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PROVISIONAL INTELLIGENCE REPORT

PETROLEUM IN THE SOVIET BLOC

DOCUMENT NO
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DECLASSIFIED
CLASS. CHANGED TO:
NEXT REVIEW DATE:
AUTH: HR 70-2
DATE: 2-10-79 REVIEWER:

SURVEY OF POSSIBILITIES AND POTENTIALS IN FUTURE PETROLEUM REFINING IN THE USSR

CIA/RR PR-17 (1-D)

23 September 1952

Note

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

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Survey of Possibilities and Potentials in Future Petroleum Refining in the USSR

Introduction

Possible Future Soviet Refining Programs.

Available intelligence does not contain sufficient information [illegible] an actual general trend in Soviet plans for future refinery construction [illegible] is entirely probable, however, that the Soviets do have an overall [illegible] construction program of some kind. It is further possible by means of [illegible] considerations to establish the probability that the principal [illegible] overall scheme fall within the limits attainable by two distinct general [illegible] These limiting plans or programs are in some respects contradictory, and [illegible] be said to represent practicable extremes. One limiting scheme may be [illegible] designated as a high octane rating program and the other as a high general [illegible] late yield program. The two programs are similar in that they emphasize [illegible] or practicable maxima in distillate yields. In the ultimate analysis the [illegible] mental difference is in the emphasis placed upon the type and quality of [illegible] lates. The high octane rating program involves the practicable maxima [illegible] octane ratings, and other quality ratings of gasolines. The high general [illegible] yield program involves the practicable maxima in distillate yields for [illegible] range of use, and it does not necessarily have controlling factors in the [illegible] ties and qualities of gasoline.

The limiting or alternate programs differ in consequence. For the [illegible] of a given quantity of crude oil the high octane rating program would [illegible]

refining installations considerably more complex in type and considerably more expensive in structural material utilization. But as a result of this more expensive construction, the stated program would result in a larger percentage yield in comparison to the alternate and a much better quality rating in the gasoline product stocks. While the distillate yields would represent larger percentages of the crude in the alternate program, the gasoline portion of the total distillates would be a smaller percentage of this crude and would have lower quality ratings. Nevertheless for a maximization of primary structural materials such as steel when a balance is maintained between refinery construction on the one hand, and expanded production or increasing crude production on the other, the alternate program would permit the production and processing of more crude in a stated period of time sufficiently to produce a larger total quantity of the gasolines.

The program for high octane ratings would produce quantities of the best quality gasolines. The better quality gasolines would be suitable for the needs of high compression engines in a manner similar to the pattern during the competitive enterprise in the US. This quality production would normally be for motor gasoline although the program would also result in a greatly expanded potential for the production of high octane gasoline for aircraft. In the forecasting program for yields of distillates of more general types, the gasoline would be produced with qualities adequate for the low compression engines reported to prevail in civilian use in the USSR. The larger program for yields would reasonably provide for the production of jet fuels so as to meet the military requirements for high octane avgas.

Part I of this study consists of a survey of plausible potentials if [illegible] plans were predominantly directed towards high octane ratings. Part II [illegible] similar possibilites if the contrasting program were adopted. Part III [illegible] were probable and perhaps more realistic intermediate course. The following table provides a summary of the estimated and postulated product yield [illegible] developed in detail in the text. From the technological standpoint for the [illegible] refining of a given increased natural petroleum production in the [illegible] postulated for 1955 for comparison, the three hypothetical programs [illegible] under about the same requirements in total new refining capacities, and [illegible] mainly in the types, complexities, and material requirements in the new [illegible]

[illegible]

[illegible] of Refinery Petroleum Products in the [illegible]

	Percent Wt.	Percent Vol.	Yield	Percent Wt.	Percent Vol.	Yield	Percent Wt.	Percent Vol.	Yield	Percent Wt.	Percent Vol.	Yield
	Percent 1950			High Distillate Yields			Intermediate Yields			Low Gasoline Yields		
Jet Fuels and Low Base	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Total Distillate Base and Blend Stocks	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Total Intermediate or Heavy Distillates	25.8	26.5	9,679	32.6	34.2	16,952	26.9	28.2	13,962	22.7	22.8	11,302
Lubes, Waxes, Road Oils, Tars, Asphalts, Etc.	[illegible]	[illegible]	[illegible]	5.2	5.2	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Total Residual Fuel Oil Stocks	30.5	27.5	11,423	25.2	22.4	13,131	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Crude Charge	100.0	100.0	37,500	100.0	100.0	52,000	100.0	100.0	52,000	100.0	100.0	52,000
Thermal Cracked Distillates	2.8	2.9	1,065	1.6	1.7	846	2.3	2.4	[illegible]	2.2	2.3	1,162
Visbreaker Distillates	0.0	0.0	0	11.5	12.0	5,996	5.5	5.3	2,638	0.0	0.0	0
Thermal Conversion Distillates	2.8	2.9	1,065	13.1	13.7	6,812	7.4	7.7	3,821	2.2	2.3	1,162
Virgin Kerosenes, Diesel Oils, Naphthas, Etc.	23.0	23.6	8,614	19.5	20.5	10,140	19.5	20.5	10,140	19.5	20.5	10,140
Total Intermediate or Heavy Distillates	25.8	26.5	9,679	32.6	34.2	16,952	26.9	28.2	13,962	22.7	22.8	11,302

a. Thousands of metric tons per year.
b. Charge of estimated total crude production
c. Gross product yields from refining units
d. Base and blend stocks shown for engine fuels [illegible] gasolines, tractor fuels, diesel fuels, jet fuels; [illegible] for finished engine fuel oil [illegible] (none of these finished blends would logically [illegible] not derived from natural crude oil)

V. Future Petroleum Refining for High Octane Ratings.

Summary.

Plausible New Refinery Constructions for High Octane Ratings.

Catalytic cracking is a basic process for high relative yield of high [illegible] gasoline in modern refinery practice. Thermal cracking is ancillary to catalytic cracking for practicable balance in operations and from the [illegible] of maximum efficiency in recovery, the catalytic alkylation types of [illegible] are supplementary even if not strictly ancillary. In order to compliance with respect to motor gasoline quality, thermal reforming stands in [illegible] although more subordinate or secondary status. The present study [illegible] future Soviet refinery construction will obtain a balance in total [illegible] facilities for the conversions as above described, at least compatible with [illegible] enterprise has developed in the US. This balanced construction [illegible] be so attained by 1955 for analysis purposes. All such assumptions are [illegible] convenience to illustrate the calculation of plausible potentials, and [illegible] results are here considered to be in the category of possibility rather [illegible] probability.

"New" refinery constructions are postulated in this analysis with [illegible] to the refining facilities estimated to have been existing in 1950. [illegible] of the "new" capacities are selected upon the basis of central points [illegible] service to oil-producing regions and further for the distribution of oil [illegible]. These plausible sites are correlated with estimates of the prospective 1955 Soviet crude productions by regions.

An assumption is here made that all [illegible] of the Houdry [illegible] projects will be completed according to [illegible] designs and that these plants will be completed at designated critical [illegible] [illegible] adoption of plans to construct plants for [illegible] [illegible] cracking technique. The latter would replace the Houdry cracking [illegible] in the construction program. It is assumed that the [illegible] the most advanced processing developments, namely, the Fluid Catalytic [illegible] [illegible] the Houdry. Sites and capacities of the hypothetical [illegible] catalytic cracking systems are as shown below, with capacity ratings [illegible] terms of virgin gas oil charge:

Postulated Catalytic Cracking Systems in the USSR

Thousand Metric Tons per Year

Catalytic Cracking Systems a		
Site	Type	Charge Capacity
I. Systems Assumed Existing in 1950		
Gorkiy	Houdry (Lend-Lease)	380
Orsk	Houdry (Lend-Lease)	375
II. "New" Systems Assumed Completed After 1950 and Prior to 1955		
Kuibyshev	Houdry (Lend-Lease)	380
Krasnovodsk	Houdry (Lend-Lease)	380
Ufa	Houdry	380
Grozny	Houdry	380
Ufa	Houdry	380
Moscow	Fluid	618
Orsk	Fluid	996
Odessa	Fluid	1,272
Komsomolsk	Fluid	330
Baku	Fluid	3,000
Yaroslavl	Fluid	500
Krasnovodsk	Fluid	1,000
Tuapse	Fluid	1,500
Saratov	Fluid	600
Ufa	Fluid	600

a Houdry units include supplementary catalytic reforming.

In the two Lend-Lease Houdry system projects assumed to have been [illegible] in 1950, the Badger design catalytic alkylate production capacity of 90 thousand metric tons per year is considered to be included. The "new" Houdry and Fluid systems are assumed to include additional alkylate production capacity totaling 1,920 thousand metric tons per year. In all refining facilities assumed to

been existing in the USSR in 1950, the only other catalytic conversion [illegible] is represented by 80 thousand metric tons per year of technical isoc[illegible] [illegible]ced in the coordinated polymerization and hydrogenation units instal[illegible] in the "new" refining facilities here postulated to be constructed by th[illegible] The only other catalytic conversion capacity is represented by a polymer[illegible] type of gas reversion. The latter capacity is in connection with the [illegible] Hendry system project at Krasnovodsk, and is included as designed by [illegible] 10 thousand metric tons per year of polymer gasoline product.

With regard to non-catalytic refining it is here postulated that [illegible] installations will consist of facilities equivalent to those estimated [illegible] existed in place in 1950, plus the "new" facilities required in the vari[illegible] to complete the hypothetical balance. Estimates for the USSR show that [illegible] ing 1950 crude distillation charge capacity was about 20 weight percent, [illegible] of the total crude production. This is a normal ratio compatible with m[illegible] practice in the US, and the same relative status is included for the USS[illegible]

The following table provides a summary of the USSR refining capacit[illegible] types, estimated or assumed as above stated. Here the capacity ratings [illegible] charge stocks except that they are shown in terms of product for the re[illegible] and hydrogenation units. Cracking and reforming units constitute all fa[illegible] with thermal conversion capacity.

Estimated and Postulated Refining Capacities in the USSR

Data for High Octane Rating Program in 1955

Type of Facility	Thousand Barrels Per Day Capacity: Estimated Existing in 1959	Postulated "New" in 1955
Crude Distillation	44,320	47,400
Thermal Reforming	980	4,167
Thermal Cracking	16,[illegible]	2,053
Total Thermal Conversion	17,0[illegible]	6,163
Heavy Catalytic Cracking a/	75[illegible]	1,9[illegible]
Other Catalytic Cracking a/	[illegible]	10,316
Total Catalytic Cracking a/	75[illegible]	12,115
Alkylate Production b/	20	1,[illegible]
Isomerate Production c/	80	0
Polymer Gasoline Production b/	0	45
Total Catalytic Conversion	924	13,[illegible]
Total Conversion	18,[illegible]	19,[illegible]

a/ Units include supplementary catalytic reforming.
b/ Catalytic gas reversion.
c/ Catalytic gas reversion plus catalytic reforming.

Since total crude production constitutes potential indigenous [illegible] in a country, the foregoing USSR data may be resolved relative to [illegible] estimates of Soviet crude oil productions, and compared with the US [illegible]

Capacity Ratio Comparison for 1955 High Octane Rating Program

	Relative Weight Ratios Annual Basis		
	USSR		
Type of Capacity	Estimated Existing 1950	Postulated for 1955	US 19[illegible]
Crude Production	1.000	1.000	1.[illegible]
Crude Distillation	1.158	1.200	1.[illegible]
Thermal Conversion	0.461	0.451	[illegible]
Catalytic Conversion	0.025	0.278	[illegible]
Total Conversion	0.486	0.729	[illegible]

The following table shows the geographic distribution of the hypothe[illegible] USSR capacities for 1955. As thus shown for thermal reforming the total [illegible] capacity is within the range of US practice and is on a weight [illegible]

[redacted]

[illegible] % of the estimated average crude oil production. For Soviet thermal [illegible] the corresponding percentage is about 35.4. Thermal cracking on capacity [illegible] includes a relatively small quantity of production by thermal gas reforming [illegible]

Postulated Capacity Data for 1955 in the USSR

	High Octane Rating Program					Thousand [illegible]
Capacity	Southeastern European Russia; Soviet Caucasus	Southeastern European Russia; Soviet Central Asia	Northern European Russia	Soviet Far East	[illegible]	[illegible] USSR
1955 Crude Production	20,400	11,000	19,600	1,000		[illegible]
Estimated for 1950	28,850	5,560	8,765	1,280	46	[illegible]
Added "New"	0	3,270	14,210	0		[illegible]
1955 Crude Distillation	28,850	8,830	22,975	1,280	46	[illegible]
Estimated for 1950	0	213	773	0		[illegible]
Added "New"	1,061	354	2,640	52		[illegible]
1955 Thermal Reforming	1,061	572	3,413	52		[illegible]
Estimated for 1950	6,086	3,721	6,033	474		[illegible]
Added "New"	272	0	1,794	0		[illegible]
1955 Thermal Cracking	6,358	3,721	7,833	474		[illegible]
Estimated for 1950	0	754	[illegible]	0		[illegible]
Added "New"	6,732	2,876	2,379	330		[illegible]
1955 Catalytic Cracking a/	6,732	3,630	2,179	330		[illegible]
Estimated for 1950	0	89	0	0		[illegible]
Added "New"	790	337	255	39		[illegible]
1955 Alkylate Production	790	426	255	39		[illegible]
Estimated for 1950	0	0	80	0		
Added "New"	0 b/	0	0	0		
1955 Isooctane Production	0	0	80	0		
Estimated for 1950	0	0	[illegible]	0		
Added "New"	0	10	[illegible]	0		
1955 Polymer Production	0	10	0	0		

a/ Houdry systems include supplementary catalytic reforming.
b/ Soviet Caucasus codimer polymer contributes to isooctane.

Product Yield Potentials in High Octane Rating Programs

Quantitative and percentage product yields indicate the ultimate [illegible] of the program for high octane ratings. The pertinent overall refinery yields are presently calculated upon the basis of crude oil charges equal to [illegible] local annual productions estimated for the USSR. The calculations further [illegible] gross yields obtained from separate processing systems, based upon this [illegible] low total estimated crude production. The resulting gross yields are [illegible] straight balance with the charge, and they show the gross non-gaseous (liquid) products which have economic use, plus a yield accounting convertible [illegible] classified as process loss. The latter in turn consists of the tail or [illegible] generally utilized as fuel gas, plus the carbon deposits and fractionated [illegible] during the process. Useful heat recovery is often obtained by subsequent [illegible] of the carbon or coke deposited in the process, and this is especially [illegible] in the case of a catalytic cracking operation.

A convenient and consistent basis for comparison is provided by assuming estimated total crude production to be the charge to refining. Upon this [illegible] the net oil product yields may be calculated for consumption if there is [illegible] prorating of loss factors to the gross product yields, providing that the [illegible] accounting properly accounts for all miscellaneous oil loss or unavailability [illegible] prevails in addition to the refinery process loss in the general petroleum industry. Relative potentials are here indicated by comparing the gross [illegible] including the products suitable for economic use. The comparison directly [illegible] the production of stable gasoline base and blend stocks. The latter serve [illegible]

suitable basis of comparison since approximate calculations of practical [illegible] yields have inferred no appreciable alternation in the essential features [illegible] comparison.

A primary objective of crude oil processing usually relates to the [illegible] of fluid (i.e., mostly liquid) fuels for internal combustion engines; the [illegible] most considerations generally relate to the reciprocating or piston class [illegible] engines. The turbine class of internal combustion engines is, however, becoming increasingly important for the jet propulsion of aircraft even though [illegible] stationary-fired gas turbines remain of minor consequence. The high octane rat[illegible] gives emphasis upon the gasoline varieties of internal combustion eng[illegible] An indirect inference in the present survey is that the Soviets will have [illegible] use for the potential gasolines, mostly applied in the usual manner as fuels [illegible] the spark-ignition (i.e., Otto-cycle) type of the reciprocating class of in[illegible] combustion engines. This use would be in addition to the use of gases and [illegible] fuels for the Otto-cycle engines, particularly including volatile condensate (liquified petroleum gases, or LPG) as a substitute fuel for the true gaso[illegible] where the LPG are mostly derived from natural gas fluids although they are [illegible] obtained in crude oil refining and the synthetic oil industries. However, [illegible] calculations do take into accounting the utilization of fuels of the kerosene t[illegible] heavy duty Otto-cycle engines. But while yields are postulated so as to [illegible] fuels of the lighter varieties for the compression-ignition (i.e., Diesel-cy[illegible] type of the piston class of internal combustion engines, some modification [illegible] necessary to account for considerable requirements for the heavy Diesel fuel[illegible] and Diesel oils of the so-called marine and similar varieties). Mention has

been made of the separate consideration of jet fuels for aircraft.

The following table summarizes the comparison of yield potentials for [illegible] refining, referring to the estimated overall operation in 1950 and the [illegible] hypothetical operation for high octane ratings in 1956. In calculating the yields by types for comparative purposes, the overall processings are thus much generalized, simplified, and in some cases idealized with respect to probable actual operations.

Gross Yields in Soviet Refining

1950 Operation Versus the Operation for High Octane Rating

Yields in Thousands of Metric Tons with Weight Percentages

Type of Yield	Estimated 1950 Processing: Gross Yield	Estimated 1950 Processing: Percent Crude	Hypothetical High Octane: Gross Yield	[illegible]
Motor	2,721	7.26	1,593	[illegible]
Aviation a/	1,018	2.71	1,137	
Total Straight Run Base	3,739	9.97	2,730	
Thermal Reformed Base	724	1.93	3,730	
Total Base from Virgin Naphtha	4,463	11.90	6,160	
Motor	23	0.06	1,236	
Aviation	186	0.50	3,256	
Total Catalytic Cracked Base	209	0.56	4,492	
Isopentane	20	0.05	375	
Total by Catalytic Cracking	229	0.61	4,867	
Thermal Cracked Base	5,776	15.40	4,874	
Total by Cracking	6,005	16.01	9,741	[illegible]
Alkylation Blend Stock b/	42	0.11	703	
Motor	8	0.02	142	
Aviation	81	0.22	1,368	
Total Alkylate	89	0.24	1,510	
Polymer Stock c/	0	0.00	10	
Isooctane d/	80	0.21	80	
Total Gas Reversion Blend Stock e/	169	0.45	1,600	
TOTAL STABLE GASOLINE BASE AND BLEND STOCKS	10,679	28.5	18,504	[illegible]
Straight Run	8,614	23.0	10,110	[illegible]
Thermal Cracked	1,065	2.8	1,162	[illegible]
TOTAL INTERMEDIATE DISTILLATES	9,679	25.8	11,302	2[illegible]

(Continued on next page)

Gross Yields in Soviet Refining (cont'd)

1950 Operation Versus the Operation for High Cet[illegible] Ratings in 19[illegible]
(Continued)

Type of Yield	Estimated 1950 Processing: Gross Yield	Estimated 1950 Processing: Percent Crude	Hypothetical High Cetane: Gross Yield	Hypothetical High Cetane: Percent Crude
LUBES, SPECIALTY RESIDUALS	2,778	7.4	2,730	[illegible]
Thermal Reformed	97	0.26	500	[illegible]
Thermal Cracked	7,364	19.64	10,034	[illegible]
Total by Thermal Conversion	6,461	19.90	19,534	[illegible]
Catalytic Polymer f/	14	0.03	50	[illegible]
Total Conversion Residual	7,475	19.93	10,584	[illegible]
Straight Run Residual	3,948	10.53	3,900	[illegible]
TOTAL RESIDUAL FUEL OIL	11,423	30.5	14,484	[illegible]
OVERALL PROCESS LOSS	2,941	7.8	4,980	
GROSS PRODUCTS	34,559	92.2	47,020	[illegible]
TOTAL CRUDE CHARGE g/	37,500	100.0	52,000	[illegible]
Thermal Reformed Base	724	1.93	3,730	[illegible]
Thermal Cracked Base	5,776	15.40	4,874	[illegible]
Thermal Conversion Base	6,500	17.33	8,604	[illegible]
Catalytic Cracked Base	209	0.56	4,492	[illegible]
Total Conversion Base	6,709	17.89	13,096	[illegible]
Straight Run Base	3,739	9.97	2,730	[illegible]
TOTAL STABLE GASOLINE BASE STOCKS	10,448	27.86	15,826	[illegible]
Catalytic Cracking Isopentane	20	0.05	375	[illegible]
Gas Reversion Blend Stock e/	169	0.45	1,600	[illegible]
Direct Catalytic Conversion Blend Stock	189	0.50	1,975	[illegible]
Alkylation Blend Stock b/	42	0.11	703	[illegible]
TOTAL STABLE GASOLINE BLEND STOCKS	231	0.61	2,678	[illegible]

(Continued on next page)

[illegible]

Gross Yields in Soviet Refining

1950 Operation Versus the Operation for High Octane Ratings in [illegible]
(Continued)

Type of Yield	Estimated 1950 Refining: Gross Yield	Estimated 1950 Refining: Percent Crude	Hypothetical High Octane [illegible]: Gross Yield
Thermal Conversion Base	6,500	[illegible]	[illegible]
Catalytic Cracked Base	23	0.06	[illegible]
Total Conversion Motor Base	6,523	17.[illegible]	[illegible]
Straight Run Motor Base	2,721	7.[illegible]	[illegible]
Total Motor Base	9,244	24.65	[illegible]
Motor Alkylate	8	0.02	[illegible]
Reformer Stock c/	0	0.00	10
Alkylation Blend Stock b/	42	0.11	703
TOTAL STABLE MOTOR GASOLINE BASE AND BLEND STOCKS	9,294	24.78	12,[illegible]
Catalytic Cracked Base	186	0.[illegible]	[illegible]
Straight Run Aviation Base a/	1,018	2.71	[illegible]
Total Aviation Base	1,204	3.21	4,[illegible]
Aviation Alkylate	81	0.[illegible]	[illegible]
Isooctane d/	80	0.[illegible]	80
Catalytic Cracking Isopentane	20	[illegible]	[illegible]
TOTAL STABLE AVIATION GASOLINE BASE AND BLEND STOCKS	1,365	3.69	6,226

a/ Potential virgin naphthenic stocks. These potential yields obviously include excesses over the quantities utilizable with other available avgas stocks in the final avgas blends.

b/ Excess charge stock to alkylation, essentially consisting of excess [illegible] stock derived by crude fractionation, reforming, and cracking.

c/ Polymer gasoline at Krasnovodsk.

d/ Derived by hydrogenation of codimer polymer.

e/ In part as represented in isooctane.

f/ Produced in the supplementary catalytic reforming stage in the [illegible] Catalytic Cracking systems.

g/ Later estimates have indicated a total 1950 production value of [illegible] 38.0 million metric tons for Soviet crude oil.

[illegible]

Possible Potentials in Finished High Octane Gasolines:

As already noted in the preceding discussion, tentative [illegible] have indicated that the inclusion of reasonable finished gasoline blends [illegible] have little effect upon the generalities of the foregoing generalizations [illegible] yield potential comparison. It is evident, however, that certain [illegible] considerations need to be analyzed in this respect. The research survey [illegible] in itself cover the general composition details actually necessary for [illegible] comparison of the logical and probable finished gasoline blends. In the [illegible] of certain of the necessary details it is believed that the available data [illegible] are too fragmentary to presently warrant such a general comparison, [illegible] there are studies currently in progress to provide the missing information.

Nevertheless in the preceding yield potential comparison, it is [illegible] certain that practicable aviation gasoline blends would leave some of the [illegible] base and blend stocks in excess relative to the others available, and that [illegible] enhanced utilization the final motor gasoline blends would need to absorb [illegible] excesses. The particular reference is to the relatively straight [illegible] base, and especially so in the case of the 1550 data. The given data further [illegible] account for certain additional gasoline blend stocks probably utilized [illegible] cases to satisfy technical requirements, and in other cases to give optimum [illegible] gasoline blend yields with the base and blend stocks available.

The additional gasoline blend stocks are of three general types. They [illegible] of volatile motor stocks such as natural gasoline, utilizable within vapor [illegible] limits in motor gasolines; of high octane additives for motor blends;

and of synthetic oil gasoline derivatives, consisting of base and blend stocks of various types. High octane avgas additives are typically required to supplement the isooctane type of catalytic high octane blend stock, generally constituted by technical isooctane and the usual aviation alkylate. The additives in question are ordinarily cyclic hydrocarbons in commercial practice, either naphthenic or aromatic but usually aromatic. Important commercial sources of the additives are in particular processes of the synthetic oil industry, and in special processes (usually catalytic) applied in natural petroleum refining.

Available intelligence on the Soviet synthetic oil industry is not considered to be complete enough for correlation in the present survey of potentials. For derivation of the avgas additives from petroleum, an important prevailing process in modern practice has been a type of catalytic reforming called Hydroforming. Catalytic alkylation of benzene is also an important commercial source of the additives, where the benzene is derived either from petroleum or from synthetic oil processing. Current intelligence provides practically no information with respect to the possible Soviet applications of Hydroforming and benzene alkylation. Intelligence is further extremely fragmentary in regard to the reported Soviet use of, and experimentation with, special thermal reforming processes possibly producing aromatic additives from petroleum naphthas. The latter are respectively known as the Pyrolysis and Dubrovai processes, and they both appear to be very inefficient in results.

Although intelligence estimates have been made of possible Soviet avgas production through fiscal 1953, these estimates are not extended to cover the potentials possible upon completion of the major features of the high octane rating program. The preceding comparison of potential yields is made upon the basis of ultimate yields of aviation gasoline: comparing yields as percentages of the crude with the estimated 1950 data taken as the basis of comparison, the hypothetical high octane rating program provides for a larger production increase in the potential avgas stocks than in the total for all gasoline stocks. Referring to the estimated and nominal potential for avgas stock production in 1950, the high octane rating program brings this potential to a hypothetical crude percentage value in the USSR, about equivalent to the present corresponding value in the US. The latter was a value approximately attained during actual World War II operations in the US.

Even assuming that the Soviets have facilities to utilize the hypothetically expanded avgas yields in question, the utilization of the full potential would presumably occur only in time of total war, similarly as in the US. The high octane rating program facilities would presumably otherwise have utilization to a larger extent for the production of motor gasolines of still better quality, in lieu of the aviation gasolines that could be produced if required. Further technical considerations show that the preceding general comparison of yield potentials would still be applicable in this case, except that the high octane rating facilities might have an overall capacity to convert a somewhat larger percentage of crude into potential gasoline stocks.

1. Purpose of the Analysis.

Technical data and available intelligence are correlated in this survey to determine what might be a logical and advantageous program for the construction of new refining facilities to obtain high octane ratings in the USSR. In view of the limited availability of detailed technical data on Soviet oil stocks, the application of engineering factors is in large part idealized for this purpose. Considerations necessarily become theoretical and generalized where definite intelligence is fragmentary or lacking. It is possible, however, to indicate optimum locations where catalytic and other units of designated size and type appear to be plausible and practical. Although the available intelligence reveals few definite facts in regard to the actual Soviet refinery construction programs, it is known that the Soviets are currently giving much attention to the theories of catalytic refining. Conclusions as to an optimum program are here developed from a condensed critical survey of the economy, applicabilities, and limitations of modern refinery practices, and of the related indications, probabilities, and possibilities in the USSR.

2. Basis of the Study.

The present study assumes that future Soviet refinery construction will attain a total relative capacity for catalytic conversion at least compatible with what

presently exists in the US. It is noted, however, that this trend is not formally established as a prevailing factor in the actual Soviet plans. The present study merely resolves as an estimate of practible results if the trend does prevail. This trend is one of two distinct and possible alternates that might be followed, depending upon the considerations listed below.

a. For handling cracking charge stock ordinarily available in a given quantity of crude oil, the steel requirement is greater for an optimum combination of catalytic and thermal cracking facilities than it is for thermal cracking facilities alone.

b. Compared to thermal cracking the optimum combination of catalytic and thermal cracking gives higher antiknock rating and better quality in the average gasoline. By typical processing of a typical crude the optimum combination also produces more total gasoline as percentage of the crude. For the USSR processing this potential increase is estimated to be about 6.5 percent by weight, or about 8.2 percent by volume.

c. If reasonably good prospects exist for increasing crude production by making use of more steel, however, and if the supply of steel is limited in a given area of operation, the maximum yields of gasoline and other light distillates usually result by applying the steel to increase crude production and non-catalytic refining capacity in balance. By the alternate use of the steel for a lesser increase in crude production with new catalytic and thermal cracking facilities installed to process the increase, the total increase in gasoline yield

is generally less although the gasoline is of better quality and is a larger percentage of the crude processed. Stock and yield correlations such as these probably apply in the USSR.

While many intelligence reports show evidence of Soviet interest in oil cracking and other types of catalytic conversion, available data on Soviet motor gasoline specifications do not necessarily indicate anticipation of better quality due to expanded catalytic cracking. Contradictions thus result with respect to possible plans, and the present analysis is one phase of a general study of the problem.

A variety of correlations enter into the conclusions here developed. Emphasis is placed upon catalytic refining potentials, and among the basic considerations the most important pertain to the following data.

a. Available intelligence with respect to catalytic conversion plants either existing, or very probably in immediate prospect, in the USSR. Facilities of this sort include cracking, reforming, and gas reversion units.

b. A condensed review of modern catalytic processes so as to select the types probably the most advantageous for Soviet purposes. From the realistic standpoint, the selected types must come within the apparent Soviet capabilities for construction and operation.

c. Systems of generalized yield factors in all of the refinery processing assumed for the Soviets. These are factors referred to the average Soviet oil stocks as indicated by the best available data.

d. Availability of crude oils to yield charge stocks for catalytic refining. As indicated by analysis of the basic catalytic processes suitable for Soviet requirements, it appears that the Soviets primarily need the fundamental types used to crack virgin gas oils. Large gas oil contents are characteristic in the USSR crudes.

e. Availability of straight run avgas base stock as derived from crude oil. This base stock is practically essential for bulk in high octane aviation blends in modern practice. It is indicated that the Soviets have primary interest in catalytic processes because of the potential yields of catalytic base stocks suitable for such blends.

f. Existing and potential crude distillation facilities. The crude distillation would be required for the fractionation of crude oil, to prepare the virgin gas oils for charge to catalytic cracking on the one hand and the straight run base for aviation gasoline blends on the other.

g. Existing and potential thermal cracking facilities. In order to realize practicable benefits from catalytic cracking, thermal cracking is usually required to further process the refractory catalytic gas oil typically produced as the liquid residue.

h. Idealized refining balances for the processing of Soviet crude oil production. Soviet requirements in this respect relate to a minimum yield of residue fuel oils so as to obtain maximum yields of gasolines and other distillates. The special emphasis then resolves upon maximum yields of high octane aviation gasoline blend stocks.

i. Optimum sites for catalytic conversion plants. Site selections result from a correlation of charge and blend stock availabilities, existing refining facilities, and distribution centers.

5. Soviet Oil Stock Availability and Installed Refining Facilities in 1950.

Table 1, Appendix I, shows basic data directly related to the catalytic process potentials. These data include estimates (1950) of a. crude production, b. straight run gasoline availability, and c. charge capacities in the existing non-catalytic refining facilities. In these data the crude productions and charge capacities are based upon two papers included in this report on Petroleum in the Soviet Bloc, entitled Production and Exploration of Petroleum in the USSR, and Refining of Petroleum in the USSR. The straight run gasoline availabilities resolve as broad generalizations based upon available analytical data for Soviet crude oils. 1/ 2/ 3/ 4/ 5/ 6/ 7/*

Existing non-catalytic refining facilities are shown to be concentrated in thirty-one particular city areas together with three areas of more general extent with the available intelligence considered to be inadequate for firm designation of particular sites in the latter areas. The indicated facilities are usually situated for potential service to major oil productive areas. Major exceptions are evident, however, and most of these are covered by the footnotes to Table 1.

If only the UOP polymerization and hydrogenation installations, and in addition the Gurev and Orsk Houdry and alkylation systems, all summarized in the paper entitled Refining of Petroleum in the USSR, are assumed to comprise the catalytic conversion facilities operating in 1950, the total catalytic conversion capacity was in that year as follows for the USSR:

* Footnote references in arabic numerals are to sources listed in the Annex.

Estimated USSR Catalytic Process Capacity	Metric Tons/Year
Cracking case charge to Houdry systems (Gurev, Orsk)	730,741
Alkylate product from alkylation units (Gurev, Orsk)	89,524
Iso-octane product from UOP installed units (Groszny, Saratov, Ufa)	80,000
Total Capacity*	900,265

*These values conform to the conventions adopted in most engineering reports. For the fundamental units in natural petroleum processing, the capacity ratings are conventionally reported as follows: for the crude distillation, ordinary cracking, and ordinary reforming units, the rating is in terms of charge; for the reversion and supplementary process units, the rating is in terms of reacted product.

The resulting 1950 USSR data compare with the corresponding US values as shown below. Processing capacities and crude production may be presumed to be in sustained balance in the US, and the deficiency of catalytic conversion capacity is clearly indicated in the USSR.

	US	USSR
1950 crude productions (thousands of metric tons)	270,248	37,500
1950 annual capacity ratios:	1.000	1.000
Crude production capacity	1.192	1.198
Crude distillations capacity	0.395	0.461
Thermal conversion capacity	0.316	0.025
Catalytic conversion capacity	0.711	0.486
Total conversion capacity		

4. General Survey of Conversion Refining Techniques for Soviet Use.

In refinery operations resulting in a chemical change or chemical conversion in the molecular sturctures of the petroleum hydrocarbon compounds, the natural objectives pertain to the stocks produced in the gasoline boiling range. The

conversion processes are normally applied to increase the quantity of the gasoline fraction, or otherwise to improve gasoline quality characteristics such as the octane (i.e., antiknock) rating. These conversion processes are distinguished from the ordinary distillation and extraction operations which cause no chemical change. The latter merely serve to fractionate, or separate, the hydrocarbon compounds according to specified ranges in physical and/or chemical properties. In the most common practice, these specified ranges are defined by minimum and maximum boiling points. True conversion is further distinguished from the simple chemical treating techniques, directly applied for removal or modification of impurities (typically sulfur-derivative and gum-forming impurities).

Conversion reactions may take place chiefly because of thermal or high temperature effects, or they may be promoted by the controlling influence of catalysts. Thermal effects are in general supplementary where catalysts are predominant, and extraneous catalysis due to container materials is on the other hand seldom absent in typical thermal conversions. Catalytic conversion is, however, more selective and generally much more effective when applicable for specified results. As compared to the wide and extensive application of thermal and subsequently catalytic conversion refining in the US, Russia was late in adapting the techniques. In regard to catalytic installations, the Soviets appear to be currently restricted to capacities relatively minor, all constructed during the past decade or so. It is probable that the Soviets are endeavoring to expand the latter capacities.

It is probable that these efforts are having, and will have, realistic results.

It is here convenient to classify hydrocarbon conversion reactions in three principal types. These three type reactions are generally concurrent in any specific conversion process, with one or another of the types predominating. True cracking is the type involving pyrolytic molecular decomposition of heavier and higher boiling hydrocarbons, producing lighter and lower boiling hydrocarbons. Cracking is in this sense distinct from true reforming, a second principal type of conversion reaction and one featured by molecular rearrangements in the hydrocarbons without essential or major shift in boiling point range. The chief benefit of reforming is in quality improvement, especially in the octane rating of gasoline stocks. It is noted that mild processes of hydrogenation and dehydrogenation may be considered to result in a variety of reforming, whereas destructive hydrogenation, chiefly applied to tar and residual stocks, results in a variety of cracking. The third principal type of conversion reaction is reversion, consisting of the molecular combination of lighter and lower boiling hydrocarbons, producing heavier and higher boiling hydrocarbons. The last type of process reverses the result of cracking, and it is a process of gas reversion in most commercial applications since the gaseous state is usually normal for one or more of the reacting hydrocarbons.

Existing Soviet thermal conversion facilities appear to be mostly for cracking, and the installations of this sort appear to be relatively extensive. The Soviet thermal cracking apparatus constitutes one type

of equipment for the essential or primary type of conversion: cracking serves to increase the yields of gasoline and other light distillates obtainable from natural petroleum. Catalytic and thermal cracking have, however, become supplementary processes in modern refining technology, together augmenting the total light distillate yields as compared to the use of either form of cracking alone. Catalytically cracked gasoline base stocks have become practically essential in modern high-octane avgas blends. In the aviation alkylate produced by the usual alkylation types of gas reversion, another important stock is obtained for such blends.

5. Survey of Catalytic Cracking Techniques for Soviet Use.

It is assumed that the Soviets have continued and will continue with a program of completing and constructing Houdry Catalytic systems. The basic premise is that the Soviets have capabilities for manufacture of the Houdry process equipment, and for installation and operation of it. Useful patterns exist in the comprehensive process and engineering designs furnished to the Soviets for the four lend-lease refineries, with equipment for two of the latter plants, at Gurev and Orsk, completely supplied and in a large part installed under US supervision. While there is no firm data on Soviet programs for the construction of catalytic refining units, active Soviet interest in these refining processes is directly indicated and is further evident in numerous reports of Soviet research work. 2/ 11/ Intensified Soviet interest in the techniques is logical, and it is reasonable to assume that the Soviets have been (and possibly still are) engaged in completing the lend-lease Houdry Catalytic Cracking plants.

The Gurev and Orsk Houdry plants are here assumed to have been placed on stream and to have been in full operation during all of 1950. Prior to termination of the Soviet lend-lease arrangement in 1946, the Kuibyshev and Krasnovodsk Houdry plants were completely designed, and Houdry equipment was in part supplied for the Kuibyshev project. In the US during wartime an estimate of 30 months was applied for the completion time of a catalytic cracking plant, but it is probable that some additional time would be required by the Soviets. It is probable, however, that the Soviets will have had time to fabricate equipment and install the Kuibyshev and Krasnovodsk Houdry plants at least by the end of 1952. The Krasnovodsk plant was not as far advanced as the Kuibyshev plant in 1946, but since the Krasnovodsk construction would be in a milder climate compared to the somewhat severe weather conditions often prevailing at Kuibyshev, and would be furthermore just across the Caspian Sea from the important oil region at Baku, it is probable that high priority has also been given to this Krasnovodsk project.

The Badger lend-lease refinery designs were based upon technical characteristics of typical USSR oil stocks. For the charge and product stocks the material and volumetric data were mostly calculated as pounds per hour (#/hr) and barrels per stream day. These data applied various service (i.e., operation time) factors for the different units on stream. 5/ In the diagrams of Appendix D, the Badger data are completely recast into equivalent values for the present intelligence study, in terms of metric tons per year and barrels per calendar day (BPCD). Tables 2 to 8, Appendix B, show projected percentage production upon basis of complete recovery of the C_4/ stock (i.e., 4-carbon-atom and heavier hydrocarbons).

Tables 7 and 8, Appendix B, show projected yields as percentages on charge, considering the stabilization and fractionation efficiencies in the gas recovery systems. Tables 9 and 10, Appendix B, resolve the Badger design data for hypothetical standard systems of the Houdry and alkylation types, operating upon what appear to be Soviet charge stocks with average characteristics.

Average Soviet stock characteristics are derived for the purpose of

the present study by overall correlation of the technical data contained in numerous intelligence reports, both classified and unclassified. In the individual reports, the available data on Soviet oil characteristics are mostly fragmentary. By technical analysis of a compilation of the available data in total, however, reasonably consistent Soviet oil stocks are revealed as typical. Certain intelligence reports contain the technical data in some detail, with various degrees of completeness in covering the different Soviet oils. 1/ 2/ 3/ 4/ 5/

Six types of catalytic cracking processes are important commercially. These are available to the Soviets, and they bear proprietary names as follows: Houdry, Fluid, Thermofor, Cycloversion, Houdriflow, and Suspersoid. The six processes all utilize hydrous aluminum silicate clay types of catalysts, either natural or synthetic.

An estimate of potentials for Soviet use depends upon a critical general review of the essential technology. The Soviets would probably compare salient features of the six processes, in outline as follows.

In the first four of the catalytic cracking processes or systems above listed (Houdry, Fluid, Thermofor, and Cycloversion) the totals of liquid yield vary but little when derived by a given overall conversion of a suitable hydrocarbon charge. The respective yields of different products then vary within rather narrow limits so as to be generally compensating, even though the limited variations may represent large ultimate quantity differences while quality variations may be

likewise important factors to consider. Density and quality of suitable feed has little effect upon the yields in these four systems. The lighter and lower boiling charges do tend to give, however, a slightly higher yield of gasoline, with the gasoline more aromatic, slightly higher in octane rating, and slightly lower in boiling point range. While a physical property function called the characterization factor may serve as an index to the convertibility of hydrocarbon feed stock, this factor is not in itself sensitive with respect to feeds otherwise suitable for the four catalytic cracking processes.

All six catalytic cracking processes are effective upon aliphatic (open-chain, or acyclic) hydrocarbons, but the usual high-boiling charge to them is complex and of mixed base. The processes typically yield catalytic gasolines high in the aromatic type of cyclic (i.e., carbocyclic) hydrocarbons. Compared to thermally converted gasoline products, these catalytic gasolines have higher octane rating and are more susceptible to the knock inhibiting effects of TEL. The "cat" crackers all cause some reduction in sulfur; they thus eliminate some of the knock-producing, TEL susceptibility-reducing, and often corrosive effects of sulfur derivatives in the stocks. All six catalytic cracking processes likewise result in carbon reduction and usually net dehydrogenation, with carbon deposited as coke upon the catalyst. Due to excessive deposition of carbon upon the catalyst, the six processes are not generally applicable to the heavy oil residues which contain asphalt or tar components.

Charge stocks are usually virgin gas oils boiling below 750 °F, 22 °API (7.68 #/gal) to 35 °API (7.08 #/gal) in density. As compared to the fixed-bed catalyst processes such as the Houdry, the circulating-bed catalyst processes such as the Thermofor will, however, accomodate higher carbon deposition due to heavier gas oil charge, or with a given charge, due to a higher degree of conversion. Among the six techniques, the T.C.C. (Thermofor Catalytic Cracking) process is the only one that will actually handle residue charge without prohibitive loss of efficiency.

The six processes normally yield catalytic gas oil residues boiling above the gasoline fractions. This gas oil residue is about equivalent to the gas oil charge in density. The percentage conversion in the attendant process is conventionally given as 100 minus the volume percent of the residue or recycle gas oil, referred to the charge. It is noted that in comparison to virgin or straight-run stocks, the various types of converted (i.e., cracked or reformed) gas oil and residue fractions are generally more refractory. The latter tend to be more resistant to further cracking, and they result in more coke deposition upon being catalytically cracked. Because of this increased coke deposit, recycle or conversion stocks of these types are not usually charged as fresh feed to the catalytic cracking processes. The catalytic processes are for the same reason typically although by no means always operated with the fresh feed sent once-through without recycling of the residue catalytic gas oil. If the recycle ratio is high enough the net yield of catalytic gas oil may be negligible in catalytic cracking. Although the recycling

generally results in higher relative yields of higher octane gasoline with increase in the conversion percentage, the recycling also [illegible] the fresh feed charge capacities in [illegible] thermal cracking [illegible] most cases, however, readily adaptable to the catalytic gas oil [illegible] giving percentage yields about equal to those obtainable by thermal cracking of the virgin stock originally charged to the catalysis. It is here assumed that the Soviets would not provide additional catalytic cracking capacity for recycling, but would utilize the large existing thermal cracking capacity plus relatively small additions to this as required.

The Houdry, Cycloversion, and Suspensoid processes use catalysts in fixed beds. Cycloversion and Suspensoid cracking result in [illegible] advanced degrees or depths of reaction in the overall process, and they produce gasolines lower in octane rating compared to other catalytic gasolines. The latter two processes use relatively simple equipment and they are apparently more suitable for catalytic reforming [illegible] than cracking. Cycloversion is especially effective with respect to desulfurization. The Suspensoid process applies a comparatively new technique developed in Canada, and it uses a cheap catalyst (spent bleaching oil clay). It differs from the other five catalytic cracking processes in that the catalyst is sent once-through, filtered out and not regenerated. The Houdry Catalytic Cracking process was probably the first commercially successful technique for catalytic cracking. It is a process utilizing elaborate reactor cases of complex design, equipped with a complicated array of automatic electric controls and electric motor valves. Although the Houdry cracking cases are operated individually, batteries or series of the cases provide for overall continuous flow the

to alternating sequences of the reaction, purge, and regeneration cycles among the cases. Houdry cracking is dependent upon complete vaporization of case charge and case products.

The Fluid, Thermofor, and Houdriflow processes provide for a degree of simplicity with true continuous operation, inasmuch as the catalyst beds circulate in a cycle through the zone of cracking reaction, and then the zone of regeneration where the carbon residue is burned off from the catalyst. In the Fluid system inlet charge oil vapor sweeps powdered catalyst into the reaction zone, and regeneration air sweeps the spent catalyst into the regeneration zone. In the T.C.C. system, mechanical elevators circulate the catalyst. In the Houdriflow system, a technique of recent origin, and apparently a system incorporating features of both the Houdry and Fluid processes, regenerator outlet flue gas is used for lifting the catalyst.

The circulating catalyst cracking processes are in general simpler in both equipment and operation, compared to the intricate Houdry process. The Fluid and T.C.C. processes were World War II developments for high yields of high-octane gasolines. These latter two processes have effectively supplanted the Houdry in the current US installation activities. The Fluid process preceded the T.C.C. in date of original development, and the former is probably the catalytic cracking technique most widely applied in non-Communist countries today, in refineries under construction as well as in existing plants. It is noted that all six commercial catalytic cracking processes are effective in certain respects for the catalytic reforming of a

gasoline or heavy naphtha feed, particularly to cause desulfurization, isomerization, and dehydrogenation with octane number increase. However, the silica-alumina catalyst probably has limited effect in the actual cyclization of initial charge stock acyclics. For practible production of modern high-octane avgas base by the Houdry process, a second stage may be needed as shown in the Badger design data for Soviet Houdry systems. The second Houdry stage serves for catalytic reforming, charging catalytic cracked gasoline produced in the first stage. Similar two stage operation may likewise be desirable for corresponding results by the T.C.C. and fluid processes.

(Once-through processing without recycle is involved in the separate stages just discussed.)

Early in 1951 in the US at least fifty-seven separate Fluid Catalytic Cracking systems were in existence. Corresponding numbers were 20 for the T.C.C., five for the Houdriflow, 17 for the Houdry, and one for the Cycloversion systems. At least one Suspensoid plant is currently in operation in Canada. A Fluid plant of large capacity has been installed at the Abadan refinery in Iran, in the Middle East. In Western Europe with US assistance, several Fluid and a lesser number of T.C.C. plants have been installed, or are being installed. Of these six catalytic cracking processes, the leading Fluid technique appears to be the one most suitable for Soviet purposes. Furthermore, it is apparent that the Soviet technical intelligence agents could have almost as ready access in covert fashion to the Fluid process designs and plant patterns in non-Communist areas, as they actually have in overt fashion to the Houdry process data and plants in the USSR.

While the Fluid and T.C.C. processes are not in any ultimate sense simple in either equipment or operation, it is believed that if the Soviets have actually become successful in duplicating the complex Houdry plants they could likewise become capable of projecting and constructing somewhat simpler but more effective plants for the Fluid process. It is not improbable that the Soviets have a program for construction of Fluid or very similar plants, and that this will take the place of Houdry construction programs upon completion of the Houdry projects supposedly now in progress. Although the T.C.C. process features a relatively slow moving bed of pelletized catalyst physically similar to the Houdry catalyst already in use in the USSR, and further produces results compatible with those obtained by the Fluid process where use is made of a more rapidly moving bed of a more finely divided catalyst, the Fluid is an earlier and more extensively applied technique offering certain incidental advantages for high-octane motor gasoline production.

Tables 11 and 12, Appendix B, show typical US technical literature data for Fluid cracking. By correlation of these with Houdry yields in the US and the USSR (cf. Table 9), the Fluid cracking yields of Table 13, Appendix B, are derived for an average Soviet gas oil.

Compared to the Houdry process the Fluid offers economy in plant construction and plant operation alike. The economy involves reduced requirements of intricate equipment, critical raw materials, utility commodities, and total labor. The Fluid process further gives definite relative yield benefits. The technique has taken the lead in non-Communist countries because of the various advantages. The Fluid

process is here assumed to be the Soviet selection even though the T.C.C. technique would cause no essential difference in results and might provide a somewhat simpler transition for the Soviets, starting with the Houdry.

At the same percentage conversions with similar charge stocks in once-through operations, the Houdry and Fluid systems give about the same yields in aviation base gasolines and in the total C_4- liquid recoveries. But where the Houdry system produces some refractory fuel

oil (polymer gas oil), the Fluid plants yield no residual not suitable for thermal cracking. Fluid units further attain the given percentage conversion with a lesser yield of C_4 gas (i.e., alkylation charge stock), and with a larger yield of high-octane motor naphtha (i.e., motor gasoline). In the generalized case it is also practicable from the standpoint of mechanical efficiency involving carbon deposit, for a somewhat higher percentage conversion to be obtained with the Fluid process in comparison to the Houdry (cf. Tables 9 and 13). Since higher conversion does not usually take all advantage of the fact that the Fluid units are capable of being operated with more carbon deposit upon the catalyst, the Fluid process charge can be a larger portion of a given crude in comparison to the optimum Houdry charge. Therefore from a given volume of crude oil, the Fluid and Houdry units are capable of ultimate yields of about the same quantities of alkylation charge stock as well as of recycle gas oil for thermal cracking. This is considering the operations to be once-plus retreating (i.e., second stage catalytic reforming) as required through, with the quantity of virgin gas oil charge and not percentage conversion/higher in the Fluid plants. Further in comparison to Houdry systems upon this basis, the Fluid units produce much larger separate quantities of aviation gasoline base, motor naphtha, and isopentane.

Table 14, Appendix B, tabulates general comparisons between Houdry and Fluid operations in terms of numerical results when the processes are applied to Soviet oil stocks.

6. Survey of Gas Reversion Techniques for Soviet Use.

In formulating an estimate of gas reversion potentials for Soviet use, it is necessary to consider purely technological correlations in somewhat more detail than is the case with cracking. Gas reversion is represented in modern refining processes of prime importance, serving for increase in the relative yields of gasoline stocks with special reference to high quality components. The feasibility and applicability of gas reversion depends in a large part upon various technical factors, however, and among these the following may be said to be basic for the present purpose: volatility or vapor pressure values in the liquid phase; availability of particular types of hydrocarbons in gases; isomerism and unsaturation in the molecular structures of the gaseous components and their reversion products; octane ratings of the gaseous components and their reversion products.

In cracking and reforming the conversion reactions yield relatively large volumes of excess gaseous hydrocarbons. In the typical case most of the refinery reject gas is constituted by cracked and reformed gases. High olefin contents feature the latter gases especially when the gases are of catalytic origin. The Soviets would presumably consider catalytic gas reversion processes for recovery of the reject gaseous stock in more useful (i.e., liquid) form in the gasoline blends, since the latter are the lightest and most volatile (i.e., lowest boiling) of the principal liquid products recovered in petroleum refining. In the usual ideal case before gas reversion, hydrocarbons in the refinery reject gas consist of all C_3 (3-carbon-atom hydrocarbons) and lighter stocks produced, plus the production of C_4 hydrocarbons

exceeding the quantities retainable in finished gasoline blends, or in a plus the effective total production of C_4 hydrocarbons if priority is to be given to subsequent gas reversion, before maximum retention in gasoline blends is made of the C_4 components not reacted in the gas reversion.

In general refinery operations the four-carbon hydrocarbon (i.e., C_4 stocks are the heaviest and least volatile (i.e., highest boiling) of the components normally rejected in net gas if the refining is efficient. In actual cases the C_4 and lighter hydrocarbon gases are essentially composed of the simplest (and lowest) members of the simplest homologous series, namely, the aliphatic paraffins and olefins, respectively the alkanes (saturates) and the alkenes (single double-bond unsaturates). The lowest paraffins also constitute the bulk of most common natural gas stocks.

Simple paraffin and olefin gases therefore predominate in the available gas reversion reactants except where special hydrocarbons (usually aromatics) are involved for special products (usually new aromatic hydrocarbons). In typical balanced refining operations the gasolines contain all C_4 or C_5 and heavier stocks, up to and including the heaviest or highest boiling hydrocarbons in the gasoline boiling point range. Within the maximum volatility (i.e., vapor pressure) limits normally specified, the ordinary gasolines can also retain in liquid solution a portion but commonly not all of the C_4 stock typically produced. If the volatility stabilization of the gasolines is ideal, maximum relative liquid yield is obtained by selective

retention of the least volatile fraction of the C_4 stock available. Normal butane (i.e., the simplest of the C_4 paraffins) is the least volatile of the C_4 paraffins and olefins, and in a given refinery balance with ideal gasoline stabilization, the actual refinery production of the n-butane may or may not be in excess of the allowable final retention in gasolines.

In a given and efficient refinery balance, particularly if gas reversions are applied to react at least all available butanes, thus also reacting isobutane and possibly some n-butane if there are alkylation types of gas reversion, there is often an actual insufficiency of the refinery C_4 hydrocarbons then remaining for maximum vapor pressures, and therefore maximum yields, in the finished gasoline blends. If such a deficiency does result, practical benefits are commonly derived by importing C_4 or other volatile stocks, with common natural gas liquids including the usual natural gasolines as examples, to be used for the finishing of gasoline blends. Or, small quantities of propane may be used in these gasolines, if the maximum vapor pressures do not result from the other stocks conveniently available. Propane has a clear octane number of about 125, but in the liquid state at 100 °F, its vapor pressure is about 186 psia.

The important gas reversion processes consist of alkylation and polymerization. In commercial applications of these techniques, the reactions depend upon breaking the multiple bonds between carbon atoms of unsaturated aliphatics. The unsaturates are nearly always olefins in practice. Alkylation is the union of an olefin with either a paraffin or an aromatic. Typical commercial alkylation combines a volatile or gaseous olefin (commonly C_4) with a similarly gaseous paraffin (commonly C_4), producing liquid alkylate

or gasoline stock, theoretically paraffinic and usually high in its octane rating because of isomerism in these paraffinic products (commonly [illegible] octanes in fact). Or, the gaseous olefin is combined with benzene in special applications, yielding a low freezing point, high-octane aromatic liquid in the gasoline boiling range. Typical commercial polymerization combines two or more molecules of gaseous olefins, producing an olefinic poly gasoline with moderately high octane rating.

The Soviets already have acid catalyst types of alkylation and polymerization plants. Similar acid catalyst alkylation units will probably be primary in Soviet refinery construction programs, in correlation with catalytic cracking systems. The principal application of this catalytic alkylation is for the union of isobutane with butenes, producing high-octane alkylates. In a program to increase the yields of avgas and other gasolines, it would be logical for the Soviets to associate alkylation with Fluid cracking similarly as with the Houdry systems.

In the usual petroleum processing balance to obtain maximum yields of high octane gasolines including avgas, the optimum aviation alkylate is the stock chiefly produced by the chemical union between isobutene (an isomeric four-carbon olefin) and isobutane (the isomeric four-carbon paraffin). A typical gas reversion process thus occurs with the components normally gaseous. The resulting alkylates in this case are liquids containing up to 90 volume percent of octanes (eight-carbon paraffins) includ-

ing 2,2,4-trimethylpentane. The latter is the reference isooctane with 100 octane number, and it is one of the three isomeric octanes theoretically produced by the chemical combination of isobutane with isobutane.

In actual alkylation practice, however, the common charge is a mixture with all varieties of the butanes (four-carbon paraffins) and butenes (four-carbon olefins) present and predominating. The normal (straight chain) butane is mostly inert while the chief reactions typically yield iso octanes according to theory, by the respective combinations of isobutane with iso-butene and both normal butenes (butene-1 and butene-2). The resulting alkylates are still sufficient for the typical processing balance as stated, inasmuch as the alkylates have high octane rating (the aviation alkylates have octane blend values exceeding 100). High-octane liquid recovery is thus made of volatile stocks too high in vapor pressure for large percentage inclusions in gasoline (in the five possible butanes and butenes at 100 °F, the vapor pressures range from about 50 psia to about 75 psia). The maximum possible reversion liquid recovery is also obtained from the available reactive gaseous olefins. (Paraffins are in general much more prevalent in petroleum vapors and natural gas, in comparison to olefins. Alkylation reacts an olefin with a paraffin, whereas polymerization usually reacts olefins only).

Commercial reversion processes are both thermal and catalytic in type. The important commercial reversion processes are nearly always gas reversion operations in regard to at least some of the reactant hydrocarbons, as

already noted. Catalytic reversions are much more important than the thermal types in practice. As is generally true where thermal and catalytic conversions are corresponding processes, the thermal reversions require higher temperatures and especially higher pressures (thermal alkylation is carried on up to 5,000 psig, and thermal polymerization is carried on up to 2,000 psig).

The more common and optimal alkylation processes are almost invariably the catalytic types using anhydrous acid catalysts, either sulfuric (i.e., hydrogen sulfate) or hydrofluoric (i.e., hydrogen fluoride). These acid alkylation reactions are generally restricted to the four-carbon and lighter olefins, and to the isomeric rather than normal paraffins. Thermal alkylation has more effect upon the lighter olefins (ethene and propene), and will further react all forms of paraffins. HF alkylation is a more recent development and has proved to be more efficient as compared to the H_2SO_4 types. One reason is the enormous recycle ratio required for paraffins relative to olefins in the latter process, whereas the ratio can be satisfactorily held down to a value of six in the former. (While an aqueous solution of HF forms the powerful and dangerous hydrofluoric acid that is reactive to siliceous materials such as glass as well as most metals, anhydrous HF is relatively inert to ordinary carbon steel equipment.)

H_2SO_4 alkylation units were proposed under lend-lease and were furnished to the USSR as previously stated. Intelligence analyses have assumed

that the Soviets have continued to construct H_2SO_4 alkylation units similar as they have Houdry systems. There is, on the other hand, no contrailing reason to believe that the Soviets have ignored the efficiency benefits of the HF process, and have been unable to duplicate the numerous HF plants now present in Western countries. This speculative matter is, however, of small overall importance in the present study. HF and H_2SO_4 alkylation units give about the same potentials, and construction of H_2SO_4 units may be assumed (cf. Table 10, Appendix B).

Other important catalytic alkylation processes are the techniques for benzene alkylation as previously described. These benzene alkylation processes yield low freezing point aromatic hydrocarbons with extremely high octane ratings. The Friedel-Crafts reaction with aluminum chloride catalyst is adapted in one process, serving for the alkylation of benzene with the C_2 olefin, ethene. Theoretically thus produced is ethyl benzene, an aromatic hydrocarbon that may be dehydrogenated to form styrene, the aromatic derivative hydrocarbon that is one of the two reactants used in the synthesis of Buna S rubber. A second process uses phosphoric acid catalyst for the alkylation of benzene with the C_3 olefin, propene. The latter process theoretically yields another aromatic hydrocarbon, cumene. Butyl benzenes result from the catalytic alkylation of benzene with butenes. Alkyl benzenes such as these are powerfully effective as high octane additives for avgas. The Soviets possibly now apply, and might well attach much importance to

the catalytic benzene alkylation processes and even give primary status to them. While benzene is itself the simplest of the aromatic homologues and has moderate volatility and high octane rating, it has limited use in avgas due to its high freezing point (41 °F).

Thermal alkylation is not comparable with the catalytic techniques in efficiency. Without equivalent catalytic processes available, thermal methods are, however, sometimes applied to alkylate isobutane with ethene and propene. With ethene, neohexane (2,2-dimethyl butane) is one of two isomeric hexanes (C_6 paraffins) theoretically produced. With propene, triptane (2,2,3-trimethyl butane) is one of four isomeric heptanes (C_7 paraffins) theoretically produced. The alkylation with propene is very difficult. Neohexane and triptane are both effective as high octane blending additives in avgas. Triptane is the more powerful, ranking with ethyl benzene, but due to the inefficiency of the thermal operations the Soviets will probably favor catalytic processes for production of high octane avgas additives.

Commercial polymerization involves a process of polymerization in the technical chemical sense. That is to say, the basic chemical reaction forms olefin polymers by the direct union of two or more molecules of lighter olefins. A dimer is the product if two lighter molecules unite, a trimer is the product if three unite, and so on. The polymer is mixed if the united lighter molecules are unlike, and it is a copolymer if the united lighter molecules are alike. Thermal polymerization tends to produce dimers while the catalytic operations may produce higher polymers in addi-

tion to dimers. Polymerization of a mixed gaseous charge produces a mixed component olefinic poly gasoline, generally with octane rating [illegible] at a lower level compared to the commercial alkylates described above. A catalytic hydrogenation type of reforming is used for the commercial conversion of poly gasoline to a paraffinic gasoline, with the paraffinic constituents (i.e., hydropolymers) isomeric and very high in octane rating if the olefinic polymers are isomeric.

The catalytic polymerization processes are more efficient and more widely applied than the thermal types. Commercial catalytic polymerization techniques use acid types of catalysts, consisting of phosphoric (orthophosphoric) and sulfuric acids. The phosphoric acid process normally yields a mixture of dimers and trimers although it may be controlled so that dimers predominate. The sulfuric acid process is less efficient and less generally used. It typically yields a mixture of higher polymers although it is likewise subject to control for emphasis upon dimers.

The Soviets are known to have catalytic polymerization installations of the phosphoric acid type, plus a plant for catalytic hydrogenation using nickel catalyst, where the latter is the commercial process apparatus used to convert the polymer products to hydropolymers. It is reported that the Soviet polymerization units are largely used for the selective production of a codimer isooctene from isobutene, subsequently hydrogenated to yield the hydrocodimer, reference isooctane. Phosphoric acid catalysis is fairly satisfactory for this codimer yield; the sulfuric acid process is, however,

supposed to cause more selective although less complete reversion.

While thermal alkylation and polymerization would not seem to be very desirable in the Soviet plans because of inefficiency of the processes, phosphoric acid catalytic polymerization would probably be included, but with secondary rather than primary priority. Although nickel catalyst hydrogenation plants might also be projected to yield high octane hydropolymers (typically isooctane hydrocopolymers), using polymerization product as charge material, catalytic alkylation would probably be more favored for the production of high octane blend stock (i.e., isooctane alkylate). The principal use of polymerization units would probably be to produce poly gasoline for mogas blends.

7. Survey of Reforming Techniques for Soviet Use.

Isoparaffins are generally more reactive to alkylation than are the normal forms, especially when the process is catalytic. Alkylation (i.e., typically thermal alkylation) rather than polymerization is, however, the means for direct gas reversion of normal paraffins. The normal paraffins constitute large portions of the net and final refinery gases. These gaseous normal paraffins ordinarily consist of the three lowest homologues, i.e., the typical dry fuel gas components C_1 (methane), C_2 (ethane), and C_3 (propane). N-butane ($n\text{-}C_4$) may be present, but it is not usually in much excess. Significant excess of $n\text{-}C_4$ gas would not be expected in an efficient refinery balance.

Commercial dehydrogenation types of thermal and catalytic reforming are applicable to the normal paraffins above C_4, converting each of them

into an olefin without change in the formula number of carbon atoms. A commercial isomerization type of catalytic reforming is also applicable for derivation of an isoparaffin from the corresponding normal form. The C_2, C_3 and n-C_4 paraffins are thus respectively sources of the three lowest possible olefin types, namely, C_2 (ethene), C_3 (propene), and C_4 (butenes). Isobutane (i-C_4) is also obtainable by isomerization of n-C_4.

Chrome-alumina catalyst is used for the catalytic dehydrogenation of paraffin hydrocarbons, producing unsaturation in the aliphatic hydrocarbon molecules. The catalyst consists of a mixture of chromic and aluminum oxides, with the chromic oxide supported upon the alumina mineral earth substance, bauxite. The process in question is representative of a number of catalytic techniques using metallic oxide catalysts, commercially applied for net dehydrogenation of non-residual hydrocarbon charges. The same techniques also serve for the destructive hydrogenation of heavy residual oils and hydrocarbon tars. Metallic oxide catalysis of this general type appears to involve both dehydrogenation and hydrogenation, depending upon the hydrocarbon reactants. Hydroforming Catalytic Reforming is a variation of much commercial significance, using molybdenum-alumina catalyst. Hydroforming specifically yields aromatic hydrocarbons by net dehydrogenation of less unsaturated hydrocarbons. Typically subjected to Hydroforming are the carbocyclic naphthenes (i.e., cycloparaffins or cycloalkanes), and the acyclic (aliphatic) olefins and paraffins, contained in naphthas.

Applied to butanes, the chrome-alumina catalytic dehydrogenation yields butenes in the first stage, and by further dehydrogenation the product is butadiene. The latter is a diolefin (i.e., an unsaturated aliphatic hydrocarbon with two double bonds), and it is the second of the two reactants used in the synthesis of Buna S rubber. A variation of this same technique results in the dehydrogenation of ethyl benzene to styrene, the other reactant for Buna S rubber.

By thermal dehydrogenation, a paraffin is pyrolytically decomposed or dissociated into an equilibrium mixture of hydrogen and the corresponding olefin, so that the latter may be separated or absorbed from the zone of reaction. Similarly as in most cases where thermal and catalytic processes serve similar purposes, this thermal dehydrogenation is much less efficient than the chrome-alumina catalysis, where the conversion of butanes to butenes may exceed 90%. The thermal dehydrogenation equipment is relatively simple, however, and the technique has been especially applied to mixed gaseous charge where the product olefins are charged to subsequent gas reversion, with the gas reversion process also thermal and therefore likewise an operation making use of relatively simple equipment.

Commercial catalytic isomerization of n-butane constitutes one of the many adaptations of the Friedel-Crafts type of catalysis using aluminum chloride catalyst. With a naphtha charge chiefly constituted by normal paraffins, the process yields high octane isomate gasoline featured by its content of the resultant isoparaffins.

While the dehydrogenation and isomerization processes may be used as above described, to convert volatile normal paraffins into olefins and isoparaffins so as to produce potential charge stocks for gas reversion, they are here described only as potential techniques, rather than as process types that would rate probable priority in Soviet refinery expansion programs. Typical refinery balances leave little stock other than ethane and propane as charge for these processes, if the operations are to serve merely for increased liquid recovery from reject gases. Ethane and propane charge would be applicable for the dehydrogenation operations only, and would yield the ethene and propene olefins that are of little potential value except for special use, as in the selective alkylation of benzene. In actual commercial practice, the two process types are restricted to special use.

The thermal dehydrogenation operation is typically integrated with thermal polymerization when the latter process is applied. But in most cases if liquid recovery is to be made of C_3 and lighter stocks remaining in the refinery reject gases, with these stocks mostly constituted by the C_1, C_2, and C_3 normal paraffins recovery of liquid propane is the more practicable ultimate operation as compared to dehydrogenation followed by gas reversion of the resulting C_2 and C_3 olefins. Liquid mixtures of butanes with propane constitute most of the valuable commercial liquid petroleum gases (L.P.G.). Together with natural gasoline, cycle products, and retrograde condensate, L.P.G. comprise the natural gas liquids recovered from wet common natural gas.

In comparison to attention given to new facilities for catalytic cracking, it is improbable that the Soviets will give as much priority to an immediate program

for increased general reforming of the naphtha stocks normally contained in gasolines. Although general reforming of this type may result in much improvement of special qualities such as octane rating, the technique usually results in a decreased yield of gasoline and also of total liquid products. This is true even if those liquid products include all gas reversion stock obtained from the excess reformed gases.

New catalytic cracking is definitely required if the USSR gasoline yields are to approach the high percentages of the crude obtainable in modern refinery practices. Catalytic cracking would produce high avgas base stock in sufficiency for the apparent USSR potentials, requiring no general catalytic reforming except where the latter is in a second stage following cracking, as in the Houdry Catalytic system. Thermal cracking and reforming do not ordinarily produce avgas stock except insofar as they yield alkylation charge. Expanded catalytic and thermal reforming capacity in general use would not appear to be otherwise needed in an immediate program to increase the relative gasoline yield, with high potentials to be attained in high octane avgas production. The general reforming would actually decrease the total gasoline yield.

General reforming, probably thermal, would almost certainly receive secondary priority, however, in an ultimate plan to modernize Soviet refining. The thermal reforming would be urgently needed for motor gasoline quality, and would also increase potential yields of high octane gas reversion liquids. Catalytic reforming for special rather than general use is actually a factor of primary importance in the program. This special use pertains particularly to the avgas

potentials, and it is in addition to the use with catalytic cracking for base stoc production, as in the Houdry system. Examples of the special use without much apparent advantage for the Soviets include the dehydrogenation and isomerization o normal paraffins for gas reversion charge. Another and much more important exampl relates to production of aromatics for avgas additives.

It is noted here that thermal reforming is not necessarily rendered obsolete by the modern catalytic techniques. Some results are still satisfactorily accomplished by thermal reforming, without warranting use of the more complicated apparatus and operations of the catalytic units. Thermal and catalytic cracking operations are somewhat similarly supplementary to each other, although the reason in that case are more technical and fundamental. Thermal reforming capacity appear to be limited in the USSR at present.

8. Survey of Potentials for Avgas Additives Production in the USSR.

Avgas additives may be defined as special blending agents exhibiting high anti-knock characteristics in the gasoline under rich mixture operating conditions (full power). These avgas additives must be generally available in sufficient quantities in oil fractions that do not themselves constitute avgas base stocks, if the latter are to be actually used as bases so as to attain the theoretical maximum avgas production. In non-Communist practice the positive additives thus available are restricted to aromatics and certain isoparaffins (mostly iso octane mixtures and isopentane). There is no reason to believe but that the same status would prevail in the USSR. Lower boiling naphthenes are comparable to aromatics in power, but the

only commercial availability of these naphthenes is in straight run avgas base stocks. Virgin base stocks of this sort comprise naphthenic gasoline fractions in the naphthenic crudes as distinguished from the so-called paraffinic, asphalt base, and mixed base crudes. (In the latter three crude types, virgin gasoline fractions are generally aliphatic.)

Isopentane is produced in quantity by the catalytic cracking of virgin stocks, and it is in general satisfactorily separable from the catalytic avgas base product. Isopentane is moderate in avgas additive effect. It is further a low boiling compound that may serve as a necessary vapor pressure blending agent in avgas. The available isooctane mixtures, generally containing the reference isooctane, consist on the one hand of the aviation alkylates produced by the chemical union of isobutane with butenes, and on the other hand, of the hydrocodimer mixture produced by the direct hydrogenation of the codimer polymers of butenes. Moderate additive effect is a feature of these isooctane mixtures and likewise of the reference isooctane itself. Otherwise sometimes available, but not in commercial quantities ordinarily and probably not in the USSR, neohexane and triptane also constitute isoparaffin additives. The latter two hydrocarbons are among the theoretical products commercially obtained by thermal alkylation of isobutane with ethene and propene, respectively. Neohexane is about equivalent to the reference isooctane as an avgas additive, while triptane has power ranking with the aromatics.

In considerable part, as a result of utilization of stocks produced by the catalytic cracking systems, isooctane alkylates and isopentane would probably be produced in quantities sufficient for the avgas potential in the Soviet program.

Excess production of these or similar moderately effective additives would not eliminate the requirement of additives as powerfully effective as aromatics. The latter are required in attaining the high-octane avgas potential, the most important phase of the general avgas program.

There would probably be little advantage in auxiliary dehydrogenation and isomerization of charges derived from the relative abundance of normal paraffinic stocks, merely to increase potential yields of moderately effective additives such as the reference isooctane. There would likewise be little benefit in special production of other moderately effective additives, such as by application of the difficult thermal alkylation process yielding neohexane. Neither would close and difficult fractionation operations be indicated, for obtaining additives as heart cuts from hydrocarbon stocks such as natural gasolines, aliphatic straight run gasolines, and other common non-aviation grade gasolines. While this fractionation might result in considerable yields of isoparaffins for additives, these would be mostly the moderately effective types unless the charge to the fractionation is unusual.

Aromatics may be considerable in certain crudes not predominantly paraffinic, but these are not generally in the boiling point range of additives even though they do occur in this range in certain naphthenic straight run gasolines suitable as avgas base stocks in themselves. Maximum relative gasoline yields will probably result from a general USSR pattern little different from that in countries such as the US where modern practices are already applied. This pattern involves balanced

catalytic and thermal techniques in petroleum refining, with full use made of available natural gas liquids for blending. Intelligence tends to show that natural gas liquids may be available in relatively large quantities in the USSR. The latter liquids are not, however, a source of the extra additives of the highly effective type required.

The metallic oxide catalyst Hydroforming Process is probably the most effective technique available for possible Soviet use, for obtaining aromatic additives from the ordinarily available petroleum fractions not suitable for aviation gasoline base stock. Hydroforming appears to be more suitable and selective for this purpose, as compared to the aluminum silicate clay catalyst cracking units. It is noted that the latter are also serviceable for efficient reforming although the capacity of the clay catalyst to cause actual cyclization and aromatization of aliphatics is not clearly confirmed. The Soviets might reasonably be expected to supplement Hydroforming in some cases, by applying the catalytic processes for alkylation of benzene to obtain selective yields of ethyl benzene and cumene. The latter applications would depend upon the availability of benzene in excess over other requirements for it. Benzene is not present in quantity in typical petroleums and thermal conversion products. Because of limited use of benzene in aviation gasoline, commercial catalytic cracking is ordinarily controlled to minimize the production of it.

Catalytic conversions would be much preferable for yield of aromatic additives, as compared to limited or inefficient processes yielding highly effective isoparaffins. An example of the latter is the very difficult thermal alkylation producing

triptane. Hydroforming would be selectively applied to aliphatic virgin naphthas or gasolines, to yield high octane aromatics resulting from conversions to them of as much as 50% in practice. This would be in contrast to the alternate use of Hydroforming to produce yields of up to 75% of 85 octane number reformed gasoline from the same stocks. Thermal cracking and reforming do not yield aviation gasoline base stocks, and do not ordinarily produce aromatics in quantity: even catalytic reforming is incapable of producing aviation gasoline base stocks with practible efficiency, when applied to the usual types of virgin and thermally converted naphtha charges. Hydroforming catalysis is, however, highly efficient for selective reforming to yield aromatics.

Hydroforming is efficient for aromatic production from special charge stocks as well as from the complete naphtha cuts. With a charge of heptane and methyl cyclohexane, using a variety of metallic oxide catalysts, including chromic as well as molybdic oxides, Hydroforming selectively yields toluene, a powerful aromatic aviation gasoline additive. Toluene is further a principal stock for explosives production by nitration. Methyl cyclohexane is one of the less effective aviation gasoline additives among naphthenes, and quantities of it probably could be satisfactorily spared from the potential supplies of straight run aviation gasoline base stock in the USSR. Soviet naphthenic crudes occur in considerable abundance. The Baku crude is, for example, composed of 80 per cent of naphthenes. Eighty per cent of the Baku crude is assumed to contain suitable straight run aviation gasoline base stock (cf. Table I).

If thermal hydrocarbon conversion is drastic with respect to elevated temperatures, and especially if thermal stress is severe due to the imposition of an abrupt and large final temperature rise upon the charge stock, dehydrogenation and cyclization may result to give a highlt aromatized liquid yield together with large quantities of light gas and residue carbon. A conversion such as this is usually not very efficient in regard to the relative liquid yield, and the essential feature of such a process is the method employed to attain the "kicker" rise in temperature. The Soviets have reportedly experimented with a thermal technique using partial oxidation or burning to develop the "kicker" increment in the charge stock. This Soviet development is known as the Dubrovai process. 2/ The process is described in the paper entitled Refining of Petroleum in the USSR in this report. It is not known to have had significant commercial application to date for the production of aromatics or other stocks in the USSR.

Of uncertain status in the USSR also as discussed in Refining of Petroleum in the USSR, there is the "Pyrolysis" process used by the Soviets during World War II for the production of gasoline aromatics by high pressure cyclization of kerosene. 8/ Available technological details are very meager for this process at present, and an appraisal of the potential in the technique is not possible in this survey.

While the actual status of hydroforming in the USSR is unknown, note is taken of potentials and technology of the process in Refining of Petroleum in the USSR. Due to the peculiar need for Hydroforming in the USSR processing balance, it may well be that the Soviets already have such units in service although confirming intelligence is lacking. More detailed analyses are required with respect to the USSR coal carbonization and other synthetic oil installations, if an intelligence

estimate is to be made of the probable status of aromatic additives production by benzene alkylation and Hydroforming. A survey of refining potentials is here developed based upon the assumption that avgas additives production is sufficient for the final blending of the oil stocks shown.

9. Estimated 1950 Operation Balances.

In Table 15, Appendix B, a correlation is compiled for the 1950 Soviet petroleum processing, assuming a gross and total basis* so as to develop reasonable over-all yield factors. The table provides a reconstruction of the plausible relative yields if the probable Soviet capabilities and efficiencies are applied. This estimate assumes full use of the equipment indicated to have been in service, or otherwise probably in service. The results are computed within practical limits of technical engineering possibilities, based upon the indicated and probable characteristics of Soviet oil stocks (intelligence sources of the latter data are discussed in 3. Soviet oil Stock Availability and Installed Refining Facilities in 1950). Estimates as already summarized are applied for capacities in crude distillation, thermal cracking, and thermal reforming. The Gurev and Orsk lend-lease refineries are assumed to have been operating. Included are the Houdry and alkylation units at design capacities in the latter refineries. These catalytic units are, however, calculated to give the generalized yields of Table 9 and 10.

The following variations of very minor magnitudes are applied to the alkylation units at Gurev and Orsk and further to the Houdry Catalytic cracking-reforming

* The basis is assumed for consistency in the application of percentage factors where total annual operations and the resulting net product availabilities are to be calculated and compared. Gross yields of the essential base and blend stocks are indicated with the unit refinery operations in material balance assuming the total estimated crude production to be the charge to refining. Net product availabilities result by applying percentage factors later to be developed. A probability prevails and an assumption is made that no considerable difference would exist between the total quantities of the base and blend stocks and the derived finished products.

system at Orsk. With quantities stated as thousands of metric tons per year, the design alkylate production in these units was 89.5, and this is rounded off as 90 for the designation of potentials although it is reduced to a production value of 89 in Table 15. This production of 89 is derived in Table 15 by applying the generalized yields of Table 10 to a reduced total charge of 134 in place of the 140.6 total charge given in Badger designs. In similar quantity units with respect to catalytic cracking-reforming at Orsk, the Badger design case charge capacity of 371 is applied in the designation of the 1950 potentials and in the calculation of production in Table 15. However, since this design capacity includes some recycle the virgin gas oil charge capacity for future projections is increased to 374.

Table 15 includes thermal cracking and reforming units in operation at Kuibyshev and Krasnovodsk, at capacities which are at least equal to that Badger proposed in connection with the Houdry lend-lease refineries projected for those places. Catalytic

polymerization and hydrogenation units are likewise shown to have been operating to produce 80,000 metric tons of the isooctane hydrocopolymer. Together with the Houdry and alkylation units, the latter account for all catalytic processing assumed for the year. It is especially noted that considerable flexibility is reasonable and possible with respect to the overall yields of lubes, waxes, and products of the gas oil and specialty residual types, as reflected in the remaining yield of residual fuel oil.

For comparative purposes, Table 15 records British intelligence estimates of what the Soviets probably proposed to do in 1950, in promulgating the fourth Five Year State Plan. 1950 US refinery yields are in addition summarized for reference. Recovery of stock from refinery gases for seasonal gasoline blending is not inferred in the Table 15 balance. As stated in a footnote to Table 15 finished gasoline blending would not seem to theoretically permit the absorption of natural gas liquids within vapor pressure limits if proper use is made of the available plant C_4 recovery gasoline. It is probable, however, that natural gas liquids are currently utilized in quantity in the USSR, not only for special fuel purposes, but also in motor gasolines as a consequence of inefficient C_4 stock recovery systems in the Soviet refineries. Certain available intelligence reports deal with the Soviet utilization of natural gas liquids. 2/ 9/ 10/ If natural gas liquid blend stock is actually available as natural gasoline with moderate vapor pressure, then as compared to the high vapor pressure C_4 stock it may be actually added in larger quantity to give a definite vapor pressure blend with a given gasoline.

10. Modernized Soviet Processing Balances with Catalysis (Postulated for 1955).

If Soviet refining installations were modernized to include a balance of catalytic and non-catalytic processes, assuming that the existing relationships in the US

reasonably indicate what might be practible, the resulting potential for high-octane avgas production would be obviously many times greater than the present USSR maximum. Realization of such a potential would not only depend upon Soviet capabilities for fabrication and construction of the required equipment, but would also be involved with USSR requirements and the capacity of Soviet economy to utilize the larger quantities of avgas, if and when the latter becomes available.

The present hypothesis is not, however, directly concerned with those contingencies. The immediate proposition is to indicate what appears to be the catalysis reasonably to be expected, if the Soviets strive to attain the balance, and succeed in attaining it at some future date. Capacity for the avgas utilization is not necessarily a very critical factor in itself. The new catalytic units would be useful for high relative yields of quality motor fuels, as is true in the US during peace, without being applied for the ultimate or even very high yields of avgas. When new catalytic cracking and alkylation units are here designated as possible features in Soviet construction programs, a basic promise of the study calls for a service to give the maximum yields of high octane avgas stock although this equipment would still be of fundamental value even if primarily operated to yield motor gasolines. But with respect to capabilities for construction of the new refinery systems, more realistic aspects would be involved if the hypothetical balance is applied to some estimated future production, rather than to the probable 1950 and 1951 values, inasmuch as the balance is virtually known to be far from realized at present.

Table 16, Appendix B, shows estimated USSR petroleum productions by areas in 1955, compared with the corresponding productions from identified regions in 1950 (cf., X-B, Production and Exploration in the USSR, in this report). Of the net productivity increase thus indicated in this period, the major part is about equally divided between Soviet Central Asia and the Second Baku. Table 16 also consolidates and recapitulates the data on existing 1950 refining facilities as already discussed (cf. Tables 1, 7, and 15).

Although the matter of actual probability might well be questioned, it is still within reason, under favorable conditions, for the Soviets to attain by 1955 a balance in the catalytic and non-catalytic refining installations in the USSR, comparable with what existed in 1950 in the US. The previous discussions in this paper have indicated the probability and logic of Soviet emphasis upon catalytic cracking with attendant alkylation. It is reasonable to suppose that a Soviet Houdry installation program has been continued since 1946, following the comprehensive design data and actual construction supervision furnished by the Badger Company. It is also plausible that the Soviets have formulated a Fluid plant construction plan to replace this Houdry program.

Table 17, Appendix B, is compiled to show an estimate of a plausible overall refinery operation for 1955 in the USSR, developed upon a gross and total basis as in the Table 15 data which refer to what appears to have been the actual 1950 operation. Table 17 is based upon the assumption that a catalytic refining balance has been attained as previously inferred. Tables 18 and 19, Appendix B, in turn summarize what might prevail in utilization of refinery installations carried over from 1950, with designation of the considerable

Tables 34 and 35, Appendix B, relate to the derivation of certain data thus applied additional capacities required for the 1955 balance. Table 19 also provides an estimate of what might be then involved in this 1955 processing, in catalytic cracking plants by sites and in catalytic alkylation capacities by general areas. Certain old non-catalytic units could well have questionable operable status in the future, however, and the real usefulness of some would of course depend upon the facilities for intermediate movements of stocks, sometimes over appreciable distances. The additional non-catalytic capacities are probably minimum requirements as shown, and might well be higher in view of processing convenience even if the older equipment is still in operable condition.

The estimate in Table 17 includes in thermal processing, about 40% as much reforming capacity as there is cracking capacity. The latter is a relationship not abnormal in modern petroleum refining with emphasis upon catalysis. Thermal reforming would seem to be particularly valuable to the Soviets for proper utilization of the low grade virgin distillates in prospect in the Second Baku. In the catalytic cracking construction to be completed before 1955 involving a shift to the construction of Fluid units only, it is assumed that Houdry systems will be completed at a total of seven sites before the shift to Fluid units is completed. (See p. 74 below.) If this assumption is applied it is scarcely probable that Fluid units would be in operation prior to 1953. The 1955 capacity relationships given in Table 17 may be summarized as shown below, with new capacities indicated relative to what is supposed to have been existing in 1950 and with these latter capacities carried over in total.

POSTULATED 1955 CRUDE PRODUCTION AND REFINING CAPACITIES IN THE USSR:

Plausible End Results If Program Is Adopted for High Octane Ratings

Oil Quantities in Thousands of Metric Tons per Year

Indicating Capacities "new" Since 1950

Crude Production (14,500 new)	52,000
Crude Distillation (17,480 new)	62,400
Thermal reforming (4,107 new)	5,096
Thermal cracking (2,056 new)	18,368
Total thermal conversion (6,163 new)	23,464
Houdry catalytic cracking and reforming (1,900 new)	2,654
Fluid catalytic cracking (all new)	10,216
Catalytic cracking and reforming (12,116 new)	12,870
Catalytic alkylate product (1,420 new)	1,510
Catalytic polymerization-hydrogenation product (none new)	80
Catalytic polymerization gasoline product (all new)	10
Total catalytic conversion (13,546 new)	14,470
Total thermal conversion (6,163 new)	23,464
Total conversion (19,709 new)	37,934
Annual capacity ratios:	
Crude production capacity	1.000
Crude distillation capacity	1.200
Thermal conversion capacity	0.451
Catalytic conversion capacity	0.278
Total conversion capacity	0.729

An imposing task is thus postulated for the Soviets to obtain between 1950 and 1955, an annual capacity of 37,189,000 metric tons in new refining installations. 17,480,000 metric tons of new crude distillation capacity is represented in this total, with the new crude distillation to accommodate an increase of 14,500,000 metric tons in the annual rate of petroleum production within the four years. The refining capacities result as annual rates based upon 330 days of actual equipment operation within each year, and the postulated refining facilities include 20 percent for reserve in the case of crude distillation capacity. This reserve is for potential service in peak operations, constituting a normal excess in modern practice if crude oil is to be processed in large quantities.

The 37,189,000 metric tons of new annual refining capacity is in the order of about 750,000 barrels per calendar day on the average. If the actual details of Soviet refinery construction programs were to be revealed, it is quite probable that such plans are more realistic, with a lesser capacity increase proposed within such a short period of time. If no reserve excess were to result in the postulated crude distillation capacity, the increase in the latter would be reduced to 7,080,000 metric tons and the total capacity increase would be reduced to 26,769,000 metric tons.

It would be logical for the Soviets to complete all of the lend-lease Houdry projects before total change is made to a program for the construction of catalytic cracking systems more modern than the Houdry. It is also probable that there would be a transition period with the basic and available Houdry designs applied at certain other sites. These other sites would probably be selected as the ones where there is an obvious special use for high-octane avgas facilities (i.e., catalytic refining). Sites of this nature would include industrial centers servicing the more prolific Soviet oil-productive regions.

Among the lend-lease Houdry plants, the Krasnovodsk plant might service the Turkmen, Southeastern Soviet Central Asia, Emba, and Caucasus Regions, in decreasing order of directness; the Gurev and Orsk plants might service the Emba, Second Baku, Soviet Central Asia, and Caucasus Regions, in decreasing order of directness; the Kuibyshev plant might service the Volga Region directly, and the other Second Baku and Northern European Russia Regions less directly. Thus remaining without direct service there would be the Caucasus Regions, and the Ural and Kama Regions to the east and north in the Second Baku, together accounting for more than 70% of the current Soviet crude production.

More than 70% of the Soviet Caucasus crude is presently produced in the Baku Region. This old and famous Region is at the Caspian shore in the eastern part of the Caucasus. To the west of Baku there is the Grozny Region, the major productive area most centrally situated on the Caucasus isthmus. The Baku and Grozny Regions would therefore appear to be logical areas with high priority in regard to catalytic refining installations. Particular sites in these regions would be respectively the cities of Baku and Grozny, already known to be the major industrial centers of refining in the Caucasus. Similarly identified as an industrial center of existing refining there is the city of Ufa in the Ural Region. Grozny and Ufa already contain UOP catalytic polymerization units, and Ufa is further the site of the UOP catalytic hydrogenation plant for the production of hydrocopolymers (chiefly iso-octane hydrocodimers).

Baku is probably the most favorable Soviet location for the installation of high-octane aviation gasoline facilities since it is established as the largest center of refining in the USSR and has a good supply of crude oil containing the fractions desired for straight-run avgas base stock. In view of the importance of the Baku Region in the USSR petroleum economy, it is probable that the Soviets made plans for the construction of a catalytic cracking plant with alkylation facilities at Baku, representing their own modification or version of the lend-lease plants, as soon as all of the details of these plants were available to them. The Soviets did not know until 1946 that they would not receive all of the lend-lease equipment for Kuibyshev and Krasnovodsk, and they probably did not arrange for fabrication of the equipment until after that time although the plans for fabrication were probably well advanced by 1946.

Numerous reports have indicated refinery construction and modernization at Grozny and Saratov, and there is a strong possibility that catalytic cracking and alkylation units have been, are being, or will be installed in each place. Saratov, as well as Grozny, contains a catalytic polymerization unit previously constructed by UOP. Saratov is an important refining center in the Volga Region, an oil-productive area containing the site of one lend-lease Houdry project (i.e., at Kuibyshev). Grozny is the second largest refining center presently identified in the USSR, and in view of the much larger crude production in the Caucasus compared to the Volga Region, it is probable that Grozny and Baku would have higher priority than Saratov for early new catalytic refining of the type described. This is especially true since the new construction at Saratov would parallel the lend-lease Houdry plant projected at Kuibyshev in the same productive Region.

Ufa is a logical site for catalytic cracking and alkylation facilities. Indications were prevalent in 1947 and 1948 that plans were underway for expansion of high-octane avgas production facilities at Ufa, where the existing facilities consist of the catalytic hydrogenation plant producing technical isooctane. Ufa is an important and established refining center, servicing the Ural, Kama, and Pechora Regions.

For the present purpose it is assumed that the lend-lease catalytic alkylation and Houdry Cracking systems were operating throughout 1950 at Gurev and Orsk. It is also assumed that the Soviets will have had sufficient time by early 1953 to complete the similar lend-lease projects at Kuibyshev and Krasnovodsk, and in addition to these, three other catalytic cracking and alkylation systems, respectively located at Baku, Grosny, and Ufa. It is considered to be a logical assumption that all four of the lend-lease projects would be completed according to original designs, and it is considered to be an assumption not illogical that the following or contemporaneous

constructions at Baku, Grozny, and Ufa would each have design and capacity similar to the standard lend-lease Houdry system. Five Houdry systems are thus postulated to be completed for operation during 1951 and 1952. Each of these systems is assumed to have a cracking case charge capacity of 380,000 metric tons per year, and a definite order of capacity completion would appear to be plausible as follows: two systems (760,000 tons charge capacity) completed by the beginning of 1952; a third system (380,000 tons charge capacity) completed by midyear 1952; and the remaining two systems (760,000 tons charge capacity) completed by the beginning of 1953.

Although there is no firm basis to establish just where the Fluid type of construction would replace the Houdry type in the postulated Soviet program, the influence of expediency and priority could very well lead to the duplication of the standard lend-lease Houdry system at Baku, Grozny, and Ufa, prior to the time after which all subsequent catalytic cracking plant completions would be restricted to the Fluid type. A sequence for the present study is assumed as just stated, even though it would also be plausible to assume the presence of the Fluid system in some of the earlier completions such as at Ufa, and likewise the presence of the Houdry system in some of the following completions.

Thus in catalytic cracking plants, a total annual charge capacity of 2,654,000 metric tons in Houdry units is assumed to have been completed essentially prior to 1953, in the six years following 1946. Actually for these Houdry systems at prior dates, there had been already completed essentially all of the basic design work, and furthermore on two-sevenths of the total capacity, essentially all of the major construction work. It is here further assumed that a high-priority program was inaugurated after 1949 for the construction of Fluid Catalytic Cracking plants. Then after three years of work

variously related to the basic designs, the organization of the program, the establishment of facilities for equipment manufacture, and actual construction upon the project. the postulated catalytic alkylation and Fluid Cracking units are assumed to have been completed in the following two years, 1953 and 1954. In the postulated Fluid Catalytic Cracking units, the total annual charge capacity is 10,216,000 metric tons, or about four times the capacity of the Houdry units. Of the capacity in Fluid units, the postulate shows a 1953 completion of about a third, or 3,416,000 metric tons, and a 1954 completion of the remainder.

In the construction of Fluid Catalytic Cracking units in the USSR, a practicable procedure would be for the Soviets to plan installation of smaller capacity plants first. Early special attention might be given to important distribution centers such as Odessa, Orsk, Moscow, and Komsomolsk. With plans and designs becoming workable in 1950, active construction of the Fluid units might begin in 1951, carried on in coordination with the Houdry systems initiated at earlier dates. Assuming that the basic engineering designs have been completed and that benefits have been derived from the earlier experience; and further, that the later projects are in progress simultaneously with the facilities already set up for the fabrication and erection of equipment; then under those conditions a rapid increase in the rate of project completion would be logical

in the Fluid construction program.

The need of early and greatly expanded catalytic cracking would be obvious at Baku. While the lush Baku oilfields appear to be well past peak exploitation, they remain as potential sources of more than a fifth of the total USSR petroleum productions for years to come. Baku is further an important oil port on the land-bound Caspian Sea, for service to future oil productions in other parts of the Soviet Caucasus. Catalytic cracking units at Baku would more than justify the construction by reason of usefulness during normal periods of operable equipment life.

A correlated order is shown below for the possible completion dates of the catalytic cracking plants in question.

CORRELATED ORDER OF POSSIBLE COMPLETION DATES IN THE USSR

Catalytic Cracking Systems Attendant upon a Possible Program for High Octane Ratings

	Thousand Metric Tons per Year
	Charge Capacity
Houdry Systems Assumed Existing in 1950	
Gurev	380
Orsk	374
Additional Houdry Systems Assumed Completed Prior to 1953	
Kuibyshev	380
Krasnovodsk	380
Baku	380
Grozny	380
Ufa	380
Fluid Units Assumed Completed in 1953 and Operating Part Time	
Moscow	618
Orsk	996
Odessa	1,472
Komsomolsk	330
Fluid Units Assumed Completed in 1954 and Operating Part Time	
Baku	3,000
Additional Fluid Units Assumed Completed for 1955 Operation	
Tashkent	500
Krasnovodsk	1,000
Tuapse	1,500
Saratov	400
Ufa	400

As stated in footnotes to Tables 15 and 17, these tables do not account for the aromatic additives normally required to complete the high-octane aviation gasoline blends. For the 1955 balance in Table 17, large Hydroforming units would appear to be desirable to produce aromatic additives with paraffinic naphthas used as charge stocks for this catalytic reforming. Further, special catalytic units might also reasonably exist for the alkylation of benzene with light gaseous olefins, producing specific aromatic additives such as cumene (i.e., isopropyl benzene). The valuable

aromatic additive toluene might be likewise produced in commercial quantities by application of the Hydroforming process to reform a charge of heptane and methyl cyclohexane. All of these catalytic productions of aromatic additives are, however, closely related to the potentials in the Soviet coal carbonization and other synthetic oil industries. A comprehensive intelligence correlation of the latter appears to be necessary for a similar study of the former. For these and various other reasons it is likewise not possible at present to evaluate the probable potentials in Soviet use of the Dubrovai and "Pyrolysis" processes for aromatization reforming.

It is known that trends of Western practices are being followed in the USSR, in that jet propulsion engines are being applied with this application tending to reduce the high octane avgas requirements for certain ultra high speed aircraft. Catalytic processing is not necessarily reduced in importance in the general Soviet refining balance by reason of this. The Soviets are known to be carrying on intensive research into catalytic process applications, apparently with chief emphasis upon the applications of Western processes to Soviet stocks, without evidence of fundamentally novel or original developments. Some reports have particular reference to this type of Soviet research. 11/ Available intelligence documents also include translations of Soviet technical papers on research and development, especially dealing with the catalytic Hydroforming and benzene alkylation processes. 12/

II. Future Petroleum Refining for High General Distillate Yields.

Summary.

Plausible New Refinery Constructions for High Distillate Yields.

While the coking of residue serves for ultimate distillate yield from natural petroleum, the coking process is not generally economical and it is probable that the Soviets would have more use for residual fuel oils than for the coke, coker distillate fuel oil, and coker gas. Visbreaking* or mild cracking of the crude residue would probably serve the Soviets for practicable maximum yields of distillate stock. In comparison to more advanced degrees of cracking as applied to gas oils and oil residues for a given conversion to lighter fractions, visbreaking yields less tail gas and more total distillates although the gasoline distillate product is in smaller quantity and of lower quality. For practicable operation in the USSR, however, it is probable that thermal cracking would be correlated with visbreaking in order to convert the heavy gas oil distillates (i.e., distillate fuel oils) to lighter and more useful products. The thermal cracking charge would then consist of the heavier gas oils produced by crude distillation, visbreaking, and catalytic cracking.

The present hypothesis of a high distillate yield program is based upon utilization of simpler and less extensive equipment. The basic premise would thus preclude the complicated and elaborate equipment of catalytic refining. Destructive catalytic hydrogenation of crude residuals might otherwise be considered in the status of a cracking technique to accomplish the results of the thermal pro-

* Only the usual (i.e., thermal) type of visbreaking is involved in the present study.

cesses of visbreaking and true cracking. It is noted that by this hydrogenation as compared to the thermal processes, there would be a practicable possibility of more complete conversion of the heavy stocks to lighter fractions, leaving a smaller percentage of the final heavy residues. Further, there would be a practicable possibility of more effective gas recycling so as to result in alkylation and other polymerization reactions, producing hydrocarbon liquids (i.e., true "oils") generally within a distillate boiling range, and in this fashion substantially reducing the potential process gas loss. Thus the hydrogenation could be applied for higher relative yields of the distillates.

It is also noted that some intelligence analysts have inferred active interest on the part of the Soviets in the destructive hydrogenation of crude residues. Reports have been cited which describe excellent results obtained with Soviet "mazut" in the Bergius hydrogenation plant at Boehlen in the Soviet Zone of Germany. The Soviets are also said to be sending junior technologists for training in the Boehlen plant. In the case of Western refining practice, however, destructive hydrogenation is now generally considered to be as economically desirable as the usual cracking techniques. Milder forms of catalytic hydrogenation have had more important and more extensive applications in the typical natural petroleum refinery practice, resulting in conversions more in the category of reforming as compared to cracking. Historically a mild form of catalytic hydrogenation has served to produce technical isooctane from isooctane codimer. More recently there have been important developments in applying a similar technique to certain intermediate distillates, causing quality improvements in jet and Diesel fuels.

With respect to catalytic refining it is nevertheless considered to be probable that the Soviets will have at least all four of the Lend-Lease Houdry catalytic cracking-reforming systems in operation by 1955. It is also considered to be a

realistic probability that the sulfuric and catalytic alkylation units will be similarly completed according to the original Lend-Lease project designs. Alkylation and other types of gas reversion would actually serve to increase the total distillate yield although the necessary equipment would be relatively extensive and complex, but with the exception of the correlated polymerization-hydrogenation system already existing by 1950, no other catalytic facilities are here postulated for the high distillate yield program.

For comparative purposes the high distillate yield program is then postulated to be completed and operating in 1955. With exceptions as presently noted, this is upon a basis of specific definitions and assumptions corresponding to those applied for the analysis of the high octane rating alternate. Referring in particular to crude distillation and virgin naphtha reforming, equipment and operation are calculated to be the same in the alternate analyses. Adequate thermal reforming is assumed to be a practicable requirement in both programs, considering the characteristics of the virgin naphtha as indicated for 1955. Compared to the estimated 1950 yields the larger percentage of thermal reformed gasoline would in part compensate for an over-all reduction in gasoline quality due to the presence of visbreaker gasoline and the smaller percentage of thermal cracked stock. The polymerization-hydrogenation system operation is assumed to be unchanged from 1950 and is therefore the same in both analyses. The Lend-Lease catalytic polymerization unit is included at Krasnovodsk in the high octane rating analysis only, and the essential differences between the alternate limiting operations are otherwise as indicated in the following table.

Postulated Operations in 1955:

Charge Stocks in High Octane Rating and High Distillate Yield Operations

	Thousand Metric Tons Alternate Operations	
	High Octane Rating	High Distillate Yield
Virgin Gas Oil		
Charge (Total Charge) to Catalytic Cracking	12,870	1,514
Thermal Cracking Charge	0	11,356
Total Production	12,870	12,870
Crude Residuum		
Thermal Cracking Charge	13,650	0
Fuel Oil Product	3,900	0
Charge (Total Charge) to Thermal Visbreaking	0	17,550
Total Production	17,550	17,550
Thermal Cracking Charge		
Crude Residuum	13,650	0
Catalytic Gas Oil	4,718	606
Virgin Gas Oil	0	11,356
Visbreaker Gas Oil	0	1,053
Total Charge	18,368	13,015
Catalytic Alkylation Charge	2,254	276

The following table provides a summary of the USSR refining capacities by types, estimated or assumed as above stated with reference to the high distillate yield program. Here the capacity ratings are of charge stocks except that they are shown in terms of product for the gas reversions and isooctane systems.

Estimated and Postulated Refining Capacities in the USSR:

Data for High Distillate Yield Program in 1955

Thousand Metric Tons per Year

Type of Facility	Capacity: Estimated Existing in 1950	Postulated Modified to Visbreaking by 1955	Postulated "New" by 1955	Postulated Total 1955
Crude Distillation	44,920		17,480	62,400
Thermal Reforming	989		4,107	5,096
Thermal Visbreaking	0	3,297	14,253	17,550
Thermal Cracking	16,312	-3,297	0	13,015
Total Thermal Conversion	17,301		18,360	35,661
Houdry Catalytic Cracking a/	754		760	1,514
Alkylate Production b/	90		95	185
Isooctane Production c/	80		0	80
Total Catalytic Conversion	924		855	1,779
Total Conversion	18,225		19,215	37,440

a. Houdry units include supplementary catalytic reforming.
b. Catalytic gas reversion.
c. Catalytic gas reversion plus catalytic reforming.

Similarly as in the case of the high octane rating analysis, the foregoing USSR data may be compared with the 1950 US status as follows:

Capacity Ratio Comparison for 1955 High Distillate Yield Program

Type of Capacity	Relative Weight Ratios Annual Basis		
	USSR		
	Estimated Existing 1950	Postulated for 1955	US 1950
Crude Production	1.000	1.000	1.000
Crude Distillation	1.198	1.200	1.192
Thermal Conversion a/	0.461	0.686	0.395
Catalytic Conversion	0.025	0.034	0.316
Total Conversion	0.486	0.720	0.711

a. Consists of reforming, visbreaking, cracking, and in the instance of the US, also some minor capacity for thermal gas reversion. But where the capacity factor is not very significant for visbreaking in the US, the corresponding factor is a ratio of 0.338 as here defined in this postulate for the USSR.

The following table shows the geographic distribution of the hypothetical USSR capacities for high distillate yields:

Postulated Capacity Data for 1955 in the USSR:

High Distillate Yield Program

	Thousand Metric Tons per Year					
	Southwestern European Russia: Soviet Caucasus	Southeastern European Russia; Soviet Central Asia	Northern European Russia	Soviet Far East	Minor Sites	Total USSR
1955 Crude Production	20,400	11,000	19,600	1,000	0	52,000
Estimated for 1950	28,850	5,560	8,765	1,280	465	44,920
Added "New"	0	3,270	14,210	0	0	17,480
1955 Crude Distillation	28,850	8,830	22,975	1,280	465	62,400
Estimated for 1950	0	218	771	0	0	989
Added "New"	1,061	354	2,640	52	0	4,107
1955 Thermal Reforming	1,061	572	3,411	52	0	5,096
Modified from 1950 Thermal Cracking	567	0	2,598	132	0	3,297
Added "New"	3,513	2,200	8,472	68	0	14,253
1955 Thermal Visbreaking	4,080	2,200	11,070	200	0	17,550
Estimated for 1950	6,086	3,721	6,031	474	0	16,312
Modofied for Visbreaking	567	0	2,598	132	0	3,297
1955 Thermal Cracking	5,519	3,721	3,433	342	0	13,015
Estimated for 1950	0	754	0	0	0	754
Added "New"	0	380	380	0	0	760
1955 Catalytic Cracking a/	0	1,134	380	0	0	1,514
Estimated for 1950	0	89	0	0	0	89
Added "New"	0	47	49	0	0	96
1955 Alkylate Production	0	138	47	0	0	185
Estimated for 1950	0	0	80	0	0	80
Added "New"	0 b/	0	0	0	0	0
1955 Isooctane Production	0	0	80	0	0	80

a. Houdry systems including supplementary catalytic reforming.
b. Soviet Caucasus codimer polymer contributes to isooctane.

Product Yield Potentials in High Distillate Yield Program.

The following table summarizes the comparison of yield potentials for Soviet refining, referring to the estimated over-all operations in 1950 and the over-all hypothetical operation for high distillate yields in 1955. In direct correspondence to the preceding analysis for the high octane rating program, the basis of this table involves gross yields at the refining units as developed from an initial charge of the estimated total Soviet crude production.

Gross Yields in Soviet Refining

1950 Operation Versus the Operation for High Distillate Yields in 1955

	Thousand Metric Tons			
	Estimated 1950 Processing		Hypothetical 1955 High Distillate Yield Processing	
	Gross Yield	Percent Crude	Gross Yield	Percent Crude
Motor	2,721	7.26	1,593	3.06
Aviation a/*	1,018	2.71	1,137	2.19
Total Straight Run Base	3,739	9.97	2,730	5.25
Thermal Reformed Base	724	1.93	3,730	7.17
Total Base from Virgin Naphtha	4,463	11.90	6,460	12.42
Motor	23	0.06	47	0.09
Aviation	186	0.50	376	0.72
Total Catalytic Cracked Base	209	0.56	423	0.81
Isopentane	20	0.05	40	0.08
Total by Catalytic Cracking	229	0.61	463	0.89
Thermal Visbreaker Base	0	0.00	2,633	5.06
Thermal Cracked Base	5,776	15.40	4,607	8.87
Total by Visbreaking and Cracking	6,005	16.01	7,703	14.82
Alkylation Blend Stock b/	42	0.11	86	0.17
Motor	8	0.02	17	0.03
Aviation	81	0.22	168	0.33
Total Alkylate	89	0.24	185	0.36
Isooctane c/	80	0.21	80	0.15
Total Gas Reversion Blend Stock d/	169	0.24	265	0.51
Total Stable Gasoline Base and Blend Stocks	10,679	28.5	14,514	27.9
Thermal Visbreaker	0	0.0	5,966	11.5
Thermal Cracked	1,065	2.8	846	1.6
Total by Thermal Visbreaking and Cracking	1,065	2.8	6,812	13.1
Straight Run	8,614	23.0	10,140	19.5
Total Intermediate Distillates	9,679	25.8	16,952	32.6

* Footnotes follow on p. 87.

(Continued on next page)

Gross Yields in Soviet Refining

1950 Operation Versus the Operation for High Distillate Yields in 1955 (Continued)

	Thousand Metric Tons			
	Estimated 1950 Processing		Hypothetical 1955 High Distillate Yield Processing	
	Gross Yield	Percent Crude	Gross Yield	Percent Crude
Lubes, Speciality Residuals	2,778	7.4	2,730	5.2
Thermal Visbreaker	0	0.00	7,020	13.50
Thermal Cracked	7,364	19.64	5,883	11.32
Total by Thermal Visbreaking and Cracking	7,364	19.64	12,903	24.82
Thermal Reformed	97	0.26	500	0.96
Total by Thermal Conversion	7,641	19.90	13,403	25.78
Catalytic Polymer e/	14	0.03	28	0.05
Total Conversion Residual	7,475	19.93	13,431	25.83
Straight Run Residual	3,948	10.53	0	0.00
Total Residual Fuel Oil	11,423	30.5-	13,431	25.9-
Over-all Process Loss	2,941	7.8	4,373	8.4
Gross Products	34,559	92.2	47,627	91.6
Total Crude Charge f/	37,500	100.0	52,000	100.0
Thermal Visbreaker Base	0	0.00	2,633	5.06
Thermal Cracked Base	5,776	15.40	4,607	8.87
Total by Thermal Visbreaking and Cracking	5,776	15.40	7,240	13.93
Thermal Reformed Base	724	1.93	3,730	7.17
Thermal Conversion Base	6,500	17.33	10,970	21.10
Catalytic Cracked Base	209	0.56	423	0.81
Total Conversion Base	6,709	17.89	11,393	21.91
Straight Run Base	3,739	9.97	2,730	5.25
Total Stable Gasoline Base Stocks	10,448	27.86	14,123	27.16

(Continued on next page)

Gross Yields in Soviet Refining

1950 Operation Versus the Operation
for High Distillate Yields in 1955
(Continued)

	Thousand Metric Tons			
	Estimated 1950 Processing		Hypothetical 1955 High Distillate Yield Processing	
	Gross Yield	Percent Crude	Gross Yield	Percent Crude
Catalytic Cracking Isopentane	20	0.05	40	0.08
Gas Reversion Blend Stock d/	169	0.45	265	0.51
Direct Catalytic Conversion Blend Stock	189	0.50	305	0.59
Alkylation Blend Stock b/	42	0.11	86	0.17
Total Stable Gasoline Blend Stocks	231	0.61	391	0.75
Thermal Conversion Base	6,500	17.33	10,970	21.10
Catalytic Cracked Base	23	0.06	47	0.09
Total Conversion Motor Base	6,523	17.39	11,017	21.19
Straight Run Motor Base	2,721	7.26	1,593	3.06
Total Motor Base	9,244	24.65	12,610	24.25
Motor Alkylate	8	0.02	17	0.03
Alkylation Blend Stock b/	42	0.11	86	0.17
Total Stable Motor Gasoline Base and Blend Stocks	9,294	24.78	12,713	24.45
Catalytic Cracked Base	186	0.50	376	0.72
Straight Run Aviation Base a/	1,018	2.71	1,137	2.19
Total Aviation Base	1,204	3.21	1,513	2.91
Aviation Alkylate	81	0.22	168	0.33
Isooctane c/	80	0.21	80	0.15
Catalytic Cracking Isopentane	20	0.05	40	0.08
Total Stable Aviation Gasoline Base and Blend Stocks	1,385	3.69	1,801	3.47

(Continued on next page)

Gross Yields in Soviet Refining

1950 Operation Versus the Operation
for High Distillate Yields in 1955
(Continued)

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a. Potential virgin naphthenic stocks. These potential yields obviously include excesses over the quantities usable with other available avgas stocks in the final avgas blends.

b. Excess charge stock to alkylation, essentially consisting of excess butanes; stock derived by crude fractionation, reforming, cracking, and visbreaking.

c. Derived by hydrogenation of codimer polymer.

d. In part as represented in isooctane.

e. Produced in the supplementary catalytic reforming stage in the Houdry Catalytic Cracking systems.

f. Later estimates have indicated a total 1950 production value of nearer 38.0 million metric tons for Soviet crude oil.

Possible Potentials in Finished Distillate Blends.

Similarly as explained in connection with the high octane rating analysis, additional gasoline blend stocks may be involved if finished gasoline blends are prepared from the gasoline derivatives shown in the high distillate yield analysis. But further as explained in the previous analysis, the inclusion of finished gasoline blends would probably cause little change in the general comparisons here developed between the operations estimated for 1950 and the operations indicated in the hypothetical construction program. In the high distillate yield analysis the gasoline stock production represents a crude percentage nearly the same as the one in the 1950 estimate and much less than that in the high octane rating program. As inferred by the original hypotheses and in contrast to the high octane rating program, the high distillate yield operation is shown to cause very little change in the high octane avgas stocks production, compared to 1950 in terms of percentages of the crude. In the high distillate yield plan and the 1950 estimate the gasoline productions differ chiefly because the thermal reformed and visbreaker gasolines of the hypothetical plan replace some of the straight run and thermal cracked gasolines of 1950.

A salient feature of the high distillate yield operation is in the larger percentage productions and therefore quantitative productions of the various stocks commonly classified as intermediates and sometimes heavy distillates. These distillates are the "intermediates" (heavy naphthas and light gas oils) which presumably have an over-all distillation end point in the order of 650°F. As the result of increased use of virgin naphtha for thermal reforming in the high octane

rating and high distillate yield programs, however, the straight run fractions such as kerosenes and Diesel oils are considerably decreased among the "intermediates," compared to 1950 in terms of percentages of the crude. Thermal visbreaker distillates account for the net increase in the total "intermediates" in the high distillate yield program.

Referring to final or finished products it is convenient to classify the total virgin and conversion "intermediates" within four general categories: kerosenes and other stocks for direct heating and illumination purposes; kerosenes and other stocks for "tractor fuel" (that is, fuel for lower compression spark-ignition reciprocating engines); stocks for Diesel fuel (that is, fuel for compression-ignition reciprocating engines); and kerosenes and other stocks for jet fuel (that is, fuel for jet or turbine engines in aircraft). While the available data are far from adequate for estimating the octane ratings, cetene ratings, flame characteristics, and other physical and chemical properties of the "intermediates" obtainable from Soviet crudes, the lack of this information is not necessarily critical in the present study.

Although there may be more or less loss in the engine efficiency in doing so, it is still possible to design and operate the various internal combustion engines so as to utilize most "intermediates" as fuel if it is assumed that the "intermediates" have the range of distillation and quality characteristics normally prevailing for them. Thus the compression ratio may be reduced in the spark-ignition reciprocating engines so as to be suitable for low octane ratings; operating conditions may be established and the speed reduced in Diesel engines so as

to be suitable for low cetene ratings; and jet engines have been developed to utilize cracked kerosenes as well as straight run stock, within a range of specifications flexible enough to allow more than half of the typical crude to be processed and converted to the specified fuel. Jet fuel specifications are subject to rapid experimental development and change outside of the Soviet Bloc, and this status probably likewise prevails within the Bloc.

It is important to note that while jet fuels potentially constitute a much greater percentage yield from the crude as compared to possible yields of suitable aviation gasolines, and further provide for greater travel speed in aircraft as compared to gasolines for reciprocating engines, jet fuels are nevertheless by no means indicated to be universal engine fuels replacing gasolines even in aircraft. Jet planes are limited to high speed service. Significant limiting factors are further connected with the relative fuel consumptions and the correlated initial deadweight fuel loads required for scheduled operations, and also with certain mechanical complications not directly involved in the combustion and power characteristics of the fuel. The mechanical complications are especially represented by excessive corrosion and carbon deposits still prevailing in practice in the turbine engines of jet aircraft.

1. Purpose of the Analysis.

Technical data and available intelligence are correlated in this survey to determine what might be a logical and advantageous program for the construction of relatively simple and less extensive new refining apparatus in the USSR, serving for the attainment of high yields of general petroleum distillates. A correlation for this purpose is developed for direct comparison with the analysis of a program for high ratings as shown in Part I of this paper. The pertinent operations are therefore postulated for 1955 as in Part I, conforming to identical definitions, assumptions, and other considerations wherever applicable.

2. Basis of Study.

Residue coking is a typical refining technique for ultimate general distillate yields from natural petroleum. The coking process may be applied to eliminate the usual residual fuel oil, replacing this stock with fuel gas, distillate fuel oil, and coke. Because the coker distillate oil is in general unsuitable for engine fuel or subsequent cracking, however, the coking process is economical only under certain conditions. In the case of the USSR it is probable that there would be more practicable use for the residual fuel oil than there would be for the coker products. Visbreaking or mild cracking of crude residue would probably be more suitable to the Soviets for practicable maximum yields of distillate stock.

For a given conversion of residual charge visbreaking yields less process gas and more total distillates as compared to the results of more advanced degrees of cracking. It is noted, however, that only the usual (that is, thermal) type of visbreaking is involved in the present analysis, and the visbreaker gasoline would therefore represent a smaller percentage of the crude and lower quality stock as

compared to thermal cracked gasoline. It is noted further that if thermal cracking were eliminated altogether in the high distillate yield program, the Soviets would probably obtain an excessive production of the heavy gas oil distillates which comprise distillate fuel oils. Thermal cracking would in consequence probably be correlated with the visbreaking in order to convert these heavier gas oils into more useful products with cracked gasoline and cracked kerosene especially included. The thermal cracking charge would then consist of the heavy gas oil distillates produced by crude distillation, visbreaking, and catalytic cracking.

The present hypothesis of a high distillate yield program is based upon utilization of simpler and less extensive equipment. The basic premise would thus preclude the complicated and elaborate equipment of catalytic refining. Destructive catalytic hydrogenation of crude residuals might otherwise be considered in the status of a cracking technique to accomplish the results of the thermal processes of visbreaking and true cracking. It is noted that by this hydrogenation as compared to the thermal processes, there would be a practicable possibility of more complete conversion of the heavy stocks to lighter fractions, leaving a smaller percentage of the final heavy residues. Further, there would be a practicable possibility of more effective gas recycling so as to result in alkylation and other polymerization reactions, producing hydrocarbon liquids (that is, true "oils") generally within a distillate boiling range, and in this fashion substantially reducing the potential process gas loss. Thus the hydrogenation could be applied for higher relative yields of the distillates.

It is also noted that some intelligence analysts have inferred active interest

on the part of the Soviets in the destructive hydrogenation of crude residues. Reports have been cited which describe excellent results obtained with Soviet "mazut" in the Bergius hydrogenation plant at Boehlen in the Soviet Zone of Germany. The Soviets are also said to be sending junior technologists for training in the Boehlen plant. In the case of Western refining practice, however, destructive hydrogenation is not generally considered to be as economically desirable as the usual cracking techniques. Milder forms of catalytic hydrogenation have had more important and more extensive applications in the typical natural petroleum refinery practice, resulting in conversions more in the category of reforming as compared to cracking. Historically a mild form of catalytic hydrogenation has served to produce technical isooctane from isooctene codimer. More recently there have been important developments in applying a similar technique to certain intermediate distillates, causing quality improvements in jet and Diesel fuels.

While catalytic refining would not conform to the hypothesis of simple and less extensive equipment, it is considered to be probable from the realistic standpoint that the Soviets will have at least all four of the Lend-Lease Houdry Catalytic cracking-reforming systems, plus the four catalytic sulfuric acid alkylation units originally designed with these Lend-Lease Houdry systems, in operation by 1955. Alkylation and other types of gas reversion would actually serve to increase the total distillate yield although the necessary equipment would be relatively extensive and complex. With the exception of the correlation polymerization-hydrogenation system already existing by 1950, however, no other catalytic facilities

are here postulated for the high distillate yield program.

For comparative purposes as previously stated, hypothetical 1955 operations upon a consistent basis are presently developed for the alternate high distillate yield and high octane rating programs. Equipment and operations are assumed to be the same in the alternate analyses for crude distillation and virgin naphtha reforming. Adequate thermal reforming is assumed to be a practicable requirement in both programs, considering the characteristics of the virgin naphthas as indicated for 1955. Compared to the estimated 1950 yields the larger percentage of thermal reformed gasoline would in part compensate for an over-all reduction in gasoline quality due to the presence of visbreaker gasoline and the smaller percentage of thermal cracked stock. As finally postulated the high distillate yield operation differs chiefly from the high octane rating alternate in the visbreaking, reduced extent of thermal cracking, and effective reduction of catalytic refining to what would seem to be fairly certain to be present.

3. Modernized Soviet Processing Balances for High General Distillate Yields (Postulated for 1955).

Table 20, Appendix B, is compiled to show an estimate of a plausible over-all refinery operation for high distillate yields in the USSR in 1955. This table is developed upon a basis as above inferred to be consistent with the preceding Table 17 of Appendix B, where this preceding tabulation pertains to the corresponding or alternate operation using modernized catalytic equipment for high octane rating. Respectively corresponding in a similar manner to Tables 18 and 19 of Appendix B, Tables 21 and 22, Appendix B, further summarize what might prevail in the high

distillate yield program in the utilization of refining installations carried over from 1950, with designation of the considerable additional capacities required for the 1955 balance. Tables 34 and 35, Appendix B, relate to the derivation of certain data thus applied. The analyses and annotated tables for Part I are considered to be sufficient to cover the developments of the corresponding tables for Part II, providing that note is made of important exceptions constitued by the visbreaking and thermal cracking yields shown in the tables. Thermal cracking units are here considered to be utilizable for thermal visbreaking without change in charge capacity. It is noted that these charge rates could normally be increased for the mild cracking (that is, visbreaking).

The 1955 capacity relationships given in Table 20 may be summarized as shown below, with new capacities indicated relative to what is supposed to have been existing in 1950 and with the 1950 capacities carried over in total. By comparing the following summary table with the similar one given in Section 10 of Part I, it is seen that the refining capacity values are about the same for the total required and total new by 1955, referring to the crude distillation and total conversion apparatus thus developed for the hypothetical alternate plans as above described. Where more than a two-thirds portion of the new conversion equipment is indicated to be catalytic in the high octane rating program, however, more than 95 percent of the new conversion equipment is thermal in the alternate.

Postulated 1955 Crude Production and Refining Capacities in the USSR
Plausible End Results If Program Is Adopted for High Distillate Yields
Indicating Capacities "New" Since 1950

	Thousand Metric Tons per Year
Crude Production (14,500 new)	52,000
Crude Distillation (17,480 new)	62,400
Thermal reforming (4,107 new)	5,096
Thermal visbreaking (3,297 former thermal cracking; 14,253 new)	17,550
Thermal cracking (none new)	13,015
Total thermal conversion (3,297 modified; 18,360 new)	35,661
Houdry catalytic cracking and reforming (760 new)	1,514
Catalytic alkylate product (95 new)	185
Catalytic polymerization-hydrogenation product (none new)	80
Total catalytic conversion (855 new)	1,779
Total thermal conversion (3,297 modified; 18,360 new)	35,661
Total conversion (3,297 modified; 19,215 new)	37,440
Annual capacity ratios:	
Crude production capacity	1.000
Crude distillation capacity	1.200
Thermal conversion capacity	0.686
Catalytic conversion capacity	0.034
Total conversion capacity	0.720

Table 23, Appendix B, shows the essential capacity and operation relationships here postulated, in the analyses of the alternate or contrasting programs for high octane rating and high distillate yield.

4. Detail Data for Relative Yields.

The hypothetical alternate programs fundamentally differ only in the visbreaking operation, the relative yields by thermal cracking, and the large reduction in catalytic refining in the case of high distillate yields. Part I of the present survey provides comprehensive coverage of the technological principles applied to

establish relative yields in the high octane rating program. Yields and distributions of virgin oil stock for conversion charge effectively provide the basis of both hypothetical operations, however, and a similar status prevails in the estimated operation for 1950 where the latter is summarized in Table 15, Appendix B. Crude distillation operations actually bear strong influence upon the application of technological principles to determine the plausible yields by thermal and catalytic conversion. As a matter of convenience in further analysis with specific reference to probable yields by visbreaking and cracking, Tables 24, 25, 26, Appendix B, recapitulate the respective over-all crude still operations in condensed form.

In the application of crude residue to a given process of cracking with the mild types of cracking called visbreaking included, the relative yields of the conversion distillates generally increase with an increase in the content of potential gas oil distillates remaining in the crude residue. Heavy gas oils are more refractory (that is, less susceptible to cracking) than are the light gas oils, and a stripped crude residuum is still more refractory. Recovery of vacuum distillate or heavy gas oil is an indicated feature of Soviet refining in the probable vacuum distillation of crude residue to prepare road oils, tars, asphalts, and possibly other residue bitumens from the stripped crude bottoms.

Nevertheless, as inferred or discussed in Part I of this paper, and as shown in the three summary Tables 24, 25, 26, various over-all degrees of incomplete crude residuum stripping appear in the analyses of the three annual operations. The respective over-all crude residues result with considerable quality as potential

charge material for visbreaking and thermal cracking due to the presence of normally recoverable gas oils in the stocks with appreciable quantities of heavy bottoms actually removed for asphalt and other residue products, leaving only the equivalents of gas oils insofar as the residue products are removed. The degrees of incomplete stripping are indicated by comparing the three summary tables with Table 28, Appendix B. The latter table consists of a condensed recapitulation of the data in Table 14, Appendix B. Tables 14 and 28 pertain to the virgin gas oil charge stocks potentially available for catalytic cracking, and at least in the case of the potential charge for the Fluid process, the indicated gas oil yield probably represents the maximum practicably recoverable from the crude bottoms.

It is entirely probable that thermal visbreaking is currently employed to some extent in the true sense in Soviet refining, and that the visbreaking would likewise be a nominal feature in the hypothetical high octane rating operation. But inasmuch as these estimated existing and postulated future Soviet practices presumably involve visbreaking in a minor status similarly as in the US, the visbreaking is not considered to be of sufficient consequence to warrant a separate accounting in the over-all analyses of the Soviet operations either for 1950 or for high octane ratings in 1955. Visbreaking is in contrast to this a fundamental process in the hypothetical Soviet operation for high distillate yields, and the plausible yields for the process then resolve from the boiling point range and other characteristics postulated for the crude residue charge.

With a charge of a good quality short residuum such as is indicated in Table 20, Appendix B, technical correlations infer typical and plausible yields as fol-

lows if thermal visbreaking is applied to advance the conversion to optimum gasoline production:

Plausible Visbreaking of Short Residuum in the USSR

Conversion for Optimum Gasoline Production

	Weight Percent	Volume Percent	Lb/Gal a/	Bbl/Te b/
Coke and Gas Loss	5.75	6.25	c/	c/
Stable Visbreaker Gasoline	17.50	22.25	6.06	8.66
Visbreaker Gas Oil	11.25	11.75	7.38	7.11
Visbreaker Residual Fuel Oil	65.50	59.75	8.45	6.21
Short Residuum Charge	100.00	100.00	7.71	6.81

a. Pounds per gallon.
b. Barrels per metric ton.
c. Data not applicable.

In Table 20 the actual available crude residuum for visbreaker charge is more than half a long residuum stock, and the long resid contains essentially all of the gas oil in the crude although this gas oil is of a low quality heavy type. The latter potential gas oil is here considered to constitute a charge more suitable for visbreaking, as compared to a charge for true cracking if it were separated from the bottoms. Reasonably plausible technical yields are therefore developed for a process of visbreaking applied to a charge of the total available crude residuum with the short residuum included, assuming that emphasis is placed upon the general yield of distillates rather than gasoline alone.

It is probable in this latter case that the heavy gas oil portion of the charge will be predominantly converted to heavy naphtha distillates boiling between gasoline and heavier gas oil. It is further probable that while the coke and gas loss will represent a weight percentage in the same order of magnitude as

with the short residuum alone, the net volumetric expansion will result in a total liquid product volume very little less than the volume of the charge stock. The composite visbreaking yield percentages are as summarized below and applied in Table 20.

Probable Visbreaking of Crude Residuum in the USSR

1955 Operation for High Distillate Yield

	Weight Percent	Volume Percent	Lb/Gal a/	Bbl/Ton b/
Coke and Gas Loss	5.0	0.5	c/	c/
Stable Visbreaker Gasoline	15.0	18.5	6.34	8.28
Heavy Visbreaker Naphtha Distillates	34.0	38.0	7.00	7.50
Visbreaker Gas Oil	6.0	6.0	7.82	6.71
Visbreaker Residual Fuel Oil	40.0	37.0	8.45	6.21
Crude Residuum Charge	100.0	100.0	7.82	6.71

a. Pounds per gallon.
b. Barrels per metric ton.
c. Data not applicable.

For the development of plausible thermal cracking yields, resolved fundamentally upon the basis of the constitution of charge stock similarly as for visbreaking, the critical data for the constitution of charge stock are as shown in Table 29, Appendix B. The critical data are thus summarized in tabular form, and the data especially indicate the relative extents to which crude bottoms are eliminated from the virgin oils charged to the thermal cracking, referring to the annual operations as designated.

Reduction in the refractory character of the charge results by eliminating refractory crude bottoms from the total straight run stock charged to thermal cracking, and this is a factor in deriving plausible thermal cracking yields.

Catalytic gas oil is only slightly, if any, more refractory than the corresponding virgin oil. Visbreaker gas oil is, however, considerably more refractory upon the same basis. The relative data in Table 29 indicate that the thermal cracking charge in the 1950 estimate has over-all cracking characteristics no more than equivalent, if not inferior, to those in the thermal cracking charge for high distillate yields in 1955. The corresponding cracking characteristics appear to be degraded relative to these two annual charges in the thermal cracking charge for high octane ratings in 1955. Plausible thermal cracking yields are accordingly derived and applied as summarized in Table 30, Appendix B. Thermal cracking yields are for convenience shown to be comparable in the 1950 estimate and in the postulate for high distillate yields in 1955. The degradation of the over-all charge is reflected in the corresponding thermal cracking yields applied in the postulate for high octane ratings in 1955.

5. Possible Potentials in Finished Distillate Blends.

Similarly as explained in connection with the high octane rating analysis, additional gasoline blend stocks may be involved if finished gasoline blends are prepared from the gasoline derivatives shown in the high distillate yield analysis. As explained in the previous analysis, the inclusion of finished gasoline blends would probably cause little change in the general comparisons here developed between the operations estimated for 1950 and the operations indicated in the hypothetical construction programs. In the high distillate yield analysis the gasoline stock production represents a crude percentage nearly the same as the one in the 1950 estimate and much less than that in the high octane rating program. As

inferred by the original hypotheses and in contrast to the high octane rating program, the high distillate yield operation is shown to cause very little change in the high octane avgas stocks production compared to 1950 in terms of percentages of the crude. In the high distillate yield plan and the 1950 estimate the gasoline productions differ chiefly because the thermal reformed and visbreaker gasolines of the hypothetical plan replace some of the straight run and thermal cracked gasolines of 1950.

A salient feature of the high distillate yield operation is in the larger percentage productions and therefore quantitative productions of the various stocks commonly classified as intermediate and sometimes heavy distillates: these distillates are the "intermediates" (heavy naphthas and light gas oils) which presumably have an over-all distillation end point in the order of 650°F. But due to the increased use of virgin naphtha for thermal reforming in the high octane rating and high distillate yield programs, the straight run fractions such as kerosenes and Diesel oils are considerably decreased among the "intermediates" compared to 1950 in terms of percentages of the crude. Thermal visbreaker distillates account for the net increase in the total "intermediates" in the high distillate yield program.

Referring to final or finished products it is convenient to classify the total virgin and conversion "intermediates" within four general categories, thus: kerosenes and other stocks for direct heating and illumination purposes; kerosenes and other stocks for "tractor fuel" (i.e., fuel for lower compression spark-ignition reciprocating engines); stocks for Diesel fuel (i.e., fuel for compression-

ignition reciprocating engines); and kerosenes and other stocks for jet fuel (i.e., fuel for jet or turbine engines in aircraft). While the available data are far from adequate for estimating the octane ratings, cetene ratings, flame characteristics, and other physical and chemical properties of the "intermediates" obtainable from Soviet crudes, the lack of this information is not necessarily critical in the present study.

Although there may be more or less loss in the engine efficiency in doing so, it is still possible to design and operate the various internal combustion engines so as to utilize most "intermediates" as fuel if it is assumed that the "intermediates" have the range of distillation and quality characteristics normally prevailing for them. Thus the compression ratio may be reduced in the spark-ignition reciprocating engines so as to be suitable for low octane ratings; operating conditions may be established and the speed reduced in Diesel engines so as to be suitable for low cetene ratings; and jet engines have been developed to utilize cracked kerosenes as well as straight run stock, within a range of specifications flexible enough to allow more than half of the typical crude to be processed and converted to the specified fuel. Jet fuel specifications are subject to rapid experimental development and change outside of the Soviet Bloc, and this status probably likewise prevails within the Bloc.

It is important to note that while jet fuels potentially constitute a much greater percentage yield from the crude as compared to possible yields of suitable aviation gasolines, and further provide for greater travel speed in aircraft as compared to gasolines for reciprocating engines, jet fuels are nevertheless

by no means at present indicated to be universal engine fuels replacing gasolines even in aircraft. Jet planes are limited to high speed service. Significant limiting factors are further connected with the relative fuel consumptions and the correlated initial deadweight fuel loads required for scheduled operations, and also with certain mechanical complications not directly involved in the combustion and power characteristics of the fuel. The mechanical complications are especially represented by excessive corrosion and carbon deposits still prevailing in practice in the turbine engines of jet aircraft.

III. Future Petroleum Refining for Intermediate Results.

Summary.

Plausible New Refinery Construction for Intermediate Results.

Practicable extremes for the Soviets were postulated in the preceding analyses of two hypothetical future refining programs, respectively comprising alternate and contrasting schemes for high octane ratings and high general distillate yields. It is quite possible that a more realistic course would be intermediate between these extremes, and it is further plausible that the Soviets would obtain optimum results for their requirements by means of the intermediate course. An intermediate program would be at least more probable, and the present survey covers what is considered to be a logical hypothesis with respect to an intermediate plan.

The intermediate plan is developed as a program more nearly resembling the general schedule for high distillate yields as compared to the other extreme. Upon an over-all basis the intermediate program essentially differs from the high distillate yield schedule only in a reduction of visbreaking charge, an increase in the thermal cracking charge, and a small increase in catalytic conversion capacity.

For comparative purposes the intermediate program is postulated to be completed and operating in 1955, similarly as for the alternate extremes. With exceptions as presently noted, this third hypothetical program is based upon specific definitions and assumptions corresponding to those applied for the alternate extremes. In total the three hypothetical 1955 refinery systems and operations are calculated to be the same with respect to crude distillation, thermal reforming, and polymerization-hydrogenation. The respective hypotheses for intermediate results

and for high distillate yields each omit, however, the Krasnovodsk catalytic polymerization unit and the Fluid Catalytic Cracking facilities of the high octane rating plan. With regard to the catalytic cracking postulated for the high octane ratings, the high distillate yield program includes only the four lend-lease Houdry systems whereas the intermediate plan involves in addition the other three Houdry systems assumed in the high octane rating postulate. A separate catalytic sulfuric acid alkylation unit is assumed to be correlated with each Houdry system. The total thermal cracking charges are nearly equal in the plans for intermediate results and for high octane ratings.

The following table summarized the basic comparative data for the three hypothetical operations.

Postulated Operations in 1955

Charge Stocks in High Octane Rating,

High Distillate Yield,

and Intermediate Operations

Thousand Metric Tons

	Alternate Operations		
	High Octane Rating	High Distillate Yield	Intermediate Program
Virgin Gas Oil			
Charge to Fluid Catalytic Cracking	10,216	0	0
Charge to Houdry Catalytic Cracking	2,654	1,514	2,654
Charge (Total Charge) to Catalytic Cracking	12,870	1,514	2,654
Thermal Cracking Charge	0	11,356	10,216
Total Production	12,870	12,870	12,870
Crude Residuum			
Long Residuum to Thermal Cracking	5,850	0	5,850
Short Residuum to Thermal Cracking	7,800	0	0
Thermal Cracking Charge	13,650	0	5,850
Fuel Oil Product (Low Quality Long Residuum)	3,900	0	0
Long Residuum to Thermal Visbreaking	0	5,850	0
Short Residuum to Thermal Visbreaking	0	7,800	7,800
Low Quality Long Residuum to Thermal Visbreaking	0	3,900	3,900
Total Production	17,500	17,550	17,550
Charge (Total Charge) to Thermal Visbreaking	0	17,550	11,700
Thermal Cracking Charge			
Fluid Catalytic Gas Oil	3,658	0	0
Houdry Catalytic Gas Oil	1,060	606	1,060
Catalytic Gas Oil (Total)	4,718	606	1,060
Virgin Gas Oil	0	11,356	10,216
Visbreaker Gas Oil	0	1,053	1,170
Crude Residuum	13,650	0	5,850
Total Charge	18,368	13,015	18,296

Postulated Operations in 1955

Charge Stocks in High Octane Rating,

High Distillate Yield,

and Intermediate Operations
(Continued)

Thousand Metric Tons

	Alternate Operations		
	High Octane Rating	High Distillate Yield	Intermediate Program
Catalytic Alkylation Charge			
To Units with Fluid Systems	1,765	0	0
To Units with Houdry Systems	489	276	489
Total Charge	2,254	276	489

The following table provides a summary of the USSR refining capacities by types, estimated or assumed as above stated with reference to the program for intermediate results. Here the capacity ratings are of charge stocks except that they are shown in terms of product for the gas reversion and isooctane systems.

Estimated and Postulated Refining Capacities in the USSR

Data for Intermediate Program in 1955

Type of Facility	Thousand Metric Tons per Year Capacity: Estimated Existing in 1950	Postulated "New" by 1955	Postulated Total 1955
Crude Distillation	44,920	17,480	62,400
Thermal Reforming	989	4,107	5,096
Thermal Visbreaking	0	11,700	11,700
Thermal Cracking	16,312	1,984	18,296
Total Thermal Conversion	17,301	17,791	35,092
Houdry Catalytic Cracking a/	754	1,900	2,654
Alkylate Production b/	90	238	328
Isooctane Production c/	80	0	80
Total Catalytic Conversion	924	2,138	3,062
Total Conversion	18,225	19,929	38,154

a. Houdry units include supplementary catalytic reforming.
b. Catalytic gas reversion.
c. Catalytic gas reversion plus catalytic reforming.

Similarly as in the analyses of the limiting or alternate programs the foregoing USSR data may be compared with the 1950 US status as follows:

Capacity Ratio Comparison for 1955 Intermediate Program

Type of Capacity	Relative Weight Ratios Annual Basis: USSR Estimated Existing 1950	USSR Postulated for 1955	US 1950
Crude Production	1.000	1.000	1.000
Crude Distillation	1.198	1.200	1.192
Thermal Conversion a/	0.461	0.675	0.395
Catalytic Conversion	0.025	0.059	0.316
Total Conversion	0.486	0.734	0.711

a. Consists of reforming, visbreaking, cracking, and in the instance of the US, also some minor capacity for thermal gas reversion. But where the capacity factor is not very significant for visbreaking in the US, the corresponding factor is a ratio of 0.225 as here defined in this postulate for the USSR.

The following table shows the geographic distribution of the hypothetical USSR capacities for intermediate results:

Postulated Capacity Data for 1955 in the USSR

Intermediate Program

Thousand Metric Tons per Year

	Southwestern European Russia; Soviet Caucasus	Southwestern European Russia; Soviet Central Asia	Northern European Russia	Soviet Far East	Minor Sites	Total USSR
1950 Crude Production	20,400	11,000	19,600	1,000	0	53,000
Estimated for 1950	28,850	5,560	8,765	1,280	465	44,920
Added "New"	0	3,270	14,210	0	0	17,480
1955 Crude Distillation	28,850	8,830	22,975	1,280	465	62,400
Estimated for 1950	0	218	771	0	0	989
Added "New"	1,061	354	2,640	52	0	4,107
1955 Thermal Reforming	1,061	572	3,411	52	0	5,096
Estimated for 1950	0	0	0	0	0	0
Added "New"	4,080	2,200	5,220	200	0	11,700
1955 Thermal Visbreaking	4,080	2,200	5,220	200	0	11,700
Estimated for 1950	6,086	3,721	6,031	474	0	16,312
Added "New"	270	0	1,714	0	0	1,984
1955 Thermal Cracking	6,356	3,721	7,745	474	0	18,296
Estimated for 1950	0	754	0	0	0	754
Added "New"	760	380	760	0	0	1,900
1955 Catalytic Cracking a/	760	1,134	760	0	0	2,654
Estimated for 1950	0	89	0	0	0	89
Added "New"	96	47	96	0	0	239
1955 Alkylate Production	96	136	96	0	0	328
Estimated for 1950	0	0	80	0	0	80
Added "New"	0 b/	0	0	0	0	0
1955 Isooctane Production	0	0	80	0	0	80

a. Houdry systems including supplementary catalytic reforming.
b. Soviet Caucasus codimer polymer contributes to isooctane.

Product Yield Potentials in Intermediate Program.

The following table summarizes the comparison of yield potentials for Soviet refining, referring to the estimated over-all operations in 1950 and the over-all hypothetical operation for intermediate results in 1955. In direct correspondence to the preceding analyses for the practicable limiting programs, the basis of this table involves gross yields at the refining units as developed from an initial charge of the estimated total Soviet crude production.

Gross Yields in Soviet Refining

1950 Operation Versus the Operation for Intermediate Results in 1955

Thousand Metric Tons

	Estimated 1950 Processing		Hypothetical 1955 Intermediate Program Processing	
	Gross Yield	Percent Crude	Gross Yield	Percent Crude
Motor	2,721	7.26	1,593	3.06
Aviation a/*	1,018	2.71	1,137	2.19
Total Straight Run Base	3,739	9.97	2,730	5.25
Thermal Reformed Base	724	1.93	3,730	7.17
Total Base from Virgin Naphtha	4,463	11.90	6,460	12.42
Motor	23	0.06	82	0.16
Aviation	186	0.50	661	1.27
Total Catalytic Cracked Base	209	0.56	743	1.43
Isopentane	20	0.05	69	0.13
Total by Catalytic Cracking	229	0.61	812	1.56
Thermal Visbreaker Base	0	0.00	1,580	3.04
Thermal Cracked Base	5,776	15.40	6,477	12.46
Total by Visbreaking and Cracking	6,005	16.01	8,869	17.06
Aklylation Blend Stock b/	42	0.11	152	0.29
Motor	8	0.02	31	0.06
Aviation	81	0.22	297	0.57
Total Alkylate	89	0.24	328	0.63
Isooctane c/	80	0.21	80	0.15
Total Gas Reversion Blend Stock d/	169	0.24	408	0.78
Total Stable Gasoline Base and Blend Stocks	10,679	28.5	15,889	30.6
Thermal Visbreaker	0	0.0	2,632	5.1
Thermal Cracked	1,065	2.8	1,189	2.3
Total by Thermal Visbreaking and Cracking	1,065	2.8	3,821	7.4
Straight Run	8,614	23.0	10,140	19.5
Total Intermediate Distillates	9,679	25.8	13,961	26.9

(Continued on next page)

* Footnotes follow on page 116.

Gross Yields in Soviet Refining

1950 Operation Versus the
Operation for Intermediate Results in 1955
(Continued)

	Thousand Metric Tons			
	Estimated 1950 Processing		Hypothetical 1955 Intermediate Program Processing	
	Gross Yield	Percent Crude	Gross Yield	Percent Crude
Lubes, Speciality Residuals	2,778	7.4	2,730	5.2
Thermal Visbreaker	0	0.00	5,616	10.80
Thermal Cracked	7,364	19.64	8,270	15.90
Total by Thermal Visbreaking and Cracking	7,364	19.64	13,886	26.70
Thermal Reformed	97	0.26	500	0.96
Total by Thermal Conversion	7,461	19.90	14,386	27.66
Catalytic Polymer e/	14	0.03	50	0.10
Total Conversion Residual	7,475	19.93	14,436	27.76
Straight Run Residual	3,948	10.53	0	0.00
Total Residual Fuel Oil	11,423	30.5-	14,436	27.7/
Over-all Process Loss	2,941	7.8	4,984	9.6
Gross Products	34,559	92.2	47,016	90.4
Total Crude Charge f/	37,500	100.0	52,000	100.0
Thermal Visbreaker Base	0	0.00	1,580	3.04
Thermal Cracked Base	5,776	15.40	6,477	12.46
Total by Thermal Visbreaking and Cracking	5,776	15.40	8,057	15.50
Thermal Reformed Base	724	1.93	3,730	7.17
Thermal Conversion Base	6,500	17.33	11,787	22.67
Catalytic Cracked Base	209	0.56	743	1.43
Total Conversion Base	6,709	17.89	12,530	24.10
Straight Run Base	3,739	9.97	2,730	5.25
Total Stable Gasoline Base Stocks	10,448	27.86	15,260	29.35

(Continued on next page)

Gross Yields in Soviet Refining

1950 Operation Versus the
Operation for Intermediate Results in 1955
(Continued)

	Thousand Metric Tons			
	Estimated 1950 Processing		Hypothetical 1955 Intermediate Program Processing	
	Gross Yield	Percent Crude	Gross Yield	Percent Crude
Catalytic Cracking Isopentane	20	0.05	69	0.13
Gas Reversion Blend Stock d/	169	0.45	408	0.78
Direct Catalytic Conversion Blend Stock	189	0.50	477	0.91
Alkylation Blend Stock d/	42	0.11	152	0.29
Total Stable Gasoline Blend Stocks	231	0.61	629	1.20
Thermal Conversion Base	6,500	17.33	11,787	22.67
Catalytic Cracked Base	23	0.06	82	0.16
Total Conversion Motor Base	6,523	17.39	11,869	22.83
Straight Run Motor Base	2,721	7.26	1,593	3.06
Total Motor Base	9,224	24.65	13,462	25.89
Motor Alkylate	8	0.02	31	0.06
Alkylation Blend Stock b/	42	0.11	152	0.29
Total Stable Motor Gasoline Base and Blend Stocks	9,294	24.78	13,645	26.24
Catalytic Cracked Base	186	0.05	661	1.27
Straight Run Aviation Base a/	1,018	2.71	1,137	2.19
Total Aviation Base	1,204	3.21	1,798	3.46
Aviation Alkylate	81	0.22	297	0.57
Isooctane c/	80	0.21	80	0.15
Catalytic Cracking Isopentane	20	0.05	69	0.13
Total Stable Aviation Gasoline Base and Blend Stocks	1,385	3.69	2,244	4.31

(Continued on next page)

Gross Yields in Soviet Refining

1950 Operation Versus the
Operation for Intermediate Results in 1955
(Continued)

a. Potential virgin naphthenic stocks. These potential yields obviously include excesses over the quantities utilizable with other available avgas stocks in the final avgas blends.

b. Excess charge stock to alkylation, essentially consisting of excess butanes; stock derived by crude fractionation, reforming, cracking, and visbreaking.

c. Derived by hydrogenation of codimer polymer.

d. In part as represented in isooctane.

e. Produced in the supplementary catalytic reforming stage in the Houdry Catalytic Cracking systems.

f. Later estimates have indicated a total 1950 production value of nearer 38.0 million metric tons for Soviet crude oil.

Possible Potentials in Finished Product Blends.

As previously explained or inferred in the present survey, the 1955 operations for all three hypothetical programs show only the potentials for base and blend stocks. No direct accounting is made of balances for the probable finished product blends or of the relatively small amounts of additional hydrocarbon stocks possibly required for some of the finished products, especially of the gasoline and other distillate types. But again in accordance with previous discussions and correlations in this survey, the lack of this accounting probably has insignificant effect upon the generalized comparisons and intrinsic evaluations of the potentials. The present or intermediate program is directly derived from the limiting or extreme plans, and since the potentials of the intermediate operations are therefore summarized and explained by means of the preceding summary developments and comparative (i.e., corresponding) tables, further discussion is here omitted as unnecessary.

1. Purpose of the Analysis.

Technical data and available intelligence are correlated in this survey to determine what might be a logical and possible optimum program for the construction of new refining apparatus in the USSR, so as to attain goals intermediate between the practicable limiting schedules respectively analyzed in Parts I and II of the present paper. A correlation for this purpose is developed for direct comparison with the data in Part I which relate to high octane ratings, and also the data in Part II which relate to high general distillate yields. The pertinent operations are therefore postulated for 1955 as in Parts I and II, conforming to identical definitions, assumptions, and other considerations wherever applicable.

2. Basis of Study.

The intermediate USSR refining program is constituted by various features with certain modifications, contained in the developments of Parts I and II of this paper. The plan for intermediate results more nearly resembles the practicable extreme for high distillate yields as postulated in Part II, in comparison to the alternate extreme for high octane ratings as postulated in Part I. The developments of Parts I and II cover the theoretical and generalized economic aspects of the refining techniques thus selected for intermediate results. Upon an over-all basis the intermediate plan essentially differs from the high distillate yield schedule in three features only, consisting of a reduction in visbreaking charge, an increase in thermal cracking charge, and a small increase in catalytic conversion capacity.

In total the three hypothetical future refining programs are calculated to be the same with respect to crude distillation, thermal reforming, and polymerization-hydrogenation. The respective hypotheses for intermediate results and for high distillate yields each omit, however, the Krasnovodsk catalytic polymerization unit and the Fluid Catalytic Cracking facilities of the high octane rating plan. With regard to catalytic cracking postulated for the high octane ratings, the high distillate yield program includes only the four lend-lease Houdry systems/postulated for high octane ratings. A separate catalytic sulfuric acid alkylation unit is assumed to be correlated with each Houdry system. The total thermal cracking charges are nearly equal in the plans for intermediate results and for high octane ratings.

In the intermediate plan as compared to the practicable limiting schedule for high distillate yields, the reduced visbreaking and increased true thermal cracking

serve to increase the quality ratings and relative yields of gasolines; there is a correlated decrease in the total yield of liquid distillate stocks by reason of this increase in the over-all degree of conversion. Similar results develop from the corresponding small increase in catalytic conversion. The intermediate program includes catalytic conversion facilities where such constructions are believed to be very probable in the immediate future in the USSR.

3. Modernized Soviet Processing Balances for Intermediate Results (Postulated for 1955).

Table 31, Appendix B, is compiled to show an estimate of a plausible over-all refinery operation for intermediate results in 1955. This table is developed upon a basis as above inferred, so as to be consistent with the preceding Tables 17 and 20 of Appendix B, respectively pertaining to the alternate practicable limiting schedules for high octane ratings and for high general distillate yields. Respectively corresponding in a similar manner to Tables 18 and 19 which are correlated with Table 17 in Appendix B, and to Tables 21 and 22 which are correlated with Table 20 in the same Appendix, Tables 32 and 33, Appendix B, further summarize what might prevail in the intermediate program in the utilization of refining installations carried over from 1950, with designation of the considerable additional capacities required for the 1955 balance. Tables 34 and 35, Appendix B, relate to the derivation of certain data thus applied. The analyses and annotated Tables for Parts I and II are considered to be sufficient to cover the developments of the corresponding tables for Part III, providing that note is made of important exceptions constituted by the visbreaking and thermal cracking yields shown in the tables.

The 1955 capacity relationships given in Table 31 may be summarized as shown below, with new capacities indicated relative to what is supposed to have been existing in 1950 and with the 1950 capacities carried over in total. By comparing the following summary table with the similar tables given in Section 10 of Part I, and in Section III of Part II, it is seen that the refining capacity values are about the same for the total required and total new by 1955, referring to the crude distillation and total conversion apparatus thus developed for the three hypothetical plans. The three plans essentially differ in the types of conversion apparatus as indicated.

Postulated 1955 Crude Production and Refining Capacities in the USSR

Plausible End Results If Intermediate Program Is Adopted

Oil Quantities in Thousands of Metric Tons Per Year

Indicating Capacities "New" Since 1950

Crude Production (14,500 new)	52,000
Crude Distillation (17,480 new)	62,400
Thermal reforming (4,107 new)	5,096
Thermal visbreaking (all new)	11,700
Thermal cracking (1,984 new)	18,296
Total thermal conversion (17,791 new)	35,092
Houdry catalytic cracking and reforming (1,900 new)	2,654
Catalytic alkylate product (283 new)	328
Catalytic polymerization-hydrogenation product (none new)	80
Total catalytic conversion (2,138 new)	3,062
Total thermal conversion (17,791 new)	35,092
Total conversion (19,929 new)	38,154
Annual capacity ratios:	
Crude production capacity	1.000
Crude distillation capacity	1.200
Thermal conversion capacity	0.675
Catalytic conversion capacity	0.059
Total conversion capacity	0.734

Table 23, Appendix B, shows the essential capacity and operation relationships here postulated in the three hypothetical future refining programs.

4. Detail Data for Relative Yields.

The analyses of Parts I and II of the present survey cover the relative yields applied in Part III, excepting the yields in visbreaking and thermal cracking. The analysis of Part II correlates visbreaking and thermal cracking yields by use of summary data in Tables 24, 25, 26, 28, and 29, Appendix B. The latter tables may be applied to develop similar yields for Part III if the summary data of Table 27, Appendix B, are also considered.

By comparing the summary data in Tables 24, 25, 26, and 28 it is indicated that the over-all visbreaking charge in Table 31 for Part III, i.e., in the schedule for intermediate results in 1955, is more predominantly crude bottoms as compared to the corresponding visbreaking charge in Table 20 for Part II, i.e., in the schedule for high general distillate yields in 1955. Technical principles are therefore applied to develop the Part III visbreaking yields as shown below and as applied in Table 31. This visbreaking operation is less efficient as compared to that in Table 20 (cf. the visbreaking data and yield tables in Section 4, Part II).

Probable Visbreaking of Crude Residuum in the USSR

1955 Operation for Intermediate Results

	Weight Percent	Volume Percent	Lb/Gal a/	Bbl/Ts b/
Coke and Gas Loss	5.0	0.5	c/	c/
Stable Visbreaker Gasoline	13.5	16.5	6.39	8.22
Heavy Visbreaker Naphtha Distillates	22.5	25.0	7.02	7.48
Visbreaker Gas Oil	10.0	10.0	7.80	6.73
Visbreaker Residual Fuel Oil	48.0	45.0	8.32	6.31
Crude Residuum Charge	100.0	100.0	7.80	6.73

a. Pounds per gallon.
b. Barrels per metric ton.
c. Data not applicable.

The summary data of Table 29 may be then applied to correlate the plausible thermal cracking yields shown in Appendix B tables, i.e., in Table 15 for the estimated 1950 operation in Table 17 for the hypothetical 1955 high octane rating operation, in Table 20 for the hypothetical 1955 high distillate yield operation, and in Table 31 for the hypothetical 1955 intermediate operation. Table 29 indicates that the thermal cracking charge in the 1950 estimate is possibly superior but still reasonably equivalent to that in the 1955 hypothesis for intermediate results. Thermal cracking yields are for convenience shown to be comparable in the 1950 estimate and in the postulate for intermediate results in 1955 (cf. Tables 30 and 31, Appendix B).

5. Possible Potentials in Finished Product Blends.

As previously explained or inferred in the present survey, the 1955 operations for all three hypothetical programs show only the potentials for base and blend stock No direct accounting is made of balances for the probable finished product blends or of the relatively small amounts of additional hydrocarbon stocks possibly required for some of the finished products, especially of the gasoline and other distillate types. But again in accordance with previous discussions and correlations in this survey, the lack of this accounting probably has insignificant effect upon the generalized comparisons and intrinsic evaluations of the potentials. The present or intermediate program is directly derived from the limiting or extreme plans, and since the potentials of the intermediate operations are therefore summarized and explained by means of the preceding summary developments and comparative (i.e., corresponding) tables, further discussion is here omitted as unnecessary.

APPENDIX A

Table 1. Estimated Crude Stock Production and Non-Catalytic Refining in the USSR
Basis 1950

Place or Area	Existing Crude Distillation Facilities: Charge	Existing Crude Distillation Facilities: Percent to Total	Existing Thermal Conversion Facilities: Charge	Existing Thermal Conversion Facilities: Percent to Total	Crude Producing Regions in Current Area: Region	Crude Produced: Quantity	Crude Produced: Percent to Total	Crude Available for Straight Run Base Stock	Thousand Metric Tons per Year: Available Straight Run Base Stock t/: Quantity	Available Straight Run Base Stock t/: Percent to Total
Drogobych	360	0.60	46	0.28	Carpathian	305	0.81	31	2.0	0.20
Odessa g/	250	0.56	238	1.38	*	*	*	*	*	*
Kherson g/	**	**	238	1.38	*	*	*	*	*	*
Berdiansk g/	**	*	237	1.36	*	*	*	*	*	*
North Black Sea Coast	250	0.56	713	4.12	Ukraine-Crimea g/	40	0.11	4	0.3	0.03
Tuapse d/	2,000	4.45	304	1.76	*	*	*	*	*	*
Krasnodar	900	2.00	**	**	*	*	*	*	*	*
Kuban-Maikop Region	2,900	6.45	304	1.76	Kuban-Maikop	2,420	6.45	363	23.8	2.34
Batum d/ e/	3,100	6.90	785	4.54	Georgian g/	115	0.31	11	0.7	0.07
Grozny f/	6,400	14.25	2,557	14.78	Grozny f/	2,045	5.45	525	34.4	3.38
Makhachkala	90	0.20	**	**	Daghestan	925	2.47	46	3.0	0.29
Baku	15,750	35.06	1,679	9.70	Baku	15,150	40.40	12,120	795.3	78.17
Krasnovodsk	1,020	2.27	1,040	6.01	*	*	*	*	*	*
Cheleken	160	0.36	**	**	*	*	*	*	*	*
Nebit-Dag	250	0.55	349	2.02	*	*	*	*	*	*
Turkmen Region	1,430	3.18	1,389	8.03	Turkmen	1,200	3.20	300	19.7	1.94
Southeastern Central Asia	1,830	4.07	452	2.61	Southeastern Central Asia	1,255	3.34	251	16.5	1.62
Gurev	600	1.34	528	3.05	Emba	1,220	3.25	244	16.0	1.57

* Data and entries applicable only for the total areas with productive regions corresponding.
** No facilities indicated.
*** Footnotes follow on p. 133.

Table 1. (Continued)

Place or Area	Existing Crude Distillation Facilities: Charge	Existing Crude Distillation Facilities: Percent to Total	Existing Thermal Conversion Facilities: Charge	Existing Thermal Conversion Facilities: Percent to Total	Region	Crude Producing Regions in General Area: Crude Produced: Quantity	Crude Produced: Percent to Total	Value of Available for Straight Run Base Stock	Available Straight Run Base Stock: Quantity	Available Straight Run Base Stock: Percent to Total
Sterlitamak g/	530	1.18	[illegible]	1.28	*	*	*	*	*	*
Ishimbaevo g/	410	0.91	—	—	*	*	*	*	*	*
Ufa g/	1,500	3.34	[illegible]	2.01	*	*	*	*	*	*
Tuimaza h/	—	—	570	3.29	*	*	*	*	*	*
Kuibyshev h/	470	1.05	1,000	5.78	*	*	*	*	*	*
Batraki h/	200	0.45	**	**	*	*	*	*	*	*
Syzran h/	500	1.11	[illegible]	2.56	*	*	*	*	*	*
Ural-Volga Region	3,610	8.04	2,582	14.92	Ural-Volga	11,200	29.87	1,120	73.5	7.22
Molotov Area i/	1,010	2.25	629	3.65	Kama i/	325	0.87	33	2.2	0.22
Ukhta i/	250	0.55	**	**	Pechora i/	480	1.28	48	3.2	0.31
Pacific Coast Soviet Far East	1,280	2.85	474	2.73	Sakhalin	820	2.19	410	26.9	2.64
Orsk j/	1,500	3.34	570	3.29	*	*	*	*	*	*
Chkalov j/	**	**	1,000	5.78	*	*	*	*	*	*
Stalingrad	200	0.45	**	—	*	*	*	*	*	*
Central Area, Volga to Ural Rivers	1,700	3.79	1,570	9.07	*	*	*	*	*	*
Saratov j/ k/	1,800	4.01	2,343	13.54	*	*	*	*	*	*
Kazan j/	160	0.36	**	**	*	*	*	*	*	*
Gorki j/	600	1.34	452	2.61	*	*	*	*	*	*
Yaroslavl j/	415	0.92	190	1.10	*	*	*	*	*	*
Moscow j/	820	1.83	380	2.20	*	*	*	*	*	*
Central European Russia	3,795	8.46	3,365	19.45	*	*	*	*	*	*
Leningrad j/	100	0.22	226	1.31	*	*	*	*	*	*
Other	465	1.03	**	**	*	*	*	*	*	*
TOTAL USSR	44,920	100.00	17,301	100.00		37,500	100.00	15,506	1,017.5	100.00

* Data and entries applicable only for the total areas with productive regions corresponding.
** No facilities indicated.

a. Quantity of crude having a content of straight run gasoline in practicable percentage, with this gasoline suitable for avgas base stock.

b. Quantity of stabilized straight run gasoline practicably obtainable from the crude, with this gasoline suitable for avgas base stock. The base stock is assumed to have 300 °F E.P. (Engler) and 70-72 ON (motor, clear).

c. Distribution centers for the inland movement of oil stock from the Black Sea. Minor Ukraine and Crimea Regions are respectively to the north and south. Charge stocks are indicated to be mostly imported and largely composed of oils for conversion charge (crude residue, heavy naphtha, and gas oil). Origin of imported charge is probably in producing regions to the east in the USSR, in the Caucasus and elsewhere; origin also indicated in Rumania and possibly other European Satellites.

d. Oil distribution centers on the eastern coast of the Black Sea. Charge stocks are indicated to be imported to some extent, similarly as for the facilities on the northern Black Sea coast except that the eastern coast imports would appear to be mostly crude. Special reference is to Batum notwithstanding the questionable status of the Batum refinery equipment.

e. Site of old installations with the existing degree of modernization and operable condition open to question. Connected to Baku Region by means of pipelines extending across the Caucasus isthmus. Present condition and even existence of these lines especially uncertain. The minor Georgian Region is offset to the north of the route of the lines.

f. Modernized excess facilities that possibly handle stocks produced in excess of facilities elsewhere in the USSR. Inadequate facilities are indicated in the Emba Region and in the Second Baku area (Kama, Ural, and Volga Regions).

g. Ural Region. Pending further data firm enough to warrant revision, the indicated annual thermal conversion charge may be increased to the order of 1.5 million metric tons at Ufa, considering the actual plant constructions made by Alco and Lummus.

h. Volga Region.

i. Molotov area facilities possibly also process Pechora Region stock.

j. Industrial centers with installations presumably in service on excess stocks produced in the Second Baku.

k. In the largest natural gas producing region in the USSR.

APPENDIX B

Table 2. Soviet Lend - Lease Houdry Projects
Badger Design Percentage Yields of Stocks
Houdry Processing

	Gorev #1		Orsk #2		Kuibyshev #1-2		Krasnovodsk #1-2	
Houdry Cracking a/	Vol. %	Wt. %	Vol. %	Wt. %	Vol. %	Wt. %	Vol. %	Wt. %
Kalin (Emba) G. O.	71.73	72.73	*	*	*	*	*	*
Imported Gas Oil	28.27	27.77	*	*	100.00	100.00	23.51 b/	23.53 b/
Emba Gas Oil	*	*	100.00	100.00	*	*	*	*
Nebetdag (Turkmen) G. O.	*	*	*	*	*	*	76.49 b/	76.47 b/
Total Gas Oil Charge	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00
Dry Gas	*	6.78	*	7.37	*	5.79	*	5.80
C_4 Stock	15.01	9.96	16.45	11.13	13.91	9.01	15.93	10.69
Gasoline (C_5+)	42.13	36.13	55.02	49.12	41.20	34.43	44.20	38.27
Houdry Gas Oil	41.00	42.18	24.80	26.10	44.81	45.95	40.89	41.44
Coke	*	4.95	*	6.28	*	4.82	*	3.80
Total Yield	*	100.00	*	100.00	*	100.00	*	100.00
C_4+ Recovery	98.14	88.27	96.27	86.35	99.92	89.39	101.02	90.40
Houdry Reforming								
Houdry Gaso (C_5+) Charge	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00
Dry Gas	*	3.97	*	3.70	*	5.14	*	5.21
C_4 Stock	7.85	5.95	7.54	5.70	*	*	*	*
C_4 - C_5 Stock	*	*	*	*	7.28	5.57	8.56	6.56
Isopentane	7.03	5.85	6.94	5.74	6.08	5.11	13.07	10.92
Avgas Base Stock	71.20	69.53	69.86	67.73	67.07	65.75	58.49	59.26
Motor Naphtha	4.43	5.09	8.51	9.59	6.50	7.33	8.68	9.81
Polymer Gas Oil	4.43	5.51	3.39	4.44	4.79	6.15	2.68	3.44
Coke	*	4.10	*	3.10	*	4.95	*	4.80
Total Yield	*	100.00	*	100.00	*	100.00	*	100.00
C_4+ Recovery	94.94	91.93	96.24	93.20	91.72	89.91	91.48	89.99
Houdry Processing								
Virgin Gas Oil Charge	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00
Dry Gas	*	8.22	*	9.19	*	7.56	*	7.79
C_4 Stock	18.31	12.11	20.60	13.93	13.91	9.01	15.93	10.69
C_4 - C_5 Stock	*	*	*	*	3.00	1.92	3.78	2.51
Isopentane	2.96	2.11	3.82	2.81	2.50	1.76	5.78	4.18
Avgas Base Stock	30.00	25.12	38.43	33.28	27.63	22.64	25.85	22.68
Motor Naphtha	1.87	1.84	4.68	4.71	2.68	2.52	3.83	3.75
Houdry Gas Oil	41.00	42.18	24.80	26.10	44.81	45.95	40.90	41.44
Polymer Gas Oil	1.87	2.00	1.87	2.18	1.97	2.12	1.19	1.32
Coke	*	6.42	*	7.80	*	6.52	*	5.64
Total Yield	*	100.00	*	100.00	*	100.00	*	100.00
C_4 Recovery	96.01	85.36	94.20	83.01	96.50	85.92	97.26	86.57
Gas Oil Charge, °API	29.1		34.7		26.7		26.9	

a. 0 recycle to cases except Fresh Feed/Recycle = 4 at Orsk (by volume).
b. Estimated.
* Data either nil or not applicable.

Table 3. Soviet Land - Lease Houdry Projects
Badger Design Percentage Yields of Stocks
Crude Distillation and Thermal Conversions

	Gurev #1		Kuibyshev #3-1		Kuibyshev #3-2		Krasnovodsk #4-1		Krasnovodsk #4-2	
Crude Distillation	Vol. %	Wt. %	Vol. %	Wt. %	Vol. %	Wt. %	Vol. %	Wt. %	Vol. %	Wt. %
Kalin (Baku) Crude	100.00	100.00	*	*	*	*	*	*	*	*
Buguruslan (Volga) Crude	*	*	100.00	100.00	100.00	100.00	*	*	*	*
Nebit-Dag (Turkmen) Crude	*	*	*	*	*	*	100.00	100.00	100.00	100.00
Dry Gas	*	*	*	1.40	*	1.40	*	1.31	*	*
Straight Run Gasoline	4.05	3.36	*	*	*	*	6.00	4.92	6.00	4.88
Thermal Reforming Naphtha	22.09	20.20	27.00	23.17	27.00	23.17	20.10	18.33	12.00	10.89
Gas Oil to Houdry	48.91	49.04	*	*	*	*	*	*	57.46 a/	57.18 a/
Residue to Thermal Cracking	24.95	27.40	71.00	75.43	*	*	72.90	75.44	24.54 a/	27.11 a/
Residue to Fuel Oil	*	*	*	*	71.00	75.43	*	*	*	*
Total Yield	*	100.00	*	100.00	*	100.00	*	100.00	*	100.00
Liquid Recovery	100.00	100.00	98.00	98.60	98.00	98.60	99.00	98.69	100.00	100.00
Thermal Reforming										
Kalin Virgin Naphtha	100.00	100.00	*	*	*	*	*	*	*	*
Buguruslan Virgin Naphtha	*	*	100.00	100.00	100.00	100.00	*	*	*	*
Nebit-Dag Virgin Naphtha	*	*	*	*	*	*	100.00	100.00	52.26	52.20
Imported Naphtha	*	*	*	*	*	*	*	*	47.74	47.80
Total Charge	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00
Dry Gas	*	14.79	*	13.14	*	13.14	*	13.97	*	12.41
C_4 Stock	7.78	5.79	8.35	6.59	*	*	*	*	*	*
C_4-C_5 Stock	*	*	*	*	13.05	10.52	6.00	4.50	11.93	9.13
Gasoline (C_5+) Stock	68.85	67.67	73.54	73.52	*	*	*	*	*	*
Gasoline Base Stock	*	*	*	*	68.84	69.59	70.85	70.51	67.20	67.38
Residue to Fuel Oil	9.79	11.75	5.31	6.75	5.31	6.75	9.55	11.02	9.63	11.08
Total Yield	*	100.00	*	100.00	*	100.00	*	100.00	*	100.00
C_4+ Recovery	86.42	85.21	87.20	86.86	87.20	86.86	86.40	86.03	88.76	87.59
Thermal Cracking										
Kalin Virgin Residue	41.28	43.13	*	*	*	*	*	*	*	*
Imported Gas Oil	12.53	11.69	*	*	48.03	49.29	*	*	22.10 a/	21.87 a/
Buguruslan Virgin Residue	*	*	100.00	100.00	*	*	*	*	*	*
Nebit-Dag Virgin Residue	*	*	*	*	*	*	100.00	100.00	34.59 a/	36.48 a/
Houdry Gas Oil	46.21	45.13	*	*	51.97	50.71	*	*	43.31	41.65
Total Charge	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00
Dry Gas	*	9.00	*	7.99	*	8.40	*	10.95	*	10.26
C_4 Stock	7.02	4.17	5.27	3.31	*	*	*	*	*	*
C_4-C_5 Stock	*	*	*	*	8.42	5.41	8.20	5.72	10.40	6.93
Gasoline (C_5+) Stock	45.43	37.83	35.76	28.97	*	*	*	*	*	*
Gasoline Base Stock	*	*	*	*	24.92	20.48	44.86	37.69	36.10	30.68
Residue Fuel Oil	43.81	49.00	54.49	50.73	58.08	65.71	41.22	45.64	46.59	52.13
Total Yield	*	100.00	*	100.00	*	100.00	*	100.00	*	100.00
C_4+ Recovery	90.28	91.00	95.52	92.01	91.34	91.60	94.28	89.05	93.09	89.74

a. Estimated in part. * Data either nil or not applicable.

Table 4. Soviet Lend-Lease Noudny Projects
Badger Design Percentage Yields of Stocks
Catalytic Reforming, Acid Treating, and Rerunning

	Gurev #1		Orsk #2		Kuibyshev #3-1		Kuibyshev #3-2		Krasnovodsk #4-1		Krasnovodsk #4-2	
H_2SO_4 Alkylation	Vol. %	Wt. %	Vol. %	Wt. %	Vol. %	Wt. %	Vol. %	Wt. %	Vol. %	Wt. %	Vol. %	Wt. %
C_3 Stock	[illegible]	[illegible]	[illegible]	[illegible]			[illegible]	[illegible]			[illegible]	[illegible]
C_4 Stock	[illegible]	[illegible]	[illegible]	[illegible]			[illegible]	[illegible]			[illegible]	[illegible]
C_5 Stock	*	*	11.70	12.59			14.34	15.44			16.16	17.43
Total Charge	[illegible]	[illegible]	[illegible]	[illegible]			[illegible]	[illegible]			[illegible]	[illegible]
C_3 Stock	2.03	1.63	1.95	1.69			1.20	1.01			0.96	0.81
Light Blend Stock	27.58	27.63	37.71	37.72			29.46	29.97			30.34	30.85
Motor Alkylate	5.49	7.77	5.24	6.46			3.24	4.34			3.30	4.37
Aviation Alkylate	51.93	62.77	43.09	51.78			52.23	63.1[illegible]			51.67	62.40
Process Loss	*	*	*	2.35			*	1.52			*	1.57
Total Yield	*	100.00	*	100.00			*	100.00			*	100.00
C_4 Recovery	85.00	98.37	86.04	95.56			84.93	97.4[illegible]			85.31	97.62
Phosphoric Acid Polymerization												
C_1 Stock									0.79	0.47	2.91	1.66
C_2 Stock									9.47	6.88	14.41	11.29
C_3 Stock									36.89	35.19	78.98	82.78
C_4 Stock									33.97	37.27	3.70	4.27
C_5 Stock									18.88	20.19	*	*
Total Yield									100.00	100.00	100.00	100.00
Dry Gas									*	32.98	*	72.47
Light Blend Stock									8.17	8.82	*	*
Polymer Gasoline									46.80	58.20	19.13	27.53
Total Yield									*	100.00	*	100.00
C_4 Recovery									54.97	67.02	19.13	27.53
H_2SO_4 Treating a/												
Treated Reformed Gasoline					95.30	95.30	95.34	95.39	94.31	94.74	94.10	94.00
Sludge Loss					4.70	4.70	4.66	4.61	5.69	5.26	5.90	6.00
Reformed Gasoline Charge					100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00
Treated Cracked Gasoline					83.15	78.50	83.15	83.20				
Sludge Loss					16.85	21.50	16.85	16.80				
Cracked Gasoline Charge					100.00	100.00	100.00	100.00				
Gasoline Rerunning b/												
Rerun Reformed Gasoline					99.12	99.05	99.12	99.03	99.03	98.95	98.97	98.97
Polymer Residue					0.88	0.95	0.88	0.97	0.97	1.05	1.03	1.03
Treated Reformed Gasoline					100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00
Rerun Cracked Gasoline					92.95	92.2[illegible]	92.65	92.35				
Polymer Residue					7.05	7.7[illegible]	7.35	7.65				
Treated Cracked Gasoline					100.00	100.00	100.00	100.00				

a. Thermal gasoline charge stock.
b. H_2SO-treated thermal gasoline charge stock
* Data either nil or not applicable.

S-E-C-R-E-T

Table [illegible]

Badger Design Percentage Yields of Stocks

Solvent Extraction

Solvent Extraction	Deck #2 Vol. %	Deck #2 Wt. %
Imported Reduced Crude Charge	100.00	100.00
Aviation Lube	44.53	43.45
Neutral Oil	7.32	7.55
Gas Oil Product	0.29	0.29
High Pour Point Oil	1.82	5.86
High Melting Point Wax	4.35	
Duo-Sol Extract	38.54	40.28
Oil Loss	2.65	2.57
Total Yield	*	100.00
Stock Recovery	97.35	97.43

* No value applicable.

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Table 6. Soviet Land-Lease Houdry Projects
Badger Design Percentage Compositions
Gasoline Blends with Houdry Stocks

	Gurev #1		Orsk #1		Kuibyshev #1-2				Krasnovodsk #1-2			
	Vol. %	Wt. %	Vol. %	Wt. %	Vol. %	Wt. %	[illegible]	ON	Vol. %	Wt. %	[illegible]	ON
Aviation Gasoline Blend												
Houdry Aviation Base	70.42	71.10	69.88	70.58	74.96	75.88	7.0	97.5	51.63	53.79	7.0	96.5
Houdry Isopentane	*	*	*	*	4.08	3.54	20.5	107.5	8.38	7.20	20.5	100.5
Aviation Alkylate	29.58	28.90	30.12	29.42	20.96	20.58	2.0	107.5	31.61	30.92	2.0	107.5
Straight Run Base	*	*	*	*	*	*	*	*	8.38	8.15	7.0	86.2
Total a/	100.00	100.00	100.00	100.00	100.00	100.00	6.5	100.0	100.00	100.00	6.5	100.0
Motor Gasoline Blend												
Straight Run Base	7.29	7.05	*	*								
Thermal Reformed Base	27.40	28.69	63.22	67.10								
Thermal Cracked Base	49.52	50.38										
Houdry Motor Naphtha	2.29	2.62	10.41	11.51								
Houdry Isopentane	3.64	3.01	8.48	6.88								
Motor Alkylate	1.64	1.20	4.48	4.23								
C_4 Stock	8.22	6.45	*	*								
C_4-C_5 Stock	*	*	13.41	10.28								
Total	100.00	100.00	100.00	100.00								
Reformed Gasoline Blend												
Thermal Reformed Base					73.95	76.03	3.6	70.6	84.23	87.48	3.3	72.0
Houdry Motor Naphtha					9.40	10.66	0.1	80.0	*	*	*	*
Houdry Isopentane					*	*	*	*	*	*	*	*
Liquid C_3					0.56	0.38	185.0	125.0	4.22	3.47	20.5	107.5
C_4-C_5 Stock					16.09	12.93	39.2	91.1	11.55	9.05	37.9	88.1
Total b/					100.00	100.00	10.0	75.0	100.00	100.00	8.0	75.1
Cracked Gasoline Blend												
Thermal Cracked Base					79.15	82.13	3.4	70.2	68.92	71.11	3.9	71.0
Polymer Gasoline					*	*	*	*	6.54	6.17		
Houdry Isopentane					*	*	*	*	1.26	1.03	20.5	107.5
Houdry Motor Naphtha					*	*	*	*	7.75	8.75	0.1	80.0
Motor Alkylate					4.47	4.73	0.1	80.0	2.05	2.13	0.1	80.0
Liquid C_3					0.58	0.41	185.0	125.0	*	*	*	*
C_4-C_5 Stock					15.80	12.73	39.2	91.1	13.48	10.81	37.9	88.1
Total b/					100.00	100.00	10.0	74.2	100.00	100.00	8.3	74.5

a. At Gurev and Orsk, 100 ON at 3cc TEL; at Kuibyshev and Krasnovodsk, 100 ON (AFD-IC) at 4cc TEL.
b. ON by CFR-Motor, clear.
* Data either nil or not applicable.

Table [illegible] Soviet Land Lease Refineries
Summer Design Data

Productions in Hourly Systems

I. Weight Data

Stock	Gurev Te/Yr a/	Gurev Wt. %	Orsk Te/Yr a/	Orsk Wt. %	Kuibyshev Te/Yr a/	Kuibyshev Wt. %	Krasnovodsk Te/Yr a/	Krasnovodsk Wt. %
Liquid Propane	*	*	*	*	13,339	3.42	*	*
Polymerization Charge	*	*	*	*	*	*	15,995	4.28
Alkylation Charge	42,2[illegible]0	11.12	39,267	13.35	38,724	9.93	44,900	12.00
Isopentane	8,033	2.11	8,291	2.81	6,866	1.76	15,628	4.18
Aviation Base Gasoline	95,502	25.12	97,895	33.28	88,258	22.64	84,845	22.68
Motor Base Gasoline	6,993	1.84	13,860	4.71	9,843	2.52	14,843	3.75
Houdry Gas Oil	160,304	42.18	76,809	26.10	179,201	45.95	155,016	41.44
Polymer Fuel Oil	7,570	2.00	6,411	2.18	8,255	2.12	4,931	1.32
Liquid Recovery	320,662	84.37	242,533	82.43	344,486	88.34	335,358	89.65
Residue Gas	35,024	9.21	28,756	9.77	20,029	5.14	17,614	4.71
Coke	24,455	6.42	22,959	7.80	25,430	6.52	21,096	5.64
Fresh Case Charge	380,141	100.00	294,248	100.00	389,945	100.00	374,068	100.00
Recycle Case Charge	*	*	76,355	25.95	*	*	*	*
Total Case Charge	380,141	100.00	370,603	125.95	389,945	100.00	374,068	100.00

a. Metric Tons per year.
* Data either nil or not applicable.

Table 7. Soviet Lend-Lease Refineries
Budget Design Data

Productions in Jewdry Systems (Continued)

II. Volume Data

Stock	Gurev BPCD b/	Gurev Vol. %	Orsk BPCD b/	Orsk Vol. %	Kuibyshev BPCD b/	Kuibyshev Vol. %	Krasnorodsk BPCD b/	Krasnorodsk Vol. %
Liquid Propane	*	*	*	*	449	5.98	*	*
Polymerization Charge	*	*	*	*	*	*	565	7.52
Alkylation Charge	1,232	16.42	1,190	19.83	1,156	15.42	1,348	17.94
Isopentane	222	2.96	229	3.82	188	2.50	434	5.78
Aviation Base Gasoline	2,250	30.00	2,306	38.43	2,074	27.63	1,942	25.85
Motor Base Gasoline	140	1.87	281	4.68	201	2.68	288	3.83
Houdry Gas Oil	3,075	41.00	1,488	24.80	3,363	44.81	3,072	40.90
Polymer Fuel Oil	140	1.87	112	1.87	148	1.97	89	1.19
Liquid Recovery	7,059	94.12	5,606	93.43	7,579	100.99	7,738	103.01
Liquid Increment	441	5.88	394	6.57	-74	-0.99	-226	-3.01
Fresh Case Charge	7,500	100.00	6,000	100.00	7,505	100.00	7,512	100.00
Recycle Case Charge	*	*	1,500	25.00	*	*	*	*
Total Case Charge	7,500	100.00	7,500	125.00	7,505	100.00	7,512	100.00

b. Barrels per calendar day.
* Data either nil or not applicable.

Table 3. Soviet Lend-Lease Refineries
Weight Balance Data

Alkylation Units

I. Weight Data

	Gurev Te/Yr a/	Gurev Wt. %	Orsk Te/Yr a/	Orsk Wt. %	Kuibyshev Te/Yr a/	Kuibyshev Wt. %	Krasnovodsk Te/Yr a/	Krasnovodsk Wt. %
Light Blend Stock	17,215	27.83	29,718	37.72	19,546	29.97	24,131	30.85
Aviation Alkylate	38,828	62.77	40,805	51.72	41,135	63.16	48,818	62.40
Motor Alkylate	4,807	7.77	5,094	6.46	2,830	4.34	3,415	4.37
Liquid Products	60,840	98.37	75,617	95.96	63,561	97.47	76,364	97.62
Gas and Loss	1,009	1.63	3,178	4.04	1,651	2.53	1,861	2.38
Charge	61,849	100.00	78,795	100.00	65,212	100.00	78,255	100.00

II. Volume Data

	Gurev BPCD b/	Gurev Vol. %	Orsk BPCD b/	Orsk Vol. %	Kuibyshev BPCD b/	Kuibyshev Vol. %	Krasnovodsk BPCD b/	Krasnovodsk Vol. %
Light Blend Stock	522	27.58	870	37.71	563	29.46	698	30.34
Aviation Alkylate	948	51.93	994	43.09	993	52.23	1,189	51.67
Motor Alkylate	100	5.49	121	5.24	62	3.24	76	3.30
Liquid Products	1,547	85.00	1,985	86.04	1,623	84.93	1,963	85.31
Liquid Increment	272	15.00	322	13.96	288	15.07	338	14.69
Charge	1,820	100.00	2,307	100.00	1,911	100.00	2,301	100.00

a. Metric Tons per year.
b. Barrels per calendar day.

Table 6. Generalized Houdry System Assumed for USSR

Combined Houdry Cracking and Reforming

Production Data a/

Product Stock	BPCD e/	Te/Yr f/	Vol %	Wt %	Lb/Gal	Bbl/Te g/
Alkylation Charge Stock	1,300	44,690	17.3	11.8	4.95	10.60
Isopentane	275	9,940	3.7	2.6	5.20	10.09
74 Aviation Base	2,200	94,470	29.3	24.9	6.18	8.19
Motor Naphtha	240	11,840	3.2	3.1	7.10	7.39
Houdry Gas Oil b/	2,950	151,710	39.4	39.9	7.40	7.09
Polymer Gas Oil c/	130	7,200	1.7	1.9	7.95	6.60
Liquid Recovery d/	7,095	319,850	94.6	84.2	*	*
Coke and Gas	*	60,150	*	15.8	*	*
Virgin Charge	7,500	380,000	100.0	100.0	7.29	7.20

a. Basis of Badger design data, generalized for the apparent characterization factors of the typical and suitable USSR gas oil charge stocks. 100 percent of Houdry reforming charge assumed to be the Houdry cracked gasoline, debutanized at 400°F.

b. Charge stock for thermal cracking.

c. Residual fuel oil product.

d. Exclusive of liquified stocks mostly comprised by propane and lighter, insofar as these may be derived from the gas for product or for polymerization charge.

e. Barrels per calendar day.

f. Metric tons per year.

g. Barrels per metric ton.

* Data not applicable.

Table 10. Generalized H_2SO_4 Alkylation Unit for USSR

Correlated in Refinery with Houdry System

Production Data a/

Product Stock	BPCD d/	Te/Yr e/	Vol %	Wt. %	t/Cal	Bbl/Te f/
Light Blend Stock b/	650	22,170	31.0	31.2	4.90	10.71
Aviation Alkylate	1,050	43,060	50.0	60.7	5.90	[illegible]
Motor Alkylate	100	4,500	4.7	6.3	6.50	8.08
Liquid Recovery	1,800	69,730	85.7	98.2	*	
Gas and Loss	*	1,270	*	1.8	*	
Total Charge g/	2,100	71,000	100.0	100.0	4.86	10.80

a. Basis of Badger design data; generalized for a typical refinery project having thermal conversion units, both reforming and cracking, operated together with a similarly generalized Houdry system.

b. For gasoline blends. Essentially composed of C_4 (4-carbon hydrocarbon) stocks including all normal (straight-chain) components, contained and not reacted in the charge.

c. Essentially C_4 stocks. In this hypothesis, varies from a third to less than half by weight in components derived by non-catalytic processes (chiefly thermal cracking and reforming).

d. Barrels per calendar day.

e. Metric tons per year.

f. Barrels per metric ton.

* Data not applicable.

Table [illegible]

Fluid Catalytic Cracking

Motor Gasoline Production

Charge and Operation	Gasolines C5 + 400 °F E.P. 5#-6# RVP	Gasolines Motor 400 °F E.P. 10# RVP	Catalytic Gas Oil 26°-27° API	4-Carbon Hydrocarbon Stocks Butanes	Butenes	Total	Excess	Recovery Ch+	Volume Percent Yields of Product Stocks: 3-Carbon Stocks Propane	Propene	Total	Yield Lighter Gas Un %	Yield Coke Wt %
US Mid-Continent Gas Oils Once-Through (0% Recycle)													
1. Silica-magnesia catalyst	53.0	*	35.0	5.5	5.5	11.0	*	99.0	1.9	3.8	5.7	1.9	n.a.
2. Natural catalyst	50.0	*	35.0	7.4	5.8	13.2	*	98.2	3.4	4.8	[illegible]	1.7	n.a.
3. Synthetic catalyst a. e/	38.0	*	50.0	n.a.	n.a.	11.8	*	99.8	In lighter gas			5.8	3.2
b.	*	40.6	50.0	*	*	*	9.2	99.8	In lighter gas			5.8	3.2
4. Silica-alumina catalyst	47.0	*	35.0	6.2	10.9	17.1	*	99.1	3.7	6.8	10.5	1.7	n.a.
5. Silica-alumina catalyst a.	45.0	*	40.0	8.7	5.8	14.5	*	99.5	2.4	5.2	7.6	[illegible]	n.a.
b.	*	55.4 a/**	40.0	*	*	*	4.1	99.5	2.4	5.2	7.6	2.5	n.a.
US Mid-Continent Gas Oils Fresh Feed/Recycle = ?													
6. Synthetic catalyst a. e/	47.3	*	35.0	n.a.	n.a.	16.1	*	98.4	In lighter gas			8.2	5.2
b.	*	50.2	35.0	*	*	*	13.2	98.4	In lighter gas			8.2	5.2
7. Silica-alumina catalyst a.	53.0	*	25.0	9.4	7.1	16.5	*	94.5	3.3	6.4	9.7	3.1	n.a.
b.	*	65.7 b/	25.0	*	*	*	3.8	94.5	3.3	6.4	9.7	3.1	n.a.
Average on Stream													
8. East Texas 31.7 °API G.O.	*	45.0	51.2	*	*	*	4.3	100.5	In lighter gas			4.3	3.1
9. West Texas 27.3 °API G.O.	*	43.2	51.2	*	*	*	3.0	97.4	In lighter gas			6.3	4.1
10. West Texas 22.3 °API G.O.	*	46.0	51.2	*	*	*	2.0	99.2	In lighter gas			5.6	3.4
11. Gulf Coast 22.1 °API G.O.	*	46.2	51.2	*	*	*	4.0	101.4	In lighter gas			5.4	2.6

n.a. Data not available in reports.

* Data either undetermined or not applicable.

** Footnotes follow on page 140.

Table 11. (Continued)

Octane Numbers for Gasolines (400 °F E.P., 10# RVP)

Gasoline Example	ASTM (CFR-Motor), F2			CFR-Research, F1		
	Clear	1.5cc TEL	3cc TEL	Clear	1.5cc TEL	3cc TEL
1. c/	79.1	*	85.2	89.0	*	95.4
2. c/	80.3	*	86.5	90.8	*	96.5
3b. d/	82.0	*	*	95.1	*	*
4. e/	82.1	*	87.7	93.0	*	98.7
5b. d/	81.8	*	86.8	93.7	*	98.7
6.	82.1	*	*	95.1	*	*
7b. d/	81.8	*	87.4	94.2	*	99.1
8.	80.5	84.6	*	92.0	97.0	*
9.	79.4	83.0	*	91.9	95.9	*
10.	77.9	81.2	*	91.3	95.3	*
11.	80.5	84.7	*	94.3	98.1	*

a. Includes 47.4 percent of catalytic gasoline, 8.0 percent of polymer gasoline. Other polymerization data n.a.

b. Includes 55.8 percent of catalytic gasoline, 9.9 percent of polymer gasoline. Other polymerization data n.a.

c. Presumably the 400 °F E.P., 10# RVP equivalent of the reported C5+ gasoline.

d. The 400 °F E.P., 10# RVP catalytic gasoline.

e. Presumably silica-alumina catalyst.

n.a. Data not available in reports.
* Data either undetermined or not applicable.

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Table 12. Representative American Operations
Fluid Catalytic Cracking
Aviation Base Stock Production

Operation a/	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Gas Oil Charge, °F B.P.	25.2	25.2	25.2	n.a.	n.a.	n.a.	n.a.	33.4	n.a.	33.4
Gas Oil Charge, °API	High	High	High	High	High	Medium	Low	n.a.	n.a.	n.a.
Catalysis Temperature										
Weight Percent Yields										
Coke	2.1	4.7	9.7	3.9	1.2	4.9	7.7	6.2	5.5	
Dry Gas (C3 and Lighter)	6.0	10.1	14.5	9.5	7.7	7.2	4.9	12.7	12.0	
C_4 Stock	5.6	9.4	12.8	9.5	9.2	10.0	10.9	11.3	13.5	
C_4 Stock	3.4	5.5	7.7	6.1	8.1	7.5	9.2	8.0	9.4	
C_6 / Gasoline, 400 °F E.P.	28.0	34.5	30.2	25.9	19.4	27.5	27.1	25.0	31.9	
Gas Oil, 400 °F I.P.	54.9	35.8	25.1	45.1	54.4	42.5	40.2	37.8	27.7	
C_4/Recovery	91.9	85.2	75.8	86.6	91.1	87.6	87.4	82.1	82.5	
Volume Percent Yields										
i-Butene	1.2	1.6	1.2	2.3	2.9	1.0	0.5	n.a.	n.a.	
n-Butene-1	1.3	1.6	1.2	2.3	2.9	1.0	0.5	n.a.	n.a.	
n-Butene-2	0.5	1.0	1.4	1.2	1.4	2.1	1.8	n.a.	n.a.	
i-Butane	4.7	8.8	14.0	6.6	4.5	9.1	11.6	n.a.	n.a.	
n-Butane	0.9	1.4	1.9	1.4	1.3	1.5	1.6	n.a.	n.a.	
C_4 Stock	8.6	14.4	19.7	13.8	13.0	14.7	16.0	16.8	19.9	
Pentenes	2.2	2.9	2.9	4.1	6.2	3.2	2.4	n.a.	n.a.	
i-Pentanes	2.3	4.3	7.3	3.6	3.6	6.3	9.2	n.a.	n.a.	
n-Pentane	0.4	0.7	0.8	0.6	0.9	0.8	1.0	n.a.	n.a.	
C_5 Stock	4.9	7.9	11.0	8.3	10.7	10.3	12.6	10.9	12.9	
C_6/ Gasoline, 400 °F E.P.	30.9	37.9	33.2	28.2	20.8	29.8	29.3	26.8	34.8	
Gas Oil, 400 °F I.P.	53.8	34.7	24.1	44.0	53.6	41.6	39.3	36.9	26.7	
C_4/ Recovery	98.3	94.9	88.0	94.3	98.1	96.4	97.2	91.4	94.3	
C_6/ Gasoline, 400 °F E.P.										
C_6/ Aviation Base, 340 °F E.P.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	
Percent of Charge	40.0	60.0	75.0	42.0	28.0	42.0	42.0	n.a.	n.a.	
Weight Percent Aromatics	52.0	47.0	42.0	50.0	55.0	50.0	50.0	n.a.	n.a.	
°API	90.8	94.0	97.0	89.8	88.0	92.3	94.2	n.a.	n.a.	
ON, 1-C_3/4cc TEL										
Heavy Naphtha, 340-400 °F B.P.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	
Percent of Charge	67.0	73.0	81.0	69.0	80.0	67.0	69.0	n.a.	n.a.	
Weight Percent Aromatics	30.8	29.6	27.7	33.5	33.4	32.1	33.2	n.a.	n.a.	
°API	87.7	90.0	90.5	83.0	83.7	85.0	83.3	n.a.	n.a.	
ON, ASTM, Clear	90.5	91.5	91.7	87.2	87.3	86.6	87.4	n.a.	n.a.	
ON, ASTM, + 3cc TEL	22.7	20.3	19.2	28.7	36.9	28.5	28.5	n.a.	n.a.	
Catalytic Gas Oil, 400 °F I.P., °API										

a. Apparently single stage with synthetic (silica-alumina?) catalyst.
b. Total Feed/Fresh Feed = 1.53.
n.a. Data not available in reports.

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Table 13. Fluid Catalytic Cracking of Soviet Gas Oils:

Correlated Yield Data for Average Charge Stocks a/

Product Stock	Vol %	Wt %	Lb./Gal	Bbl/Ton c/
Alkylation Charge Stock	14.5	9.6	5.00	10.50
Isopentane	4.3	3.0	5.20	10.09
Aviation Base (340 °F E.P.)	30.0	25.5	6.40	8.20
Motor Naphtha (340 °F-400 °F B.I.)	11.5	11.2	7.32	7.17
Catalytic Gas Oil b/	34.7	35.8	7.76	6.76
Liquid Recovery d/	95.0	85.1	*	*
Coke	*	4.7	*	*
Gas	*	10.2	*	*
Virgin Charge	100.0	100.0	7.53	6.97

a. Once-through operation with Fluid process yields correlated with the Houdry design processing yields. General technical considerations applied, assuming the optimum average charge stock for Fluid units, at 25°API or 7.53 #/gal., to be slightly heavier than the similar gas oil charge for Houdry units, at 27°API or 7.39 #/gal.

b. Thermal cracking charge stock.

c. Barrels per metric ton.

d. Exclusive of liquified stocks mostly comprised by propane and lighter, insofar as these are derived from the gas for product or for polymerization charge.

* Data not applicable.

Table 14. Comparative Indicated Yields with Houdry and Fluid Catalytic Cracking Applied to Average USSR Oil Stocks

	Houdry Catalytic System						Fluid Catalytic System					
	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Percents in Average USSR Crudes Yielding Charge												
Fraction with B.P. above 300 °C (572 °F)			65.0						55.0			
Reduced Crude above 650 °F B.P. Diesel Oil			60.0						50.0			
Gas Oil Charge next below Reduced Crude			15.0						15.0			
Gas Oil Charge in Reduced Crude			35.0						41.1			
Total Gas Oil Charge Suitable			50.0						56.1			
Crude Residue above Gas Oil Charge			25.6	26.8					18.9	20.3		
I. From 1,000 Gallons of Charge												
Alkylation Charge Stock	170	856.4	17.3	11.8	4.95	10.60	145	725.0	14.5	9.6	5.00	10.50
Isopentane	37	192.4	3.7	2.6	5.20	10.09	43	223.6	4.3	3.0	5.20	10.09
Aviation Base Gasoline	293	1,810.8	29.3	24.9	6.18	8.49	300	1,920.0	30.0	25.5	6.40	8.20
Motor Naphtha (Gasoline)	32	227.2	3.2	3.1	7.10	7.39	115	841.8	11.5	11.2	7.32	7.17
Catalytic Gas Oil (For thermal cracking)	394	2,915.6	39.4	39.9	7.40	7.09	347	2,692.7	34.7	35.8	7.76	6.76
Polymer Gas Oil (For fuel oil)	17	135.2	1.7	1.9	7.95	6.60	*	*	*	*	*	*
Liquid Recovery	946	6,137.6	94.6	84.2	*	*	950	6,403.1	95.0	85.1	*	*
Coke and Gas Loss	54	1,152.4	5.4	15.8	*	*	50	1,126.9	5.0	14.9	*	*
Total Gas Oil Charge	1,000	7,290.0	100.0	100.0	7.29 d/	7.20 d/	1,000	7,530.0	100.0	100.0	7.53 d/	6.97 d/
Total Gasolines	325	2,038.0	32.5	28.0	*	*	415	2,761.8	41.5	36.7	*	*
Total Gasolines and Isopentane	362	2,230.4	36.2	30.6	*	*	458	2,985.4	45.8	39.7	*	*
II. From Charge in 1,000 Gallons of Average Crude												
Alkylation Charge Stock	86.5	428.2	17.3	11.8	4.95	10.60	81.3	406.7	14.5	9.6	5.00	10.50
Isopentane	18.5	96.2	3.7	2.6	5.20	10.09	24.1	125.4	4.3	3.0	5.20	10.09
Aviation Base Gasoline	146.5	905.4	29.3	24.9	6.18	8.49	168.3	1,077.1	30.0	25.5	6.40	8.20
Motor Naphtha (Gasoline)	16.0	113.6	3.2	3.1	7.10	7.39	64.5	472.2	11.5	11.2	7.32	7.17
Catalytic Gas Oil (For thermal cracking)	197.0	1,457.8	39.4	39.9	7.40	7.09	194.8	1,510.7	34.7	35.8	7.76	6.76
Polymer Gas Oil (For fuel oil)	8.5	67.6	1.7	1.9	7.95	6.60	*	*	*	*	*	*
Liquid Recovery	473.0	3,068.8	94.6	84.2	*	*	533.0	3,592.1	95.0	85.1	*	*
Coke and Gas Loss	27.0	576.2	5.4	15.8	*	*	28.0	632.2	5.0	14.9	*	*
Total Gas Oil Charge	500.0	3,645.0	100.0	100.0	7.29 d/	7.20 d/	561.0	4,224.3	100.0	100.0	7.53 d/	6.97 d/
Total Gasolines	162.5	1,019.0	32.5	28.0	*	*	232.8	1,549.3	41.5	36.7	*	*
Total Gasolines and Isopentane	181.0	1,115.2	36.2	30.6	*	*	256.9	1,674.7	45.8	39.7	*	*

* Data either nil or not applicable.

** Footnotes follow on page 144.

a. Based upon technical data directly derived for USSR petroleums, with these data correlated with what are known to be plausible and reasonable properties in average crude oils having the general characteristics indicated for Soviet stocks. Certain critical details of the properties result from technical and engineering interpretation of the data given in Reference 1/ and in less complete and often fragmentary form, in numerous other intelligence reports. In Reference 1/ analytical data are given for more than 150 representative USSR crude oil samples, selected from the various oil productive regions in the country. Badger design data for Houdry systems also provide technical details for typical Soviet stocks. Older published papers include engineering analyses of Soviet oil types still being produced in quantity. In the present correlation, the minor effects of slight variations in average crude oil densities are neglected (cf. Table 15 and the subsequent Table 17.)

b. These percentage and density data are those previously derived for average applications to USSR stocks. (Cf. Tables 9 and 13.) The values are rounded off numerically, and the volume and weight yields are here based upon the rounded off volumetric percentages and densities. The rounded-off weight percentages are sometimes slightly inconsistent with the weight yields.

c. Barrels per metric ton.

d. These gas oil charge densities are here applied for comparison and consistency with the data in other tables. The given gas oil charge densities are, however, slightly inconsistent with the given gas oil charge percentages, referred to a crude charge containing the other stocks (light distillates and crude residues) with densities and percentages as shown.

Table 15. Estimated 1950 Petroleum Refinery Yields in the USSR
(Gross or Total Product Yields Calculated from the Soviet Refinery Units and Systems)

				Thousand		**
Crude Distillation (Volume Yields)						
Gas Loss	1.0	1.4	*	108	[illegible]	*
Straight Run Gasoline	[illegible]	7.6	6.94	273	[illegible]	8.69
Reforming Naphtha	15.0	13.5	6.47	1,622	200	8.21
Virgin Gas Oil to Houdry	50.9	50.7	7.29	5,407	753	7.20
Residue for Fuel Oil or Thermal Cracking	25.9	26.8	7.71	2,204	297	6.81
Crude Charge	100.0	100.0	7.19	10,614	1,481	7.30
Other Crude Distillation						
Gas Loss	1.0	1.8	*	2,629	648	*
Straight Run Gasoline	12.0	10.1	6.03	31,552	3,627	8.70
Reforming Naphtha	2.4	2.2	6.48	6,391	789	8.10
Kerosenes, Diesel Oils, Specialty Naphthas, Etc.	24.6	23.9	7.00	64,602	8,614	7.50
Lubes, Waxes, Road Oils, Tars, Asphalts, Etc.	7.5	7.7	7.39	19,720	2,778	7.10
Residue for Fuel Oil or Thermal Cracking	52.5	54.3	7.43	138,042	19,563	7.06
Crude Charge	100.0	100.0	7.19	262,936	36,019	7.30
Overall Crude Distillation						
Gas Loss	1.0	1.7	*	2,737	669	*
Straight Run Gasoline	11.9	10.0	6.03	32,525	3,739	8.70
Reforming Naphtha	2.9	2.6	6.48	8,013	989	8.10
Kerosenes, Diesel Oils, Specialty Naphthas, Etc.	23.6	23.0	7.00	64,602	8,614	7.50
Virgin Gas Oil to Houdry	2.0	2.0	7.29	5,407	751	7.20
Lubes, Waxes, Road Oils, Tars, Asphalts, Etc.	7.2	7.4	7.39	19,720	2,778	7.10
Residue For Fuel Oil or Thermal Cracking	51.4	53.3	7.45	140,746	19,960	7.05
Crude Charge	100.0	100.0	7.19	273,750	37,500	7.30
Houdry Cracking and Reforming						
Coke and Gas Loss	5.4	15.8	*	292	119	*
Alkylation Charge Stock	17.3	11.8	4.95	935	89	10.60
Isopentane	3.7	2.6	5.20	200	20	10.09
7 # Aviation Base Gasoline	29.3	24.9	6.18	1,585	186	8.49
Houdry Motor Naphtha	3.2	3.1	7.10	173	23	7.39
Houdry Gas Oil for Thermal Cracking	39.4	39.9	7.40	2,130	300	7.09
Polymer Gas Oil to Residual Fuel Oil	1.7	1.9	7.95	92	14	6.60
Virgin Gas Oil Charge	100.0	100.0	7.29	5,407	751	7.20

* Data either nil or not applicable.
** Footnotes follow on p. 145

Table 25. Estimated 1960 Petroleum Refinery Yields in the USSR (Continued)
(Gross or Total Product Yields Calculated from the Soviet Refinery Units and Systems)

	Percent			Thousands		
	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Thermal Reforming						
Gas Loss	17.0	17.0	*	1,362	168	*
Stable Reformed Gasoline	75.0	73.2	6.32	6,010	724	8.30
Residual Fuel Oil	8.0	9.8	7.94	641	97	6.51
Reforming Naphtha Charge	100.0	100.0	6.48	8,013	989	8.10
Thermal Cracking						
Gas Loss	11.0	12.9	*	12,556	2,107	*
Stable Cracked Gasoline	42.0	35.4	6.32	47,940	5,776	8.30
Heavy Cracked Distillates	7.0	6.5	7.00	7,990	1,065	7.50
Residual Fuel Oil	40.0	45.2	8.47	45,658	7,364	6.20
Thermal Cracking Charge	100.0	100.0	7.50	114,144	16,312	7.00
Houdry Gas Oil Charge	*	*	7.40	-2,130	- 300	7.09
Crude Distillation Residue Charge	*	*	7.50	112,014	16,012	7.00
Sulfuric Acid Alkylation						
Process and Gas Loss	14.3	1.8	*	206	3	*
Gasoline Blend Stock (Unreacted Butanes)	31.0	31.2	4.90	447	42	10.71
Aviation Alkylate	50.0	60.7	5.90	721	81	8.90
Motor Alkylate	4.7	6.3	6.50	68	8	8.08
Alkylation Charge	100.0	100.0	4.88	1,442	134	10.76
Houdry Charge Stock to Alkylation	*	*	4.95	- 935	- 89	10.60
Recovery Thermal Stock to Alkylation	*	*	4.66	507	45	11.27
Recovery to Isooctane (Polymerization-Hydrogenation)	*	*	5.77	728	80	9.10
Total Recovery from Process Gas Loss	*	*	*	1,235	125	*
Crude Distillation Gas Loss	16.0	21.8	*	2,737	669	*
Houdry Coke and Gas Loss	1.7	3.9	*	292	119	*
Thermal Reforming Gas Loss	7.9	5.5	*	1,362	168	*
Thermal Cracking Gas Loss	73.2	68.7	*	12,556	2,107	*
Alkylation Process and Gas Loss	1.2	0.1	*	206	3	*
Total Process and Gas Loss	100.0	100.0	*	17,153	3,066	*
Recovery from Process Gas Loss	- 7.2	- 4.1	*	-1,235	- 125	*
Net Process and Gas Loss	92.8	95.9	*	15,918	2,941	*

* Data either nil or not applicable.

Table 15. Estimated 1950 Petroleum Refinery Yields in the USSR (Continued)
(Gross or Total Product Yields Calculated from the Soviet Refinery Units and Systems)

	[illegible]	[illegible]	[illegible]	Thousands [illegible]	[illegible]	[illegible]
Straight Run Aviation Base Gasoline	9.6	9.5	6.28	8,653	[illegible]	8.50
Other Straight Run Gasoline	26.[illegible]	25.5	5.99	23,872	2,723	8.77
Total Straight Run Gasoline	36.0	35.0	6.03	32,525	3,739	[illegible]
Stable Reformed Gasoline	6.6	6.8	6.33	6,010	724	8.30
Stable Cracked Gasoline	53.0	54.0	6.32	47,940	5,776	8.30
Houdry Motor Naphtha	0.2	0.2	7.10	173	23	7.39
Alkylation Gasoline Blend Stock	0.5	0.4	4.90	447	42	8.90
Motor Alkylate	0.1	0.1	6.50	68	8	8.08
74 Aviation Base Gasoline	1.8	1.7	6.16	1,585	186	8.49
Isopentane	0.2	0.2	5.20	200	20	10.09
Aviation Alkylate	0.8	0.8	5.90	721	81	8.90
Isooctane	0.8	0.8	5.77	728	80	9.10
Total Gasoline Stocks	100.0	100.0	*	90,397	10,679	*
Crude Distillation Residue	*	*	7.45	140,746	19,960	7.05
Crude Residue to Thermal Cracking	*	*	7.50	-112,014	-16,012	7.00
Excess Crude Residue	38.2	34.3	7.21	28,732	3,948	7.28
Houdry Polymer Gas Oil	0.1	0.1	7.95	92	14	6.60
Thermal Reforming Residual	0.9	0.9	7.94	641	97	6.61
Thermal Cracking Residual	60.8	64.7	8.47	45,658	7,364	6.20
Total Residual Fuel Oil	100.0	100.0	7.98	75,123	11,423	6.58
Net Process and Gas Loss a/	5.8	7.8	*	15,918	2,941	*
Total Gasoline Stocks b/	33.0	28.5	*	90,397	10,679	*
Kerosenes, Diesel Oils, Specialty Naphthas, Etc.	23.6	23.0	7.00	64,602	8,614	7.50
Heavy Cracked Distillates	2.9	2.8	7.00	7,990	1,065	7.50
Lubes, Waxes, Road Oils, Tars, Asphalts, Etc. c/	7.2	7.4	7.39	19,720	2,778	7.10
Total Residual Fuel Oil	27.5	30.5	7.98	75,123	11,423	6.58
Crude Charge to Distillation (Production)	100.0	100.0	7.19	273,750	37,500	7.30
British Estimate of 1950 Operation Projected in Fourth Plan f/						
Total Gasoline	*	29.9	*	*	10,600	*
Kerosene and Diesel Oil	*	27.7	*	*	9,800	*
Other Products and Loss	*	42.4	*	*	15,000	*
Crude Production	*	100.0	*	*	35,400	*

* Data either nil or not applicable.

Table

(Gross or Total Product Yields Calculated from the Soviet Refinery Units and Systems)

	Volume %	Weight %	Lb /Gal	Thousands Bbl/Yr	Thousands Te/Yr d/	Bbl/Te e/
1950 US Refinery Yields g/						
Material Losses; Byproduct Dry Fuel Gas; Petroleum Products Directly Consumed in Refining	9.5	13.5	*	199,535	38,761	*
Finished Gasoline Stocks for Blends h/	43.2	37.0	6.18	902,569	106,185	8.5
Kerosenes	5.6	5.2	6.57	118,138	14,767	8.0
Other Distillate Oils	19.0	19.0	7.19	397,706	54,480	7.3
Lubes, Greases, Etc.	2.5	2.6	7.50	51,431	7,347	7.0
Residual Stocks	20.2	22.7	8.08	423,768	65,195	6.5
Total Refinery Runs (Crude)	100.0	100.0	7.19	2,093,167	286,735	7.3
Total Crude Produced	94.2	94.2	7.19	1,971,845	270,248	7.3

* Data either nil or not applicable.

a. Various miscellaneous stock losses are considered to be included in the separate losses as designated. The miscellaneous losses include those in blending, chemical treating, lubricant manufacture, asphalt preparation (i.e., blowing, etc.), and the like. Volumetric losses are not above liquid recovery in the processes. It should be noted that if the total liquid product volume is calculated in a process, with this total including the equivalent liquid volumes of gases, and if this total is compared with the similar total for charge stocks, the two totals may differ considerably. This difference results from chemical conversion of components, and it may otherwise result by the mere physical separation of components from a mixture or solution. Either liquid volume total may be the larger, computed at a given temperature and pressure. The product total is usually the larger in cracking and reforming, and tends to be the larger in simple fractionation. The charge total is typically much the larger in gas reversion.

b. Final residue gas in this estimate includes C_4 stock possibly recoverable for seasonal blends of the indicated gasoline stocks. Finished gasoline blends are not indicated in the correlation. Completely omitted are the aromatic additives virtually required in avgas blends. With respect to gasoline vapor pressure limits, the indicated gasolines are probably incapable of absorbing natural gas liquids if use is made of the recovery C_4 stock available in the indicated residue gas. This condition prevails since the gas reversion of C_4 hydrocarbons is trivial, compared to the typical large production of the C_4 stocks when thermal cracking is practised to the high relative degree here indicated.

c. This total includes a separate estimate of about 2.0 million metric tons for the production of lubricants.

d. Metric tons per year.

e. Barrels per metric ton.

f. Probably considered to be net yields from the refineries.

g. Cf. Reference 13/. Net products shown in contrast to the gross or total values calculated for all Soviet refinery units and systems. The US values are based upon published statistics giving volumetric data and apparently not otherwise composited so as to eliminate certain minor inconsistencies in these data. Average density data are estimated for the US stock productions.

h. Essentially comprised of virgin and conversion stocks, obtained from crude for seasonal gasoline blends with natural gasoline. Small quantities of natural gasoline may be actually included in blends, however, in the net products reported from refineries.

Table 16. Estimated Crude Productions and Existing 1950 Refinery Installations in the USSR
Composite Data for Areas with Estimated 1955 Crude Productions

General Soviet Areas Including Oil Productive Regions of 1950	Estimated Natural Petroleum Productions Millions of Metric Tons per Year		Estimated Processing Capacities Existing in 1950 (Thousands of Metric Tons per Year)					
			Thermal Systems (Charge)			Catalytic Systems		
						Hourly Cracking -Reforming	Alkylation	Polymerization Hydrogenation
	1950	1955	Crude Distillation	Cracking	Reforming	Gas oil Case Charge	Alkylate Product Yield	Hydrogenated Product Yield
Ukraine and Crimea Area								
Carpathian, Eastern Ukraine, Crimea Oil Regions	0.34	0.4						
New Oil Productive Regions	*							
North Black Sea Coast Processing Area (Odessa, Kherson, Berdiansk)			250	[illegible]	*	*	*	*
Carpathian Processing Area (Drogobych)			500	48	*	*	*	*
Western Soviet Caucasia								
Kuban-Maikop Oil Region	2.4	[illegible]						
New Oil Productive Regions	*							
Northwest Black Sea Coast Processing Area (Tuapse, Krasnodar)			2,200	304	*	*	*	*
Southwest Black Sea Coast Processing Area (Batum)			3,100	785	*	*	*	*
Central Soviet Caucasia								
Grozny Oil Region	2.1	2.0						
New Oil Productive Regions	*							
Processing Area (Grozny)			6,400	2,557	*	*	*	a/
Eastern and Southeastern Soviet Caucasia								
Baku, Daghestan, South Georgian Oil Regions	16.16	15.0						
New Oil Productive Regions	*							
Western Caspian Sea Coast Processing Area (Baku, Makhachkala)			[illegible]	1,679	*	*	*	*
Soviet Central Asia Including Kazakhstan								
Emba, Turkmen, Southeastern (Fergana, etc.) Oil Regions	3.7	11.0						
New Oil Productive Regions	*							
Northern Caspian Sea Coast Processing Area (Gurev)			600	415	113	380.1	43.6	*
Eastern Caspian Sea Coast Processing Area (Krasnovodsk, Cheleken, Nebit-Dag)			1,430	1,284	105	*	*	*
Southeastern Processing Area (Tashkent, Fergana, etc.)			1,830	452	*	*	*	*

* Data either nil or not applicable.

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Table 16. Estimated Crude Productions and Existing 1950 Refinery Installations in the USSR (Continued)

General Soviet Areas Including Oil Productive Regions of 1950	Estimated Natural Petroleum Productions Millions of Metric Tons per Year 1950	1955	Estimated Processing Capacities Existing in 1950: Thermal Systems (Charge) Crude Distillation	Cracking	Reforming	Hundry Cracking-Reforming Gas Oil Base Charge	Alkylation Alkylate Product Yield	Polymerization Hydrogenation Hydrogenated Product Yield
Second Baku Including Saratov Gas Fields								
Volga, Ural, Kama Oil Regions	11.5	19.0						
New Oil Productive Regions	*							
Volga Region Oil Processing Area (Saratov, Syzran, Batraki, Kuibyshev)			2,970	3,236	550	*	*	80 a/
Ural Region Oil Processing Area (Ufa, Tuimaza, Sterlitamak, Ishimbaevo)			2,440	918	221	*	*	
Kama Region Oil Processing Area (Molotov, etc.)			1,010	629	*	*	*	*
Northeastern European Russia								
Pechora Oil Region	0.5	0.6						
New Oil Productive Regions	*							
Processing Area (Ukhta)			250	*	*	*	*	*
Far Eastern USSR								
Sakhalin Oil Region	0.8	1.0						
New Oil Productive Regions	*							
Pacific Coast Processing Area (Khabarovsk, Komsomolsk, etc.)			1,280	474	*	*	*	*
Other Major Processing Areas								
Central Area, Volga to Ural Rivers (Stalingrad, Orsk, Chkalov)			1,700	1,570	*	370.6	45.9	*
Central European Russia (Moscow, Yaroslavl, Gorki, Kazan)			1,995	1,022	*	*	*	*
Baltic Area (Leningrad)			100	226	*	*	*	*
Minor Crude Distillation Sites (European Russia, Sakhalin, etc.)			465	*	*	*	*	*
TOTAL	37.5	52.0	44,920	16,312	989	750.7	89.5	80

a. Grozny polymerization unit reportedly contributes charge for the hydrogenation.
* Data either nil or not applicable.

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Table [illegible]. Hypothetical Operation with Modernized Soviet Refining Equipment in 1955
(Gross or Total Product Yields Calculated for the Soviet Refinery Units and Systems)

[illegible]	Volume %	Weight %	[illegible]	Thousands [illegible]	Thousands [illegible]	[illegible]
Gas Loss	0.6	[illegible]	*	[illegible]	[illegible]	*
Reforming Naphtha	28.1	23.6	6.30	25,556	3,066	8.33
Long Residuum (Fuel Oil and Thermal Cracking Charge)	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Crude Charge	100.0	100.0	7.50	91,000	33,000	7.00
Other Crude Distillation						
Gas Loss	1.0	1.8	*	2,848	392	*
Straight Run Gasoline	8.4	7.0	6.03	23,751	2,730	8.70
Reforming Naphtha	5.6	5.2	6.77	15,722	2,028	7.75
Kerosenes, Diesel Oils, Specialty Naphthas, Etc.	27.1	26.0	7.00	76,050	10,140	7.50
Lubes, Waxes, Road Oils, Tars, Asphalts, Etc.	6.9	7.0	7.39	19,383	2,730	7.10
Virgin Gas Oil for Catalytic Cracking	32.1	33.0	7.48	90,315	12,870	7.02
Short Residuum (Thermal Cracking Charge)	18.9	20.0	7.71	53,118	7,800	6.81
Crude Charge	100.0	100.0	7.28	281,187	39,000	7.21
Overall Crude Distillation						
Gas Loss	1.0	1.7	*	3,586	884	*
Straight Run Gasoline	6.4	5.2	6.03	23,751	2,730	8.70
Reforming Naphtha	11.1	9.8	6.46	41,278	5,096	8.10
Kerosenes, Diesel Oils, Specialty Naphthas, Etc.	20.4	19.5	7.00	76,050	10,140	7.50
Lubes, Waxes, Road Oils, Tars, Asphalts, Etc.	5.2	5.2	7.39	19,383	2,730	7.10
Virgin Gas Oil for Catalytic Cracking	24.2	24.8	7.48	90,315	12,870	7.02
Short Residuum (Thermal Cracking Charge)	14.3	15.0	7.71	53,118	7,800	6.81
Long Residuum (Fuel Oil and Thermal Cracking Charge)	17.4	18.8	7.91	64,706	9,750	6.64
Crude Charge b/	100.0	100.0	7.33	372,187	52,000	7.16
Houdry Catalytic Cracking and Reforming						
Coke and Gas Loss	5.4	15.8	*	1,032	419	*
Alkylation Charge Stock	17.3	11.8	4.95	3,306	313	10.60
Isopentane	3.7	2.6	5.20	707	69	10.09
Aviation Base Gasoline	29.3	24.9	6.18	5,599	661	8.49
Motor Naphtha	3.2	3.1	7.10	611	82	7.39
Catalytic Gas Oil	39.4	39.9	7.40	7,529	1,060	7.09
Polymer Gas Oil (Fuel Oil)	1.7	1.9	7.95	325	50	6.60
Virgin Gas Oil to Houdry Process	100.0	100.0	7.29	19,109	2,654	7.20
Virgin Gas Oil to Fluid Process	*	*	7.53	71,206	10,216	6.97
Total Virgin Gas Oil to Catalytic Cracking	*	*	7.48	90,315	12,870	7.02

* Data either nil or not applicable.
** Footnotes follow on p. 157.

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Table 17. Hypothetical Operation with Modernized Soviet Refining Equipment in 1955 (Continued)
(Gross or Total Product Yields Calculated from the Soviet Refinery Units and Systems)

	Percent			Thousands		
Fluid Catalytic Cracking						
Coke and Gas Loss	5.0	14.9	*	3,560	1,522	*
Alkylation Charge Stock	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Isopentane	4.3	3.9	5.20	3,062	306	10.09
Aviation Base Gasoline	30.0	25.5	6.40	21,362	2,605	8.20
Motor Naphtha	12.5	11.2	7.32	8,189	1,344	7.17
Catalytic Gas Oil	34.7	35.8	7.76	24,708	3,658	6.76
Virgin Gas Oil to Fluid Process	100.0	100.0	7.53	71,206	10,216	6.97
Thermal Reforming						
Gas Loss	17.0	17.0	*	7,017	866	*
Stable Reformed Gasoline	75.0	73.2	6.32	30,959	3,730	8.30
Residual Fuel Oil	8.0	9.8	7.94	3,302	500	6.61
Reforming Naphtha Charge	100.0	100.0	6.48	41,278	5,096	8.10
Thermal Cracking Charge Source						
Long Residuum	*	*	7.91	64,706	9,750	6.64
Poor Quality Long Residuum to Fuel Oil	*	*	8.00	-25,584	-3,900	6.56
Long Residuum to Thermal Cracking	*	*	7.85	39,122	5,850	6.69
Short Residuum	*	*	7.71	53,118	7,800	6.81
Houdry Catalytic Gas Oil	*	*	7.40	7,529	1,060	7.09
Fluid Catalytic Gas Oil	*	*	7.76	24,708	3,658	6.76
Total Thermal Cracking Charge	*	*	7.74	124,477	18,368	6.78
Thermal Cracking						
Gas Loss	11.0	12.5	*	13,692	2,298	*
Stable Cracked Gasoline	32.5	26.6	6.32	40,455	4,874	8.30
Heavy Cracked Distillates	7.0	6.3	7.00	8,713	1,162	7.50
Residual Fuel Oil c/	49.5	54.6	8.55	61,617	10,034	6.14
Thermal Cracking Charge	100.0	100.0	7.74	124,477	18,368	6.78

* Data either nil or not applicable.

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Table 17. Hypothetical Operation with Modernized Soviet Refining Equipment in 1955 (Continued)
(Gross or Total Product Yields Calculated from the Soviet Refinery Units and Systems)

	[illegible]	[illegible]	[illegible]	Thousands [illegible]	[illegible]	[illegible]
Process and Gas Loss	[illegible]	1.8	*	3,481	41	*
Gasoline Blend Stock (Unremoted Butanes)	[illegible]	[illegible]	4.90	7,546	[illegible]	[illegible]
Aviation Alkylate	50.0	60.7	5.90	12,172	1,368	8.90
Motor Alkylate	4.7	6.3	6.50	1,144	142	8.08
Alkylation Charge	100.0	100.0	4.86	24,343	2,254	10.80
Houdry and Fluid Alkylation Charge Stock	*	*	4.98	-13,631	-1,294	10.53
Recovery Thermal Stock to Alkylation	*	*	4.70	10,712	960	11.16
Recovery to Isooctane (Polymerization-Hydrogenation)	*	*	5.77	728	80	9.10
Recovery to Poly Gasoline d/	*	*	5.88	89	10	8.93
Total Recovery from Process Gas Loss	*	*	*	11,529	1,050	*
Crude Distillation Gas Loss	11.1	14.7	*	3,586	884	*
Houdry Coke and Gas Loss	3.2	6.9	*	1,032	419	*
Fluid Coke and Gas Loss	11.0	25.2	*	3,560	1,522	*
Thermal Reforming Gas Loss	21.7	14.4	*	7,017	866	*
Thermal Cracking Gas Loss	42.3	38.1	*	13,692	2,298	*
Alkylation Process and Gas Loss	10.7	0.7	*	3,481	41	*
Total Process and Gas Loss	100.0	100.0	*	32,368	6,030	*
Recovery from Process Gas Loss	-35.6	-17.4	*	-11,529	-1,050	*
Net Process and Gas Loss	64.4	82.6	*	20,839	4,980	*
Straight Run Aviation Base Gasoline	6.2	6.2	6.18	9,665	1,137	8.50
Other Straight Run Gasoline	9.0	8.6	5.94	14,086	1,593	8.84
Total Straight Run Gasoline	15.2	14.8	6.03	23,751	2,730	8.70
Stable Reformed Gasoline	19.7	20.1	6.32	30,959	3,730	8.30
Stable Cracked Gasoline	25.8	26.2	6.32	40,455	4,874	8.30
Houdry Motor Naphtha	0.4	0.4	7.10	611	82	7.39
Fluid Motor Naphtha	5.2	6.2	7.32	8,189	1,144	7.17
Alkylation Gasoline Blend Stock	4.8	3.8	4.90	7,546	703	10.71
Motor Alkylate	0.7	0.8	6.50	1,144	142	8.08
Poly Gasoline d/	0.1	0.1	5.88	89	10	8.93
Houdry Aviation Base Gasoline	3.6	3.6	6.18	5,599	661	8.49
Fluid Aviation Base Gasoline	13.7	14.1	6.40	21,362	2,605	8.20
Houdry Isopentane	0.5	0.4	5.20	707	69	10.09
Fluid Isopentane	2.0	1.7	5.20	3,062	306	10.09
Aviation Alkylate	7.8	7.4	5.90	12,172	1,368	8.90
Isooctane	0.5	0.4	5.77	728	80	9.10
Total Gasoline Stocks	100.0	100.0	*	156,374	18,504	*

* Data either nil or not applicable.

Table 37. Hypothetical Operation with Modernized Soviet Refining Equipment in 1955 (Continued)
(Gross or Total Product Yields Calculated from the Soviet Refinery Units and Systems)

	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Long Residuum to Fuel Oil	28.2	26.9	8.00	25,584	3,900	6.58
Houdry Polymer Gas Oil	0.4	0.3	7.95	325	50	6.60
Thermal Reforming Residual	3.6	3.5	6.48	3,302	500	6.61
Thermal Cracking Residual	62.8	69.3	8.55	61,617	10,034	6.14
Total Residual Fuel Oil	100.0	100.0	8.37	90,828	14,484	6.27
Net Process and Gas Loss e/	5.6	9.6	*	20,839	4,987	*
Total Gasoline Stocks f/	42.0	35.6	*	156,374	18,504	*
Kerosenes, Diesel Oils, Specialty Naphthas, Etc.	20.5	19.5	7.00	76,050	10,140	7.50
Heavy Cracked Distillates	2.3	2.2	7.00	8,713	1,162	7.50
Lubes, Waxes, Road Oils, Tars, Asphalts, Etc. g/	5.2	5.2	7.39	19,383	2,730	7.10
Total Residual Fuel Oil	24.4	27.9	8.37	90,828	14,484	6.27
Crude Charge to Distillation (Production)	100.0	100.0	7.33	372,187	52,000	7.16

* Data either nil or not applicable.

a. Assumed to be confined to production in the Second Baku.

b. This average crude is estimated to be heavier than the 1950 average, due to the expanded productions in Soviet Central Asia and the Second Baku. While the Soviet Central Asia crude tends to be somewhat higher in liquid density as compared with what seemed to be the USSR average in 1950, the Central Asia stock has good quality. Low quality appears to be on the other hand a feature in heavy crudes comprising about two-thirds of the Second Baku production. From this low grade two-thirds of Second Baku production, about 25 weight percent of distillate may be obtained with the liquid distillate recovery unfit for gasoline but suitable for reforming charge. The remaining 75 weight percent of the latter stock appears to be too high in sulfur, and also too high in carbon content because of condensed carbocyclic nuclear structures in the hydrocarbons, to yield gas oil suitable for catalytic cracking. The 75 weight percent residuum is furthermore described to be of two types. One type comprises about 40 weight percent of the total, and is a residual fuel oil too refractory even for thermal cracking.

c. This thermal cracking charge is heavier than the corresponding charge in the 1950 operation, and is shown to yield a lesser percentage of gasoline. Cf. TABLE 15.

d. This poly gasoline is assumed to be produced at Krasnovodsk, in a phosphoric acid catalytic polymerization unit installed with the Houdry System according to Badger Company design data. Cf. Appendix 2.

e. Cf. Note a/, TABLE 15.

f. Cf. Note b/, TABLE 15. Recovery of C_4 stock for seasonal blends is again not inferr Due to the high relative degree of gas reversion in the present case, however, it is probable that even if all available plant C_4 recovery gasoline is used, these gasolines may still be blended out with considerable quantities of natural gasoline or even lighter natural gas liquid.

g. This total includes lubricants separately estimated at 2.4 million metric tons to meet requirements.

h. Metric tons per year.

i. Barrels per metric ton.

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Table 18. Hypothetical 1955 Process Capacity Requirements by Areas a/

(Thousands of Metric Tons per Year)

Thousand Metric Tons per Year

Area Numbers	1	2	3	4	5	6	7	8	9	10	11	
	Ukraine and Crimea	Western Soviet Caucasia	Central Soviet Caucasia	Southeastern Soviet Caucasia	Asia Including Kazakhstan	Asia Including Saratov Gas Fields	Eastern European Russia	Far Eastern USSR	Volga to Ural Rivers	European Russia and Baltic Area	Crude Distillation Sites	Total USSR
Crude Production	400	3,000	2,000	15,000	11,000	19,000	600	1,000				52,000
Crude for Straight Run Avgas Base	40	450	513	11,250	2,640	1,900	60	500				17,353
Potential Straight Run Avgas Base	2.6	29.5	33.6	737.1	173.0	124.5	3.9	32.8				1,137
Crude for Catalytic Cracking Charge	400	3,000	2,000	15,000	11,000	6,000	600	1,000				39,000
Prorated Process Capacities Required												
Crude Distillation Charge (20% Reserve)												
From 1950	610	6,000	6,400	15,840	3,860	6,420	250	1,280	1,700	2,095	465	44,920
Additional	*	*	*	2,160	9,340	16,380	470	*	*	*	*	17,480 b/
Excess from 1950	130	2,400	4,000	*	*	*	*	80	1,700	2,095	465	
Total for Productive Area	480	3,600	2,400	18,000	13,200	22,800	720	1,200	*	*	*	62,400
Catalytic Cracking Charge												
Houdry Units from 1950	*	*	*	*	380	*	*	*	374	*	*	754
New Houdry Units	*	*	380	380	380	760	*	*	*	*	*	1,900 b/
Total Houdry Units	*	*	380	380	760	760	*	*	374	*	*	2,654
Fluid Units	132	990	280	4,570	2,870	1,220	198	330	(-374)c/	*	*	10,216 b/
Total for Productive Area	132	990	660	4,950	3,630	1,980	198	330	*	*	*	12,870
Catalytic Alkylate Production												
With Houdry Units from 1950	*	*	*	*	44	*	*	*	46	*	*	90
With New Houdry Units	*	*	48	48	47	104	*	*	*	*	**	238
Total with Houdry Units	*	*	48	48	91	104	*	*	46	*	*	328
With Fluid Units	15	116	29	534	335	128	23	39	(-46)c/	*	*	1,182 b/
Total for Productive Area	15	116	77	582	426	232	23	39	*	*	*	1,510
Thermal Reforming Charge												
From 1950	*	*	*	*	218	771	*	*	*	*	*	989
Additional	21	156	104	780	354	2,609	31	52	*	*	*	4,107 b/
Excess from 1950	*	*	*	*	*	*	*	*	*	*	*	
Total for Productive Area	21	156	104	780	572	3,380	31	52	*	*	*	5,096
Thermal Cracking Charge												
From 1950	761	1,089	2,557	1,679	2,151	4,783	*	474	1,570	1,248	*	16,312
Additional	*	*	*	3,136	1,380	2,992	193	*	*	*	*	2,056 b/
Excess from 1950	633	129	1,915	*	*	*	*	153	1,570	1,248	*	
Total for Productive Area	128	963	642	4,815	3,531	7,775	193	321	*	*	*	18,368

a/ Data prorated from TABLES 1, 15 and 16 where applicable. **Data considered to be plausible if program is adopted for high octane ratings.**

b/ Indicated net new capacity as compared to 1950.

c/ Value to be deducted from the total derived for productive areas alone, with the summation then the net total new for the USSR.

* Data either nil or not applicable.

Table 19. Sites and Capacities of Catalytic Cracking Units with Process Capacity Balances by Combined Areas Resolved for Indicated 1955 Operation a/

Data considered to be plausible if program is adopted for high octane ratings.

	Areas 1 & 2 & 3 & 4			Areas 5 & 9			Areas 6 & 7 & 10		
	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Crude Production Capacity	20,400	400,175	*	11,000	215,761	*	19,600	384,482	*
Crude Distillation Charge Required (20% Reserve)	24,480	480,210	*	13,200	258,937		23,520	461,378	*
Charge Capacity from 1950	28,850	565,934	*	5,560	109,067	*	8,765	171,938	*
Excess	4,370	85,724	*	*	*	*	*	*	*
Deficiency b/	*	*	*	7,640	149,870	*	14,755	289,440	*
Thermal Reforming Charge Capacity Required	1,061	23,545	*	572	12,694	*	3,421	75,696	*
Charge Capacity from 1950	*	*	*	218	4,838	*	771	17,110	*
Deficiency b/	1,061	23,545	*	354	7,856	*	2,640	58,586	*
Thermal Cracking Charge Capacity Required	6,548	121,631	*	3,532	65,590	*	7,968	148,008	*
Charge Capacity from 1950	6,086	113,050	*	3,721	69,119	*	6,031	112,028	*
Excess	*	*	*	190	3,529	*	*	*	*
Deficiency b/	462	8,581	*	*	*	*	1,937	35,980	*
Houdry Catalytic Cracking Charge and Yield	760	14,992	4,392	1,134	22,369	6,554	760	14,992	4,392
Charge and Yield at Grozny	380	7,496	2,196	*	*	*	*	*	*
Baku	380	7,496	2,196	*	*	*	*	*	*
Krasnovodsk d/	*	*	*	380	7,496	2,196	*	*	*
Gurev e/	*	*	*	380	7,496	2,196	*	*	*
Orsk c/	*	*	*	374	7,377	2,162	*	*	*
Kuibyshev d/	*	*	*	*	*	*	380	7,496	2,196
Ufa	*	*	*	*	*	*	380	7,496	2,196
Fluid Catalytic Cracking Charge and Yield	5,972	114,041	34,212	2,496	47,663	14,299	1,418	27,078	8,123
Charge and Yield at Baku	3,000	57,288	17,186	*	*	*	*	*	*
Tuapse	1,500	28,644	8,593	*	*	*	*	*	*
Odessa	1,472	28,109	8,433	*	*	*	*	*	*
Tashkent	*	*	*	500	9,548	2,864	*	*	*
Krasnovodsk	*	*	*	1,000	19,096	5,729	*	*	*
Orsk	*	*	*	996	19,019	5,706	*	*	*
Ufa	*	*	*	*	*	*	400	7,638	2,291
Saratov	*	*	*	*	*	*	400	7,638	2,291
Moscow	*	*	*	*	*	*	618	11,802	3,541
Komsomolsk	*	*	*	*	*	*	*	*	*
Gasoline from Catalytic Cracking	2,405	52,199	38,604	1,232	27,050	20,853	734	16,109	12,515
Avgas Base from Catalytic Cracking	1,712	38,604	38,604	919	20,853	20,853	551	12,515	12,515
Motor Naphtha from Catalytic Cracking	693	13,595	*	313	6,197	*	183	3,594	*
Isopentane from Catalytic Cracking	198	5,473	*	104	2,875	*	63	1,742	*
Alkylation Production	790	19,097	*	426	10,297	*	255	6,164	*
Aviation Alkylate Production	716	17,459	*	386	9,412	*	231	5,633	*
Motor Alkylate Production	74	1,638	*	40	885	*	24	531	*
Straight Run Avgas Base from Crude	803	18,700	18,700	173	4,029	4,029	128	2,981	2,981

a/ Here applied are the quantity and density data of Tables 17 and 18. b. Additional installations in the areas when excess capacities are unavailable in other areas. c. The only catalytic cracking systems believed to have been in operation in 1950. d. Remaining Badger Design Houdry plants. e. Barrels per calendar day. * Data either nil or not applicable. f. Thousands of metric tons per year.

Table 19. Sites and Capacities of Catalytic Cracking Units with Process Capacity Balances by Combined Areas (Continued)**
Resolved for Indicated 1954 Operation a/

Data considered to be plausible if program is adopted for high octane ratings

	Area 8			Minor Sites		Total USSR		
	Te/Yr b/	BPCD c/	LPCD c/	Te/Yr b/	BPCD c/	Te/Yr b/	BPCD c/	BPCD c/
Crude Production Capacity	1,000	19,636	*	*	*	[illegible]	[illegible]	*
Crude Distillation Charge Capacity Required (20% Reserve)	1,200	23,539	*	*	*	62,[illegible]	1,224,064	*
Charge Capacity from 1950	1,280	25,109	*	165	9,322	44,220	881,170	*
Excess	80	1,570	*	165	9,322	17,480 b/	342,894 b/	*
Deficiency b/	*	*	*	*	*			
Thermal Reforming Charge Capacity Required	52	1,154	*	*	*	5,096	113,069	*
Charge Capacity from 1950	*	*	*	*	*	989	21,948	*
Deficiency b/	52	1,154	*	*	*	4,107	91,121	*
Thermal Cracking Charge Capacity Required	321	5,963	*	*	*	18,368	345,292	*
Charge Capacity from 1950	474	8,805	*	*	*	16,312	303,002	*
Excess	153	2,842	*	*	*	2,056 b/	38,190 b/	*
Deficiency b/	*	*	*	*	*			
Houdry Catalytic Cracking Charge and Yield	*	*	*	*	*	2,654	52,353	15,338
Charge and Yield at Grozny	*	*	*	*	*	380	7,496	2,196
Baku	*	*	*	*	*	380	7,496	2,196
Krasnovodsk d/	*	*	*	*	*	380	7,496	2,196
Gurev e/	*	*	*	*	*	380	7,496	2,196
Orsk e/	*	*	*	*	*	374	7,377	2,162
Kuibyshev d/	*	*	*	*	*	380	7,496	2,196
Ufa	*	*	*	*	*	380	7,496	2,196
Fluid Catalytic Cracking Charge and Yield	330	6,302	1,891	*	*	10,216	195,084	58,525
Charge and Yield at Baku	*	*	*	*	*	3,000	57,288	17,186
Tuapse	*	*	*	*	*	1,500	28,644	8,593
Odessa	*	*	*	*	*	1,472	28,109	8,433
Tashkent	*	*	*	*	*	500	9,548	2,864
Krasnovodsk	*	*	*	*	*	1,000	19,096	5,729
Orsk	*	*	*	*	*	996	19,019	5,706
Ufa	*	*	*	*	*	400	7,638	2,291
Saratov	*	*	*	*	*	400	7,638	2,291
Moscow	*	*	*	*	*	618	11,802	3,541
Komsomolsk	330	6,302	1,891	*	*	330	6,302	1,891
Gasoline from Catalytic Cracking	121	2,616	1,891	*	*	4,492	97,974	73,863
Avgas Base from Catalytic Cracking	84	1,891	1,891	*	*	3,266	73,863	73,863
Motor Naphtha from Catalytic Cracking	37	725	*	*	*	1,226	24,111	*
Isopentane from Catalytic Cracking	10	276	*	*	*	375	10,366	*
Alkylate Production	39	942	*	*	*	1,510	36,500	*
Aviation Alkylate Production	35	853	*	*	*	1,368	33,357	*
Motor Alkylate Production	4	89	*	*	*	142	3,143	*
Straight Run Avgas Base from Crude	33	769	769	*	*	1,137	26,479	26,479

** Notes on first sheet of table
* Data either nil or not applicable.

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Table 20. Hypothetical Operation with High Distillate Yield Soviet Refining Equipment in 1955 a/ **
(Gross on Total Product Yields Calculated from the Soviet Refinery Units and Systems)

	Volume %	Weight %	Lb/Gal b/	Thousands Bbl/Yr c/	Thousands Te/Yr d/	Bbl/Te e/
Low Grade Crude Distillation						
Gas Loss	0.8	1.4	*	738	182	*
Reforming Naphtha	28.1	23.6	6.30	25,556	3,068	8.33
Low Quality Long Residuum to Visbreaking	28.1	30.0	8.00	25,584	3,900	6.56
Other Long Residuum to Visbreaking	43.0	45.0	7.85	39,122	5,850	6.69
Crude Charge	100.0	100.0	7.50	91,000	13,000	7.00
Typical Good Quality Crude Distillation						
Gas Loss	1.0	1.8	*	2,848	702	*
Straight Run Gasoline	8.4	7.0	6.03	23,751	2,730	8.70
Reforming Naphtha	5.6	5.2	6.77	15,722	2,028	7.75
Kerosenes, Diesel Oils, Specialty Naphthas, Etc.	27.1	26.0	7.00	76,050	10,140	7.50
Virgin Gas Oil to Houdry Catalysis	3.9	3.9	7.29	10,901	1,514	7.20
Virgin Gas Oil to Thermal Cracking	28.2	29.1	7.51	79,414	11,356	6.99
Lubes, Waxes, Road Oils, Tars, Asphalts, Etc.	6.9	7.0	7.39	19,383	2,730	7.10
Short Residuum to Visbreaking	18.9	20.0	7.71	53,118	7,800	6.81
Crude Charge	100.0	100.0	7.28	281,187	39,000	7.21
Overall Crude Distillation						
Gas Loss	1.0	1.7	*	3,586	884	*
Straight Run Gasoline	6.4	5.2	6.03	23,751	2,730	8.70
Reforming Naphtha	11.1	9.8	6.48	41,278	5,096	8.10
Kerosenes, Diesel Oils, Specialty Naphthas, Etc.	20.4	19.5	7.00	76,050	10,140	7.50
Virgin Gas Oil to Houdry Catalysis	2.9	2.9	7.29	10,901	1,514	7.20
Virgin Gas Oil to Thermal Cracking	21.3	21.9	7.51	79,414	11,356	6.99
Lubes, Waxes, Road Oils, Tars, Asphalts, Etc.	5.2	5.2	7.39	19,383	2,730	7.10
Low Quality Long Residuum to Visbreaking	6.9	7.5	8.00	25,584	3,900	6.56
Other Long Residuum to Visbreaking	10.5	11.3	7.85	39,122	5,850	6.69
Short Residuum to Visbreaking	14.3	15.0	7.71	53,118	7,800	6.81
Crude Charge	100.0	100.0	7.33	372.187	52,000	7.16

* Data either nil or not applicable.
** Footnotes follow on p. 165.

Table 20. Hypothetical Operations with High Distillate Yield Soviet Refining Equipment in 1955 a/ (Continued)
(Gross or Total Product Yields Calculated from the Soviet Refinery Units and Systems)

Houdry Catalytic Cracking and Reforming	Volume %	Weight %	Lb/Gal b/	Thousands Bbl/Yr c/	Thousands Te/Yr d/	Bbl/Te e/
Coke and Gas Loss	5.4	15.8	*	589	239	*
Alkylation Charge Stock	17.3	11.8	4.95	1,886	178	10.60
Isopentane	3.7	2.6	5.20	403	40	10.09
Aviation Base Gasoline	29.3	24.9	6.18	3,194	376	3.49
Motor Naphtha	3.2	3.1	7.10	349	47	7.39
Catalytic Gas Oil	39.4	39.9	7.40	4,295	606	7.09
Polymer Gas Oil (Fuel Oil)	1.7	1.9	7.95	185	28	6.60
Virgin Gas Oil Charge	100.0	100.0	7.29	10,901	1,514	7.20
Thermal Reforming						
Gas Loss	17.0	17.0	*	7,017	866	*
Stable Reformed Gasoline	75.0	73.2	6.32	30,959	3,730	8.30
Reforming Residual Fuel Oil	8.0	9.8	7.94	3,302	500	6.61
Virgin Naphtha Charge	100.0	100.0	6.48	41,278	5,096	8.10
Thermal Visbreaking						
Coke and Gas Loss	0.5	5.0	*	589	878	*
Stable Visbreaker Gasoline	18.5	15.0	6.34	21,797	2,633	8.28
Heavy Visbreaker Naphtha Distillates	38.0	34.0	7.00	44,774	5,966	7.50
Visbreaker Gas Oil	6.0	6.0	7.82	7,069	1,053	6.71
Visbreaker Residual Fuel Oil	37.0	40.0	8.45	43,595	7,020	6.21
Virgin Residue Charge	100.0	100.0	7.82	117,824	17,550	6.71
Short Residuum Charge	45.1	44.4	7.71	53,118	7,800	6.81
Long Residuum Charge	54.9	55.6	7.91	64,706	9,750	6.64
Thermal Cracking Charge Source						
Virgin Gas Oil	87.5	87.2	7.51	79,414	11,356	6.99
Catalytic Gas Oil	4.7	4.7	7.40	4,295	606	7.09
Visbreaker Gas Oil	7.8	8.1	7.82	7,069	1,053	6.71
Thermal Cracking Charge	100.0	100.0	7.53	90,778	13,015	6.97

* Data either nil or not applicable.

Table 20. Hypothetical Operation with High Distillate Yield Soviet Refining Equipment in 1955 a/ (Continued)
(Gross or Total Product Yields Calculated from the Soviet Refinery Units [illegible])

Sulfric Acid Alkylation	Volume %	Weight %	Lb/Gal b/	Thousands Bbl/Yr c/	Thousands Te/Yr d/	Thousands Bbl/Te e/
Process and Gas Loss	14.3	1.8	*	425	5	*
Gasoline Blend Stock (Unreacted Butanes)	31.0	31.2	4.90	921	86	10.71
Aviation Alkylate	50.0	60.7	5.90	1,485	168	8.90
Motor Alkylate	4.7	6.3	6.50	139	17	8.08
Alkylation Charge	100.0	100.0	4.88	2,970	276	10.76
Houdry Charge Stock to Alkylation	*	*	4.95	1,886	178	10.60
Recovery Thermal Stock to Alkylation	*	*	4.75	1,084	98	11.06
Recovery to Isooctane (Polymerization-Hydrogenation)	*	*	5.77	728	80	9.10
Total Recovery from Process Gas Loss	*	*	*	1,812	178	*
Process and Gas Loss Balance						
Crude Distillation Gas Loss	16.1	19.4	*	3,586	884	*
Houdry Coke and Gas Loss	2.7	5.3	*	589	239	*
Thermal Reforming Gas Loss	31.6	19.0	*	7,017	866	*
Visbreaking Coke and Gas Loss	2.7	19.3	*	589	878	*
Thermal Cracking Gas Loss	45.0	36.9	*	9,986	1,679	*
Alkylation Process and Gas Loss	1.9	0.1	*	425	5	*
Total Process and Gas Loss	100.0	100.0	*	22,192	4,551	*
Recovery from Process Gas Loss	8.2	3.9	*	1,812	178	*
Net Process and Gas Loss	91.8	96.1	*	20,380	4,373	*
Residual Fuel Oil Stocks						
Houdry Polymer Gas Oil	0.2	0.2	7.95	185	28	6.60
Thermal Reforming Residual	4.0	3.7	6.48	3,302	500	6.61
Thermal Visbreaker Residual	52.3	52.3	8.45	43,595	7,020	6.21
Thermal Cracked Residual	43.5	43.8	8.51	36,311	5,883	6.17
Total Residual Fuel Oil Stock	100.0	100.0	8.45	83,393	13,431	6.21

* Data either nil or not applicable.

Table 20. Hypothetical Operation with High Distillate Yield Soviet Refining Equipment in 1955 a/ (Continued)
(Gross or Total Product Yields Calculated from the Soviet Refinery Units and Systems)

Gasoline Base and Blend Stocks	Volume %	Weight %	Lb/Gal b/	Thousands Bbl/Yr c/	Thousands Te/Yr d/	Bbl/Te e/
Straight Run Aviation Base Gasoline	7.9	7.8	6.18	9,665	1,137	8.50
Other Straight Run Gasoline	11.6	11.0	5.94	14,086	1,593	8.84
Total Straight Run Gasoline	19.5	18.8	6.03	23,751	2,730	8.70
Stable Reformed Gasoline	25.4	25.7	6.32	30,959	3,730	8.30
Stable Visbreaker Gasoline	17.9	18.1	6.34	21,797	2,633	8.28
Stable Cracked Gasoline	31.3	31.7	6.34	38,127	4,607	8.28
Houdry Motor Naphtha	0.3	0.3	7.10	349	47	7.39
Alkylation Gasoline Blend Stock	0.8	0.6	4.90	921	86	10.71
Motor Alkylate	0.1	0.1	6.50	139	17	8.08
Houdry Aviation Base Gasoline	2.6	2.6	6.18	3,194	376	8.49
Houdry Isopentane	0.3	0.3	5.20	403	40	10.09
Aviation Alkylate	1.2	1.2	5.90	1,485	168	8.90
Isooctane	0.6	0.6	5.77	728	80	9.10
Total Gasoline Base and Blend Stocks	100.0	100.0	*	121,853	14,514	*
Overall Production Balance						
Net Process and Gas Loss	5.5	8.4	*	20,380	4,373	*
Total Gasoline Base and Blend Stocks	32.7	27.9	*	121,853	14,514	*
Kerosenes, Diesel Oils, Specialty Naphthas, Etc.	20.5	19.5	7.00	76,050	10,140	7.50
Heavy Visbreaker Distillates	12.0	11.5	7.00	44,774	5,966	7.50
Heavy Cracked Distillates	1.7	1.6	6.99	6,354	846	7.51
Lubes, Waxes, Road Oils, Tars, Asphalts, Etc.	5.2	5.2	7.39	19,383	2,730	7.10
Total Residual Fuel Oil Stocks	22.4	25.9	8.45	83,393	13,431	6.21
Crude Charge to Distillation (Production)	100.0	100.0	7.33	372,187	52,000	7.16

a. This table is developed upon a basis corresponding to that of Tables 15 and 17, Appendix B, in accordance with the discussions in the text and the annotations to Tables 15 and 17. Specifically in correspondence to the latter Tables, gross yields are shown for the potential base and blend stocks, but no accounting is made of finished engine fuel product blends such as gasolines, tractor fuels, Diesel fuels, and jet fuels.
b. Pounds per gallon.
c. Barrels per year.
d. Metric tons per year.
e. Barrels per metric ton.
* Data either nil or not applicable.

Table 21. Hypothetical 1955 Capacity Requirements by Areas, Results in Plausible Program for High Distillate Yields

Thousand Metric Tons per Year

Area Numbers	1	2	3	4	5	6	7	8	9	10	11	
	Ukraine and Crimea	Western Soviet Caucasia	Central Soviet Caucasia	Eastern and South-Eastern Soviet Caucasia	Soviet Central Asia Including Kazakhstan	Second Baku Including Saratov Gas Fields	North-Eastern European Russia	Western Siberia; Far Eastern USSR	Central Area, Volga to Ural Rivers	Central European Russia and Baltic Area	Minor Crude Distillation Sites	Total USSR
Crude Production	400	3,000	2,000	15,000	11,000	19,000	600	1,000	*	*	*	52,000
Prorated Process Capacities Required												
Crude Distillation Charge (20% Reserve)												
From 1950	610	6,000	6,400	15,840	3,860	6,420	250	1,280	1,700	2,095	465	44,920
Additional	*	*	*	2,160	9,340	16,380	470	*	*	*	*)	17,480 b
Excess from 1950	130	2,400	4,000	*	*	*	*	80	1,700	2,095	465)	
Total for Productive Area	480	3,600	2,400	18,000	13,200	22,800	720	1,200	*	*	*	62,400
Houdry Catalytic Cracking Charge												
From 1950	*	*	*	*	380	*	*	*	374	*	*	754
Additional	*	*	*	*	380	380	*	*	*	*	*	760 b
Total for Productive Area	*	*	*	*	760	380			374			1,514
Catalytic Alkylate Production												
With Houdry Units from 1950	*	*	*	*	44	*	*	*	46	*	*	90
With Additional Houdry Units	*	*	*	*	47	48	*	*	*	*	*	95 b
Total for Productive Area	*	*	*	*	91	48	*	*	46	*	*	185
Thermal Reforming Charge												
From 1950	*	*	*	*	218	771	*	*	*	*	*	989
Additional	21	156	104	780	354	2,609	31	52	*	*	*	4,107 b
Total for Productive Area	21	156	104	780	572	3,380	31	52	*	*	*	5,096
TC (Thermal Cracking) Charge												
Applied from 1950	681	1,026	2,133	1,679	2,151	2,185	*	342	1,570	1,248	*	13,015
Additional Required from 1950	*	*	*	3,451	1,155	*	205	*	*	*	*)	0
Excess Applied from 1950	544	*	1,449	*	*	*	*	*	1,570	1,248	*)	
Total for Productive Area	137	1,026	684	5,130	3,306	2,185	205	342	*	*	*	13,015

Table 21. Hypothetical 1955 Capacity Requirements by Areas, Results in Plausible Program for High Distillate Yields (Continued)

Thousand Metric Tons per Year

Area Numbers	1	2	3	4	5	6	7	8	9	10	11	12
Thermal Visbreaking Charge	Ukraine and Crimea	Western Soviet Caucasia	Central Soviet Caucasia	Eastern and South-Eastern Soviet Caucasia	Soviet Central Asia Including Kazakhstan	Second Baku Including Saratov Gas Fields	North-Eastern European Russia	Western Siberia; Far Eastern USSR	Central Area, Volga to Ural Rivers	Central European Russia and Baltic Area	Minor Crude Distillation Sites	Total USSR
TC Capacity Total from 1950	761	1,080	2,557	3,679	2,151	4,783	*	474	1,570	1,248	*	16,312
TC Capacity Applied from 1950	681	1,026	2,133	3,679	2,151	2,185	*	342	1,570	1,248	*	13,015
TC Capacity Available from 1950	80	63	424	0	0	2,598	*	132	0	0	*	3,297
Additional Visbreaking Capacity	*	537	*	3,000	2,200	8,452	120	68	*	*	*)	14,253 b/
Excess TC Capacity Available from 1950	*	*	24	*	*	*	*	*	*	*	*)	
Total for Productive Area	80	600	400	3,000	2,200	10,950	120	200	*	*	*	17,550

a. Data prorated from Tables 1, 16 and 20 where applicable. Data considered to be applicable if program is adopted for high distillate yields. Table correspond to Table 18, Appendix B. cf. also Table 34.

b. Indicated net new capacity as compared to 1950.

* Data either nil or not applicable.

Table 22. Thermal Refining Process Capacity Balances by Combined Areas
Resolved for Indicated 1955 Operation a/
Data Considered to Be Plausible If Program Is Adopted for High Distillate Yields

	Areas 1/2/3/4 Capacity		Areas 5/9 Capacity		Areas 6/7/10 Capacity		Area 8 Capacity		Minor Sites Capacity		Total USSR Capacity	
	Te/Yr c/	BPCD d/	Te/Yr c/	BPCD d/	Te/Yr c/	BPCD d/	Te/Yr c/	BPCD d/	Te/Yr c/	BPCD d/	Te/Yr c/	BPCD d/
Crude Production Capacity	20,400	400,175	11,000	215,871	19,600	384,482	1,000	19,616	*	*	52,000	1,020,054
Crude Distillation Charge Capacity Required												
(20% Reserve)	24,480	480,210	13,000	258,937	23,500	461,378	1,200	23,530	*	*	62,400	1,224,064
Charge Capacity from 1950	28,850	565,934	5,560	109,067	8,765	171,938	1,280	25,109	465	9,122	44,920	881,170
Excess	4,370	85,724	*	*	*	*	80	1,570	465	9,122)	17,480	342,894
Deficiency b/	*	*	7,640	149,870	14,755	289,440	*	*	*	*)		
Thermal Reforming Charge Capacity Required	1,061	23,545	572	12,694	3,411	75,696	52	1,154	*	*	5,096	113,089
Charge Capacity from 1950	*	*	218	4,838	771	17,110	*	*	*	*	989	21,948
Deficiency b/	1,061	23,545	354	7,856	2,640	58,586	52	1,154	*	*	4,107	91,141
Thermal Cracking Charge Capacity Required	6,977	133,326	3,306	63,175	2,390	45,671	342	6,535	*	*	13,015	248,707
Charge Capacity Applied from 1950	5,519	105,464	3,721	71,106	3,433	65,602	342	6,535	*	*	13,015	248,707
Additional Required from 1950 b/	1,458	27,861	*	*	*	*	*	*	*	*)	0	0
Excess Applied from 1950	*	*	415	7,930	1,043	19,931	*	*	*	*)		
Thermal Visbreaking Charge Capacity Required	4,080	75,045	2,200	40,466	11,070	203,615	200	3,679	*	*	17,550	322,805
Thermal Cracking Capacity Total from 1950	6,086	115,893	3,721	71,106	6,031	113,388	474	8,963	*	*	16,312	309,350
Thermal Cracking Capacity Applied from 1950	5,519	105,464	3,721	71,106	3,433	65,602	342	6,535	*	*	13,015	248,707
Thermal Cracking Capacity Available from 1950	567	10,429	0	0	2,598	47,786	132	2,428	*	*	3,297	60,643
Additional Visbreaking Capacity Required b/	3,513	64,616	2,200	40,466	8,472	155,829	68	1,251	*	*	14,253	262,162

a. This Table corresponds to the thermal conversion capacity correlation in Table 19, Appendix B. Here applied are the quantity and density data of Tables 20 and 21.
b. Additional installations in the areas when excess capacities are unavailable in other areas.
c. Metric tons per year.
d. Barrels per calendar day.
* Data either nil or not applicable.

Table 23

Postulated Operations in 1955 a/

Thousand Metric Tons

	Alternate Operations		
	High Octane Rating	High Distillate Yield	Intermediate Program
Crude Distillation b/			
Gas Loss	884	884	884
Straight Run Gasoline	2,730	2,730	2,730
Naphtha Charge (Total Charge) to Thermal Reforming	5,096	5,096	5,096
Intermediate Distillates to Products	10,140	10,140	10,140
Virgin Gas Oil	12,870	12,870	12,870
Lubes and Specialty Residual Products	2,730	2,730	2,730
Crude Residuum	17,550	17,550	17,550
Crude Charge	52,000	52,000	52,000
Virgin Gas Oil			
Charge (Total Charge) to Catalytic Cracking	12,870	1,514	2,654
Thermal Cracking Charge	0	11,356	10,216
Total Production	12,870	12,870	12,870
Crude Residuum			
Thermal Cracking Charge	13,650	0	5,850
Fuel Oil Product	3,900	0	0
Charge (Total Charge) to Thermal Visbreaking	0	17,550	11,700
Total Production	17,550	17,550	17,550
Thermal Cracking Charge			
Crude Residuum	13,650	0	5,850
Catalytic Gas Oil	4,718	606	1,060
Virgin Gas Oil	0	11,356	10,216
Visbreaker Gas Oil	0	1,053	1,170
Total Charge	18,368	13,015	18,296
Catalytic Gas Reversion and Hydrogenation			
Alkylation Charge	2,254	276	489
Polymerization-Hydrogenation Product	80	80	80
Polymer Gasoline Product	10	0	0

a. Summary of details shown in Tables 17, 20, and 31, Appendix B.
b. More explicit summaries of the crude distillation operations are provided in Tables 25, 26, and 27, Appendix B.

Table 24. Crude Distillation Yields in the USSR a/
Estimated Operations in 1950

	Basis Crude			Thousands		
	Volume %	Weight %	Lb/Gal b/	Bbl/Yr c/	Te/Yr d/	Bbl/Te e/
Gas Loss	1.0	1.7	*	2,837	669	*
Straight Run Gasoline	11.9	10.0	6.03	32,525	3,739	8.70
Reforming Naphtha	2.9	2.6	6.48	8,013	989	8.10
Kerosenes, Diesel Oils, Specialty Naphthas, Etc.	23.6	23.0	7.00	64,602	8,614	7.50
Virgin Gas Oil for Houdry Catalysis	2.0	2.0	7.29	5,407	751	7.20
Lubes, Waxes, Road Oils, Tars, Asphalts, Etc.	7.2	7.4	7.39	19,720	2,778	7.10
Crude Residue to Fuel Oil and Thermal Cracking	51.4	53.3	7.45	140,746	19,960	7.05
Total Crude Charge (Production)	100.0	100.0	7.19	273,750	37,500	7.30
Crude Residue to Fuel Oil and Thermal Cracking	51.4	53.3	7.45	140,746	19,960	7.05
Crude Residue to Thermal Cracking	40.9	42.8	7.50	112,014	16,012	7.00
Crude Residue to Fuel Oil	10.5	10.5	7.21	28,732	3,948	7.28
Lubes, Waxes, Road Oils, Tars, Asphalts, Etc.	7.2	7.4	7.39	19,720	2,778	7.10
Total Virgin Residual Products	17.7	17.9	7.29	48,452	6,726	7.20

a. Summary of details in Table 15, Appendix B.
b. Pounds per gallon.
c. Barrels per year.
d. Metric tons per year.
e. Barrels per metric ton.
* Data not applicable.

Table 25. Crude Distillation Yields in the USSR a/
Hypothetical Operations for High Octane Ratings in 1955

	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Gas Loss	0.8	1.4	*	730	182	*
Reforming Naphtha	28.1	23.6	6.30	25,556	3,068	8.33
Low Quality Long Residuum to Fuel Oil	28.1	30.0	8.00	25,584	3,900	6.56
Long Residuum to Thermal Cracking	43.0	45.0	7.85	39,122	5,850	6.69
Low Grade Crude Charge	100.0	100.0	7.50	91,000	13,000	7.00
Gas Loss	1.0	1.8	*	2,848	702	*
Straight Run Gasoline	8.4	7.0	6.03	23,751	2,730	8.70
Reforming Naphtha	5.6	5.2	6.77	15,722	2,028	7.75
Kerosene, Diesel Oils, Specialty Naphthas, Etc.	27.1	26.0	7.00	76,050	10,140	7.50
Virgin Gas Oil for Houdry Catalysis	6.8	6.8	7.29	19,109	2,654	7.20
Virgin Gas Oil for Fluid Catalysis	25.3	26.2	7.53	71,206	10,216	6.97
Lubes, Waxes, Road Oils, Tars, Asphalts, Etc.	6.9	7.0	7.39	19,383	2,730	7.10
Short Residuum to Thermal Cracking	18.9	20.0	7.71	53,118	7,800	6.81
Typical Good Quality Crude Charge	100.0	100.0	7.28	281,187	39,000	7.21
Gas Loss	1.0	1.7	*	3,856	884	*
Straight Run Gasoline	6.4	5.2	6.03	23,751	2,730	8.70
Reforming Naphtha	11.1	9.8	6.48	41,278	5,096	8.10
Kerosenes, Diesel Oils, Specialty Naphthas, Etc.	20.4	19.5	7.00	76,050	10,140	7.50
Virgin Gas Oil for Houdry Catalysis	5.1	5.1	7.29	19,109	2,654	7.20
Virgin Gas Oil for Fluid Catalysis	19.1	19.7	7.53	71,206	10,216	6.97
Lubes, Waxes, Road Oils, Tars, Asphalts, Etc.	5.2	5.2	7.39	19,383	2,730	7.10
Long Residuum to Fuel Oil and Thermal Cracking	17.4	18.8	7.91	64,706	9,750	6.64
Short Residuum to Thermal Cracking	14.3	15.0	7.71	53,118	7,800	6.81
Total Crude Charge (Production)	100.0	100.0	7.33	372,187	52,000	7.16
Total Residuum	31.7	33.8	7.82	117,824	17,550	6.71
Short Residuum to Thermal Cracking	14.3	15.0	7.71	53,118	7,800	6.81
Total Long Residuum	17.4	18.8	7.91	64,706	9,750	6.64
Long Residuum to Thermal Cracking	10.5	11.3	7.85	39,122	5,850	6.69
Low Quality Long Residuum to Fuel Oil	6.9	7.5	8.00	25,584	3,900	6.56
Lubes, Waxes, Road Oils, Tars, Asphalts, Etc.	5.2	5.2	7.39	19,383	2,730	7.10
Total Virgin Residual Products	12.1	12.7	7.74	44,967	6,630	6.78
Total Virgin Gas Oil for Catalysis (Catalytic Cracking)	24.2	24.8	7.48	90,315	12,870	7.02

a. Summary of details in Table 17, Appendix B. Cf. also Table 23, Appendix B.
b. Pounds per gallon.
c. Barrels per year.
d. Metric tons per year.
e. Barrels per metric ton.
* Data not applicable.

S-E-C-R-E-T

Table 26. Crude Distillation Yields in the USSR a/
Hypothetical Operations for High Distillate Yields in 1955

	Volume %	Weight %	Lb/Gal b/	Bbl/Yr c/	Te/Yr d/	Bbl/Te e/
Gas Loss	0.8	1.4	*	738	182	*
Reforming Naphtha	28.1	23.6	6.30	25,556	3,068	8.33
Low Quality Long Residuum to Visbreaking	28.1	30.0	8.00	25,584	3,900	6.56
Other Long Residuum to Visbreaking	43.0	45.0	7.85	39,122	5,850	6.69
Low Grade Crude Charge	100.0	100.0	7.50	91,000	13,000	7.00
Gas Loss	1.0	1.8	*	2,848	702	*
Straight Run Gasoline	8.4	7.0	6.03	23,751	2,730	8.70
Reforming Naphtha	5.6	5.2	6.77	15,722	2,028	7.75
Kerosenes, Diesel Oils, Specialty Naphthas, Etc.	27.1	26.0	7.00	76,050	10,140	7.50
Virgin Gas Oil for Houdry Catalysis	3.9	3.9	7.29	10,901	1,514	7.20
Virgin Gas Oil for Thermal Cracking	28.2	29.1	7.51	79,414	11,356	6.99
Lubes, Waxes, Road Oils, Tars, Asphalts, Etc.	6.9	7.0	7.39	19,383	2,730	7.10
Short Residuum to Visbreaking	18.9	20.0	7.71	53,118	7,800	6.81
Typical Good Quality Crude Charge	100.0	100.0	7.28	251,187	39,000	7.21
Gas Loss	1.0	1.7	*	3,856	884	*
Straight Run Gasoline	6.4	5.2	6.03	23,751	2,730	8.70
Reforming Naphtha	11.1	9.8	6.48	41,278	5,096	8.10
Kerosenes, Diesel Oils, Specialty Naphthas, Etc.	20.4	19.5	7.00	76,050	10,140	7.50
Virgin Gas Oil for Houdry Catalysis	2.9	2.9	7.29	10,901	1,514	7.20
Virgin Gas Oil for Thermal Cracking	21.3	21.9	7.51	79,414	11,356	6.99
Lubes, Waxes, Road Oils, Tars, Asphalts, Etc.	5.2	5.2	7.39	19,383	2,730	7.10
Long Residuum to Visbreaking	17.4	18.8	7.91	64,706	9,750	6.64
Short Residuum to Visbreaking	14.3	15.0	7.71	53,118	7,800	6.81
Total Crude Charge (Production)	100.0	100.0	7.33	372,187	52,000	7.16
Total Residuum to Visbreaking	31.7	33.8	7.82	117,824	17,550	6.71
Short Residuum to Visbreaking	14.3	15.0	7.71	53,118	7,800	6.81
Total Long Residuum to Visbreaking	17.4	18.8	7.91	64,706	9,750	6.64
Virgin Residual Products (Lubes and Special ties)	5.2	5.2	7.39	19,383	2,730	7.10
Total Virgin Gas Oil to Cracking (Thermal and Catalytic)	24.2	24.8	7.48	90,315	12,870	7.02

a. Summary of details in Table 20, Appendix B. Cf. also Table 23, Appendix B.
b. Pounds per gallon.
c. Barrels per year.
d. Metric tons per year.
e. Barrels per metric ton.
* Data not applicable.

Table 27. Crude Distillation Yields in the USSR a/
Hypothetical Intermediate Operations in 1955

	Volume %	Weight %	Lb/Gal b/	Bbl/Yr c/	Te/Yr d/	Bbl/Te e/
Gas Loss	0.8	1.4	*	738	182	*
Reforming Naphtha	28.1	23.6	6.30	25,556	3,068	8.33
Low Quality Long Residuum to Visbreaking	28.1	30.0	8.00	25,584	3,900	6.56
Long Residuum to Thermal Cracking	43.0	45.0	7.85	39,122	5,850	6.69
Low Grade Crude Charge	100.0	100.0	7.50	91,000	13,000	7.00
Gas Loss	1.0	1.8	*	2,848	702	*
Straight Run Gasoline	8.4	7.0	6.03	23,751	2,730	8.70
Reforming Naphtha	5.6	5.2	6.77	15,722	2,028	7.75
Kerosenes, Diesel Oils, Specialty Naphthas, Etc.	27.1	26.0	7.00	76,050	10,140	7.50
Virgin Gas Oil for Houdry Catalysis	6.8	6.8	7.29	19,109	2,654	7.20
Virgin Gas Oil for Thermal Cracking	25.3	26.2	7.53	71,206	10,216	6.97
Lubes, Waxes, Road Oils, Tars, Asphalts, Etc.	6.9	7.0	7.39	19,383	2,730	7.10
Short Residuum to Visbreaking	18.9	20.0	7.71	53,118	7,800	6.81
Typical Good Quality Crude Charge	100.0	100.0	7.28	281,187	39,000	7.21
Gas Loss	1.0	1.7	*	3,586	884	*
Straight Run Gasoline	6.4	5.2	6.03	23,751	2,730	8.70
Reforming Naphtha	11.1	9.8	6.48	41,278	5,096	8.10
Kerosenes, Diesel Oils, Specialty Naphthas, Etc.	20.4	19.5	7.00	76,050	10,140	7.50
Virgin Gas Oil for Houdry Catalysis	5.1	5.1	7.29	19,109	2,654	7.20
Virgin Gas Oil for Thermal Cracking	19.1	19.7	7.53	71,206	10,216	6.97
Lubes, Waxes, Road Oils, Tars, Asphalts, Etc.	5.2	5.2	7.39	19,383	2,730	7.10
Low Quality Long Residuum to Visbreaking	6.9	7.5	8.00	25,584	3,900	6.56
Long Residuum to Thermal Cracking	10.5	11.3	7.85	39,122	5,850	6.69
Short Residuum to Visbreaking	14.3	15.0	7.71	53,118	7,800	6.81
Total Crude Charge (Production)	100.0	100.0	7.33	372,187	52,000	7.16
Total Residuum	31.7	33.8	7.82	117,824	17,550	6.71
Long Residuum to Thermal Cracking	10.5	11.3	7.85	39,122	5,850	6.69
Total Residuum to Visbreaking	21.2	22.5	7.80	78,702	11,700	6.73
Lubes, Waxes, Road Oils, Tars, Asphalts, Etc.	5.2	5.2	7.39	19,383	2,730	7.10
Total Residual Stocks Not to Thermal Cracking	26.4	27.7	7.72	98,085	14,430	6.80
Total Long Residuum	17.4	18.8	7.91	64,706	9,750	6.64
Total Virgin Gas Oil to Cracking (Thermal and Catalytic)	24.2	24.8	7.48	90,315	12,870	7.02

a. Summary of details in Table 31, Appendix B. Cf. also Table 23, Appendix B.
b. Pounds per gallon.
c. Barrels per year.
d. Metric tons per year.
e. Barrels per metric ton.
* Data not applicable.

Table 28. Estimated Maximum Catalytic Cracking Charge Stocks in the USSR a/
Basis of 1,000 Barrels of Estimated Typical Good Quality Crude

Stock	Estimated Typical Crude of 1950						Estimated Typical Good Quality Crude of 1955					
	Barrels	Metric Tons	Percent Volume	Percent Weight	Density Lb/Gal b/	Density Bbl/Te c/	Barrels	Metric Tons	Percent Volume	Percent Weight	Density Lb/Gal b/	Density Bbl/Te c/
Maximum Charge for Houdry												
Gas and Light Distillates	250	30.822	25.0	22.5	*	*	250	32.081	25.0	23.1	*	*
650°F EP Naphtha (Light Gas Oil)	150)	69.452	50.0	50.7	7.29	7.20	150)	69.444	50.0	50.1	7.29	7.20
Gas Oil	350)						350)					
Residue Stock	250	36.712	25.0	26.8	7.71	6.81	250	37.171	25.0	26.8	7.80 e/	6.73 f/
Crude Charge	1,000	136.986	100.0	100.0	7.19	7.30	1,000	138.696	100.0	100.0	7.28	7.21
Maximum Charge for Fluid d/												
Gas and Light Distillates							250	32.081	25.0	23.1	*	*
650°F EP Naphtha (Light Gas Oil)							150)	78.876	56.1	56.1	7.38 g/	7.11 h/
Gas Oil							411)					
Residue Stock							189	27.739	18.9	18.9	7.71	6.81
Crude Charge							1,000	138,696	100.0	100.0	7.28	7.21

a. This Table is developed from Table 14, Appendix B.
b. Pounds per gallon.
c. Barrels per metric ton.
d. Data not applied to the 1950 crude.
e. Difference between this value and 7.71 neglected in correlating the potentials.
f. Difference between this value and 6.81 neglected in correlating the potentials.
g. Difference between this value and 7.53 neglected in correlating the potentials.
h. Difference between this value and 6.97 neglected in correlating the potentials.
* Data not applicable.

Table 29. Data for Charge Stocks in Soviet Thermal Cracking a/

			Quantity (Thousands)		Basis Total Charge		Basis Original Crude Oil: Charge Stock		Basis Original Crude Oil: Not in Charge Stock (Boiling Below or Otherwise Not in Charge Stock)	
	Lb/Gal b/	Bbl/Te c/	Bbl/Yr d/	Te/Yr e/	Weight Percent	Volume Percent	Weight Percent	Volume Percent	Weight Percent	Volume Percent
Estimated 1950 Operation										
Crude Residue	7.50	7.00	112,014	16,012	98.1	98.1	42.7	40.9	17.9	17.7
Catalytic Gas Oil	7.40	7.09	2,130	300	1.9	1.9	*	*	*	*
Total Charge	7.50	7.00	114,144	16,312	100.0	100.0	*	*	*	*
Hypothetical 1955 Operation for High Octane Ratings										
Long Crude Residuum	7.85	6.69	39,122	5,850	31.8	31.4	75.0	71.1	0.0	0.0
Short Crude Residuum	7.71	6.81	53,118	7,800	42.5	42.7	20.0	18.9	6.9	7.0
Catalytic Gas Oil	7.69	6.83	32,237	4,718	25.7	25.9	*	*	*	*
Total Charge	7.74	6.78	124,477	18,368	100.0	100.0				
Hypothetical 1955 Operation for High Distillate Yields										
Virgin Gas Oil	7.51	6.99	79,414	11,356	87.2	87.5	29.1	28.2	27.0	25.8
Catalytic Gas Oil	7.40	7.09	4,295	606	4.7	7.7	*	*	*	*
Visbreaker Gas Oil	7.82	6.71	7,069	1,053	8.1	7.8	*	*	*	*
Total Charge	7.53	6.97	90,778	13,015	100.0	100.0	*	*	*	*
Hypothetical 1955 Operation in Intermediate Program										
Long Crude Residuum	7.85	6.69	39,122	5,850	32.0	31.1	75.0	71.1	0.0	0.0
Virgin Gas Oil	7.53	6.97	71,206	10,216	55.8	56.6	26.2	25.3	27.0	25.8
Catalytic Gas Oil	7.40	7.09	7,529	1,060	5.8	6.0	*	*	*	*
Visbreaker Gas Oil	7.80	6.73	7,870	1,170	6.4	6.3	*	*	*	*
Total Charge	7.64	6.87	125,727	18,296	100.0	100.0	*	*	*	*

a. Cf. these Appendix B Tables; 15,17, 20, 31; 24, 25, 26, 27; 23.
b. Pounds per gallon.
c. Barrels per metric ton.
d. Barrels per year.
e. Metric tons per year.
* Data not applicable.

Table 30

Thermal Cracking Yields a/

	Applied in Analyses of Soviet Refining			
	Weight Percent	Volume Percent	[illegible]/Gal	Bbl/[illegible]
a. Estimated 1950 Operation				
Gas Loss	12.9	11.0	*	*
Stable Cracked Gasoline	35.4	42.0	6.32	8.3[illegible]
Heavy Cracked Distillates	6.5	7.0	7.00	7.5[illegible]
Residual Fuel Oil	45.2	40.0	8.47	6.2[illegible]
Total Charge	100.0	100.0	7.50	7.0[illegible]
b. Hypothetical 1955 High Distillate Yield Operation				
Gas Loss	12.9	11.0	*	*
Stable Cracked Gasoline	35.4	42.0	6.34	8.2[illegible]
Heavy Cracked Distillates	6.5	7.0	6.99	7.5[illegible]
Residual Fuel Oil	45.2	40.0	8.51	6.1[illegible]
Total Charge	100.0	100.0	7.53	6.9[illegible]
c. Hypothetical 1955 High Octane Rating Operation				
Gas Loss	12.5	11.0	*	*
Stable Cracked Gasoline	26.6	32.5	6.32	8.3[illegible]
Heavy Cracked Distillates	6.3	7.0	7.00	7.50
Residual Fuel Oil	54.6	49.5	8.55	6.1[illegible]
Total Charge	100.0	100.0	7.74	6.7[illegible]
d. Hypothetical 1955 Intermediate Operation				
Gas Loss	12.9	11.0	*	*
Stable Cracked Gasoline	35.4	42.0	6.44	8.1[illegible]
Stable Cracked Distillates	6.5	7.0	7.09	7.4[illegible]
Residual Fuel Oil	45.2	40.0	8.63	6.0[illegible]
Total Charge	100.0	100.0	7.64	6.8[illegible]

a. Applied in Tables 15, 17, 20, 31, Appendix B.
* Data not applicable.

Table 31. Hypothetical Operation in an Intermediate or Plausible Optimum Soviet Refining Program in 1955 a/ **
(Gross or Total Product Yields Calculated from the Soviet Refining Units and Systems)

	Volume %	Weight %	Lb/Gal b/	Bbl/Yr c/	Te/Yr d/	Bbl/Te e/
Low Grade Crude Distillation						
Gas Loss	0.8	1.4	*	738	182	*
Reforming Naphtha	28.1	23.6	6.30	25,556	3,068	8.33
Low Quality Long Residuum to Visbreaking	28.1	30.0	8.00	25,584	3,900	6.56
Long Residuum to Thermal Cracking	43.0	45.0	7.85	39,122	5,850	6.69
Crude Charge	100.0	100.0	7.50	91,000	13,000	7.00
Typical Good Quality Crude Distillation						
Gas Loss	1.0	1.8	*	2,848	702	*
Straight Run Gasoline	8.4	7.0	6.03	23,751	2,730	8.70
Reforming Naphtha	5.6	5.2	6.77	15,722	2,028	7.75
Kerosenes, Diesel Oils, Specialty Naphthas, Etc.	27.1	26.0	7.00	76,050	10,140	7.50
Virgin Gas Oil to Houdry Catalysis	6.8	6.8	7.29	19,109	2,654	7.20
Virgin Gas Oil to Thermal Cracking	25.3	26.2	7.53	71,206	10,216	6.97
Lubes, Waxes, Road Oils, Tars, Asphalts, Etc.	6.9	7.0	7.39	19,383	2,730	7.10
Short Residuum to Visbreaking	18.9	20.0	7.71	53,118	7,800	6.81
Crude Charge	100.0	100.0	7.28	281,187	39,000	7.21
Over-all Crude Distillation						
Gas Loss	1.0	1.7	*	3,586	884	*
Straight Run Gasoline	6.4	5.2	6.03	23,751	2,730	8.70
Reforming Naphtha	11.1	9.8	6.48	41,278	5,096	8.10
Kerosenes, Diesel Oils, Specialty Naphthas, Etc.	20.4	19.5	7.00	76,050	10,140	7.50
Virgin Gas Oil to Houdry Catalysis	5.1	5.1	7.29	19,109	2,654	7.20
Virgin Gas Oil to Thermal Cracking	19.1	19.7	7.53	71,206	10,216	6.97
Lubes, Waxes, Road Oils, Tars, Asphalts, Etc.	5.2	5.2	7.39	19,383	2,730	7.10
Low Quality Long Residuum to Visbreaking	6.9	7.5	8.00	25,584	3,900	6.56
Long Residuum to Thermal Cracking	10.5	11.3	7.85	39,122	5,850	6.69
Short Residuum to Visbreaking	14.3	15.0	7.71	53,118	7,800	6.81
Crude Charge	100.0	100.0	7.33	372,187	52,000	7.16

* Data either nil or not applicable.
** Footnotes follow on p. 181.

Table 31. Hypothetical Operation in an Intermediate or Plausible Optimum Soviet Refining Program in 1955 (Continued) a/
(Gross or Total Product Yields Calculated from the Soviet Refining Units and Systems)

	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Houdry Catalytic Cracking and Reforming						
Coke and Gas Loss	5.4	15.8	*	1,032	419	*
Alkylation Charge Stock	17.3	11.8	4.95	3,306	313	10.60
Isopentane	3.7	2.6	5.20	707	69	10.09
Aviation Base Gasoline	29.3	24.9	6.18	5,599	661	8.49
Motor Naphtha	3.2	3.1	7.10	611	82	7.39
Catalytic Gas Oil	39.4	39.9	7.40	7,529	1,060	7.09
Polymer Gas Oil (Fuel Oil)	1.7	1.9	7.95	325	50	6.60
Virgin Gas Oil Charge	100.0	100.0	7.29	19,109	2,654	7.20
Thermal Reforming						
Gas Loss	17.0	17.0	*	7,017	866	*
Stable Reformed Gasoline	75.0	73.2	6.32	30,959	3,730	8.30
Reforming Residual Fuel Oil	8.0	9.8	7.94	3,302	500	6.61
Virgin Naphtha Charge	100.0	100.0	6.48	41,278	5,096	8.10
Thermal Visbreaking						
Coke and Gas Loss	3.5	6.0	*	2,754	702	*
Stable Visbreaker Gasoline	16.5	13.5	6.39	12,986	1,580	8.22
Heavy Visbreaker Naphtha Distillates	25.0	22.5	7.02	19,676	2,632	7.48
Visbreaker Gas Oil	10.0	10.0	7.80	7,870	1,170	6.73
Visbreaker Residual Fuel Oil	45.0	48.0	8.32	35,416	5,616	6.31
Virgin Residue Charge	100.0	100.0	7.80	78,702	11,700	6.73
Short Residuum Charge	67.5	66.7	7.71	53,118	7,800	6.81
Long Residuum Charge	32.5	33.3	8.00	25,584	3,900	6.56
Thermal Cracking Charge Source						
Virgin Gas Oil	56.6	55.8	7.53	71,206	10,216	6.97
Catalytic Gas Oil	6.0	5.8	7.40	7,529	1,060	7.09
Visbreaker Gas Oil	6.3	6.4	7.80	7,870	1,170	6.73
Long Residuum	31.1	32.0	7.85	39,122	5,850	6.69
Thermal Cracking Charge	100.0	100.0	7.64	125,727	18,296	6.87

* Data either nil or not applicable.

Table 31. Hypothetical Operation in an Intermediate or Plausible Optimum Soviet Refining Program in 1955 (Continued) a/
(Gross or Total Product Yields Calculated from the Soviet Refining Units and Systems)

	Volume %	Weight %	Lb/Gal b/	Thousands Bbl/Yr c/	Thousands Tn/Yr d/	Bbl/Tn e/
Thermal Cracking						
Gas Loss	11.0	12.9	*	13,830	2,360	*
Stable Cracked Gasoline	42.0	35.4	6.44	52,805	6,477	8.15
Heavy Cracked Distillates	7.0	6.5	7.09	8,801	1,189	7.40
Cracked Residual Fuel Oil	40.0	45.2	8.63	50,291	8,270	6.08
Thermal Cracking Charge	100.0	100.0	7.64	125,727	18,296	6.87
Sulfuric Acid Alkylation						
Process and Gas Loss	14.3	1.8	*	753	9	*
Gasoline Blend Stock (Unreacted Butanes)	31.0	31.2	4.90	1,631	152	10.71
Aviation Alkylate	50.0	60.7	5.90	2,631	297	8.90
Motor Alkylate	4.7	6.3	6.50	247	31	8.08
Alkylation Charge	100.0	100.0	4.88	5,262	489	10.76
Houdry Charge Stock to Alkylation	*	*	4.95	3,306	313	10.60
Recovery Thermal Stock to Alkylation	*	*	4.72	1,956	176	11.11
Recovery to Isooctane (Polymerization-Hydrogenation	*	*	5.77	728	80	9.10
Total Recovery from Process Gas Loss	*	*	*	2,684	256	*
Process and Gas Loss Balance						
Crude Distillation Gas Loss	12.4	16.9	*	3,586	884	*
Houdry Coke and Gas Loss	3.6	8.0	*	1,032	419	*
Thermal Reforming Gas Loss	24.2	16.5	*	7,017	866	*
Visbreaking Coke and Gas Loss	9.5	13.4	*	2,754	702	*
Thermal Crackihg Gas Loss	47.7	45.0	*	13,830	2,360	*
Alkylation Process and Gas Loss	2.6	0.2	*	753	9	*
Total Processand Gas Loss	100.0	100.0	*	28,972	5,240	*
Recovery from Process Gas Loss	9.3	4.9	*	2,684	256	*
Net Process and Gas Loss	90.7	95.1	*	26,288	4,984	*

* Data either nil or not applicable.

Table 31. Hypothetical Operation in an Intermediate or Plausible Optimum Soviet Refining Program in 1955 (Continued) a/
(Gross or Total Product Yields Calculated from the Soviet Refining Units and Systems)

	Volume %	Weight %	Lb/Gal b/	Bbl/Yr c/	Te/Yr d/	Bbl/Te e/
Gasoline Base and Blend Stocks						
Straight Run Aviation Base Gasoline	7.3	7.2	6.18	9,665	1,137	8.50
Other Straight Run Gasoline	10.6	10.0	5.94	14,086	1,593	8.84
Total Straight Run Gasoline	17.9	17.2	6.03	23,751	2,730	8.70
Stable Reformed Gasoline	28.3	23.5	6.32	30,959	3,730	8.30
Stable Visbreaker Gasoline	9.8	9.9	6.39	12,986	1,580	8.22
Stable Cracked Gasoline	39.8	40.7	6.44	52,805	6,477	8.15
Houdry Motor Naphtha	0.5	0.5	7.10	611	82	7.39
Alkylation Gasoline Blend Stock	1.2	1.0	4.90	1,631	152	10.71
Motor Alkylate	0.2	0.2	6.50	247	31	8.08
Houdry Aviation Base Gasoline	4.2	4.2	6.18	5,599	661	8.49
Houdry Isopentane	0.5	0.4	5.20	707	69	10.09
Aviation Alkylate	2.0	1.9	5.90	2,631	297	8.90
Isooctane	0.6	0.5	5.77	728	80	9.10
Total Gasoline Base and Blend Stocks	100.0	100.0	*	132,655	15,889	*
Residual Fuel Oil Stocks						
Houdry Polymer Gas Oil	0.4	0.3	7.95	325	50	6.60
Thermal Reforming Residual	3.7	3.5	7.94	3,302	500	6.61
Thermal Visbreaker Residual	39.6	38.9	8.32	35,416	5,616	6.31
Thermal Cracked Residual	56.3	57.3	8.63	50,291	8,270	6.08
Total Residual Fuel Oil Stock	100.0	100.0	8.48	89,334	14,436	6.19
Over-all Production Balance						
Net Process and Gas Loss	7.0	9.6	*	26,288	4,984	*
Total Gasoline Base and Blend Stocks	35.6	30.6	*	132,655	15,889	*
Kerosenes, Diesel Oils, Specialty Naphthas, Etc.	20.5	19.5	7.00	76,050	10,140	7.50
Heavy Visbreaker Distillates	5.3	5.1	7.02	19,676	2,632	7.48
Heavy Cracked Distillates	2.4	2.3	7.09	8,801	1,189	7.40
Lubes, Waxes, Road Oils, Tars, Asphalts, Etc.	5.2	5.2	7.39	19,383	2,730	7.10
Total Residual Fuel Oil Stocks	24.0	27.7	8.48	89,334	14,436	6.19
Crude Charge to Distillation (Production)	100.0	100.0	7.33	372,187	52,000	7.16

* Data either nil or not applicable.

a. This table is developed upon a basis corresponding to that of tables 17, 19, and 20 Appendix B. In correspondence with the discussions, in the text and the annotations to the three preceding tables as noted. Specifically in correspondence to these preceding Tables, gross yields are shown for the potential base and blend stocks, but no accounting is made of finished engine fuel product blends such as gasolines, tractor fuels, Diesel fuels, and jet fuels.

b. Pounds per gallon.

c. Barrels per year.

d. Metric tons per year.

e. Barrels per metric ton.

Table 32. Hypothetical 1955 Process Capacity Requirements by Areas a/
Results in Plausible Intermediate Program

Thousand Metric Tons per Ye

Area Numbers	1	2	3	4	5	6	7	8	9	10	11	
	Ukraine and Crimea	Western Soviet Caucasia	Central Soviet Caucasia	and South-Eastern Soviet Caucasia	Soviet Central Asia Including Kazakhstan	Second Baku Including Saratov Gas Fields	North-Eastern European Russia	Western Siberia; Far Eastern USSR	Central Area, Volga to Ural Rivers	European Russia and Baltic Area	Minor Crude Distillation Sites	Total USSR
Crude Production												
Crude Production	400	3,000	2,000	15,000	11,000	19,000	600	1,000	*	*	*	52,000
Prorated Process Capacities Required												
Crude Distillation Charge (20% Reserve)												
From 1950	610	6,000	6,400	15,840	3,860	6,420	250	1,280	1,700	2,095	465	44,920
Additional	*	*	*	2,160	9,340	16,380	470	*	*	*	*)	17,480 b
Excess from 1950	139	2,400	4,000	*	*	*	*	80	1,700	2,095	465)	
Total for Productive Area	480	3,600	2,400	18,000	13,200	22,800	720	1,200	*	*	*	62,400
Houdry Catalytic Cracking Charge												
From 1950	*	*	*	*	380	*	*	*	374	*	*	754
Additional	*	*	380	380	380	760	*	*	*	*	*	1,900 b
Total for Productive Area	*	*	380	380	760	760	*	*	374	*	*	2,654
Catalytic Alkylate Production												
With Houdry Units from 1950	*	*	*	*	44	*	*	*	46	*	*	90
With Additional Houdry Units	*	*	48	48	47	95	*	*	*	*	*	238 b
Total for Productive Area	*	*	48	48	91	95	*	*	46	*	*	328
Thermal Reforming Charge												
From 1950	*	*	*	*	218	771	*	*	*	*	*	981
Additional	21	156	104	780	354	2,609	31	52	*	*	*	4,107 b
Total for Productive Area	21	156	104	780	572	3,380	31	52	*	*	*	5,096
Thermal Cracking Charge												
From 1950	761	1,089	2,557	1,679	2,151	4,783	*	474	1,570	1,248	*	16,312
Additional	*	*	*	3,343	1,242	2,876	210	*	*	*	*)	1,984 b
Excess from 1950	621	39	2,085	*	*	*	*	124	1,570	1,248	*)	
Total for Productive Area	140	1,050	472	5,022	3,393	7,659	210	350	*	*		18,296
Thermal Visbreaking Charge												
Additional (Total) for Productive Area	80	600	409	3,000	2,200	5,100	120	200	*	*	*	11,700 b

a. Data prorated from Tables 1, 16, and 31 where applicable. Data considered to be applicable if intermediate program is adopted. Table corresponds to Table 18 and 21, Appendix B. Cf. also Table 34.
b. Indicated net new capacity as compared to 1950.
* Data either nil or not applicable.

~~S-E-C-R-E-T~~

Table 33. Thermal Refining Process Capacity Balances by Combined Areas
Resolved for Indicated 1965 Operations a/

	Areas 1&2&3&4 Capacity		Areas 5&7 Capacity		Areas 6&7&10 Capacity		Area 8 Capacity		Minor Sites Capacity		Total USSR Capacity	
	Te/Yr c/	BPCD d/	Te/Yr c/	BPCD d/	Te/Yr c/	BPCD d/	Te/Yr c/	BPCD d/	Te/Yr c/	BPCD d/	Te/Yr c/	BPCD d/
Crude Production Capacity	20,[illegible]	400,[illegible]75	11,000	215,8[illegible]	19,[illegible]	384,4[illegible]	[illegible],000	[illegible]	*	*	5[illegible],000	1,020,094
Crude Distillation Charge Capacity Required (20% Reserve)	24,480	480,210	13,000	258,932	23,500	461,278	1,[illegible]00	[illegible]	*	*	6[illegible],400	1,224,064
Charge Capacity from 1950	28,850	565,934	5,560	109,067	8,765	171,938	1,280	25,109	465	9,122	44,920	882,170
Excess	4,370	85,724	*	*	*	*	80	1,570	465	9,122)	27,480	342,894
Deficiency b/	*	*	7,640	149,870	14,755	289,440	*	*	*	*)		
Thermal Reforming Charge Capacity Required	1,061	23,545	572	12,694	3,411	75,696	52	1,154	*	*	5,096	113,089
Charge Capacity from 1950	*	*	218	4,838	771	17,110	*	*	*	*	989	21,948
Deficiency b/	1,061	23,545	354	7,856	2,640	58,586	52	1,154	*	*	4,107	91,141
Thermal Cracking Charge Capacity Required	6,684	125,821	3,393	63,880	7,869	148,168	350	6,589	*	*	18,296	344,458
Charge Capacity from 1950	6,086	115,893	3,721	71,106	6,031	113,388	474	8,963	*	*	16,312	309,350
Excess	*	*	328	7,226	*	*	124	2,374	*	*)	1,984	35,108
Deficiency b/	598	9,928	*	*	1,838	34,780	*	*	*	*)		
Thermal Visbreaking Charge Capacity Required	4,080	75,191	2,200	40,544	5,220	96,201	200	3,686	*	*	11,700	215,622
Deficiency b/	4,080	75,191	2,200	40,544	5,220	96,201	200	3,686	*	*	11,700	215,622

a. This Table corresponds to Table 22, Appendix B, and the thermal conversion capacity correlation in Table 19, Appendix B. Here applied are the quantity and density data of Tables 31 and 32.
b. Additional installations in the areas when excess capacities are unavailable in other areas.
c. Metric tons per year.
d. Barrels per calendar day.
* Data either nil or not applicable.

Table 34. Derivation of Thermal Conversion Charge Stocks for Hypothetical 1955 Operations
(Quantities in Thousands of Metric Tons With Over-all Weight Percentages Applied to Component Stocks) a/
I. Thermal Reforming, All Programs

Area	Type of Charge Stock Postulated for Thermal Conversion in 1955							
	Virgin Naphtha			Virgin Naphtha			Total	
	Crude Charge	Percent Factor	Thermal Charge	Crude Charge	Percent Factor	Thermal Charge	Total	Assumed
Area 1	400	5.2	21	*	*	*	21	21
" 2	3,000	5.2	156	*	*	*	156	156
" 3	2,000	5.2	104	*	*	*	104	104
" 4	15,000	5.2	780	*	*	*	780	780
" 5	11,000	5.2	572	*	*	*	572	572
" 6	6,000	5.2	312	13,000	23.6	3,068	3,380	3,380
" 7	600	5.2	31	*	*	*	31	31
" 8	1,000	5.2	52	*	*	*	52	52
Total	39,000	5.2	2,028	13,000	23.6	3,068	5,096	5,096

a. Over-all weight percentage applied to each component source charge, to derive stock for thermal charge or other distribution.
* Data either nil or not applicable.

Table 34. Derivation of Thermal Conversion Charge Stocks for Hypothetical 1955 Operations (Continued)
(Quantities in Thousands of Metric Tons With Over-all Weight Percentages Applied to Component Stocks) a/
II. Thermal Cracking, High Octane Rating

Area	Type of Charge Stock Postulated for Thermal Conversion in 1955												Total	
	Long Residuum			Short Residuum			Catalytic Gas Oil			Catalytic Gas Oil				
	Crude Charge	Percent Factor	Thermal Charge	Crude Charge	Percent Factor	Thermal Charge	Houdry Charge	Percent Factor	Thermal Charge	Fluid Charge	Percent Factor	Thermal Charge	Total	Assumed
Area 1	*	*	*	400	20.0	80	*	*	*	132	35.8	47	127	128
" 2	*	*	*	3,000	20.0	600	*	*	*	990	35.8	354	954	963
" 3	*	*	*	2,000	20.0	400	380	39.9	152	280	35.8	100	652	642
" 4	*	*	*	15,000	20.0	3,000	380	39.9	152	4,570	35.8	1.636	4,788	4,815
" 5	*	*	*	11,000	20.0	2,200	760	39.9	303	2,870	35.8	1,028	3,531	3,531
" 6	13,000	45.0	5,850	6,000	20.0	1,200	760	39.9	303	1,220	35.8	437	7,790	7,775
" 7	*	*	*	600	20.0	120	*	*	*	198	35.8	71	191	193
" 8	*	*	*	1,000	20.0	200	*	*	*	330	35.8	118	318	321
Total Apparent	13,000	45.0	5,850	39,000	20.0	7,800	2,280	39.9	910	10,590	35.8	3,791	18,351	18,368
With Orsk Houdry for Fluid	13,000	45.0	5,850	39,000	20.0	7,800	2,654	39.9	1,060	10,216	35.8	3,658	18,368	18,368

	Other Stock Distribution		
	Long Residuum		
	Crude Charge	Percent Factor	Fuel Oil Stock
Area 6	13,000	30.0	3,900
Total Apparent	13,000	30.0	3,900
With Orsk Houdry for Fluid	13,000	30.0	3,900

a. Over-all weight percentage applied to each component source charge, to derive stock for thermal charge or other distribution.
* Data either nil or not applicable.

Table 34. Derivation of Thermal Conversion Charge Stocks for Hypothetical 1955 Operations (Continued)
(Quantities in Thousands of Metric Tons with Over-all Weight Percentages Applied to Component Stocks) a.
III. Thermal Cracking, High Distillate Yield

Area	Type of Charge Stock Postulated for Thermal Conversion in 1955									Total	
	Virgin Gas Oil			Catalytic Gas Oil			Visbreaker Gas Oil				
	Crude Charge	Percent Factor	Thermal Charge	Houdry Charge	Percent Factor	Thermal Charge	Visbreaker Charge	Percent Factor	Thermal Charge	Total	Assumed
Area 1	400	33.0	132	*	*	*	80	6.0	5	137	137
" 2	3,000	33.0	990	*	*	*	600	6.0	36	1,026	1,026
" 3	2,000	33.0	660	*	*	*	400	6.0	24	684	684
" 4	15,000	33.0	4,950	*	*	*	3,000	6.0	180	5,130	5,130
" 5	8,700	33.0	2,870	760	39.9	303	2,200	6.0	133	3,306	3,306
" 6 (With Orsk Houdry)	3,715	33.0	1,226	754	39.9	303	10,950	6.0	656	2,185	2,185
" 7	600	33.0	198	*	*	*	120	6.0	7	205	205
" 8	1,000	33.0	330	*	*	*	200	6.0	12	342	342
Total	34,415	33.0	11,356	1,514	39.9	606	17,550	6.0	1,053	13,015	13,015

	Other Stock Distribution					
	Virgin Gas Oil			Long Residuum		
	Crude Charge	Percent Factor	Houdry Charge	Crude Charge	Percent Factor	Visbreaker Charge
Area 5	2,300	33.0	760	*	*	*
" 6 (With Orsk Houdry)	2,285	33.0	754	13,000	75.0	9,750
Total	5,585	33.0	1,514	13,000	75.0	9,750

a. Over-all weight percentage applied to each component source charge, to derive stock for thermal charge or other distribution.
* Data either nil or not applicable.

Table 34. Derivation of Thermal Conversion Charge Stocks for Hypothetical 1955 Operations (Continued)
(Quantities in Thousands of Metric Tons with Over-all Weight Percentages Applied to Component Stocks) a/
IV. Thermal Cracking, Intermediate Program

Area	Type of Charge Stock Postulated for Thermal Conversion in 1955												Total	
	Long Residuum			Virgin Gas Oil			Catalytic Gas Oil			Visbreaker Gas Oil				
	Crude Charge	Percent Factor	Thermal Charge	Crude Charge	Percent Factor	Thermal Charge	Houdry Charge	Percent Factor	Thermal Charge	Visbreaker Charge	Percent Factor	Thermal Charge	Total	Assumed
Area 1	*	*	*	400	33.0	132	*	*	*	80	10.0	8	140	140
" 2	*	*	*	3,000	33.0	990	*	*	*	600	10.0	60	1,050	1,150
" 3	*	*	*	850	33.0	280	380	39.9	152	400	10.0	40	472	472
" 4	*	*	*	13,850	33.0	4,570	380	39.9	152	3,000	10.0	300	5,022	5,022
" 5	*	*	*	8,700	33.0	2,870	760	39.9	303	2,200	10.0	220	3,393	3,393
" 6 (With Orsk Houdry)	13,000	45.0	5,850	2,565	33.0	846	1,134	39.9	453	5,100	10.0	510	7,659	7,659
" 7	*	*	*	600	33.0	198	*	*	*	120	10.0	12	210	210
" 8	*	*	*	1,000	33.0	330	*	*	*	200	10.0	20	350	350
Total	13,000	45.0	5,850	30,965	33.0	10,216	2,654	39.9	1,060	11,700	10.0	1,170	18,296	18,296

	Other Stock Distribution					
	Virgin Gas Oil			Long Residuum		
	Crude Charge	Percent Factor	Houdry Charge	Crude Charge	Percent Factor	Visbreaker Charge
Area 3	1.150	33.0	380	*	*	*
" 4	1.150	33.0	380	*	*	*
" 5	2,300	33.0	760	*	*	*
" 6 (With Orsk Houdry)	3,435	33.0	1,134	13,000	30.0	3,900
Total	8,035	33.0	2,654	13,000	30.0	3,900

a. Over-all weight percentage applied to each component source charge, to derive stock for thermal charge or other distribution.
* Data either nil or not applicable.

Table 35. Catalytic Avgas Stocks in Houdry and Hydrogenation Systems

I. Potential Availability Assumed for Avgas Blend Calculations

Source Units	Avgas Base Thousands Bbl/Yr	Avgas Base Thousands Te/Yr b/	Isopentane Thousands Bbl/Yr a/	Isopentane Thousands Te/Yr b/	Aviation Alkylate Thousands Bbl/Yr a/	Aviation Alkylate Thousands Te/Yr b/	Isooctane Thousands Bbl/Yr a/	Isooctane Thousands Te/Yr b/
Ufa Hydrogenation System	*	*	*	*	*	*	694	**
Houdry Catalytic Systems								
Gurev and Orsk	1,606	**	164	**	712	**	*	*
2 Additional Systems	1,606	**	185	**	730	**	*	*
Total Above 4 Systems	3,212	**	349	**	1,442	**	*	*
3 Additional Systems	2,409	**	301	**	1,168	**	*	*
Total Above 7 Systems	5,621	**	650	**	2,610	**	*	*

II. Gross Yields Shown in the Analyses of 1950 and Future Operations

Source Units	Avgas Base Thousands Bbl/Yr	Avgas Base Thousands Te/Yr b/	Isopentane Thousands Bbl/Yr a/	Isopentane Thousands Te/Yr b/	Aviation Alkylate Thousands Bbl/Yr a/	Aviation Alkylate Thousands Te/Yr b/	Isooctane Thousands Bbl/Yr a/	Isooctane Thousands Te/Yr b/
Ufa Hydrogenation System	*	*	*	*	*	*	728	80
Houdry Catalytic Systems								
Gurev and Orsk	1,585	156	200	20	721	81	*	*
Other 2 Lend-Lease Systems	1,609	220	203	20	764	87	*	*
Total Above 4 Systems	3,194	376	403	40	1,485	168	*	*
3 Additional Systems	2,405	285	304	29	1,146	129	*	*
Total Above 7 Systems	5,599	661	707	69	2,631	297	*	*
7 Standard Systems	5,621	663	703	69	2,683	301	*	*

a. Barrels per year.
b. Metric tons per year.
* Data not applicable.
** Data not available.

APPENDIX C

Comparison of Intelligence Estimates for the USSR

1950 Data for the Natural Petroleum Industry

Regional Productions, Refining Facilities, and Refining Operations

Introductory Note

The annotated tables of this Appendix serve to compare and correlate the basic 1950 data of the foregoing text with various corresponding estimates independently derived by other intelligence groups, primarily referring to the estimates of this sort recently made available by another or second agency directly integrated with the present agency in the intelligence community here involved. 14/ 15/ 16/ The tables specifically pertain to this principal or primary objective as follows: Table 36 refers to the estimates of crude oil productions by regions; Table 37 refers to the estimates of installed refinery capacities; Table 38 refers to the estimates of refinery productions.

The present study of future Soviet refining potentials is based upon the estimated 1950 data shown in Tables 36, 37, and 38. As thus shown and applied in the subject text the estimates for regional crude production and installed refinery capacity were directly derived from two provisional reports preceding the present in the correlated series of papers, CIA/RR PR-17, Petroleum in the Soviet Bloc, I-B, Production and Exploration of Petroleum in the USSR which develops the estimates of regional crude productions with estimates of corresponding future (i.e., 1955) productions included (cf. Appendixes A, B, C of Paper B); and I-C, Refining of Petroleum in the USSR which develops the refinery capacity estimates. In contrast to the three sets of estimates thus noted, two for

regional crude productions and one for installed refinery capacities, all estimates for future refinery installations and likewise all estimates for the 1950 and future potential refinery productions are initially developed in the present provisional paper of the series, i.e., in I-D, Survey of Possibilities and Potentials in Future Petroleum Refining in the USSR. The following comparisons are here included in tabular form because of the importance of the estimates originating with the second intelligence agency as above noted, with these estimates made available subsequently to the final preparations of Papers B and C. The comparisons appear to show that the second agency estimates are generally reconcilable with, and in the same order of magnitude as, the present agency estimates if the respective values are resolved as applicable group totals.

Table 36. Natural Petroleum Production in the USSR
Intelligence Estimates of 1950 Regional Productions

Productive Region or Other Area	Thousand Metric Tons References: Plan a/*	Present Agency b/	Second Agency c/
Carpathian (Western Ukraine)	d/	305	d/
Eastern Ukraine (Summy-Romny)	d/	25	d/
Ukraine SSR	325	330	400 e/
Volga-Ural		11,200	10,000
Kama		325	400
Second Baku	9,190	11,525	10,400
Pechora		480	400
Sakhalin		820	1,100
Crimea		15	f/
Kuban-Maikop	5,310	2,520	2,500
Grozny		2,045	2,800
Daghestan		925	600
RSFSR	14,500	18,230	17,800 e/
South Georgian	110	115	f/
Baku	17,000	15,150	15,000
Soviet Transcaucasia	17,110	15,265	15,000 e/
Kirghiz	80	d/	d/
Uzbek	1,066	d/	d/
Tadzhik	60	d/	d/
Southeastern Soviet Central Asia	1,206 g/	1,255	1,700
Turkmen	1,104	1,200	2,000
Emba	1,200 h/	1,220	1,100
Soviet Central Asia	3,510	3,675	4,800
Total USSR i/	35,445	37,500	38,000
Kuban-Maikop	d/	2,420	2,500
Grozny	d/	2,045	2,800
Daghestan	d/	925	600
Soviet Ciscaucasia	5,310 j/	5,390	5,900 e/
Soviet Transcaucasia	17,110	15,265	15,000 e/
Soviet Caucasia	22,420 j/	20,655	20,900 e/
Crimea	d/	15	f/
Ukraine SSR	325	330	400 e/
Western-Southern Regions	22,745	21,000	21,300 e/
Second Baku		11,525	10,400
Pechora	9,190	480	400
Sakhalin		820	1,100
Soviet Central Asia	3,510	3,675	4,800
Eastern Regions	12,700	16,500	16,700
Western-Southern Regions	22,745	21,000	21,300 e/
Total USSR i/	35,445	37,500	38,000

* Footnotes follow on p. 192.

a. 1950 goals projected in the Soviet Fourth Five-Year Plan. Cf. the correlated provisional paper CIA/RR PR-17, Petroleum in the Soviet Bloc, I-B, Production and Exploration of Petroleum in the USSR: Appendix A (Table 2); Appendix B (Section 2: Table 3, Table 3A; Section 3: Reference k (1), k (2), k(8)). For a different breakdown of the Fourth-Five-Year Plan, cf. ibid.: Appendix B (Section 2 Table 3, Table 3A; Section 3: Reference a (8)).

b. Regional production estimates applied in the present series of provisional papers which comprise CIA/RR PR-17, Petroleum in the Soviet Bloc. Cf. ibid. as in footnote a above: Appendix A (Table 1, Table 2); Appendix B (Section 2: Text, Table 3, Table 3A; Section 3: References a (20), j, k(1), k(2), k(7), k(8), k(11)). These estimates are essentially based upon the reported "Plan" fulfillments, correlated with pre-war statistics (mostly for 1939) believed to be authentic. The 1939 regional production values are commonly accepted as sufficiently accurate, are frequently recorded with insignificant variations, and are often reported as "actual" although this designation appears to involve unfortunate choice of terms in that no record of "official" Soviet government confirmation is presently known.

c. Intelligence agency estimates mostly based upon an erratic sequence of annual production percentages, variously reported and usually referred to annual production values of earlier date. The percentages collectively form a correlated chain extending over a several year period, and the derived estimates for 1950 appear to involve comprehensive even if not exhaustive analysis of them. 14/ The results of this analysis and of the methodology per footnote b above seem to be generally compatible within the margin of deviation to be expected. For summaries of additional regional production estimates, cf. ibid. as in footnote a above: Appendix

B (Section 2: Table 3, Table 3A; Section 3: References k(14), k(18)).

d. Data not broken down by areas.

e. Cf. footnote f.

f. No accounting appears to be made of the Crimea and South Georgian productions separately; values for these regions are presumably involved in the totals designated by footnote e.

g. Exclusive of the small production possible from Kazak SSR in this productive region.

h. For all of Kazak SSR, including the small production possible from Kazak in the Southeastern Soviet Central Asia region.

i. Intelligence estimates generally range from 37.5 to 38.0 million metric tons for the total 1950 production of natural petroleum in the USSR. These values are in most cases applied as representing crude oil only, but the question is complicated by the possibility that natural gas fluids - probably liquids in the typical instance, but sometimes even the true gases - may be included in the generalized production reports released by Soviet and other sources. For summary of important data relating to 1950, cf. ibid. as in footnote a above: Appendix B (Section 2: Text, Table 3, Table 3A; Section 3: References k(7), k(8), k(9), k(11), k(13), k(14), k(18)).

j. Including the small production of the Crimea region.

Table 37. Comparison of Estimates of Charge Capacities
USSR Natural Petroleum Refineries Essentially as of 1950
Crude Distillation and Thermal Conversion (Cracking, Reforming)

Thousand Metric Tons per Year

Site	I. Basic Data a/ Present Agency a/* Basis 1 January 1951 Crude	Thermal	Second Agency a/ Basis Midyear 1952 Crude	Thermal b/
Drogobych	360	48	360	0 b/
Odessa	250	238	0 d/	250 e/
Kherson	0	238	0	250 e/
Osipenko	0	237	0	0 c/
Tuapse	2,000	304	2,000	500 e/
Krasnodar	900	0 f/	1,000 e/	300 f/
Batum	3,100	785	2,000 g/	480 e/
Grozny	6,400	2,557	7,000 g/	2,800 e/
Baku	15,750	1,679	15,000 e/	2,000 e/
Makhachkala	90	0	0 i/	0
Krasnovodsk	1,020	1,040	1,020	600 j/
Nebit-Dag	250 k/	349	250 k/	0 c/
Cheleken	160	0	0 i/	0
Gurev	600	528	560 e/	730 e/
Iskine	77	0	0 d/	0
Stalingrad	200	0	0 d/	0
Orsk	1,500	570	1,500	300 e/
Chkalov	0	1,000	0	0 l/
Saratov	1,800	2,343	0 d/	2,400 e/
Kuybyshev	470	1,000	1,000 e/	420 e/
Batraki	200	0	0 e/	0
Syzran	500	443	2,000 h/	500 e/
Ufa	1,500	348	4,000 h/	0 m/
Ishimbaevo	410	0	1,000 e/	0
Sterlitamak	530	221	0 n/	0 m/
Tuimaza	0	570	0	0 n/
Kazan	160	0	0 e/	0
Krasnokamsk	200 o/	222 o/	300 p/	0 c/
Chusovskiye Gorodki	265 o/	226 o/	0 c/	0 c/
Molotov	545 o/	181 o/	0 c/	0 c/
Ukhta	250	0	250	0
Moscow	820	380	0 d/	700 e/
Yaroslavl (Konstantinovski)	415	190	500 e/	400 e/
Gorki	600	452	600	0 c/
Leningrad	100	226	0 d/	0 c/
Eastern Soviet Central Asia	1,750 o/	452 o/	800 c/	0 c/
Fergana	1,150 o/	o/	0 e/	0 e/
Vannovskaya	0 o/	o/	750 r/	0 c/
Kim	300 o/	o/	50 r/	0 c/
Stalinabad	300 o/	o/	0 s/	0 c/
Komsomolsk	605 o/	158 o/	600 e/	250 e/
Khabarovsk	545 o/	158 o/	550 e/	250 e/
Nikolaevsk	0 o/	158 o/	0	0 c/
Okha	90 o/	0 o/	0 e/	0
Lwow	45	0	0	0
Tiflis	20	0	20	0
Dzerhinsk	50	0	150 e/	0
19 Minor Sites	393 o/	0	0 c/	0
Total USSR	44,920	17,301	42,440	12,930

* Footnotes follow on p.197.

Table 37. Comparison of Estimates of Charge Capacities (Continued)
USSR Natural Petroleum Refineries Essentially as of 1950
Crude Distillation and Thermal Conversion (Cracking, Reforming)

Thousand Metric Tons per Year

II. Summary for Crude Distillation Charge Capacities

Sites			Estimates				Estimate Differences				
	Number		Present Agency		Second Agency			Percentage of			
Category	Present Agency	Second Agency	Quantity	Percent	Quantity	Percent	Quantity	Present Agency Total	Second Agency Total	Present Agency Value	Second Agency Value
Major Different	17	*	6,802	15.14	*	*	6,802	15.14	16.02	*	*
Major Different	*	1	*	*	750	1.77	750	1.67	1.77	*	*
Major Different	17	1	6,802	15.14	750	1.77	6,052	13.47	14.25	*	*
Minor Different	19	0	393	0.88	0	0.00	393	0.88	0.93	*	*
Total Different	36	1	7,195	16.02	750	1.77	6,445	14.35	15.18	*	*
Total Different	36	*	7,195	16.02	*	*	7,195	16.02	16.95	*	*
Total Different	*	1	*	*	750	1.77	750	1.67	1.77	*	*
Total Different	36	1	7,195	16.02	750	1.77	6,445	14.35	15.18	*	*
Corresponding	23	23	37,725	83.98	41,690	98.23	3,965	8.83	9.34	10.51	9.51
Total	59	24	44,920	100.00	42,440	100.00	2,480	5.52	5.84	5.52	5.84

* Data not applicable.

Table 37. Comparison of Estimates of Charge Capacities (Continued)
USSR Natural Petroleum Refineries Essentially as of 1950
Crude Distillation and Thermal Conversion (Cracking, Reforming)

Thousand Metric Tons per Year

III. Comparison of Estimates by Areas
Crude Distillation Charge Capacities

Site	Source: Present Agency	Second Agency	Third Source 18/
Drogobych	360	360	360
Odessa	250	0	250
Lwow	45	0	50
Borislav	20	0	20
Minor Sites	105	0	0
Ukraine Area	780	360	680
Tuapse t/	2,100	2,000	1,500
Krasnodar t/	900	1,000	1,000
Grozny t/	6,400	7,000	6,500
Makhachkala	90	0	100
Armavir	0	0	200
Astrakan	0	0	50
Ciscaucasia Area	9,390	10,000	9,350
Batum t/	3,100	2,000	1,000
Baku t/	15,750	15,000	16,000
Tiflis	20	0	0
Mirzaana	10	0	0
Transcaucasia Area	18,880	17,000	17,000
Krasnovodsk	1,020	1,020	1,000
Nebit-Dag	250	250	250
Cheleken	160	0	0
Gurev	600	560	600
Iskine	77	0	0
Stalingrad	200	0	400
Novobogotinsk	23	0	0
North and East Caspian Area	2,330	1,830	2,250
Fergana	1,150	0	0
Vannovskaya	0	750	750
Kim	300	50	300
Stalinabad	300	0	300
4 Minor Sites	80	0	0
Central Asia Area	1,830	800	1,350
Orsk	1,500	1,500	1,000
Saratov	1,800	0	1,800
Kuybyshev	470	1,000	500
Batraki	200	0	0
Syzran	500	2,000	1,000
Ufa	1,500	4,000	1,500
Ishimbaevo	410	1,000	1,000
Sterlitamak	530	0	0
Kazan	160	0	160
Krasnokamsk	200	300	200
Chusovskiye Gorodki	265	0	120
Moletov	545	0	0
Ukhta	250	250	500
2 Minor Sites	100	0	0
Eastern Volga-Ural Area	8,430	10,050	7,780
Moscow	620	0	700
Yaroslavl (Konstantinovski)	415	500	500
Gorki	600	600	600
Leningrad	100	0	0
Dzerhinsk	50	150	0
Riga	15	0	15
Western Volga-Baltic Area	2,000	1,250	1,815
Komsomolsk	605	600	600
Khabarovsk	545	550	500
Okha	90	0	0
2 Minor Sites	40	0	0
Far East Area	1,280	1,150	1,100
TOTAL USSR	44,920	42,440	41,325

a. General Notes.

These comparative data summarize two set of estimates of natural petroleum refinery capacities in the USSR. One set is as developed by the present agency in the paper designated as follows in the present series of provisional reports: CIA/RR PR-17, Petroleum in the Soviet Bloc, I-C, Refining of Petroleum in the USSR. The other set is as quoted orally from files by a second intelligence agency coordinated with the present. 15/ These data of the second agency are understood to be based upon conclusions drafted in files and partially published in a series of information memoranda. 17/ The comparison is primarily concerned with estimated charge ratings in Te/Yr (thousands of metric tons per year), referring to crude distillation facilities and thermal conversion systems. It is noted that the latter are presumably restricted to cracking and to a lesser extent reforming in the case of the Soviet Union.

The two sets of estimates differ considerably in details by sites. It is apparent, however, that these differences result because of variation in the interpretation and evaluation of data, and not because of essential difference in range and content of the many reports used as basis of analysis. It is indicated that the second agency analysts consider their own estimates to be as definitive and conclusive as possible under the circumstances, and further consider that they have analysis programs in progress to result in revisions with the same status. In contrast to this, the present agency analysts consider all such estimates to be no more than tentative values at the present time, and have interpreted the available data to derive estimates sometimes varying from those of the second ag

The present agency has reviewed the pertinent intelligence and has concluded that there is some basis to support, and no firm evidence to refute, the variously similar and different values shown in the two sets of estimates. One reason for variance appears to result from the second agency attaching more significance to aerial photographs now as much as ten years old. The tabulated data show the comparison between estimated charge capacities for crude distillation and thermal conversion. Although the second agency estimates appear to be referred to a date later than the basis of the present agency estimates, this difference in date does not account for the major differences in values.

For the crude distillation charge capacity ratings in the USSR, the estimated total values seem to be compatible within the range of accuracy to be expected, considering the confusion, contradictions, and fragmentary character of the available intelligence. The present agency total is 44,920 Te/Yr as compared to the second agency total of 42,440 Te/Yr, giving a difference of 2,480 Te/Yr. This difference is a net value resulting from more considerable differences in the details by sites. The detail differences are compensating in part, and they consist of three general types, namely: (1) variations in capacities derived for the 23 sites which correspond in the two sets of estimates; (2) variations due to capacities derived for 18 major sites which do not correspond, where all but one of these major sites are restricted to the present agency estimates; and (3) variations due to capacities derived for 19 minor sites, all restricted to the present agency estimates. Footnotes in the attached table explain the major reasons for the value differences at particular sites. The difference between totals is equal to 5.5% of the present agency total and 5.8% of the second agency total.

For crude distillation charge capacities at the 23 corresponding sites, the aggregate is about 84% of the total in the present agency estimates, and about 98% of the total in the second agency estimates. The second agency aggregate exceeds the present agency aggregate by 3,965 Te/Yr. The difference constitutes 10.5% of the present agency aggregate, 8.8% of the present agency total, 9.5% of the second agency aggregate, and 9.3% of the second agency total. The two sets of estimates for crude distillation charge are therefore not only reasonably compatible with respect to totals, but also with respect to the aggregates of detail values at 23 corresponding sites, where these aggregates in turn constitute most of the respective total values.

For crude distillation charge capacities at the 18 major sites which do not correspond, the aggregate of values at 17 places in the present agency correlation is 6,052 T/Yr more than the second agency value at the remaining or 18th site. This difference is equal to 13.5% of the present agency total and 14.3% of the second agency total.

For crude distillation charge capacities at the 19 minor sites not represented in the second agency correlation, the aggregate of the present agency values is 393 Te/Yr, constituting less than 1% of either total.

Inasmuch as the second agency analysts do not consider their thermal conversion capacity estimates to be complete, whereas the present agency estimates are tentatively derived for complete coverage, the two sets of estimates have no comparable basis in this respect.

b. Second Agency considers this compilation of thermal charge capacity to be tentative and incomplete.

c. Second Agency considers the available data to be insufficient for confirmation of existing facilities.

d. Second Agency considers the available data to be insufficient to establish the status of facilities although the facilities are admittedly possible.

e. Divergence from the Present Agency value appears to arise from differences in judgment and evaluation of available data.

f. Present Agency has been unable to find firm inference of conversion facilities at this site, and believes that an existing extensive road oil and asphalt plant has been called a cracking plant through error.

g. The decrease from 3,100 to 2,000 appears to be a matter of arbitrary estimate, to account for possible obsolescence of old equipment and reflect the poor condition of installations in situ as indicated by photographs ten years old.

h. The increase above the Present Agency value appears to be a matter of arbitrary estimate, to account for unconfirmed reports of new construction where existence of the new construction is sometimes indefinitely indicated by reported movements of oil.

i. Second Agency considers the available data to be insufficient to confirm the present existence of facilities even though former existence is admittedly possible.

j. It appears that the Second Agency does not include a value for lend-lease thermal conversion facilities.

k. This value is based upon old installations and the Second Agency conclusion is that the current status is doubtful.

l. Second Agency considers that later data have been insufficient to confirm earlier reports of existence.

m. Second Agency omits accounting of facilities, even including those known to have been installed by Lummus and Alco.

n. Second Agency considers the available data to be insufficient to confirm the present existence of facilities even though definite constructions have been planned in the past.

o. Present Agency believes that data are sufficient for reasonably consistent estimates of the total capacities by types in the Kama, Eastern Soviet Central Asia, and Soviet Far East Region, but that the component values are doubtful at particular sites.

p. Second Agency considers the available data to be sufficient to establish no Kama Region capacity except as shown.

q. Present Agency does not consider the available data to be adequate for estimating thermal capacities by sites in the Eastern Soviet Central Asia Region.

r. Second Agency considers the available data to be sufficient to establish no Eastern Soviet Central Asia Region capacity except as shown.

s. No more than 1,000 BPCD (50,000 metric tons per year) at any one site.

t. Corresponding crude distillation capacity estimates are currently given as follows in a fourth source: 19/

Site	Capacity
Tuapse	2,000
Krasnodan	1,000
Grozny	6,700
Batum	3,055
Baku	15,000

Table 38. Comparison of Estimates of Soviet Refined Product Yields
Variously Reported and Calculated as Potentials Derived from Natural Petroleum in 1950
(Quantities in Thousands of Metric Tons with Weight Percentages)

I. Present Agency Estimates a/**

	Estimated Gross Refinery Unit Yields and Correlated Data											
	Refining on Basis of Charge of Total Crude Production			Refining on Basis of Charge of Available Crude			Distribution on Basis of Gross Non-Gaseous Products Available from Refining			Accounting of Non-Gaseous Petroleum Products Available for Consumption		
	Quantity	Percent Total	Percent Non-Gaseous Products	Quantity	Percent Total	Percent Non-Gaseous Products	Quantity	Percent Total	Percent Net Available Products	Quantity	Percent Total Crude Available	Percent Total Crude Production
Refining Process and Gas Loss b/	2,941	7.8	*	2,850	8.0	*	*	*	*	2,850	7.9	7.6
Extraneous Material Loss in Refining	*	*	*	356	1.0	*	*	*	*	356	1.0	1.0
Product Distribution Loss	*	*	*	*	*	*	648	2.0	*	648	1.8	1.7
Loss Total	2,941	7.8	*	3,206	9.0	*	648	2.0	*	3,854	10.7	10.3
Total Gasoline Base and Blend Stocks	10,679	23.5	30.9	10,017	28.1	30.9	9,817	30.3	30.9	9,817	27.3	26.2
Total Intermediate Distillate Stocks	9,679	25.8	28.0	9,077	25.5	28.0	8,896	27.4	28.0	8,896	24.7	23.7
Lubes and Residual Stocks	14,201	37.9	41.1	13,325	37.4	41.1	13,058	40.3	41.1	*	*	*
Lubes, Residuals, and Crude for Consumption	*	*	*	*	*	*	*	*	*	13,433	37.3	35.8
Crude Charge or Other Total Shown	37,500	100.0	100.0	35,625	100.0	100.0	32,419	100.0	100.0	36,000	100.0	96.0
Crude Material Loss Before Refining	1,500	4.0	*	*	*	*	*	*	*	*	*	*
Crude for Refining and Consumption	36,000	96.0	*	*	*	*	*	*	*	*	*	*
Crude Consumption Before Refining	375	1.0	*	*	*	*	*	*	*	*	*	*
Crude Available for Refinery Charge	35,625	95.0	*	*	*	*	*	*	*	*	*	*

* Data either unavailable or not applicable to the correlation.
** Footnotes follow on p.

Table 38. Comparison of Estimates of Soviet Refined Product Yields (Continued)
Variously Reported and Calculated as Potentials Derived from Natural Petroleum in 1950
(Quantities in thousands of Metric Tons with Weight Percentages)

II. Present and Second Agency Estimates of Refinery Yields c/**

	Present Agency Estimates			Second Agency Estimates		
	Quantity	Percent Refinery Charge	Percent Total Crude Production	Quantity	Percent Refinery Charge	Percent Total Crude Production
Refining and Distribution Losses	3,854	10.8	10.3	*	*	*
Refinery Consumption of Residual Fuel Oil	1,069	3.0	2.8	*	*	*
Loss from Availability by Refining	4,923	13.8	13.1	4,750	13.0	12.5
Gasolines	*	*	*	8,070	22.1	21.3
Ligroin d/	*	*	*	1,570	4.3	4.1
Total Gasoline Stocks	9,817	27.5	26.2	9,640	26.4	25.4
Kerosene	*	*	*	8,160	22.3	21.5
Diesel Oil	*	*	*	2,530	6.9	6.7
Total Intermediate Distillates	8,896	25.0	23.7	10,690	29.2	28.2
Motor Fuel d/	*	*	*	1,680	4.6	4.4
Lubes	*	*	*	1,830	5.0	4.8
Residuals and Other	*	*	*	7,950	21.8	20.9
Total Lubes, Residuals, and Other	11,989	33.7	32.0	11,460	31.4	30.1
Refinery Charge	35,625	100.0	95.0	36,540	100.0	96.2
Total Crude Production	37,500	*	100.0	38,000	*	100.0

* Data either unavailable or not applicable to the correlation.
** Footnotes follow on p.

a. General Notes for the Present Agency Estimates.

The subject estimates were derived by the present agency and then applied in the series of provisional reports or papers collectively called CIA/RR PR-17, Petroleum in the Soviet Bloc. The estimates were primarily developed in two papers of this series as follows: the present paper in I-D, Survey of Possibilities and Potentials in Future Petroleum Refining in the USSR; and a paper in I-A, Soviet Bloc. In the designated I-D the various refinery yield percentages were established upon the basis of technology generally contained within three categories thus: technology applicable to the capacities and process facilities estimated to be present in the Soviet refineries; technology with respect to practicable yields obtainable by means of the Soviet distillation and conversion refinery processes, applied to the crude oils having the qualities reportedly, probably, or reasonably present in the USSR; technology as reported for actual Soviet refining operations, with plausibility checked by correlating with US practices.

Three simplifying generalizations were next assumed as follows, in order to apply the several refinery unit yields and thereby develop the over-all production percentages. As a first generalization the estimated total crude production was considered to be the charge to refining. As a second, the gross production yields were calculated from the separate refinery units, and the over-all production of a stock was calculated as the total of the unit gross yields of that type of stock. As a third and last generalization, base and blend stocks were shown for engine fuels such as gasolines, "tractor" fuels, Diesel fuels, jet fuels, and no accounting was shown for the finished engine fuel blends (some of these finished blends would

logically utilize hydrocarbon stocks not derived from natural crude oil). In IV-A as designated above, and as here summarized in the two parts of Table 33, probable and plausible loss factors were derived so as to establish, first, a probable reduced quantity of crude oil available for refinery charge, and second, the probable reduced and net quantities of petroleum products available for consumption after accounting for a plausible over-all refinery consumption of residual fuel oil. It is assumed in the present analyses that an accounting for finished engine blends would have insignificant effect upon total values.

b. This loss constitutes a typical difference between non-gaseous products and the original crude charge. The loss is mostly composed of the refinery or tail gas which serves as fuel gas in the usual case. The remainder consists of normal material losses such as in carbon deposits and sludge waste. The calculated loss factor of 7.8% is rounded off to 8% in applying the data for net yields (cf. IV-A as designated in footnote a above).

c. The second agency estimates are derived by a comprehensive and detailed correlation of the many fragmentary refinery production data reported in a number of Soviet publications, covering a period of several years preceding the present time. These reported data are usually in terms of percentages referred to prior annual productions but without explicit evaluations of the prior yields. The study of the second agency has, however, developed and applied a chain of factors so as to establish estimated values for the net Soviet annual refinery productions since 1946. 16/ Referring to the total stocks by types classified according to a basis believed to be consistent, the present table shows that the present and second

agency estimates are at least in the same order of magnitude. The present agency estimates were derived as plausible and probable values upon a technological basis, and there would probably be sufficient flexibility in the Soviet refining facilities to produce yields as shown in the second agency estimates.

d. Reported Soviet petroleum product specifications show that "ligroin" is a naphtha blend reasonably classified as a heavy gasoline; and that "motor fuel" is a heavy or marine type of Diesel fuel containing heavy gas oil and residual stocks, probably to be classified in the residual group of products for comparison with the present agency estimates. 20/

APPENDIX D

USSR HOUDRY SYSTEM REFINERY FLOW DIAGRAMS*

Material Balances and Liquid Volume Correlations

Plant No. 1 (Gurev)

Plant No. 2 (Orsk)

Plant No. 3 (Kuybyshev) Original Proposal

Plant No. 3 (Kuybyshev) Supplementary Proposal

Plant No. 4 (Krasnovodsk) Original Proposal

Plant No. 4 (Krasnovodsk) Supplementary Proposal

* Numerical data are either nil or not applicable where omitted in the tabulations in these figures.