
Distribution losses							47	52	57	
Total new supply							2,397	2,631	2,888	
Imports							35	45	62	
Yield from crude oil refining (gross = net)							2,362	2,586	2,826	
Year-end storage reserve	31	155	184	210	239	267	295	323	353	378

a. Data are based on Appendix B, Section 5, p. 89, above, and Tables 17 and 18, pp. 65 and 66, respectively, above. Blank spaces indicate that values are not completely available.
b. Quantities not independently estimated but here inserted as calculated values, thus developing complete hypothetical material balances for the years for which the component quantities are otherwise all available.
c. Algebraically negative in this balance.

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Table 27

Estimated Balances of Petroleum Distillates and Lubricants in the USSR a/*
1945-54

Thousand Metric Tons

	1945	1946	1947	1948	1949	1950	1951	1952	1953	1954
Products from crude oil refining		10,016	12,519	14,431	16,391	18,843	21,235	23,645	27,746	30,948
Products from synthetic petroleum		66	70	75	80	84	96	108	119	129
Products from natural gas liquids		200	300	400	600	800	1,200	2,100	3,100	4,000
Product yields (gross = net)		10,282	12,889	14,906	17,071	19,727	22,531	25,853	30,965	35,077
Distribution losses		207	257	299	341	395	450	517	620	702
Net availability yields		10,075	12,632	14,607	16,730	19,332	22,081	25,336	30,345	34,375
Storage increment		662	326	253	270	332	350	415	640	485
Balance I (indigenous yields)		9,413	12,306	14,354	16,460	19,000	21,731	24,921	29,705	33,890
Civil consumption		8,931	11,408	13,606	15,815	18,290	21,756	25,229	28,489	32,293
Balance II (indigenous yields)		482	898	748	645	710	-25	-308	1,216	1,597
Military consumption							2,585 b/	2,910 b/	4,388	
Balance III (indigenous yields)							-2,610	-3,218	-3,172	
Exports c/							-535	-792	-1,053	
Imports							3,145	4,010	4,225	
Balance IV							0	0	0	
Total consumption							24,341	28,139	32,877	

* Footnotes for Table 27 follow on p. 111.

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Table 27

Estimated Balances of Petroleum Distillates and Lubricants in the USSR a/
1945-54
(Continued)

Thousand Metric Tons

	1945	1946	1947	1948	1949	1950	1951	1952	1953	1954
Storage increment							350	415	640	
Exports							535	792	1,053	
Total utilization of new supply							25,226	29,346	34,570	
Distribution losses							450	517	620	
Total new supply							25,676	29,863	35,190	
Imports							3,145	4,010	4,225	
Product yield (gross = net)							22,531	25,853	30,965	
Year-end storage reserve	623	1,285	1,611	1,864	2,134	2,466	2,816	3,231	3,871	4,356

a. Data are based on Appendix B, Section 5, p. 89, above, and Tables 17, 18, and 19, pp. 65, 66, and 68, respectively, above, and are developed as a composite of Tables 22, 23, 24, and 25, pp. 101, 103, 104, and 106, respectively, above. Blank spaces indicate that values are not completely available.
b. Quantities not independently estimated but here inserted as calculated values, thus developing complete hypothetical material balances for the years for which the component quantities are otherwise all available.
c. Algebraically negative in this balance.

Table 28

Estimated Balances of Residual and Other Petroleum Products in the USSR a/*
1945-54

Thousand Metric Tons

	1945	1946	1947	1948	1949	1950	1951	1952	1953	1954
Product from crude oil refining		8,482	9,469	10,703	12,269	13,107	14,119	15,054	13,991	13,774
Crude oil use as residual product		217	260	294	336	376	416	456	496	536
Product from synthetic petroleum		80	93	123	147	166	224	282	336	389
Gross product yield		8,779	9,822	11,120	12,752	13,649	14,759	15,792	14,823	14,699
Distribution losses		162	183	205	237	251	273	290	268	264
Net availability yield		8,617	9,639	10,915	12,515	13,398	14,486	15,502	14,555	14,435
Storage increment		877	130	161	205	112	139	130	-122	13
Balance I (indigenous yield)		7,740	9,509	10,754	12,310	13,286	14,347	15,372	14,677	14,422
Civil consumption							b/	b/	14,724 d/	
Balance II (indigenous yield)							b/	b/	-47	
Military consumption							b/	b/	-423	
Balance III (indigenous yield)							b/	b/	-470	
Exports c/							-136	-121	-192	
Imports		829	513				525	660	662	
Balance IV							b/	b/	0	
Total consumption							14,736 d/	15,911 d/	15,147 d/	

* Footnotes for Table 28 follow on p. 113.

Table 28

Estimated Balances of Residual and Other Petroleum Products in the USSR a/
1945-54
(Continued)

Thousand Metric Tons

	1945	1946	1947	1948	1949	1950	1951	1952	1953	1954
Storage increment							139	130	-122	
Exports							136	121	192	
Total utilization of new supply							15,011	16,162	15,217	
Distribution losses							273	290	268	
Total new supply							15,284	16,452	15,485	
Imports							525	660	662	
Gross product yield		8,779	9,822	11,120	12,752	13,649	14,759	15,792	14,823	14,699
Net product yield		8,169	9,097	10,291	11,807	12,596	13,594	14,516	13,429	13,171
Crude oil refinery consumption		610	725	829	945	1,053	1,165	1,276	1,394	1,494
Other civil consumption									13,330 d/	
Total civil consumption									14,724 d/	
Military consumption									423	
Total consumption							14,736	15,911	15,147 d/	
Year-end storage reserve	221	1,098	1,228	1,389	1,594	1,706	1,845	1,975	1,853	1,866

a. Data are based on Appendix B, Section 5, p. 89, above, and Tables 17, 18, and 19, pp. 65, 66, and 68, respectively, above. Blank spaces indicate that values are not completely available.
b. Hypothetical total consumption value is developed independently of these values which are unavailable at present.
c. Algebraically negative in this balance.
d. Quantities not independently estimated but here inserted as calculated values, thus developing complete hypothetical material balances for the years for which the component quantities are otherwise all available.

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Table 29

Estimated Balances of Total Nongaseous Petroleum Products in the USSR a/*
1945-54

Thousand Metric Tons

	1945	1946	1947	1948	1949	1950	1951	1952	1953	1954
Products from crude oil refining		18,498	21,988	25,134	28,660	31,950	35,354	38,699	41,737	44,722
Crude oil use as residual product		217	260	294	336	376	416	456	496	536
Products from synthetic petroleum		146	163	198	227	250	320	390	455	518
Products from natural gas liquids		200	300	400	600	800	1,200	2,100	3,100	4,000
Gross product yields		19,061	22,711	26,026	29,823	33,376	37,290	41,645	45,788	49,776
Distribution losses		369	440	504	578	646	723	807	888	966
Net availability yields		18,692	22,271	25,522	29,245	32,730	36,567	40,838	44,900	48,810
Storage increments		1,539	456	414	475	444	489	545	518	498
Balance I (indigenous yields)		17,153	21,815	25,108	28,770	32,286	36,078	40,293	44,382	48,312
Civil consumption							b/	b/	43,213 c/	
Balance II (indigenous yields)							b/	b/	1,169	
Military consumption							b/	b/	4,811	
Balance III (indigenous yields)							b/	b/	-3,642	
Exports d/							-671	-913	-1,245	
Imports		3,374	2,469				3,670	4,670	4,887	
Balance IV							- b/	- b/	0	
Total consumption							39,077 c/	44,050 c/	48,024 c/	

* Footnotes for Table 29 follow on p. 115.

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Table 29

Estimated Balances of Total Nongaseous Petroleum Products in the USSR a/
1945-54
(Continued)

Thousand Metric Tons

	1945	1946	1947	1948	1949	1950	1951	1952	1953	1954
Storage increment							489	545	518	
Exports							671	913	1,245	
Total utilization of new supply							40,237	45,508	49,787	
Distribution losses							723	807	888	
Total new supply							40,960	46,315	50,675	
Imports							3,670	4,670	4,887	
Gross product yields		19,061	22,711	26,026	29,823	33,376	37,200	41,645	45,788	49,776
Net product yields		18,451	21,986	25,197	28,878	32,323	36,125	40,369	44,394	48,282
Crude oil product refinery consumption		610	725	829	945	1,053	1,165	1,276	1,394	1,494
Other civil consumption									41,819 c/	
Total civil consumption									43,213 c/	
Military consumption									4,811	
Total consumption									48,024 c/	
Year-end storage reserve	844	2,383	2,839	3,253	3,728	4,172	4,661	5,206	5,724	6,222

a. Data are based on Appendix B, Section 5, p. 89, above, and Tables 17, 18, and 19, pp. 65, 66, and 68, respectively, above, and are developed as a composite of Tables 27 and 28, pp. 110 and 112, respectively, above. Blank spaces indicate that values are not completely available.

b. Hypothetical total consumption value is developed independently of these values, which are unavailable at present.

c. Quantities not independently estimated but here inserted as calculated values, thus developing complete hypothetical material balances for the years for which the component quantities are otherwise all available.

d. Algebraically negative in this balance.

Table 30

Estimated Balances of Nongaseous Petroleum in the USSR a/*
1945-54

Thousand Metric Tons

	1945	1946	1947	1948	1949	1950	1951	1952	1953	1954
Indigenous crude oil production	19,400	21,700	26,000	29,400	33,600	37,600	41,600	45,600	49,600	53,600
Gross synthetic oil products		146	163	198	227	250	320	390	455	518
Gross natural gas liquids		200	300	400	600	800	1,200	2,100	3,100	4,000
Total new indigenous supply		22,046	26,463	29,998	34,427	38,650	43,120	48,090	53,155	58,118
Crude oil and product imports		3,374	2,469				3,840	4,870	5,087	
Total new supply		25,420	28,932				46,960	52,960	58,242	
Gasoline consumption							7,808 b/	9,817 b/	10,856	
Ligroine consumption							548	649	732	
Kerosine category consumption							9,342 b/	9,375 b/	11,209	
Diesel fuel consumption							4,375 b/	5,809 b/	7,336	
Lubricants consumption							2,268 b/	2,489 b/	2,744	
Residual and other products consumption							14,736 c/	15,911 c/	15,147 b/	
Total product consumption							39,077 b/	44,050 b/	48,024 b/	
Crude oil and product storage increment							989	1,045	1,018	
Crude oil and product exports							1,010	1,407	1,587	
Total utilization of new supply							41,076	46,502	50,629	
Crude oil and product gas and loss							5,884	6,458	7,613	
Total new supply							46,960	52,960	58,242	

* Footnotes for Table 30 follow on p. 117.

Table 30

Estimated Balances of Nongaseous Petroleum in the USSR a/
1945-54
(Continued)

Thousand Metric Tons

	1945	1946	1947	1948	1949	1950	1951	1952	1953	1954
Crude oil storage increment		288	537	425	525	500	500	500	500	500
Product storage increment		1,539	456	414	475	444	489	545	518	498
Crude oil and product storage increment		1,827	993	839	1,000	944	989	1,045	1,018	998
Crude oil exports		0	0	0	0	230	339	494	342	618
Product exports							671	913	1,245	
Crude oil and product exports							1,010	1,407	1,587	
Crude oil imports		0	0	115	100	120	170	200	200	0
Product imports		3,374	2,469				3,670	4,670	4,887	
Crude oil and product imports		3,374	2,469				3,840	4,870	5,087	
Crude oil handling losses		868	1,040	1,176	1,344	1,504	1,664	1,824	1,984	2,144
Crude oil refinery gas and loss		1,829	2,175	2,486	2,835	3,160	3,497	3,827	4,741	5,030
Product distribution losses		369	440	504	578	646	723	807	888	966
Crude oil and product gas and loss		3,066	3,655	4,166	4,757	5,310	5,884	6,458	7,613	8,190
Product year-end storage reserve	844	2,383	2,839	3,253	3,728	4,172	4,661	5,206	5,724	6,222
Crude oil year-end storage reserve	2,425	2,713	3,250	3,675	4,200	4,700	5,200	5,700	6,200	6,700
Nongaseous petroleum year-end storage reserve	3,269	5,096	6,089	6,928	7,928	8,872	9,861	10,906	11,924	12,922

a. Data are based on Appendix B, Section 5, p. 89, above, and Tables 21, 25, and 28, pp. 99, 106, and 112, respectively, above, and are developed as a composite of Tables 21 through 26 and 28, pp. 99 through 108 and 112, respectively, above. Blank spaces indicate that values are not completely available.
b. Values are partly estimated independently and partly calculated by difference.
c. Values are calculated by difference.

Table 31

Estimated Annual Yields of Products from Crude Oil Refining in the USSR a/
1946-50

Thousand Metric Tons

	1946		1947		1948		1949		1950		1951		1952		1953		1954	
	Yield	Percent	Yield	Percent	Yield	Percent	Yield	Percent	Yield	Percent	Yield	Percent	Yield	Percent	Yield	Percent	Yield	Percent
Gasoline	2,604	12.8	3,546	14.7	3,948	14.3	4,282	13.6	4,978	14.2	5,882	15.1	7,186	16.9	7,669	16.5	8,112	16.3
Ligroine	682	3.4	620	2.5	632	2.3	519	1.7	529	1.5	564	1.5	676	1.6	757	1.6	233	0.5
Kerosine	4,760	23.4	5,922	24.5	6,901	25.0	7,997	25.4	8,546	24.3	8,577	22.1	8,037	18.9	9,578	20.6	9,610	19.3
Diesel fuel	734	3.6	962	4.0	1,271	4.6	1,678	5.3	2,655	7.6	3,850	9.9	5,160	12.1	6,916	14.9	9,965	20.0
Lubricants	1,236	6.1	1,469	6.1	1,679	6.1	1,915	6.1	2,135	6.1	2,362	6.1	2,586	6.1	2,826	6.1	3,028	6.1
Residual and other products	8,482	41.7	9,469	39.2	10,703	38.7	12,269	38.9	13,107	37.3	14,119	36.3	15,054	35.4	13,991	30.1	13,774	27.6
Total nongaseous products	18,498	91.0	21,988	91.0	25,134	91.0	28,660	91.0	31,950	91.0	35,354	91.0	38,699	91.0	41,737	89.8	44,722	89.8
Refining gas and loss	1,829	9.0	2,175	9.0	2,486	9.0	2,835	9.0	3,160	9.0	3,497	9.0	3,827	9.0	4,741	10.2	5,080	10.2
Crude oil refinery charge	20,327	100.0	24,163	100.0	27,620	100.0	31,495	100.0	35,110	100.0	38,851	100.0	42,526	100.0	46,478	100.0	49,802	100.0

a. Compilation of the yields separately developed in Tables 21 through 26 and 28, pp. 99 through 108 and 112, respectively, above, which are based on Appendix B, Section 5. Condensed summaries of various portions of these data are also shown in Tables 5 and 9, pp. 24 and 34, respectively, above. The yield percentages are correlated graphically in Figure 1, following p. 36.

APPENDIX C

WORLD STATUS OF THE USSR IN THE OUTPUT OF PETROLEUM PRODUCTS

Significant results may be developed by comparing derived Soviet data with corresponding data for certain other areas. With respect to petroleum product yields and yield potentials, comparisons with similar data for the European Satellites, Western Europe, and the US are useful.

Petroleum product yields in the European Satellites are covered in a report now being prepared. 167/ Annual petroleum product yields in Western Europe for selected years from 1938 through 1953 are shown in Table 32.* Corresponding Soviet data are shown in Tables 6 and 7,** and corresponding US data are shown in Tables 8 and 9.*** The manufacture and consumption of petroleum products are similar in the USSR and in the US: most of the indigenous petroleum product yields are derived by crude oil refining; most of the indigenously derived products are indigenously consumed; and most indigenous product consumption is restricted to indigenously derived products. In Western Europe, however, net petroleum product imports and indigenously derived synthetic petroleum products are relatively important.

Although this report is not primarily concerned with the principal petroleum product yield potentials which relate to the source material potentials and installed processing facilities, installed processing facilities are generally involved in the estimates of the actual product yields. Therefore, a tentative summary of crude oil refining capacities in the Free World and the Sino-Soviet Bloc in 1953 is shown in Table 33.**** The footnotes to the table indicate that the available information on the refining facilities of the Sino-Soviet Bloc is at present incomplete and preliminary, but the estimates are realistic enough for generalized use in an analysis.

* Table 32 follows on p. 120.
** Pp. 27 and 29, respectively, above.
*** Pp. 32 and 34, respectively, above.
**** Table 33 follows on p. 121.

Table 32

Yields of Petroleum Products in Western Europe a/
Selected Years, 1938-53

Type of Product	1938		1946		1950		1953	
	Yield b/ (Thousand Metric Tons)	Percent of Total	Yield b/ (Thousand Metric Tons)	Percent of Total	Yield c/ (Thousand Metric Tons)	Percent of Total	Yield (Thousand Metric Tons)	Percent c/ of Total
Gasoline	5,462	37.3	2,743	35.4	7,861	22.5	19,280	25.0
Kerosine category	862	5.9	450	5.8	937	2.7	3,045	4.0
Gas oil products	1,717	11.7	1,113	14.4	7,418	21.2	16,141	20.9
Lubricating oils	637	4.3	451	5.8	1,388	4.0	1,340	1.7
Residual fuel oil	4,177	28.5	2,000	25.8	14,631	41.8	33,153	43.0
Other products	1,808	12.3	993	12.8	2,739	7.8	4,181	5.4
Total products	14,663	100.0	7,741	100.0	34,974	100.0	77,140	100.0

a. With some minor exceptions these yields are those in countries which are in OEEC as of 1955. Product yield figures refer to indigenous gross product yields.
b. Estimates published in a statistical handbook. 168/ For volume-to-weight conversion factors, see Table 16, p. 62, above.
c. Extracted from an unpublished report based on official statistics. 169/

Table 33

Installed Annual Crude Oil Refining Capacities in the Free World and the Sino-Soviet Bloc a/*
1953

Thousand Metric Tons

Type of Facilities	Free World b/			Sino-Soviet Bloc c/				World Total
	US d/	Other e/	Total	USSR	European Satellites	Communist China and the Asiatic Satellites	Total	
Low pressure distillation f/								
Crude oil (atmospheric) distillation	364,170 g/	289,050	653,220	51,530	11,795	680	64,005	717,225
Vacuum distillation	45,718 h/							
Total	409,888							
Thermal cracking and reforming f/								
Cracking	103,828 i/	50,839	154,667			50		
Reforming	15,425 j/	17,123	32,548			0		
Total	119,253	67,962	187,215	13,670	2,460	50	16,180	203,395
Catalytic cracking and reforming f/								
Cracking	125,799	25,094	150,893	1,645	0	0	1,645	152,538
Reforming	12,085	1,397	13,482	0	0	0	0	13,482
Total	137,884 k/	26,491	164,375	1,645	0	0	1,645	166,020
Total cracking and reforming f/								
Cracking	229,627	75,933	305,560					
Reforming	27,510	18,520	46,030					
Total	257,137	94,453	351,590	15,315	2,460	50	17,825	369,415

* Footnotes for Table 33 follow on p. 122.

Table 33

Installed Annual Crude Oil Refining Capacities in the Free World and the Sino-Soviet Bloc a/
1953
(Continued)

Thousand Metric Tons

Type of Facilities	Free World b/			Sino-Soviet Bloc c/				World Total
	US d/	Other e/	Total	USSR	European Satellites	Communist China and the Asiatic Satellites	Total	
Atmospheric distillation, cracking, and reforming f/								
Noncatalytic facilities	483,423	357,012	840,435	65,200	14,255	730	80,185	920,620
Catalytic cracking and reforming	137,884	26,491	164,375	1,645	0	0	1,645	166,020
Total	621,307	383,503	1,004,810	66,845	14,255	730	81,830	1,086,640
Alkylation and polymerization 1/								
Thermal	543 m/			0	0	0	0	
Catalytic	3,213 n/			(180) o/	0	0	(180) o/	
Alkylation		991		90	0	0	90	
Polymerization		1,036		90	0	0	90	
Total	3,756	2,027	5,783	180	0	0	180	5,963

a. Separate or total data are not available where spaces remain blank. The facility capacities are quantified on the basis of general availability in 1953.
b. Reported statistics.
c. Estimated. 170/ These estimates are tentative and incomplete. 171/
d. Extracted from an unpublished analysis based on source 172/ and a trade-journal survey (source 173/).
e. Extracted from an unpublished analysis based on source 174/.
f. Charge capacities.
g. 349 refineries represented.
h. 90 refineries represented.

Table 33

Installed Annual Crude Oil Refining Capacities in the Free World and the Sino-Soviet Bloc a/
1953
(Continued)

i. 244 refineries represented.
j. 64 refineries represented.
k. Details of the US catalytic refining facilities:

	Separate Refineries Represented	Capacity (Thousand Metric Tons)
Fixed-bed catalytic cracking		
Houdry	8	7,117
Cycloversion	3	619
Total		7,736
Circulating-bed catalytic cracking		
Fluid	89	87,508
Thermofor	33	25,381
Houdriflow	8	5,174
Total		118,063
Fixed-bed catalytic reforming		
Cycloversion (modified cracking)	1	550
Platforming	29	6,663
Houdriforming (modified platforming)	2	773
Catforming (modified platforming)	5	622
Hydroforming	2	747
Houdry dehydrogenation (modified hydroforming)	4	2,179
Total		11,494

Table 33

Installed Annual Crude Oil Refining Capacities in the Free World and the Sino-Soviet Bloc a/
1953
(Continued)

	Separate Refineries Represented	Capacity (Thousand Metric Tons)
Circulating-bed catalytic hydroforming reforming		
Fluid	1	82
Thermofor	1	509
Total		591

l. Production capacities.
m. 19 refineries represented.
n. 112 refineries represented.
o. The alkylation and polymerization facilities are indicated as catalytic only.

APPENDIX D

GAPS IN INTELLIGENCE

An over-all gap in intelligence exists with respect to petroleum product yields in the USSR. This gap is the result of the lack of any firm statistics which relate to the yields obtained since 1936. The 1937 yields, moreover, are the latest that may be estimated by extrapolation and still have indirect confirmation of a realistic type in available Soviet source data.

Although it may be possible to extend the extrapolated yields estimates through 1938 with some degree of certainty, and although the captured 1941 State Plan may be used as a base for estimates of the later yields through 1940 with some sort of logic, the gap in intelligence is nearly complete for the subsequent period. The gap is complete for yields obtained from the end of 1941 to the end of World War II. In the series of link relatives published for the postwar period, some of the link relatives are missing and others are subject to interpretation at variance with the conclusions of this report.

For the postwar yields there are major specific intelligence gaps which limit the over-all applications of the methodology of this report. The major specific intelligence gaps refer to the following data for which there are no values or realistic estimates available.

1. Soviet yields of gasoline, kerosine, and diesel fuel in 1945.

2. Soviet postwar civil consumption in the category of residuals and other products.

3. Soviet postwar civil consumption of lubricants -- this report makes tentative use of certain estimates which are available.

4. Soviet postwar military consumption of petroleum products -- estimates of such consumption are available for 1953 only.

5. Soviet postwar imports and exports of petroleum products -- estimates of these trade data are available as follows: imports, 1946-47; imports and exports, 1951-53.

Specific minor intelligence gaps also exist with respect to the methodology of this report. The minor gaps refer to the present lack of adequate intelligence directly relating to the following data:

1. Use of unrefined crude oil as a product.

2. Crude oil handling loss.

3. Crude oil storage increment.

4. Crude oil refining gas and loss.

5. Distribution losses in petroleum products.

6. Storage increments for the petroleum products.

7. Consumption of nongaseous petroleum products in processing operations.

APPENDIX E

SOURCE REFERENCES

Evaluations, following the classification entry and designated "Eval.," have the following significance:

Source of Information	Information
Doc. - Documentary	1 - Confirmed by other sources
A - Completely reliable	2 - Probably true
B - Usually reliable	3 - Possibly true
C - Fairly reliable	4 - Doubtful
D - Not usually reliable	5 - Probably false
E - Not reliable	6 - Cannot be judged
F - Cannot be judged	

"Documentary" refers to original documents of foreign governments and organizations; copies of translations of such documents by a staff officer; or information extracted from such documents by a staff officer, all of which may carry the field "Documentary."

Evaluations not otherwise designated are those appearing on the cited document; those designated "RR" are by the author of this report. No "RR" evaluation is given when the author agrees with the evaluation on the cited document.

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1. CIA. CIA/RR RA (ORR Project 25.470), Petroleum Terminology, 31 May 55, p. 16-17. C.
2. Ibid., p. 24. C.
3. Ibid., p. 21-24. C.
4. Ibid., p. 7-8. C.
5. Ibid., p. 28. C.
6. Ibid., p. 25, 28. C.

7. Ibid., p. 8-9. C.
8. Ibid., p. 10. C.
9. Ibid., p. 10-11. C.
10. CIA. CIA/RR RA (ORR Project 25.192), Production of Natural Gas and Natural-Gas Liquids in the USSR, 28 May 54, p. 1, 2, and 6-9. S/
11. USSR, State Planning Commission. Socialist Construction in the USSR: Statistical Abstract, Moscow, Soyuzorgouchet, 1941, p. 138. U. Eval. Doc. (hereafter referred to as USSR, State Planning Commission. Socialist Construction)
12. Ibid.
Nekrasov, N. Planovoye khozyaystvo, no 1, 1938. U. Eval. RR 1.
13. Nekrasov, op. cit. (12, above).
14. USSR, State Planning Commission. Socialist Construction (11, above), p. 138, 140. U. Eval. Doc.
15. Air, AFOIN. 1A1-102-54, 2 Feb 54, Survey of World and Soviet Petroleum Industry in 1930. U. Eval. RR 1.
16. Nekrasov, op. cit. (12, above).
17. Air, AFOIN. 1A1-302-54, AF 637134, 22 Sep 54, Preparation of Fuel for the 1937 Sowing Campaign, p. 6-10. U. Eval. RR 2. (tr of L.M. Muratov. Neftyanoye khozyaystvo, no 3, 1937. U)
18. RAND Corporation. RM-804, A Dollar Index of Soviet Petroleum Output, by A. Gerschenkron and N. Nimitz, 4 Apr 52, p. 4-6 and 8-9, info 1927-28 to 1937. U. Eval. RR 1.
19. Air. The Output of Refined Petroleum Products in the USSR (EIC Working Paper), Jul 52, p. 29. S. Eval. RR 1 for data before 1946 and RR 4 for subsequent data.
20. RAND Corporation. RM-804 (18, above).
21. Ibid.
USSR, State Planning Commission. Socialist Construction (11, above), p. 138, 140. U. Eval. Doc.
Nekrasov, op. cit. (12, above).
Air, AFOIN. 1A1-302-54 (17, above).
CIA. CIA/RR RA (ORR Project 25.192) (10, above), p. 3. S/
Air. The Output of Refined Petroleum Products in the USSR (19, above), p. 26. S. Eval. RR 1 for data before 1946 and RR 4 for subsequent data.
22. Nekrasov, op. cit. (12, above).
Lisichkin, S. Pravda, 17 Dec 40. U. Eval. RR 2.
Air. AF-256-723, "Specifications for Soviet Petroleum Bases," 20 Dec 50. C. Eval. RR 2. (tr from I.L. Chernyak. Neftebazy /Petroleum Bases/, Moscow, 1947. U)

35. Neftyanoye khozyaystvo, no 1, 1939. U. Eval. RR 6.
36. Ibid., no 2, 1948, U. Eval. Doc.
37. Ibid.
Pravda, 18 Jan 48. U. Eval. Doc.
CIA. FBIS, Daily Report (USSR and Eastern Europe), 18 Jan 48. U/OFF USE. Eval. Doc.
38. Pravda Ukrainy, 20 Jan 49. U. Eval. Doc.
Joint Committee on Slavic Studies. Current Digest of the Soviet Press, vol 1, no 4, 2 Feb 48. U. Eval. Doc.
39. Pravda, 18 Jan 50. U. Eval. Doc.
Joint Committee on Slavic Studies. Current Digest of the Soviet Press, vol 2, no 4, 13 Mar 50. U. Eval. Doc.
40. Izvestiya, 27 Jan 51. U. Eval. Doc.
Joint Committee on Slavic Studies. Current Digest of the Soviet Press, vol 3, no 3, 3 Mar 51. U. Eval. Doc.
41. Izvestiya, 29 Jan 52. U. Eval. Doc.
State, Moscow, Joint Press Reading Service. Moscow Daily Press Review, no 29, sec B, 29 Jan 52. U. Eval. Doc.
42. Pravda, 23 Jan 53. U. Eval. Doc.
State, Moscow, Joint Press Reading Service. Moscow Daily Press Review, no 32, sec B, 23 Jan 53. U. Eval. Doc.
43. Planovoye khozyaystvo, no 1, 1954. U. Eval. Doc.
State, Moscow, Joint Press Reading Service. Moscow Daily Press Review, no 35, sec B, 4 Feb 54. U. Eval. Doc.
44. Izvestiya, 21 Jan 55. U. Eval. Doc.
Joint Committee on Slavic Studies. Current Digest of the Soviet Press, vol 7, no 2, 23 Feb 55. U. Eval. Doc.
45. CIA. CIA/RR PR-17 (I-D), Survey of Possibilities and Potentials in Future Petroleum Refining in the USSR, 22 Sep 52, p. 145-148, 170, 202-203. S.
46. CIA. CIA/RR RA (ORR Project 25.186), Civil Consumption of Petroleum Products in the USSR, 1945-55, 27 Sep 54, p. 3. S/
47. Air. The Output of Refined Petroleum Products in the USSR (19, above), p. 29, 33-34. S. Eval. RR 1 for data before 1946 and RR 4 for subsequent data.
48. CIA. CIA/RR (ORR Project 25.186) (46, above).
49. Air. The Output of Refined Petroleum Products in the USSR (19, above), p. 34. S. Eval. RR 1 for data before 1946 and RR 4 for subsequent data.
50. CIA. CIA/RR PR-17 (I-D) (45. above), p. 202-203. S.
51. CIA. SO, 17 Sep 51. S Eval. RR 4.
52. CIA. CIA/RR RA (ORR Project 25.186) (46, above).

[p 129 blank]

53. CIA. CIA/RR RA (ORR Project 25.192) (10, above), p. 4. S/
54. CIA. CIA/RR IP-373, The Economy of Communist China through the Five Year Plan, 5 Nov 54. S.
55. CIA. CIA/RR IP-385, Soviet Capabilities and Probable Soviet Courses of Action, 1954-60, 7 Mar 55. S.
56. CIA. CIA/RR IP-373 (54, above).
CIA. CIA/RR PR-119, Soviet Bloc Exports of Petroleum to the West, 1950-54, 29 Jul 55, p. 5. S/
57. Navy. Ships That Have Called at Albania, Rpts 1-23 in response to CIA request no 6279.2. S. Eval. RR 2.
State, Vienna. Rpt 11, encl 1, 31 Jan 49. R. Eval. RR 2.
State, Vienna. Rpt 1076, 9 Apr 51. U. Eval. RR 2.
58. CIA. CIA/RR IP-385 (55, above).
59. CIA. CIA/RR RA (ORR Project 25.192) (10, above), p. 4. S/
60. USSR Embassy, Washington. "Oil Workers Fulfill Five Year Plan Ahead of Schedule," by N. Baibakov, Information Bulletin, 12 Jan 51. U. Eval. Doc.
61. CIA. CIA/RR PR-17 (I-C), Refining of Petroleum in the USSR, 27 Jun 52, p. 21-23, 31, 56-57. S.
62. Ibid., p. 6-7, 12-23, 27-35, 49-53, 57-59, 67-71; annex, p. 4-10, 26-33. S.
63. Ibid.
64. Struth, op. cit. (35, above).
65. Ibid.
66. CIA. CIA/RR PR-17 (I-D) (45, above).
67. Ibid.
68. Ibid.
69. Air, AFOIN. 1A1-100-55, 3 Jan 55, Current Soviet Petroleum Refining Methods. C. Eval. RR 2.
70. CIA. CIA/RR RA (ORR Project 25.195). Petroleum Refineries in the Soviet Bloc, Sep 54, p. 4. S/
CIA. CIA/RR PR-17 (I-D) (45, above).
71. CIA. CIA/RR RA (ORR Project 25.186) (46, above).
72. CIA. FDD U-5349, 23 Dec 53. U/OFF USE. Eval. RR 3. (tr from Za ekonomiyu topliva, no 11, 1949. U)
Za ekonomiyu topliva, no 1, 1951. U. Eval. RR 3.
73. Struth, op. cit. (32, above)
Interior, US Bureau of Mines. Minerals Yearbook, 1950 (and preprints of chapters on petroleum for later years). U. Eval. RR 1.

American Petroleum Institute. Petroleum Facts and Figures, no 9, 1950. U. Eval. RR 1.
Ibid., no 10, 1952. U. Eval. RR 1.
Ibid., no 11, 1954. U. Eval. RR 1.
American Petroleum Institute and American Natural Gas Association. Proved Reserves of Crude Oil, Natural Gas Liquids, and Natural Gas, vol 1, 31 Dec 46, vol 9, 31 Dec 54. U. Eval. RR 2.

74. CIA. CIA/RR RA (ORR Project 25.470) (1, above), p. 19-20. C.
75.
76. CIA. CIA/RR RA (ORR Project 25.192) (10, above), p. 5. S.
77. CIA. CIA/RR RA (ORR Project 25.470) (1, above), p. 7-9. C.
78. CIA. CIA/RR RA (ORR Project 25.194), Statistical Analysis of Petroleum Production in the Soviet Bloc, 24 Jan 55, p. 7. S
79. RAND Corporation. RM-804 (18, above).
USSR, State Planning Commission. Socialist Construction (11, above), p. 138, 140. U. Eval. Doc.
80. Struth, op. cit. (32, above).
NIS 26, USSR, Supplement V, "Petroleum," Oct 52, p. 6-6. S.
81. RAND Corporation. RM-804 (18, above).
USSR, State Planning Commission. Socialist Construction (11, above), p. 138, 140. U. Eval. Doc.
82. USSR, State Planning Commission. The Second Five Year Plan (23, above).
83. USSR, State Planning Commission. Socialist Construction (11, above), p. 140. U. Eval. Doc.
84. CIA. CIA/RR RA (ORR Project 25.192) (10, above), p. 3. S/C
RAND Corporation. RM-804 (18, above).
USSR, State Planning Commission. Socialist Construction (11, above), p. 138, 140. U. Eval. Doc.
85. CIA. CIA/RR RA (ORR Project 25.192) (10, above), p. 3. S
86. RAND Corporation. RM-804 (18, above).
USSR, State Planning Commission. Socialist Construction (11, above), p. 138, 140. U. Eval. Doc.
87. CIA. CIA/RR RA (ORR Project 25.192) (10, above), p. 3. S C
RAND Corporation. RM-804 (18, above).
USSR, State Planning Commission. Socialist Construction (11, above), p. 138, 140. U. Eval. Doc.

88. CIA. CIA/RR RA (ORR Project 25.192) (10, above), p. 3. S/
RAND Corporation. RM-804 (18, above).
89. RAND Corporation. RM-804 (18, above).
90. Air. The Output of Refined Petroleum Products in the USSR (19, above), p. 26, S. Eval. RR 1 for data before 1946 and RR 4 for subsequent data.
91.
92. Air, AFOIN. 1A1-102-54 (15, above).
93. USSR, State Planning Commission. Socialist Construction (11, above), p. 141-142. U. Eval. Doc.
94. Air, AFOIN. 1A1-102-54 (15, above).
95. Nekrasov, op. cit. (12, above).
96. Air. The Output of Refined Petroleum Products in the USSR (19, above).
97. Air, AFOIN. 1A1-302-54 (17, above).
98. Air. The Output of Refined Petroleum Products in the USSR (19, above), p. 29, 34. S. Eval. RR 1 for data before 1946 and RR 4 for subsequent data.
99. Kozhevnikov, A.V. GIZ Nauchnaya Literatura, Tartu, Estonia, vols 1, 2, and 3, 1947. U. Eval. RR 2.
100. Krumin, P. Review of the Estonian Oil Shale Industry, with a Brief Account of Oil Shale Development in the United States, Ohio State University Studies, Engineering Series, vol 18, no 6, Nov 49. U. Eval. RR 2. (hereafter referred to as Review)
Krumin, P. "The Oil Shale Industry of Estonia," The Economist, Riga, Latvia, no 8, 1940. U. Eval. RR 2.
101. Krumin, P. Review (100, above).
102. CIA. CIA/RR RA (ORR Project 25.470) (1, above), p. 31-45. C.
103. Air. AF-256-723 (22, above).
Air, AFOIN. 1A1-29-52, AF 526333 (22, above).
USSR. Voprosy (22, above).
104. Air, AFOIN. 1A1-29-52, AF 526333 (22, above).
105. CIA. CIA/RR RA (ORR Project 25.186) (46, above).
106. Ibid.
107. Ibid.
108. Ibid.
109. CIA. ORR Project 10.400 (EIC-P-6), Economic Capabilities of the Soviet Bloc to Support a General War under Certain Assumptions. (to be published). S.
110. CIA. CIA/RR IP-385 (55, above).
111. NIS 26 (80, above).
112. Navy. Ships That Have Called at Albania, Rpts 1-23 in response to CIA request no 6279.2. S. Eval. RR 2.
State, Vienna. Rpt 11, encl 1, 31 Jan 49. R. Eval. RR 2.
State, Vienna. Rpt 1076, 9 Apr 51. U. Eval. RR 2.

113. CIA. CIA/RR IP-373 (54, above).
114. Ibid.
CIA. CIA/RR PR-119 (56, above).
115.

116. Ibid., p. 9, 27. S. Eval. RR 2.
117. Air. AIS 3-3, AF 611369, 29 Jan 54, Production of Liquid Fuels from Coal in the USSR, p. 21-68. S. Eval. RR 2.
CIA. CIA/RR RA (ORR Project 25.195) (70, above), p. 7. S
118.
Kutt, A. The Estonian Oil Shale Industry, unpublished, Committee for a Free Estonia. U. Eval. RR 3.
CIA. CS, Feb-Mar 52. C. Eval. RR 4.
119. Air. AIS 3-3 (117, above), p. 1, 62, 63. S. Eval. RR 2.
120. Army, Quartermaster General, Fuel and Lubricants Division. Petroleum Facilities of Germany, Mar 45, p. 153-154. C. Eval. RR 2.
121. Gt Brit, BIOS. Over-all Rpt no 1, 1947, Report on the Petroleum and Synthetic Oil Industry of Germany, p. 2. U. Eval. RR 2.
122. Air. AIS 3-3 (117, above), p. 1, 11, 62, 63. S. Eval. RR 2.
CIA. CIA/RR RA (ORR Project 25.195) (70, above), p. 7. S/
123. Sovetskaya Estoniya, 30 Jan 51. U. Eval. Doc.
124. Ibid., 15 Jan 50. U. Eval. Doc.
125. Ibid., 26 Jan 49. U. Eval. Doc.
126. Ibid., 16 Jan 48. U. Eval. Doc.
127. Ibid., 18 Dec 46. U. Eval. Doc.
128. Ibid.
129. Kutt, op. cit. (118, above).
130. Ibid.
131. Ibid.
132. Ibid.
133. Sovetskaya Estoniya, 18 Apr 51. U. Eval. Doc.
134. Kozhevnikov, op. cit. (99, above).
135. Kutt, op. cit. (118, above).
136. Ibid.
137. Ibid.

138. CIA. CIA/RR RA (ORR Project 25.192) (10, above), p. 4. S

162. Air, AFOIN. 1A1-184-53, AF 559392, Jun 53. R. Eval. RR 3. (tr of Neft', no 2, 1938. U)
CIA. FDD U-2199, 23 Jul 52. R. Eval. RR 3.
163. CIA. FDD U-2199 (162, above).
164. Interior, Petroleum Administration for Defense. Transportation of Oil, Dec 51, p. 58-60. U. Eval. RR 1.
165. CIA. CIA/RR RA (ORR Project 25.186)* (46, above).
166. CIA. CIA/RR RA (ORR Project 25.192) (10, above), p. 4. S/
167. CIA. ORR Project 25.675, Output of Refined Petroleum Products in the European Satellites and Communist China (to be published). S/I
168. Struth, op. cit. (32, above).
169. OEEC, Oil Committee Secretariat. DT/E/PE/54.285, 10 Dec 54, info Jan-Jun 54. R. Eval. Doc.
Ibid., DT/E/PE/54.177, 20 Jul 54, info 1953. R. Eval. Doc.
Ibid., DT/E/PE/53.172, 25 Jul 53, info 1952. R. Eval. Doc.
Ibid., DT/E/PE/53.168, 21 Jul 53, info Jul-Dec 52. R. Eval. Doc.
Ibid., DT/E/PE/53.167, 18 Jul 53, info Jan-Jun 52. R. Eval. Doc.
Ibid., DT/E/PE/52.141, 17 Jun 52, info 1951. R. Eval. Doc.
Ibid., DT/E/PE/52.94, 25 Apr 52, info Jul-Dec 51. R. Eval. Doc.
Ibid., DT/E/PE/51.288, 3 Oct 51, info Jan-Jun 51. R. Eval. Doc.
Ibid., DT/E/PE/51.136, 28 Apr 51, info Jul-Dec 50. R. Eval. Doc.
Ibid., DT/E/PE/312, 9 Nov 50, info Jan-Jun 50. R. Eval. Doc.
Ibid., DT/E/PE/162, 24 May 50, info 1949. U. Eval. Doc.
170. CIA. CIA/RR RA (ORR Project 25.195) (70, above), p. 4-5 and 8-13. S/
171. CIA. CIA/RR PR-17 (I-C) (61, above).
172. Interior, US Bureau of Mines. "Petroleum Refineries, including Cracking Plants, in the United States, 1 January 1953," by J.G. Kirby, US Bureau of Mines Information Circular, no 7667, 1953. U. Eval. RR 1.
173. "Report on United States Operating Refineries," Oil and Gas Journal, vol 51, no 46, 23 Mar 53, p. 312-330. U. Eval. RR 1.
174. Interior, Petroleum Administration for Defense. Summary Report of 1953 Survey of Foreign Refining Capacities, 31 Aug 53. C. Eval. RR 2.

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Figure 2

Product Yield Pattern in US Crude Oil Refining, 1930-54

(Gross product yield percentage trend lines)

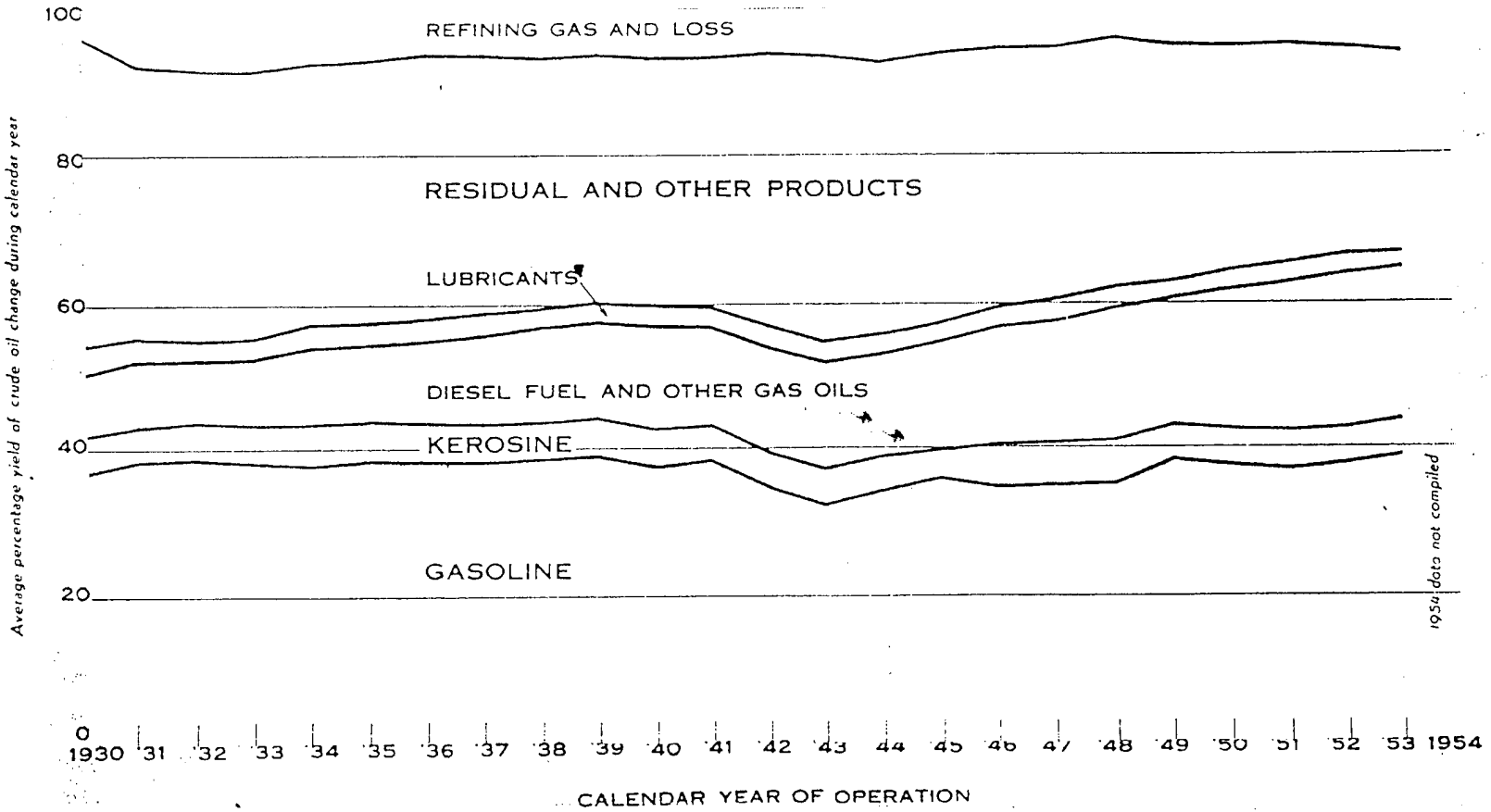

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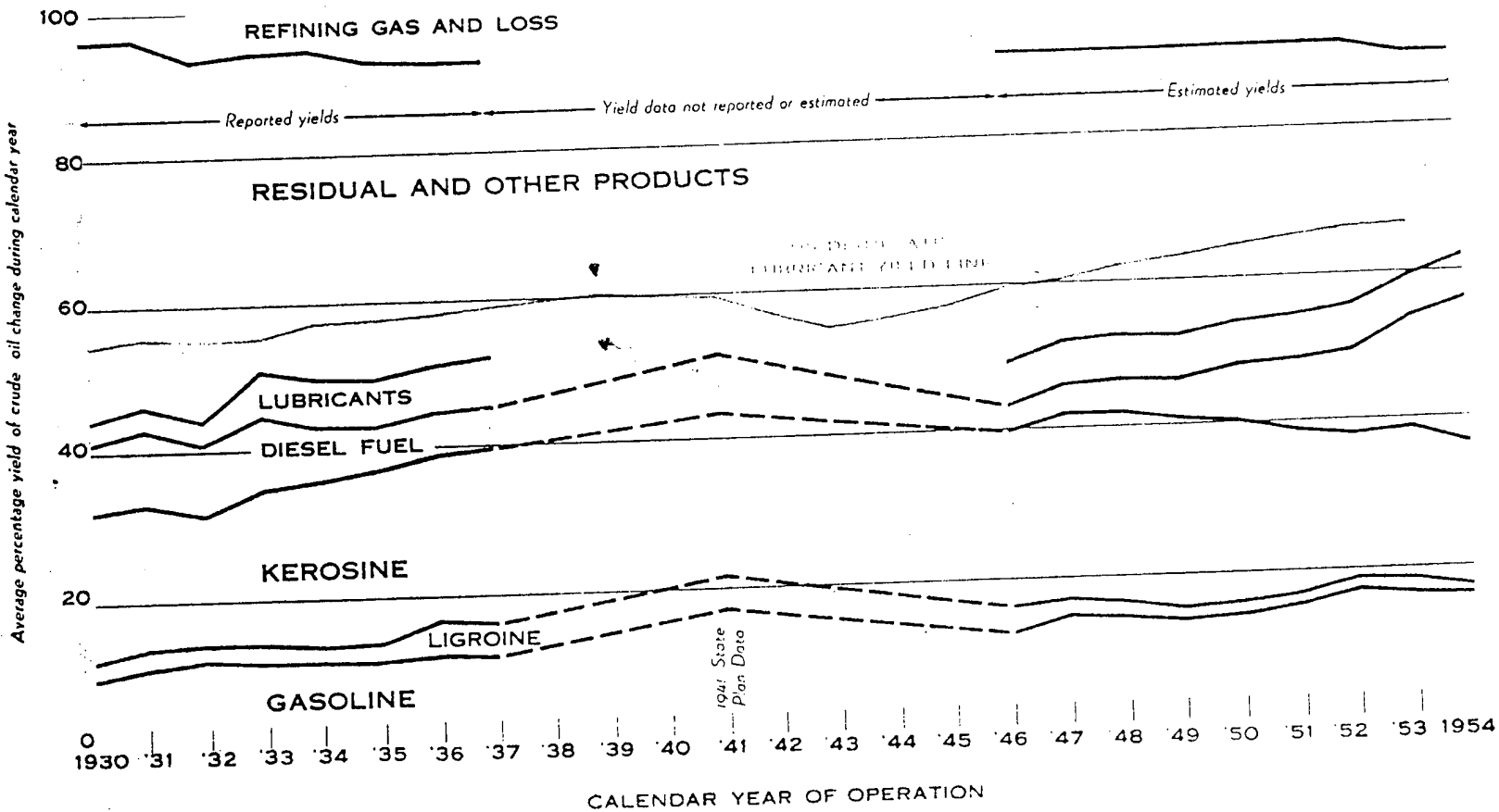
Figure 1

Product Yield Pattern in Soviet Crude Oil Refining, 1930-54

(Gross product yield percentage trend lines)



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