CORPS OF ENGINEERS
DEPARTMENT OF THE ARMY

REPORT FOR
BUREAU OF MINES
DEPARTMENT OF THE INTERIOR

THE SYNTHETIC LIQUID FUEL POTENTIAL OF KANSAS

MAY 14, 1951

Ford, Bacon & Davis
Incorporated
Engineers

NEW YORK PHILADELPHIA CHICAGO LOS ANGELES

U.S. Engineer Dept.

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NEW YORK
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CONSTRUCTION VALUATIONS REPORTS MANAGEMENT

PHILADELPHIA
LOS ANGELES

39 BROADWAY
NEW YORK 6

New York, May 14, 1951

The Chief of Engineers
Department of the Army
Washington 25, D.C.

Dear Sir:

We submit herewith our report upon "The Synthetic Liquid Fuel Potential of Kansas", in accordance with Contract No. W 49-129 eng-137 concluded between us May 3, 1949.

Our survey disclosed widespread interest in synthetic liquid fuels. Informed public opinion recognizes the need for utilizing to the utmost all possible resources for the maintenance of our national welfare and security. Both public and private agencies have been very helpful in supplying data and entering into frank discussions with us on the subject. We welcome this opportunity to thank them for their cooperation.

Supplies of crude petroleum, the source of liquid fuels, are not inexhaustible. Provision must be made for the day when such fuel reserves become dangerously low. Foresight is required of all of us in facing this problem.

Over-all requirements of our natural resources are constantly changing. Obviously, no survey can do more than describe conditions in the light of present knowledge.

We believe that this report will be of value in formulating policy with respect to the future development of synthetic liquid fuels.

Very truly yours,

(Signed) Ford, Bacon & Davis, Inc.

REPORT

REPORT

Corps of Engineers
Department of the Army

THE SYNTHETIC LIQUID FUEL POTENTIAL
OF
KANSAS

LOCATION OF
SUITABLE GENERAL AREA
FOR
SYNTHETIC LIQUID FUEL MANUFACTURE

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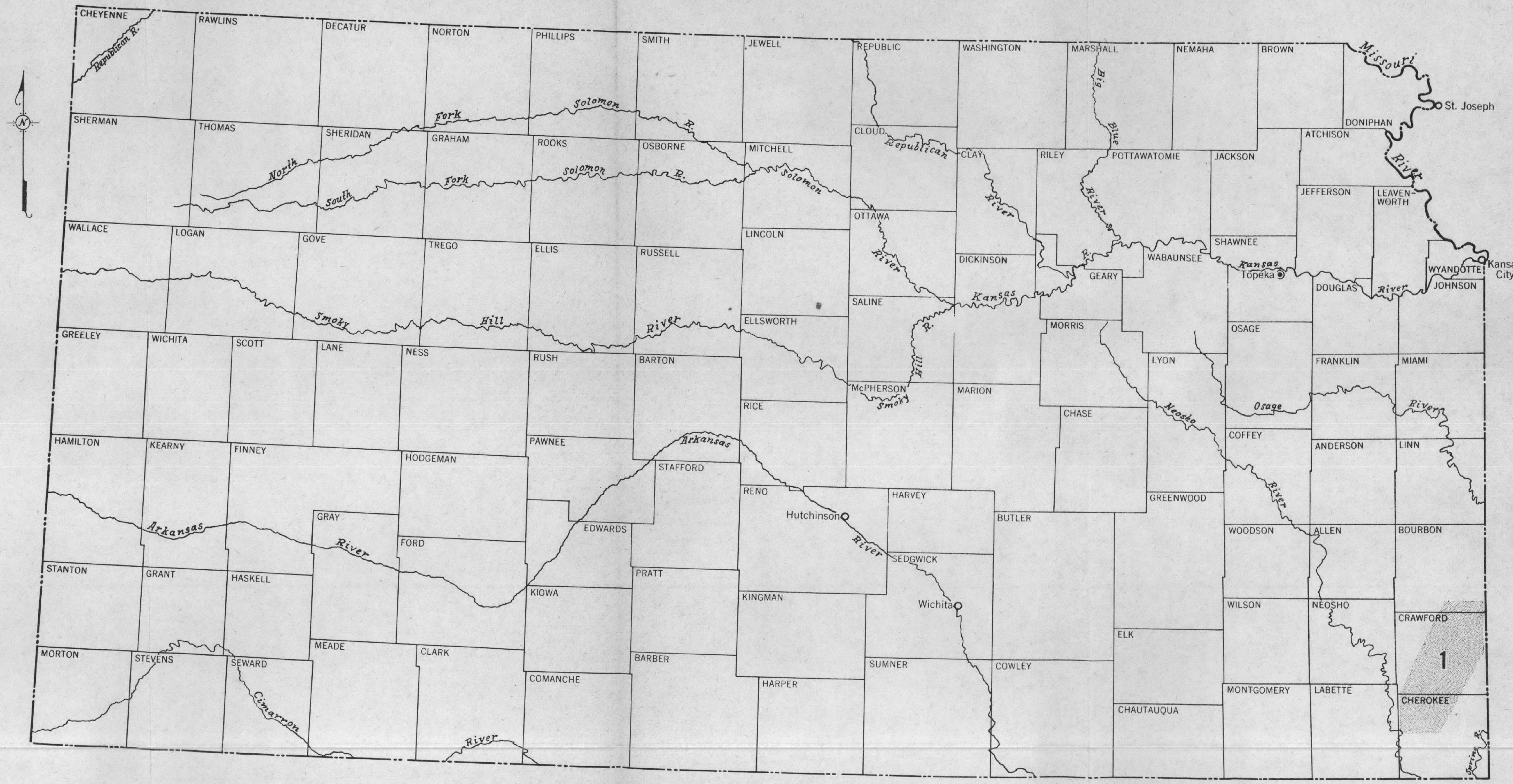
SCALE OF MILES
10 0 10 20 30 40

IDENTIFICATION OF GENERAL AREA

No.	General Area
1	Crawford-Cherokee



CORPS OF ENGINEERS
DEPARTMENT OF THE ARMY

REPORT FOR
BUREAU OF MINES
DEPARTMENT OF THE INTERIOR

THE SYNTHETIC LIQUID FUEL POTENTIAL OF KANSAS

MAY 14, 1951

SUMMARY

Introduction

The Department of the Interior, as part of its broad program of synthetic liquid fuels research, requested the Department of the Army in 1947 to assist in the development of the synthetic liquid fuels program. This investigation and report on Kansas are in part fulfillment of a contract to that effect awarded by the Corps of Engineers of the Department of the Army. The contract calls for a survey of 37 states and Alaska to determine Suitable General Areas and their potential capacity for the production of synthetic liquid fuels from coal, natural gas, oil shale, and oil-impregnated strippable deposits.

For General Areas containing raw materials and water supply of proper quantity and quality required by synthetic liquid fuels plants, various economic factors further affecting the suitability of such Areas for plant location are critically examined. No core drillings, extensive sampling, or detailed field examinations were made, and studies are based on information now available. Suitable General Areas are determined and defined, but no specific plant sites are selected. There was one such General Area determined for the State of Kansas as indicated on the map on the facing page.

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Raw Materials

The raw materials considered in this survey of Kansas are coal and natural gas. No report was authorized in relation to oil shale or oil-impregnated strippable deposits because it was considered that any deposits of such raw materials in Kansas were of doubtful economic importance.

Coal. Of the two raw materials considered in Kansas, coal was found to be the only one meeting the survey requirements for synthetic liquid fuels production.

Natural Gas. The total reserves of natural gas in Kansas, as of January 1, 1949, are estimated at 15,654,009,000 Mcf with a heating value in the order of 950 Btu per cubic foot under standard conditions. Essentially all of these reserves are under contract to gas pipe lines for domestic, commercial, and industrial use or will be used in local field operations. The volume of gas remaining as available (184,450,000 Mcf) is dominantly in the "probable" classification; the total Btu content approximates 175 trillion units. Consequently, none could be considered sufficient to meet the survey requirements which call for undedicated deposits containing, within a radius of 40 miles, at least 225 trillion Btu (236,840,000 Mcf of 950-Btu gas) with a heating value of at least 400 Btu per cubic foot under standard conditions.

General Features

The land surface in Kansas is a rolling prairie which is part of the Great Plains, and the altitude rises from 750 feet in the east to 4,000 feet in the west. Almost all of the State is drained by the Kansas and Arkansas Rivers and their tributaries. The coal measures occur in the eastern quarter of the State where there is some relief in the Ozark Plateaus. The climate is relatively mild and dry. The 1950 population density averages 23.1 per square mile throughout the 82,113 square miles of the State, with a population density of 46.3 per square mile in Crawford, Cherokee, and Bourbon Counties, the three counties containing important coal deposits. Wheat is the major product. The principal industries are flour milling, meat packing, petroleum refining, and manufacturing of chemical products and transportation equipment. The eastern coal fields are served by a number of major railroads. When synthetic liquid fuels are required, plants in the Kansas General Area would be well located for distribution of their products within the defined marketing territory.

Plant Processes

Since coal is found to be the only raw material available in requisite quality, only two processes of synthetic liquid fuels manufacture are considered; namely, hydrogenation and the synthine process.

In the hydrogenation process, coal is liquefied by combination with hydrogen at high pressures and temperatures in the presence of a catalyst. In the synthine process, coal is first converted to a gaseous mixture of carbon monoxide and hydrogen, which gases, in the presence of a suitable catalyst, combine to form liquid fuels.

Both processes require major quantities of coal for direct conversion to liquid fuels and to provide energy for such conversion, and of water, chiefly as a cooling medium. The unit plant size adopted in the survey as a basis for estimates for comparison is 10,000-barrel-per-day capacity.

As a synthetic liquid fuels program of any magnitude would necessarily require a considerable period of years for its realization, estimates of unit quantities of raw materials required and unit costs of plant construction and operation, used in this survey for determining ultimate production potential, have been based on the assumed use of certain improvements in equipment and process which are still under development but which seem reasonably likely to be available by the time such a program could be well under way. Moreover, the estimated data and costs for the coal synthine process have been taken from preliminary studies made by the U.S. Bureau of Mines for a report which is not yet completed. The final estimates of the Bureau, when available, may differ materially from these preliminary figures. While the data used have been selected as offering a fair basis for comparison, it must be understood that if synthetic fuels plants were to be built at the present day, using only equipment and processes already commercially available, coal requirements and plant product costs might be appreciably higher than those shown in this report.

Subject to the above comments, daily requirements of Kansas coals, as received at the synthetic liquid fuels plant, should average about 3,900 tons for a hydrogenation unit plant and 5,000 tons for a synthine unit plant.

General Areas of Coal Availability

Coal-bearing formations solidly underlie approximately
Kans the eastern one-fourth of Kansas, occupying an area of about 20,000
square miles and including all or parts of 35 counties. All coal
5b beds of Kansas belong to the Pennsylvanian system, which is here
6a divided into nine stratigraphic groups, of which five contain one
10 or more coal horizons. Numerous coal beds are known, of which 19
70021 are of some importance.

Of the 35 coal-bearing counties, 3 contain coal deposits which are too close to the outermost edge of the coal-bearing formations to contain appreciable minable areas. In 23 other counties, the reserves are either isolated and insufficient in amount, are essentially depleted, are too thin, or are without adequate available information to permit estimates of reserves. As a result these 23 counties were also eliminated from further consideration. An additional six counties contain isolated reserves insufficient to support even one synthetic liquid fuels unit plant. The remaining three counties contain reserves satisfactory for synthetic liquid fuels production. These counties contain one area, not larger than a county or 1,000 square miles, with adequate reserves for a 40-year supply of at least one 10,000-barrel-per-day synthetic liquid fuels plant. Identified by the names of the counties in which principal portions lie, this area is designated as the Crawford-Cherokee General Area of Coal Availability.

The total tonnage of coal considered for synthetic liquid fuels manufacture in Kansas as of January 1, 1950, based on available information and within the limits of reserves specified for this survey as described in Part II of this report under "Survey Specifications" and in Part IV under "Survey Methods and Procedure", was estimated at 686,259,000 tons in place of which 452,832,000 tons were estimated as being recoverable. These estimates of reserves considered for synthetic liquid fuel production are, therefore, not comparable with other coal estimates which generally include the total coal reserves in Kansas without the limitations imposed by this survey. For example, in Circular 94 of the U.S. Geological Survey, the total recoverable coal reserves for Kansas, as of January 1, 1950, (assuming 50 percent recovery) are reported to be 8,777,200,000 tons. This estimate of the Geological Survey adopts 1945 and 1946 estimates by Abernathy, Jewett, and Schoewe on the basis of geologic data collected by the State Geological Survey of Kansas and drilling records obtained from coal mining companies.

The total available coal reserves considered are distributed by beds as follows:

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Estimated Tonnage of Recoverable Coal Reserves
Considered for Synthetic Liquid Fuels Manufacture
as of January 1, 1949
(Thousands of Tons)

Coal Bed	Coal-bearing Counties (A)	Crawford-Cherokee General Area (B)
Williamsburg (Upper)	8,035	-
Mulberry	9,870	-
Weir-Pittsburg	165,299	165,299
Bevier	86,284	86,284
Mineral	151,503	151,503
Croweburg	2,862	-
Thayer	28,979	-
Total	452,832	403,086

Note: (A) Before elimination of tonnage in unsatisfactory areas.
(B) After elimination of tonnage in unsatisfactory areas.

After giving consideration to the isolated areas with insufficient reserves to provide at least one synthetic liquid fuels plant, to commercial requirements over the next 50 years, and further contract limitations as to the use of primary and secondary reserves, the total tonnage of coal recoverable and available for the manufacture of synthetic liquid fuels in the Crawford - Cherokee General Area of Kansas was estimated to be 150,578,000 tons.

The following table lists, for the Crawford-Cherokee General Area, the recoverable coal reserves, the average heating value of the coal, and the potential synthetic liquid fuels production in total and as a daily average over a 40-year period. These estimates assume the use of either the hydrogenation process or the synthine process; but the potential production is not additive.

Potential Synthetic Liquid Fuels Production from Available Coal Reserves as a Daily Average over 40 Years for Crawford-Cherokee General Area, Kansas (as of January 1, 1950)

Coal Reserves (1,000 tons)		Average Btu Value	Potential Production: Total (1,000,000 Barrels)		Potential Production: Daily Average (1,000 Barrels)	
Total	Available		Hydrogenation	Synthine	Hydrogenation	Synthine
403,086	150,578 (A)	12,485	384	298	26	20

Note: (A) Total estimated coal is 75,289,000 tons primary underground, 90,010,000 secondary underground, and 237,787,000 secondary strip, but total primary and secondary reserves for synthetic liquid fuels plant supply are limited by definition to twice the primary reserves or, in this case, 150,578,000 tons.

The foregoing reserves are contained in three coal beds; Weir-Pittsburgh, Bevier, and Mineral, ranging in rank from high-volatile A bituminous to high-volatile B bituminous. Ranges in selected items of representative analyses (selected by the Coal Subcontractor from available analyses, mostly mine samples, as representative of the coal reserves or beds under consideration) of the three beds containing coal reserves are as follows:

Representative Analyses of Coal Reserves in Crawford-Cherokee General Area from Face Samples, As-received Basis

Coal Bed	Moisture (Percent)	Ash (Percent)	Sulfur (Percent)	Btu per Pound
Weir-Pittsburgh:				
Maximum	6.1%	9.2%	3.5%	13,080
Minimum	5.1	8.3	3.3	12,690
Bevier:				
Average	5.0	14.5	3.3	11,790
Mineral:				
Maximum	4.5	12.9	4.1	12,530
Minimum	4.2	12.7	3.4	12,380

The U.S. Bureau of Mines has published the results of one petrographic assay of a Kansas coal from the Bevier bed. This analysis indicates the coal is of the "bright" petrographic type, wherein anthraxylon and translucent attritus predominate with opaque attritus and fusain being present in minor amounts. No data are available on the remaining two beds, but they are closely similar in rank and in appearance and chemical composition to the Bevier coal on which the reported petrographic assay was made. There is no reason to expect any substantial differences in the degree of heterogeneity or adaptability to hydrogenation of the Kansas coals.

The value of petrography in predicting hydrogenation yield lies in the fact that the degree of heterogeneity of lithologic components is readily indicated and the approximate proportions of high-carbon opaque constituents (difficult to liquefy) are revealed, whereas chemical analysis represents only the average composition of unlike components existing in undetermined proportions in the sample.

Information on the organic and inorganic sulfur content of Kansas coals is limited. These beds, however, are similar in rank and chemical composition to other midwestern coals, and it is assumed that organic sulfur (considered as not amenable to reduction by commercial mechanical cleaning) represents 30 to 50 percent of the total sulfur of Kansas coals. Further study of these coals appears necessary to establish their sulfur composition and to evaluate the reduction in total sulfur which might result from mechanical cleaning.

Weathering and slacking characteristics of Kansas coals are similar to those of other coals of the same rank; that is, the coals do not usually slack readily or ignite spontaneously when exposed to air, although midwestern coals are generally more susceptible to spontaneous combustion than Appalachian coals. When properly stored, however, there is no problem of spontaneous combustion.

These coals also appear to be similar to comparable industrial coals in grindability and may be expected to respond without undue difficulty to fine grinding. Information on their friability indicates that coals of the Crawford-Cherokee General Area in Kansas crumble easily on handling and show a relatively high friability percentage.

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The majority of the Kansas coal beds contain thin bands
8b and lenses of pyrite and sulfur-bearing bands of shale. They are
9a cut by numerous clay veins and, under shallow cover, the upper foot
tends to be somewhat oxidized and discolored. Although roof condi-
10 tions are fairly satisfactory, the floor is often a soft pyritifer-
70021 ous underclay which is frequently mixed with the coal in mining.
Such characteristics affect the type and capacity of required clean-

ing facilities. Nevertheless available data indicate that Kansas coals are generally amenable to commercial type cleaning to yield a product with from 7 to 11 percent ash on an as-received basis. Further washability investigations would be required to determine the specific quality of the cleaned coal. The refuse from cleaning, consisting largely of shale partings and contaminating matrial from roof or floor, is estimated to be about 26.6 percent of the resulting clean, marketable coal. Such refuse is estimated to amount to about 1,590 tons per working day or 381,600 tons per year for a hydrogenation unit plant or about 2,040 tons per working day, 489,600 tons per year, for a synthine unit plant. These quantities are equivalent, respectively, to about 254,400 or 326,400 cubic yards per year.

The greater Btu input requirement for coal synthine plants, as compared with hydrogenation, results in larger quantities and thus higher total costs of coal supply. Estimated initial capital costs to provide coal mining facilities in the Crawford-Cherokee General Area of Kansas are as follows for the indicated conversion process and mining method:

Tonnages of Coal Required and Capital Costs of Coal Supply for 10,000-barrel-per-day Plants (As of March 31, 1950)

	Type of Mining	
	Underground	Strip
Hydrogenation Process		
Daily Production in Tons (240 days per year)	5,835	6,108
Capital Costs	$7,000,000	$5,864,000
Coal Synthine Process		
Daily Production in Tons (240 days per year)	7,502	7,854
Capital Costs	$9,000,000	$7,540,000

Factors influencing these costs include depth and character of coal bed and associated strata, and also the quantity and quality of the coal. The cost estimates provide for all necessary structures and mine operating equipment, facilities for transporting the output from two or more adjacent mining operations to a joint preparation plant, as well as for mechanical cleaning to produce merchantible coal, waste disposal from the cleaning of raw coal, surge storage at the mine, engineering, development, and contingencies.

Costs of supplying coal may vary as a result of differences in mining characteristics, in nature of the coal beds and partings in the beds, and in calorific value of the coals. For the Crawford-Cherokee General Area of Kansas, the calorific value of the coals, the productivity, and the estimated cost of production, after making allowances for preparation costs, are shown below. All costs are based upon retirement of property in 15 years and exclude return on investment and selling expense. Contract requirements specify that recoverable coal must be available in sufficient quantity to supply each plant for a period of 40 years, of which 20 years' supply must be from primary reserves and the additional 20 years' supply from either primary or secondary reserves. The available reserves in the Crawford-Cherokee General Area consist of equal volumes of primary reserves consisting of underground coal and secondary reserves consisting of strip coal. Costs of coal for a plant operating on half primary and half secondary reserves are obtained by the average of costs for primary and secondary coals as indicated below.

Estimated Coal Production Costs in the
Crawford-Cherokee General Area in Kansas
(As of March 31, 1950)

Type of Mining	Btu Per Pound	Cost per Ton	Costs per Million Btu	Costs per Barrel of Products: Hydrogenation	Synthine
Strip	12,200	$3.55	$0.1455	$1.43	$1.83
Underground	12,770	5.19	.2032	1.99	2.56
Average	12,485	$4.37	$0.1750	$1.72	$2.21

General Area of Coal and Water Availability

Kans
Investigation of potential water sources for the large
10b quantities of water required for synthetic liquid fuels plants shows
11a that there is available enough water in the Neosho River basin in
excess of known and proposed water uses to supply all the produc-
10 tion capacity for which coal is available in the Crawford-Cherokee
0021 General Area, but not without some water storage works to maintain
adequate minimum river flow during dry periods. Water required for

full development would approximate 40.5 cubic feet per second (cfs) or 26.2 million gallons per day (mgd) for process and domestic uses.

Estimates of water quantities and costs are based upon the greater requirements of the coal synthine process. Most of the process water is needed for cooling, and for the figures used, it is assumed that cooling water would be recirculated through cooling towers.

In the Crawford-Cherokee General Area in Kansas, a storage reservoir on Lightning Creek, a tributary of the Neosho River, would probably provide sufficient water for a 10,000-barrel-per-day plant. Full development of the coal resources of the Area would require utilization of the Lightning Creek reservoir and of an additional reservoir on Canville Creek, which would help to maintain desired minimum flows in the Neosho River.

Since the Crawford-Cherokee General Area in Kansas has sufficient coal and water for at least one 10,000-barrel-per-day plant for a period of 40 years, it is designated a General Area of Coal and Water Availability.

The estimated initial capital cost as of March 31, 1950 to supply adequate water for a single unit plant in the Crawford-Cherokee General Area is $5,848,000. This cost is based upon a water supply system consisting of an impounding and storage reservoir, pumping station, 8-mile aqueduct, and a storage basin at the plant site with necessary treatment works and filter plant.

The estimated operating costs as of March 31, 1950, exclusive of return on investment, for water supply to a unit plant in the Crawford-Cherokee General Area for process use are $264,150 per year or approximately 7.2 cents per barrel of products.

The unit cost of water for process use for complete development in the General Area would be comparable to the per-barrel cost for a single unit plant.

Suitability of the General Area

Power requirements for a unit hydrogenation plant amount to a total load of about 65,000 kw of which 40,000 kw can be supplied either from the outside or from a system integral with the plant proper. For the coal synthine process, waste heat can supply the steam necessary to generate the required power. Sufficient power for construction purposes could be obtained (possibly with some minor transmission line construction) from the local utility. It seems probable that the same source could also furnish required power for plant operation at an average cost of about 6.3 mills per kilowatthour. Since the estimated cost, exclusive of return on investment, of the generation of such power, even at 100 percent load factor, in a power plant of a hydrogenation unit project is 7 mills, careful consideration should be given to the relative economy of purchased power and the integration of any plant generating facilities with those of the utility company.

Construction and operation of synthetic liquid fuels plants will in general require direct rail or water connection and a highway connection. Railroad facilities are well distributed in the eastern part of Kansas; plants in the Crawford-Cherokee General Area would be readily accessible to common carrier railroad lines. They would also be adjacent to improved highways, so that only connecting plant facilities would have to be constructed. The initial capital cost for providing access transportation facilities in the General Area is estimated to be $130,000; the unit cost of operation and maintenance, exclusive of return on investment, is less than one cent per barrel of synthetic liquid fuel products.

An ample supply of plant, mine, and service labor is indicated as available in Kansas for at least one unit plant in the General Area. The average straight-time wage rate prevailing in Kansas as of March 31, 1950 in industries with skills comparable to those required in a synthetic liquid fuels plant is estimated at $1.62 per hour. The average net investment required for rental housing and community development in the Crawford-Cherokee General Area, exclusive of one-half the residential property (assumed to be sold) and exclusive of property used for commercial enterprises and domestic water supply (assumed to be self-supporting), is estimated as of March 31, 1950, at about $12,960,000 for a hydrogenation unit plant and about $14,654,000 for a coal synthine unit plant. It is assumed that rental housing will pay for its operating and maintenance costs and cost of domestic water supply plus a required return on the investment.

For the purpose of analyzing potential markets, since neighboring states also have raw materials and water supply available for production of synthetic liquid fuels and since the Kansas synthetic liquid fuels potential is very small in relation to the present and predicted future demand for liquid fuels in that State, the marketing territory for Kansas plants is defined as limited to
Kans the State of Kansas. In the marketing territory, motor fuel consumption in 1948 amounted to 16.1 million barrels, exclusive of
12b aviation and military use. This is equivalent to the gasoline output
13a put of six synthetic liquid fuels unit plants. It is estimated
10 that, by 1975, motor fuel requirements will reach an annual volume
70021 of 23.4 million barrels, the equivalent of the output of 9 synthetic liquid fuels unit plants.

While the major product of hydrogenation and coal synthine plants is motor gasoline, minor quantities of other fuels are specified to be produced, including Diesel fuel, heavy fuel oil, and liquefied petroleum gases. The proportions of these fuels in relation to gasoline are considerably different from the present demand in the marketing territory. There is, however, some leeway in the processes, particularly the hydrogenation process, for varying the proportions of the various products. Consequently, it would appear that any large-scale development in the future would require synthetic liquid fuels plants to be designed so as to produce the products then in demand. In Kansas, however, since the synthetic liquid fuels potential is small in relation to the liquid fuel requirements, the differences might be immaterial.

Kansas is an important producer of crude oil and of petroleum products, the demand for liquid fuels in the marketing territory is already economically supplied; as a result, synthetic liquid fuels plants in that State would have no competitive advantage due to location. Wholesale prices as of June 1, 1950, of petroleum products, fob. refineries in Kansas, amount to $3.74 per barrel when weighted in the same proportions as the liquid fuel products specified to be produced by hydrogenation plants and to $4.20 when weighted in the same proportions as for coal synthine plants. The estimates of future demand for liquid fuels in the marketing territory may be substantially reduced by a major increase in liquid fuel prices, altering the basic competitive positions of fuels. The prospective future supply of petroleum appears adequate to satisfy at least the major portion of future requirements for liquid fuels for a long period of years.

Synthetic liquid fuels plants situated in the Crawford-Cherokee General Area in Kansas would be well located for the distribution of their products within the marketing territory whether the output of a single unit plant or of complete development were to be marketed. A single unit plant in the General Area could probably market its output within a reasonable trucking distance of the plant. In the event of total development of the synthetic liquid fuels potential in Kansas, a short pipe line constructed from the General Area to nearby petroleum products pipe lines would provide for economical transportation of products. Within the defined marketing territory, plants in the Kansas General Area would have minimum costs for distribution of synthetic liquid fuels.

The operation of synthetic liquid fuels plants, and of Kan
the coal mines to supply them with raw material, involves the pro-
duction of wastes, for the disposal of which provision has been 13b
made. Liquid wastes may require skimming and sedimentation and, in 14a
some cases, chemical treatment before return to the streams; solid 10
wastes (principally ash from the plant and refuse from coal clean- 7002
ing) must be transported to the disposal areas and there piled up

or compacted.

It is believed that development in the Crawford-Cherokee General Area could be planned to conform to all strategic considerations outlined in publications of the National Security Resources Board.

Costs in Suitable General Area

All of the foregoing economic features are reflected in the total capital cost and operating cost for a synthetic liquid fuels plant in Kansas. Both cost estimates utilize the Bureau of Mines method for estimating typical unit plant costs as adjusted to existing conditions in the Crawford-Cherokee General Area.

Initial capital costs for a hydrogenation unit project, shown in Exhibit No. 51, are estimated, as of March 31, 1950, to be $125,265,000; the initial capital costs for a coal synthine unit project, shown in Exhibit No. 52, are estimated at $119,079,000. These estimates provide for adequate coal and water supply, plant facilities and access transportation and include net capital amounts for housing. In addition, there is provision for adequate plant waste disposal. Coal production costs include provision for cost of disposal of waste from mining operations and coal cleaning to provide a merchantable coal.

The costs estimated per barrel of products for one plant in the Crawford-Cherokee General Area (from Exhibit No. 51 for the hydrogenation process and Exhibit No. 52 for the coal synthine process) consider the use of combined underground and strip mining operations providing equal tonnages of coal. The operation of more than one unit plant in the Area or continuance of one unit plant beyond a 40-year period assumes mine operations on the same basis.

Operating costs in the Crawford-Cherokee General Area (excluding return on investment) as of March 31, 1950, are estimated to be as follows:

Operating Costs as of March 31, 1950

	Operating Cost, Exclusive of Return on Investment	
Type of Plant	Per Barrel	Per Gallon
Hydrogenation	$5.80	13.8¢
Coal Synthine	$5.98	14.3¢

Although the specified use of coal for synthetic liquid fuel manufacture is of all primary reserves or of 50 percent primary and 50 percent secondary, the cost of secondary coal (strip) reported herein as $3.55 per ton would make it more economical to use all secondary coal. The exclusive use of such secondary coal would result in decreased costs of initial capital and of operating costs, as shown by Exhibit No. 53; in which event operating costs, exclusive of return on investment, would be reduced to $5.51 per barrel (13.1¢ per gallon) for the hydrogenation process and $5.61 per barrel (13.4¢ per gallon) for the coal synthine process.

Costs as stated herein, as directed by the Contracting Officer, are based on operating costs of the process rather than on a "cost of service" or selling price basis. Such costs are based on the Bureau of Mines formula and include a basic allowance for plant maintenance of approximately 3 percent of plant investment. They also include an allowance equal to 10 percent of direct labor, plant maintenance, and operating supplies for general administrative and general office overhead (which includes the salaries and wages of a General Manager or a Plant Manager, and his immediate staff reporting directly to management); 6-2/3 percent of plant investment for depreciation; and 1 percent of plant investment for insurance and local, county, and State real estate taxes; but they include no allowance for head office or top management costs, selling expenses, return on investment, or sales and corporate (including income) taxes. Costs of coal used in the process have been computed without including selling cost or return on the investment. The cost of water has been estimated on the same basis. Return on total initial capital investment, including coal and water as indicated herein, would require about 32.6 cents for the coal synthine and 34.3 cents for the hydrogenation per barrel of products for each 1 percent gross return.

The costs herein are reported as per barrel of total products irrespective of composition. Estimates of the equivalent cost of gasoline and credits for sale of by-products were not considered necessary. Because the product grades and quantities are different for each process, the raw material and process selected in any General Area would be the one whose products most satisfactorily meet the particular market demand. Therefore, estimates of cost for each process have been made separately.

PART I - INTRODUCTION

INTRODUCTION

Authorization

At the request of the Secretary of the Interior, the Department of the Army directed the Corps of Engineers to make a survey of the United States and Alaska to determine areas suitable for synthetic liquid fuels manufacture. In order to accomplish this survey, a contract (W 49-129 eng-137) was made between the United States of America and Ford, Bacon & Davis, Inc., (sometimes hereinafter referred to as the Contractor). This investigation and report have been made as a part of that required by the contract. By approval of the Corps of Engineers, Department of the Army, portions of the contract obligations were subcontracted to other firms engaged as experts in their particular fields of operation, as follows:

Subcontract No. 1 to Paul Weir Company, Inc., Chicago, Ill., for coal investigations.

Subcontract No. 2 to DeGolyer and MacNaughton (a corporation), Dallas, Texas, for natural gas investigations.

Subcontract No. 3 to DeGolyer and MacNaughton (a corporation), Dallas, Texas, for oil shale investigations.

Subcontract No. 4 to Malcolm Pirnie Engineers, (a partnership), New York City, for water supply investigations.

Subcontract No. 5 to Max W. Ball (an individual), Washington, D.C., for investigations of oil-impregnated strippable deposits.

Purpose

This study was undertaken to determine the potential synthetic liquid fuels production capacity of the State of Kansas. To make such a determination, three categories of study are usually required; in order, they are:

1. Investigate the reserves of coal, natural gas, oil shale, and oil-impregnated strippable deposits available for the manufacture of synthetic liquid fuels.

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2. Select General Areas of Raw Material and Water Availability.

3. Determine the suitability of each General Area so selected for the production of synthetic liquid fuels.

<u>Scope of Survey</u>

In the selection of General Areas suitable for the location of synthetic liquid fuels plants, where all plant requirements can be met, the survey does not select or establish specific sites for the construction of a plant. The studies are based primarily on available information and data obtained from various authoritative sources. No detailed field surveys were carried out but a brief reconnaissance was made of the General Area in Kansas.

The raw materials considered in this survey are:

(a) Coal
(b) Natural gas

No report was authorized in relation to oil shale and oil-impregnated strippable deposits in Kansas because it was considered that Kansas either did not have such raw materials or that known deposits of such raw materials were of doubtful economic importance.

Because of the known large deposits of coal and natural gas in Kansas and their economic importance a detailed study of these raw materials was authorized by the Corps of Engineers. This comprised, in addition to the determination of raw material reserves, a determination of water availability and a critical examination of the suitability of other conditions affecting plant location for the manufacture of synthetic liquid fuels.

The conclusions contained in this report as to availability of natural gas for synthetic liquid fuels manufacture obviate the necessity for making an investigation in respect of this material as to General Areas suitable for the location of synthetic liquid fuels plants.

To facilitate the study, those coal reserves found to be of satisfactory quality and quantity were grouped into an area not larger than a county or 1,000 square miles. Since such an area
contained reserves adequate for 40 years' operation of at least one Kan
10,000-barrel-per-day synthetic liquid fuels plant, it was designated as a General Area of Coal Availability. Since it was 18
found also to have adequate supply of water for at least one 10,000-barrel-per-day plant, it was further designated as a General Area 700
of Coal and Water Availability.

This General Area of Coal and Water Availability was then critically examined with reference to the following factors:

1. Raw material
2. Water supply
3. Power
4. Access transportation
5. Labor
6. Housing
7. Marketing and products transportation
8. Waste disposal
9. Plant investment
10. Processing costs
11. Strategic considerations.

PART II - GENERAL

GENERAL

The terminology used in this report is that in general use and acceptance. Such terms, together with those idiomatic to this survey, are defined in the following paragraphs:

Definition of General Terms

General terms used in this report are defined as follows:

A General Area as used herein is not larger than a county or 1,000 square miles, depending on local conditions. General Areas are used to facilitate the detailed study of parts of the state, and are designated by name or number.

A General Area of Coal Availability is one where adequate coal reserves are available for 40 years' operation of at least one 10,000-barrel-per-day synthetic liquid fuels plant, in conformity with raw material requirements for such plants.

A General Area of Coal and Water Availability is one where both adequate coal reserves and water supply are available for 40 years' operation of at least one 10,000-barrel-per-day synthetic liquid fuels plant, in conformity with raw material and water requirements.

A Suitable General Area is one which meets all requirements for 40 years' operation of at least one 10,000-barrel-per-day synthetic liquid fuels plant using coal, in conformity with plant requirements as to raw materials, water supply, power, transportation, labor, housing, marketing and transportation of plant products, waste disposal, and strategic considerations.

A Unit Plant is the amount of production capacity adopted in the survey for purposes of comparison and for estimation of investment, operating costs, etc. It is not necessarily the most efficient size for an independent plant. The sizes adopted in the survey as unit plants are:

Sizes of Unit Plants

Process	Barrels per Day
Hydrogenation of coal	10,000
Synthine process using coal	10,000

Definitions of Coal

Bituminous Coal - Coal having less than 86 percent fixed carbon (dry, mineral-matter-free basis) and, if fixed carbon is less than 69 percent, having a heating value of 11,000 or more Btu (moist, mineral-matter-free basis) and either agglomerating or non weathering.

Lignite - A dull, brown, compact fossil wood having a heating value of less than 8,300 Btu (moist, mineral-matter-free basis).

Types of Coal Mining and Related Terms

Strip Mining - The method of first removing the overburden so as to expose the coal seam, usually by power shovels or drag lines, and then "loading" the coal.

Underground Mining - The method of coal extraction through underground operations, usually by driving a tunnel or drift, or by sinking a slope or shaft.

Overburden - In strip operations, comprises the soil or surface material, or the geological formation overlying the coal seam.

Stripping Ratio - The ratio between the thickness of the overburden and the thickness of the underlying coal seam.

Overburden Ratio - The ratio between the cubic yards of overburden and the tons of recoverable coal.

Geological Terms

Geological terms in common use include the following:

Horizon (Geological) - Strata formed at the same geological time at different locations.

Stratigraphic Section - A vertical cross section showing the relative position and thickness of geological formations in a particular area.

Coal Bed or Seam - A well-marked or homogeneous division of a
stratified series, characterized by a more or less well-defined 22
divisional plane from its neighbors above and below. 23a

Dip - The angle which the plane of a bed makes with the 15
horizontal plane. 70021

Outcrop - The occurrence of any geologic stratum at or immediately below the surface of the ground.

Parting - Extraneous material in a coal seam, in a relatively thin layer, separating parts of the seam. When parallel to the plane of the coal, partings usually consist of sedimentary material, such as clay, shale, or sandstone. Partings which cross the plane of the coal seam commonly may contain calcite, kaolinite or pyrite.

Bone (or Bony Coal) - Slaty coal or carbonaceous shale found in coal seams.

Terms Relating to Classification and Analysis of Coal

Among the terms in general use relating to analysis, classification, and mining of coal are the following:

Raw Coal - Coal as it comes out of the mine, not having been subjected to cleaning or any other preparation.

Merchantable Coal - Processed or cleaned coal of a quality acceptable for commercial use, and generally equivalent (or in some cases superior) in analysis to that of a channel sample, i.e., secured from coal in place. (See definition of "Mine Sample", "Face Sample", etc.)

Recoverable Coal - That portion of the total estimated coal in place that can be delivered as merchantable coal, after being mined and (where necessary) washed or otherwise cleaned, primarily to remove ash.

Proximate Analysis - An analysis made of coal for the determination of moisture, volatile matter, fixed carbon, and ash.

Ultimate Analysis - An analysis made of coal for the determination of constituent elements, as sulfur, hydrogen, carbon, nitrogen, oxygen (by difference), and ash.

As-received - The condition representing the sample as received at the laboratory and, for mine samples it approximates closely the condition of the coal in the mine.

Moisture-free - A condition, actual or assumed, permitting the determination or calculation of the analysis of a coal sample excluding its moisture content.

Moisture- and ash-free (Maf) - An assumed condition permitting calculation of the analysis of a coal sample excluding its moisture content and its ash content.

Rank - The stage of coalification in the series as listed below in order of decreasing completeness:

Rank of Coal

Class	Group	Abbreviation
Bituminous	Low-volatile bituminous	Lvb
	Medium-volatile bituminous	Mvb
	High-volatile A bituminous	Hvab
	High-volatile B bituminous	Hvbb
	High-volatile C bituminous	Hvcb
Lignite	Lignite	Lig
	Brown coal	Bc

Heating Value - Heat (gross) resulting from combustion of one pound of coal, expressed as Btu per pound with specification of sample condition, as "as-received", "moist, mineral-matter-free", "moisture- and ash-free" or "dry".

Mine Samples - Face Samples or Channel Samples - A sample secured from coal in place in the ground in accordance with procedure specified by the U.S. Bureau of Mines, which requires that such sample be obtained by collecting material in a uniform channel extending from roof to floor of bed, except that partings of shale, bone, and pyrite 3/8 inch or thicker and lenses or concretions of pyrite or other impurities more than 2 inches in maximum diameter, or 1/2 inch in thickness, are excluded. Such analyses are representative of merchantable coals obtainable from a mine.

"Tipple" Samples - Samples collected in accordance with Bureau of Mines procedure after the coal has received final treatment at the tipple or cleaning plant, or as it is loaded into railroad cars or trucks.

Delivered Samples - Samples taken in accordance with Bureau of Mines procedure from coal delivered for use as unloaded from the railroad cars or trucks.

Inorganic Sulfur - That portion of the total sulfur content (in coal) which exists in the form of sulfides and sulfates, the former commonly being iron pyrites, marcasite, chalcopyrite, arsenopyrite, and stibnite, with calcium sulfate (gypsum) the more usual sulfate.

Organic Sulfur - That portion of the total sulfur content other than the mineral sulfides and sulfates, which is combined in organic compounds.

Hydrogenation Yield - The relative quantity of liquid hydrocarbon products obtained by hydrogenation of a unit quantity of a particular coal.

Washability of Coal - The extent to which extraneous objectionable impurities (such as mineral matter, bone, and/or inorganic sulfur) can be reduced by treatment in commercial coal cleaning plants, with due consideration to the loss of coal which accompanies such treatment and the size limits of the coal before and after treatment.

Survey Specifications as to Minimum Requirements for Coal

The minimum requirements for coal deposits considered in this survey are as follows:

1. Thickness

   A. For coal to be mined by underground methods:

      (1) Bituminous - At least 24 inches.

      (2) Lignite - At least 48 inches.

   B. For strip-mined coal - Minimum thickness 12 inches.

2. Depth

   A. Underground-mined Coal - Not more than 1,500 feet below drainage level.

   B. Strip-mined Coal - Not more than 200 feet of overburden.
      Stripping Ratio (for coal mined by stripping) - Not more than 40 to 1 up to 75 feet of overburden, and 8 to 1 for overburden in excess of 75 feet.

   The classification of coal deposits as "strippable" shall be governed by the experience and good judgment of the coal subcontractor as to the economy of that operation.

3. Minimum Recoverable Tonnage (in an area of 3 miles radius)- 30,000,000 tons for underground mining or 5,000,000 tons for stripping.

Survey Classification of Coal Reserves

Coal reserves have been classified into three groups, and the tonnages of each have been computed, on the basis of the following definitions:

Measured Coal - Coal for which tonnage is computed from dimensions revealed in outcrops, trenches, mine workings, and drill holes, with the points of observation, in general, on the order of 1/2 mile apart.

Indicated Coal - Coal for which tonnage is computed partly from specific measurements, and partly from projection of visible data for a reasonable distance on geologic evidence; the points of observation, in general, are of the order of 1 mile apart but may be as much as 1-1/2 miles for beds of known geologic continuity.

Inferred Coal - Coal for which quantitative estimates are based largely on broad knowledge of the geologic character of the bed or region, and for which there are few, if any, measurements. The estimates are based on an assumed continuity, for which there is geologic evidence. Where there are only outcrop data on which to base estimates, such inferred coal is that lying more than 2 miles in from the outcrop and within limited areas (established as described by Paul Averitt, of the U.S. Geological Survey in a paper published in the magazine "Mining Engineering" of June 1949).

Classification of Coal Reserves in Respect of Plant Requirements

Available Coal Reserves - The amount of estimated recoverable coal remaining after deduction of estimated commercial and industrial requirements. Available coal reserves include primary and secondary reserves.

The classification of bituminous coal reserves as primary or secondary is based upon thickness of seam and class of reserve as measured, indicated, or inferred. Thus, primary reserves for underground mining include only beds 28 inches or more in thickness which are classed as either measured or indicated. The complete classification is as follows:

1. Primary Reserves ("Measured" and "Indicated" only)

   (a) Underground - At least 28 inches in thickness. Kans

   (b) Strip - Minimum thickness of 12 inches. Not more than an average depth of 75 feet of overburden; stripping ratio not to exceed 15 to 1. 26 15 70021

2. Secondary Reserves ("Measured", "Indicated", and "Inferred" not included in Primary Reserves)

   (a) Underground - At least 24 inches in thickness.

   (b) Strip - Minimum thickness of 12 inches. Not more than an average depth of 200 feet of overburden; stripping ratio not to exceed 40 to 1 up to 75 feet of overburden and 8 to 1 for overburden in excess of 75 feet.

Terms Relating to Water Supply

Surface Water - Water in a natural open channel or a natural lake.

Ground Water - Water existing below the surface of the ground in a porous material. It may be either stationary or moving.

Firm Water - A quantity of water that is available for use at all times - year in and year out.

Acre-Foot (AF) - A quantity of water which would cover an area of one acre with water one foot deep.

Collection of Data

Data for this survey were obtained from publications of the U.S. Bureau of Mines, Geological Survey, Corps of Engineers and Public Health Service and public records of the Federal Power Commission, together with publications of the State Geological
Kans Survey and Board of Agriculture of Kansas and the University of Kansas. Additional information was supplied by the Kansas State
27 Employment Service, Board of Health, Chamber of Commerce and the State Industrial Development and Highway Commissions together with
15 fuel and power companies, railroads, coal operators and coal
'0021 associations and oil and gas companies in the State.

PROCESSES AND PLANT REQUIREMENTS

Processes Considered for Kansas

The term "synthetic liquid fuels" as used in this report is applied to liquid fuels made by the hydrogenation or synthine processes using high-volatile bituminous coal as raw material.

Unit Plant

As a basis for estimates for purposes of comparison in this survey, a unit plant (unit of plant capacity or unit capacity) has been adopted which is not necessarily the most efficient size for an independent plant. The production capacity to be understood for both the coal hydrogenation and coal synthine processes, when the term "unit plant" is used, is 10,000 barrels per calendar day.

Basis of Estimates

The prime purpose of the estimates of construction and manufacturing cost presented in this report is for use in determining the relative desirability of individual areas as potential locations for synthetic liquid fuels plants. Since it is probable that some years would be required to construct any significant number of plants of this magnitude, it was decided for comparative purposes to base estimates of plant requirements and plant product costs upon the assumed use of certain improvements in process (including the direct pressure gasification of coal) which are still under development here or abroad, but which appear reasonably likely to be applicable by the time any synthetic liquid fuels program could be well under way. If synthetic liquid fuels plants were constructed today, basic requirements and costs might be appreciably higher than the estimates given, due to the necessity for the use of equipment and processes now commercially available. In drawing other than relative conclusions from these estimates, this qualification must be clearly recognized.

Detailed data as to plant requirements, products and plant wastes, for typical plants operating on both the hydrogenation and synthine processes, as furnished for use in this report, are shown in Exhibit No. 1.

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28 ## Hydrogenation Process

15 *History.* Hydrogenation of coal to yield synthetic
0021 liquid fuels was the original concept of Franz Bergius, for

which German Patent No. 301,231 was granted in 1913. The process, after intensive development and modification, was used to produce about 85 percent of German aviation gasoline in World War II. Germany then had available a total daily nominal liquid fuels producing capacity of about 90,000 barrels in 12 plants.

In the United States, hydrogenation of coal has been studied intensively by the Bureau of Mines at Bruceton, Pa., and at Louisiana, Mo. At the latter location a coal hydrogenation plant has been erected and operated experimentally and for demonstration purposes with a daily capacity of about 200 barrels per stream day. Commercially, hydrogenation has been limited in the United States to the occasional upgrading of various petroleum fractions in four or five separate commercial units.

<u>Nature of Process.</u> The conversion of coal into liquid fuels by hydrogenation consists of combining hydrogen with the coal substance at elevated temperatures (about 700 to 900 deg F) and pressures (ranging from 3,000 to 10,000 psi) in the presence of catalysts. The process is extremely flexible with respect to the nature and proportions of products. As an example, by varying plant equipment, operating conditions, nature of catalyst, and/or plant design, gasoline output may be varied from less than 20 to over 90 percent, or fuel oils from zero to about 80 percent.

In condensed summary, the hydrogenation of coal consists in preparation of the raw material by careful washing, drying, and grinding and formation of a paste by mixing part of the heavy oils from the first stage of hydrogenation with the prepared coal and a suitable solid catalyst. This paste, under high temperature and pressure, reacts with hydrogen in the first or liquid phase hydrogenation. Phenols may be separated from the products at this point or may be carried on with the rest of the products to the second or vapor phase hydrogenation. This phase consists in passing a gaseous mixture of hydrogen and the vaporized products from the first stage through beds of appropriate granular solid catalysts. The output of the second stage of hydrogenation is separated into the various final products, mainly by distillation employing equipment and methods not varying greatly from those commonly used in the petroleum industry.

Hydrogen for the first stage (liquid phase) and second stage (vapor phase) hydrogenation is obtained in part from water gas produced by reaction between steam, oxygen, and coal and in part by cracking with steam the light hydrocarbon gases which are by-products of the main hydrogenation. Provision is also made for recovery and reuse of the portion of hydrogen not consumed in the reaction vessels. Pressure operation of coal gasification and hydrocarbon cracking equipment is assumed. Kans

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Cooling water is injected into the hot gas streams leaving the hydrogenation converters. This water, together with 15
additional water formed in the reaction, condenses out and is 70021

separated from the product oil streams before distillation, carrying with it some dissolved hydrogen sulfide and phenols and constituting the major contaminated liquid process waste.

The appended block flow diagram, Exhibit No. 2, indicates a typical arrangement for such a plant, consistent with the above description and with the specific unit plant design for which estimated construction and operating costs are given in this report. It should be remembered, however, that the principle of coal hydrogenation is extremely flexible in application and that variations in methods of hydrogen production, ash elimination, product processing and number and balance of hydrogenation steps may be used in individual plants designed to meet different local conditions.

Plant Requirements. The principal materials required for the hydrogenation process are coal and water. Other materials include catalysts used in hydrogenation and hydrogen production and chemicals used in gas scrubbing. Remaining other materials and relatively insignificant in both value and volume.

Coal. Coal is used in the hydrogenation process for conversion to liquid fuels, for the manufacture of hydrogen and fuel gas, and as fuel, both for steam power generation and in certain direct-fired operations. That portion of the coal to be hydrogenated to liquid fuels should be of good quality; the balance may be of inferior grade. Roughly one-half of the total coal used in the plant is converted into liquid fuels, the other half being consumed to supply energy and hydrogen for the process. A unit plant of 10,000 barrels daily capacity would require daily about 3,900 tons of Kansas coals, the exact amount dependent upon the heating value.

Coals readily washed to low-ash content are preferable to less easily washed coals of the same type.

Coal is a complex and variable material. Actual trial of an adequate sample in a pilot plant is the only sure criterion of the practicality and ease of hydrogenation. The following properties of coal are, however, indicative of its amenability to the process:

1. The following factors should be high -

(a) Net hydrogen content
Kans Hydrogen in excess of that theoretically required to combine with all oxygen,
30 nitrogen, and sulfur of the coal.

15 (b) Volatile matter
70021 Not less than 31 percent (maf).

(c) Tar and bitumen yields on carbonization

(d) Iron and chlorine
Of the inorganic constituents of coal, iron and chlorine usually affect the catalysts favorably.

2. The following factors should be low -

(a) Fixed carbon content
Not over 69 percent (maf).

(b) Oxygen
Oxygen of the coal appears in part in the form of phenols, the balance combining with hydrogen to form water and with carbon to form oxides. Phenols may be converted in the second stage hydrogenation to hydrocarbons and additional water.

(c) Ash
Low-ash content is desirable as reducing both the total amount of coal to be handled, and loss of oil (carried out of the system with rejected ash). Ash content should be minimized by washing. Fusion point of the ash is not of major importance. Maximum permissible ash content (dry basis) is 15 percent for process coal and 20 percent for other uses.

(d) Calcium and alkali
These constituents may cause operating difficulties by their effect on the catalysts.

(e) Fusain and opaque attritus
These constituents of coal (determined by petrographic analysis) are difficult to convert but may be in part hydrogenated to liquid fuels. Fusain is normally largely removable by proper preparation.

(f) Nitrogen
Largely converted to ammonia by hydrogenation.

(g) Sulfur
Largely converted to hydrogen sulfide and other sulfur compounds.

Water. The hydrogenation of coal and the production of the energy required by the process develop large amounts of heat which must be removed. The availability of an adequate supply of cooling water is therefore of great importance. Although more than 120 mgd must pass through a unit plant with a 33 deg F rise in temperature, the total water requirements can be reduced to 7.3 mgd by recirculation through cooling towers. Two-thirds of the make-up water is lost by evaporation when recirculation is used. The balance is returned to the source as wastes from coal sepration, as blowdown from cooling towers and boilers, and as sewage.

Power. The hydrogenation of coal requires installed generating capacity to supply 68,000 kw at 100 percent load factor for the operation of a unit plant which includes an allowance of 3,000 kw for mine operation. Of the total, approximately 25,000 can be supplied in connection with the production of process steam. Purchase of the excess prime power requirements of about 40,000 kw from outside sources could decrease the total coal requirement of the process by approximately 12 percent, water requirement by about 17 percent, and would also effect reductions in manpower requirements and in investment in power generating facilities. However, the magnitude of the installation required for handling process coal alone, together with the desirability of an outlet for the higher ash fractions of the washed coal, would usually make purchase of outside power disadvantageous. Outside power sources are desirable as stand-by capacity. The possible mutual advantage of integrating the electric generation of the plant into an existing power network should be considered.

Personnel. Plant operating personnel must be high grade, semitechnical labor as in the chemical and petroleum refining industries. Highly qualified machinists and mechanics are required for the effective and safe maintenance of high-pressure equipment. Indirect labor includes such classifications as material handlers, stock clerks, guards, watchmen, and janitors. Technical workers will require a certain amount of training in specialized plant operations and maintenance. The Bureau of Mines has estimated that 80 percent of the manpower required for a hydrogenation plant can be trained in the plant, and would require no specialized skill prior to employment.

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The number of employes of a unit plant, including
32 labor and supervision, will vary slightly according to the pro-
portion of the total output represented by the various final
15 products, but may be stated for a typical example in continental
0021 United States as follows:

Personnel Required for
a Typical Hydrogenation Unit Process Plant
in Continental United States

Classification	Number of Personnel: Operational	Administrative	Total
Operations:			
Labor	365	-	365
Supervision	37	-	37
Maintenance:			
Labor	430	-	430
Supervision	43	-	43
Indirect Labor	50	53	103
Indirect Salaried Personnel	-	197	197
Total	925	250	1,175

Plant Products and By-products. The hydrogenation process can produce, from coal as raw material, liquid fuels covering the entire range from heavy fuel oil, through Diesel fuel, jet fuel, and motor gasoline, to 100-octane aviation gasoline. By varying operating conditions, number of hydrogenation steps, and choice of catalyst any one of these grades may be made the principal product, as local markets may require.

The gasoline produced by hydrogenation of coal contains a high proportion of aromatics (benzene, toluene, and xylene), which may be separated if required, making the hydrogenation process an important potential source of those products.

Liquefiable petroleum gases (propane and butane) form an appreciable percentage of total plant products. A considerable amount of phenolic compounds, including phenol, cresol, and xylenols, may also be separated as optional by-products. If left in the main product stream, they are ultimately converted to additional gasoline.

Wastes. The hydrogenation of coal produces gaseous,
solid, and liquid wastes. Gaseous wastes result in part from the
combustion of coal in the power plant and at other points. Sul-
fur in the coal fed to the hydrogenation converters is separated
from the process stream as hydrogen sulfide. This may be con- Kans
verted to sulfuric acid or elemental sulfur and sold, or burned
in the power plant and dissipated from the stack with the other 33
flue gases, according to local conditions. Small amounts of
ammonia which might be discharged could be rendered inoffensive 15
by passage through a combustion zone. 70021

Solid wastes of the process are comparable to and would be disposed of in the same manner as solid wastes from any large coal-burning industrial plant. Although coal hydrogenation ash will contain about 8 pounds of spent catalyst per barrel of plant products, its volume and nature will present no disposal problems not adequately met by usual methods employed to prevent the carrying off of excessive suspended solids by rainfall.

Various liquid wastes of the hydrogenation plant may carry small amounts of oil, removable by separators such as are commonly used by petroleum refineries. Of the total amount of liquids to be discharged, a relatively small and segregable portion will consist of so-called "foul water" containing dissolved gases (such as hydrogen sulfide) and solids, principally phenolic in nature.

A variety of methods is available for removing phenolic compounds. They may be applied in a series of consecutive steps, the number of steps depending on the degree of purification required by local conditions. These would be arranged in the following order:

1. Preliminary removal of remaining oil by solvent extraction, followed by removal of the bulk of the dissolved gases by pressure release and heating or aeration.

2. Removal and recovery of phenols by ion exchange on highly alkaline exchange resins; or, alternatively, destruction of phenols by biochemical action.

3. Oxidation of remaining traces of phenols by ozone.

A more detailed discussion will be found in the section on Waste Disposal, in a later part of this report.

Choices between methods will be largely determined by economic factors at specific locations. Treated water can be rendered suitable for return to streams without harm to aquatic life and may be rendered potable by standard treatments.

<u>Typical Hydrogenation Plant for Continental United States.</u> In selecting a form of coal hydrogenation plant suited
to the conditions imposed in the continental United States by the
types of coal available and the required types and proportions
of products, the Bureau of Mines has prepared estimates in its
Kans publication, R.I. No. 4564 (August 1949), for several typical
plants, each of 30,000-barrel-per-day capacity. These data for
34 a plant to use Wyoming bituminous coal, a specific case, have
been adopted for this survey for estimating construction and
15 operating costs of a unit plant. More generalized data may be
70021 summarized as follows for a typical unit plant:

Basic Data and Estimates
for Typical Unit Coal Hydrogenation Plant
in Continental United States
(Based on U.S. Bureau of Mines Data)

Plant area - Acres (minimum)	70
Estimated approximate total steel requirements - Tons	60,000
Estimated personnel:	
Operations and maintenance	925
Administrative, clerical, and engineering	250
Total daily coal requirements - Billions of Btu	98
Power required at 100 percent load factor - Kw	65,000
Daily water requirement - Gallons	7,286,000
Total production - Barrels per calendar day:	
Gasoline	7,220
Liquefied petroleum gas (L.P.G.)	2,367
Phenols	413(A)

Note: (A) Convertible, without additional equipment, to 463 barrels additional gasoline.

The current stage of development of a synthetic liquid fuels program does not permit the statement that any specific plant represents average conditions for those which may be constructed. Variations from the mean, however, will not seriously affect the utility of such a plant as a basis for the purpose of this survey; i.e., the determination of the relative suitability of General Areas.

Synthine Process Using Coal

History. Early work in Germany by F. Fischer and H. Tropsch developed a process to combine carbon monoxide and hydrogen, producing a mixture of alcohols which was called synthol. In 1926, the same men announced a modification of their process to produce, from the same gases, a mixture of hydrocarbons. To indicate the close similarity, this product was termed synthine and has given its name to the process itself. Kahs

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Intensive development after 1926 resulted in the construction of a commercial plant in 1936 by Ruhrchemie, A.G. Fol- 15
lowing this installation, the number of synthine plants in Germany 70021

increased to a total of ten by the end of World War II. Required carbon monoxide and hydrogen were produced by conventional water gas equipment.

Development of the process by others has been followed for many years by the U.S. Bureau of Mines, which since 1945 has itself carried on active work at Bruceton, Pa. Simultaneously, research on the continuous production of synthesis gas (a carefully proportioned mixture of carbon monoxide and hydrogen) has been under way at Morgantown, W.Va. A 50 to 100-barrel-per-day demonstration plant for the Bureau of Mines is nearing completion at Louisiana, Mo.

Private capital has nearly completed a 7,000-barrel-per-day synthine plant to use natural gas near Brownsville, Tex.

Nature of Process. Except for obvious necessary differences in the production of synthesis gas, and in disposal of waste products, the synthine process is the same whether coal or natural gas is used as the primary raw material.

The synthine process consists essentially of the combination, over a suitable catalyst at pressures of from 200 to 400 psi and at temperatures of from 550 deg to 650 deg F, of carbon monoxide and hydrogen to form a condensable mixture of hydrocarbon vapors. The reaction releases large amounts of heat and, since the temperature may be allowed to vary only within narrow limits, adequate provision for cooling is important. The liquid products are recovered and, for the most part, separated by methods and equipment well known in petroleum technology. Subsequent catalytic cracking or hydrogenation of the heavier oil fractions may be used according to the desired product distribution.

In the reaction, most of the oxygen of the carbon monoxide is converted to water but a part reacts to form carbon dioxide and a series of both water- and oil-soluble oxygenated organic compounds consisting of alcohols, aldehydes, ketones, and acids.

The nature and quality of products of the synthine process depend entirely upon the type of catalyst used and the operating conditions regardless of the raw material used to produce the synthesis gas. This gas can be produced from any material containing combustible carbon, the hydrogen being obtainable by reaction of steam and carbon monoxide.

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The principal raw materials suitable for the synthine
36 process are coal of all ranks and natural gas. Of these, the
former is available in much larger quantities. Although the
15 latter is commonly less expensive, it is also usually less
70021 available when existing commercial demands are satisfied.

The appended block flow diagram, Exhibit No. 3, indicates a typical arrangement for such a plant, consistent with the above description and with the specific unit plant design, for which estimated construction and operating costs are given in this report. However, the synthine process is more or less flexible in application, and variations in method of synthesis gas production, type of synthesis reactors, number of reaction stages, steps in product processing and manner of separation or reuse of oxygenated chemical by-products may be used in individual plants designed to meet different local conditions.

Plant Requirements. The synthine process uses major quantities of coal and of water, both for consumption in the process, and the latter as coolant and for miscellaneous purposes.

Other necessary materials, including chemicals for catalyst manufacture, for the treatment of intermediate liquid products, and for imparting anti-knock properties to finished gasoline, are of relatively small amount.

Coal. Coal for the synthine process may be of any rank and of almost any quality although low quality (heating value) will obviously increase the quantity required for a given plant capacity. A unit plant of 10,000 barrels daily capacity would require daily about 5,000 tons of Kansas coal, the exact amount dependent upon the heating value. Ash content is not inherently objectionable but should preferably be as low as possible. To this end, good washability is desirable. The maximum permissible ash content is 20 percent (dry basis). High sulfur content in the coal is to be avoided because of the necessity for nearly complete sulfur removal from the synthesis gas, in order to maintain catalyst activity.

Water. Water is required in a synthine plant mainly for cooling purposes. Too high a solids content will somewhat increase the requirements for solids control in cooling towers and boilers. From one-eighth to one-fourth of the water used must be capable of treatment to provide satisfactory boiler feed. Less than 1 percent need be of potable quality or fit to be made so by chlorination and other treatment. For a unit plant, the total daily requirement is about 11,150,000 gallons per day.

Power. The basic chemical reactions of the synthine process liberate quantities of waste heat sufficient for the generation of all required electric power and no additional fuel for power would be required. Outside power is required for starting up and in the event of temporary failure of plant generating facilities. Integration where possible of plant facilities with an existing power network merits consideration.

Personnel. Operating personnel for a synthine process plant must be largely of a high class of semitechnical labor as in the petroleum refining and chemical industries. Because of the use of pressure equipment, the same is true of a substantial proportion of maintenance labor. Indirect personnel includes such classifications as material handlers, stock clerks, guards, watchmen, janitors, and laborers. Technical workers will require a certain amount of training in specialized plant operations and maintenance. The Bureau of Mines has estimated that 80 percent of the technical workers can be trained from an inexperienced labor supply.

The number of employes of a unit plant will vary slightly according to the proportions of the total output represented by the various final products, but may be stated for a typical example as follows:

Personnel Required for
a Typical Unit Coal Synthine Process Plant
in Continental United States

Classification	Number of Personnel
Operations:	
Wage Earners	338
Supervision	34
Maintenance:	
Wage Earners	420
Supervision	42
Indirect Labor (Wage Earners)	103
Indirect Salaried Personnel	198
Total	1,135

Plant Products and By-products. The synthine process can produce a series of hydrocarbon liquid products comparable to petroleum fractions and meeting similar commercial specifications. Although it is expected that normally a preponderant part of the output will be gasoline, a certain limited flexibility is possible in design and operation through variations in the catalyst used and in operating conditions.

Kans Gasoline quality from a synthine plant varies widely
with the type of catalyst used. The German practice of using
38 cobalt produced gasoline of markedly low octane number. Use
of iron catalysts and higher operating pressures as contem-
15 plated by the Bureau of Mines are expected to result in entire-
70021 ly satisfactory motor gasolines.

Diesel oil by the synthine process is expected to be of good quality with a cetane number of about 55. The typical fuel oil product is expected to meet specifications for a higher grade than No. 6 (Bunker C), possibly as high as No. 3.

A small amount of liquefiable petroleum gases (L.P.G.), principally propane, may be produced as final product or may be recycled or burned as plant fuel. The same is true with respect to a series of oxygenated organic compounds formed by part of the oxygen content of the synthesis gas. Most of these products, alcohols, aldehydes, and acids, have a definite though limited market which probably could not absorb the output of such chemicals from any large production capacity of synthetic liquid fuels by the synthine process. Recycling of any of these materials is entirely possible and would result not only in solving a disposal problem but also in somewhat increased liquidfuel output or alternatively decreased raw material consumption. Recycling of only the oxygenated compounds is assumed in the specific plant design for which cost estimates are given in this report.

Wastes. Solid wastes of a typical synthine plant processing coal will consist principally of ash from the coal processed or burned as fuel. The small amounts of spent catalyst (mainly iron oxide) included will be no more obnoxious than the ash. Disposal of this waste offers no problem, except perhaps in quantity, that is not readily met in the case of any large coal-burning industrial plant.

Gaseous wastes will be principally those removed in the purification of the synthesis gas, especially hydrogen sulfide resulting from sulfur in the coal. In order to avoid atmospheric pollution, the hydrogen sulfide may be converted to sulfuric acid or elemental sulfur, the sale of which would provide a credit against cost of sulfur removal.

Liquid wastes of the plant can be handled so as to skim those carrying oils and to segregate those containing dissolved organic compounds from the process. Such segregated water, before discharge, may be treated for recovery of these compounds, either for sale or for recycling. Alternatively, it may be fed to special boilers to produce a contaminated steam replacing part of the normal process requirement. Relatively small quantities of sanitary and storm sewage can be handled by well-known methods. Some water from cooling tower operation and boiler blowdown will be discharged with an increased content of dissolved solids.

Typical Synthine Plant (Using Coal) for Continental United States. Based on the results of extensive research and development work of its own, as well as upon available data of other investigators in the United States and in Germany, the Bureau of Mines has in the course of preparation estimates of construction and operating costs of a synthine plant of commercial scale. Preliminary data from this study, for a plant producing 10,000-barrels of synthetic liquid fuels per day from western Kentucky bituminous coal, a specific case, have been adopted for this survey for estimating construction and operating costs of a unit plant, to be used as a basis of comparison for determining relative suitability of General Areas. In drawing other than relative conclusions from these cost estimates, however, the preliminary nature of the data so far available must be remembered. The final estimates determined by the Bureau at the completion of its work may differ appreciably from the present figures.

More generalized data may be summarized as follows for a typical unit plant:

Basic Data and Estimates
for a Typical Coal Synthine Unit Plant
in Continental United States

(Based on Preliminary Data from U.S. Bureau of Mines)

Plant Area - Acres (Minimum)	77
Estimated personnel:	
Operations and maintenance (including all indirect labor)	937
Administrative, clerical and engineering (salaried personnel only)	198
Total daily coal requirements - Billions of Btu	126
Power required at 100% load factor - Kw (produced from waste heat)	114,500
Daily water requirements - Gallons	11,150,000
Total production - Barrels per calendar day:	
Propane	470
Gasoline	7,280
Diesel oil	1,900
Fuel oil	350

The current stage of development of the synthetic
Kans liquid fuels program does not permit the statement that any
specific plant represents average conditions for those which
40 may be constructed. Variations from the mean, however, will
not seriously affect the utility of such a plant as a basis
15 for the purpose of the survey; i.e., the determination of the
0021 relative suitability of General Areas.

PART III - SUMMARY OF STATE CHARACTERISTICS

SUMMARY OF STATE CHARACTERISTICS

Surface Features

The land surface of Kansas is a rolling prairie, a part of the Great Plains which slope up to the Rocky Mountains on the west. The altitude rises from 750 feet in eastern Kansas to 4,000 feet on the western edge of the State. There are no mountains.

Kansas is almost totally drained by the Kansas and Arkansas Rivers and their tributaries.

The coal measures of Kansas occur in the eastern quarter of the State.

Climate

The Kanas climate is relatively mild. Exhibit No. 4 shows the mean monthly temperature and precipitation at Fort Scott, assumed representative of the coal-bearing portion of the State. Here the annual mean temperature is 57 deg F. The mean temperature is 33 deg in January, the coldest month and 80 deg in July, the warmest month. Precipitation at Fort Scott averages 40 inches annually. Western Kansas experiences a much drier climate.

Population

According to a preliminary count of the 1950 U.S. census the population of Kansas is 1,894,390. This represents a population density of 23.1 per square mile over the whole State. The number of persons per square mile in eastern Kansas is somewhat greater. The total population of the three counties of Kansas (Crawford, Cherokee, and Bourbon Counties) containing important coal deposits, as discussed later, is according to this census 84,373, equal to a population density here of 46.3 per square mile. The city of Joplin, Mo., is across the State line from Cherokee County. Kansas City, Mo., is the major trade center for the eastern Kansas area.

Industry and Agriculture

Kansas is the leading wheat-producing state in the nation. The industry of food and kindred products ranks first in the State in value added by manufacture, with grain-mill and meat products accounting for the largest portion of the value in this industry. Major industries in Kansas, in addition to food and kindred products, include chemicals and allied products, petroleum and coal products, and transportation equipment. The 1947 Census of Manufactures reported a total of 1,946 establishments in the State, with 719 establishments manufacturing food and kindred products and 453 establishments in the printing and publishing industries. In the coal-producing counties in southeastern Kansas, the principal economic activities are agriculture and mining.

The table which follows shows the size of manufacturing establishments in Kansas as compared to the United States total. These figures for establishments are from the 1947 Census of Manufactures and illustrate that small establishments in Kansas are somewhat proportionately greater than the United States total, whereas the percentage of large establishments, employing over 500, is slightly less than that for the United States.

Manufacturing Establishments in Kansas
and the United States Total by Size Groups

	Kansas		United States		Kansas
Employes per Establishment	Number of Establishments	Percent of Total	Number of Establishments	Percent of Total	Percent of the United States
1-19	1,407	72.3%	157,651	65.4%	
20-99	414	21.3	58,688	24.4	
100-499	101	5.2	19,878	8.3	
over 500	24	1.2	4,664	1.9	
Total	1,946	100.0%	240,881	100.0%	0.81%
Population (1950 census)	1,894,390		150,697,361		1.26%

Transportation

The eastern Kansas coal fields are crossed by a number of major railroads available to serve synthetic liquid fuels plants. Kansas highway mileage, one-third hard surfaced, ranks second in the country.

PART IV - RAW MATERIALS

COAL

General Geology of Coal Deposits
(See Exhibit No. 5, Coal Bibliography, for references below)

Approximately the eastern one-fourth of Kansas is solidly underlain by Pennsylvanian coal-bearing formations, comprising an area of approximately 20,000 square miles and including all or parts of 35 counties. This area is a portion of the coal basin extending through Arkansas, Oklahoma, Nebraska, Missouri and Iowa, which is designated as the Western Region of the Interior province by the U.S. Geological Survey.

With the exception of a few small and unimportant lignite deposits of upper Cretaceous age, in the north-central part of the State, and one minor coal occurrence in a lower Permian formation, the coal beds of Kansas occur in Pennsylvanian formations. The Pennsylvanian stratigraphic series consists of approximately 2,000 feet of marine and non-marine shales, interbedded limestones, sandstones, and relatively thin beds of bituminous coal which are widely distributed throughout the section. These strata cross the eastern end of the State in a general north-south direction, with a broad outcrop band nearly 100 miles in width. The average dip is from 20 to 30 feet per mile toward the northwest, so that progressively higher beds in the series appear across the State in a westerly direction. No significant structural irregularities are developed contrary to the regional dip, except for a few gentle folds and loca, minor fault zones.

The Pennsylvanian strata of Kansas have been divided into nine stratigraphic groups which, in ascending order, are named the Cherokee, Marmaton, Bronson, Kansas City, Lansing, Pedee, Douglas, Shawnee, and Wabaunsee. Each group except the Bronson, Lansing, Pedee, and Shawnee contains one or more coal horizons, with the greatest number of commercially important coal beds occurring in the lowermost group, the Cherokee shale.

The stratigraphic relationships and coal bed designations, in descending order, are shown by the following:

(References: 3, 4, 11, 13, 15, 16, 17, 19)

Stratigraphic Relationships and Principal Coal Beds in Kansas

Series	Group	Principal Coal Beds
Virgil	Wabaunsee	Nyman
		Elmo
		Nodaway
	Shawnee	No coal beds
Missouri	Douglas	Williamsburg
		Sibley
		Blue Mound
	Pedee	No coal beds
	Lansing	No coal beds
	Kansas City	Thayer
	Bronson	No coal beds
	Marmaton	Mulberry
		Summit
Des Moines	Cherokee	Mulky
		Bevier
		Croweburg
		Fleming
		Mineral
		Pilot
		Weir-Pittsburg
		Rowe
		Columbus
		Riverton

The basal Cherokee group, which was deposited unconformably on underlying strata of Mississippian age, varies from 375 to 560 feet in vertical thickness and contains at least 15 coal horizons, among which occur the most important coal beds of the State. These beds largely outcrop in the southeastern part of the State and include, in ascending order, the Riverton, Columbus, Rowe, Weir-Pittsburg, Pilot, Mineral, Fleming, Croweburg, Bevier and Mulky coals. The Weir-Pittsburg bed, which occurs near the middle of the Cherokee group and averages 3 feet in thickness, has produced more coal than any other single bed in Kansas.

The Marmaton group, overlying the Cherokee, consists of 250 feet of shales, sandstones and limestones, with two coal beds, the Summit (Fort Scott) bed near the base of the section and the Mulberry bed near the middle. The Summit bed measures less than 1 ft 6 in. in thickness and has not been mined except for local consumption. The Mulberry ranges in thickness from 5 inches in the southern part of Bourbon County to 40 inches in northern Linn County.

The Kansas City group contains only one important coal bed, the Thayer, which occurs near the middle of this formation. The Thayer coal has been mined primarily in Neosho and Wilson Counties, but seldom exceeds 2 feet in thickness, increasing, however, to a maximum thickness of 29 inches in southern Montgomery County.

The Douglas group outcrops from Atchison and Leavenworth Counties on the Missouri River in the northeastern part of the State, to Chautauqua County in the southern part of the State and contains numerous coal horizons, of which only the Blue Mound (Ottawa), the Sibley, and the Williamsburg (Ransomville) beds are of importance. These beds are locally well developed and have been mined in a number of scattered localities, but the coal changes in thickness and quality within short distances. Thicknesses seldom exceed 2 feet and these beds have been mined primarily by stripping operations. The principal mining area of the Blue Mound coal is southwest of the town of Lawrence in Douglas County where the bed averages 1 ft 2 in. in thickness. The Ottawa coal, equivalent to the Blue Mound bed, has been mined locally southeast of the town of Ottawa in Franklin County, where it approximates 0 ft 10 in. in thickness. The Sibley coal has been mined to a certain extent in Leavenworth County, where the bed is composed of upper and lower benches measuring 1 ft 1 in. and 1 ft 8 in., respectively. Coal of the Williamsburg horizon is mined in Franklin, Osage, Coffey, Anderson, Greenwood, and Woodson Counties, commonly on a limited scale of production.

The highest coal-bearing group, the Wabaunsee, measures 300 to 400 feet in vertical thickness and contains twelve coal beds, of which the Nodaway, Elmo, and Nyman are the most important. The Nodaway bed is relatively persistent and has been mined in Nemaha, Doniphan, Atchison, Jefferson, Shawnee, Osage, Coffey, Greenwood, and Elk Counties. It seldom exceeds 2 feet in thickness, however. The Elmo coal, although widespread in occurrence, is not of minable thickness.

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The remaining beds within the State are generally variable in thickness and rarely exceed 1 ft 6 in. in thickness. These beds have only been opened by small wagon-mine operations for local household fuel.

Topography and Drainage

Eastern Kansas largely lies within the Great Plains province of the continental interior and is characterized physiographically by a relatively low relief, with occasional broad, flat valleys which mark the low-gradient drainage system. The most pronounced land forms are a series of east-facing ridges of resistant bedrock strata which occur in parallel alignment across the State in a northeast-southwest direction. The extreme southeastern part of Kansas is crossed by the edge of the Ozark Plateaus, in which the land surface consists of rolling hills. The coal-bearing area is drained toward the east and southeast by the Missouri, Kansas, Osage, and Neosho Rivers and their tributaries.

Sources of Information

The first comprehensive report dealing with the coal deposits of Kansas was published in 1898 by the Kansas University Geological Survey and dealt primarily with the coal field developments in the southeastern part of the State. In subsequent years, as the coal industry gained in importance, additional reports based on scattered coal field investigations in various parts of the State were released.

A comprehensive program of field study was initiated in 1935 for the purpose of collecting all the field evidence relating to the coal resources of the State. Since that date a total of more than 20 bulletins, along with several geological and mine depletion maps, have been released, covering the coal field investigations made by the State Geological Survey of Kansas. The U.S. Geological Survey has collaborated in the preparation of much of these regional studies, and the U.S. Bureau of Mines has published mine production statistics and tables of analyses covering Kansas coals. In addition, the coal industry, the railroads, and the petroleum and natural gas industries have contributed considerable specialized information relating to the coal-bearing areas.

Survey Methods and Procedure

In estimating the coal reserves of Kansas, all pertinent available information was posted on previously prepared base maps, with sources of information being appropriately indicated. Each such base map covered an area consisting of one degree of longitude (east-west) and one-half degree of latitude (north-south) on a scale of 1:62,500. Such an area comprises eight 15-minute topographic quadrangle maps as ordinarily prepared by the U.S. Geological Survey. A separate print of each base map was used for each coal bed within the area, provided sufficient information was available to permit an evaluation of reserves.

Having posted all available information on outcrop, depth, and thickness of each bed on each base map area, including the extent of underground and/or strip-mine depletion, if present, the areas underlain by coal in each township for which specific data or any other types of relevant information were available, were carefully analyzed and evaluated prior to delineation of classified areas of reserves. Individual areas depleted by underground or strip operations were demarcated and eliminated from further measurement by enclosure within a limiting line located sufficiently far outside the outermost extents of the mined-out area to represent the limit of the probable barrier pillars which would be left between the depleted area and subsequent mining operations. Where individual depleted areas approached other depleted areas to such an extent that subsequent mining operations in the intervening areas would not be practical, as in many areas of major depletion by groups of mines located relatively close together, the entire area was demarcated and eliminated from further measurement by a similar limiting line. Since the property lines toward which mining operations in active mines may be expected to proceed were not determined in this survey, it is probable that some portions of such intervening areas thus eliminated may be underoing current depletion. The amounts of such reserves, which are considered relatively minor in extent, would thus not be included in the total amount of estimated reserves.

The delineation of measured, indicated, and inferred strippable reserves was based on detailed and individual examination of areas adjacent to the coal bed outcrop in each township containing such outcrop locations. Factors taken into account in estimating the presence and extent of strippable reserves included the distribution, frequency, and reliability of available information, the accuracy of location of the line of outcrop, the character of the slope immediately adjacent to the outcrop and the thickness of cover and width of the potential strippable area as shown by topographic maps, if available, the character of the overburden, if known, and the size, shape and extent of areas already depleted by stripping or shallow underground operations, if present. In estimating strippable reserves, the amount and character of the available information and relatively much more important than in estimating underground reserves because of the determinative interdependence of factors such as the thickness and continuity of coal bed and the thickness and character of overburden in a relatively small proportion of the general coal-bearing area.

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An additional factor in estimating areas of strippable reserves is the economic relationship between the costs of recovery of reserves under relatively heavy cover by the stripping method and by underground mining. While the determination of reserves available for the manufacture of synthetic liquid fuels properly precedes any consideration of costs in this survey, it is considered relevant and proper to classify such areas of reserves as primary reserves for underground operation rather than as secondary reserves for strip-mine operation when it is estimated that underground mining will result in more economic recovery than strip mining. The inclusion of this factor in the several determinative criteria enumerated above has been adopted as a portion of the procedure followed in this survey.

Having demarcated and eliminated from further measurement all depleted areas and having delineated any areas of strippable reserves as described above, the remaining areas of reserves adjacent to such depleted and strippable areas and to outcrops, including any portions of the bed disclosed by drill hole or isolated shaft records, were classified by lines defining the various areas of measured, indicated, and inferred underground reserves as warranted by the available information and according to the definitions established as Part II of this report. Distinctions between primary and secondary underground reserves were based on average thicknesses of bed within each township.

Each classified area of reserves within each township, as thus delineated, was measured by planimeter to determine acreage, this figure then being multiplied by average thickness of the bed as developed from the data and by a constant of 1,800 tons per acre-foot, following U. S. Geological Survey procedure, to determine the number of tons in place. The data on thickness of coal and cover and on acreage and quantity of reserves were then tabulated, by townships, on basic Coal Data Sheets*, with the information and estimated quantities of reserves in each township being grouped by individual beds in each county.

Preliminary analysis of available data on Kansas coal
deposits indicated that consideration of coal reserves as raw mate-
rial for synthetic liquid fuels plant supply could best be conducted
on selected coal beds in the specific counties underlain by such
coal beds. Where it was found that information on minor coal beds
either indicated that specific beds were too discontinuous or too Kans
thin for estimation of reserves according to the definitions em- 49b
ployed in this survey, or was insufficient to permit any estimates 50a
of reserves, such beds were excluded from further consideration.
The coal beds selected for continuing consideration, in descending 70021
order of stratigraphic occurrence, were as follows:

*Complete sets of the basic Coal Data Sheets are available at the specific depositories listed in Exhibit No. 6.

Williamsburg
Thayer
Mulberry
Bevier
Croweburg
Mineral
Weir-Pittsburg

Although the coal production of Kansas is frequently subdivided into three coal-producing districts in industrial practice, the use of districts as definitive areas is commonly restricted to areas of producing mines. Reserves of individual coal beds removed from such productive areas would not commonly be recognized as portions of these districts. The analyses of available data on Kansas coal deposits, accordingly were conducted by counties rather than by districts. Brief descriptions of the industrial coal-producing districts are appended to this report in Exhibit No. 7.

Under the definitions employed in this survey for delineating areas of measured, indicated, and inferred coal reserves, estimates of measured and indicated classes of reserves are largely based upon positive points of observation at maximum intervals, as provided by the respective definitions. Estimates of inferred reserves, however, are based largely upon assumptions of extent, continuity, and thickness, for which there is reasonable geologic evidence. While available evidence of continuity and persistence of individual coal beds has thus been taken into account in projecting areas of inferred reserves beyond areas of measured and indicated reserves, the resultant estimates are regarded only as provisional until further evidence from new or hitherto undisclosed exploration becomes available.

The information used in this survey was generally based on data from major sources such as Federal, State and university publications, railroads, coal trade associations, etc. Neither time nor funds were available to this project for complete collection of all potential information in the hands of private interests. Since information from these sources would probably increase the usable information on extent of demonstrated coal reserves above that now available from most publications, the estimated reserves in this survey would probably tend to increase rather than de-
Kans crease as and when such additional information may become avail-
able in the future. The diagram following has been prepared to
50b indicate graphically the results of the previously described
51a Survey Methods and Procedure, as these may appear on the individual
base maps on which the various coal data are shown in detail.
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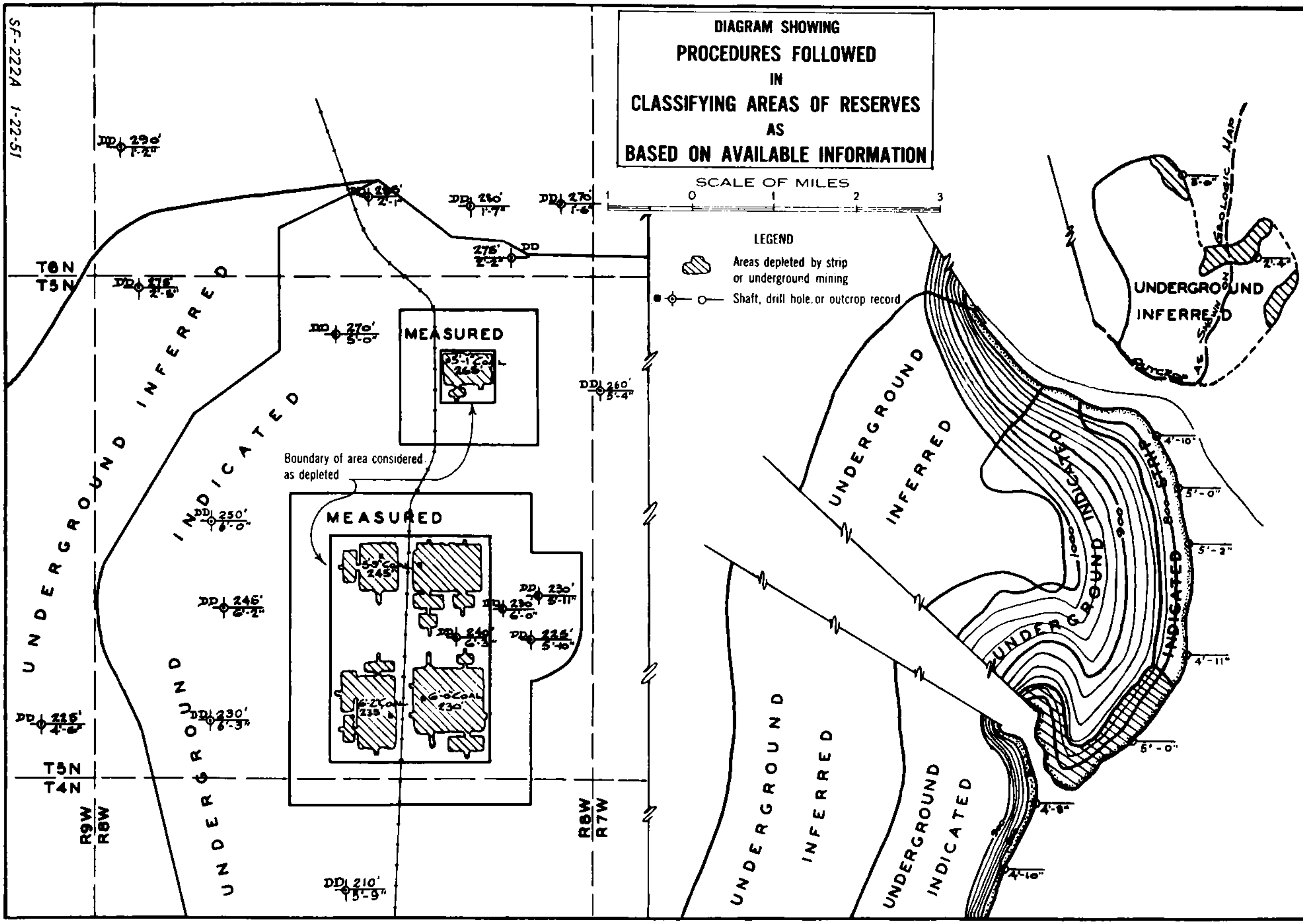
Elimination of Counties Not Meeting Requirements of Survey

As indicated in the table following, there are 35 counties in Kansas which are entirely or in part underlain by coal-bearing strata. Three of these counties (second column of table) were eliminated from further consideration because preliminary information revealed they were largely underlain by strata younger in age than the coal-bearing formations, which effectively concealed any surface indications of coal reserves; and there was no additional evidence of continuation of coal reserves at depth.

The available information on each of the remaining 32 counties was then compiled by coal beds and examined in detail. Twenty-three additional counties (third column of table) were eliminated after the detailed examination because either the reported reserves were insufficient in amount to warrant consideration as synthetic liquid fuels plant supply or because available information on depth, continuity, thickness, and number of coal beds was insufficient to permit estimates of reserves. Detailed descriptions of these 23 counties are attached as Appendix A.

The elimination of 26 counties, as described above, left 9 of the original 35 counties in which the coal reserves appeared to qualify as suitable for synthetic liquid fuels production. These counties are enumerated in the last column of the table and a summary of their recoverable coal reserves is shown in Exhibit No. 8. The following section of the report describes the nature and extent of the coal beds in these counties and presents some data relating to present commercial production.


SF-222A 1-22-51
DIAGRAM SHOWING
PROCEDURES FOLLOWED
IN
CLASSIFYING AREAS OF RESERVES
AS
BASED ON AVAILABLE INFORMATION
SCALE OF MILES
1 0 1 2 3
LEGEND
Areas depleted by strip or underground mining
Shaft, drill hole, or outcrop record
MEASURED
MEASURED
Boundary of area considered as depleted
INDICATED
UNDERGROUND INFERRED
UNDERGROUND INDICATED
UNDERGROUND
INFERRED
STRIP
INDICATED
GEOLOGIC MAP
OUTCROP AS SHOWN
T6N
T5N
T5N
T4N
R9W
R8W
R8W
R7W

Selection of Counties in Kansas
Containing Coal Reserves Suitable
for Production of Synthetic Liquid Fuels

All Counties Containing Coal-bearing Strata	Counties Eliminated Because of: Fringe Position near Outermost Limit	Counties Eliminated Because of: Isolated and Insufficient Reserves (A)	Counties Selected for Consideration
Allen		Allen	
Anderson		Anderson	
Atchison		Atchison	
Bourbon			Bourbon
Brown		Brown	
Chautauqua		Chautauqua	
Cherokee			Cherokee
Coffey		Coffey	
Cowley	Cowley		
Crawford			Crawford
Doniphan		Doniphan	
Douglas		Douglas	
Elk		Elk	
Franklin			Franklin
Greenwood		Greenwood	
Jackson		Jackson	
Jefferson		Jefferson	
Johnson		Johnson	
Labette		Labette	
Leavenworth		Leavenworth	
Linn			Linn
Lyon		Lyon	
Marshall	Marshall		
Miami		Miami	
Montgomery			Montgomery
Nemaha		Nemaha	
Neosho			Neosho
Osage			Osage
Pottawatomie		Pottawatomie	
Riley	Riley		
Shawnee		Shawnee	
Wabaunsee		Wabaunsee	
Wilson			Wilson
Woodson		Woodson	
Wyandotte		Wyandotte	

Note: (A) Descriptions of these counties rejected from further consideration for synthetic liquid fuels plant supply are in Appendix A.

Description of Coal Reserves in Selected Counties

Franklin County. (See Exhibit No. 5 for references A below). Franklin County is located in the north-central portion of the coal-bearing area of eastern Kansas. Bureau of Mines Publication M.M.S. No. 1807, "Bituminous Coal and Lignite in 1948", indicates that in that year slightly over 1,000 tons were produced from one stripping operation in Franklin County.

The available information on coal deposits in Franklin County indicates that a small area of estimated strippable reserves of the Upper Williamsburg coal bed is present near the center of the west line of the county, where it is adjacent to, and contiguous with, additional strippable reserves of the same bed in southeastern Osage County. These reserves are considered suitable for further consideration as synthetic liquid fuels plant supply.

The Upper Williamsburg bed is considered to be stratigraphically higher than the main Williamsburg bed, which outcrops across the western part of Franklin County, and has been mined extensively in the southwestern portion of the county. In this latter area, the Williamsburg bed averaged approximately 1 ft 4 in. in thickness. The available information indicates that remaining reserves of the Williamsburg bed are insufficient for further consideration. The coal bed designated as the Upper Williamsburg occurs largely as a horizon marker over the Williamsburg bed, but in the west-central portion of the county thickens to from 1 ft 0 in. to 1 ft 8 in. in thickness. In this area the bed has been depleted locally by a number of small shaft, drift, and stripping operations. Where thus depleted, the Upper Williamsburg bed approximated 2 ft 0 in. in thickness.

While lower beds are known to outcrop in a general north-south direction across the central and eastern portions of Franklin County, these beds are limited in continuity and thickness and have been opened only by small wagon mines for local domestic consumption.

Osage County. (See Exhibit No. 5 for references B below) Osage County is located near the western limit of the principal coal-bearing area of Kansas, in the north-central portion of the area. Bureau of Mines data on bituminous coal production in 1948 indicate that approximately 32,000 tons were produced in that year, of which 6,000 tons were obtained from three stripping operations.

A small area of estimated strippable reserves of the Upper Williamsburg coal bed occurs near the southern end of the

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(References A: 6, 7, 8, 14, 18, 27)
(References B: 7, 8, 14, 18, 22, 24, 31)

eastern line of Osage County, where it is adjacent to, and connected with, a small area of reserves of the same bed in western Franklin County. This bed ranges from 1 ft 0 in. to 1 ft 4 in. in thickness and has been mined but locally for domestic use. These reserves are considered suitable for further consideration as synthetic liquid fuels plant supply.

The Nodaway bed has been extensively mined across the eastern part of Osage County, where it ranges from 1 ft 0 in. to 1 ft 10 in. in average thickness, occasionally reaching a maximum thickness of 3 ft 0 in. The available information indicates essentially no reserves of minable thickness in this bed meeting the survey limitations as suitable for synthetic liquid fuels production. Outcrops of higher coal beds are present in Osage County, west of the outcrops of the Upper Williamsburg and Nodaway beds, but such beds exist largely as horizon markers, with but limited thickening in small local areas.

Linn County. (See Exhibit No. 5 for references A below) Linn County is located in the east-central portion of the coal-bearing area in Kansas and borders the Missouri State line on the east. Bureau of Mines data on bituminous coal production in 1948 indicate that 279,000 tons were produced in that year, of which approximately 275,000 tons were produced from three stripping operations.

A small area of estimated reserves of the Mulberry bed occurs in the east-central portion of Linn County, with an average thickness of 3 ft 0 in. The Mulberry bed outcrops in an irregular line across the southeastern corner of Linn County and has been extensively mined along the eastern edge of the county. In the area of its occurrence, this bed ranges from 1 ft 6 in. to 3 ft 6 in. in thickness and contains a characteristics pyrite band near the base of the bed. These reserves are considered suitable for further consideration as synthetic liquid fuels plant supply.

The Thayer bed outcrops largely as a horizon marker in the northwestern portion of Linn County, averaging less than 0 ft 6 in. in thickness, with local thickening up to 1 ft 0 in. The bed has been mined intermittently during the past 50 years, but because of its thin, irregular occurrence the production has been limited to very small local mines. Available information indicates that further consideration as synthetic liquid fuels plant supply is not warranted.

Bourbon County. (See Exhibit No. 5 for references B below). Bourbon County is located in the south-central part of the first tier of counties bordering the Missouri-Kansas State line.

(References A: 7, 8, 17, 18, 19, 24)
(References B: 6, 7, 8, 14, 16, 17, 18, 19, 28)

Bureau of Mines data on bituminous coal production in 1948 indicate that approximately 148,000 tons were produced in that year, with the entire production having been obtained from four stripping operations.

The available information indicates that small, strippable reserves in both the Weir-Pittsburg and Bevier coal beds are located in the extreme southeastern corner of Bourbon County, where they are adjacent to, and connected with, larger reserves of these same beds in northeastern Crawford County. These reserves are considered suitable for further consideration for the production of synthetic liquid fuels. The Weir-Pittsburg bed ranges from 2 ft 2 in. to 3 ft 0 in. in thickness, while the Bevier averages 1 ft 6 in. in thickness. Mining operations have been conducted for a long period of time in these two beds, as well as in the Mineral, Lexington, and Mulky beds, which occur in the same portion of the county. The reserves of the Weir-Pittsburg bed are located west of worked-out areas and can only be operated by underground mining. Reserves of other than the Weir-Pittsburg and Bevier beds in the basal Cherokee group, which occur in the southwestern portion of this county, do not appear to be sufficient in extent, thickness, or occurrence for further consideration in the production of synthetic liquid fuels.

The Mulberry and Summit coal beds outcrop across the central and northeastern parts of Bourbon County, with thicknesses ranging from a few inches to 2 ft 0 in. for the Summit bed and to 1 ft 11 in. for the Mulberry bed. The latter bed thins rapidly toward the southern portion of the county. Small local operations have been conducted intermittently in these coals, but the available information indicates that these beds contain insufficient evidences of occurrence and continuity to justify the estimating of reserves for synthetic liquid fuels plant supply.

Crawford County. (See Exhibit No. 5 for references below) Crawford County is located in the southeastern portion of the coal-bearing area of Kansas, in the first tier of counties west of the Missouri State line. Bureau of Mines data on bituminous coal production in 1948 indicate that 1,176,000 tons were produced in Crawford County in that year, of which 1,054,000 tons were produced from 17 stripping operations. This county produced approximately 40 percent of the total State production in 1948.

The available information indicates that relatively substantial reserves of underground in the Weir-Pittsburg bed, of strippable coal in the Bevier bed, and of strippable coal in the Mineral and Croweburg beds remain in the eastern half of Crawford County. The thicknesses of the strippable reserves range from 1 ft 0 in. to 1 ft 10 in., while thicknesses of the underground reserves of the Weir-Pittsburg bed range from 2 ft 2 in. to 3 ft 0 in. These reserves are considered suitable for further consideration as synthetic liquid fuels plant supply.

(References: 6, 7, 8, 14, 16, 17, 18, 19, 28)

In addition to information on the above four coal beds, outcrop data and mining records indicate that the Rowe and the Mulky beds are present in the same general portion of the county. The Rowe bed averages 1 ft 6 in. in thickness and has been mined in the south and southeastern part of the county. The Mulky bed has been mined in the northeastern part of the county, where it approximates 0 ft 10 in. in thickness. The available information indicates that further consideration of the Rowe and Mulky coals in this report is not warranted.

Neosho County. (See Exhibit No. 5 for references A below). Neosho County is located in the southern portion of the coal-bearing area. No production from this county is recorded for 1948 by the Bureau of Mines.

The available information indicates the presence of a relatively small area of estimated strippable reserves in the Thayer bed, located in the southwestern corner of Neosho County, which is considered suitable for further consideration as synthetic liquid fuels plant supply. This bed ranges from 0 ft 3 in. to 1 ft 2 in. in thickness, occasionally thickening to 2 ft 0 in. The bed has been mined across the western portion of the county. Several additional beds of coal outcrop above the Thayer bed, but are thin and discontinuous in nature, seldom measuring over 0 ft 6 in. in thickness.

Wilson County. (See Exhibit No. 5 for references B below). Wilson County is located in the southwestern portion of the main coal-bearing area of eastern Kansas. No production is reported from this county for 1948 by the Bureau of Mines.

A relatively small area of estimated strippable reserves in the Thayer bed is present in the southeastern corner of Wilson County and is considered suitable for further consideration as potential synthetic liquid fuels plant supply. This bed has been mined locally across the southeastern quarter of the county, where it ranges from 1 ft 0 in. to 1 ft 10 in. in thickness. Other coal horizons within Wilson County seldom exceed 0 ft 6 in. in thickness.

Cherokee County. (See Exhibit No. 5 for reference C below). Cherokee County is located in the extreme southeastern corner of Kansas. Bureau of Mines data on bituminous coal production for 1948 indicate that approximately 899,000 tons were produced in Cherokee County in that year, of which all but 10,000 tons were produced from 12 stripping operations. This county is second to Crawford County in total production within the State.

The coal occurrences in Cherokee County are very similar to those in Crawford County, and it is estimated that substantial reserves of underground Weir-Pittsburg coal, strippable Bevier coal,

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58 (References A: 3, 7, 8, 18, 27)

(References B: 7, 17, 18, 27)

0021 (References C: 1, 2, 4, 6, 7, 8, 14, 16, 17, 23, 28, 30, 33) and strippable Mineral coal are present in the northwestern quarter of the county. The thicknesses of these three beds range from an average of 1 ft 6 in. in the Bevier bed, and an average of 1 ft 10 in. in the Mineral bed, to 3 ft 4 in. in the Weir-Pittsburg bed. These reserves are considered suitable for further consideration as synthetic liquid fuels plant supply.

The Weir-Pittsburg bed has been extensively mined by both underground and strip operations. The mined-out area extends almost solidly from the line of outcrop for a distance of approximately six miles down the dip, toward the west and northwest. The western limit of possible mining in both Cherokee and Crawford Counties is defined by the presence of a channel sandstone discovered by drilling and in underground operations which replaces all or portions of the coal bed. The average depth of the coal at this western limit of mining approximates 150 feet. The areas of estimated reserves occur largely between the western limits of past and present underground mining operations and the eastern edge of the channel sandstone.

The Mineral and Bevier beds have been extensively stripped in the west-central and northwestern portions of the county. Some reserves are estimated to remain in areas which have not yet been depleted by stripping, but are contiguous with past and present stripping operations under generally deeper cover.

Outcrops of the Rowe, Croweburg and Mulky coal beds are present in the northwestern portion of Cherokee County. While mining operations have been conducted in these beds, the available information indicates that potential reserves are insufficient in extent to warrant further consideration in this report.

Montgomery County. (See Exhibit No. 5 for references below). Montgomery County is located in the southwestern corner of the main coal-bearing area of Kansas. No production was reported from this county in 1948 by the Bureau of Mines.

Relatively limited estimated reserves of strippable coal in the Thayer bed are present in the northeastern and south-central portions and are considered suitable for further consideration as synthetic liquid fuels plant supply. This bed outcrops in an irregular line across the central and northeastern portions of the county. The thickness ranges from 0 ft 4 in. to 1 ft 3 in. and in most places is less than 0 ft 10 in. Because of its thin occurrence and its relatively remote location from consuming markets, this bed has been opened only locally for domestic use. Although the horizons of other coal beds are present in Montgomery County, these beds seldom exceed 0 ft 6 in. in thickness.

(References: 7, 8, 18, 24, 27)

Estimated Percentage of Recovery of Coal in Place

Broad over-all records of percentage of recovery from coal reserves in place in existing underground and strip mine operations in Kansas are not available. In 1923 the U.S. Bureau of Mines prepared a summary report on "Amount and Nature of Losses in Mining Bituminous Coal in Eastern United States", which was published in 1925 as a portion of the Report of the United States Coal Commission established in accordance with Public Act No. 347 by Congress on September 22, 1922. This report, which covered only the underground mining which prevailed at that time, found that in 1921 the average amount of coal lost in mining operations in 10 eastern states was 34.7 percent, indicating a recovery of 65.3 percent. The maximum average recovery was 80.0 percent in Virginia, and the minimum average recovery was 51.0 percent in Illinois. No investigations were conducted in Kansas.

In estimating percentage of recovery from reserves in place across broad areas such as those established in this report, the amount of over-all bed losses entailed in future mining operations would normally be considered as exceeding the average percentage of losses involved in present individual operations, assuming that methods of mining were not essentially changed. The causes of such decreases in over-all recovery in broad areas, include coal left in barrier pillars between mines, coal left in mined-over areas when individual active operations are abandoned, coal unmined because of undetected local decreases in thickness, quality or continuity, coal left in place under towns, cemeteries, railroads, schools, or other reservations, coal left in pillars around oil and gas wells, etc. The recovery from coal reserves in place by underground mining in this report, based upon available data and on providing for possible contingencies cited above, is estimated as 60 percent.

Although individual stripping operations recover a materially higher percentage of the original coal in place than underground operations, the estimating of over-all recovery of strippable reserves over substantial areas requires consideration of the bearing of a number of economic factors on final percentage of recovery. These factors include allowances for areas which probably will not be stripped because of the presence of town developments, improved highways, existing facilities of all kinds, and because of possible excessive costs of acquisition, local decreases in thickness, quality or continuity of the coal bed, etc. In order to provide for possible contingencies thus indicated, the recovery by stripping operations in this report is estimated as 70 percent.

Summary Description of Estimated Recoverable Coal Reserves

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60a The total tonnage of coal considered for synthetic liquid fuels manufacture in Kansas as of January 1, 1950, based on available information and within the limits of reserves specified for

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this survey, as described in Part II of this report under "Definitions" and in Part IV under "Survey Methods and Procedure", is estimated as 686,259,000 tons in place or 452,832,000 tons recoverable. Because of the limitations imposed by this survey, the estimates presented herein of reserves considered for synthetic liquid fuels production, are not comparable with other coal estimates which generally include the total coal reserves in Kansas. For example, in Circular 94 of the U.S. Geological Survey, the total recoverable reserves for Kansas, as of January 1, 1950 (assuming 50 percent recovery) are reported to be 8,777,200,000 tons. This adopts 1945 and 1946 estimates by Abernathy, Jewett, and Schoewe.

The detailed data were presented in a volume of Coal Data Sheets, which are available for examination at certain depositories listed in Exhibit No. 6. The recoverable coal reserves are also indicated on the Coal Data Sheets in Exhibit No. 8 and summarized by counties and beds in the table following. The estimated total recoverable coal reserves (452,832,000 tons) are recapitulated by counties and beds in the table, following. Diagrammatic outlines of the areas underlain by reserves of the several coal beds are indicated on Exhibit No. 9.

As shown in the table, seven coal beds were found to contain suitable reserves for production of synthetic liquid fuels according to the definitions and procedures established for this survey. One bed, the Weir-Pittsburg, contains 165,299,000 tons of estimated recoverable reserves, with these reserves being located in three counties for which reserves were estimated. The Mineral bed contains approximately 151,503,000 tons, these reserves being largely concentrated in the southeastern part of the coal-bearing area. Reserves of the Bevier bed are located in three counties for which reserves were estimated, with the largest area of reserves occurring in Crawford County. Total reserves of this bed approximate 86,284,000 tons. The estimated reserves in the remaining beds are relatively small in extent and in total.

With estimated reserves in each of the three major coal beds, the largest amount of reserves in a single county occurs in Crawford County, where it totals 283,825,000 tons. The total reserves in Cherokee County approximate 117,021,000 tons. The reserves in the remaining counties range from 14,907,000 tons in Wilson County to 3,255,000 tons in Osage County.

Commercial Coal Production

Trends in Production. The earliest record of coal production in Kansas by the U. S. Geological Survey was in 1869 and amounted to 36,891 tons. Since that time, Bureau of Mines data as of 1948 indicate that 264,020,000 tons of coal have been produced. Achieving its maximum annual production of 7,562,000 tons in 1918, the an- Kans
nual coal production of Kansas has followed the general rise and fall of industrial activity for the entire country. Coal produc- 60b
tion in 1931, a year of serious depression, was only 2,247,636 tons. 61
Since 1938, production has ranged between 2,493,000 and 4,230,000 tons annually, with a total of 2,538,000 tons in 1948, the last year 7002
of record.

Estimated Total Recoverable Coal Reserves in Kansas Considered for Synthetic Liquid Fuels Production by Counties and Beds in Thousands of Tons (A)
(As of January 1, 1950)

County	Coal Beds							
	Williamsburg Upper	Mulberry	Weir-Pittsburg	Bevier	Mineral	Crowe-burg	Thayer	Total
Bourbon			4,582	520				5,102
Cherokee			43,446	13,270	60,305			117,021
Crawford			117,271	72,494	91,198	2,862		283,825
Franklin	4,780							4,780
Linn		9,870						9,870
Montgomery							8,951	8,951
Neosho							5,121	5,121
Osage	3,255							3,255
Wilson							14,907	14,907
Total	8,035	9,870	165,299	86,284	151,503	2,862	28,979	452,832

Note: (A) Estimated in accordance with specifications and procedures established for this survey, as described in Part II and Part IV.

Almost from the beginning of substantial coal production in Kansas, mining has been conducted by both underground and strip operations. Beginning on a small scale, the coal produced by stripping has increased steadily from 5.3 percent of total State production in 1914 to 93.6 percent in 1948.

The mechanical loading of underground coal, commonly used as an index of underground coal mechanization, has not been adopted in Kansas coal operations. The 1948 data by the Bureau of Mines indicated that all underground coal production was hand-loaded.

In common with most other important coal-producing states, average size of mines has increased in Kansas. In consequence, the number of active mines has decreased from a high of 390 in 1923 to 65 in 1948 of which 23 were underground operations and 42 were strip mines. The average number of employes has also decreased from approximately 13,000 in 1915 to 1,286 in 1948.

With increases in strip mining operations as described above, the average productivity in tons per man per day in the Kansas coal field has increased from 2.78 in 1916 to 10.66 in 1948. A special study of productivity by the Bureau of Mines in 1945 indicated that in that year the average production per man per day was 1.86 in underground mining and 13.01 in strip mining. In 1948 the average production per man per day in strip mining was 13.48 tons and in underground mining was 2.62 tons.

<u>Coal Beds Mined.</u> The largest production in Kansas is obtained from the Weir-Pittsburg bed, which is worked by both underground and stripping operations. Next in relative importance are the Mineral and the Bevier beds. Commercial production from other coal beds is of minor importance.

<u>Thickness of Coal Beds.</u> The thickness of coal beds being mined by commercial operations in Kansas vary from less than 2 feet to slightly over 4 feet, the weighted average thickness being approximately 2.7 feet for underground and 1.6 feet for strip. A special study by the Bureau of Mines in 1945 on underground and strip mining in the United States indicated the following percentage of production in Kansas by thickness of bed:

	Percent of Total Production		
Bed Thickness	Underground	Strip	
Less than 2 feet	27.2%	88.7%	
2 to 3 feet	30.0	8.6	Kans
3 to 4 feet	42.8	1.7	
4 to 5 feet	0.0	1.0	63
Weighted average thickness	2.7 feet	1.6 feet	7002

Quality of Coal. (See Exhibit No. 5 for references below). The coal beds of eastern Kansas range from high-volatile C to high-volatile A bituminous in rank, with the rank generally increasing from the northwest toward the southeast. In general, Kansas coals are similar in quality to coals of Iowa, Missouri, and northern Oklahoma, with specific coals in the southeastern corner of Kansas being superior in quality to the general average.

Specific representative analyses of the coal beds determined to contain reserves for potential synthetic liquid fuels plant supply are presented in the summary and detailed tabulations accompanying this report. In large part, the available analyses of coal beds in Kansas have been obtained from operating mines which are primarily located in the higher-quality beds. The analyses herein presented may not be fully representative of the entire reserves in any specific county, for this reason. But few analyses are available from beds of inferior quality, inasmuch as these have not been developed and operated for commercial industrial competition. The following ranges in selected items of analysis (wherever taken throughout the State) summarize the general quality of the individual beds considered during this survey, and for which information was available, with the beds being listed in decending order:

(References: 2, 6, 7, 8, 18)

Summary of General Quality of Coal Beds in Kansas
(Mine Samples, As-received Basis)

Coal Bed	Item of Analysis	Representative Low	Representative High	
Williamsburg	Moisture, percent	7.0	15.0	
	Ash, "	9.0	10.5	
	Sulfur, "	1.0	4.5	
	Btu	10,500	11,000	
Thayer	Moisture, percent	3.0	8.0	
	Ash, "	7.5	16.5	
	Sulfur, "	0.7	2.0	(5.2 in Miami County)
	Btu	11,500	13,000	
Mulberry	Limited data			
Bevier	Moisture, percent	3.5	5.0	(11.8 in Leavenworth County)
	Ash, "	13.0	14.5	(6.9 in Labette County)
	Sulfur, "	2.0	4.5	
	Btu	10,800	13,500	
Mineral	Moisture, percent	4.0	5.0	
	Ash, "	12.0	13.0	
	Sulfur, "	3.0	4.0	
	Btu	12,000	13,000	
Weir-Pittsburg	Moisture, percent	5.0	11.0	
	Ash, "	8.0	13.0	
	Sulfur, "	2.5	3.5	
	Btu	11,000	13,500	

Distribution and Use. Over 90 percent of present commercial production is loaded directly at the mine into railroad cars for shipment to destination. Except for coal used at the mine, the remaining production is loaded into trucks. Principal railroad carriers in Kansas, in the approximate order of production by mines served by each line, are as follows:

Missouri Pacific
St. Louis - San Francisco
Atchison, Topeka and Santa Fe
Missouri-Kansas-Texas
Kansas City Southern
Joplin-Pittsburg
Northeast Oklahoma

The available information on distribution of coal does not permit an analysis of the distribution of Kansas coal by destination and use, inasmuch as production was included with that of District 15 (Kansas, Missouri, Texas, and portions of Oklahoma) in compiling such information during the years when these data were available. In general, Kansas coals are used mainly for locomotive fuel, power generation, and industrial fuel. Production from the smaller fields is commonly used for industrial and domestic consumption. While prepared at the mines in a variety of sizes, production from Kansas, Missouri, Texas, and northern Oklahoma (District 15) moves primarily as lump coal and double screened coal with top sizes over 2 inches, as resultant or dedusted screenings with top sizes over 3/4 inch but not exceeding 2 inches, and as modified mine-run coal with top sizes over 2 inches.

Future Coal Requirements. The demand for Kansas coal, used largely for industrial power generation and railroad and domestic fuel, varies closely in accordance with nationwide industrial activity. Kansas coals are generally not adapted for special purpose uses and future requirements appear to be confined to the general industrial uses for which they are now being employed. At the 1948 production rate of approximately 2,538,000 tons, the total demand for Kansas coal in the next 50 years would approximate 126,900,000 tons. Since the average future rate of production over a 50-year period could obviously deviate from the 1948 rate in either direction, the above figure is used solely as an estimate of future requirements other than for the development of a synthetic liquid fuels industry.

Selection of General Areas of Coal Availability

Elimination of Unsatisfactory Areas. On completion of basic mapping and tabulation, each area of reserves was then examined as to location, extent, amount of recoverable reserves and relationship to other adjacent or nearby reserve areas. Iso-
Kans lated areas with insufficient reserves to provide at least one
66 synthetic liquid fuels plant for a 40-year life were eliminated
from further consideration. Where large reserves of one or two
70021 principal beds were overlain or underlain by one or more coal beds of relatively limited extent, or of inferior quality, which would probably not be mined concurrently with mining of the more extensive beds, these intermediate beds were likewise eliminated. The locations, coal bed designations, and amounts of estimated

recoverable reserves of such eliminated areas are shown in the following table.

Eliminated Areas of Unsatisfactory Reserves

County	Coal Bed	Estimated Recoverable Reserves (Thousands of Tons) Primary	Secondary	Total
Crawford	Croweburg	-	2,862	2,862
Franklin	Williamsburg Upper	-	4,780	4,780
Linn	Mulberry	9,870	-	9,870
Montgomery	Thayer	-	8,951	8,951
Neosho	Thayer	-	5,121	5,121
Osage	Williamsburg Upper	-	3,255	3,255
Wilson	Thayer	-	14,907	14,907
Total		9,870	39,876	49,746

Deduction of Coal Reserves for Future Commercial Requirements. The total recoverable reserves in Kansas, as shown in a previous table, are estimated at approximately 452,832,000 tons. It is estimated that the future commercial requirements of Kansas coal for the next 50 years, based on the 1948 production rate of 2,538,000 tons, would approximate 126,900,000 tons. On these bases there are approximately 325,932,000 tons available for the production of synthetic liquid fuels.

Substantial areas of both underground and strip reserves of coals of superior quality, continuity, or thickness in Kansas are in the hands of operating companies. While no attempt was made in this survey to confine estimates of reserves to areas now owned or controlled by operating or holding companies, some allowances for present ownership of both underground and strippable coal were probably unavoidably effected by excluding from the mapping and tabulation certain minor areas not yet depleted but lying within major areas of depletion, as previously described under "Survey Methods and Procedure". It is considered that such eliminated reserves, at least some of which are probably being depleted by active mines, will supply some portion of the estimated future commercial requirements. The total amount of potential supply thus provided, however, is considered as relatively minor in extent.

Demarcation of General Area of Coal Availability

After elimination of the unsatisfactory areas of reserves listed in the last table, the remaining areas of reserves were grouped into one General Area of Coal Availability, in accordance with the definitions and procedures established in this survey. Reference to the summary of recoverable coal reserves by counties and beds (Exhibit No. 8) indicates that, with the exception of a minor amount of strippable reserves (eliminated) in the Mulberry bed in Linn County, the only primary reserves in Kansas are those represented by the measured and indicated underground reserves of the Weir-Pittsburg bed in Crawford and Cherokee Counties. Since the definition of raw material availability for synthetic liquid fuels plant supply states that, "---- the quantity considered sufficient for one or more plants is based upon a recoverable amount sufficient to supply such plant for a period of 40 years, of which 20 years' supply is from primary reserves and the additional 20 years' supply is from either primary or secondary reserves", it is evident that the demarcation of a General Area of Coal Availability in Kansas can only be related to such underground reserves of the Weir-Pittsburg bed in Crawford and Cherokee Counties.

Since subsequent information indicated the availability of adequate water in this General Area, it is the same as the General Area of Coal and Water Availability shown on Exhibit No. 10. The location, boundaries, and areas underlain by included coal reserves for the General Area are diagrammatically shown by this Exhibit. Identified by the names of the counties in which principal portions lie, this is designated the Crawford-Cherokee General Area. The detailed data pertaining to the Crawford-Cherokee General Area are shown by Exhibit No. 11. These data include information on thicknesses of beds, depths of cover, rank and quality of coal, areas underlain by coal reserves, estimated recoverable reserves (by classes), and the daily capacity of synthetic liquid fuels plants, in thousands of barrels, which could be supported by the estimated reserves.

The detailed data in Exhibit No. 11 show that the Crawford-Cherokee General Area contains primary and secondary underground reserves of the Weir-Pittsburg bed. It also contains secondary strippable reserves of the Bevier and Mineral beds. The total primary reserves are 75,289,000 tons. The total secondary reserves are 327,797,000 tons. In accordance with the definition of raw material availability cited above, the usable reserves in the Crawford-Cherokee General Area total 150,578,000 tons (comprised of one-half primary underground and one-half secondary strip reserves). The amount of secondary reserves thus eliminated from the actual total of recoverable reserves in the Crawford-Cherokee General Area is 252,508,000 tons. The daily synthetic liquid fuels plant capacity which could be supported by the total usable reserves is 26,000 barrels for the hydrogenation process
Kans or 20,000 barrels for the synthine process.

57b
58 It has been previously shown that deduction of the future commercial requirements for Kansas coal (126,900,000 tons)
70021 from the total recoverable reserves in Kansas (452,832,000 tons) provides approximately 325,932,000 tons as available for the production of synthetic liquid fuels. The total estimated usable

reserves in the Crawford-Cherokee General Area of Coal Availability (150,578,000 tons) is less than the 325,932,000 tons stated above as being available for production of synthetic liquid fuels. Since the available reserves exceed the reserves allotted to the one General Area of Coal Availability, therefore, no reductions in potential synthetic liquid fuels plant capacity are indicated.

It is possible that a portion of either synthetic fuels supply or future commercial requirements will eventually be obtained from the 49,746,000 tons contained in the eliminated areas of unsatisfactory reserves itemized in the preceding section of this report, or from the 252,508,000 tons of excess secondary reserves eliminated as shown above. It is likewise possible that, as of January 1, 1950, present operating companies either own or control relatively minor amounts of reserves for future commercial production which were not included in the total amounts of reserves estimated herein as available for synthetic liquid fuels plant supply, as previously described under, "Survey Methods and Procedure". There is also the probability of additional reserves being developed in the areas for which there is not now sufficient information to warrant the estimation of reserves for the purpose of this report. In addition it is recognized that certain reserves not meeting the requirements of the survey, especially with respect to thickness of bed, are now being mined, and may be future sources of coal supply for commercial use and/or for synthetic liquid fuels plants.

Under the definitions and procedures employed in this survey and with specified allowances for future commercial production, it is concluded that sufficient coal reserves are available in the Crawford-Cherokee General Area of Coal Availability in Kansas to supply synthetic liquid fuels plants having a minimum capacity of 26,000 barrels per day using the hydrogenation process or 20,000 barrels per day using the synthine process. It is probable that continued exploration and development of Kansas coal reserves will result in the discovery of additional reserves for both synthetic liquid fuels plant supply and future commercial requirements in areas not now containing sufficient information to permit the present estimation of reserves.

NATURAL GAS

The investigation included a study of all natural gas and oil fields in Kansas, with special reference to the quantity of gas to be recovered, the gas available for synthetic liquid fuels plants, and the cost of gas in the field. The map, Exhibit No. B-1, shows the oil and gas fields and natural gas pipelines in Kansas. Data relating to the oil and gas fields in Kansas are tabulated in Exhibit No. B-2.

The dominant oil productive formations in Kansas are the Lansing and Kansas City limestones of Pennsylvania age, the Upper Mississippian sands and limestones, the Hunton limestone of Siluro-Devonian ages, and the Viola and Arbuckle limestones of Ordovician age. Extensive gas production has been developed from shallow Pennsylvanian sands in eastern Kansas, from Mississippian limestones west of the Nenaha uplift, and from the Permian dolomites and limestones in the Hugoton field in western Kansas. Depths of production range from 100 to 6,500 feet.

Extensive production will continue to be developed in Kansas by the extensions and development of the presently known producing areas. Also, production will be developed from stratigraphic traps occurring on the flanks of the main buried structural features.

The total recoverable reserves of natural gas in Kansas as of January 1, 1949 are estimated at 15,654,009,000 Mcf, with a heating value in the order of 950 Btu per cubic foot. The breakdown of these reserves into commercial requirements and undedicated reserves is summarized in the following table:

Summary of Estimated Recoverable Natural Gas Reserves in Kansas
(In Mcf under Standard Conditions)

As of January 1, 1949 (A)

Total		15,654,009,000
Commercial Requirements:		
Contract	14,678,380,000	
To Be Used in Field	791,179,000	
Total Commercial Requirements		15,469,559,000
Undedicated Reserves:		
Proved Drilled	32,580,000	
Proved Undrilled	13,730,000	
Probable	138,140,000	
Total Undedicated Reserves as of January 1,1949		184,450,000

Note: (A) Modified by interim reserve dedications.

As shown by the above table essentially all of the available gas reserves are under contract to gas pipe lines for domestic, commercial and industrial use. The major portion is under contract for a term ranging from 20 years to the life of production. The available volume of gas is dominantly in the "probable" classification and the total Btu approximates 175 trillion units. These reserves are found in three main areas: Eastern Kansas, Western Kansas, and Western Kansas - Hugoton field.

The Eastern Kansas recoverable gas reserves are estimated at 46,598,000 Mcf, of which 29,163,000 Mcf are to be used in the field, and the remainder are under contract. The reserves are widely scattered, many wells serving to supply small local communities and farms. The average daily well production is small and delivery pressures are low.

The Western Kansas gas reserves, omitting the Hugoton field, are dominantly associated and dissolved gas reserves estimated to total (recoverable) 601,011,000 Mcf in many fields scattered throughout large areas. Of this amount, 56,950,000 Mcf are estimated as remaining recoverable gas reserves not dedicated to contract or field use.

The total recoverable gas reserves in the Hugoton field in Kansas are estimated at 15,006,400,000 Mcf., of which commercial requirements and undedicated reserves are as follows:

Summary of Estimated Recoverable Natural Gas Reserves in the Hugoton Field, Kansas
(in Mcf under Standard Conditions)

As of January 1, 1949		
Total		15,006,400,000
Commercial Requirements:		
Contract	14,270,000,000	
To Be Used in Field	608,900,000	
Total Commercial Requirements		14,878,900,000
Undedicated Reserves:		
Proved Drilled	0 (A)	
Proved Undrilled	0 (A)	
Probable	127,500,000	
Total Undedicated Reserves as of January 1, 1949		127,500,000

Note: (A) Proved drilled reserves totaling 58,600 million cubic feet and proved undrilled reserves totaling 1,655,200 million cubic feet available as of January 1, 1949 have been contracted for during the interim period.

The weighted average field price for gas under contract in Kansas during 1948 ranged from 3.5 cents to 12 cents per Mcf, with the average being on the order of 6 cents per Mcf. However, any appreciable volume of reserves cannot be acquired under present conditions for less than 12 cents to 14 cents per Mcf. This price is compared with an estimated national average field price of about 6 cents per Mcf.

Minimum requirements for a reserve, for this study, call for undedicated deposits of natural gas within a radius of 40 miles containing at least 225 trillion Btu with a heating value of at least 400 Btu per cubic foot at standard conditions. Such a reserve would be equal to 236,840,000 Mcf of 950-Btu gas.

For the purposes of this study, there are no gas reserves in the State of Kansas that can be considered as suitable for synthetic fuels manufacture because of the insufficient volume of undedicated reserves, the "probable" classification of available gas reserves, and the scattered area distribution of those reserves available. Discoveries of new fields and extensions of old fields from January 1, 1949, to the date of this report warrant no changes in this conclusion.

Detailed natural gas information forming the basis for conclusions here expressed is contained in the report prepared by DeGolyer and MacNaughton which accompanies this report as Appendix B.

WATER SUPPLY

Hydrological Features

There is one General Area of Raw Material Availability in Kansas. This Area is located in the southeastern corner of Kansas, in Crawford, Cherokee, and Bourbon Counties, as shown on Exhibit No. 12, in relation to principal communities and the more important streams and sources of water supply.

The topography of Kansas is generally flat with a gradual dropping off from an elevation of about 4,000 feet in the western end to 750 feet along the eastern border. Some relief is found in the Ozark Plains in the east and in the hill areas of the north and south. The northern half of Kansas is drained by the Kansas River system; the east central counties by the Osage River; and the southern portion of the State by the Arkansas River or its tributaries the Cimarron, Verdigris, and Neosho Rivers. The average annual precipitation in Kansas varies from less than 15 inches in the western part of the State to more than 40 inches in the southeastern corner. At Fort Scott, in Bourbon County, near the eastern boundary of the State, the 72-year mean annual rainfall is 40 inches. The variations in annual rainfall are greater in the western part of the State than they are in the eastern section.

The mean runoff of the rivers in Kansas ranges from low values of 0.1 inch per year for the Smoky Hill, Arkansas, and Cimarron Rivers in the west, to the relatively high value of 11 inches, or 0.8 cfs per square mile of drainage area, in the southeastern part of the State. The small stream runoff in the western part of the State is due not only to the low rainfall, but also to the high evaporation. Measurements at Manhattan, Kans., in 1939 showed an annual evaporation of 60 inches, and the losses are progressively greater at points farther west.

Water Requirements for Synthetic Liquid Fuels Plants

Water is quite essential for synthetic liquid fuels production, not only for steam generated for power but for synthesis gas production in connection with the synthine process and hydrogen manufacture in the hydrogenation process. In both processes, water is used for cooling purposes and for boiler and cooling tower blowdown to remove accumulation of salts left by the evaporated water.

In a hydrogenation process unit plant there are approximately 35 billion Btu and in a coal synthine process unit plant 54 billion Btu that have to be dissipated daily by cooling waters.

Quantity. The following table shows the quantity of water required both for process and domestic use in connection with a synthetic liquid fuels unit project:

Water Requirements for Unit Project

	Make-up		Consumed		Return	
	Mgd	Cfs	Mgd	Cfs	Mgd	Cfs
Hydrogenation Process:						
Plant Use	7.29	11.28	5.36	8.29	1.93	2.99
Domestic Supply	1.73	2.68	0.43	0.67	1.30	2.01
Total	9.02	13.96	5.79	8.96	3.23	5.00
Coal Synthine Process:						
Plant Use	11.15	17.25	7.71	11.93	3.44	5.32
Domestic Supply	1.94	3.00	0.49	0.76	1.45	2.24
Total	13.09	20.25	8.20	12.69	4.89	7.56

Process. It is obvious that the total water requirement for any specific project would depend upon the choice of either the hydrogenation or the coal synthine manufacturing process, the total water requirement being 45 percent greater for the latter process. However, water costs represent as a rule less than 2 percent of the total costs of products, exclusive of return on investment. Therefore, it appears possible and on the safe side to adopt the coal synthine process requirements as the basis for estimates of water quantities and costs.

A detailed statement of the coal synthine process water requirements, given in Exhibit No. 13, shows most of the water use in the plant to be for cooling purposes. The estimates assume recirculation of cooling water over cooling towers.

Once-through cooling without the towers would require about 18 times more water but the consumptive use would be much less. It would be feasible only for a unit development located on the bank of a large river or a large lake. The cost of delivering large quantities of water to a remote site would be relatively prohibitive.

In estimating water supplies for the General Area of Coal Availability in the State of Kansas, total plant requirements have been used without allowance for water returned to the stream as possible waste or sewage. Such waste water might be returned at a considerable distance from the point of withdrawal and might contain considerably more natural salts than the original water diverted and be less desirable for some purposes.

Water use data and cost estimates are based upon average annual demands. Water required for complete development of the fuel resources in the General Area of Coal Availability in Kansas would be 40.5 cfs, using the synthine process.

<u>Domestic.</u> The amount of water to be supplied for domestic purposes, as shown in table at the beginning of this chapter, is affected not only by the total number of workers (determined by the choice of process), but also by the proportion of those workers that would come from already established communities having their own water supplies. Again, in view of the small relative cost of water as compared with the other items contributing to total product costs, variations in conditions affecting domestic water requirements are relatively small. It is, therefore, assumed for this report that domestic water would have to be supplied for all the workers in plant and mine, the service people and the families of both. A per capita allowance of 150 gallons per day has been made uniformly for the population of the plant-city. This population is arrived at by multiplying the number of plant and mine workers by five. For the coal synthine process this amounts to 12,955 persons.

<u>Quality.</u> Process water must be relatively clear and free from turbidity and substances capable of clogging condenser tubes, cooling towers, and other equipment. The dissolved solids content is not of major importance except that a high concentration would require frequent blowdown of cooling towers and boilers and would increase the amount of make-up water. Boiler feed waters must be free of organic matter and insoluble solids and suitable for softening. Water for drinking and sanitary purposes in the mines and plants and in the communities serving the developments would have to be potable and of a quality satisfactory to the public health authorities of the State. Water softening might be required for domestic use.

<u>Water Resources</u>

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Water for synthetic liquid fuels plants in the Crawford-
75b Cherokee General Area in Kansas could be obtained from the Neosho
76a River, Marmaton River, Spring River, or from one or more of their
10 tributaries and possibly from ground water resources. Since the
0021 Neosho River and its tributary streams is the most logical source
of water supply in the Area, a detailed discussion of this possible
source is presented.

The principal references consulted for statistical and technical information used in conjunction with the water-supply sections of this report are listed in the Water Resources Bibliography, Exhibit No. 14. Acknowledgments for Technical Information on Water Supply, Exhibit No. 15, lists the individuals and agencies who rendered assistance in obtaining material for this report.

Neosho River Basin. This basin in Kansas is an elongated, irregularly shaped area of approximately 6,285 square miles. The basin is nearly 180 miles long and averages between 30 and 35 miles in width. It extends from the central easterly part of the State in a southeasterly direction to its point of discharge into the Arkansas River at Fort Gibson, Okla. The river is known as the Grand River in Oklahoma.

The boundaries of the valleys in the Neosho River basin are generally marked by sharp bluffs rising to considerable elevations above the level of the bottom lands. The valleys are smooth and vary in width from 1 to 4 miles along the main streams and principal tributaries. The principal tributaries of the Neosho River in Kansas are shown in the following table:

Principal Tributaries of Neosho River in Kansas

Stream	Drainage Area (Sq Mi)
Cottonwood River	1,830
Neosho River above junction with Cottonwood	825
Lightning Creek Cherry Creek Labette Creek Miscellaneous tributaries of Neosho River below junction with Cottonwood	3,125
Spring River	505
Total Neosho River Drainage Basin in Kansas	6,285

The total drainage area of the Neosho River basin to its confluence with the Arkansas River in Oklahoma is 12,600 square miles.

The runoff characteristics of the rivers in and near the Neosho River basin are indicated in the following table:

Stream Runoff Characteristics in Southeastern Kansas

Gaging Station	Marmaton River near Fort Scott, Kans.	Spring River near Waco Mo.	Neosho River near Parsons, Kans.
Drainage Area, (Sq Mi)	411	1,160	4,828
Period of Record	1922-24; 1930-48	1924-48	1923-48
Mean Flow, (Cfs)	298	936	2,421
Minimum Annual Flow (Cfs)	23.2	166	327
Year of Occurrence	1939	1934	1939
Minimum Monthly Flow (Cfs)	0.4	25.4	0
Month of Occurrence	Aug. 1934	Aug. 1936	Aug. 1936
Minimum Daily Flow (Cfs)	0	12	0
Date of Occurrence	Many days	July 24, 1934	Many days

A more complete tabulation of runoff records collected in the vicinity of the General Area is shown on Exhibit No. 16.

It will be noted that the minimum annual flows are very much less than the mean annual flows. The daily flow of the Neosho River near Parsons has been zero on more than 100 days during the past 25 years and similar conditions prevail on the other streams. The driest periods of record occurred during 1930-35 and 1939-41, and all estimates of storage required have been based upon the low flows during these critical periods. A hydrograph for the Neosho River near Parsons from September 1938 to December 1940 is shown on Exhibit No. 17. The stream flow records are not long enough to indicate how frequently such shortages can be expected, but in general, it is believed that the estimates represent conditions that will recur on the average not more often than once in 50 years.

Water Quality and Stream Pollution. Typical mineral analyses of the water from the Neosho River and the Marmaton River and other tributaries in the area are shown in Exhibit No. 18. It will be noted that none of the surface waters is excessively hard and that the total dissolved solids are generally considerably less than 500 ppm. The water would require filtration for domestic purposes and for some of the process uses, but otherwise could be used satisfactorily for cooling water without treatment. The Neosho River water temperature ranges from winter values of about 32 deg F to high values in the summer months of 90 deg F. The average temperature is approximately 60 deg F with summer temperatures generally somewhat above 80 deg F. The water is frequently turbid but could be used without difficulty for cooling and coal preparation.

Serious pollution from oil field brines has occurred in the past but is less important now that methods have been developed for re-injection of these wastes into subsurface formations. In the mining areas, the tributaries of the Neosho River are badly polluted by acid mine wastes. The Lowell Reservoir and the Spring River below the Lowell Dam sometimes are blanketed by deposits of iron oxide. Lightning and Cherry Creeks are highly acid at periods of low flow.

The nuisance caused by pollution and other difficulties experienced during periods of low flow and costly flood damages have encouraged activity in favor of river regulating works in the Neosho River basin. Both State and Federal authorities have recommended the construction of reservoirs for flood control and low flow regulation. In connection with these studies, the U.S. Public Health Service recommended that a minimum flow of 50 cfs be maintained in the Neosho River below Strawn in order to prevent nuisance.

Ground Water. Except for the municipal water supply at Pittsburg, there are no large ground water supplies in the southeastern part of the State. The Roubidoux sandstone is the best source of water and yields moderately good supplies for municipal and industrial use in the Tri-State district. This bed ranges from 70 feet to 200 feet in thickness and is found 700 feet below the surface at the Kansas-Missouri line and 1,200 feet below the surface in eastern Labette County. Water-bearing strata below the Roubidoux yield salt water that cannot be used for municipal or industrial purposes. Formations above the Roubidoux also yield some water but generally not in large quantities nor of quite such good quality. All of these water-bearing strata which dip gently to the west are fed through the out-crops in the Ozark Mountains of western Missouri. Most of the strata yield artesian water in the southeastern corner of Kansas, with the water rising to levels between 75 and 175 feet below the ground surface. The wells are generally 600 to 1,500 feet deep. There has been some decline in the ground water level in this part of the State during the past few years. The water supply for a single 10,000-barrel-per-day plant would be much larger than any existing ground water supply, and many wells spread out over a wide area would be needed to develop a water supply system of this size. While detailed study and test drilling in the Crawford-Cherokee General Area might prove ground water resources suitable for at least part of the synthetic liquid fuels demand, a surface water development is more promising and has been assumed in preparing cost estimates.

Quality. The character of the ground water in southeastern Kansas is indicated by the mineral analyses for the two wells in Labette County shown in Exhibit No. 18. This water is fairly hard with total solids in one of the wells ranging up to 801 ppm, and both waters have large amounts of iron that would have to be removed by treatment for domestic supplies. The temperature of ground waters in this area would normally range between 55 deg F and 60 deg F.

Water Uses - Existing

Before making a detailed analysis of the development of the possible water resources for synthetic liquid fuels plants, the rights of existing and future downstream users are to be considered.

Municipal and Industrial Uses. In the relatively humid eastern part of Kansas, the surface streams are the principal sources of water supply. According to the 1940 census there were 20 municipalities in Kansas having a population of more than 10,000 and all of these are located in the eastern half of the State. Thirteen of these municipalities obtain their water supplies from rivers or reservoirs. The principal ground water supplies are located along the Arkansas River at Hutchinson, Newton, Wichita, and Arkansas City, and there is one ground water supply in the Neosho River Valley at Pittsburg.

The Neosho River and its tributaries in Kansas furnish approximately 7 mgd or 11 cfs for municipal water supplies, and 3.4 mgd or 5.3 cfs for several large industrial water supplies. The principal municipalities taking surface water in the Neosho River basin are as follows: Emporia, 3.1 cfs; Parsons, 3.9 cfs; Chanute, 1.1 cfs; Iola, 1.1 cfs; and Council Grove, 1.0 cfs. The largest industrial water supply use is at the Lehigh Portland Cement Company near Iola. These water uses are chiefly nonconsumptive and none is large enough to have significant effect upon the stream flow of the Neosho River or its principal tributaries.

Large quantities of water from the Spring River which flows into the Neosho River near Wyandotte, Okla., are used by the Jayhawk Works of the Spencer Chemical Company near Galena and by the Empire District Electric Company near Lowell, Kans. The Jayhawk Works, built by the Federal Government as an ordnance plant, was taken over by the Spencer Chemical Company after the war. The consumption use of water at the works is between 2 and 3 mgd or 3.1 to 4.6 cfs; nearly 50 mgd is pumped from the river through the plant for cooling and process purposes and then back into the stream. The Empire District Electric Company uses Spring River water for condenser cooling and in the generation of hydroelectric power to meet peak loads. The Electric Company has filed a vested right claim under the Water Appropriation Act of 1945 to the waters of Spring River in a maximum amount of 222 cfs. The claims filed under this Act have not been processed by the State authorities, but it is believed that vested rights certificates will be issued in accordance with the claims. The Electric Company also has filed an application for a permit to appropriate 71.3 cfs in addition to their vested right.

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The Neosho River is of importance to this section of the State as a means for the disposal of sewage, and to a lesser extent, for the disposal of industrial wastes. Most of the principal towns in the Neosho River basin have sewage treatment plants and complete treatment is provided at the larger cities such as Emporia, Parsons, and Pittsburg. Some of the plants were built many years ago and are inadequate for the population presently served. The industrial wastes are principally from dairies and packing plants.

Control Flow. In estimating the amount of water available for synthetic liquid fuels production, it has been assumed that it would not be practicable or desirable to divert water for such purposes during periods when the river flows were extremely low. In the case of the Neosho River, it has been assumed that water would not be taken from the river at any time when the flow was less than 50 cfs near Parsons, Kans. In preparing mass diagrams for estimating the storage required on the smaller rivers, it has been assumed that water would not be impounded at any time when the stream flow was less than the flow that normally is exceeded 90 percent of the time. This allowance for downstream water uses is defined in this report as the "control flow". The existing water uses along most of the tributary streams are nominal, and the allowance made is considered adequate.

Flood Control and Conservation. There are already numerous small reservoirs on the upper Neosho River in Kansas, but none of these are large enough to provide adequate stream regulation or flood control. The principal existing storage reservoirs in the Neosho River basin in Kansas are as follows:

Principal Existing Storage Reservoirs in Neosho River Basin in Kansas

Reservoir	Stream	Purpose	Capacity (Acre-feet)
Yates Center	Owl Creek	Water Supply	610
Santa Fe	Tributary near Chanute	Water Supply	580
Lake Neosho	Tributary near Parsons	Recreation	756
Kahola	Kahola Creek	Water Supply	6,600
Marion County Lake	Woolford Creek	Recreation	2,472
Council Grove	Canning Creek	Water Supply	8,400
Total Capacity of Reservoirs			19,418

In addition to these reservoirs there are at least 150 small farm ponds, ranging in capacity from 1.5 to 150 AF.

Water Uses - Proposed

Potential water uses which might affect synthetic liquid fuels development and which are under consideration by the U.S. Corps of Engineers and other agencies are discussed in this section. Future water uses which might arise from the development of synthetic liquid fuels plants are discussed in a later section of this report entitled "Water Available for Synthetic Liquid Fuels Development".

Flood Control and Conservation. The Flood Control Act of 1936 authorized the construction of three large reservoirs on the Neosho River (Grand River), all to be located in Oklahoma below the Kansas State line. These reservoirs are as follows:

Reservoirs on the Neosho River (Grand River)
Authorized by Flood Control Act of 1936

	Storage in Acre-feet		
Name	Flood Control	Power	Total
Pensacola	540,000	1,650,000	2,190,000
Markham Ferry	233,000	187,000	420,000
Fort Gibson	922,000	365,000	1,287,000
Total	1,695,000	2,202,000	3,897,000

The Pensacola Reservoir was completed in 1941, and construction of the other two reservoirs has been started. For protection of the upper Neosho River basin, the Corps of Engineers recommended the construction of five reservoirs on the tributary streams and main stem as follows:

Dam and Reservoir Projects

	Neosho River at Council Grove	Cotton- wood River at Marion	Cedar Creek at Cedar Point	Neosho River at Strawn	Spring River at Waco, Mo.
Drainage Area (Sq Mi)	250	206	121	2,910	1,150
Reservoir Storage (AF)					
Flood Control	60,000	60,000	36,000	322,000	286,000
Conservation	20,000	27,500	17,000	16,000	-
Sedimentation	5,000	2,500	1,800	36,000	14,000
Total AF	85,000	90,000	54,800	374,000	300,000
Maximum Pool Elevation (Feet)	1,288	1,352.5	1,307.3	1,082.2	896.1

The Kansas officials have looked favorably upon the construction of other smaller reservoirs in the upper basin, but the Army has rejected some as not justified for flood control purposes alone. The State of Missouri objected to the construction of a large flood control reservoir at Waco on the Spring River, and this has been eliminated from the flood control project. Construction of the remaining four dams at Council Grove, Marion, Cedar Point, and Strawn, was authorized by the Congress in 1950. No appropriations have been made and when construction will start is not known.

A small part of the Crawford-Cherokee General Area extends over into the Marmaton River basin in Bourbon County. The Corps of Engineers has proposed as part of a comprehensive plan for flood control and improvement of the Osage River, a large reservoir on the Marmaton River near Fort Scott. This reservoir would have a capacity of 137,000 AF, of which conservation storage is estimated at only 6,250 AF.

Water Rights

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The appropriation doctrine of water rights is applicable
to the surface and ground water rights of Kansas. Under the appro- 82b
priation doctrine, the user of water from a stream first in time is 83a
first in right and has the right to continue his use without in- 10.
terference by later appropriators so long as the use is beneficial. 70021
The appropriative principles as they are applied to ground waters recognize the ownership of such waters by the public, subject to appropriation for beneficial use. The place of use need not be on lands which overlie the source of ground water supply.

In 1945, the Kansas Legislature passed a general act which provides that every person intending to acquire an appropriation right to any of the waters of the State for beneficial purposes other than domestic use, may do so by making application to the Chief Engineer of the Division of Water Resources, State Board of Agriculture. All applications are approved if the proposed use does not interfere with an existing use and does not prejudicially and unreasonably affect the public interest. Upon the completion of the work and the application of the water to the proposed use, a certificate of appropriation will be issued granting the right to use the water for definite beneficial purposes and at a definite location, subject to prior rights. The right terminates upon failure to execute the right for three years.

Application of the appropriation doctrine to surface waters allows the first appropriators to take water at all times, the later appropriators being limited to the remainder during periods of higher flow. In applying the appropriation doctrine to ground waters, certain difficulties arise. One interpretation holds that those users whose aggregate appropriations fall within the limit of recharge and whose appropriations do not result in the progressive lowering of the water table, might be entitled to the continuous withdrawal of water, while later applicants would then be denied any part of the water supply. The administration of the appropriation doctrine with regard to ground water is difficult, especially in western Kansas where large quantities of water are stored underground, but where recharge is relatively limited. In any event, the Chief Engineer of the Division of Water Resources is authorized to deny or limit the development of wells in areas of high pumpage.

Dams and diversion works are under the jurisdiction of the Division of Water Resources.

Kansas is a party to compacts with Colorado and Nebraska for division of the waters of the Republican River, and with Colorado for the division of the waters of the Arkansas River.

The Kansas State Board of Health maintains supervision over public water supplies, and plans for such works must be submitted to the Board. This jurisdiction does not extend to industrial water supplies, except where they serve 10 or more families with water for domestic purposes.

Kans Water Available for Synthetic Liquid Fuels Development

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84a Water supply for synthetic liquid fuels development in
10 Kansas could be obtained economically from the Neosho River and
70021 its tributaries. However, since the minimum flow of the river is not great enough to supply even a unit synthetic liquid fuels plant, reservoirs for low flow regulation would be required.

If some of the proposed reservoirs on the Neosho River were built for flood control and for low flow regulation, undoubtedly there would be enough water available from these reservoirs to meet the requirements of one or more synthetic liquid fuels plants. However, in the absence of definite information as to the availability of water and the date when such reservoirs might be constructed, these projects have not been considered in developing water supplies or in estimating costs for synthetic liquid fuels plants.

There are numerous sites where reservoirs adequate for this purpose could be built. These include sites on Lightning Creek, Canville Creek, and Big Creek in Kansas, and Spring River in Missouri.

The storage to be provided in reservoirs on small tributary streams has been estimated on the basis of the stream flow records during the drought periods of 1930 to 1935, and 1939 to 1941. Mass diagrams and storage-yield curve based on the runoff of the Neosho River are shown in Exhibit No. 19. If the water supply was pumped from the Neosho River itself, storage would be needed only for regulation of low stream flows and the reservoir could be substantially smaller. However, in this case, much of the water released from the reservoir might be lost by evaporation or seepage into a dry river bottom.

In estimating the quantity of storage to be provided, the control flow has been included as an existing water use that would not be available for synthetic liquid fuels production.

An allowance for the evaporation loss from the reservoir has been calculated at a maximum of 8 feet extending over the maximum drought period, times the surface area of the reservoir at two-thirds full capacity. Siltation has been allowed for at the annual rate of 1 AF per square mile of drainage area tributary to the reservoir for a period of 40 years.

If future development of other tributaries of the Neosho River should make it necessary to use the Spring River as a source of supply for synthetic liquid fuels plants, sufficient water could be obtained without infringing upon existing rights by building suitable storage reservoirs on one or more of the branches of the Spring River.

The proposed Army reservoir on the Marmaton River near Fort Scott could be built to provide additional water supply, if necessary, and it could serve conveniently the northern part of the coal area in Kansas.

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<u>General Area of Coal and Water Availability</u>

In view of the foregoing discussion with respect to water, it appears that the General Area of Coal Availability previously established and shown on the map, Exhibit No. 10, would have available water sufficient for at least one 10,000-barrel-per-day synthetic liquid fuels plant. Consequently, the Crawford-Cherokee General Area may be classed as a General Area of Coal and Water Availability for the purpose of this report.

PART V - SUITABILITY OF GENERAL AREA

COAL

Area of Coal and Water Availability

The Crawford-Cherokee General Area of Coal and Water Availability in Kansas, which was demarcated after preliminary study as being capable of supplying raw material for synthetic liquid fuels production, was next studied in detail from an economic standpoint to ascertain its further general suitability for synthetic liquid fuels production. This General Area is underlain by approximately 200 square miles of coal reserves. Available information indicates that sufficient quantities of coal are recoverable to support one or more 10,000-barrel-per-day plants over a period of 40 years, of which 20 years' supply is from primary reserves and the additional 20 years' supply is from secondary reserves. The total usable reserves are recoverable either by strip or underground mining, or by a combination thereof.

Detailed estimates of coal producing costs are shown in Exhibit No. 20. Basic data on coal bed characteristics, estimates of recoverable reserves, estimated capital cost requirements, and estimated cost of coal supply per barrel of synthetic liquid fuel final products, are presented in Exhibit No. 21.

Coal Characteristics and Properties
(See Exhibit No. 5 for references below)

Rank and Chemical Analysis. Descriptions and evaluations of the chemical and physical characteristics of the coal reserves in the Crawford-Cherokee General Area are generally available. These reserves, located in three principal coal beds, range from high-volatile B bituminous (Hvbb) to high volatile A bituminous (Hvab) in rank. Ranges in items of typical analyses of coal samples, generally mine samples, (as-received basis) selected by the coal subcontractor as representative as possible of the reserves or beds under consideration follow:

(References: 9, 7, 12, 14, 17, 20, 21, 23, 25, 26, 30, 34, 36, 39, 40, 41)

Representative Analyses of Coal Reserves
in Crawford-Cherokee General Area
from Face Samples, As-received Basis

Coal Bed	Moisture (Percent)	Ash (Percent)	Sulfur (Percent)	Btu per Pound
Weir-Pittsburgh:				
Maximum	6.1%	9.2%	3.5%	13,080
Minimum	5.1	8.3	3.3	12,690
Bevier:				
Average	5.0	14.5	3.3	11,790
Mineral:				
Maximum	4.5	12.9	4.1	12,530
Minimum	4.2	12.7	3.4	12,380

Detailed analyses and other characteristics of the coals are presented in Exhibit No. 21 of this report.

Type and Petrographic Analysis. The Bureau of Mines gives results of one petrographic assay on a Bevier coal in Kansas, in percentages as follows:

County	Bed	Anthraxylon	Translucent Attritus	Opaque Attritus	Fusain
Cherokee	Bevier	68	22	6	4

This analysis indicates that the coal is of the "bright" petrographic type, wherein anthraxylon and translucent attritus predominate, with opaque attritus and fusain being present in minor amounts. No data are available on the remaining two beds, but they are closely similar in rank and visual and chemical composition to the Bevier coal on which the above petrographic assay was made, and there is no reason to expect any substantial differences in the degree of heterogeneity or adaptability to hydrogenation of the Kansas coals.

The value of petrography in predicting hydrogenation yield lies in the fact that the degree of heterogeneity of lithologic components is readily indicated and the approximate proportion of high-carbon opaque constituents (difficult to liquefy) are revealed, whereas chemical analysis represents only the average composition of unlike components existing in undetermined proportions in the sample.

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Organic and Inorganic Sulfur Content. Information on the organic and inorganic sulfur content of Kansas coal beds is limited. These beds, however, are similar in rank and chemical composition to other midwestern coals, such as those in Indiana and Illinois, for which sulfur determinations have been made, indicating that organic sulfur represents from 30 to 40 percent of the total sulfur content. It is herein assumed, from such results, that organic sulfur, which is not considered as amenable to reduction by mechanical cleaning, represents from 30 to 50 percent of the total sulfur in the original coal in Kansas.

The reduction of inorganic sulfur by mechanical cleaning of the coal, if possible, should result in a cleaned product with decreased total sulfur content. The extent of such reduction, however, depends upon the amounts, sizes and types of occurrences of the pyritic or inorganic sulfur-bearing ingredients in the raw coal. Since representative total sulfur contents of coal reserves in the Crawford-Cherokee General Area range between 3.3 and 4.1 percent on the as-received basis, it appears probable that the percentage of organic sulfur content would range between 1.0 and 2.0 percent. The remainder of the total sulfur would then be considered to be pyritic sulfur. Further study of Kansas coals is necessary, however, to establish the composition of sulfur in the coal and to evaluate the reduction which might become possible by mechanical cleaning.

Storage, Weathering, and Slacking Characteristics. The high volatile "A" and "B" bituminous rank coal reserves in the Crawford-Cherokee General Area are similar to other coals of equal rank in weathering and slacking characteristics and present no particular problems when stored properly. These coals slack readily, but do not ignite spontaneously when exposed to air. These characteristics reduce the problems of coal storage necessary in synthetic liquid fuels manufacture. Surge storage at the mine would be necessary to provide daily shipments to the synthetic fuels plant because the mines probably will operate only two shifts per day for five days each week, while the synthetic liquid fuels plant will operate continuously three shifts per day throughout the year. It is probable that substantial additional storage facilities will be necessary at the process plant to protect it from interruptions or decreases in production at the coal mines and from possible transportation stoppages between mine and plant. As only cleaned coal will be stored in volume, no especial hazards are expected, and the coal may be stored in necessary quantities for indefinite periods. Costs of surge storage at the mine, together with those of handling the coal into and out of storage, are provided for in the estimates of mine capital investment and mine production costs. Estimates of required working capital for the process plant allow for reserve storage of a 30 day coal supply. Facilities for such storage and their operation are included in process plant costs.

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Grindability and Friability. Information on grindability of the coals in the Crawford-Cherokee General Area indicates that they are similar in grindability to comparable industrial coals and will respond without undue difficulty to fine grinding. The degree of ease with which a coal may be pulverized depends not only on its relative grindability index, but also upon the fineness of grinding and on its moisture content. The standard of grindability (Hardgrove index 100) is arbitrarily selected, according to American Society for Testing Materials, as represented by low volatile run-of-mine bituminous coal from the Jerome Mine, Upper Kittanning Bed, Somerset County, Pennsylvania. Coals of low surface moisture content, such as those in Kansas, accelerate pulverization by their lack of tendency toward coherence and formation in cakes.

The relative grindability index of the coals in Kansas ranges between 59 and 74, with an average of 67, as related to the standard coal with an index of 100. Available grindability data indicate that the Mineral bed has an index of 59, for a single test. Reliable test data are not available for the other coals. The relatively low index numbers indicate that Kansas coals resist pulverization to a greater extent than the standard coal, requiring an increase in pulverizer capacities, which results in an increase in the cost of pulverization over that of a coal with an index of 100.

In addition to grindability, the comparative ease of crushing varies directly with the friability percentage of the individual coals. Information on the friability of the Kansas General Area coals indicates that they are comparable with other high volatile "A" bituminous coals in the respect that they crumble easily due to handling and show a relatively high friability percentage.

Nature of Partings. The available information on Kansas coal bed characteristics indicates that the majority of the beds frequently contain thin bands and lenses of pyrite and sulfur-bearing bands of shale. The beds are cut by numerous clay veins and may also be partially displaced with rolls and "horsebacks". Under shallow cover the upper 1 ft 0 in. of the coal beds tends to be oxidized and discolored. The roof strata are generally gray shales of varying degrees of hardness, with soft gray calcareous shale occurring in some areas. The floor is commonly a pyritiferous underclay, locally called "black jack", which is soft and tends to heave. This bottom material frequently becomes mixed with the coal, in mining. The Weir-Pittsburg bed is fairly uniform in quality, without bone or shale bands, but locally containinghorsebacks or rolls, which displace all or portions of the coal bed. The coal is overlain by gray shale and underlain by black bituminous underclay. The above factors were taken into consideration in estimating mine investment and operating costs.

Mechanical Cleaning. While the presence of partings in Kansas coals is generally not such as to seriously interfere with mining operations, they do affect the type and capacity of the necessary cleaning facilities and the amount of refuse that must be handled during the cleaning process.

Data on washability characteristics and performance of Kansas coals are limited. One test by the Bureau of Mines on strip-mined coal from the Bevier bed indicated that the plus 1-1/2 inch lump coal, as mined, contained 9 to 10 percent ash, but that when crushed to minus 1/4 inch and washed, the resultant product contained approximately 7 percent ash, on the dry basis. Information on other General Area coal beds is lacking, but these beds are similar in character, number, and thickness of contained partings to other bituminous coals of comparable rank and grade on which washability tests have been made. Such data indicate that Kansas coals are generally amenable to commercial-type cleaning. With installation of relatively simple facilities for removal of solid impurities and other high-ash refuse, the cleaned mine products from the Crawford-Cherokee General Area in Kansas should contain ash contents ranging from 7 to 11 percent on the as-received basis. Since removal of ash-forming constituents from raw bituminous coal generally includes the rejection of a portion of the pyritic sulfur, total sulfur contents of the cleaned coal should range from 2.0 to 3.5 percent, depending on the nature, distribution and total amount of sulfur occurring in the coal bed as mined. Available information indicates that mechanical cleaning of Kansas coals, in addition to reduction of ash and sulfur, also reduces the proportion of opaque lithologic constituents in the raw coal, thus improving amenability to hydrogenation. Information on specific quality of the cleaned coal resulting from mechanical preparation, however, requires further washability investigations of typical samples of the available coal reserves.

The foregoing discussion of washability of Kansas coals applies only to the preparation of raw coal from the available reserves to a "merchantable" quality, as would be done in ordinary commercial practice. The possibilities of further reduction of ash, sulfur, and opaque constituents for purposes of hydrogenation require additional study beyond the scope of this phase of the synthetic liquid fuels survey and are not herein considered.

Modern mechanical mining, because of its lack of selectivity at the working face, requires mechanical cleaning facilities to obtain economic production costs. Mechanical cleaning also insures the removal of solid impurities which might otherwise
Kans severely damage pulverizers or other synthetic liquid fuel plant
90b equipment. Provision is made in the estimates of capital and pro-
91 duction costs for a mechanical cleaning plant designed simply to
3 remove solid and high-ash impurities from the mine-run coal. There
70021 is no indication that such cleaning would present any unusual problems or require abnormal expenditures.

Mine Waste Disposal. The refuse from the coal preparation plant at the mine is expected to consist largely of shale partings and contaminating material from roof or floor, together with some bone and fusain from the coal bed. According to Bureau of Mines report on bituminous coal for 1948, the ratio of refuse to raw coal which was cleaned in Kansas was 21.0 percent. On the basis of 21.0 percent of refuse from the total raw coal moved to cleaning plants, the estimated percentage of refuse to clean marketable coal would be 26.6 percent. At 26.6 percent of daily production of merchantable coal, the refuse would be about 1,590 tons per working day or 381,600 tons per year, equivalent to 254,400 cubic yards, based on supplying merchantable coal to a hydrogenation plant; and about 2,040 tons per working day or 489,600 tons per year, equivalent to 326,400 cubic yards based on supplying merchantable coal to a synthine plant.

The disposal of this type and quantity of refuse presents no particular problems. It could be transported by tramway or by trucks from the preparation plant to nearby mine property, or to selected areas of rugged land, or other land unfit for farm use, of which there are many acres in the Crawford-Cherokee General Area. With proper precautions, the possibilities of contamination of water supply would be negligible. The estimated capital and operating costs hereinafter established in this report provide for waste disposal from the coal preparation plant, assuming that the waste-disposal tract is within three miles of the coal preparation plant.

Hydrogenation Yield. No data are available on the hydrogenation yield of the coals in the Kansas General Area. The degree of liquefaction of coals by hydrogenation is, roughly, inversely proportional to their moisture- and ash-free carbon content, as determined by ultimate analysis. Coals with high carbon contents are generally low in liquefaction yield. Normal carbon contents (maf) range from approximately 55 percent in peat to 95 percent in anthracite. The coals in the Crawford-Cherokee General Area in Kansas range in carbon content (maf) between 81.7 and 84.6 percent, with an average of 83.3 percent in the Weir-Pittsburg bed, and between 78.7 and 82.2 percent with an average of 80.3 percent in the Bevier bed. These coals are similar in rank and quality to other coals which have been assayed by the Bureau of Mines, and it is reasonable to expect a relatively suitable hydrogenation yield from them, although the suitability of a particular coal for hydrogenation purposes can best be determined by actual tests.

Land Ownership, Coal Rights, and Surface Valuation

(See Exhibit No. 5 for references below)

Private Ownership and Purchase Costs. Essentially all coal-bearing lands in Kansas are privately owned. Underground coal

(References: 5, 37)

areas without surface rights are available at costs ranging from $25 to $150 per acre, depending on thickness, quality, and location of the coal bed. Strippable coal areas with surface rights are available at costs ranging from $40 to $200 or more per acre, depending on the thickness and location of coal and the agricultural value of the specific property. Coal reserves in areas of unusually favorable mining conditions or locations may cost up to 25 cents per ton on a lease or royalty basis. Surface land values range from $30 to $100 per acre. Stripped-over surface lands are commonly valued at $5 per acre.

Legislation Affecting Production of Coal

Taxes. Real estate taxes in Kansas average 3 percent on assessed valuations based on 100 percent of full cash value, as determined by the local taxing officials. Taxes on personal property take the same rate, with assessed valuations generally being 100 percent of the true cash value. Coal lands held in reserve for mining by coal companies are only assessed the normal tax. Other taxes such as corporate organization and qualification fee, corporation franchise tax, and intangible tax are nominal and would not apply to coal mining if conducted as a captive operation with all production going to a synthetic liquid fuels plant. The State levies a corporate income tax of 2 percent.

Restitution of Surface Damaged by Mining. There is no specific legislation in Kansas which requires restoration of surface damaged by strip mining, or payment of damages resulting from subsidence caused by underground mining.

Production Costs

(See Exhibit No. 5 for references below)

The data on coal bed occurrences in the Crawford-Cherokee General Area are in no wise sufficient in scope or in detail to permit the preparation of actual layouts and of specific estimates of mining costs based thereon. Extensive drilling programs are necessary before precise location and extent of reserves available for mining can be determined. Comprehensive engineering studies, based on the results of the drilling programs, will then be necessary to determine the equipment and methods of mining best adapted to the efficient and economic production of fuel for synthetic liquid fuels plant supply. The estimates of coal production costs hereinafter presented are necessarily generalized in nature and are based on the assumption that thorough drilling and engineering will

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(References: 29, 38, 42)

precede any development of mining operations in connection with coal supply for synthetic liquid fuels manufacture, thereby permitting more precise estimates of costs.

In estimating over-all mining costs for the General Area in Kansas as of March 31, 1950, the total estimated investment costs are considered to include erection of all necessary mine structures, together with purchase and installation of all necessary operating equipment. They also include investment costs of facilities for transporting the output from two or more adjacent mining operations to a joint preparation plant, a mechanical cleaning plant designed largely to remove solid and high-ash impurities from the raw fuel, waste disposal from the preparation plant, sufficient coal surge storage at the mine to provide uniform daily shipments to the synthetic liquid fuels plant, engineering, development, and contingencies. While the estimated investment costs do not include purchase price of surface or coal lands, a royalty charge of $0.10 per ton of cleaned coal for underground mining, and of $0.15 per ton of cleaned coal for strip mining, as included in producing costs, is considered to represent the cost of acquisition of coal reserves. In the case of strip mining, the royalty figure of $0.15 per ton is also considered to provide for the return of a portion of the cost of necessary surface acquisition, or its equivalent, through reclamation and reuse after strippable reserves are depleted.

In estimating producing costs for the General Area in Kansas, separate consideration was given to each of the following principal items of cost, their total being taken as the total producing cost per ton of cleaned coal:

(1) All labor. This item incudes all labor costs paid in the form of wages for mining (pieceworkers and dayworkers) and for yardage and dead work and in the form of salaries paid to supervisory, technical, and clerical employes at the mines. Weighted average wage rates were calculated from the schedules of wages established by the National Bituminous Coal Wage Agreement of 1950 for the various mining districts, with suitable adjustment for the concentration of high-wage workers in a fully mechanized underground or stripping operation. The labor cost per ton was calculated by dividing the estimated weighted average daily wage rate by the estimated productivity in tons of cleaned coal per man-shift.

(2) Vacation payments. This item represents the vacation allowance of $100 per year to each employe, where applicable, and is computed by dividing $100 by the

estimated annual production per man (240 days times productivity per man-shift). In actual practice this may be increased slightly due to injured men or others carried on the payroll but not actually engaged in production.

(3) Welfare fund. This item represents a flat payment of $0.30 per ton which is paid into the U.M.W.A. welfare fund for each ton of coal produced for use or for sale in accordance with the National Bituminous Coal Wage Agreement of 1950.

(4) All supplies. This item includes the costs of all materials and supplies used in mining and in operating the mine equipment and facilities, including the maintenance and repair of mine structures and equipment. Additional included costs consist of freight, drayage, expressage and storage of supplies, mine office supplies, fuels other than coal, and rentals of equipment. The costs of such supplies per ton are estimated at $0.81 for underground operations, and $0.96 for stripping operations.

(5) Power. This item includes the cost of all power requirements at the mining operations, whether purchased from outside sources or produced by a mine-operated central power station. It also includes the cost of any coal required to produce heat at the mine. While small variations in cost of power may be expected to exist among the General Areas considered in this survey, an assumed cost of $0.15 per ton is herein employed for estimating purposes.

(6) Payroll taxes. This item includes the costs of social security (old-age benefits), unemployment taxes, and any other Federal or State taxes levied upon the amount of the payroll. These taxes average approximately 4 percent of the labor cost.

(7) Other taxes, insurance, miscellaneous. This item includes the following types of costs:

a. Real estate, personal property, and other taxes on mine property and equipment, including reserves. These taxes may range from 1 to 6 percent of the fair cash value of the property as established by the local assessors, depending on locality.

b. Corporate, privilege, and severance taxes which average approximately $0.02 per ton.

c. Workmen's compensation and vocational disease insurance, including the sums paid to an insurance company or to a State fund for protection of the employes, which aggregate approximately 5 percent of the payroll.

d. Other insurance such as fire, tornado, and other classes of insurance applicable to the mine property which is estimated to average approximately $0.01 per ton.

e. Costs arising from unforeseeable and unpredictable conditions of all kinds which are herein estimated at a flat rate of $0.10 per ton. This item is added to the producing costs as estimated in this survey because of the limited available information on mining conditions in the General Area.

(8) Depreciation. This item represents the cost of providing for replacement of the mining facilities and equipment at the end of their useful life. In determining producing costs the weighted average useful life of all items of mine property and equipment, exclusive of coal reserves, is estimated to be 15 years. The rate of depreciation, accordingly, is taken at 6.67 percent of the initial investment.

(9) Royalty or depletion. As discussed in a preceding paragraph, the estimated investment costs do not include the purchase costs of surface and coal properties. A royalty charge of $0.10 per ton of cleaned coal for underground mining and of $0.15 per ton of cleaned coal for strip mining is herein considered to represent the cost of acquisition of coal reserves.

(10) Engineering, management, administration. This item includes the costs represented by salaries and expenses of administrative, management and engineering personnel, together with salaries of associated assistants, bookkeepers, clerks, and stenographers. It also includes legal expenses and office expenses, or rent, including depreciation on office equipment. The cost of this item is herein estimated at $0.10 per ton.

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The maximum ranges in daily and annual synthetic liquid fuels plant and mine requirements for the production of 10,000 barrels of synthetic liquid fuel final products per calendar day in the General Area, based on 98 billion Btu per calendar day for the hydrogenation process and 126 billion Btu per calendar day for the synthine process, may be summarized as follows:

Range in Daily and Annual Coal Requirements for a Unit Plant

	Maximum Btu Value		Minimum Btu Value	
	Hydrogenation	Synthine	Hydrogenation	Synthine
Average Btu content of coal (as-received)	12,770(A)	12,770(A)	12,200(B)	12,200(B)
Tons per day -				
Plant (365 working days)	3,837	4,933	4,016	5,164
Mine (240 working days)	5,835	7,502	6,108	7,854
Annual requirements (thousands of tons)	1,400	1,800	1,466	1,885

Note: (A) Underground.
(B) Strip.

Although estimated aggregate recoverable reserves in the Crawford-Cherokee General Area are sufficient to supply synthetic liquid fuels plants having a combined capacity of from 20,000 to 26,000 barrels a day for 40 years, depending on whether the synthine or hydrogenation process is used, the following estimates on coal production costs are based on the capacity of mine operations necessary to supply one 10,000 barrel-per-day unit synthetic liquid fuels plant.

Strip Mining Cost. Because of inherent limitations in uncovering capacity of single stripping units, and to minimize the effects of such hazards as failure of excavating, loading, or transportation equipment, it is assumed that mining would be conducted in two or three separate pits from which coal would be handled through joint facilities, including a central preparation plant, to the transportation system by which the coal would be delivered to the synthetic liquid fuels plant. Surge storage facilities at the mine would be provided at or near the joint facilities to assure continuous supply for year-round, three-shift-per-day operation of the synthetic liquid fuels plant from mine operations on a five-day-per-week, two-shift-per-day basis.

Approximate capital investments required for production of synthetic liquid fuels plant supply by strip mining in quantities cited hereinbefore are estimated, as of March 31, 1950, to be $5,864,000 to supply a hydrogenation plant and $7,540,000 to supply a synthine plant. Factors affecting strip-mine investment costs are depth and character of the overburden and quantity and quality of the coal. The quantity to be mined is governed by the Btu content and by the specific synthetic liquid fuel process in which the coal is to be used. The quality affects the type and capacity of preparation facilities necessary to produce a merchantable coal.

Actual producing costs for strip mines in Kansas have been relatively the same as the average for the United States, the figures having been $2.10 per ton for the United States and $2.02 per ton for District 15 (Kansas, Missouri, Texas, and northern Oklahoma) in 1945, according to Economic Data, Office of Price Administration, for that year.

An estimated over-all labor productivity in new operations, measured by the average tons produced per shift per man employed in the stripping operations and in necessary auxiliary facilities, may be partially based upon experience at present stripping operations because of their relatively high degree of mechanization and their comparable capacity of output.

The Bureau of Mines statistics on bituminous coal production in 1948 indicated that average productivity in stripping operations in Kansas by counties ranged from 3.66 to 15.29 tons per man-shift, averaging 13.48 tons for the entire State. Assuming that the installation of modern high-capacity operations, including the purchase and use of large stripping shovels, draglines, trucks, and other modern equipment, would result in an estimated productivity of 12 tons per man-shift in the difficult mining conditions characterizing the Crawford-Cherokee General Area, the estimated costs of strip mining are as follows:

Estimated Costs of Strip-mine Production
in the Crawford-Cherokee General Area
(As of March 31, 1950)

	Btu per Pound of Coal	Tons per Man-shift	Cost per Ton	Cost in Cents per Million Btu
Crawford-Cherokee	12,200	12	$3.55	14.55¢

Details of above estimated costs are shown in Exhibit No. 20. Attention is directed to the thinness of these coal beds estimated to average 18 to 22 inches thick, so that even a small reduction in thickness of coal mined would in itself tend toward materially increased production costs, while any reduction in the percentage of coal that could be recovered because of its thinness, will tend to further increase such production costs. They are based on retirement of the property in 15 years, and exclude selling expense. Estimates of labor cost are based on weighted average wage rates resulting from the 1950 wage agreement.

These costs reflect the concept of most efficient applications of present-day strip mining methods and equipment. Opportunities for possible future improvements of mining methods or equipment in areas similar to Kansas probably best await potential development of high-speed, high-capacity excavating, loading, and hauling equipment. It is not possible at this time, however, to predict successful development and application of such equipment to Kansas coal reserves, or to estimate possible future saving in producing costs which might accrue through their use.

Underground Mining Cost. Because of inherent limitations on transporting coal to the surface and to minimize the possible effects of such hazards as mine fires, roof falls, floods, etc., it is assumed that the annual requirements in the Crawford-Cherokee General Area would not be obtained through a single opening. From two to three underground mining operations would probably be opened, at appropriate intervals, for concurrent operations. Although obtained from separate underground operations, it is assumed that the raw coal would be handled through joint surface facilities, including a central preparation plant, to the transportation system, by which the coal would be delivered to the synthetic liquid fuels plant. Surge storage facilities at the mine would be provided, at or near the joint surface facilities, to assure continuous supply for year-round, three-shift-per-day operations of the synthetic liquid fuels plant from mines operating on a five-day-per-week, two-shift-per-day basis.

Approximate capital investments required for underground production of synthetic liquid fuels plant coal supply in the quantities previously cited are estimated as of March 31, 1950, to be $7,000,000 to supply a hydrogenation plant and $9,000,000 to supply a synthine plant. Factors affecting mine investment costs are depth and character of the bed and its associated strata, together with quantity and quality of the coal. The quantity to be mined is governed by the Btu content and by the specific synthetic liquid fuels process in which the coal is to be used. The quality affects the type and capacity of preparation facilities necessary
Kans to produce a merchantable coal.

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99a Actual producing costs for mechanical underground mining
3 in the southwestern states have been relatively higher than average
0021 costs for the United States, these having been $2.64 per ton for

the United States and $3.14 per ton for District 15 (Kansas, Missouri, Texas, and northern Oklahoma) in 1945, according to Economic Data, Office of Price Administration, for that year.

Estimated over-all labor productivity in new operations, measured by the average tons produced per shift by each man employed in the underground operation and in necessary surface facilities, cannot be based upon experience at present underground operations because of their limited experience in mechanization and their low productivity.

Bureau of Mines statistics on bituminous coal production in 1948 indicated that Kansas underground mines had an average productivity of 2.62 tons per man-shift. Assuming that the installation of modern high-capacity operations, including the purchase and use of all necessary mechanical equipment, would result in an estimated productivity of 5 tons per man-shift for the underground mining conditions in the Crawford-Cherokee General Area, the estimated costs of production by underground operations are as follows:

Estimated Costs of Production
by Underground Operations
in the Crawford-Cherokee Area
(As of March 31, 1950)

	Btu per Pound of Coal	Tons per Man-shift	Cost per Ton	Cost in Cents per Million Btu
Crawford-Cherokee	12,770	5	$5.19	20.32¢

Details of these estimated total costs are shown in Exhibit No. 20. They are based on retirement of the property in 15 years and exclude selling expense. Estimates of labor cost are based on weighted average wage rates resulting from the 1950 agreement.

These costs reflect the concept of most efficient appli- Kans
cation of present-day underground mining methods and equipment. 99b
Opportunities for possible future improvements of mining methods 100a
or equipment in areas similar to Kansas probably best await de- 3
velopment of: (1) high-capacity loading equipment especially de- 70021
signed for longwall mining as practiced in the United Kingdom, and
(2) low-seam continuous mining machines which combine cutting,

drilling, blasting, and loading operations, now under scrutiny and development at a number of points in the United States. Both of these types of equipment are being actively tested, and, when perfected, could result in changes in mining methods which would reduce the estimated producing costs in Kansas. It is not possible at this time, however, to predict the successful application of such equipment to Kansas coal reserves or to estimate possible future savings in production costs which might accrue through their use.

In considering possible revolutionary techniques in utilizing areas of coal reserves, the underground gasification of coal in place offers considerable potential promise since it would eliminate the relatively costly processes of mining the coal and gasifying the mined output in gas generators to produce synthesis gas. This method of utilization would also provide a low-cost fuel for power generation and would permit utilization of coal from beds which would otherwise be costly or uneconomic of operation. The results of experiments in underground gasifications now in progress by the Bureau of Mines and the Alabama Power Company indicate that the process has distinct possibilities and is worthy of continued experimentation. It is not possible at this time, however, to predict the successful application of this method of utilization to the coal reserves in the one General Area in Kansas.

Coal Transportation. Provision has been made in the estimated capital and operating costs for transportation of coal from the several mine openings to a joint distribution point for handling onto the transportation system by which the coal is delivered to the synthetic liquid fuels plant. As elsewhere indicated, it has been assumed for the purposes of this survey that the site of the synthetic liquid fuels plant would be located within a three-mile radius of the mining operations. Under this assumption no additional facilities or costs for transportation, other than that provided for in the estimates of costs already established, are contemplated.

Coal Supply from Present Operations. Bureau of Mines data on bituminous coal production in 1948 indicate that one synthetic liquid fuels plant in the Crawford-Cherokee General Area could have been supplied with sufficient coal in that year to have produced synthetic liquid fuel products at the rate of 10,000 barrels per day. For one unit 10,000 barrel-per-day synthine plant, a total of approximately 1,885,000 tons of coal would have been required. This amount represents approximately 75 percent of
Kans the total State production in that year.

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101a In Kansas, the 1948 total production of 2,538,000 tons
3 was produced in 185 working days, an average of 13,719 tons per
70021 day. At such a daily rate, the additional coal which could have

been produced during a 240-day work-year would have amounted to 754,545 tons, sufficient for approximately 4,000 barrels of synthetic liquid fuel products per day.

Accurate information on current costs of production at present operations in Kansas is not available. Consideration of all known factors of increased wage rates, costs of supplies, contributions to welfare funds, and other items of cost, since the last complete calendar year of available cost data (1945) indicates that coal is now being mined in Kansas at costs ranging from approximately the equivalent of or slightly less than the estimated average costs of mine operations as herein presented to as much as 75 cents per ton above such costs.

Mine-run coal could possible be purchased from current operations at such costs ($5.19 for underground and $3.55 per ton for strip coal), plus freight, plus $0.40 to $0.60 per ton for profits and income taxes. Selected sizes would probably run slightly higher in price, while it is possible that lower-priced sizes, such as screenings, could be purchased from current operations for production of synthetic liquid fuels, on a contract basis, at fob. mine prices comparable to or slightly less than the costs estimated herein. In general, such sizes would contain higher ash and sulfur contents than the cleaned mine-run product estimated as obtainable from reserves of the General Area.

Based on operating cost data for the first quarter of 1946 (Office of Price Administration) for large mechanized mines, the Corps of Engineers, Department of the Army, has estimated the present cost of producing coal from various seams (approximately 20 to 30 inches thick) in Kansas. These costs, which pertain only to strip mining, reflect the 1950 U.M.W.A. wage agreement and are $2.55 per ton for such strip mining. The outputs per man-shift are 17 tons. Increases in costs per ton since the spring of 1946 of 90 cents for strip mining, are based on $4.75 per day increases in wages; $25 per year increase in vacation pay; 30 cents per ton welfare payment; 35 percent increase in supply costs and 25 percent increase in all other costs. These costs are fob. tipple, excluding selling expenses, and represent large, modern, highly efficient and mechanized mines producing merchantable coal in sufficient quantities to meet the requirements of unit synthetic liquid fuels plants. However, they do not reflect improvements in coal mining techniques since 1946. The costs do not necessarily represent either the present average production costs for the entire coal area or the average production costs which might be obtained for new operations in the area but probably represent optimum operations.

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An additional cost of purchasing coal from present operations would be the transportation charges or freight rates from existing mines to the synthetic liquid fuels plant. Unless located in the heart of a group of substantial commercial operations, such additional costs for delivered coal would probably range from $0.60 to $2.00 per ton, depending on the selection of location of a synthetic liquid fuels plant.

Total Costs. The available reserves in the Crawford-Cherokee General Area of Coal and Water Availability in Kansas are unique in comparison with other states in that the total primary reserves which, in this particular situation, constitute one-half of the usable reserves, are available only for underground mining. Secondary reserves which constitute the other half of the usable reserves are available for mining either by underground or strip operations. It is assumed herein that 20 years' supply for a synthetic liquid fuels plant in the Crawford-Cherokee General Area will be obtained from the primary underground reserves, with the remaining 20 years' supply being obtained from secondary stripping reserves. Either method of mining may precede the other, or both may be carried on concurrently for the life of the plant. It is further assumed for estimating purposes that the ultimate net total investment during the 40-year period would probably not exceed that herein estimated for underground mining, regardless of the method or order of mining operations eventually established.

Under these conditions, the estimated initial capital costs as of March 31, 1950, are $7,000,000 to supply a unit hydrogenation plant and $9,000,000 to supply a unit synthine plant. These costs are based on providing complete facilities for underground and strip mining, transportation to a central preparation plant, mechanical cleaning, including refuse disposal, and loading for shipment or into surge storage at the mine with subsequent reloading. The weighted average coal producing costs, including depreciation but excluding selling expense, are estimated to be $4.37 per ton of merchantable coal.

The estimated unit cost of coal supply per barrel of synthetic liquid fuel final products is $1.72 for the hydrogenation process and $2.21 for the synthine process. The estimates of costs are summarized as follows:

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Total Coal Costs for One Unit Synthetic Liquid Fuels Plant (As of March 31, 1950)

Type of Mining	Btu per Pound	Costs per Ton	Costs per Million Btu	Total Costs Per Barrel of Products: Hydrogenation	Total Costs Per Barrel of Products: Synthine
Crawford-Cherokee General Area:					
Strip	12,200	$3.55	14.55¢	$1.43	$1.83
Underground	12,770	5.19	20.32	1.99	2.56
Average	12,485	4.37	17.50	1.72	2.21

Alternate Cost Using Only Secondary (Strip) Coal

Although the specified use of coal for synthetic liquid fuel manufacture is of all primary reserves or 50 percent primary and 50 percent secondary, the cost of secondary (strip) coal reported herein as $3.55 per ton would make it more economical to use all secondary coal. The exclusive use of such secondary coal would result in estimated initial capital costs as of March 31, 1950, of $5,864,000 to supply a unit hydrogenation plant and $7,540,000 to supply a unit synthine plant, and the coal costs for one unit synthine liquid fuels plant as tabulated above for strip coal.

Qualification

The estimates of costs presented in this survey are based on available information and on generalized, present-day methods of mining and preparation. The installation of mining operations to provide coal supply for a specific synthetic liquid fuels plant should be preceded by detailed engineering studies, including drilling programs, before final methods of operation and firm estimates of costs can be established.

WATER SUPPLY PLAN AND ESTIMATES OF COST FOR GENERAL AREA

Description of Water Supply Project for Crawford-Cherokee General Area

In order to permit more detailed studies for water supply development for the General Area and to prepare cost estimates, a representative plant site or terminal point for the water works system has been arbitrarily selected as shown on Exhibit No. 22. While proposed receiving points for coal and topographic and geographic features of the area are considered in the selection of such a point, it is in the final analysis arbitrary and is in no way intended to represent a recommended plant location.

Similarly, the source of water for the unit plant in the area is chosen as being representative of development costs. While the practicability of the project chosen for making cost estimates has been checked by field surveys, detailed investigations into foundation conditions are beyond the scope of this report.

Facilities Required. The water supply project is made up of the facilities required for conserving stream runoff and transporting water from the selected source to the arbitrary plant location and for temporary storage and treatment works at this terminal point. The project is based upon a water supply system adequate for a single 10,000-barrel-per-day synthetic liquid fuels plant and its supporting population. The principal elements of the water supply system which are discussed in the following paragraphs are assumed to be representative of the requirements for the General Area in Kansas.

Impounding Reservoir. During dry weather periods of low flow, an impounding reservoir would be required to process water for a synthetic liquid fuels plant. The method of determining the size of such a reservoir is discussed earlier in this report. A representative project on Lightning Creek would have a total capacity of 47,500 AF, of which 26,100 AF would be reserved for evaporation and siltation. The reservoir would have a maximum depth of approximately 39 feet and the dam could be an earthfill structure with a concrete spillway section. Because of the wide valley, the reservoir would be shallow and relatively expensive and evaporation losses would be large. The hydroelectric power potential that might be developed in connection with the synthetic liquid fuels plant would be negligible because of the low head and small quantity of water involved.

Pumping Station. For a unit synthetic liquid fuels plant requiring 13.1 mgd as for the synthine process using coal, the pumping station would typically consist of three electrically driven pumps of approximately 8-mgd capacity each with auxiliary stand-by gasoline engines for two of the pumps. The total pumping head would depend upon the difference in elevation between the intake and the assumed plant location and the head loss due to friction in the pipe line. In the estimate, an additional allowance of 50 feet has been made for hydraulic losses in the treatment plant and for the distribution of water in the synthetic liquid fuels plant.

Aqueduct. A 30-inch pressure pipe is proposed along the most probable route from the water works intake to the assumed plant location.

Electric Power Transmission Lines and Substations. It is assumed that electric power for operating the pumps would be generated at the synthetic liquid fuels plant and would be transmitted to the pumping station by means of a power transmission line extending along the pipe line right-of-way. The cost of power delivered to the pumping station, estimated in this manner, would be substantially the same as the cost of power available from the several utility companies in Kansas. There are no existing or proposed Federal hydroelectric power projects in Kansas from which low-cost power might be obtained.

Storage Basin at Assumed Plant Site. A 13-million gallon storage basin, equal to one day's supply, is included to provide a reserve source of water in the event of pump failures or a break in the pipe line and also to serve as a settling basin for the removal of turbidity during periods of high water. It is expected that the settled water from the basin would be of suitable quality for cooling purposes and for coal preparation.

Filter Plant. Filtered water would be required for the domestic water supply, for the sanitary water in plant and mine, for boiler make-up and for other minor process uses. It is estimated that 3.5 mgd, or 27 percent of the total supply, would require filtration. A filter plant of 5-mgd capacity is included in order to take care of peak demands, particularly during the summer months when domestic requirements might be unusually high. The cost of filtered water storage is included in the treatment plant estimates. No allowance is made for softening of boiler water since this is considered a process cost.

Cost of Water Supply Project for a Suitable General Area

The total construction cost and annual cost have been estimated on the basis of prices prevailing as of March 1950. Since it is assumed that water supply for a synthetic liquid fuels plant's supporting population would be paid for by the consumers, this cost has been allocated between domestic and process supply on the basis of use. It is to be noted that about 55 percent of the filter plant cost is chargeable to domestic supply, whereas only about 15 percent of the other water-supply components is allocated to domestic consumers.

Capital Costs. Construction cost estimates are based on works necessary for a single unit synthetic liquid fuels plant. The indicated cost trend for larger water supply for full development of the fuel resources is approximate since it assumes full development at one time. All construction cost estimates include an allowance of about 20 percent for engineering and contingencies.

Annual Costs. The principal elements of annual cost have been estimated as follows:

Power. Electric power required for pumping the water from the source to the assumed plant site is based upon a wire-to-water efficiency of 75 percent and a unit cost of 7 mills per kilowatthour. An allowance for transmission and transformer losses is included in the estimated power requirements.

Labor and Superintendence. This has been estimated at $20,000 per year.

Miscellaneous Supplies and Repairs. These have been estimated at $5,000 per year.

Filtration. A total unit operating cost of $15 per million gallons is assumed to be representative of filter plant costs in the region. This figure includes all operating costs, such as labor, chemicals, supervision, repairs and maintenance.

Fixed Charges. Property taxes and insurance have been taken as 1 percent of the total depreciable capital cost. Depreciation is estimated on a straight-line basis, with a 40-year life assumed for major structures, such as dams, buildings, and pipe lines; and a 20-year life for equipment, such as motors, pumps, and transformers. Return on the investment or interest is not included in the fixed charges for water supply, so the estimates show the cost of water without this item. There is shown, however, the additional cost to water supply which would be incurred if interest at 1 percent was included.

Costs of Water for Crawford-Cherokee General Area

The paragraphs following include a brief description of the water supply development for the General Area, as indicated on Exhibit No. 22, with a statement of the estimated construction cost and annual cost allocated between domestic and process water supply. A unit water cost per barrel of products is shown which includes only that water properly chargeable to process and mining. The cost trend for complete development of all the fuel resources is also indicated.

The capital cost of a surface water supply system for process and domestic use for a single unit synthetic liquid fuels plant in the Crawford-Cherokee General Area is shown in the following table. This cost is based upon a 47,500-AF storage reservoir on Lightning Creek, (Reservoir No. 3, Exhibit No. 22), an 8-mile pipe line from the reservoir to the assumed plant site, a storage basin, and treatment works.

Total Estimated Construction Cost for Water Supply
(As of March 31, 1950)

Item	Process	Domestic	Total
Storage Reservoir	$4,455,000	$ 775,000	$5,230,000
Pumping Station and Transmission	1,022,000	178,000	1,200,000
Storage Basin at Synthetic Liquid Fuels Plant	170,000	30,000	200,000
Filter Plant	201,000	249,000	450,000
Total	$5,848,000	$1,232,000	$7,080,000

The annual cost of water for the General Area in Kansas and the unit cost per barrel of products are shown in the following table:

Estimated Annual Cost and Unit Costs for Water Supply
(As of March 31, 1950)

Item	Process	Domestic	Total
Power	$ 25,040	$ 4,360	$ 29,400
Labor and Superintendence	17,040	2,960	20,000
Miscellaneous Supplies and Repairs	4,260	740	5,000
Filtration	8,560	10,640	19,200
Taxes and Insurance	58,480	12,320	70,800
Depreciation	150,770	34,230	185,000
Total	$264,150	$65,250	$329,400

Cost of water for process use is $64.91 per million gallons or $0.073 per barrel of products. Increase in cost per barrel for each 1 percent gross return on investment is $0.016.

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Full development of the coal resources of the Area, with a daily production of 20,000 barrels of synthetic liquid fuels, would require 40.5 cfs or 29,300 AF per year. This larger amount of water could be developed by utilizing the Lightning Creek reservoir and a 22,000-AF reservoir on Canville Creek, (Reservoir No. 4, Exhibit No. 22). This latter reservoir would regulate the flow of the Neosho River sufficiently to furnish the additional 20 cfs required.

The cost of water per barrel of products for full development would be about the same as the unit cost indicated for a single 10,000-barrel-per-day plant. Detailed cost estimates for this larger water supply system have not been prepared.

POWER

Requirements

For a 10,000-barrel-per-day plant using the coal synthine process, it is estimated that the power requirements will amount to 114,500 kw. However, waste heat recovery arrangements will have sufficient output to supply the steam needed to generate this amount of electricity plus 3,500 kw for the mine. Purchased power would be required only for starting up and stand-by purposes.

For a 10,000-barrel-per-day plant using the hydrogenation process, it is estimated that the total power load will be 65,000 kw at 100 percent load factor. Only 40,000 kw of this can be classed as prime power because the remaining 25,000 kw will be by-product power produced in conjunction with process steam. The 40,000 kw of prime power plus 3,000 kw of mine load would be supplied from the most economical source of power, whether it be a generating station constructed as an integral part of the synthetic liquid fuels plant, a hydroelectric development, or a public utility.

Existing Facilities

On the map, Exhibit No. 23, there are indicated the plant facilities now available to the coal-producing area of Kansas. On page 1, of this exhibit, are tabulated the identification, ownership, and capacity of each such power plant.

The Crawford Cherokee General Area is served by the Kansas Gas & Electric Company. This company is a single operating unit with plants totaling 144,000 kw capacity interconnected with adjacent system having a total of over 600,000 kilowatts capacity at present, with some 250,000 kilowatts additional capacity under construction.

Proposed Hydroelectric Developments

The only existing source of low-cost hydroelectric power within a reasonable distance of the Crawford-Cherokee General Area is the Grand River Dam Authority in northeastern Oklahoma, which power probably could be obtained indirectly through interconnection with existing transmission lines.

The Corps of Engineers prepared a report entitled "Potential Water Power Sites - As Summarized from Reports by the Corps of Engineers to the Congress - Edition of March 1935". In this report there were indicated no locations in Kansas within practical distance of the Crawford-Cherokee General Area.

Power Costs

An average cost of prime power at 100 percent load factor produced in a unit synthetic liquid fuels plant, using the average cost of coal for the General Area of Kansas, has been estimated to be about $0.007 per kilowatthour. This estimate includes an allowance for depreciation on a 15-year life basis, and excludes only an allowance for return on the investment or for income taxes. The application of a rational depreciation allowance even with allowances for return and profit should not materially increase the estimated cost of power. On the other hand, use of the higher ash fractions from coal washing might effect substantial savings in power costs, as compared with the cost of coals suitable for processing to synthetic liquid fuels.

Based on its existing rates, Kansas Gas & Electric Company could supply power to synthetic liquid fuels plants in the General Area at an average cost of about 6.3 mills per kilowatthour.

Conclusions

Sufficient power for plant construction can be obtained, with possibly some minor transmission line construction, in the General Area under consideration. It seems probable that power for at least a unit synthetic fuels plant could be obtained from the Kansas Gas & Electric Company upon sufficient notice to them. Possibly through a combination of their facilities plus those of the Grand River Authority and the Southwestern Power Administration operating in Oklahoma, power for more than one plant might be obtained. It would seem advisable in the final consideration of a possible plant in this Area to survey carefully the exact quality and cost of coals available and to design the power plant with equipment to use such coal economically. The possible new plant should estimate the cost of producing its own power on a basis comparable to that used by the utility. Consideration should also be given to the economies of purchased power and the integration of plant facilities with those of the utility.

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ACCESS TRANSPORTATION

The construction and operation of a synthetic liquid fuels plant and its auxiliary coal mine facilities would, in general, require a direct rail or water connection and a highway connection. Such services would be used during the construction period to move in the large volume of construction materials and plant equipment, and later to transport plant and community supplies and some plant products. The latter may also be handled by pipe line as described in the section of this report pertaining to "Marketing".

Railroad facilities are well distributed in the eastern part of the State of Kansas where a virtual network exists.

Railroad access is very necessary but it is also important that highway access be assured for truck movement in and out of the plant and transportation of personnel to and from the Area. The eastern part of Kansas is a rolling, relatively flat country so that no formidable obstacles are imposed with respect to highway construction.

The estimated cost of access facilities for the one General Area in Kansas is given in the following table. Under the heading "General Area", the first item describes the required railroad facilities and the second item the required access highway facilities from the public paved highway system. In order to prepare cost estimates, a representative plant site has been arbitrarily selected. This plant site is in no way intended to recommend a plant location.

The amounts shown for railroad facilities under construction and operating costs are based on the assumption that the plants will bear full construction and maintenance costs of the required facilities. Operating costs are to provide for maintenance at an annual rate of 5 percent of the capital costs for such facilities.

In the case of access highway facilities, costs represent one-half the construction costs with no direct maintenance charges. It has been assumed that local governments would bear one-half the construction costs and maintain the highways upon their completion. Under operating costs, the amounts charged against highway facilities are to provide for 40-year depreciation at an annual rate of 2.5 percent of the capital costs shown. Highway costs are based on a 20-foot highway of rough aggregate, bituminous-bound surface, three inches thick on a 15-inch base course.

Estimated Cost of Access Facilities for the Crawford-Cherokee General Area (As of March 31, 1950)

General Area	Capital Cost	Annual Operating Cost	Daily Operating Cost
Approximately 1.5 miles from St.Louis-San Francisco Railway north of Cherokee, easy grading	$100,000	$5,000	$13.70
Lateral roadway approximately 1.5 miles from Route 7, north of Cherokee, easy grading	30,000	750	2.05
Total	$130,000	$5,750	$15.75

LABOR

General

Determination of the labor force available to a proposed new synthetic liquid fuels unit plant involves a detailed study of the number of workers existing in and around the proposed location together with their characteristics, the nature of their present employment, the extent of unemployment, and the extent to which the proposed new plant would divert existing employment from present industry to itself. Personnel requirements of the proposed plant would then be compared with results of the detailed study to determine the size of the area containing sufficient available labor to satisfy the needs of the plant. Determination of the level of wages to be paid in a unit plant involves consideration of the wage level in such an area prevailing among existing industries comparable to synthetic liquid fuels as regards the skills and experience required of workers.

In this report, such studies by particular locations were not made. Instead, data on the number and composition of the labor force in the State and in the coal counties, data on unemployment both in the State and coal counties, and data on average wages prevailing in selected industries in the State were developed. Conclusions were drawn from such data as to the availability of labor, and as to the prevailing level of wages in an average location in the coal counties, which were applied to the General Area within the State.

Population and Employment Characteristics

The State of Kansas had a population density of 21.9 per square mile in 1940. The 1940 census showed a total population of 1,801,028, of which 753,941, or 41.9 percent lived in urban areas.

The 1950 census preliminary count shows the population of the State, as of April 1, 1950, to be 1,894,390 and the density of population at that time at 23.1 per square mile.

The General Area of Coal and Water Availability in Kansas as described in the preceding section of this report entitled "Coal", occupies parts of the 3 counties, Bourbon, Cherokee, and Crawford.

Details of the population characteristics, labor force,
Kans and employment categories for Kansas as a whole and for the coal
counties are tabulated in Exhibit No. 24 and summarized below:

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Population, Labor Force, and Employment in Kansas and in the 3 Coal Counties

	Whole State (105 Counties)	Coal Area: 3 Coal Counties	Coal Area: Percent of State
Preliminary U.S. Census Data - 1950			
Area (square miles)	82,113	1,824	2.2%
Population	1,894,390	84,373	4.5
Density per square mile	23.1	46.3	
U.S. Census Data - 1940			
Population	1,801,028	94,952	5.3
Residing in Urban Areas:			
Number	753,941	43,380	5.8
Percent	41.9%	45.7%	
Labor Force	669,815	34,550	5.2
Employed Number	583,826	26,916	4.6
Percent of Labor Force	87.2%	77.9%	
Occupations of Employed Labor, Percentages of Total:			
Agriculture	31.4%	26.2%	3.9%
Mining	2.6	12.7	22.5
Construction	4.3	3.4	3.7
Manufacturing	9.1	7.1	3.6
Service	52.6	50.6	4.4

The coal counties had a 1950 population density of 46.3 per square mile. Data for the coal area as compared with State data indicates that in 1940, relatively more people lived in urban areas, relatively fewer people were employed, relatively fewer people were engaged in agriculture, manufacturing, and service, while greater numbers were engaged in mining.

Estimated Labor Force. In Kansas, the total labor force, based on the 1940 census, has previously been stated as 669,815. If the labor force has varied proportionately to that of population, the 1950 labor force would be 704,537. The labor force of the coal counties on the same basis would be 30,701 or an average of 16,832 per 1,000 square miles.

The occupations of about half of the labor force in the State (workers covered by Federal Old-Age and Survivors Insurance) are indicated by the following tabulation. These workers include employes of an employer with as few as one employe.

Workers Covered by Federal Old-Age and Survivors Insurance as of Mid-March 1948

Industry Group Mid-March 1948	Total State		3 Coal Counties	
	Total	Percent	Total	Percent
Agriculture, Forestry, and Fishing	705	0.2%	9	0.1%
Mining	14,659	4.9	1,802	14.0
Contract Construction	21,137	7.1	701	5.4
Manufacturing	76,079	25.4	3,293	25.6
Public Utilities	29,848	10.0	1,002	7.8
Wholesale Trade	28,622	9.6	826	6.4
Retail Trade	80,498	26.9	3,191	24.8
Finance, Insurance, and Real Estate	13,402	4.5	636	4.9
Service Industries	32,945	11.0	1,308	10.1
Other (A)	1,118	0.4	114	0.9
Total	299,013	100.0%	12,882	100.0%

Note: (A) Includes groups not elsewhere classified and unclassified.

The other half of the total labor force (disregarding the increase from mid-March 1948 to April 1, 1950) was not covered and consisted of employes of government, railroads, certain non-profit organizations, agricultural, domestic and unpaid family workers, those self-employed and those unemployed. These workers generally, except some of the unemployed, are of types that do not now have the training or skills required for operation of synthetic liquid fuels plants.

From the above tabulation it may be seen that in the State as a whole, 25.4 percent of the covered employes are engaged in manufacturing and 4.9 percent in mining, whereas in the coal counties the corresponding percentages are 25.6 in manufacturing and 14.0 in mining.

The number of workers engaged in manufacturing in the entire State of Kansas, as shown in the above tabulation, is further broken down by industry groups as shown in Exhibit No. 25. Corresponding figures for workers in the coal counties are not available.

Seasonal Trends in Employment. Employment of workers covered by the Kansas Unemployment Compensation Law, is shown in the following table for a recent typical 13-months period.

Workers Covered by Kansas Unemployment Compensation Law

Month	Number	Percent of Average
1948		
June	248,000	101.6%
July	246,000	100.8
August	249,000	102.0
September	250,000	102.5
October	248,000	101.6
November	248,000	101.6
December	247,000	101.2
1949		
January	231,000	94.7
February	230,000	94.3
March	235,000	96.3
April	241,000	98.8
May	246,000	100.8
June	249,000	102.0
Average	244,000	100.0%

Using the average number of employed in the thirteen month period as a base, employment reached a peak of 102.5 percent in September, 1948, and was at its lowest in February, 1949, with a percentage of 94.3. This data indicates a seasonal variation in covered employment in Kansas of about three percent above and six percent below the average. Such a variation may be expected in an area in which almost one-third of the labor force is employed in agriculture. Year-round employment, as would be provided by a synthetic liquid fuels plant, would be desirable in such an area. Increased annual employment provided by such a plant could be offset by increased use of migratory labor.

Workers covered by this law exclude employes of government, railroads, certain non-profit organizations, agricultural, domestic, and unpaid family workers, and the self-employed. Employes of an employer with less than 8 employes in 20 weeks are also excluded.

Technical Training. Workers in Kansas are primarily engaged in agriculture and in trade and service occupations related thereto. The important industries are meat packing and slaughtering, flour milling, and processing of dairy products. In the Wichita and Kansas City areas, the war impact and the resulting location of new ordnance and aircraft plants brought about a new emphasis in metal-working and chemical industries. These new industries have largely been reconverted to production of civilian aircraft, small tools, automobile and agricultural equipment, or closed down. The result of war time expansion has been an expansion of technical training among the workers of Kansas both in war plants and in military service.

The number of workers who are engaged (as of mid-March 1948) in industries employing workers of skills comparable to those required in operating and maintaining synthetic liquid fuels plants are indicated by the following table (selected from the industry groups shown on Exhibit No. 25),which table also includes workers in electric and gas utilities.

Industries Employing Workers of Skills
Comparable to Those Required by
Synthetic Liquid Fuels Plants

	Workers Covered by Old-Age and Survivors Insurance
Manufacturing:	
Chemicals and Allied Products	4,839
Products of Petroleum and Coal	4,431
Primary Metal Industries	1,865
Fabricated Metal Products	4,243
Machinery (Except Electrical)	5,023
Electrical Machinery, etc.	795
Transportation Equipment	8,954
Total in Manufacturing	30,150
Electric and Gas Utilities	7,847
Total in All Selected Industries	37,997

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Workers in the coal counties of Kansas are engaged primarily in agriculture and trade. There exists an important bituminous coal, lead, and zinc mining industry, together with manufacturing of chemical and foundry products. Based on data of the Kansas State Employment Service it is estimated that there are about 1,800 workers in industries employing workers of skills comparable to those required by synthetic liquid fuels plants in these coal counties.

Unemployment

Unemployment varies from one area to another dependent on local conditions. For a particular area, a survey of conditions prevailing in the area would have to be made to determine its extent. In this report, however, studies by particular areas were not made. Instead, as a measure of the extent of unemployment in the coal counties, the percentage of unemployed workers covered by State Unemployment Insurance to average covered employment in the State were tabulated by months for the years 1947 to 1949, inclusive, and the first two months in 1950. These percentages were taken from Bulletins of the Bureau of Employment Security of the U.S. Department of Labor and plotted in the form of a graph as shown in Exhibit No. 26.

Unemployment in Kansas follows a seasonal pattern, reaching a maximum in February and a minimum in October. Maximum percentages of unemployment (for month of February) were 4.1 in 1947 and 1948 but increased to 4.6 in 1949 and to 7.1 in 1950. Average annual percentages of unemployment declined from 2.6 in 1947 to 2.2 in 1948 but rose to 3.0 in 1949 and, for the twelve months ended February 1950 to 3.5.

Those seasonably unemployed may be considered as available for employment in a year-round activity such as a synthetic liquid fuels plant. Eliminating the percentage of unemployment in February 1950 (7.1 percent) as being exceptional, average unemployment in February for the year 1947 to 1949, inclusive, was 4.3 percent. This percentage is somewhat greater than that for the 12 months ended in February 1950, and has been adopted in this report as representing a degree of unemployment normal to Kansas (and reflecting seasonal unemployment) as available for new employment.

Estimated Total Unemployment. Application of the 4.3 percent of unemployment to the total estimated labor force in 1950 of 704,537 would indicate a total number of unemployed in the entire State of Kansas of 30,295. On the same basis, the unemployed in the coal counties would be 1,320, or 724 per 1,000 square miles.

Unemployed Skilled Labor. Assuming that the 4.3 percentage of unemployment in Kansas applies equally to the 37,997 workers in the industries employing skilled labor (as well as to the total labor force), then the unemployed skilled labor force in the entire State would be 1,634. On the same basis the unemployed skilled labor force in the coal counties would be 77, or 42 per 1,000 square miles.

Personnel Requirements of a Synthetic Liquid Fuels Unit Plant in Typical Kansas

Total Personnel Requirements. The total requirements of personnel to operate and maintain a typical synthetic liquid fuels plant in Kansas, to produce all the coal necessary as a raw material for the plant, from mines owned or associated directly with the synthetic liquid fuels plant, and to supply the service requirements of such workers and their families, are shown in the following tabulation for the two processes using coal:

Total Personnel Requirements of a Unit Plant

	Coal Hydrogenation	Coal Synthine
Unit Plant Employes	1,175	1,135
Coal Mine Employes	811	1,043
Total Production Employes	1,986	2,178
Service Workers	1,787	1,960
Total Personnel	3,773	4,138

The numbers of unit plant employes shown above are those estimated by the U.S. Bureau of Mines for plants using the two processes as shown on the Plant Requirements Sheet, Exhibit No. 1.

The numbers of coal mine employes shown above are those required to produce sufficient coal per annum to meet the fuel requirements of a unit plant, using the heating value and productivity per man-day shown for the General Area in Kansas in the section of this report entitled "Coal". Development of such numbers of employes is shown in the following tabulation:

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Total Number of Coal Mine Employes Necessary To Produce Fuel Requirement of a Unit Plant in Kansas

	Coal Hydrogenation	Coal Synthine
Daily fuel requirement of a unit plant in billions of Btu	98	126
Heating value of coal in Btu per pound	12,485	12,485
Annual fuel requirement of a unit plant in tons of coal	1,432,519	1,841,810
Number of working days per annum in coal mines (assumed)	240	240
Productivity in tons per man-day of operational coal mine employes weighted by number of years of operation using strip and underground coal	8.50	8.50
Number of operatinal coal mine employes working daily	702	903
Number of operational coal mine employes absent due to accident, illness, etc. 10%	70	90
Total number of operational employes	772	993
Administrative employes, 5% of operational	39	50
Total coal mine employes	811	1,043

The numbers of service workers shown are 90 percent of the total production employes. Such workers and the relation between them and production employes are defined in a succeeding section of this report entitled "Housing and Community Development".

Skilled Plant Personnel Required. The U.S. Bureau of Mines estimates that 80 percent of the technical workers in synthetic liquid fuel plants can be trained from inexperienced local labor. A maximum of 20 percent must then consist of workers already possessed of skills or experiance required in such plants. The requirements of skilled personnal are tabulated below for the two processes using coal:

Skilled Personnel Requirements of a Unit Plant

	Hydrogenation	Synthine
Unit Plant Employes	235	227

It is considered that no difficulty would be encountered in obtaining the necessary skilled labor for mining operations.

Diversion of Presently Employed Labor. If a unit plant consuming large amounts of coal were to be introduced into an area already containing a large coal mining industry its requirements of coal may be presumed to have a profound effect on the economy of the industry, at least within the county or General Area in which the plant is to be located. It may reasonably be presumed that existing coal mines in the area will be able and willing to divert a portion of their present capacity (at least all of their marginal business) to supplying the unit plant at a price competitive with the cost of production in an associated mine and probably better than that now received by marginal business. Thus a portion of the total personnel requirements of a unit plant may be satisfied by more intensive use of the productivity of existing coal mines and personnel in the area surrounding the plant, the increased productivity being diverted to the use of the plant.

New Personnel Requirements. When a new industry is introduced in a community its requirement for workers in excess of that portion met by the diversion of existing production to the new industry, must be satisfied either directly or indirectly by recruiting of new workers; directly from workers who are not now employed, or indirectly from workers who will leave their present employment to work in the new industry and whose places must in turn be filled by recruiting from the ranks of the unemployed. An estimate of the number of new workers required by a unit plant is shown in the following tabulation:

Total Requirements of New Personnel for a Unit Plant

	Coal Hydrogenation	Coal Synthine
Unit Plant Employes	1,175	1,135
Coal Mine Employes	454	686
Total Production Employes	1,629	1,821
Service Workers	1,466	1,639
Total Personnel	3,095	3,460

The numbers of new plant employes are the same as those previously indicated under "Total Personnel Requirements". Since no such plant as the unit plant exists in the General Area, the total personnel requirements, including skilled workers, are new and must be filled either directly or indirectly by unemployed workers.

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The numbers of new coal mine employes are estimated to be those required to supply the fuel requirements of a unit plant on the same basis as used in developing the total personnel requirements but with the assumption that production of existing mines as of the year 1948 will be utilized to the capacity possible by working 240 days per annum (the same as that assumed in an associated mine) with the added production diverted to the unit plant, and that the balance of production required by a unit plant will be produced in an associated mine working 240 days per annum.

The estimated number of coal miners required is developed in Exhibit No. 27.

Service workers are estimated at 90 percent (service to production worker ratio previously explained) of the new production workers required. It is logical to assume that service workers would be reduced in proportion to the reduction in production workers made possible by diversion of marginal coal production to the plant and the use of more working days per year.

Comparison of Personnel Requirements of a Unit Plant and Unemployment

The extent to which the new personnel requirements of a unit plant are met by the unemployed labor in the area surrounding the plant in an average location in the coal counties of Kansas is indicated by the following tabulation.

Comparison of New Personnel Requirements of a Unit Plant and Unemployed per 1,000 Square Miles in Coal Counties of Kansas, and Size of Area Containing Sufficient Unemployed To Satisfy Requirements

Description and Process	New Personnel Requirement of a Unit Plant	Unemployed per 1,000 Sq Mi	Size of Area Containing Sufficient Unemployed To Satisfy Requirements	
			Sq Miles	Radius-Miles
Total Personnel				
Hydrogenation	3,095	724	4,275	36.9
Synthine	3,460	724	4,779	39.0
Skilled Personnel				
Hydrogenation	235	42	5,595	42.2
Synthine	227	42	5,405	41.5

The above comparison indicates that in the coal counties of Kansas it would be necessary, in order to fulfill the new personnel requirements of a unit plant, to enlist the unemployed (both in total and skilled) in an area of about 40 miles radius about the plant. Actually, there would be a greater number of workers available for new employment in such a radius, as it would include the industrialized area in Missouri centering about Joplin. It is considered that there is a sufficient supply of labor available within reasonable distance of a unit plant to meet personnel requirements both in total and inrespect of skilled labor.

Prevailing Wage Rates

The average straight-time hourly rate, as of March 31, 1950, paid in Kansas to wage earners (exclusive of supervisors) in industries similar to synthetic liquid fuels plants as regards the skills and experience required of workers has been estimated at $1.62. Since there exists in Kansas an adequate and suitable labor force, this estimated average wage rate is considered that payable in such a plant.

Should a second unit plant be introduced within about 80 miles of the first plant, it is probable that there would not be sufficient labor available locally to staff the plant and associated mine development and to supply the required service workers. Introduction of such a second plant would require recruiting of labor from outside a 40-mile radius from the plant and might necessitate increasing labor rates in order to attract workers from greater distances.

Basis of Estimated Wage Rates. Wage rates of workers of the higher skills to be employed in synthetic liquid fuels plant are governed by the rates paid in the chemical, petroleum refining, and coal mining industries, as such workers will have to be recruited from or paid in competition with them. Wages of workers of lesser skills, however, are not dependent to the same extent on wages paid in the above industries, but are governed by wages paid in the manufacturing industries presently existing in the areas in which the proposed plants are to be located.

In estimating wage rates in the synthetic liquid fuels industry, wage rates in the chemical, petroleum refining, and coal mining industries in relation to otherwidespread industries have been taken at a ratio of two to one. By dividing the number of workers (exclusive of supervisors), shown by the U.S. Bureau of Mines personnel classification for a 30,000-barrel-per-day coal hydrogenation plant, into two groups as to relative skills (above or below a wage rate of $1.70 per hour) a ratio of approximately two to one is shown as follows:

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Ratio of Wage Earners of Higher Skills to Those of Lower Skills

Department	Number of Wage Earners: Higher Skilled	Lower Skilled	Total
Operating	955	139	1,094
Maintenance	807	484	1,291
Indirect	22	288	310
Total	1,784	911	2,695
Ratio of wage earners of higher skills to those of lower skills	1,784 ÷	911 =	1.96

U.S. Bureau of Labor, Wage Rates by Regional Areas. Wage Survey Bulletins prepared by the Bureau of Labor Statistics of the U.S. Department of Labor, as of various dates, were used as a basis for development, by regional areas, of wages paid in industries similar to synthetic liquid fuels plants. After adjustment to a uniform date, March 31, 1950, the average straight-time hourly rate, exclusive of premium, for the middle Western States (which include Kansas) has been developed for selected industries.

The industries selected as representative in each group of required labor skills are those for which there are available Wage Survey Bulletins covering all areas in the United States. Development of average straight-time hourly wage rates, exclusive of premium, made in the middle Western States is shown in the following tabulation.

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Average Straight-time Hourly Wage Rates,
Exclusive of Premium, Paid in Selected Industries
in Middle Western States
(As of March 31, 1950)

Industry	Hourly Wage Rate
Industries employing workers of higher skills:	
Chemical	$1.49
Petroleum Refining	1.77
Bituminous Coal Mining	1.71
Average straight-time hourly earnings, weighted by reported total number of workers	$1.66
Industries employing workers of lesser skills:	
Fabricated Structural Steel	$1.31
Paints and Varnishes	1.41
Ferrous Foundries	1.42
Machinery	1.45
Fertilizers	1.04
Electric and Gas Utilities	1.36
Average straight-time hourly earnings, weighted by reported total number of workers	$1.40
Average straight-time hourly earnings combined by means of a weighting ratio of two to one of wages paid by industries using workers of higher skills to those using workers of lesser skills	$1.57

Wage Rates in Kansas. Straight-time average hourly wage rates, exclusive of premium, as developed for the regional area was then broken down to individual states by assuming that the ratio of the State rates to the area rates would be the same as that indicated by other wage studies such as: (a) that made by the Army-Air Force Wage Board, in 1948; (b) the Old-Age and Survivors Insurance Program during the first quarters of 1948 and 1947; and (c) the State Unemployment Insurance Program for the year 1946. This determination for the State of Kansas, is shown in the following tabulation.

Straight-time Average Hourly Wage Rates, Exclusive of Premium, Paid in Selected Industries in Kansas
(As of March 31, 1950)

	Hourly Rates as per Source of Information		Hourly Rates Adjusted to Level of Synthetic Liquid Fuels Industry	
	Regional Area	Kansas	Regional Area	Kansas
Army-Air Force Survey	$1.23	$1.15	$1.57	$1.47
OASI Program:				
1st Quarter 1948	1.45	1.49	1.57	1.61
1st Quarter 1947	1.29	1.37	1.57	1.67
Unemployment Insurance Program:				
Year 1946	1.25	1.29	1.57	1.62
Average Straight-time Hourly Wages - Kansas				$1.59

It is the practice in manufacturing industries operating on round-the-clock basis to pay a differential, or premium, to workers on the second and third shifts over hourly wages paid workers on the first shift. The differentials most prevalent in petroleum refining and bituminous coal mining are 4 cents per hour on the second shift and 6 cents per hour on the third. Assuming an equal number of workers on the three shifts in synthetic liquid fuels plants, the average amount of shift differentials would be 3 cents per hour. This amount is added to the average straight-time hourly wage rate, exclusive of premium of $1.59, to give the hourly straight time rate of $1.62 paid in selected industries similar to synthetic liquid fuels plants as regards the skills and experience required of workers.

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HOUSING AND COMMUNITY DEVELOPMENT

Population Characteristics

The State of Kansas has a population density of 23.1 per square mile. Of the entire State population in 1940, 41.9 percent lived in urban areas. There are a number of large cities in Kansas; those with 1950 metropolitan area populations of over 100,000 are tabulated below:

Estimated Metropolitan Area
Population as of January 1, 1950

City	Population
Kansas City, Missouri-Kansas	825,000
Topeka	114,600
Wichita	233,700

Source: Sales Management - Survey of Buying Power; further reproduction not licensed

In 3 southeastern counties of the State (Bourbon, Cherokee and Crawford) where the General Area for the location of a synthetic liquid fuels plant is being considered, the 1950 density of population is 46.3. There are 2 cities of over 5,000 population within these counties. A tabulation of these cities and their preliminary 1950 populations follows:

Cities of 5,000 and over Population in Counties
Containing Available Raw Material

City	1950 Census Preliminary Count
Fort Scott	9,992
Pittsburg	19,371

In these coal counties as of 1940, 45.7 percent of the population lived in urban areas, 26.5 percent in rural nonfarm, and 27.8 percent in rural farm areas.

Community Requirements and Population Determination

When a new manufacturing establishment is set up, unless it is located in an already established large community, it may be presumed necessary to develop an entire new community to house plant and associated workers conveniently near their place of employment to the extent that experience has shown it to be required.

Housing facilities alone, however, are not the only requisite of a new community. Residents of a new housing development require civic and commercial facilities reasonably convenient to their homes. It has been considered that such facilities must be provided as an integral part of a planned community rather than allowing them to develop without plan on the outskirts of the development.

An estimate follows of the population of the plant-city associated with a unit plant in Kansas based on numbers of plant and mine employes, together with associated service workers, for whom housing would be required. This estimate is based on average conditions in the coal counties of Kansas. It is subject to variation from one location to another based on conditions existent in each individual location.

Population of 10,000-barrel-per-day Synthetic Liquid Fuels Plant-city

	Coal Hydrogenation	Coal Synthine
Plant and Mine Employes	1,401	1,584
Service Workers	1,261	1,426
Total Workers	2,662	3,010
Number of Households or Dwelling Units	2,356	2,664
Total Population To Be Housed	8,246	9,324

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Number of Plant and Mine Employes To Be Housed. The percentage of plant and mine employes for whom housing would be required in a plant-city is based on a chart, Exhibit No. 28, which shows the "Ratio of Employes Housed in a Plant-city to the Relative Personnel Demand". This chart was developed from a study of the effect of density of population in the area surrounding existing communities, in which the predominant source of employment is one

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plant or factory.

The number of plant and mine employes estimated to be housed in the plant-city is shown in the following tabulation:

Number of Plant and Mine Employes Estimated To Be Housed

	Coal Hydrogenation	Coal Synthine
Population Density per square mile in southeastern Kansas coal counties	46.3	46.3
Population within 1,000 square miles (17.8 miles radius from plant)	46,300	46,300
Requirements of new plant and mine personnel (from "Labor" section)	1,629	1,821
Above requirements in percentage of population within 1,000 square miles	3.52%	3.93%
Plant and mine employes to be housed in the plant-city:		
Percent of total (from Exhibit No. 28)	86%	87%
Number	1,401	1,584

Number of Service Workers To Be Housed. In every community, there must be service workers to minister to the needs of production workers. Such workers consist of proprietors and employes of wholesale and retail trade establishments, finance, insurance, and real estate agencies, and a great variety of miscellaneous service establishments such as laundries, dry cleaners, barbers, shoe and hat cleaners and repairers, automobile repair shops, garages, motion picture houses, etc., as well as professional personnel such as doctors, lawyers, teachers, and governmental workers. Transportation and public utility workers are also considered as service workers for the purpose of this report. In sparsely settled rural counties, only the minimum services are provided in nearby centers and the more specialized services must be secured in more distant trade centers. As mining or manufacturing expands in a community, trade and service establishments spring up within it over a period of time, and the number of workers in the service industries tends to equal the number in the production group, unless the community is a satellite of a large urban center.

In estimating the service requirements of a plant-city in Kansas, it is considered that production workers living in the plant-city will receive the same degree of service as that prevalent in the southeastern portion of the State. The ratio of service workers to production workers in the three coal counties is distorted by the presence in these counties of the cities of Fort Scott and Pittsburg, both of which are within a few miles of the Missouri border, and are service centers for areas in Missouri. Instead, the nine southeastern counties of Kansas, omitting three containing cities near the State border, were chosen as typical for the purpose of determination of the ratio of service to production workers in a plant-city. This ratio is developed in the following tabulation:

Percentage of Service Workers to Production Workers
for a Plant-city in Kansas as of 1940

Class of Worker	Number (A)	
Production		
Agricultural	12,807	
Mining	3,914	
Construction	1,516	
Manufacturing	3,639	
Total Production Workers		21,876
Service		
Total Service Workers		19,635
Percentage of Service Workers in terms of Production Workers		90%

Note: (A) In counties of Allen, Cherokee, Crawford, Neosha, Wilson and Woodson.

Applying this percentage to the plant and mine employes estimated to be housed in the plant-city, the number of service workers to be so housed would be: Kans

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Estimated Number of Service Workers To Be Housed

	Coal Hydrogenation	Coal Synthine
Plant and Mine Employes	1,401	1,584
Service Workers - 90% of Plant and Mine Workers	1,261	1,426

Population of Plant-city. The number of employed persons per household may be determined for the State of Kansas, according to the 1940 census, as shown below:

Estimated Number of Employed Persons per Household as per 1940 Census

Employed Persons	583,826
Households	514,500
Employed Persons per Household	1.13

The Bureau of the Census shows, for Kansas in 1940, a population per household of 3.5.

Assuming these ratios to apply to the plant-city the total population is determined as below:

Estimated Total Population of Plant-city

	Coal Hydrogenation Process	Coal Synthine Process
Employed persons in plant-city	2,662	3,010
Households or Dwelling Units (employed persons divided by 1.13)	2,356	2,664
Total population (households multiplied by 3.5)	8,246	9,324

Estimates for this report have been based on the assumption of only one unit plant per 1,000 square miles. Simultaneous operation of two or more unit plants within such an area would require housing a substantially larger proportion of workers. This would entail increased investment in housing per plant with corresponding changes in operating costs.

Family Housing Requirements. In the past, common practice in construction of "company towns" has been to confine dwellings to those accommodating a single family. There is now, however, an increasing demand for multi-family or apartment dwellings. In this report, it has been assumed that 20 percent of all dwellings will be of this type, the balance being single homes. Analysis of single homes in existence in Oak Ridge in 1947 shows that about 75 percent had two bedrooms and 25 percent had three. For the purpose of estimating costs of the plant-city the distribution by types of dwellings is assumed to be as follows:

Distribution by Types of Dwellings

Type of Dwelling	Percent of Total	Number of Dwellings for Plant-city of a Unit Plant: Coal Hydrogenation Process	Number of Dwellings for Plant-city of a Unit Plant: Coal Synthine Process
2-Bedroom single-family	60%	1,414	1,598
3-Bedroom single-family	20	471	533
Multi-family Units	20	471	533
Total	100%	2,356	2,664

Cost of Housing and City Development for a Unit Plant

Investment in City. Based on the Contractor's experience in similar installations, a plan of a model city for employes of a synthetic liquid fuels plant was designed. This city plan provided housing, utilities, and civic and commercial facilities adequate for a population of 5,000 inhabitants. Cost estimates for such a model city were made at levels prevailing at December 1949, in the Pittsburgh, Pa., area.

From this estimate unit costs were developed for application to plant-cities of populations estimated to be required in connection with a unit plant in Kansas. An index of building construction costs applicable to a unit plant in Kansas, as of March 30, 1950, as compared to similar costs in Pittsburgh, Pa., as of

December 1949, was developed based on data on construction costs as reported by The Dow Service, Inc. This index, for Kansas, is 96.

The estimated investment required to construct a plant-city in connection with a unit plant in Kansas is shown in the following tabulation for the two processes:

Cost of Housing and Community Development
Required for a Coal Hydrogenation Unit Plant
(As of March 31, 1950)

Type of Facility	Investment
Land	
For 8,246 population at $3 per person	$ 24,738
Grading and Landscaping Site	
For 8,246 population @ $145 per person	1,195,670
Dwelling Units	
1,414 - 2-Bedroom single-family @ 806 sq ft @ $8.81 per sq ft	10,040,814
471 - 3-Bedroom single-family @ 988 sq ft @ $8.81 per sq ft	4,099,584
471 - Multi-family @ 850 sq ft @ $8.04 per sq ft	3,218,814
1,296 Garages (55% of Dwelling Units) @ $778 each	1,008,288
Total Dwelling Units	$18,367,500
Utilities	
Lighting, water distribution, sewage disposal, streets, roadways, sidewalks, curbs, and gutters	$ 3,432,692
Civic Facilities	
Municipal building, comfort station, schools, hospital, sanitation	2,655,212
Commercial Facilities	
Bus station, theatre, bank and professional building, shopping buildings	3,933,342
Total Investment for Complete Plant-city, exclusive of Water Supply	$29,609,154

Cost of Housing and Community Development Required for a Coal Synthine Unit Plant (As of March 31, 1950)

Type of Facility	Investment
Land	
For 9,324 population at $3 per person	$ 27,972
Grading and Landscaping Site	
For 9,324 population @ $145 per person	1,351,980
Dwelling Units	
1,598 - 2-Bedroom single-family @ 806 sq ft @ $8.81 per sq ft	11,347,398
533 - 3-Bedroom single-family @ 988 sq ft @ $8.81 per sq ft	4,639,232
533 - Multi-family @ 850 sq ft @ $8.04 per sq ft	3,642,522
1,465 Garages: (55% of Dwelling Units @ $778 each)	1,139,770
Total Dwellings	$20,768,922
Utilities	
Lighting, water distribution, sewage disposal, streets, roadways, sidewalks, curbs, and gutters	$ 3,881,448
Civic Facilities	
Municipal building, comfort station, schools, hospital, sanitation	3,002,328
Commercial Facilities	
Bus station, theatre, bank and professional building, shopping buildings	4,447,548
Total Investment for Complete Plant-city, exclusive of Water Supply	$33,480,198

Commercial Facilities. It is recognized that, insofar as possible, an industrial plant-city such as would be required by a synthetic liquid fuels plant should be self-supporting. Commercial establishments and services, as an integral part of a community, are profit-making entities resulting from community development. Therefore it has been considered that rental from commercial facilities would be ample to cover the charges on the investment in those facilities, including a proportionate share of the utilities and civic facilities and land. Such investment has been estimated as follows:

Allocation of Total Investment in Plant-city between Residential and Commercial Facilities, with Estimation of Appreciated Land Values

	Commercial	Residential	Total
For Unit Coal Hydrogenation Plant			
Capital investment	$3,933,342	$18,367,500	$22,300,842
Percent of total	18%	82%	100%
Allocation (based on percent of total) of:			
Utilities	$ 617,885	$ 2,814,807	$ 3,432,692
Civic facilities	477,938	2,177,274	2,655,212
Investment in land improvements	$5,029,165		
Appreciated value of land, 1/6 of improvements	838,194		
Total Commercial Investment	$5,867,359		
For Unit Coal Synthine Plant			
Capital Investment	$4,447,548	$20,768,922	$25,216,470
Percent of total	18%	82%	100%
Allocation (based on percent of total) of:			
Utilities	$ 698,661	$ 3,182,787	$ 3,881,448
Civic facilities	540,419	2,461,909	3,002,328
Investment in land improvements	$5,686,628		
Appreciated value of land, 1/6 of improvements	947,771		
Total Commercial Investment	$6,634,399		

The advantages to management in the construction, operation, and control of its own plant-city are recognized. Among them are:

(1) A more dependable and stable labor supply
(2) More desirable living conditions
(3) Better civic administration
(4) A cleaner and more orderly community
(5) Lower plant and community taxes.

Against these advantages, management will have the responsibility and expense of construction and administration of the plant-city. It is felt however that savings to the plant in municipal taxes will be sufficient to compensate for such expense.

<u>Employe Home Ownership.</u> The advantages of home ownership, both to the employes as individuals and to the company, are well recognized, and it is believed that some arrangement should be encouraged whereby at least one-half the housing could be offered to employes on liberal terms, either directly by management or by reputable builders approved by management. The cost of the several types of housing including its share of land and utilities (but excluding civic facilities) and the bare cost of a garage are estimated for a unit plant as follows:

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Estimation of Residential Housing Costs

	Coal Hydrogenation	Coal Synthine
Cost of land, grading, and landscaping	$ 1,220,408	$1,379,952
Less allocation to commercial facilities	838,194	947,771
	$ 382,214	$ 432,181
Cost of utilities allocated to residential	2,814,807	3,182,787
Residential share of land and utilities	$ 3,197,021	$3,614,968

	No. of Units	Total Cost of Dwelling Units	Allocated Cost of Share of Land and Utilities	Residential Cost: Total	Residential Cost: Per Unit
Coal Hydrogenation:					
Dwelling Units -					
2-Bedroom single-family	1,414	$10,040,814	$1,849,202	$11,890,016	$8,409
3-Bedroom single-family	471	4,099,584	755,015	4,854,599	10,307
Multi-family	471	3,218,814	592,804	3,811,618	8,093
	2,356	$17,359,212	$3,197,021	$20,556,233	$8,725
Garages	1,296	1,008,288	-	1,008,288	778
Total Residential		$18,367,500	$3,197,021	$21,564,521	
Coal Synthine:					
Dwelling Units -					
2-Bedroom single-family	1,598	$11,347,398	$2,089,773	$13,437,171	$8,409
3-Bedroom single-family	533	4,639,232	854,376	5,493,608	10,307
Multi-family	533	3,642,522	670,819	4,313,341	8,093
	2,664	$19,629,152	$3,614,968	$23,244,120	$8,725
Garages	1,465	1,139,770	-	1,139,770	778
Total Residential		$20,768,922	$3,614,968	$24,383,890	

If one-half the dwellings of each type were sold at cost to their occupants then the remaining investment in dwellings and civic development would be:

Estimated Remaining Investment in Dwellings and Civic Development for Unit Plant

	Coal Hydrogenation	Coal Synthine
Total Investment for Complete Plant-city	$29,609,154	$33,480,198
Less:		
Commercial Facilities and Related Costs	$ 5,867,359	$ 6,634,399
One-half Cost of Housing Sold to Occupants	10,782,261	12,191,945
Total	$16,649,620	$18,826,344
Balance of Investment in Land, Dwelling Units, Garages, Utilities, and Civic Development	$12,959,534	$14,653,854

This balance of investment consists of dwellings not sold to employes, together with the investment in land, grading, utilities, and civic facilities not recovered by rental of commercial facilities or sold. This investment would be operated by the plant.

Operating Costs

The annual costs of operation of investment not recovered by rental of commercial facilities or by sale are estimated below:

Annual Operating Costs

	Coal Hydrogenation	Coal Synthine
Net Total Investment	$12,959,534	$14,653,854
Operating Costs @ 6%	777,572	879,231

Annual costs of operation are estimated to comprise in terms of annual percentages on investment:

Annual Costs of Operation in
Terms of Annual Percentage on Investment

	Percent
Depreciation (40-year life)	2.5%
Maintenance Costs	2.0
State and County Taxes, Insurance, and Operation of Municipal Facilities	1.5
Total Annual Percentage	6.0%

It is considered that costs of operation of housing and community development may be recovered by rents of dwelling units without the necessity of any charge to plant operations.

The average amount per month required to offset operating costs would be $55.00 as shown below:

	Coal Hydrogenation	Coal Synthine
Annual Operating Costs	$777,572	$879,231
Number of Rental Units	1,178	1,332
Average per Unit:		
Annual	660	660
Month	$55.00	$55.00

Such an amount would be 17.3 percent of the average income per household of $3,808. The average annual wage of plant workers in Kansas has been estimated at $1.62 per hour or $3,369.60 per annum (of 2,080 hours). The average income per household on this basis
Kans would be $3,808 ($3,369.60 x 1.13 wage earners).

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Recognizing that different investors may require different rates of return upon their capital, these estimates include no allowance for return. However, as a guide, the following tabulation indicates the amounts per month for each unit and per barrel of products which would be required for each increment of one percent (before income taxes) on the estimated net total investment in housing and community development associated with a unit plant in Kansas:

Incremental Costs for Each 1 Percent Gross Return on Initial Net Investment in Housing and Community Development

	Coal Hydrogenation	Coal Synthine
Initial Net Investment	$12,959,534	$14,653,854
1 Percent Return on Above:		
Per Annum	$129,595	$146,539
Per Dwelling Unit:		
Per Annum	110	110
Per Month	9.17	9.17
Per Calendar Day	355	401
Per Barrel of Products	0.036	0.040

The monthly rental to be paid by the occupant would be the average monthly operating cost plus the required return on the investment.

MARKETING

Introduction

The agreement under which this report was prepared requires the General Areas suitable for the location of synthetic liquid fuels plants to be arranged in groups of relative desirability, with at least 2,000,000 barrels of daily production in the most desirable group for the total United States. This is equal to 730,000,000 barrels annually, or approximately 36.3 percent of the total demand for liquid fuels in the United States for the year 1949.

Motor Fuel - Major Plant Product. If a substantial part of the demand for liquid fuels in the United States were supplied by synthetic plants, the principal product would be motor gasoline.

Plants Using Coal or Natural Gas. For plants using coal or natural gas as raw materials, motor gasoline would be the major plant product. The amounts of motor gasoline specified to be produced from these raw materials by the various processes are as follows:

Percentage of Motor Gasoline
Specified To Be Produced by the Various Processes

Process	Percent
Hydrogenation	72.2%
Synthine Using Coal	72.8
Synthine Using Natural Gas	91.5

Plants Using Oil Shale. In the case of shale-oil plants, for the purpose of this report, motor gasoline is not specified as one of the products to be produced although such plants, if so designed, could produce motor gasoline. For a 10,000-barrel unit shale-oil plant, the principal products specified are 5,150 barrels of jet fuel and 3,350 barrels of Diesel fuel daily. The annual production of Diesel fuel of such a plant would be 1,220,000 barrels. In the year 1948 total sales of Diesel fuel in all of the Mountain States amounted to only 5,209,000 barrels. In other words, about five shale-oil plants would have been sufficient to satisfy the total demand for Diesel fuel in the Mountain States in that year. In the case of jet fuel, the annual output of a single 10,000-barrel-per-day shale-oil plant would be 1,880,000 barrels. This is approximately equal to the total sales of jet propulsion fuel in the year 1948 of 1,891,000 barrels in the total United States. Consequently, it appears that if a relatively large number of synthetic liquid fuels plants should be established, the principal product would be motor gasoline. Furthermore, since it appears that only enough natural gas will be available for relatively few synthetic liquid fuels plants, motor gasoline would amount to approximately 75 percent of the total productive capacity, based upon the plant product specifications.

From the foregoing, it is evident that of the total 2,000,000 barrels of daily productive capacity (which is equivalent to the capacity of 200 10,000-barrel synthetic liquid fuels plants) required to be included in the most desirable group of General Areas, gasoline would amount to approximately 1,500,000 barrels daily, or 547,500,000 barrels annually. This would be 62.3 percent of the total United States demand for motor gasoline in 1949, which amounted to 878,887,000 barrels. If the total demand for motor gasoline in 1949 had been supplied by synthetic liquid fuels plants, a total of 321 such plants would have been required. This is a relatively small number in contrast to the several thousands of plants potentially possible based on raw materials available.

Estimated Future Liquid Fuel Requirements. While the hazards of a long-range forecast of liquid fuel consumption are well recognized, it has been considered necessary in this present study to attempt to estimate probable liquid fuels requirements over the next 25 years because the usual short-term forecasts of a few years' duration would have little significance in appraising the economic factors that may have a bearing on the bringing into existence of a long-range program, such as the development of a synthetic liquid fuels industry. On the basis of present-day factors affecting motor gasoline consumption, the future demand has been projected by states and from this the total demand for the United States has been estimated, as shown in Exhibit No. 29, which demand in 1975 amounts to approximately 59 billion gallons, or 1.4 billion barrels annually. If this demand were met entirely with synthetic motor gasoline, the equivalent of 511 plants each of 10,000 barrels daily capacity would be required.

In recent years, the proportion of motor gasoline to the total demand for liquid fuels in the United States has averaged approximately 40 percent. At the present time, there are several factors which indicate that the motor gasoline percentage may rise in the next few years. There is a tendency for the percentage of residual fuel oils to decline as refining operations are altered. Furthermore, it is expected that the expansion of the natural gas industry may reduce relatively the consumption of fuel oil and kerosene. On the other hand, there may be some counterbalancing factors, such as the increasing use of jet propulsion fuel and Diesel fuel. However, on the basis of motor gasoline consumption of 40 percent, the total United States demand for liquid fuels in 1975 would be of the order of 3.5 billion barrels annually.

In order to provide a check upon the reasonableness of this estimate, the total annual energy supply for the United States was studied and projected to 1975. This is shown on the chart,

Exhibit No. 30, which indicates estimated total energy requirements in 1975 of 50 thousand trillions of Btu. In a recent study, "Energy Uses and Supplies, 1939, 1947, 1965", by the U. S. Bureau of Mines, Information Circular 7582, energy supplies in the United States are projected at approximately 48 thousand trillions of Btu in 1965. This is in close agreement with the 47 thousand trillions of Btu for 1965 shown on the chart, Exhibit No. 30. Of the estimated total energy supply in 1975 of 50 thousand trillions of Btu, the 3.5 billion barrels of liquid fuels would constitute 42 percent as contrasted with 35 percent in 1948, as shown on the chart, Exhibit No. 31. The relative proportions of energy supplied by coal, natural gas, and petroleum, which are also shown on that chart, indicate the reasonableness of the estimate. Some studies of liquid fuel demand have estimated that consumption in 1975 may be of the order of 5 or 6 billion barrels. If these quantities are related to the estimated 1975 total energy requirements, they would amount to 60 percent and 72 percent respectively. Such high percentages would appear to assume an unreasonable limitation on the use of other fuels such as coal and natural gas.

Crude Oil Reserves and Production. As of December 31, 1949, the estimated proved reserves of crude oil in the United States stood at 24,649,489,000 barrels, which is an all-time record high. This amount is 13.6 times the crude oil production of 1,818,800,000 barrels in 1949. If the proved reserves of natural gas liquids are added to the crude oil reserves, the estimated proved reserves of liquid hydrocarbons as of December 31, 1949 amounted to 28,378,501,000 barrels. In the past, new discoveries and extensions of old fields have added to the known supply. The following tabulation shows the amount of crude oil added to the supply by 5-year periods from 1925 to 1949:

Amounts of Crude Oil Added to the Supply

Period	Billions of Barrels
1925-29	10.044
1930-34	3.325
1935-39	12.161
1940-44	9.296
1945-49	13.336
Total	48.162

The above tabulation shows that, when the incentive has been strong, substantial quantities of crude oil have been discovered. It must be anticipated that further substantial quantities of oil will be discovered in the future. Recent important oil discoveries in Scurry County, Tex., and in California have increased appreciably the optimism with respect to future oil discoveries. Furthermore, the major oil discoveries made in Alberta, Canada, in recent years indicate that vast oil resources may exist in western Canada. This has led to the belief that important oil resources also may be found in North Dakota. In fact, the oil companies have under lease in the United States more than 200 million acres of untested lands having geological formations considered favorable to the discovery of oil.

Based upon the estimate of future requirements of liquid fuels in 1975, as previously developed, crude oil production during the next 25 years would be required in the amount of approximately 62 billion barrels. This may be compared to the 48.2 billion barrels added to the supply in the 25-year period 1925-1949. Stated in other terms, the estimated crude oil requirements during the next 25 years are at about the rate of additions to the supply developed in the 5-year period 1945-1949. Through 1949 the total amount of crude oil produced in the United States amounted to approximately 39 billion barrels. This, together with the estimated requirements to 1975, would indicate a total cumulative production by that time of approximately 100 billion barrels. In recent years it has been variously estimated that the total amount of oil ultimately recoverable from primary onshore operations amounts to approximately 110 billion barrels. In addition, it is estimated that approximately 40 billion barrels more might be obtained from offshore operations and from secondary recovery. In the petroleum industry, it is generally estimated at present that less than half of the oil originally in place is produced. Important changes in methods of production, therefore, might add considerably to the recoverable supply.

<u>Order of Desirability Influenced by Markets</u>. Since there are some 25 states having Suitable General Areas, it is not possible in these separate state reports, which are being prepared seriatim, and not simultaneously, to contemplate all of the factors to be developed in subsequent state reports, which might tend to vitiate some of the material presented herein. It might be shown subsequently, for example, that markets allocated to nearby General Areas could be supplied more economically from synthetic liquid fuels plants located in other distant states. In any case, the determination of the order of desirability of the General Areas must take into consideration the cost of transporting products to a designated market that could absorb the assumed output and not be based solely on estimated fob. plant costs. In these state reports, markets are defined and allocated to the General Areas under consideration with the full realization that information subsequently developed may show that the markets could be served more economically by other potential synthetic liquid fuels plants.

Definition of the Marketing Territory

As shown in Exhibit No. 10 there is only one suitable General Area of Coal and Water Availability in Kansas, located in the southeastern part of the State. The neighboring States of Missouri, Oklahoma, and Colorado also contain Suitable General Areas for the production of synthetic liquid fuels. A determination of the potential markets for the major products of synthetic liquid fuels plants in Kansas must, therefore, give consideration to the limiting factors placed upon the market by the existence of potential plant sites in neighboring states. At the present time, no General Areas suitable for the location of synthetic liquid fuels plants are known to exist in the State of Nebraska which borders on Kansas to the north. However, as demonstrated subsequently in this section of the report, the synthetic liquid fuels potential of the one Kansas General Area is very small in relation to the present and predicted future demand for liquid fuels in the State of Kansas itself. Consequently, it appears desirable to establish limits to the marketing territory to be served from synthetic liquid fuels plants in Kansas on the assumption that synthetic liquid fuels produced in Kansas would be marketed entirely within the State. While such a limitation of markets is somewhat arbitrary, it is believed to be necessary in order to avoid allocating the same marketing territory to the synthetic liquid fuels plants of more than one state.

Consumption of Motor Fuel in Kansas

The major product specified to be produced from coal by both hydrogenation and synthine plants, as shown in a previous section of this report, is motor gasoline. For both processes, motor gasoline constitutes approximately 75 percent of the total productive capacity. Since this product constitutes such a high percentage of the total proposed output, extensive consideration has been given to the factors bearing upon the present and predicted future demand and the present and predicted future supply of motor gasoline.

In this analysis, data on motor fuel consumption published by the Public Roads Administration have been used. In these figures, motor fuel consumption is reported for on-highway and off-highway uses excluding sales to the Federal Government for military purposes. Consequently, military requirements are eliminated from consideration in this report.

Although it is recognized there is some leeway in the processes, particularly the hydrogenation process, for producing some higher-grade gasolines, the quality of gasoline proposed to be produced by both the hydrogenation and coal synthine plants is specified to be about 78 to 80 octane motor method rating. Since this gasoline would be of lower standard than commonly used for aviation, aviation gasoline consumption has been eliminated from the total off-highway consumption of motor fuel as published by the Public Roads Administration. Therefore, motor fuel consumption figures given in this analysis do not include aviation use or purchases by the Federal Government for military purposes.

Motor gasoline consumption for the State of Kansas in the year 1948 amounted to 16,109,000 barrels. The annual production of motor gasoline from coal by a synthine or hydrogenation plant of 10,000-barrel-per-day capacity, would be approximately 2,737,500 barrels. Consequently, if the entire motor gasoline consumption in the State of Kansas in 1948 had been supplied by synthetic liquid fuels plants, approximately 6 such plants would have been sufficient to satisfy the total demand.

Since the motor fuel requirements of Kansas are well satisfied at the present time by petroleum products and since it appears that it may be many years before large quantities of synthetic liquid fuels will be required, it is desirable to estimate the future demand for motor fuel in Kansas. While ordinarily five or ten years might be considered the limit to which an estimate of future demand might be extended with a reasonable degree of accuracy, it was believed desirable in the present instance to attempt to estimate motor fuel consumption in the State of Kansas to 1975. Even though the hazards of such long-range prediction are realized, the main purpose of the estimate is to indicate the probable maximum number of synthetic liquid fuels plants which would be needed were no petroleum liquid fuels available.

Future Consumption of Motor Fuel in Kansas. To make an estimate of the future demand in the State of Kansas, motor fuel consumption was divided into on-highway and off-highway uses. The estimate of future on-highway use of motor fuel was based primarily on the growth trends of population, motor vehicle registrations, and consumption per vehicle. The off-highway use was determined principally from the on-farm consumption.

Population. In general, the future population estimates were based on an estimate published in November 1949, by the Bureau of Agricultural Economics of the U.S. Department of Agriculture. In the report, the population of the United States was projected to 1975 by major geographic divisions and the basis for these projections was past population figures of the Bureau of the Census.

The projections of future population by geographic divisions of the United States were based upon two estimates of future population by the Bureau of the Census. One of these, termed the high projection, was described as high fertility, low mortality, 200,000 net immigration per year, and high internal migration. The other, termed the low projection, was based upon medium fertility, medium mortality, no net immigration after 1950, and low internal migration. In this report, the high projection has been used since that forecast appears to be more reasonable, considering present population trends. On this basis, the population of the United States in 1975 is estimated by the Bureau of Agricultural Economics as 188,585,000.

Exhibit No. 32 shows the population by major geographic divisions of the United States from 1870 to 1950, with estimates to 1975. The extensions to 1975 on the chart correspond to the high projections made by the Bureau of Agricultural Economics, adjusted in the Pacific, Mountain, and South Atlantic States to reflect more recent conditions as indicated by the results of the 1950 census. It should be noted that these extensions carry out the trends in the past and may provide a fairly accurate gauge of the population growth in the years to come.

Since the State of Kansas is in the West North Central geographic division, the population of each state in that division was studied, both in absolute numbers and as percentages of the total population of the geographic division. From the percentage figures, projections of past trends were extended to 1975. The percentages so derived were then applied to the total estimated population of the geographic division in order to determine the population estimates for the various states. The figures so derived are presented in chart form in Exhibit No. 33, which shows the population of each of the states in the West North Central geographic division from 1900 to 1950 with estimates to 1975. The total estimated population of the seven states in 1975 is equal to 15,653,000 which is the estimate for the West North Central geographic division prepared by the Bureau of Agricultural Economics. The population of Kansas as of April 1, 1950 was 1,905,299 and the estimate for 1975 is approximately 2,092,000, an increase of approximately 10 percent.

<u>Motor Vehicles</u>. To obtain an approximation of the number of automobiles likely to be in use during the next 25 years, data of past automobile registrations published by the Public Roads Administration were studied. The number of persons per private and commercial automobile registration in each state was calculated and projected to 1975. In making these projections, attention was given to effects of present and possible future population density, income per capita, and other economic factors which would influence the number of persons per automobile.

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Exhibit No. 34 shows the number of persons per private and commercial automobile plotted against income payments per capita, for each of the states of the United States in 1948. It will be noted that on this chart the number of persons per private and commercial automobile decreases as the income payments per capita increase, except in the most densely populated states. The lower limit appears to be about three persons per vehicle and this limit seems to be approached only in those states where the income payments per capita are high and where the population density is not high. These data were used as guides in projecting the future number of persons per private and commercial automobile in each of the states. Exhibit No. 35 shows the number of persons per private and commercial automobile in each state of the West North Central States for the years 1930 to 1949, with projections to 1975.

The number of persons per private and commercial automobile in the State of Kansas in 1948 was approximately 3.32. The estimate for 1975 is approximately 2.97 persons per private and commercial automobile. Using the future population estimates mentioned previously and this number of persons per automobile, the number of private and commercial automobiles in the State of Kansas in 1975 is estimated to be approximately 704,400, while the number in 1949 was approximately 605,000 an increase of about 16 percent. Exhibit No. 36 shows private and commercial automobile registrations in Kansas for the years 1927 to 1949 with estimates to 1975. The number of publicly owned automobiles in 1975 was assumed to bear the same relationship to private and commercial automobiles in that year as existed in 1948. On this basis, the total number of automobiles estimated for the State of Kansas in 1975, including both publicly owned and private and commercial vehicles, is 706,700.

The number of motor trucks likely to be in use in the State of Kansas by the year 1975 was estimated in much the same manner as that employed in calculating the number of automobiles. Consideration having been given to the main economic factors which would influence the growth in number of motor trucks, the number of persons per private and commercial truck was projected to 1975. The present and possible future conditions with respect to population density and income per capita were considered. Special attention was given to the number of farm motor trucks now in use in the various states, since farm motor trucks comprise approximately 29 percent of the total number of private and commercial trucks in the United States. A study was made of the size and number of farms in each state, and the potential number of farm trucks which could be supported was taken into consideration. With this and the other guides mentioned, the number of persons per private and commercial motor truck in each of the states was projected to 1975. Exhibit No. 37 is a chart which shows the number of persons per private and commercial motor truck in the West North Central States for the years 1930 to 1948 and estimates to the year 1975. From the future projection on this chart for the State of Kansas, the number of persons per private and commercial truck in 1975 is shown to be 7.75. Using the population estimates developed previously and the same proportion of publicly owned motor trucks as existed in 1948, the total number of motor trucks expected to be in use was projected to 1975. In that year the estimate is 278,700 motor trucks as compared with 1948 registrations of 184,248, as reported by the Public Roads Administration. This is an increase of about 51 percent.

To estimate the growth in bus registrations, Public Roads Administration figures were used in conjunction with more recent figures obtained from the bus census of "Bus Transportation". From these data the number of persons per common carrier bus and per school bus were computed and projected to 1975. Using the population figures previously developed, the total number of buses for the State of Kansas was projected to 1975 with the number in that year amounting to approximately 2,400 buses.

On-Highway Consumption of Motor Fuel in Kansas. To arrive at an estimate of future on-highway use of motor fuel in Kansas, the weighted average annual use of motor fuel per vehicle by type of vehicle was calculated from information of on-highway consumption for the State of Kansas published by the Public Roads Administration for 1948. The estimated future on-highway use of motor fuel was then calculated from the number of motor vehicles previously estimated, multiplied by the weighted average annual consumption per vehicle. In other words, the estimates of future consumption are predicated on the average annual consumption per vehicle obtained in 1948. It is realized that motor vehicle efficiencies may increase somewhat in the future but data published by the Public Roads Administration covering vehicle travel per gallon of fuel consumed over the past 15 years would not indicate the likelihood of any striking changes in over-all efficiency. It may be that eventually motor vehicles will consume less fuel per vehicle-mile but it was believed preferable in this study to run the risk of overstating the future consumption rather than understating it by taking into consideration statements concerning future motor vehicle efficiencies that may not be achieved. If motor vehicle fuel efficiencies are increased appreciably in the future, the estimates of future on-highway consumption here developed will be proportionately too large. Based on the estimated number of vehicles and weighted average annual fuel consumption per vehicle, the on-highway motor fuel consumption in Kansas in 1975 is estimated at 605,467,000 gallons. This is an increase of approximately 33 percent over 1948 on-highway consumption of 455,310,000 gallons.

Off-Highway Use of Motor Fuel in Kansas. Since the consumption of motor fuel in agriculture constitutes the largest single item of off-highway use, special attention was given to the consumption of motor fuel by tractors on farms. To estimate the number of farm tractors that will be required in 1975, the amount of crop land harvested per tractor was studied. Exhibit No. 38 shows in chart form the average crop land harvested in acres per tractor for the United States from 1940 to 1949 with estimates to 1975.

To estimate the future number of tractors on farms for individual states, analyses were made of the number of farms by size groups, trends in the number of tractors on farms, the amount of crop land harvested in acres per tractor, per capita income payments, and the average amount of crop land harvested per farm. The chart, Exhibit No. 39, shows for each of the states in the United States for the year 1949 the average crop land harvested per tractor plotted against the average harvested crop land per farm. From the analysis of the number of farms by size groups, estimates were made of the maximum number of tractors which could be economically supported in each state. These numbers were then adjusted in view of the other factors mentioned above to arrive at an estimate of the number of tractors in each state. Using the estimated number of tractors in each state for 1975, the average crop land harvested per tractor was calculated and plotted against the average crop land harvested per farm, as shown in the chart, Exhibit No. 40.

The number of tractors on farms in the United States obtained for the year 1975 by totaling the individual state estimates developed as above, amounts to 5,264,000 tractors. The reasonableness of the estimate of the number of tractors in each state in 1975 is indicated by the fact that the total for the United States (obtained in this manner) agrees quite well with the total estimated by the U. S. Department of Agriculture. In a study of food and harvested crop land required in 1975, the Department of Agriculture estimated that there would be 5,000,000 tractors on farms in the United States. That Department's estimate of the harvested crop land required, however, was based upon a lower estimate of future population than now appears reasonable. These estimates for tractors in 1975 may be compared to 3,365,000 tractors (excluding garden tractors) on United States farms as of July 1, 1949.

For the State of Kansas the number of farm tractors in 1975 is estimated at 246,000. This is an increase of approximately 62 percent over the 151,650 tractors estimated on Kansas farms as of July 1, 1949. The amount of motor fuel consumed per tractor in each state in 1948 was obtained from information published by the Bureau of Agricultural Economics. These amounts were then multiplied by the estimated number of tractors in each state to arrive at estimates of future consumption of motor fuel by tractors in each state. For Kansas, motor fuel consumption by tractors in 1975 is calculated at 325,950,000 gallons.

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Other off-highway uses of motor fuel in Kansas in 1948 represent only a small percentage of the total consumption and for purposes of this estimate are assumed to bear the same relationship in the future as in the past. The total motor fuel consumption in Kansas for the years 1927 to 1948 is shown on the chart, Exhibit No. 41, which also presents the estimate of future motor fuel consumption to 1975. It will be noted from the chart that the total motor fuel consumption (excluding aviation and military uses) for 1975 is approximately 980,782,000 gallons or about 23.4 million barrels. This represents an increase of approximately 45 percent over 1948 consumption.

Number of Synthetic Liquid Fuels Plants Equivalent to Motor Fuel Consumption in the Marketing Territory

The following tabulation shows a summary of total motor fuel consumption, less aviation and military use, in the State of Kansas for the year 1948 and the estimate for 1975. The tabulation also presents the number of hydrogenation or coal synthine plants, the motor fuel productive capacity of which would be equivalent to the total motor fuel consumption in the marketing territory.

Motor Fuel Consumption and Equivalent Number of Unit Synthetic Liquid Fuels Plants

	Million of Barrels	Equivalent Number of Unit Synthetic Liquid Fuels Plants
	Kansas	
1948	16.1	6
1975 Estimate	23.4	9

While it is indicated by the above tabulation that the output of motor fuel of 9 hydrogenation or coal synthine plants of 10,000 barrels daily capacity would be the equivalent of the estimated consumption in the marketing territory in 1975, it must be emphasized that it is not implied that this number of synthetic liquid fuels plants would be required. The calculation is made to show the maximum number of such plants that would be needed if no supplies of petroleum products were available and for purposes of comparison with the number of synthetic liquid fuels plants potentially possible, based upon the coal and water availability. As shown previously, these are sufficient to support approximately 2.6 hydrogenation plants or approximately 2 synthine plants.

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Consumption of Liquid Fuel Products other than Motor Fuel in the State of Kansas

Although motor gasoline is specified as the major plant product of both hydrogenation and synthine plants using coal as a raw material, other liquid fuel products and phenols are also specified to be produced. These are listed in the following tabulation, which shows the plant product distribution for both hydrogenation and coal synthine plants and also shows the other products as percentages of the proposed motor gasoline production.

Unit Plant Product Distribution

	Barrels per Day		Percent of Gasoline	
	Hydrogenation	Synthine Using Coal	Hydrogenation	Synthine Using Coal
Gasoline	7,220(A)	7,280	100%	100%
Diesel Fuel	-	1,900	-	26.1
Fuel Oil	-	350	-	4.8
Liquefied Petroleum Gases	2,367	470	32.8	6.5
Phenols	413	-	5.7	-
Total	10,000	10,000		

Note: (A) May be increased to 7,684 barrels per day of gasoline by conversion of phenols.

The actual consumption of liquid fuels in the State of Kansas by principal product classifications is presented in the following tabulation:

Liquid Fuel Consumption in the State of Kansas in the Year 1948, by Principal Product Classifications

Description	Thousands of Barrels Kansas
Motor Fuel	16,109
Kerosene	1,147
Diesel Fuel	1,865
Other Distillates	2,229
Residual Fuel	9,876
Total	31,226

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In the above tabulation the figures for motor fuel consumption are exclusive of aviation and military uses. The data given for the other product classifications are sales figures as published by the Bureau of Mines. Consumption or sales figures for liquefied petroleum gases are not published by states but are available by Petroleum Administration for War Districts. The figures for District No. 2, which includes the State of Kansas, and 14 other states, show that sales of liquefied petroleum gases in the year 1948 amounted to approximately 5.9 percent of the motor fuel consumption in that district.

The following tabulation shows, for petroleum products similar to the products specified to be produced by synthetic liquid fuels plants, consumption in Kansas in 1948 as percentages of motor fuel consumption.

Consumption of Other Liquid Fuel Products
as a Percentage of Motor Gasoline Consumption

Description	Kansas
Motor Gasoline	100.0%
Diesel Fuel	11.6
Residual Fuel Oil	61.3

The distribution of actual product consumption evident in the above tabulation differs materially from the proposed distribution of plant products specified to be produced by the hydrogenation and coal synthine plants. In the case of Diesel fuel, the actual consumption amounts to 11.6 percent of the motor fuel consumption, whereas for synthine plants the estimated production is 26.1 percent. The output of liquefied petroleum gases by hydrogenation plants at 32.8 percent of the gasoline produced is unusually high as compared with consumption in 1948 in P.A.W. District No. 2, which amounted to approximately 5.9 percent.

It is apparent from the above analysis that the plant product distribution for both hydrogenation and coal synthine plants does not correspond to actual product consumption in Kansas. In the case of the hydrogenation type of plant, according to the proposed plant product distribution, too high a percentage of liquefied petroleum gases is specified, and in the case of the coal synthine plants
Kans the percentage of Diesel fuel specified is too high. Of course, if
151b only the 2.6 hydrogenation or the 2.0 coal synthine plants poten-
152a tially possible in Kansas were in operation, the differences would be
3 immaterial. It appears, however, that complete reliance upon syn-
70021 thetic liquid fuels plants as a source of supply is so far in the

future that the product demand pattern may change considerably in the intervening years. At such time as synthetic liquid fuels plants are economically feasible, it is probable that they would be so designed as to produce the products then in demand.

Sources of Liquid Fuel Supply for Kansas

Source of Crude Oil. The State of Kansas is an important producer of crude oil, accounting for about 5.5 percent of the total United States production in 1949. In that year, Kansas produced approximately 100 million barrels of crude oil, while proved reserves of crude oil as estimated by the American Petroleum Institute stood at 738,390,000 barrels as of December 31, 1949.

Although the total production of crude oil in Kansas is more than adequate to care for the total crude oil requirements in the State, a large portion of the crude oil produced is shipped to refineries in other states, with the consequence that refineries in Kansas obtain part of their requirements of crude oil from other producing states. Receipts of crude oil at refineries in Kansas by states of origin in the year 1948 are shown in the following tabulation:

Receipts of Crude Oil at Refineries in Kansas by States of Origin in the Year 1948 (A)

	Thousands of Barrels
Intrastate Receipts	53,483
Interstate Receipts from:	
Oklahoma	7,023
Texas	6,099
Wyoming	1,237
Colorado	391
New Mexico	24
Other Receipts	1,282
Total Interstate Receipts	16,056
Total Receipts of Crude Oil	69,539

Note: (A) Includes receipts at 5 refineries in Nebraska, total crude oil capacity of which is 6,800 barrels per day as compared with crude oil capacity of 201,550 barrels per day in Kansas.

Approximately 77 percent of the crude oil received at refineries originated within the State of Kansas, while the bulk of the interstate receipts came from Oklahoma and Texas. Furthermore, over 95 percent of the crude oil received was delivered by pipe lines with tank cars and trucks accounting for less than 5 percent of the total amount delivered. The following tabulation shows receipts of crude oil at refineries by method of transportation for the year 1948.

Receipts of Crude Oil at Refineries in Kansas
by Methods of Transportation
in the Year 1948 (A)

	Thousands of Barrels
Intrastate Receipts:	
By Pipe Lines	52,366
By Tank Car and Truck	1,117
Total Intrastate Receipts	53,483
Interstate Receipts:	
By Pipe Lines	13,860
By Tank Car and Truck	2,196
Total Interstate Receipts	16,056
Total Receipts:	
By Pipe Line	66,226
By Tank Car and Truck	3,313
Total Receipts of Crude Oil	69,539

Note: (A) Includes receipts at 5 refineries in Nebraska, total crude oil capacity of which is 6,800 barrels per day as compared with crude oil capacity of 201,550 barrels per day in Kansas.

Kans <u>Crude Oil Refining Capacity.</u> The present oil refining
153b capacity in Kansas amounts to approximately 74 million barrels of
154a crude oil annually and is much more than adequate to cover the
3 State's annual consumption of liquid fuels, amounting to about 31
70021 million barrels in 1948. In that year it is estimated that crude
oil runs to stills amounted to approximately 67 million barrels.

As of January 1, 1950, there were 16 refineries located in the State of Kansas. A list of the operating refineries with their locations, crude oil capacities, and operating companies is given below.

Oil Refineries in Kansas
as of January 1, 1950

Location	Crude Oil Capacity (Barrels per Day)	Company
Arkansas City	8,500	Kanotex Refining Co.
Augusta	26,500	Socony-Vacuum Oil Co., Inc.
Chanute	1,650	Missouri Farmers Association
Chanute	1,000	The Chanute Refining Co.
Coffeyville	18,000	Cooperative Refinery Association
El Dorado	25,000	Skelly Oil Co.
El Dorado	8,000	El Dorado Refining Co.
Kansas City	50,000	Phillips Oil Co.
McPherson	18,000	National Cooperative Refinery Assn.
McPherson	6,000	Bay Petroleum Corp.
Neodesha	10,400	Standard Oil Co. (Ind.)
Phillipsburg	4,000	Cooperative Refinery Association
Potwin	5,500	Vickers Petroleum Co., Inc.
Shallow Water	2,500	Shallow Water Refining Co.
Wichita	9,000	Derby Oil Co.
Wichita	7,500	Bareco Oil Co.
Total	201,550	

Prices of Petroleum Products in Kansas

As shown previously, production of crude oil and products in Kansas is greatly in excess of total liquid fuel requirements in the State. Consequently, potential synthetic liquid fuels plants in Kansas would be situated in an important petroleum producing region. Under such circumstances synthetic liquid fuels plants would have no competitive advantage due to location.

In this study consideration has necessarily been given to the prices of petroleum products in Kansas as being one of the important factors affecting present and future demand for liquid fuels in the marketing territory. Weighted average composite prices of petroleum products have been computed based upon the same liquid fuel products and proportions as those specified to be produced by hydrogenation and coal synthine plants. These composite prices were constructed from quotations obtained on the various petroleum products in wholesale quantities fob. refineries in Kansas, excluding taxes. While the cost calculations for synthetic liquid fuels plants and products contained in other sections of this report are based upon prices and quotations prevailing as of March 31, 1950, it was deemed preferable to use, in these calculations, quotations for petroleum products as of June 1, 1950 because refinery margins as of that date, appear to have been more nearly normal. In the tabulation on the following page, prices of the various petroleum products in Kansas, as of June 1, 1950, are weighted according to the plant product distribution specified for hydrogenation and coal synthine plants.

In the tabulation referred to, the price shown for gasoline is that of regular grade house brand containing tetraethyl lead with an octane rating of 82 or better. This product is evidently superior as a motor fuel to the gasoline specified to be produced by the hydrogenation and synthine processes using coal. The gasoline produced by these processes is stated to have an octane rating of 78 to 80 motor method and no provision has been made in the calculations for the addition of tetraethyl lead, although it is understood that improvement by such addition may be made at nominal cost above the base cost of the required tetraethyl lead. The quotation on Diesel fuel is for a product with a rating of 55 cetane. In the tabulation, the price used for fuel oil for the synthine process is that of No. 6 (residual fuel oil).

Propane is specified to be produced by the synthine process using coal and both propane and butane by the hydrogenation process in the proportions of about 72 percent propane and 28 percent butane. The price differential between propane and butane is subject to wide seasonal fluctuation. In the summertime, prices of the two products may be equal, but in the wintertime, when there is a demand for butane for mixing with motor fuel, the price may rise considerably above that for propane. In the calculations following, the price for propane alone is used since that product constitutes such a high percentage of the total.

Composite Prices of Petroleum Products Fob. Refineries in Kansas as of June 1, 1950
Weighted According to the Plant Fuel Product Distributions
Specified for Hydrogenation and Synthine Plants Using Coal

		Prices of Petroleum Products				Prices of Petroleum Products		
Product	Hydrogenation Plant Fuel Product Distribution (Percent)	Cents per Gallon	Dollars per Barrel	Weighted Composite Dollars per Barrel	Synthine Plant Product Distribution (Percent)	Cents per Gallon	Dollars per Barrel	Weighted Composite Dollars per Barrel
Gasoline	75.31%	11.00¢	$4.620	$3.479	72.80%	11.00¢	$4.620	$3.363
Diesel	-	-	-	-	19.00	9.00	3.780	.718
Fuel Oil	-	-	-	-	3.50	4.88	2.050	.072
Propane and Butane	24.69(A)	2.50	1.050	.259	4.70	2.50	1.050	.049
Total	100.00%			$3.738	100.00%			$4.202

Note: (A) 72 percent propane and 28 percent butane.

In the tabulation referred to, the composite wholesale price fob. refinery of petroleum products, as of June 1, 1950, weighted in the same proportions as the liquid fuel products specified to be produced by hydrogenation synthetic liquid fuels plants is shown to be $3.74 per barrel and for products weighted in the same proportions as those specified to be produced by coal synthine plants the composite wholesale price is shown to be $4.20 per barrel. It should be pointed out that the estimates of future demand for petroleum products have been based on projections of present-day factors affecting consumption. It is not known how or when synthetic liquid fuel products will become competitive with petroleum products in the marketing territory. If, due to difficulties in developing supplies, costs of crude petroleum rise to such an extent in the future as to cause petroleum product prices to rise substantially relative to the general price level and to alter the competitive price positions of fuels, the projected future demand no doubt may be considerably less than the amounts estimated previously for the marketing territory.

Transportation of Plant Products

When synthetic liquid fuels plants become economically feasible, they will occur first obviously in those General Areas where the over-all conditions appear most favorable for financial success. An important advantage of synthetic liquid fuels plants in certain areas would be their proximity to markets made possible by raw material resources located in or near regions of high population density. In such cases the resultant lower costs of distributing plant products to the points of consumption within the marketing territory would give an important economic advantage to the local plants. Such would not be the case, however, in Kansas which is an important crude oil producing state.

Synthetic liquid fuels plants situated in the Suitable General Area in Kansas would be well located for the distribution of plant products within the marketing territory, whether the output of a single plant or of the total number of plants potentially possible is considered. A single plant could probably dispose of its output within reasonable trucking distance of the plant, while the total number of plants potentially possible could make use of pipe line facilities which already exist for the distribution of petroleum products within the marketing territory.

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The General Area in Kansas is situated near regions of relatively high population density since the largest concentrations of population in Kansas are located in the eastern half of the State. Even though the extreme southeastern section of the State, in which the General Area is located, has considerably lower population density than the northeastern section, nevertheless fairly large aggregations of population exist in the vicinity of the General Area. The estimated population of the counties in Kansas by size groups, as of January 1, 1949, is shown on the map, Exhibit No. 42. This exhibit also shows the approximate center of the General Area. During 1948, the average annual per capita consumption of motor fuel in Kansas was about 8.5 barrels. At that rate, 322,000 persons would consume the motor gasoline production of a single hydrogenation or coal synthine synthetic liquid fuels plant. It is clear from a study of the map, Exhibit No. 42, that sufficiently large populations live within reasonable trucking distance of the General Area for the output of a single plant to be disposed of locally if the products were distributed by one of the important marketers or if there were an exchange of products between companies.

If the total synthetic liquid fuels potential of the General Area in Kansas were developed, it would be desirable to utilize transportation facilities which exist in the marketing territory since all of the products could not be marketed locally. Great Lakes and Sinclair products pipe lines run northward through the eastern portion of Kansas to the vicinity of Kansas City. These pipe lines are shown on the county population map, Exhibit No. 42. A connecting pipe line of approximately 40 miles in length would enable plants in the Kansas General Area to tie into these pipe lines. With such a connecting link, the synthetic liquid fuel produced in excess of the local demand could be moved to Kansas City.

The cost of transportation of plant products to the marketing territory is one of the factors that must be taken into consideration in determining the relative desirability of the General Areas suitable for synthetic liquid fuels plants. It has been shown previously that a single 10,000-barrel-per-day hydrogenation or coal synthine plant located in the General Area in Kansas could probably dispose of all of its output locally. Products from the General Area could probably be moved to bulk stations or to dealers by transport truck or tank truck. In this study, it is not considered feasible or necessary to measure the cost of transporting products to local distribution points or to dealers' premises.

In the case of more than one synthetic liquid fuels plant operating simultaneously, delivery of products to the points of consumption would be by pipe lines, and trucks. A large part of the cost of distributing products throughout the marketing territory would be incurred jointly and might not be segregable by plants. While the cost of transportation is one of the factors that must be considered in determining the relative desirability of General Areas, in this study this requirement has been construed not to include the cost of moving products within the marketing territory. By definition, the marketing territory for plants located in the Suitable General Area in Kansas was limited to the area in which it was assumed the local plants would have transportation cost advantages over synthetic liquid fuels plants located in states outside of the marketing territory. In other words, the transportation costs with which this study is concerned are those covering the movement of products to distant marketing territories and not those incurred in distributing products to points of consumption within the defined marketing territory. It is assumed that the cost of distribution within a given marketing territory would be about the same for plants located outside as for those within the territory but that outside plants would incur additional costs of transporting products to the market under consideration. Consequently, in determining the relative desirability of General Areas, costs of transportation need not be taken into consideration for those General Areas which lie wholly within a local marketing territory.

<u>Summary and Conclusions</u>

For the purpose of analyzing potential markets for synthetic liquid fuels plants in Kansas, the marketing territory has been defined to include the entire market in the State of Kansas. Motor fuel consumption in this marketing territory in 1948 amounted to 16.1 million barrels and is estimated to reach an annual volume of 23.4 million barrels by 1975. These amounts of motor fuel consumption would be equivalent respectively to the gasoline output of about 6 and 9 synthetic liquid fuels plants of 10,000 barrels daily capacity using coal as raw material.

The plant product distributions specified for both the hydrogenation and synthine plants using coal do not correspond to the present actual product consumption in the marketing territory. If only the 2.6 hydrogenation or the 2.0 coal synthine synthetic liquid fuels plants potentially possible in Kansas were in operation, the differences would be inconsequential.

The demand for liquid fuels in the marketing territory is economically supplied at present principally by the local production of crude oil and products. Wholesale prices as of June 1, 1950, of petroleum products fob. refineries in Kansas amount to $3.74 per
Kans barrel when weighted in the same proportion as the liquid fuel
159b products specified to be produced by hydrogenation plants and to
160a $4.20 when weighted according to the plant products specified for
3 coal synthine plants. A major increase in liquid fuel prices
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altering basically the competitive positions of fuels could have the effect of reducing substantially the estimates of demand within the marketing territory.

In the United States during the five-year period 1945-1949, the amount of crude oil added to the known supply was larger than in any similar period; and furthermore, proved reserves as of December 31, 1949 stood at an all-time record high of about 25 billion barrels. During this five-year period, proved reserves increased 4,864,959,000 barrels. From the analysis, the prospective supply of petroleum appears adequate to satisfy the demand for liquid fuels for the present and at least a major portion of future requirements for a long period of years.

When synthetic liquid fuels plants, using coal as a raw material, become commercially feasible, it appears likely that they will be constructed first in those General Areas where there is a combination of unusually favorable factors. An important advantage for synthetic liquid fuels plants in certain parts of the United States would be their proximity to large centers of consumption distant from the principal sources of Petroleum. Since Kansas is an important crude oil producing State, synthetic liquid fuels would have no competitive advantage over petroleum products due to location. At such time as synthetic liquid fuels would be required in Kansas, plants situated in the Suitable General Area established in this report, would be well located for the distribution of plant products within the marketing territory, whether the output of a single plant or of the total number of plants potentially possible were to be marketed. Within the marketing territory defined, plants in the Kansas General Area would have minimum costs for distribution of synthetic liquid fuels. For the purpose of determining the relative desirability of General Areas in the United States, costs of transportation of plant products need not be taken into consideration for those General Areas which lie wholly within a local marketing territory.

WASTE DISPOSAL

General

The manufacture of synthetic liquid fuels from coal, by either hydrogenation or synthine process, produces gaseous, liquid, and solid wastes, all of them constituting potential nuisances. Any or all of these may require special treatment or disposal in degree, depending upon the location of the plant with respect to settled communities, public water supply, farming areas, etc. The principal gaseous wastes are sulfur compounds, resulting from combustion or removal of sulfur present in the coal. Liquid wastes consist of waste water from process, carrying oil and chemical contamination; blowdown from cooling towers and boilers, which may carry excessive concentrations of dissolved solids; and plant sanitary sewage. Solid waste consists of ash originally present in the coal, any unburned coal, and spent catalysts, principally iron oxide.

Gaseous Wastes

In the coal hydrogenation process, about one-fifth of the coal consumption of the plant is burned in the boiler house. Sulfur dioxide is present in the flue gases to the same extent as in those from any other power plant of equivalent size (about 90,000 to 100,000 kw) in respect to boiler capacity. The sulfur present in the balance of the coal is removed at various points in the process, appearing as hydrogen sulfide. This may be burned in the power plant, producing additional sulfur dioxide in the stack gases; burned to sulfur dioxide and converted to by-product sulfuric acid, or converted directly to elemental sulfur, using currently established commercial processes. If burned in the power plant, the total sulfur dioxide resulting will be about equivalent to that from a very large steam power plant - say 500,000 kw. Choice of alternative disposal methods would depend on local markets for the respective by-products.

In the coal synthine process, the steam and power required are generated from waste heat. The coal received at the plant goes direct to synthesis gas manufacture, the sulfur in the coal appearing principally as hydrogen sulfide, which is removed in concentrated form in the course of gas purification. If necessary, hydrogen sulfide may be burned in flares, producing sulfur dioxide. In the case of high-sulfur coals, however, the quantity of hydrogen sulfide produced may be too great for such disposition. In such case, hydrogen sulfide may be converted to sulfuric acid or to elemental sulfur, the choice depending upon local markets for these by-products. In any event, it appears practicable to reduce the sulfur nuisance to any reasonable extent required.

Liquid Wastes

The principal contaminated liquid process waste discharged from a coal hydrogenation plant will be a relatively small amount - about 50,000 gallons per day - of foul process water, separated from the oil stream in the coal traps and pressure letdown tanks, and carrying relatively high concentrations (in the tenths of a percent) of dissolved phenols, ammonia, and hydrogen sulfide, as well as oil and tar in suspension. Industrial wastes containing phenols are of great importance because they impart objectionable tastes to drinking water supplies and, if in sufficient concentration, are toxic to fish and otheraquatic life. Although the wastes from a synthetic liquid fuels plant would be treated or recovered either to eliminate the phenols or reduce them to a point where they would be harmless, it is recognized that occasionally the treatment process might break down and that some phenols would reach the receiving streams. The effect of such possible discharges from the synthetic liquid fuels plant would depend upon the exact location of the plant and the distance from the point of discharge to the water works intake or intakes.

Preliminary studies indicate that it will be possible to remove all of these contaminants to any extent which may be required by local health or other authorities, at a total cost well within the allowance already made for this purpose in the over-all plant construction and operating cost estimates. Subject to necessary further development work, it now appears that this removal can be accomplished by a series of operations consisting of:

(a) A skimming pond for gross removal of oil and tar;

(b) Liquid-to-liquid solvent extraction of remaining oil and tar, using hydrocarbon solvent cuts obtained in the main process and recycled;

(c) Pressure release, accompanied by heating, to remove hydrogen sulfide and ammonia;

(d) Treatment with recently developed highly basic ion-exchange resin, to effect phenol removal down to perhaps 0.005 ppm; followed by

(e) Final treatment with ozone to oxidize any remaining phenol below possible taste level, if necessary.

Periodic regeneration of the ion-exchange resin with concentrated caustic soda will produce a strong solution of sodium phenolate from which crude phenol may be separated by treatment with waste carbon dioxide from the main plant and returned to process. The small quantity of sodium carbonate solution remaining could be evaporated to dryness for ultimate disposal, if necessary. A rough preliminary estimate indicates that a total sum of $500,000 to $600,000 should be adequate to cover the cost of such a disposal system, including the oil-skimming pond.

It is also possible to destroy phenols by biochemical oxidation, as for example on a tricklingfilter. This method, which is practiced on a commercial scale in the United States, requires preliminary reduction of phenol concentration, either by solvent extraction ("phenosolvan" process) or by dilution, to about 200 ppm. The combined operation would be substituted for step (d), above. However, the possible presence, in thefoul process water, of cyanides which may cause serious interference with bacterial action, has led to the consideration of ion-exchange as an alternative method.

In the case of synthine, side-reactions in the process together with scrubbing operations, result in a water stream containing large quantities of organic compounds, principally aliphatic alcohols, acids, aldehydes, and ketones. Information from the U.S. Bureau of Mines, together with preliminary studies by other engineers in the petroleum industry who have worked on this problem, indicates that scrubbing may be limited to the point where total quantity of process and scrubbing water combined amounts to about 450,000-500,000 gallons per day in a unit plant. To the extent that a market can be found for the chemical by-products, they may be recovered and sold. However, after a few synthine plants have been established, it is anticipated that the existing market for such products in refined state would be saturated, with the result that their recovery would no longer be profitable. In such case it is assumed that a crude mixture of the more volatile alcohols and ketones will be removed by a simple distillation, and either sold at fuel value or returned to process for gasification to provide additional synthesis gas. The contaminated water remaining would be used as boiler feed to provide make-up steam for synthesis gas production.

Plant sanitary sewage from either hydrogenation or synthine plants would be of the order of 100,000 gallons per day in a unit plant. If local authorities require treatment before this effluent is run into the streams, the necessary sewage disposal plant should not involve an investment of more than $100,000 to $150,000.

Engineers of the U.S. Bureau of Mines have stated that the plant cost estimates, in the case of each process, include an allowance of approximately $1,000,000 to cover waste disposal from a unit plant. This should be sufficient to cover maximum require-
Kans ments for complete treatment of contaminated liquid process wastes
163b and plant sanitary sewage. Since over-all plant operating cost
164a estimates are based primarily upon factors proportionate to con
struction cost, the inclusion of adequate construction cost pro-
2 vision for liquid waste disposal in the general estimates also
70021 implies inclusion of proportionate allowance for disposal system

operating costs. The probable adequacy of this allowance is indicated by preliminary estimates. In respect of coal synthine, some dissenting opinion exists as to whether the scrubbing water may be limited within the amount which can be reabsorbed in process. Any excess would require treatment before disposal. Further development work is necessary before the question may be resolved. At the worst, a disposal cost of $0.10 to $0.20 per barrel of products might be required, over and above the allowance already included in general process cost estimate.

The remaining liquid plant waste to be considered is that resulting from boiler and cooling tower blowdown. Since the principal water consumption in both hydrogenation and synthine processes is by evaporation loss, the water rejected from the plant, other than the process and sanitary wastes mentioned, will consist largely of these blowdowns and may contain the major part of the daily tonnage of dissolved solids in the gross water make-up drawn by the plant. As a result, the concentration of dissolved mineral salts in the blowdown water may be several times as great as that in the original make-up. For plant locations where the make-up water is not already abnormally high in dissolved salts and where the wastes can be discharged into streams of which the minimum flow is large in proportion to the waste volume, dilution of the blowdown with other plant effluents should serve to keep the whole within acceptable limits. Where large quantities of blowdown are to be discharged into small streams having a low minimum flow, the increase in solids might affect the suitability of the water for other uses. Such uses are minor, and, in general, no difficulty should be encountered in the discharge of blowdown from cooling towers. In extreme cases, however, it is possible that State authorities may require a reduction in the concentration of dissolved solids before approval is granted. This may involve added costs, over and above those included in the general allowance for waste disposal. Actual determination of these added costs (if any) for any specific plant location would require detailed information, such as individual standards applying to the particular stream which would receive the wastes, complete analysis of the water available for cooling tower make-up and for possible dilution purposes, and similar data, not available in the current general survey.

Stream Pollution. In regard to possible stream pollution and the necessity for treatment of liquid wastes for plants in Kansas, the following condition has been developed in the course of the investigation.

The State of Kansas acting through its Board of Health, is taking steps toward the elimination of stream pollution throughout the State. The low flows of the Neosho River have made sewage treatment essential at all of the larger cities in southeastern Kansas and plants have been in operation for may years. It is certain that if a synthetic liquid fuels development were initiated in southeastern Kansas, sewage treatment facilities would be required for the domestic sewage and some treatment of the industrial wastes would probably be necessary.

The domestic sewage could be treated by conventional methods to whatever degree is necessary. Primary treatment has been established as the minimum treatment for all towns on the Kansas River, but more complete treatment might very well be ordered in the Neosho River Valley because of the relatively low flows. In any event, the cost of domestic sewage treatment would be only a very small part of the total cost for providing community facilities and would present no particular problem.

The only municipal water supply taken from the Neosho River below the General Area in Kansas is that at Chetopa where a population of approximately 1,350 persons are served. In Oklahoma, the Neosho River (Grand River) is used for municipal water supply purposes at six places, the largest of which is Muskogee, Oklahoma, which has a water supply of approximately 4.5 mgd. These supplies take their water either from the Lake O' the Cherokees or from the Grand River itself below the lake. Dilution of the wastes in the Lake O' the Cherokees would effectively protect all of the Oklahoma water supplies and industrial wastes would therefore be of no great consequence. The Chetopa, Kans. supply would probably not suffer from industrial wastes to any appreciable extent, but in any event, the water requirements at Chetopa are so small that another source could be obtained or the intake moved at relatively small cost if this were necessary.

Legal Aspect. The authority of the Kansas State Board of Health and other legal requirements pertaining to industrial wastes and stream pollution are outlined in the following paragraphs.

The Kansas State Board of Health has authority to prevent the pollution of streams that might affect the public health or be detrimental to animal or aquatic life, subject to review by the district Court of the County in which the pollution occurs. Permits are required from the Board of Health for the discharge of sewage or wastes. Permits to discharge wastes are granted for an indefinite period, although any time treatment becomes inadequate because of overloading of facilities or reclassification of a stream for a higher use, the permit may be removed. The pollutor then has one year to comply with Board of Health requirements before action is initiated against him in th courts.

Special statutes have been enacted to control brine and waste discharges from oil and gas fields. Wells must be cased to prevent pollution of fresh water aquifers with salt water. Statutes also prohibit the discharge upon the ground of brine, oil or refuse
Kans from oil or gas wells, such wastes being required to be confined in tanks, pipelines, or ponds, except where storage in ponds is likely
166 to result in pollution. Brines may be disposed of by being returned to the horizons from which they were pumped.

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The policy of the Kansas State Board of Health with regard
70021 to the treatment of sewage makes allowances for the ability of receiving streams to accept pollution loads, and only that part of

the pollution load which cannot be absorbed by the stream without damaging public water supplies, or animal or aquatic life, must be handled by treatment. Primary treatment has been established as the minimum degree acceptable in the Kansas River basin. No minimum standards have as yet been established for other areas of the State.

Kansas is a member of the Missouri River Basin Health Council, and has entered into an agreement with Nebraska for a sanitary survey of the Kansas River basin.

Solid Wastes

Solid wastes of the order of 720 tons per day, consisting of coal ash, unburned coal, and spent catalysts, would be produced by a 10,000-barrel-per-day synthine plant operating on coal as raw material. A hydrogenation plant would produce in total about two-thirds of this amount, but in normal isolated plant locations about 45 percent of the ash may be dissipated from the power plant stack as fly-ash, leaving net ash quantity sent to disposal only about one-half of that from a coal synthine plant.

Cost of Solid Waste Disposal. The quantity requiring disposal is sufficient in either case to justify fairly elaborate mechanical handling and stacking in order to minimize labor cost. In the case of the coal synthine process, estimates prepared for this purpose indicate that approximately 300 acres of land will be required to provide space for the ash dumps resulting from 40 years of plant operation. The ash transport and disposal system considered assumes hydraulic and pneumatic conveying of ash and spent catalyst, from the various sources to separating and holding tanks located at the disposal area. Decanted water would be recycled. Moist ash accumulated in the tanks would be carried, after drainage, by belt conveyor to an unloader-stacker which would distribute it onto dump piles, with the assistance of a bulldozer to compact the piles and maintain formation. Total cost of ash disposal area equipment of the capacity required for a unit coal synthine plant operating on Kansas coal, (720 tons of ash per day) is estimated at approximately $840,000. This does not include ash collection equipment, which is normally covered in process plant costs. Total operating cost and fixed charges are estimated at approximately $510 per day, or $0.051 per barrel of products. Each percent of the total investment allowed as gross return would amount to about $23 per day, or to $0.0023 per barrel of products.

In the coal synthine process practically all ash appears in the gasifier (synthesis gas producer) and must be completely removed from the synthesis gas before it passes to the reactors. In coal hydrogenation fuel consumed in the power plant consists of coal, amounting to about 20 percent of total plant requirements, plus the coke from delayed coking of heavy oil from the hydrogenation process. The coke contains all the ash in the coal fed to hydrogenation (about 50 percent of plant requirements). Assuming powdered fuel operation of the power plant boilers and normal distribution of ash size between coarse and fine particles, about 45 percent of total solid waste will appear in the form of fly-ash in the stack gases from the power plant. Assuming that the plant is in a fairly isolated location, where fly-ash nuisance can be tolerated, it should be unnecessary to install collection and removal equipment. In this case the net tonnage of ash actually requiring disposal will be about two-fifths as great as for the coal synthine process, resulting in capital and operating costs of solid waste disposal only about three-fifths as great as those stated above. However, if local authorities should require fly-ash removal, total ash disposal costs would be about four-fifths of those for coal synthine.

The estimated solid waste disposal plant investment and daily operating costs for the General Area in Kansas, for both coal hydrogenation and (coal) synthine unit plants, are shown in the following tabulations:

Solid Waste Disposal - Kansas
Estimated Disposal Plant Investment
(As of March 31, 1950)

General Area	Hydrogenation (A)	Coal Synthine
Crawford-Cherokee	$493,000	$839,000

Note: (A) Assuming that removal of fly-ash from stack gases is not required.

Solid Waste Disposal - Kansas
Estimated Disposal Plant Operating and Fixed Costs
(As of March 31, 1950)

General Area	Hydrogenation (A)		Coal Synthine	
	Per Day	Per Barrel	Per Day	Per Barrel
Crawford-Cherokee	$297	$0.030	$514	$0.051

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Note: (A) Assuming that removal of fly-ash from stack gases is not required.

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The operation of such a disposal installation would require a total of about 24 employes, including direct operating and maintenance wage earners and supervisors, with a proportionate allocation of indirect personnel.

Over-all Costs of Waste Disposal

The preceding discussion indicates that treatment of liquid process wastes may absorb practically all of the allowance for waste disposal included in the general cost estimates for the process plant. In such event, costs of solid waste disposal developed above are in addition to any general processing costs and must be added separately to the total cost of product.

At certain locations, however, the study of stream pollution indicates that considerably less than maximum waste treatment may be acceptable. In such case the saving in cost of liquid waste disposal presumably could be applied as a credit against the cost of handling solid wastes.

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PROCESS COSTS

Basis of Estimates

Estimates of plant capital investment and operating costs follow for two synthetic fuel processes both using coal as the raw material, i.e., the hydrogenation process and the synthine process. These estimates are based on estimates prepared by the Bureau of Mines. Plant capital investments, as so prepared, have been adjusted by the Contractor, as explained later in the text, to changes and differences in basic costs of labor and material between the time of such estimates and the time of this report.

As noted in a preceding section, under "Processes and Plant Requirements", the estimated plant construction costs and process costs developed in the following pages are intended primarily for use in comparing the relative desirability of different areas of potential plant locations. For this reason, they were based on the assumed use of certain improvements in process and equipment which are still in the development stage but which appear reasonably likely to be applicable by the time significant number of synthetic liquid fuel plants could be constructed. For plants constructed as of today, using only equipment and processes now commercially available in this country, basic requirements and costs might be appreciably higher than the estimates given.

Process costs estimated herein, as of March 31, 1950, as directed by the Contracting Officer, have been limited to operating costs included in U.S. Bureau of Mines' cost estimating procedure, rather than costs comprising "cost of service" or selling prices. The Bureau of Mines' procedure includes an allowance of approximately 3 percent of plant investment for plant maintenance; 6-2/3 percent for depreciation; 1 percent for insurance and local, county, and state real estate taxes; and an allowance equivalent to 10 percent of direct labor, plant maintenance and operating supplies for general administrative and general office overhead (which includes the salaries and wages of the General Manager or Plant Manager and his immediate staff reporting directly to management); but they include no allowance for head office or top management costs, selling expenses, return on investment or sales and corporate (including income) taxes. Costs of coal used in the process have been computed on a "captive mine" basis and as such do not include selling expenses or return on the initial investment. The cost of water has been estimated on the same basis. To show the effect of return on investment, estimates are included herein to show the total investment required by its component parts, and the amount per barrel required for each 1 percent gross return (before income taxes) on initial capital investment.

Operating costs shown herein are reported, as directed by the Contracting Officer, in dollars per barrel of total product irrespective of its composition. Estimates of the equivalent cost of gasoline and credits for sale of by-products were not considered necessary for the determination of the most desirable General Areas. Because the product grades and quantities are different for each process, the raw material and process selected in each General Area would be the one whose products most satisfactorily meet the particular market demand. Therefore, comparison of General Areas has been made on the basis of one raw material at a time, for each applicable process.

Coal Hydrogenation Process

Plant Capital Investment. Based on an estimate by the Bureau of Mines of a typical unit plant hereinafter described, the required plant capital investment has been estimated for a 10,000-barrel-per-day unit plant in Kansas using the coal hydrogenation process. The table below compares the Bureau of Mines estimate with the estimate for a unit plant in Kansas.

Estimates of Plant Capital Investment
for a 10,000-barrel-per-day Unit Plant
Using Coal Hydrogenation Process

Item	Bureau of Mines Estimate of Typical Unit Plant as of First Quarter 1948 (A)	Adjusted Estimate of Unit Plant in Kansas as of March 31, 1950
Plant Construction Cost	$80,974,000	$91,096,000
Interest during Construction	3,037,000	3,416,000
Depreciable Investment	$84,011,000	$94,512,000
Operating Capital	4,608,000	4,890,000
Total Investment	$88,619,000	$99,402,000

Note: (A) Taken at one-third of the Bureau of Mines estimate (R.I. 4564) for a 30,000-barrel-per-day plant.

Bureau of Mines Estimate. For a 10,000-barrel-per-day coal hydrogenation unit, this survey has adopted a cost equal to one-third of the plant cost estimated as of the first quarter of 1948 by the Bureau of Mines (and reported in its publication R.I. 4564) for a 30,000-barrel-per-day plant at Rock Springs, Wyo., designed to convert Wyoming bituminous coal to synthetic liquid fuels in the proportions stated in the section of this report entitled "Processes and Plant Requirements".

Such a plant includes complete power generation facilities. The Bureau of Mines estimates for a 30,000-barrel-per-day plant represent the cost of an arbitrary production unit of substantially maximum efficiency; the actual cost of a plant of only 10,000 barrels daily capacity might be considerably greater per barrel of product. Construction costs and required total investment for a typical unit plant, as previously defined - i.e., one-third of the cost of a 30,000-barrel plant are shown in Exhibit No. 43.

Adjusted Estimate for Kansas. Since estimates in this report of processing costs in Kansas are as of March 31, 1950, it is necessary to apply factors to the Bureau of Mines costs to convert them to cost levels prevailing at that date.

Adjustment to cost levels of March 31, 1950 is shown in the following tabulation.

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Conversion of Costs of 10,000-barrel-per-day Coal Hydrogenation Plant at Rock Springs, Wyo., From First Quarter 1948 to March 31, 1950 Price Basis

	Estimated Costs		
	Cost as of 1st Quarter 1948	As of March 31, 1950 Factor (%)	As of March 31, 1950 Cost
Process Units			
Material:			
Major Equipment	$19,498,000	114.4%	$22,306,000
Other Materials and Equipment	9,410,000	109.1	10,266,000
Subtotal	$28,908,000		$32,572,000
Field Construction Labor	7,863,000	112.2	8,822,000
Field Indirect Costs	3,960,000	112.2	4,443,000
Total Construction Costs	$40,731,000	112.5%	$45,837,000
Overheads	9,950,000		11,179,000
Total Process Units Costs	$50,681,000	112.5%	$57,016,000
Auxiliary Units			
Tankage	$ 1,670,000	112.5%	$ 1,879,000
Power Plant	12,083,000	112.5	13,593,000
Plant Utilities Distribution	8,573,000	112.5	9,645,000
General Plant Facilities	7,967,000	112.5	8,963,000
Total Auxiliary Units	$30,293,000	112.5	$34,080,000
Total Plant	$80,974,000	112.5	$91,096,000
Factor	100.0%		112.5%

Factors for conversion of cost levels from the first quarter of 1948 to March 31, 1950 have been derived as follows:

Major Equipment (Material):

Bureau of Labor Statistics index of wholesale prices of iron and steel:

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As of March 1948	As of March 1950	Factor of Change
147.7	169.0	114.4%

Other Materials and Equipment:

Other Materials and Equipment may be grouped in three general classifications with costs reported in R.I. 4564 (for a 30,000-barrel-per-day plant) as below:

Building Materials	Thousands of Dollars	
Foundations	$ 1,815	
Structures and Supports	2,930	
Buildings	3,220	
Painting	178	
Total		$ 8,143
Piping		11,924
Other Materials		
Instruments	$ 1,985	
Electrical	3,326	
Insulation	764	
Other Miscellaneous	2,088	
Total		8,163
Total Other Materials and Equipment		$28,230

The factor of conversion used for Other Materials and Equipment is a weighted average of the indices of wholesale prices of Building Materials (Bureau of Labor Statistics) and of the cost of piping from the Contractor's Cost Bureau. The first index was weighted by the cost of Building Materials above and the second by the cost of piping. Other Materials were considered to follow the weighted index of Building Materials and Piping. Computation of the factor used is shown below:

Basis	As of March 1948	As of March 1950	Factor of Change	Weighting (Cost in $1,000) Amount	Product
BLS Index, Wholesale Price of Building Materials	193.1	194.2	100.6%	$ 8,143	$ 8,192
Wholesale Price of Seamless Pipe:					
8 in.	$1.445	$1.664			
10 in.	1.775	2.041			
12 in.	2.321	2.662			
Total Pipe	$5.541	$6.367	114.9%	$11,924	$13,701
Total and Average			109.1%	$20,067	$21,893

Labor:

Average of Bureau of Labor Statistics on union wage scales for selected building trades (giving building laborers a weight of three and skilled crafts a weight of one):

City	As of 4/1/48	As of 4/3/50	Factor of Change
Butte	$1.872	$2.067	110.4%
Denver	1.832	2.073	113.2
Salt Lake City	1.667	1.886	113.1
Average			112.2%

Field Indirect Costs:

This item, estimated as a percentage of labor costs, uses the conversion factor for labor.

Total Plant Costs:

The weighted average factor of total construction costs Kans
is obtained by dividing costs of March 31, 1950 by costs as of the
first quarter of 1948. This factor is used for total process units 175
and for all auxiliary units. Overheads for Kansas are the difference 10
between total process units and total construction cost. 7002

No adjustment of costs for change in location from Rock Springs, Wyo., to the General Area in Kansas has been made as such an adjustment is considered to be within the range of accuracy of the original estimates.

Interest during construction was estimated according to the Bureau of Mines practice described as follows in R.I. 4564:

"It is estimated that 4 years will be required to construct such a plant. The interest on capital expenditures during construction is calculated at 2-1/2 percent. Expenditures are estimated at 10 percent of the total cost of the plant the first year, 20 percent the second, 30 percent the third, and 40 percent the fourth. It may be expected that some units will be completed and production begun by the end of the third year of construction. Under this financing schedule, interest amounts to approximately 3.75 percent of the plant cost".

Operating capital was estimated as shown in Exhibit No. 44. The method used was that of the Bureau of Mines as described in its R.I. 4564:

"In determining the amount of operating capital required, it is assumed that the plant will reach designed production within its first year of operation. It is expected that limited plant operation will begin at the end of 3 years' construction, and that construction and operation will be carried on simultaneously during the fourth year. It is expected that the average production rate during this period will be approximately 50 percent of full normal production. Similarly, it is assumed that consumption of raw material will be 25 percent of normal for the first 6 months and 100 percent for the last 6 months. The raw materials include coal, catalysts, and water. Operating capital must cover the cost of the initial 30-day supply of coal, raw materials, consumed during the first 6 months of operation, labor, maintenance, and all other operating costs except fixed charges. Fixed charges are not assessed until construction is completed; interest during construction is treated as a part of total plant cost. Operating expenses during the second 6 months will be financed from the sale of products made during previous operations."

In estimation of operating capital the Contractor has included in the inventory prices of coal and water an allowance for return on investment in coal mines and water works.

More than one unit plant in the General Area in Kansas or extension of the initial plant beyond 40 years' life would not
ans increase the operating capital requirement as it has been assumed that equal amounts of primary underground and secondary strip coal
176a will be used until the exhaustion of either type of coal.

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70021 Although the specified use of coal for synthetic liquid fuel manufacture is of all primary reserves or 50 percent primary and 50 percent secondary, the cost of secondary (strip) coal reported herein as $3.55 per ton would make it more economical to use all secondary coal. The exclusive use of such secondary coal would decrease the operating capital requirement by $224,304 or to a total of $4,665,944.

Operating Costs. Estimates of manufacturing costs based on estimates by the Bureau of Mines for the specific hydrogenation unit plant for which estimated construction costs have been stated (considered as a typical unit plant), are summarized in the first column of the following table:

Estimated Processing Costs Using Bureau of Mines Method
10,000-barrel-per-day Coal Hydrogenation Plant

Manufacturing Costs	Bureau of Mines Estimate of Typical Plant per Calendar Day	Bureau of Mines Estimate Adjusted to General Area in Kansas as of March 31, 1950	
		Per Calendar Day	Per Barrel of Product
Direct Costs			
Direct Materials:			
Coal	$14,037	$17,161	$1.72
Catalysts and Chemicals	1,293	1,293	.13
Total Direct Materials	$15,330	$18,454	$1.85
Direct Labor:			
Wage Earners	$ 3,402	$ 3,242	$0.32
Supervision	510	486	.05
Total Direct Labor	$ 3,912	$ 3,728	$0.37
Plant Maintenance:			
Wage Earners	$ 3,858	$ 3,676	$0.37
Supervision	579	551	.05
Total Maintenance Labor	$ 4,437	$ 4,227	$0.42
Materials	2,218	2,496	.25
Total Plant Maintenance	$ 6,655	$ 6,723	$0.67
Payroll Overhead	$ 1,044	$ 994	$0.10
Operating Supplies	1,331	1,345	.14
Make-up Water	876	724	.07
Total Direct Costs	$29,148	$31,968	$3.20
Indirect Costs			
Indirect Labor	$ 927	$ 883	$0.09
Indirect Salaried Personnel	1,943	1,943	.19
Other Indirect Costs	3,079	3,072	.31
Total Indirect Costs	$ 5,949	$ 5,898	$0.59
Total Direct and Indirect Costs	$35,097	$37,866	$3.79
Fixed Costs			
Local, County, and State Taxes and Insurance	$ 2,302	$ 2,589	$0.26
Depreciation	15,344	17,262	1.72
Total Fixed Costs	$17,646	$19,851	$1.98
Total Manufacturing Costs	$52,743	$57,717	$5.77
Less Coal and Make-up Water	14,913	17,885	1.79
Other Processing Costs (A)	$37,830	$39,832	$3.98

Note: (A) Other than coal and make-up water

The figures in the first column of the above table, adopted for this survey, are one-third of the manufacturing costs (as of the first quarter of 1948) estimated by the U.S. Bureau of Mines and reported in its publication R.I. 4564 for a 30,000-barrel-per-day plant (with complete power generation facilities) designed to convert Wyoming bituminous coal to products in proportions already stated. Coal and water quantities used in these estimates differ somewhat from those shown in the tabulation of basic data in the "Processes and Plant Requirements" Section which, as stated, were based on the use of an average rather than a specific plant.

Preparation of the estimate based on that of the Bureau of Mines of daily operating costs of a typical unit plant used methods tabulated in Exhibit No. 45.

Operating costs estimated to apply as of March 31, 1950, in the General Area of Coal and Water Availability in Kansas are summarized in the second column of the table.

The bases of the adjusted estimate of daily operating costs of a unit plant in the General Area of Coal and Water Availability in Kansas as of March 31, 1950 are tabulated in Exhibit No. 46.

The items of plant maintenance materials, operating supplies, and other indirect costs might have been taken at the same cost in Kansas as at Rock Springs, Wyo., (i.e., treated similarly to catalysts and chemicals, and indirect salaried personnel) but have been computed according to methods adopted by the Bureau of Mines.

Return on Investment. Recognizing that different investors may require different rates of return upon their capital, these estimates include no allowance for return. However, as a guide, the following tabulation indicates the amounts per day and per barrel of products which would be required for each increment of one percent on the estimated plant capital in the case of Kansas:

Incremental Costs for Each 1 Percent Gross Return on Initial Investment in Process Plant in Kansas

Total Initial Capital Investment	$99,402,000
1 Percent Return on Above:	
Per Annum	$ 994,020
Per Calendar Day	$ 2,723
Per Barrel of Products	$0.2723

Effect of Coal Characteristics. In preparing estimates of coal quantity required, plant cost, and processing cost in each General Area, the calculations have been based on an (average) total daily raw material requirement of 98,000,000,000 Btu, for a typical coal hydrogenation unit plant, as specified in the plant requirements data furnished for use in this report.

Actually, for a plant of given capacity in terms of daily production of synthetic liquid fuels, the over-all efficiency of conversion, which in turn affect both daily Btu requirements and physical size of the plant (and hence construction and operating costs) varies with certain characteristics of the coal used as raw material, particularly with ash and moisture content and coal chemical reactivity.

A study of the effect of these factors was made to determine the maximum range of possible variation within the limits of the coals considered in this survey. The results of this study showed that in no case did the probable variation in coal quantity (as Btu), plant cost, or processing cost, due to individual coal characteristics, exceed plus or minus 10 percent of the mean. Only in the case of coals at the extreme upper and lower limits of the range designated as suitable for hydrogenation would indicated coal quantity and plant cost exceed by more than 10 percent the actual base figures used in the cost calculations above. In the large majority of cases, the variation should be a few percent only.

As the maximum error is within the probable limits of accuracy of the base figures themselves, in the interest of simplicity no adjustment has been made to reflect the effect of coal characteristics on Btu requirements and physical size of plant.

Coal Synthine Process

Basis of Estimates. Based on the results of extensive research and development work of its own, as well as upon available data of other investigators in the United States and in Germany, the Bureau of Mines has in the course of preparation estimates of construction and operating costs of a synthine plant of a commercial
Kans scale. Preliminary data from this study, for a plant producing 10,000 barrels of synthetic liquid fuels per day from western
179a Kentucky bituminous coal, a specific case, have been adopted for
10 this survey for estimating construction and operating costs of a
70021 unit plant, to be used as a basis of comparison for determining relative suitability of General Areas. In drawing other than relative conclusions from these cost estimates, however, the preliminary nature of the data so far available must be remembered. The final estimates determined by the Bureau at the completion of its work may differ appreciably from the present figures.

Plant Capital Investment. Based on the preliminary estimate of the Bureau of Mines for a typical unit plant, the required plant capital investment has been estimated for a 10,000-barrel-per-day unit plant in Kansas using the coal synthine process. The table below shows figures as estimated by the Bureau of Mines and as adjusted for a unit coal synthine plant in Kansas.

Estimates of Plant Capital Investment
for a Unit Plant
Using Coal Synthine Process

Item	Bureau of Mines Preliminary Estimate of Typical Unit Plant as of March 1, 1950	Adjusted Estimate of Unit Plant in Kansas as of March 31, 1950
Plant Erection Cost	$81,805,000	$81,805,000
Interest during Construction	2,455,000	2,455,000
Depreciable Investment	$84,260,000	$84,260,000
Operating Capital	4,000,000	5,078,000
Total Investment	$88,260,000	$89,338,000

Construction costs and required total investment for such a synthine unit plant are shown in Exhibit No. 47, as estimated by the Bureau of Mines.

Adjusted Estimate for Kansas. For this survey, estimates of processing costs in Kansas are as of March 31, 1950. It is considered that any difference in cost levels prevailing between that date and the date of the Bureau of Mines estimate, March 1, 1950, is within the range of accuracy of the original estimate. No adjustment of costs for change in location from Caseyville, Ky., to the General Area in Kansas has been made as such an adjustment is considered to be within the range of accuracy of the original estimate. Consequently, the Bureau of Mines estimate of plant erection cost has been adopted as directly applicable to such a cost in the General Area in Kansas.

Interest during construction was estimated, as by the Bureau of Mines, at 3 percent of plant construction costs.

Operating capital was estimated as shown in Exhibit No. 48. In the absence of information as to the method employed in the Bureau of Mines estimate of costs of a typical unit plant using the synthine process the method followed for the hydrogenation process was used.

More than one unit plant in the General Area in Kansas or extension of the initial plant beyond 40 years' life would not increase the operating capital requirement as it has been assumed that equal amounts of primary underground and secondary strip coal will be used until the exhaustion of either type of coal.

Although the specified use of coal for synthetic liquid fuel manufacture is of all primary reserves or of 50 percent primary and 50 percent secondary, the cost of secondary (strip) coal reported herein as $3.55 per ton would make it more economical to use all secondary coal. The exclusive use of such secondary coal would decrease the operating capital requirements by $288,282 or to a total of $4,789,715.

Operating Costs. Estimates of manufacturing costs, based on estimates by the Bureau of Mines, for the typical synthine unit plant for which estimated construction costs have been stated, are summarized in the first column of the following table:

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Estimated Processing Costs Using Bureau of Mines Method
10,000-barrel-per-day Coal Synthine Plant

Manufacturing Costs	Bureau of Mines Preliminary Estimate of Typical Plant per Calendar Day	Bureau of Mines Estimate Adjusted to General Area in Kansas as of March 31, 1950	
		Per Calendar Day	Per Barrel of Product
Direct Costs			
Direct Materials:			
Coal	$14,383	$22,064	$2.21
Catalysts and Chemicals	1,200	1,200	.12
Total Direct Materials	$15,583	$23,264	$2.33
Direct Labor:			
Wage Earners	$ 3,150	$ 2,950	$0.30
Supervision	473	443	.04
Total Direct Labor	$ 3,623	$ 3,393	$0.34
Plant Maintenance:			
Wage Earners	$ 3,897	$ 3,649	$0.37
Supervision	585	547	.05
Total Maintenance Labor	$ 4,482	$ 4,196	$0.42
Materials	2,241	2,241	.22
Total Plant Maintenance	$ 6,723	$ 6,437	$0.64
Payroll Overhead	$ 1,013	$ 949	$0.09
Operating Supplies	1,345	1,287	.13
Make-up Water	1,115	724	.07
Total Direct Costs	$29,402	$36,054	$3.60
Indirect Costs			
Indirect Labor	$ 963	$ 902	$0.09
Indirect Salaried Personnel	1,953	1,953	.20
Other Indirect Costs	2,930	2,704	.27
Total Indirect Costs	$ 5,846	$ 5,559	$0.56
Total Direct and Indirect Costs	$35,248	$41,613	$4.16
Fixed Costs			
Local, County, and State Taxes and Insurance	$ 2,308	$ 2,308	$0.23
Depreciation	15,390	15,390	1.54
Total Fixed Costs	$17,698	$17,698	$1.77
Total Manufacturing Costs	$52,946	$59,311	$5.93
Less Coal and Make-up Water	$15,498	$22,788	$2.28
Balance Other Processing Costs (A)	$37,448	$36,523	$3.65

Note: (A) Other than coal and make-up water.

The estimate, based on that of the Bureau of Mines of daily operating costs of a typical unit coal synthine plant, is developed by methods summarized in Exhibit No. 49.

Operating costs estimated to apply in the General Area of Coal and Water Availability in Kansas as of March 31, 1950 are summarized in the second column of the table.

The bases of the adjusted estimate of daily operating costs of a unit plant in the General Area of Coal and Water Availability in Kansas as of March 31, 1950 are tabulated in Exhibit No. 50.

The items of plant maintenance materials, operating supplies, and other indirect costs might have been taken at the same cost in Kansas as at Caseyville, Ky. (i.e. treated similarly to catalysts and chemicals and indirect salaried personnel) but have been computed according to methods adopted by the Bureau of Mines.

Return on Investment. Recognizing that different investors may require different rates of return upon their capital, these estimates include no allowance for return. However, as a guide, the following tabulation indicates the amounts per day and per barrel of products which would be required for each increment of 1 percent on the estimated plant capital in the case of Kansas.

Incremental Costs for each 1 Percent Gross
Return on Initial Investment in Process Plant in Kansas

Total Initial Capital Investment	$89,338,000
1 Percent Return on Above:	
Per Annum	$ 893,380
Per Calendar Day	2,448
Per Barrel of Products	$0.245

Effect of Coal Characteristics. In preparing estimates of coal quantity required, plant cost and processing cost in each General Area the calculations have been based on an (average) total daily raw material requirement of 126,000,000 Btu for a typical coal synthine unit plant, as specified in the plant requirements data furnished for use in this report.

Actually, for a plant of given capacity in terms of daily production of synthetic liquid fuels, the daily Btu requirements and physical size of the plant (and hence construction and operating costs) vary with certain characteristics of the coal used as raw material. The over-all Btu consumption increases with increasing moisture content of the coal, as received at the process plant, since additional Btu, over and above basic process requirements, must be consumed in evaporating surplus moisture to produce a coal of the requisite dryness for gasification. Furthermore, construction costs (dependent on physical size) of a synthine plant of given production capacity may vary through a maximum range of 20 percent, according to the rank of the coal available.

A study of the effect of these factors was made to determine the maximum range of possible variation within the limits of the coals considered in this survey. The results of this study showed that in the case of Btu requirements the maximum probable variation, over the entire range of coals included in the survey, from anthracite to the lowest grades of brown coal, is approximately plus or minus 10 percent of the mean. As stated above, there may be a variation in plant cost because of rank of coal of not more than plus or minus 10 percent from the mean. The base cost and Btu requirements for the typical plants used in the foregoing calculations differ somewhat from the actual mean. However, only the lower grades of lignites and brown coal give rise to Btu requirements and plant costs more than 10 percent greater than the base figures used. In the large majority of cases, the variation should be only a few percent.

As the maximum error is within the probable limits of accuracy of the base figures themselves, in the interest of simplicity no adjustment has been made to reflect the effect of coal characteristics on Btu requirements and physical size of plant.

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STRATEGIC CONSIDERATIONS

Based on studies made by the National Security Resources Board, it is believed that areas of industrial concentration of less than 5 square miles, or urban concentrations of less than 50,000 people separated by about 10 miles of relatively open country, will be reasonably secure from atomic bomb attack under all circumstances expected to prevail.

The largest city located within the single General Area in Kansas is Pittsburgh, (preliminary 1950 population of 19,371) in Crawford County.

The Crawford-Cherokee General Area in Kansas contains no reasonable target to be considered in establishing synthetic liquid fuels plants, according to findings of NSRB with regard to industrial and urban concentrations.

Possible targets in the State might be the lead-mining areas south of Pittsburg and the concentration of population adjacent to or in Joplin, Mo., about 30 miles to the southeast, plus the Pensacola Dam, located in Oklahoma south of the Kansas State Line; and the industrial area around Kansas City.

With due consideration for the factors indicated above, it is believed that the development of a new synthetic liquid fuels industry in Kansas could be so planned as to conform to the present published policies of the NSRB with regard to strategic considerations.

PART VI - CONCLUSIONS

CONCLUSIONS

Conclusions drawn from this investigation and the determination of Suitable General Areas in Kansas for the production of synthetic liquid fuels are based upon presently available information. It should also be noted that the determination of a Suitable General Area within a state such as Kansas does not at this stage:

(a) Constitute or propose a program for development;

(b) Imply any relationship to Suitable General Areas in other states; nor

(c) Reflect any allowance for new developments and additional future information which can be neither foreseen nor predicted.

Subject to such reservations, the following major conclusions are developed from this investigation and report:

1. Available information indicated no reserves of natural gas in Kansas adequate for synthetic liquid fuels production. Coal is the only raw material meeting the qualifications of the survey.

2. The Suitable General Area in Kansas is the Crawford-Cherokee General Area.

3. The total tonnages of coal in place in Kansas as of January 1, 1950, as used in this survey, are based on available information and within the limits of reserves specified for this survey, as described in Part II of this report under "Survey Specifications" and "Survey Classifications of Coal Reserves" and in Part IV under "Survey Methods and Procedure". Coal deposits occur in 35 counties of the eastern quarter of Kansas, underlying an area of approximately 20,000 square miles. The total coal reserves considered for synthetic liquid fuels manufacture occur in 9 counties and have been estimated as of January 1, 1950 at 686,259,000 tons in place according to specifications and procedures established for this survey. Of this tonnage, 452,832,000 tons were estimated as being recoverable, of which 165,299,000 tons (36.5 percent) are in the Weir-Pittsburg bed and 151,503,000 tons (33.5 percent) are in the Mineral bed.

4. Of the total recoverable coal reserves considered in the State, 287,533,000 tons or 63.5 percent are estimated to be suitable for strip mining.

5. The recoverable coal reserves of Kansas are distributed by counties as follows, in total and as contained within the Crawford-Cherokee General Area of Coal Availability:

Estimated Recoverable Coal Reserves
Considered for Synthetic Liquid Fuels Manufacture
by Counties
(As of January 1, 1950)

	Total Reserves (A)		Available Reserves (B)	
County	Thousands of Tons	Percent of Total	Thousands of Tons	Percent of Total
Crawford	283,825	62.68%	280,963	69.70%
Cherokee	117,021	25.84	117,021	29.03
Wilson	14,907	3.29	-	-
Linn	9,870	2.18	-	-
Montgomery	8,951	1.98	-	-
Neosho	5,121	1.13	-	-
Bourbon	5,102	1.13	5,102	1.27
Franklin	4,780	1.05	-	-
Osage	3,255	0.72	-	-
Total	452,832	100.00%	403,086	100.00%

Note: (A) Before elimination of tonnage in unsatisfactory areas.

(B) After elimination of tonnage in unsatisfactory areas but before the elimination of excess secondary reserve tonnage.

6. The recoverable coal reserves of Kansas are distributed by beds as follows, in total and as contained within the Crawford-Cherokee General Area of Coal Availability: Kan 188

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Estimated Recoverable Coal Reserves
Considered for Synthetic Liquid Fuels Manufacture
by Coal Beds
(As of January 1, 1950)

Coal Bed	Total Reserves		Available Reserves	
	Thousands of Tons	Percent of Total	Thousands of Tons	Percent of Total
Weir-Pittsburg	165,299	36.50%	165,299	41.01%
Mineral	151,503	33.46	151,503	37.58
Bevier	86,284	19.06	86,284	21.41
Thayer	28,979	6.40	-	-
Mulberry	9,870	2.18	-	-
Williamsburg Upper	8,035	1.77	-	-
Croweburg	2,862	0.63	-	-
Total	452,832	100.00%	403,086	100.00%

7. The total recoverable coal reserves within the Crawford-Cherokee General Area of Kansas and the amounts available after elimination of secondary reserves in excess of primary reserves are estimated to be:

	Total Reserves		Available Reserves	
	Thousands of Tons	Percent of Total	Thousands of Tons	Percent of Total
Primary Underground	75,289	18.68%	75,289	50.00%
Primary Strip	-	-	-	-
Primary Total	75,289	18.68%	75,289	50.00%
Secondary Underground	90,010	22.33%	-	-
Secondary Strip	237,787	58.99	75,289	50.00%
Secondary Total	327,797	81.32%	75,289	50.00%
Total Underground	165,299	41.01%	75,289	50.00%
Total Strip	237,787	58.99	75,289	50.00
Total Reserves	403,086	100.00%	150,578	100.00%

8. The available recoverable coal reserves of the Crawford-Cherokee General Area, amounting to 150,578,000 tons after elimination of excess secondary reserves, is equivalent, dependent upon the process used, to a total of from 298,000,000 to 384,000,000 barrels of synthetic liquid fuels.

9. It is probable that continued exploration and development of Kansas' coal resources will result in the discovery of additional reserves in areas for which there is not now sufficient information to permit the present estimation of reserves for this survey. Information available at the time of this survey indicates that, after an allowance of 126,900,000 tons of coal for future commercial requirements (50 years' production at the 1948 rate of production of 2,538,000 tons annually), sufficient coal reserves are available to supply, for a 40-year period, synthetic liquid fuels capacity amounting, as a minimum, to 26,000 barrels per day for the hydrogenation process or 20,000 barrels per day for the coal synthine process, all in the Crawford-Cherokee General Area.

10. No coals of Kansas are classified as not amenable to hydrogenation, since reported analyses uniformly show fixed carbon contents of less than 69 percent (maf basis).

11. Cleaning of Kansas coals as necessary to provide raw material equivalent in quality to merchantable coal for synthetic liquid fuels plants would produce, per unit plant, approximately 1,590 tons of mine refuse per working day for a hydrogenation plant and approximately 2,040 tons for a coal synthine plant. Equivalent annual quantities of refuse would amount to about 254,400 and 326,400 cubic yards, respectively. No particular disposal problem would be presented.

12. Coals of the Crawford-Cherokee General Area in Kansas are high-volatile B bituminous and high-volatile A bituminous in rank, with heating values, as received, ranging from 11,790 to 13,080 Btu per pound. Moisture, ash, and sulfur contents are:

Content of Selected Components
(Mine Sample, As-received Basis)

	Maximum	Minimum
Moisture	6.1%	4.2%
Ash	14.5	8.3
Sulfur	4.1	3.3

13. A single petrographic assay of Kansas coal from the Bevier bed indicates the coal to be of the "bright" petrographic type, in which anthraxylon and translucent attritus predominate. Since coals of the other two available beds, the Weir-Pittsburg and the Mineral, are closely similar in rank and in appearance and chemical composition, no substantial differences are expected in their adaptability to hydrogenation.

14. Estimated initial capital required in Kansas for coal mines to supply a single synthetic liquid fuels plant in the Crawford-Cherokee General Area is:

Estimated Initial Capital Requirements for Coal Mining Facilities in Crawford-Cherokee General Area in Kansas (As of March 1, 1950)

Process	Type of Mining: Underground	Strip
Hydrogenation	$7,000,000	$5,864,000
Coal Synthine	9,000,000	7,540,000

15. Coal production costs, exclusive of selling expenses and return on investment, in the Crawford-Cherokee General Area of Kansas are estimated to be:

Estimated Coal Production Costs (As of March 31, 1950)

Type of Mining	Btu per Pound	Tons per Man-shift	Cost per Ton	Cost in Cents per Million Btu
Underground	12,770	5	$5.19	20.32¢
Strip	12,200	12	$3.55	14.55¢

16. The production costs of coal per barrel of products in the Crawford-Cherokee General Area of Kansas are estimated to be:

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Estimated Coal Production Costs per Barrel of Products (As of March 31, 1950)

Process	Type of Mining: Strip	Underground	For Initial Plant
Hydrogenation	$1.43	$1.99	$1.72
Coal Synthine	1.83	2.56	2.21

17. Ample water resources exist for the supply of sufficient synthetic liquid fuels plant capacity to process all available coal in 40 years. Water conservation work would, however, be required. The maximum water requirement in the Crawford-Cherokee General Area of Kansas is estimated as 40.5 cubic feet per second (cfs) of which 34.5 cfs is for process use and 6.0 cfs for domestic use. This is equivalent in total to about 26.2 million gallons per day, including 22.3 mgd for process and 3.9 mgd for domestic use.

18. Estimated capital investment required as of March 31, 1950 for process water supply in the Crawford-Cherokee General Area for a complete unit plant is $5,848,000. Annual costs, exclusive of return on investment, for such supply are estimated as $264,150.

19. Estimated capital investment required for domestic water supply in the Crawford-Cherokee General Area as of March 31, 1950, for a complete unit project is $1,232,000. Annual costs of such supply, exclusive of return on investment, estimated to amount to $65,250, are not chargeable to plant operations since it has been assumed that these costs would be paid for by the consumers living in the plant-city.

20. Local utilities could be expected to have adequate power available for plant construction purposes and plant operating power requirements might be more economically provided from the same sources.

21. The costs of installing and operating, exclusive of return on investment, the necessary supplementary access transportation facilities for an initial synthetic liquid fuels unit plant in the Crawford-Cherokee General Area of Kansas would be an investment of $130,000 and an annual operating cost of $5,750.

22. Sufficient satisfactorily qualified labor could be expected to be available in Kansas to man at least one unit plant in the Crawford-Cherokee General Area at an estimated average straight-time hourly wage rate, as of March 31, 1950, of $1.62 per hour.

23. The necessary plant-city for an initial unit synthetic liquid fuels plant in the Crawford-Cherokee General Area of Kansas would be expected to accommodate 8,246 persons for a hydrogenation project or 9,324 persons for a coal synthine project. The corresponding initial investments required as of March 31, 1950, for housing and community development would be $29,609,154 or $33,480,198, respectively, exclusive of domestic water supply.

24. The value of commercial facilities (assumed to be self-supporting) and of one-half of the dwelling units in the plant-city (assumed to be sold) plus a proportionate share of the cost of land and utilities is estimated as $16,649,620 for a hydrogenation unit project and $18,826,344 for a coal synthine unit project. The remaining net investments in rental housing and plant-city development would therefore be $12,959,534 and $14,653,854, respectively.

25. From the standpoint of motor fuel, the annual consumption (exclusive of aviation and military use) in Kansas for 1948 was 16,100,000 barrels, equivalent to the gasoline output of approximately 6 synthetic liquid fuels unit plants. The similar consumption for 1975 is estimated to be 23,400,000 barrels, equivalent to the gasoline output of about 9 unit plants.

26. The proportion of various liquid fuel products specified for plants considered in this survey differs importantly from the distribution of actual product consumption in Kansas. At such time as large-scale development would be required, synthetic liquid fuels plants undoubtedly would be designed, since the processes are to a considerable extent flexible, to conform to the then existing demand pattern.

27. Liquid fuel requirements in Kansas are economically supplied by petroleum products at refinery prices as of June 1, 1950 in Kansas of $3.74 and $4.20 per barrel, respectively, for the fuel product
Kans distributions specified for hydrogenation and coal synthine plants.

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193a 28. When synthetic liquid fuels are required, plants in the Crawford-Cherokee General Area of Kansas would
15 be well located for the distribution of their
70021 products within the defined marketing territory.

29. No unusual methods would be required in Kansas for the inoffensive disposal of solid and gaseous wastes of synthetic liquid fuels plants.

30. The treatment of liquid wastes, before disposal, to meet any anticipated requirements is feasible at costs within allowances therefor made in the general estimates for the process plant.

31. Disposal of solid wastes from synthetic liquid fuels plants in the Crawford-Cherokee General Area of Kansas is estimated to involve the following capital investments and operating costs (before return on investment) assuming that fly-ash removal from stack gases is not required:

Estimated Costs of Solid Wastes Disposal
(As of March 31, 1950)

Process	Investment	Operating Cost (Per Barrel)
Hydrogenation	$493,000	$0.030
Coal Synthine	839,000	.051

32. A typical synthetic liquid fuels unit plant in the Crawford-Cherokee General Area in Kansas would require, as of March 31, 1950, an investment of $99,402,000 for the hydrogenation process or $89,338,000 for the coal synthine process.

33. Typical synthetic liquid fuels unit plants in the Crawford-Cherokee General Area in Kansas would incur daily processing costs, exclusive of return on investment, as follows:

Estimated Processing Costs of a Typical Plant Exclusive of Return on Investment
(As of March 31, 1950)

Processing Costs	Costs per Calendar Day: Hydrogenation	Costs per Calendar Day: Coal Synthine
Direct Materials	$18,454	$23,264
Water	724	724
Other Direct Costs	12,790	12,066
Direct Costs	$31,968	$36,054
Indirect Wages and Salaries	$ 2,826	$ 2,855
Other Indirect Costs	3,072	2,704
Indirect Costs	$ 5,898	$ 5,559
Taxes and Insurance	$ 2,589	$ 2,308
Depreciation	17,262	15,390
Fixed Costs	$19,851	$17,698
Total Manufacturing Costs	$57,717	$59,311
Less Coal and Make-up Water	17,885	22,788
Other Processing Costs	$39,832	$36,523

34. Development of a synthetic liquid fuels industry in Kansas could be planned to conform with presently published policies of the National Security Resources Board with respect to strategic considerations.

35. In the Crawford-Cherokee General Area of Kansas, the initial net capital required for the complete installation of a synthetic liquid fuels unit project shown on Exhibit No. 52, including the manufacturing plant, process water supply, rental housing, and mine and other incidental facilities, but exclusive of commercial facilities and domestic water supply for the plant-city (assumed to be self-supporting) and one-half of the dwelling units (assumed to be sold) is estimated, as of March 31, 1950, to be $125,265,000 for a hydrogenation unit project or $119,079,000 for a coal synthine unit project.

36. The initial net capital required for complete installation of a synthetic liquid fuels plant as described in the preceding paragraph, adjusted for the assumed operation on all secondary (strip) coal, as shown on Exhibit No. 53, is estimated to be $124,473,000 for a hydrogenation unit plant and $118,061,000 for a coal synthine unit plant.

37. Operating costs of synthetic liquid fuels unit projects in the Crawford-Cherokee General Area in Kansas, as of March 31, 1950, (see Exhibit No. 52) in dollars per barrel of products, exclusive of return on investment, are estimated as $5.803 for a hydrogenation unit project or $5.984 for a coal synthine project.

38. Alternate costs of operation adjusted for the reported cost of $3.55 per ton for secondary (strip) coal, assuming that all secondary coal will be used in the synthetic liquid fuels plants instead of one-half primary and one-half secondary, as required by the Contract Specifications, would be as of March 31, 1950, in dollars per barrel of products exclusive of return on investment (see Exhibit No. 53) $5.51 per barrel for a hydrogenation plant and $5.61 for a coal synthine plant.

39. The amounts required to yield 1 percent gross return on the net initial investment (see Exhibit No. 52) are estimated, as of March 31, 1950, as $0.343 per barrel of products for a hydrogenation unit project or $0.326 for a coal synthine unit project.

EXHIBITS

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Synthetic Liquid Fuels Plant Requirements
Coal Processes
(Approved by Corps of Engineers)
As of May 15, 1950

	Hydrogenation Requirements for a 10,000-barrel-per-calendar-day Unit (in Continental United States) Based on a 30,000-barrel-per-day Plant	Coal Synthine Requirements for a 10,000-barrel-per-calendar-day Unit Based on a 10,000-barrel-per-day Plant

A. DESCRIPTION OF PROCESSES

(Brief Description of Flow Sheet, Names of Equipment or Units Proposed for Use, Significant Temperatures and Pressures, Over-all Efficiency (A) for Average Rank of Coal)

Hydrogenation:

Coal, which is made into paste by mixing with oil, is hydrogenated at 10,000 psi and 900° F in two consecutive stages, Liquid and Vapor Phase. Vapor phase products are distilled into finished gasoline and L.P.G. With slight modification, alternate products such as jet fuel, Diesel fuel, furnace oil, etc., can be produced if desired. Fuel gas needed is generated from coal.

Hydrogen is produced at 350 psi pressure by gasification of coal with oxygen and conversion of hydrogenation off-gas with steam

Steam and power production facilities are provided with the plant.

A coal cleaning plant is included

The process data below are based on the following efficiency:

Over-all 50.6% (A)

Coal Synthine:

Raw coal is pulverized and gasified with oxygen and steam at 450 psi pressure. The resulting synthesis gas, composed of mainly carbon monoxide and hydrogen is purified by the removal of hydrogen sulfide and organic sulfur compounds and then fed to a single stage synthesis reaction. The synthesis reaction takes place at 300 psi pressure and about 600° F. An internally cooled reactor using liquid-suspended iron catalyst has been assumed in this estimate. Alternate types of reactors are solid bed catalyst internally cooled reactor, or iron catalyst slurry process. The liquid products are separated by distillation into motor gasoline, Diesel fuel, and heavier fractions which are refined and upgraded by conventional petroleum and refinery processes to finished products. Steam and power facilities are provided within the plant. The data below are based on the following efficiency:

Over-all 41.2% (A)

B. RAW MATERIALS

Quantity

Coal Requirements in Btu x 10^9 per Calendar Day

Hydrogenation		Coal Synthine	
Process	50	Process	126
Hydrogen Manufacturing and Fuel Gas	21	Total	126
Direct-fired (Distillation, etc.)	8		
Power and Steam	19		
Total	98		

Quality

Ash

Maximum Allowable Ash Content to Equipment (Dry Basis)

Hydrogenation		Coal Synthine	
Process	15%	Process	20%
Hydrogen Manufacturing and Fuel Gas	20%		
Direct-fired (Distillation, etc.)	20%		
Power and Steam	20%		

Other Characteristics (Chemical Analysis, etc.)

Hydrogenation:

(1) Good washability is desirable.

(a) Low calcium in process coal is preferable.

(2) Chemical analysis and physical properties should be known.

Coal Synthine:

(1) Good washability is desirable.

(2) Chemical analysis and physical properties should be known.

Sulfur

Cost of Desulfurization

Hydrogenation: Cost of desulfurization does not change materially with percent of sulfur in coal when credit of 1/5 of market price is taken for recovered sulfur.

Coal Synthine: Cost of desulfurization does not change materially with percent of sulfur in coal when credit of 1/5 of market price is taken for recovered sulfur.

Other Characteristics

Hydrogenation: High organic sulfur content in raw coal is undesirable since it is not easily removed by cleaning (of only minor importance).

Coal Synthine: High organic sulfur content in raw coal is undesirable since it is not easily removed by cleaning.

Other Characteristics (Effect of Rank, Opaque Attritus, Fusain, etc.)

Hydrogenation:

Fusain and opaque attritus should be low in process coal. Fusain normally can be removed by cleaning.

Fixed Carbon (maf)	Not to exceed 69%
Volatile Matter (maf)	31% Minimum
Sulfur	No limit
Moisture	No limit

Rank of coal has little effect on total plant required. For coals of equal rank, higher net hydrogen is desirable.

Information Required for Evaluation:

1. Proximate analysis - dry basis - include moisture as lb per lb of dry coal (face sample).
2. Fischer Assay (dry basis).
3. Ultimate analysis (maf basis).
4. Btu content.

Coal Synthine:

Fixed Carbon	No limit
Volatile Matter	No limit
Sulfur	No limit
Moisture	No limit

Decrease in rank increases amount of plant required. (Range of plant cost 20% between extremes of rank).

Information Required for Evaluation:

1. Ultimate analysis (maf basis) Btu content.
2. Proximate analysis - dry basis - include moisture as lb per lb of dry coal (face sample).

C. WATER

Quantity

Heat Capacity of Coolant Required in Btu x 10^9 per Calendar Day (includes Coolant for Power Requirements)

Hydrogenation: 35 Average for All Ranks of Coal

Coal Synthine: 54 Average for All Ranks of Coal

Water Requirements in Thousands of Gallons per Calendar Day

	Hydrogenation Make-up	Hydrogenation Consumed	Hydrogenation Returned	Coal Synthine Make-up-	Coal Synthine Consumed	Coal Synthine Returned
Evaporated (Cooling Towers)	4,180	4,180		6,410	6,410	
Blowdown from Cooling Towers	1,255	627	628	1,920	960	960
Boiler Make-up for Hydrogen Manufacturing	483	338	145			
Boiler Make-up for Boiler Blowdown	245	49	196	737	147	590
Boiler Make-up for Synthesis Gas Mfg.				578	51	527
High-pressure Injection Water (Process Water)	50	50				
Sanitary Water for Plant	72		72	60		60
Sanitary Water for Mines	37		37	48		48
Water for Coal Preparation	233	63	170	300	80	220
Water for Mines	Information not available. (Assumed to be self-sufficient)			Information not available. (Assumed to be self-sufficient)		
Water for Mine Power	69	55	14	81	65	16
Miscellaneous, 10%	662		662	1,016		1,016
Total	7,286	5,362	1,924	11,150	7,713	3,437

Quality

Hydrogenation:

1. Boiler water suitable for treatment.
2. Sanitary water suitable for chlorination and potable.
3. Cooling water is based on soft water. Water of high solids content increases water requirements or necessitates a water treatment plant.

Coal Synthine:

1. Boiler water suitable for treatment.
2. Sanitary water suitable for chlorination and potable.
3. Cooling water is based on soft water. Water of high solids content increases water requirements or necessitates a water treatment plant.

D. POWER

	Hydrogenation	Coal Synthine
Total Power Required for Mine (Kw)	3,000 (based on 2 shifts per day - 5-day week - 5 Kwhr per ton)	3,500 (based on 2 shifts per day - 5-day week - 5 Kwhr per ton)
Total Power Required for Plant (Kw)	65,000	114,500
By-product Power (Kw)	25,000 (Back-pressure power)	114,500 (Produced from waste heat)
Prime Power (Kw)	40,000 (May be procured from outside sources. Fuel requirements would be reduced in proportion) (B)	

E. PERSONNEL

Total Operating Personnel Required for Year-Round Operation

Plant (3 shifts), 365 days (year)

Hydrogenation		Coal Synthine	
Operational	925	Operational	937
Administrative	250	Administrative	198

Underground Mines (2 shifts, 240 days per year operation) (C)

Operational

Hydrogenation		Coal Synthine	
Bituminous (13,100 Btu)	782	Bituminous (13,100 Btu)	1,005
Subbituminous (9,500 Btu)	1,079	Subbituminous (9,500 Btu)	1,387
Lignite (7,000 Btu)	1,464	Lignite (7,000 Btu)	1,882

Administrative

Hydrogenation		Coal Synthine	
Bituminous (13,100 Btu)	39	Bituminous (13,100 Btu)	50
Subbituminous (9,500 Btu)	54	Subbituminous (9,500 Btu)	69
Lignite (7,000 Btu)	73	Lignite (7,000 Btu)	94

Strip Mine (2 shifts, 240 days per year operation) (D)

Operational

Hydrogenation		Coal Synthine	
		Anthracite Culm (11,500 Btu)	366
Bituminous (13,100 Btu)	312	Bituminous (13,100 Btu)	403
Subbituminous (9,500 Btu)	431	Subbituminous (9,500 Btu)	554
Lignite (7,000 Btu)	585	Lignite (7,000 Btu)	752

Administrative

Hydrogenation		Coal Synthine	
		Anthracite Culm (11,500 Btu)	18
Bituminous (13,100 Btu)	16	Bituminous (13,100 Btu)	20
Subbituminous (9,500 Btu)	22	Subbituminous (9,500 Btu)	28
Lignite (7,000 Btu)	29	Lignite (7,000 Btu)	38

F. PRODUCTS

Estimated Quantity of Products per Calendar Day (Ranges or Specific Quantities)

	Hydrogenation Barrels per Day	Hydrogenation Btu per Pound	Hydrogenation Btu x 10^9 per Day	Coal Synthine Barrels per Day	Coal Synthine Btu per Pound	Coal Synthine Btu x 10^9 per Day
Liquefied Petroleum Gases:						
Propane	1,709	21,700	6.52			
Butane	658	21,300	2.96	470	21,700	1.833
Motor Gasoline	7,220	19,450	37.76	7,280	20,310	37.26
Diesel Oil				1,900	19,990	10.72
Residual Fuel Oil				350	19,775	2.151
By-products: Phenols (E)	413	15,730	2.38			
Total	10,000		49.62	10,000		51.964

G. WASTES

Nature and Amount of Wastes

Hydrogenation:

Solid Wastes	Liquid Wastes	Gaseous Wastes
Reject from cleaning plant Spent Catalyst - 40 tons per day Ash (total ash in coal) Unburned Coal	Total - 53,000 gal per day (Composition of this waste is: Hydrogen Sulfide = 0.5% Carbon Dioxide = 2.0% Ammonia = 2.0% Phenols = 0.3%)	Total - 6,100,000 cu ft per day (Based on 1% Sulfur in coal. Composition: Hydrogen Sulfide = 1% Carbon Dioxide = 10% Air = 89%)

Coal Synthine:

Solid Wastes	Liquid Wastes	Gaseous Wastes
Reject from cleaning plant Spent Catalyst Dry Box Mass - 0.5 tons per day Ash (Total ash in coal) Unburned Coal		Hydrogen Sulfide from Girbotol 240 cu ft per 1% sulfur per ton of coal (as received). Can be converted to sulfur or burned as Sulfur Dioxide. The amount of wastes varies with sulfur in coal.

H. AREA

	Hydrogenation	Coal Synthine
Area Required in Acres (Minimum)	70	77

Note: (A) Over-all Efficiency is defined as - $\frac{\text{Btu in products}}{\text{Btu in coal}} \times 100$

(B) Water requirements would be 17.2% less total water for hydrogenation if prime power were purchased from some outside source.
(C) Assuming 8 tons of coal per man and shift; administrative personnel 5% of operational; 10% allowance for absenteeism.
(D) Assuming 20 tons of coal (25 tons of anthracite culm) per man and shift; administrative personnel 5% of operational; 10% allowance for absenteeism.
(E) Convertible in proportion 1,240 bbl phenols equivalent to 1,391 bbl gasoline; no additional equipment.

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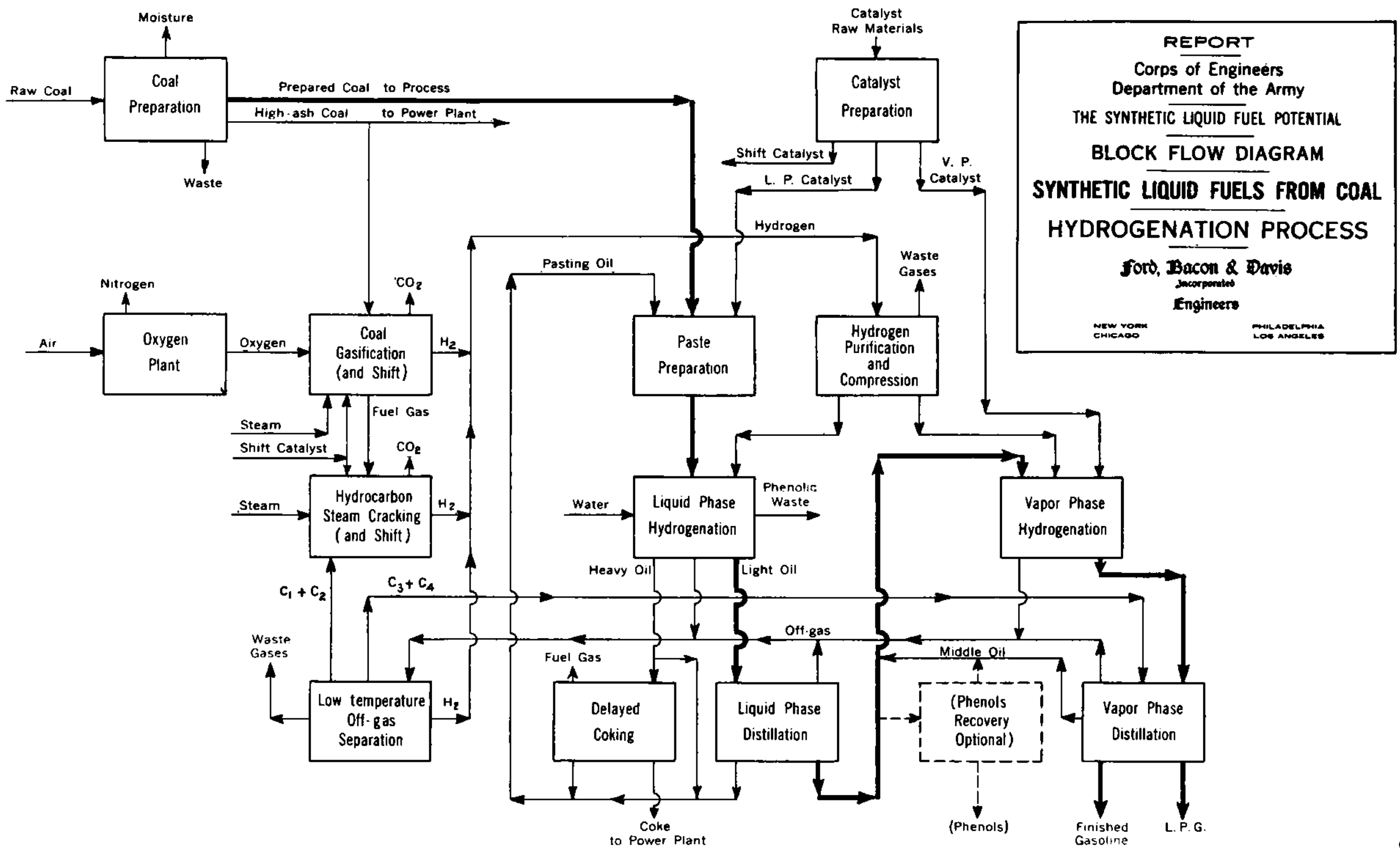

EXHIBIT NO. 2

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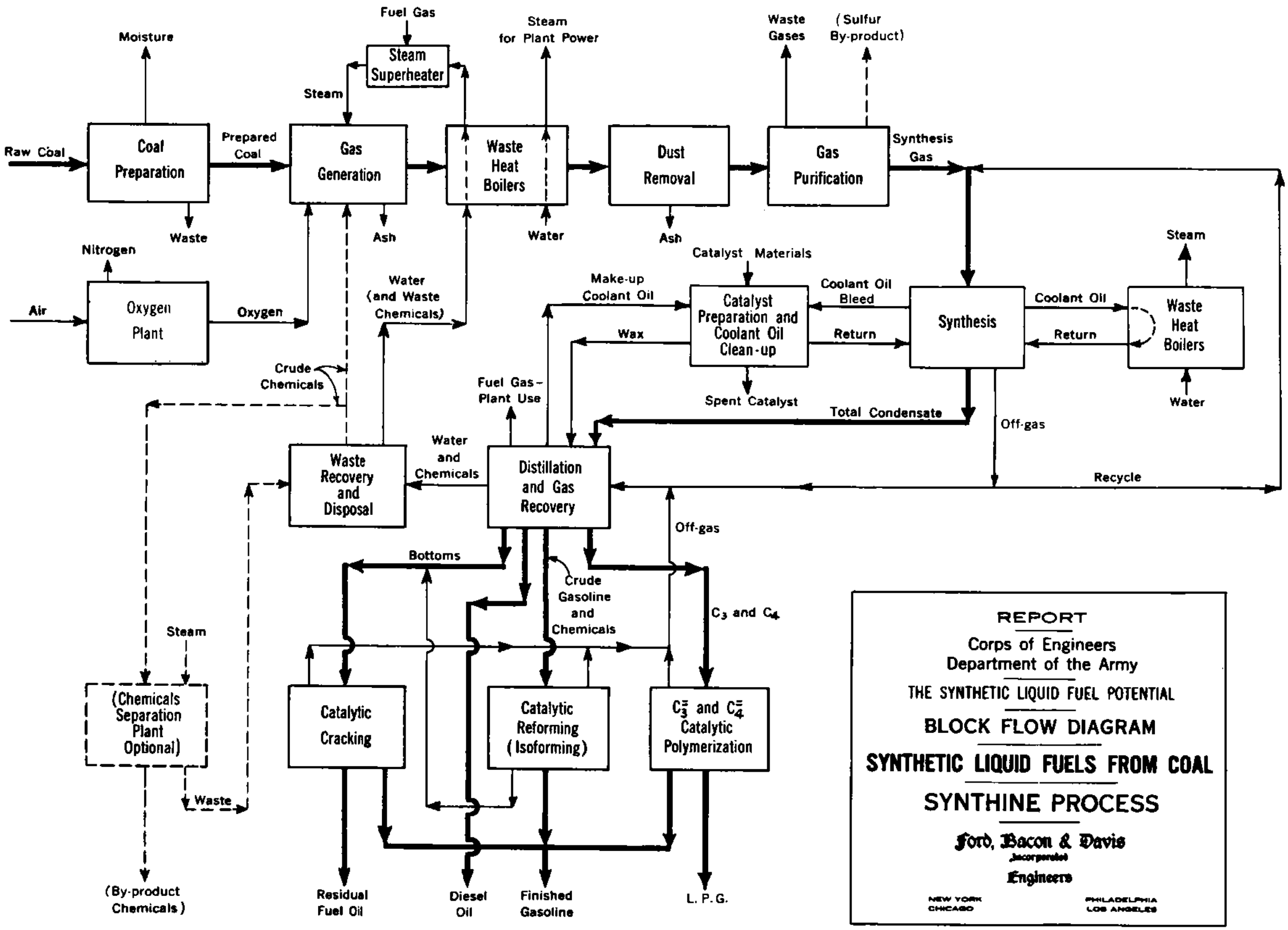

REPORT

Corps of Engineers
Department of the Army

THE SYNTHETIC LIQUID FUEL POTENTIAL

BLOCK FLOW DIAGRAM

SYNTHETIC LIQUID FUELS FROM COAL

SYNTHINE PROCESS

Ford, Bacon & Davis
Incorporated
Engineers

NEW YORK
CHICAGO
PHILADELPHIA
LOS ANGELES

EXHIBIT NO. 3

EXHIBIT NO. 4

REPORT

Corps of Engineers
Department of the Army

THE SYNTHETIC LIQUID FUEL POTENTIAL
OF

KANSAS

WEATHER DATA

AVERAGE PRECIPITATION AND TEMPERATURE

BY MONTHS

AT FORT SCOTT, KANSAS

(SELECTED AS REPRESENTATIVE OF THE COAL-BEARING AREA OF KANSAS)

Ford, Bacon & Davis
Incorporated
Engineers

NEW YORK CHICAGO PHILADELPHIA LOS ANGELES

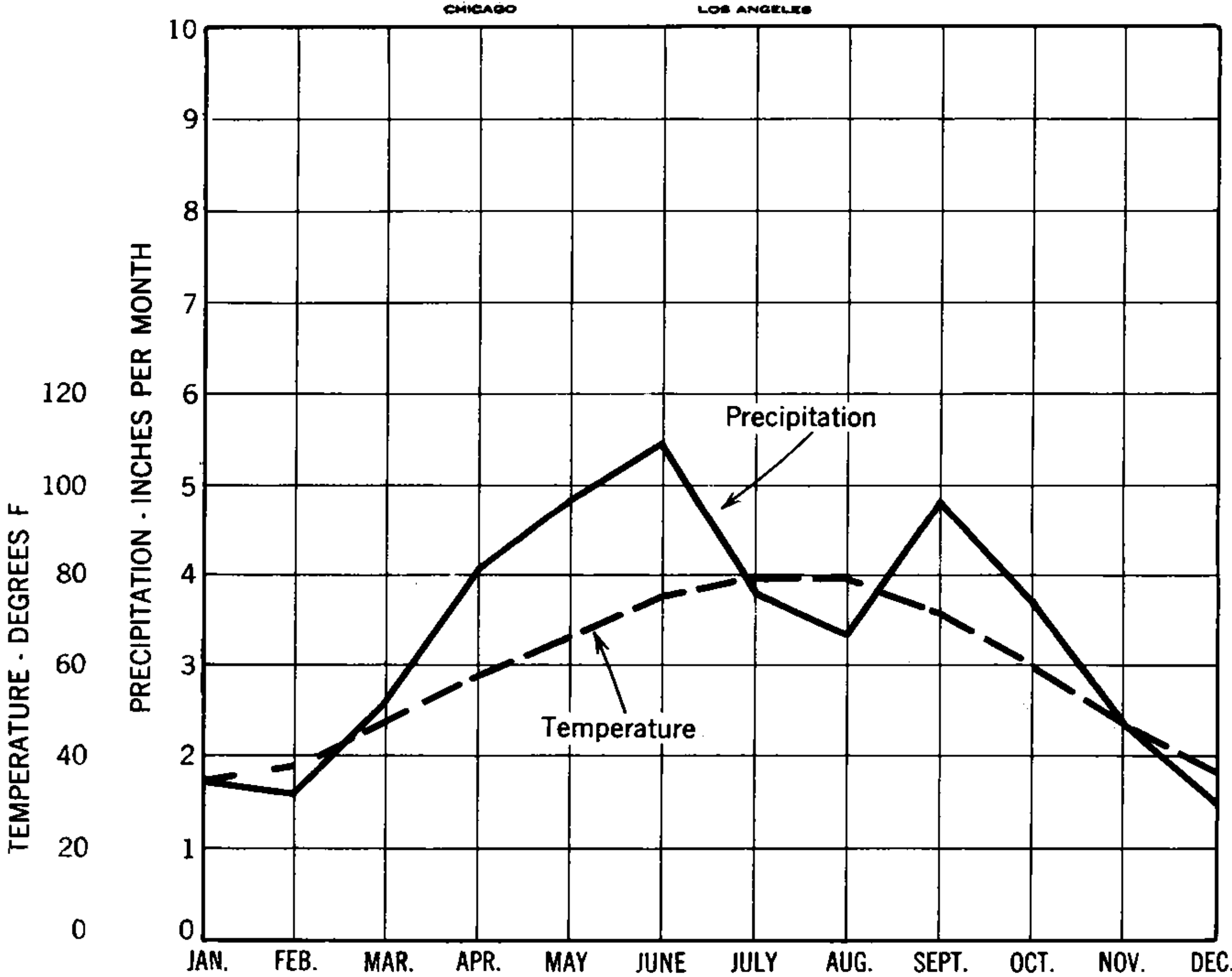

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Exhibit No. 6

Depositories for Coal Data Sheets

The Bureau of Mines has informed the Office of Chief of Engineers, Department of the Army, that it will furnish the following depository libraries with bound copies of coal data sheets where they will be available for public inspection:

Bureau of Mines Library
4800 Forbes Street
Pittsburgh, Pennsylvania

Bureau of Mines Library
University Campus
Seattle 5, Washington

Bureau of Mines Library
University Campus
Grand Forks, North Dakota

Bureau of Mines Library
University Campus
Tuscaloosa, Alabama

Bureau of Mines Library
Coal Branch
Denver Federal Center, Bldg. 2A
Denver 2, Colorado

Library of Congress
Washington, D. C.

Central Library
Department of Interior
Interior Bldg.
Washington, D. C.

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Exhibit No. 7

Description of Coal Trade Districts

Although the entire coal-producing area of Kansas was classified as only a portion of District 15, which also includes Missouri, Texas, and most of Oklahoma, under the Bituminous Coal Act of 1937, common trade practice segregates Kansas production by individual coal-producing districts. These districts are generally separate areas in which the geographic position and/or the physical characteristics of the coal beds and the accompanying strata have been such as to encourage concentrated development. These commercial producing districts may be briefly described in a general north to south direction, as follows:

The Northeastern Kansas district is located in Leavenworth and Atchison Counties, which are bordered by the Missouri River in the northeastern part of the State. Although now largely inactive, coal has been mined at depths ranging up to 1,100 feet in this area. Local strip and drift mines have also been opened at scattered operations because of their proximity to the consuming markets in the cities of Atchison and Leavenworth, and also Kansas City.

The East-central Kansas district, sometimes designated as the Osage district, is located principally in Osage County but includes parts of Franklin, Coffey, and Anderson Counties. The principal beds mined in this district are the Nodaway bed in Osage County and the Upper Williamsburg bed in Franklin County.

The Southeastern Kansas district includes the major production in the State, which is obtained in Crawford and Cherokee Counties at the southeastern corner of Kansas. The principal beds, occurring near the base of the coal measures, include the Weir-Pittsburgh, Bevier, Mineral, and Croweburg. Other beds, such as the Rowe and the Mulky beds have also been mined. The district also includes the eastern portion of Labette County, Bourbon County, and Linn County, in which the Mulberry coal has been extensively mined.

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EXHIBIT NO. 8

SYNTHETIC LIQUID FUEL SURVEY

SUMMARY OF RECOVERABLE COAL RESERVES IN KANSAS*

CONSIDERED FOR SYNTHETIC LIQUID FUELS MANUFACTURE

BY COUNTIES AND BEDS

AS OF JANUARY 1, 1950

	COUNTY	SEAM	THICKNESS OF COAL (INCHES)			DIP OF BED** (DEGREES)			THICKNESS OF COVER (FEET)					RANK OF COAL	● ANALYSIS (AS RECEIVED)									B.T.U.		AREA OF UNMINED COAL (ACRES)
									UNDERGROUND MINING			STRIP MINING			PROXIMATE				ULTIMATE							
			MAX	MIN	AVE	MAX	MIN	AVE	MAX	MIN	AVE	MAX	AVE		MOISTURE	VOLATILE MATTER	FIXED CARBON	ASH	SULPHUR	HYDROGEN	CARBON	NITROGEN	OXYGEN	AS RECEIVED	MOISTURE AND ASH FREE	
1	FRANKLIN	WILLIAMSBURG UPPER			14							50	30	Hvcb	14.9	34.8	41.4	8.9	1.1					10,820	14,200	3,251
2																										
3	OSAGE	WILLIAMSBURG UPPER			14							50	30	Hvcb	7.3	36.6	45.8	10.3	4.4					10,630	12,900	2,214
4																										
5	LINN	MULBERRY			36							75	35	Hvbb	8.3	32.0	46.2	13.5	2.9	5.3	64.3	1.3	12.7	11,540	14,760	2,611
6																										
7	BOURBON	WEIR-PITTSBURG	36	26							125			†Hvbb	8.6	30.9	49.6	10.9	3.6					11,960	14,860	1,958
8		BEVIER			18							55	30	Hvbb	4.2	37.5	45.4	12.9	2.0					11,850	14,290	275
9		TOTAL																								2,233
10																										
11	CRAWFORD	WEIR-PITTSBURG	40	26					200	125				Hvab	6.1	33.1	51.6	9.2	3.5	5.4	70.4	1.2	10.3	12,690	14,980	44,164
12		BEVIER			18							60	30	Hvbb	5.0	25.4	55.1	14.5	3.3					11,790	14,650	38,356
13		MINERAL			20							75	35	Hvab	4.5	34.4	48.4	12.7	4.1					12,380	14,950	42,834
14		CROWEBURG			12							50	25		NO ANALYSES AVAILABLE											2,272
15		TOTAL																								127,626
16																										
17	NEOSHO	THAYER			14							50	25	Hvab	5.9	33.3	53.2	7.6	0.9					12,880	14,890	3,869
18																										
19	WILSON	THAYER	18	12								45	30	Hvab	2.9	32.5	51.1	13.5	2.0					12,790	15,300	9,626
20																										
21	CHEROKEE	WEIR-PITTSBURG	40	26					175	150				Hvab	5.1	34.5	52.1	8.3	3.3	5.2	71.8	1.2	10.2	13,080	15,100	16,141
22		BEVIER			18							60	30	†Hvbb	5.0	25.4	55.1	14.5	3.3					11,790	14,650	7,021
23		MINERAL			22							75	40	Hvab	4.2	34.0	48.9	12.9	3.4					12,530	15,110	26,106
24		TOTAL																								49,268
25																										
26	MONTGOMERY	THAYER	15	12								50	30	Hvbb	8.0	34.1	45.8	12.1	0.7					11,440	14,320	5,683
27																										
28																										
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	COUNTY	SEAM	QUANTITY OF PRIMARY RESERVES (THOUSANDS OF TONS)								QUANTITY OF SECONDARY RESERVES (THOUSANDS OF TONS)												TOWNSHIPS
			UNDERGROUND MINING				STRIP MINING				UNDERGROUND MINING						STRIP MINING						
			MEASURED		INDICATED		MEASURED		INDICATED		MEASURED		INDICATED		INFERRED		MEASURED		INDICATED		INFERRED		
			ACRES	TONS	ACRES	TONS	ACRES	TONS	ACRES	TONS	ACRES	TONS	ACRES	TONS	ACRES	TONS	ACRES	TONS	ACRES	TONS	ACRES	TONS	
1	FRANKLIN	WILLIAMSBURG UPPER																			3,251	4,780	T17S·R17E
3	OSAGE	WILLIAMSBURG UPPER																			2,214	3,255	T17,18S·R17E
5	LINN	MULBERRY							2,611	9,870													T21,22S·R25E
7	BOURBON	WEIR-PITTSBURG											160	374	1,798	4,208							T27S·R25E
8		BEVIER																	115	218	160	302	T27S·R24E
9		TOTAL											160	374	1,798	4,208			115	218	160	302	
11	CRAWFORD	WEIR-PITTSBURG	5,849	18,015	13,114	41,054					147	344	10,951	25,624	14,103	32,234							T27S·R25E; T28S·R24,25E; T29S·R24E; T30S·R23,24E; T31S·R23E
12		BEVIER																	28,411	53697	9,945	18,797	T30N·R22,23E; T31N·R23,24E; T32N·R24E; T27S·R24E; T28,29S·R24,25E
13		MINERAL															9,133	19,231	25,522	54,199	8,179	17,768	T27,28S·R25E; T29S·R6E; T30S·R24,25E; T31S·R23,24E
14		CROWEBURG																	2,272	2,862			T28,29S·R25E
15		TOTAL	5,849	18,015	13,114	41,054					147	344	10,951	25,624	14,103	32,234	9,133	19,231	56,205	110,758	18,124	36,565	
17	NEOSHO	THAYER																	3,869	5,121			T29,30S·R17,18E
19	WILSON	THAYER																	9,626	14,907			T29,30S·R16,17E
21	CHEROKEE	WEIR-PITTSBURG	1427	5,138	3,079	11,082					659	1,543	6,547	15,320	4429	10,363							T31S·R22-24E; T32S·R22,23E
22		BEVIER																	7008	13,245	13	25	T29N·R22E; T30N·R22,23E
23		MINERAL															5,696	13157	15,021	34.700	5389	12,448	T31,32S·R22,23E; T33S·R22E
24		TOTAL	1,427	5,138	3079	11,082					659	1,543	6,547	15,320	4,429	10,363	5,696	13157	22,029	47.945	5,402	12,473	
26	MONTGOMERY	THAYER																	4,403	6,935	1,280	2,016	T31,32S·R16E; T33S·R15E; T34S·R15,16E

SOURCES OF INFORMATION AND OTHER FOOTNOTES: † NO ANALYSES AVAILABLE, ESTIMATED FROM ADJOINING COUNTIES

* BASED ON ESTIMATED RECOVERY FACTORS OF 60 PERCENT FOR UNDERGROUND RESERVES IN PLACE; 70 PERCENT FOR STRIPPABLE RESERVES IN PLACE.

** DIP RARELY EXCEEDS ONE DEGREE AND AVERAGES APPROXIMATELY 30 FEET PER MILE TOWARD THE NORTHWEST.

● AVERAGE ANALYSIS OF MINE SAMPLES OBTAINED BY STANDARD U. S. BUREAU OF MINES PROCEDURE.

SF-115C 1-4-51

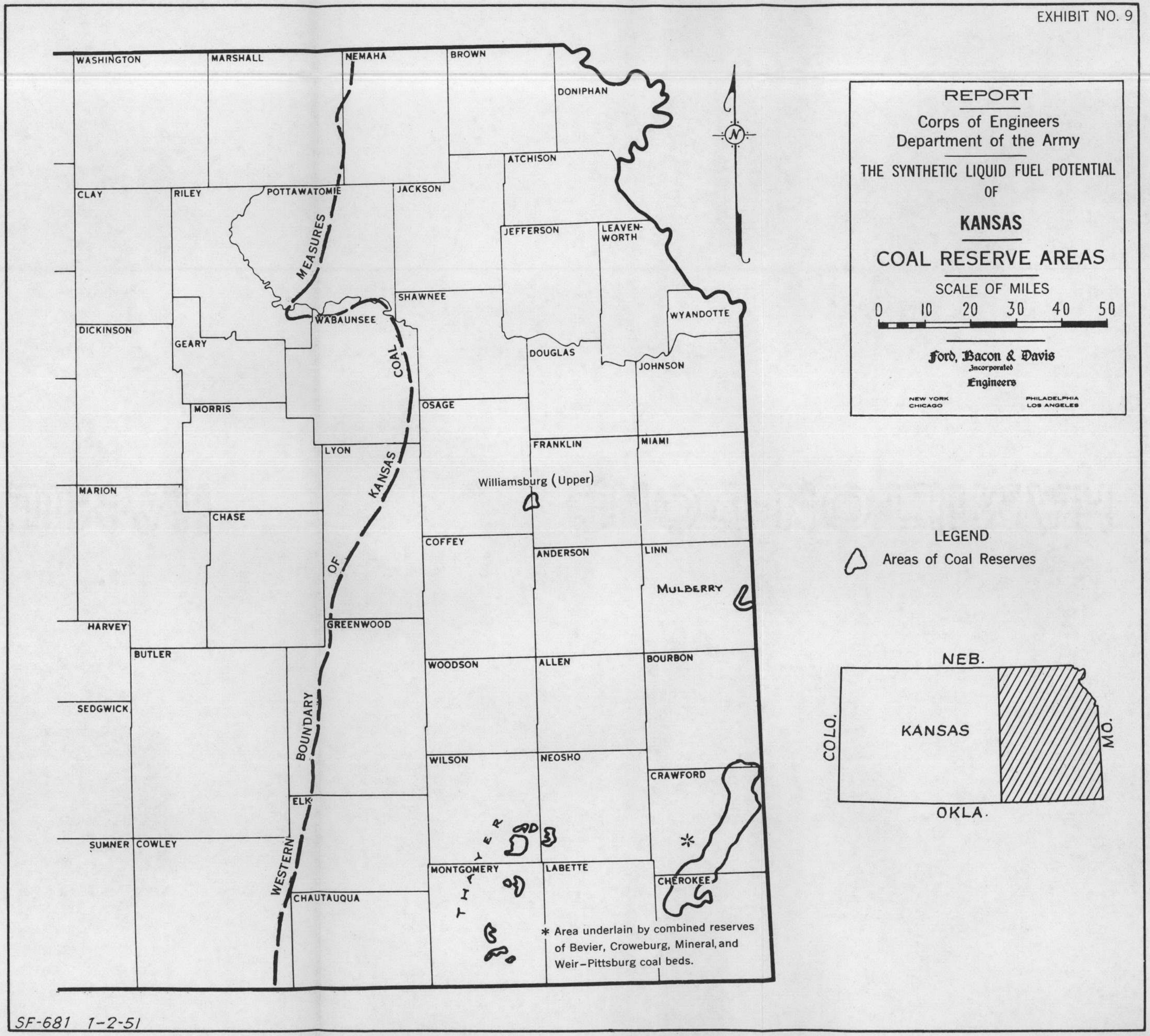


EXHIBIT NO. 9
REPORT
Corps of Engineers
Department of the Army
THE SYNTHETIC LIQUID FUEL POTENTIAL
OF
KANSAS
COAL RESERVE AREAS
SCALE OF MILES
0 10 20 30 40 50
Ford, Bacon & Davis
Incorporated
Engineers
NEW YORK
CHICAGO
PHILADELPHIA
LOS ANGELES
N
WASHINGTON
MARSHALL
NEMAHA
BROWN
DONIPHAN
ATCHISON
CLAY
RILEY
POTTAWATOMIE
JACKSON
JEFFERSON
LEAVEN-
WORTH
SHAWNEE
WYANDOTTE
DICKINSON
GEARY
WABAUNSEE
DOUGLAS
JOHNSON
MORRIS
OSAGE
LYON
FRANKLIN
MIAMI
Williamsburg (Upper)
MARION
CHASE
COFFEY
ANDERSON
LINN
MULBERRY
HARVEY
BUTLER
GREENWOOD
WOODSON
ALLEN
BOURBON
SEDGWICK
WILSON
NEOSHO
CRAWFORD
ELK
SUMNER
COWLEY
MONTGOMERY
LABETTE
CHEROKEE
CHAUTAUQUA
THAYER
WESTERN BOUNDARY OF KANSAS COAL MEASURES
* Area underlain by combined reserves of Bevier, Croweburg, Mineral, and Weir-Pittsburg coal beds.
LEGEND
Areas of Coal Reserves
NEB.
COLO.
KANSAS
MO.
OKLA.
SF-681 1-2-51

EXHIBIT NO. 10

REPORT

Corps of Engineers
Department of the Army

THE SYNTHETIC LIQUID FUEL POTENTIAL
OF

KANSAS

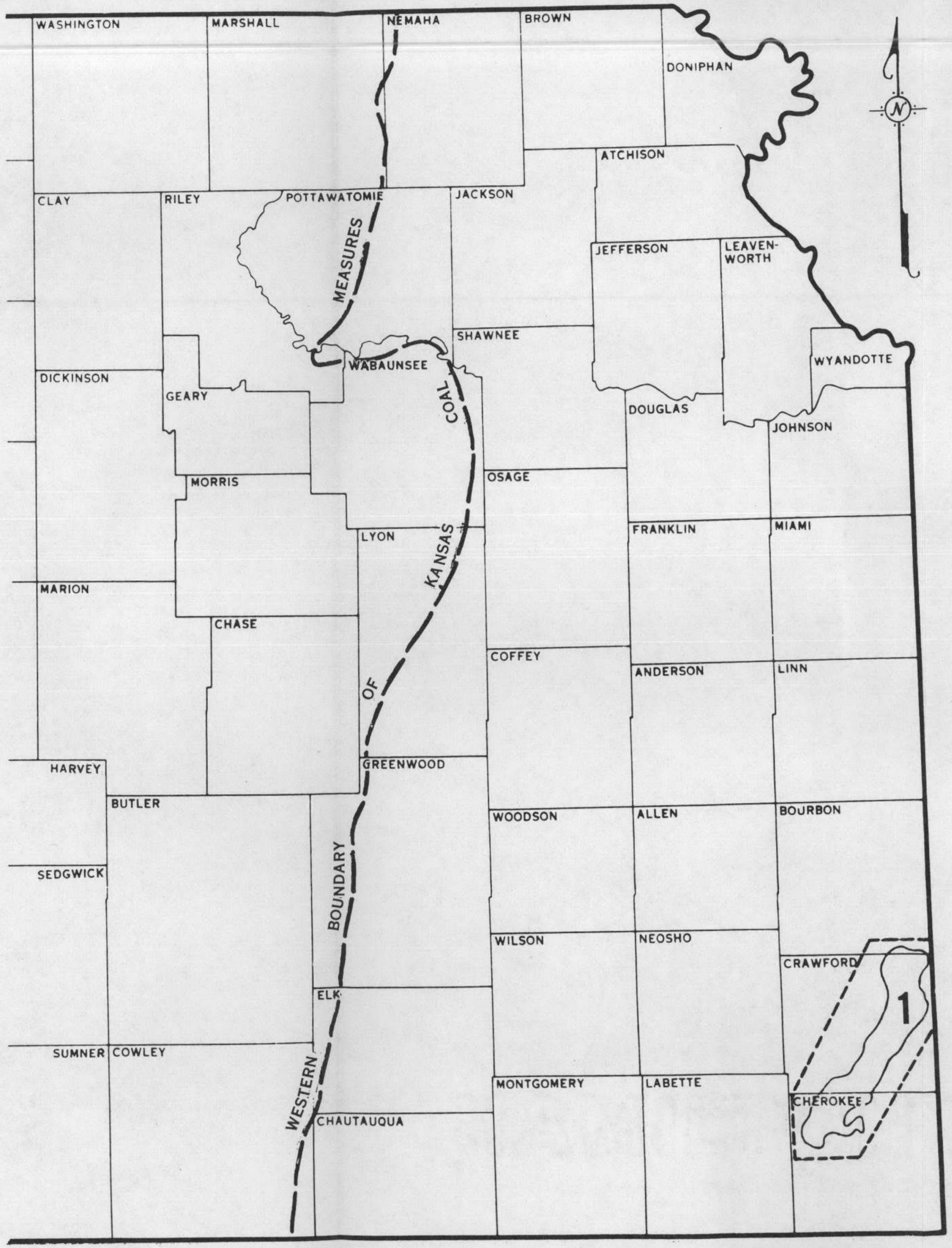
GENERAL AREA
OF

COAL AND WATER AVAILABILITY

SCALE OF MILES
0 10 20 30 40 50

Ford, Bacon & Davis
Incorporated
Engineers

NEW YORK
CHICAGO
PHILADELPHIA
LOS ANGELES



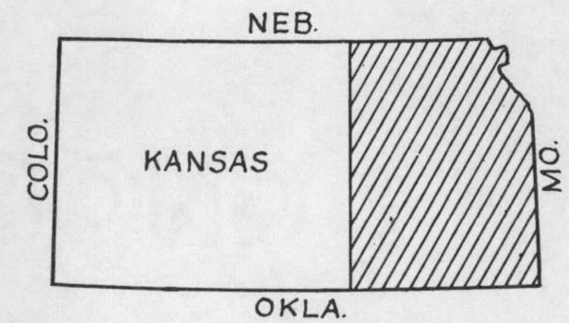
LEGEND

Area of Coal and Water Availability

Area of Coal Reserves

IDENTIFICATION OF GENERAL AREA

No.	General Area
1	Crawford-Cherokee



SF-680 1-2-51

Crawford Cherokee General Area of Coal Availability
(as of January 1, 1950)

	Coal Beds: Weir-Pittsburg			Bevier			Mineral		Totals and/or Weighted Averages
County	Bourbon	Crawford	Cherokee	Bourbon	Crawford	Cherokee	Crawford	Cherokee	
Portion of County	SE.	Eastern	NW.	SE.	Eastern	NW.	Eastern	NW.	
Thickness (inches):									
Maximum	36	40	40						
Minimum	26	26	26						
Average				18	18	18	20	22	
Dip of Bed (degrees):									
Maximum	1	1	1	1	1	1	1	1	
Minimum	0	0	0	0	0	0	0	0	
Overburden Thickness - Underground Minable Reserves (feet)									
Maximum	-	200	175	-	-	-	-	-	
Minimum	-	125	150	-	-	-	-	-	
Average	125	-	-	-	-	-	-	-	
Overburden Thickness - Strip Minable Reserves (feet):									
Maximum	-	-	-	55	60	60	75	75	
Average	-	-	-	30	30	30	35	40	
Rank (A)	Hvbb	Hvab	Hvab	Hvbb	Hvbb	Hvbb	Hvab	Hvab	
Analysis: (B)									
Moisture	8.6%	6.1%	5.1%	4.2%	5.0%	5.0%	4.5%	4.2%	5.2%
Volatile Matter	30.9	33.1	34.5	37.5	25.4	25.4	34.4	34.0	32.0
Fixed Carbon	49.6	51.6	52.1	45.4	55.1	55.1	48.4	48.9	51.2
Ash	10.9	9.2	8.3	12.9	14.5	14.5	12.7	12.9	11.6
Sulfur	3.0%	3.5%	3.3%	2.0%	3.3%	3.3%	4.1%	3.4%	3.5%
Btu	11,960	12,690	13,080	11,850	11,790	11,790	12,380	12,530	12,440
Btu - Moisture- and ash-free	14,860	14,980	15,100	14,290	14,650	14,650	14,950	15,110	14,930
Area Underlain by Reserves (acres)	1,958	44,164	16,141	275	38,356	7,021	42,834	26,106	110,000
Estimated Recoverable Reserves (thousands of tons):									
Primary Underground	-	59,069	16,220	-	-	-	-	-	75,289
Primary Strip	-	-	-	-	-	-	-	-	-
Primary Total	-	59,069	16,220	-	-	-	-	-	75,289
Secondary Underground	4,582	58,202	27,226	-	-	-	-	-	90,010
Secondary Strip	-	-	-	520	72,494	13,270	91,198	60,305	237,787
Secondary Total	4,582	58,202	27,226	520	72,494	13,270	91,198	60,305	327,797
Total Underground	4,582	117,271	43,446	-	-	-	-	-	165,299(D)
Total Strip	-	-	-	520	72,494	13,270	91,198	60,305	237,787(E)
Total Available Reserves	4,582	117,271	43,446	520	72,494	13,270	91,198	60,305	150,578(E)

Capacity of Synthetic Liquid Fuel Plant:

Thousand Barrels per Day (C)	Underground	Strip	Total
Hydrogenation Process	13	13	26
Synthine Process	10	10	20

Note:

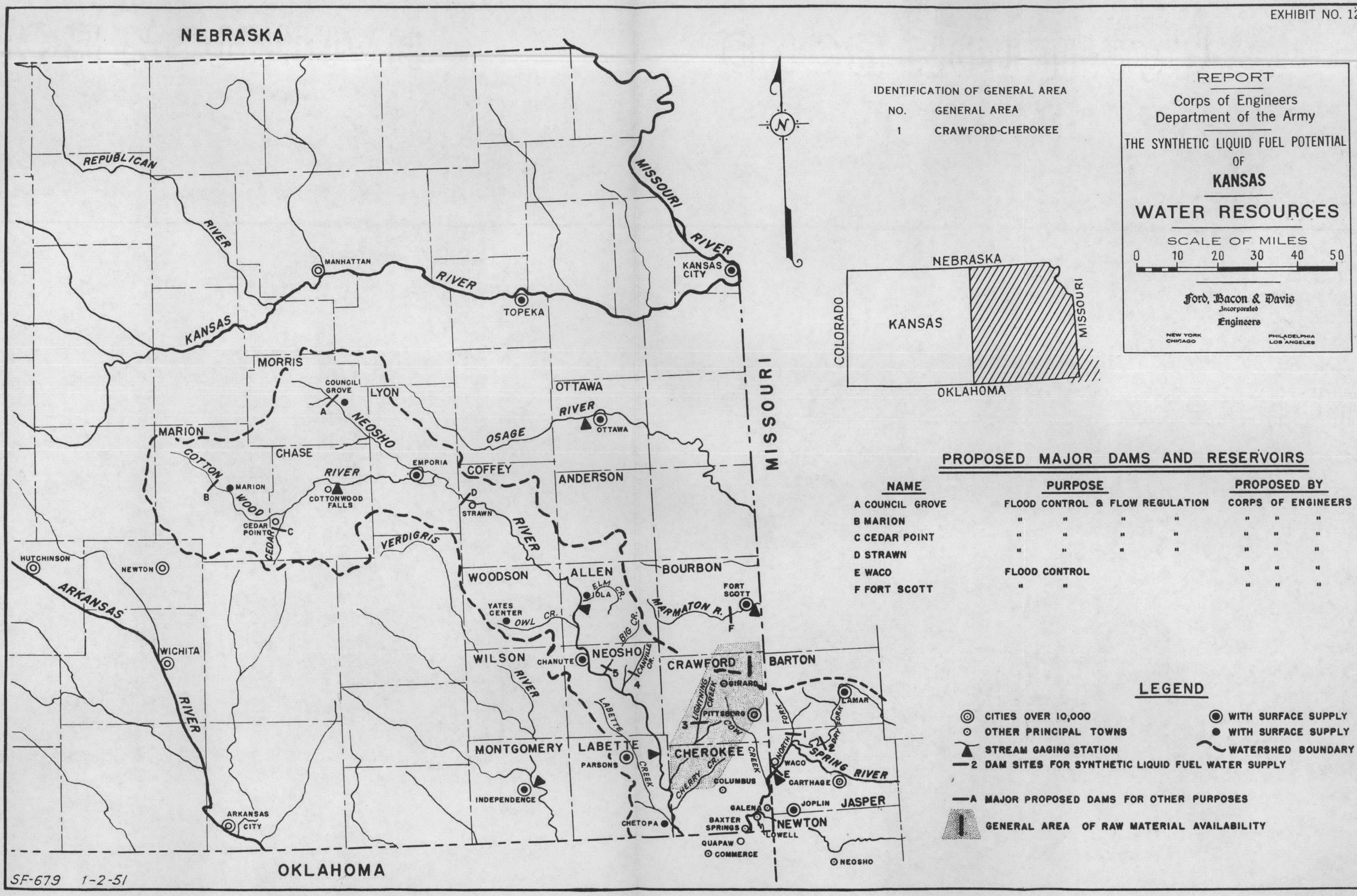
(A) Hvab: High-volatile A bituminous; Hvbb: High-volatile B bituminous.

(B) Average or representative analyses of mine samples obtained by Standard U.S. Bureau of Mines procedure; as-received basis.

(C) Based on total demand of 98 billion Btu per calendar day for hydrogenation plant and of 126 billion for synthine plant.

(D) Usable underground coal is only 75,289,000 tons, all primary, due to limitations (E); it is assumed that all secondary coal used will be strip, so that the excess secondary will consist of 90,010,000 tons underground and 162,498,000 tons strip.

(E) Total primary and secondary reserves for synthetic liquid fuels plant supply limited by definition to twice the primary reserves.



PROPOSED MAJOR DAMS AND RESERVOIRS

NAME	PURPOSE	PROPOSED BY
A COUNCIL GROVE	FLOOD CONTROL & FLOW REGULATION	CORPS OF ENGINEERS
B MARION	" " " "	" " "
C CEDAR POINT	" " " "	" " "
D STRAWN	" " " "	" " "
E WACO	FLOOD CONTROL	" " "
F FORT SCOTT	" "	" " "

Daily Process Water Requirements with Recirculation
of Cooling Water for 10,000-barrel-per-day Plant Using Coal Synthine Process

Item	Use	Make-up (A) Gallons (1,000's)	Make-up (A) AF	Make-up (A) Cfs	Consumed (B) Gallons (1,000's)	Consumed (B) AF	Consumed (B) Cfs	Returned (C) Gallons (1,000's)	Returned (C) AF	Returned (C) Cfs
1	Evaporated (Cooling Towers)	6,410	19.67	9.92	6,410	19.67	9.92	-	-	-
2	Blowdown for Cooling Towers	1,920	5.89	2.97	960	2.95	1.48	960	2.94	1.49
3	Boiler Make-up for H_2 Manufacturing	-	-	-	-	-	-	-	-	-
4	Boiler Make-up for Synthesis Gas	578	1.77	0.89	51	0.15	0.08	527	1.62	0.81
5	Boiler Make-up for Boiler Blowdown	737	2.26	1.14	147	0.45	0.23	590	1.81	0.91
6	High Pressure Injection H_2O (Process H_2O)	-	-	-	-	-	-	-	-	-
7	Sanitary H_2O for Plant	60	0.19	0.09	-	-	-	60	0.19	0.09
8	Sanitary H_2O for Mines	48	0.15	0.08	-	-	-	48	0.15	0.08
9	Water for Coal Preparation	300	0.92	0.46	80	0.25	0.12	220	0.67	0.34
10	Water for Mines	-	-	-	-	-	-	-	-	-
11	Water for Mine Power	81	0.25	0.13	65	0.20	0.10	16	0.05	0.03
12	Miscellaneous	1,016	3.12	1.57	-	-	-	1,016	3.12	1.57
13	Total	11,150	34.22	17.25	7,713	23.67	11.93	3,437	10.55	5.32

Note: For "once-through" cooling with 33° F rise in water temperature through the plant, approximately 197 mgd, or 304 cfs of water are required in place of Items 1 and 2 above.

(A) Make-up - The total amount of water required to be delivered from the source to the plant.

(B) Consumed - The amount of water evaporated or used in the coal synthine process.

(C) Returned - The amount of water returned to a stream as waste and sewage.

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11. 1948, Review Report, Osage River (Missouri and Kansas), Kansas City District, Corps of Engineers, U.S. Army

12. 1949, Project Maps, Kansas City District, Corps of Engineers, U.S. Army

13. Surface Water Supply of the United States, parts 6 and 7, Various Publications, U.S.G.S.

14. Water Levels and Artesian Pressures in Observation Wells in the United States, part 3, Various Publications, U.S.G.S.

Acknowledgements for Technical Information on Water Supply

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Kansas State Board of Health
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1203 West 6th Street
Stillwater, Oklahoma

R. F. Brown, Chief Engineer
Spencer Chemical Company
Pittsburg, Kansas

Stream Flow Records and Estimates

Stream and Gaging Station	Drainage Area (Sq Mi)	Years of Record	Mean Annual Flow Cfs	Mean Annual Flow Cfs per Sq Mi	Minimum Flow Monthly (Cfs)	Minimum Flow Daily (Cfs)	Records Used in Preparing Estimates
Recorded Flow Data							
Osage River - Ottawa	1,260	1903-1905 1920-1948	625	0.496	0	0	-
Marmaton River - Fort Scott	411	1922-1924 1930-1948	298	0.725	*	0	-
Neosho River - Iola	3,795	1919-1948	1,551	0.409	1.1	0	-
Neosho River - Parsons	4,828	1923-1948	2,421	0.501	0	0	-
Cottonwood River - Cottonwood Falls	1,444	1933-1948	473	0.328	1.5	1	-
Spring River - Waco, Mo.	1,160	1924-1948	936	0.807	25.4	12	-
Verdigris River - Independence	2,952	1923-1948	1,619	0.548	0	0	-
Estimated Flow Data							
Neosha River Basin:							
Big Creek	112	-	81	0.725	*	0	Marmaton River - Fort Scott
Canville Creek	83	-	60	0.725	*	0	Marmaton River - Fort Scott
Lightning Creek	230	-	167	0.725	*	0	Marmaton River - Fort Scott
Spring River Basin:							
Dry Fork	640	-	516	0.807	14	7	Spring River - Waco, Mo.
North Fork	97	-	78	0.807	2	1	Spring River - Waco, Mo.

* Less than 1 Cfs.

Note: All stream flow records obtained from Water Supply Papers of the U.S.G.S.

EXHIBIT NO. 17

REPORT

Corps of Engineers
Department of the Army

THE SYNTHETIC LIQUID FUEL POTENTIAL
OF
KANSAS

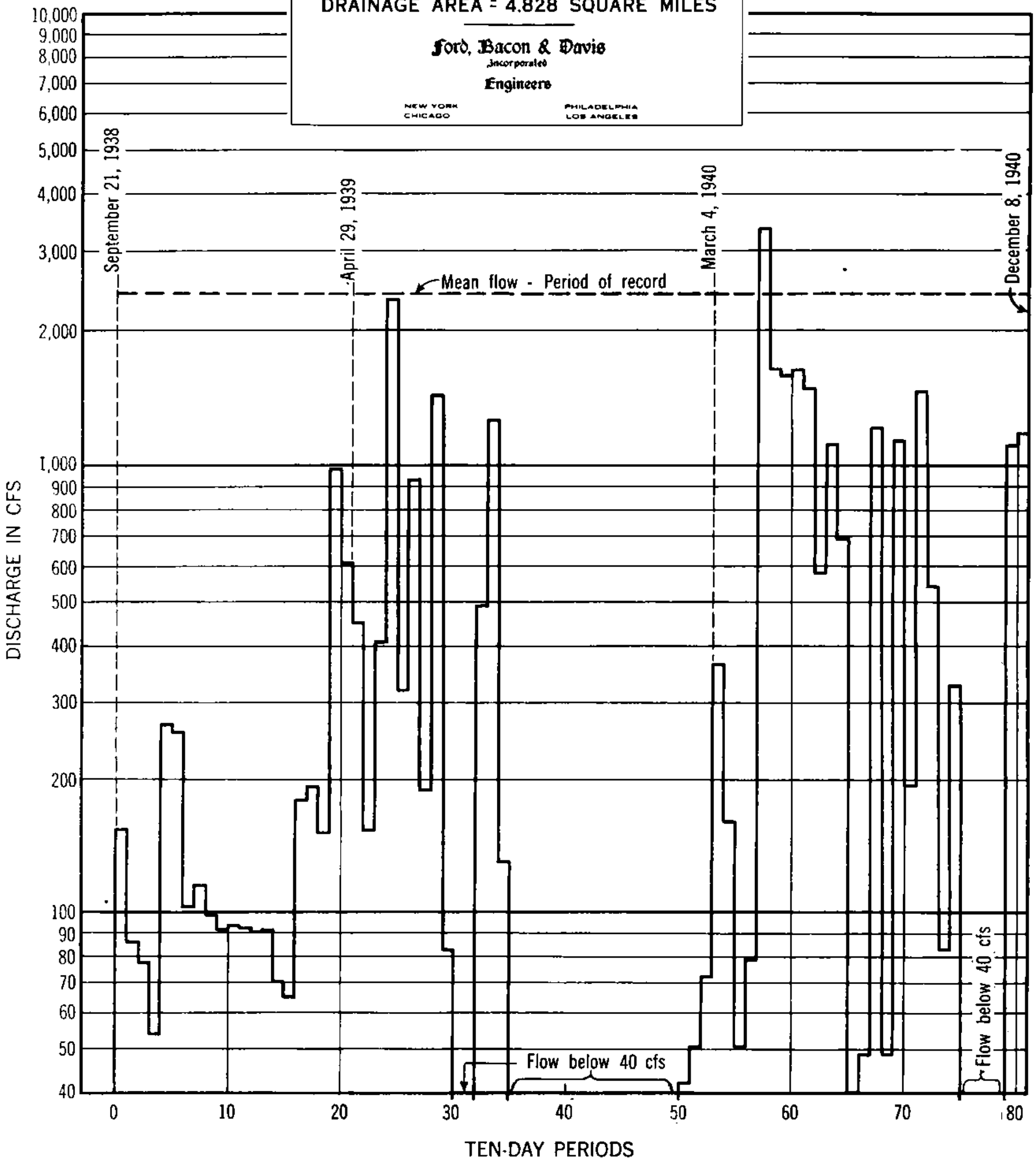
TEN-DAY HYDROGRAPH

NEOSHO RIVER NEAR PARSONS, KANS.

FOR PERIOD SEPT. 21, 1938 TO DEC. 8, 1940
DRAINAGE AREA = 4,828 SQUARE MILES

Ford, Bacon & Davis
Incorporated
Engineers

NEW YORK
CHICAGO
PHILADELPHIA
LOS ANGELES



SF-807 2-8-51

Physical and Chemical Water Analyses in Kansas at Selected Sampling Stations

Sampling Station	Surface Water: Neosho River near Commerce, Okla.			Surface Water: Spring River near Quapaw, Okla.			Surface Water: Marmaton River at Fort Scott			Ground Water: Labette Co. Test Hole 4	Ground Water: Labette Co. Test Hole 41
Source of Data	(A)	(A)	(A)	(A)	(A)	(A)	(B)	(B)	(B)	(C)	(C)
Date of Collection	7/21-31/48	1948-9	1/21-31/48	6/22-27/48	1948-9	12/21-31/47	7/16-29/07	1907-08	2-21-07 to 3- 2-07	1/22/42	1/23/42
River Discharge - Cfs	51,990	Average	141	42,420	2,050	187	High	Average	Low		
Temperature - ° F.	85	70	32	70	59	41	-	-	-	55	55
Color	-	-	-	-	-	-	-	-	-	-	-
pH	-	-	-	-	-	7.3	-	-	-	-	-
Sp. Cond. (K x 10^5)	-	362	919	143	268	548	-	-	-	-	-
Silica (SiO_2) - Ppm	-	-	-	-	-	7.8	14	14	70	-	-
Iron (Fe) - Ppm	-	-	-	-	-	.05	1.5	1.1	.10	12	8.4
Manganese (Mn) - Ppm	-	-	-	-	-	-	-	-	-	-	-
Calcium (Ca) - Ppm	16	45	102	14	36	88	58	81	91	45	100
Magnesium (Mg) - Ppm	6.9	9.9	26	5.5	6.6	9.4	12	8.7	5.5	9.2	20
Sod. and Pot. (Na + K) - Ppm	4.2	19	50	5.2	8.3	(15+2.6)	19	23	30	8.1	15
Bicarbonate (HCO_3) - Ppm	58	148	206	26	70	149	240	251	256	120	315
Sulfate (SO_4) - Ppm	20	46	154	41	62	130	28	35	45	58	105
Chloride (Cl) - Ppm	3.5	14	99	2.0	4.9	15	5.5	5.2	4.2	4	14
Fluoride (F) - Ppm	-	-	-	-	-	1.0	-	-	-	0.1	0.2
Nitrate (NO_3) - Ppm	5.0	6.0	1.0	2.5	8.0	15	1.8	1.9	2.3	0.88	1.2
Total Hardness as $CaCO_3$ - Ppm	68	153	362	58	118	258	-	-	-	150	356
Non-Carbonate - Ppm	21	32	192	36	60	136	-	-	-	52	98
M.O. Alkalinity as $CaCO_3$ - Ppm	-	-	-	-	-	-	-	-	-	-	-
Dissolved Solids - Ppm	131	250	548	112	182	368	196	267	366	381	801
Turbidity - Ppm	-	-	-	-	-	-	20	22	8	-	-

Note: (A) Data Collected by Division of Water Quality, U.S.G.S.
(B) Professional Paper No. 135, U.S.G.S.
(C) State Geological Survey of Kansas - Bulletin No. 52, Part 2

EXHIBIT NO. 19

REPORT

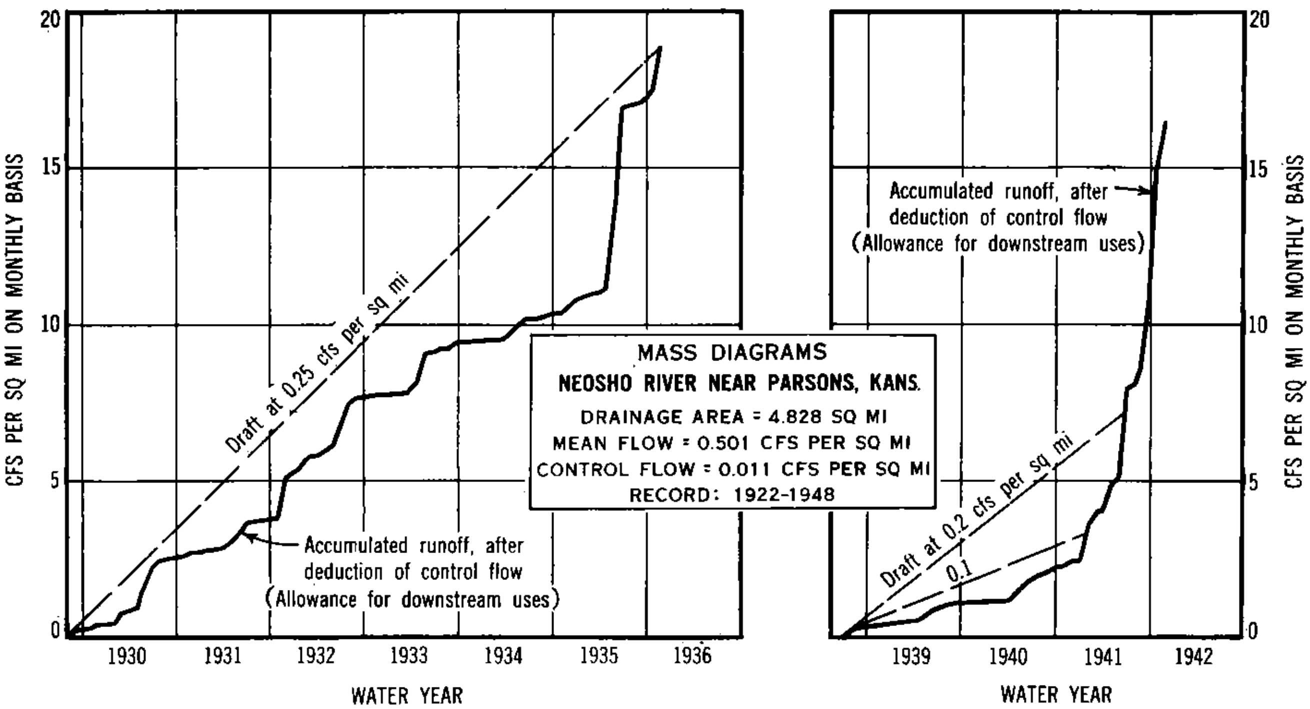
Corps of Engineers
Department of the Army

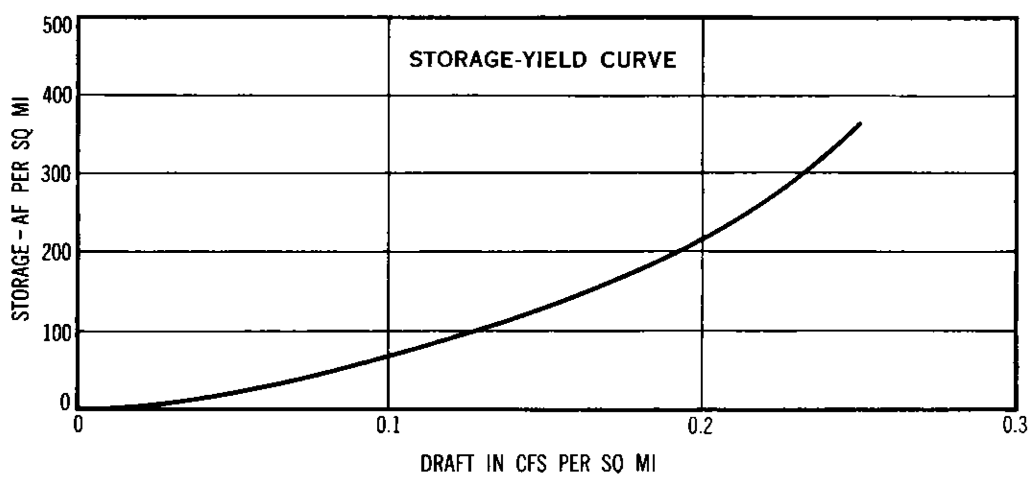
THE SYNTHETIC LIQUID FUEL POTENTIAL
OF
KANSAS

CURVES USED TO ESTIMATE
WATER STORAGE REQUIREMENTS

Ford, Bacon & Davis
Incorporated
Engineers

NEW YORK CHICAGO PHILADELPHIA LOS ANGELES





SF-808 2-8-51

Exhibit No. 20

Estimates of Coal Production Costs
(As of March 31, 1950)

General Area	Crawford-Cherokee			
Type of Mining	Underground		Strip	
Productivity (tons per man-shift)	5		12	
Hydrogenation (H) or Synthine (S) Process	H	S	H	S
Daily Production - tons (240 days per year)	5,835	7,502	6,108	7,854
Annual Production (thousands of tons)	1,400	1,801	1,466	1,885
Daily Plant Consumption - Tons (365 days per year)	3,837	4,933	4,016	5,164
Life of Reserves (years)	54	42	51	40
Plant Investment (thousands of dollars)	$7,000	$9,000	$5,864	$7,540
Items of Cost per Ton:				
All Labor	$2.77		$1.21	
Vacation Payments	.08		.03	
Welfare Fund	.30		.30	
Total Labor	$3.15		$1.54	
All Supplies	$0.81		$0.96	
Power	.15		.15	
Payroll Taxes	.11		.05	
Other Taxes, Insurance, Miscellaneous	.44		.33	
Depreciation	.33		.27	
Royalty or Depletion	.10		.15	
Engineering, Management, Administration	.10		.10	
Total Production Cost per Ton	$5.19		$3.55	
Btu per Pound of Coal (as-received)	12,770	12,770	12,200	12,200
Cost per Million Btu (cents)	20.32¢	20.32¢	14.55¢	14.55¢

Kans

70021

Coal Characteristics and Cost Summaries
Crawford-Cherokee General Area of Coal and Water Availability
(Reserves as of January 1, 1950)
(Costs as of March 31, 1950)

Hydrogenation (H) or Synthine (S) Process	H and S
Type of Mining (Underground or Strip)	U and S
Coal Bed Designations	Weir-Pittsburg Bevier Mineral
Thickness of Bed (inches):	
Maximum	40
Minimum	18
Dip of Bed (degrees):	
Maximum	1
Minimum	0
Overburden Thickness - Underground Minable Reserves (feet):	
Maximum	200
Minimum	125
Overburden Thickness - Strip Minable Reserves (feet):	
Maximum	75
Average	34
Rank of Coal (A)	Hvab-Hvbb
Proximate Analysis: (B)	
Moisture	5.2%
Volatile Matter	32.0
Fixed Carbon	51.2
Ash	11.6
Sulfur	3.5%
Btu (weighted average) (Btu, underground reserves - 12,770; strip reserves - 12,200)	12,485
Btu - moisture- and ash-free (weighted average)	14,930
Estimated Recoverable Reserves (thousands of tons):	
Primary	75,289
Secondary	327,797
Total	150,578(D)

Synthetic Liquid Fuels Plant Capacity (C) (thousands of barrels per day)	26	20
Estimated Mine Capital Cost (thousands of dollars)	$7,000	$9,000
Estimated Cost per Ton of Coal Produced:		
Available by Stripping	$3.55	$3.55
Balance from Underground	5.19	5.19
Combined (weighted average cost)	$4.37(E)	$4.37(E)
Estimated Cost per Million Btu (cents)	17.50¢	17.50¢
Estimated Cost per Barrel of Synthetic Liquid Fuel Final Products:		
Coal, Cost to Produce	$1.72	$2.21
Transportation to Process Plant	-	-
Total Cost per Barrel	$1.72	$2.21

(See following page for footnotes)

Coal Characteristics and Cost Summaries
Crawford-Cherokee General Area of Coal and Water Availability
(Reserves as of January 1, 1950)
(Costs as of March 31, 1950)

Note: (A) Hvab: High-volatile A bituminous; Hvbb: High-volatile B bituminous.
(B) Representative analyses of face samples obtained by standard Bureau of Mines procedure; as-received basis.
(C) Based on total demand of 98 billion Btu per calendar day for unit hydrogenation plant and 126 billion Btu per calendar day for unit synthine plant.
(D) Total primary and secondary reserves for synthetic liquid fuels plant supply limited by definition to twice the primary reserves.
(E) It is assumed that equal amounts of primary underground and secondary strip are used over 40-year life of a unit plant.

ans

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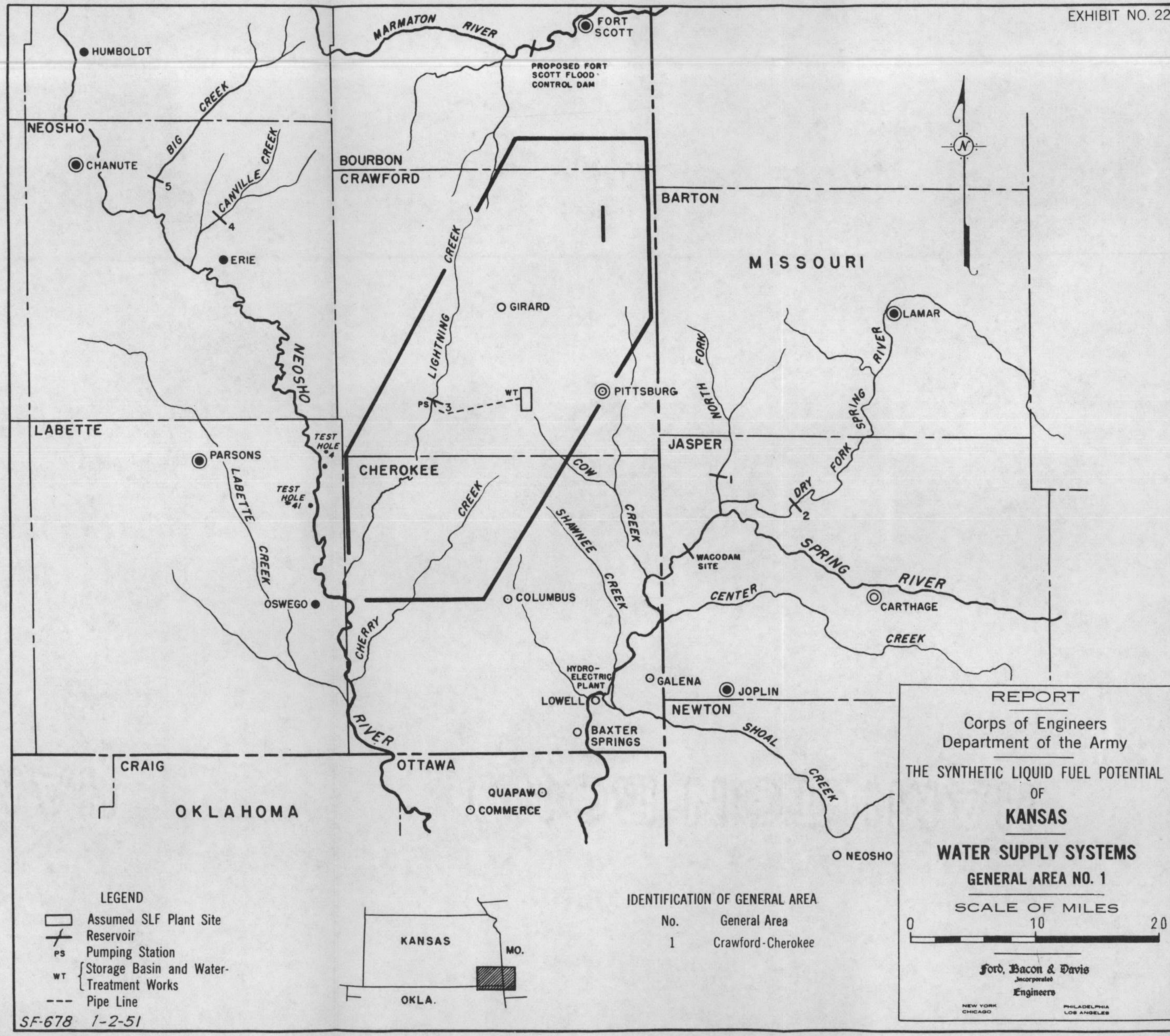


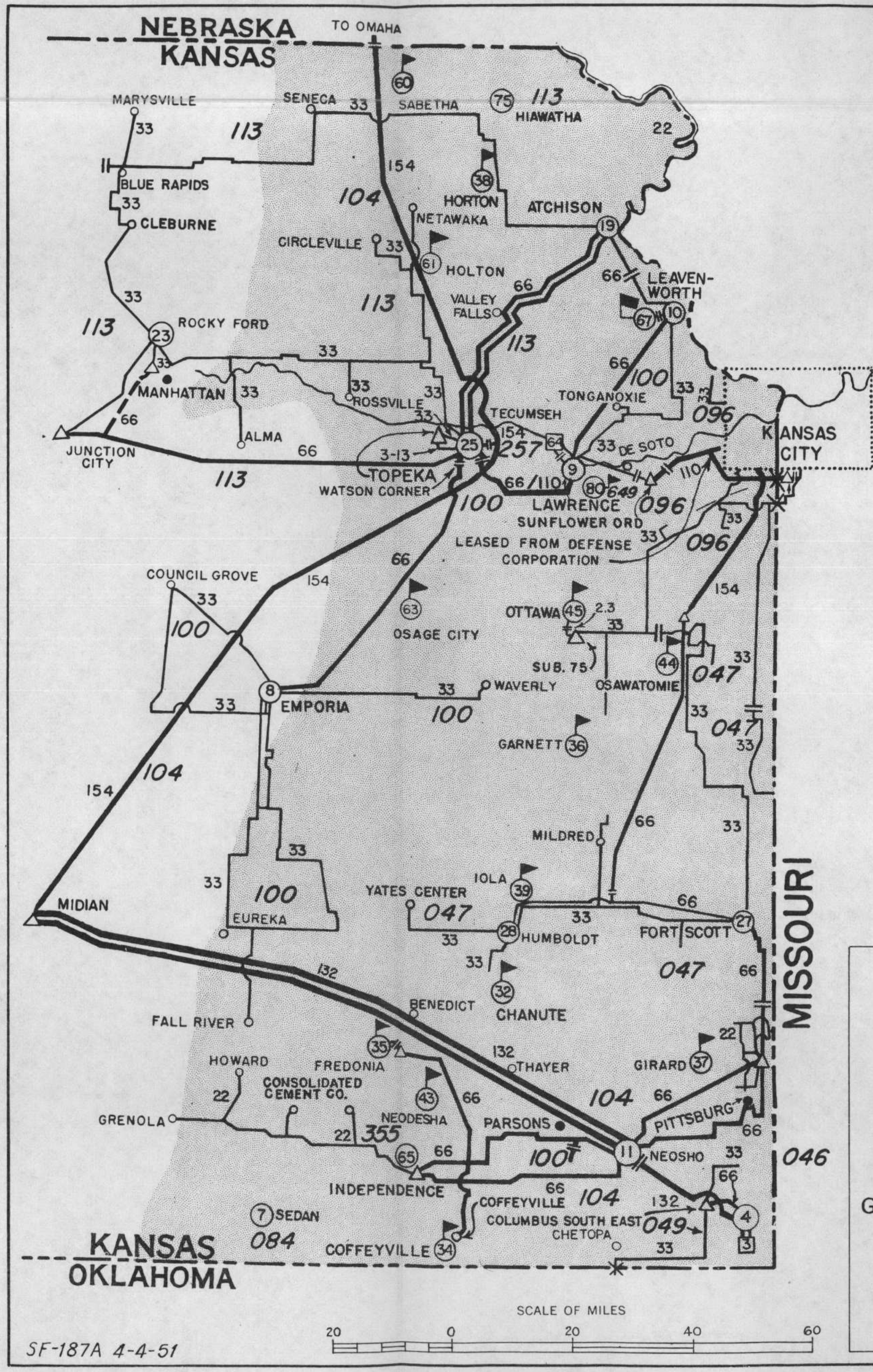
EXHIBIT NO. 22
HUMBOLDT
NEOSHO
CHANUTE
BIG CREEK
CANVILLE CREEK
ERIE
NEOSHO
LABETTE
PARSONS
LABETTE CREEK
TEST HOLE #4
TEST HOLE #41
OSWEGO
CHERRY
RIVER
CRAIG
OKLAHOMA
OTTAWA
QUAPAW
COMMERCE
MARMATON RIVER
FORT SCOTT
PROPOSED FORT SCOTT FLOOD-CONTROL DAM
BOURBON
CRAWFORD
LIGHTNING CREEK
GIRARD
PS
WT
PITTSBURG
CHEROKEE
CREEK
COW CREEK
SHAWNEE CREEK
COLUMBUS
HYDRO-ELECTRIC PLANT
LOWELL
GALENA
BAXTER SPRINGS
BARTON
MISSOURI
LAMAR
NORTH FORK
SPRING RIVER
DRY FORK
JASPER
WACODAM SITE
SPRING RIVER
CENTER CREEK
CARTHAGE
JOPLIN
NEWTON
SHOAL CREEK
NEOSHO
N
LEGEND
Assumed SLF Plant Site
Reservoir
PS Pumping Station
WT Storage Basin and Water-Treatment Works
Pipe Line
KANSAS
MO.
OKLA.
IDENTIFICATION OF GENERAL AREA
No. General Area
1 Crawford-Cherokee
REPORT
Corps of Engineers
Department of the Army
THE SYNTHETIC LIQUID FUEL POTENTIAL OF
KANSAS
WATER SUPPLY SYSTEMS
GENERAL AREA NO. 1
SCALE OF MILES
0 10 20
Ford, Bacon & Davis
Incorporated
Engineers
NEW YORK CHICAGO
PHILADELPHIA LOS ANGELES
SF-678 1-2-51

Principal Electric Utility Generating Stations and Transmission Lines

Key to Map

FPC No.	Operating Company	Generating Stations No.	Name	Type	Installed Capacity (Kilowatts)
049	The Empire District Elec. Co.	4	Riverton	Steam	67,500
104	Kansas Gas & Elec. Co.	11	Neosho	Steam	40,000
104	Kansas Gas & Elec. Co.	13	Wichita	Steam	26,000
113	Kansas Power & Light Co.	25	Tecumseh	Steam	82,000
047	Eastern Kansas Utilities, Inc.	27	Fort Scott	Steam	1,650
047	Eastern Kansas Utilities, Inc.	28	Humboldt	Int.Comb	1,760
530	Municipal Plant	50	Augusta	Int.Comb	1,656
355	Union Electric Rwy. Co.	65	Independence	Int.Comb	1,760

KAN.



LEGEND

- ④ Generating station - steam or internal combustion. Flag above indicates public ownership.
- [3] Generating station - hydro. Flag above indicates public ownership.
- △ Substation
- 22 Operating kilovolts; thickness of lines indicates relative voltage.
- 33/66 First number indicates operating voltage in kilovolts. Second number indicates insulated or design voltage in kilovolts.
- ---- Broken lines in symbols indicate construction in progress.
- *088* Slant numbers at lines or stations identify operating companies.

Notes: Shaded area indicates extent of coal measures.
See facing page for identification and capacity data.

Source of data - Federal Power Commission, June 30, 1948

REPORT

Corps of Engineers
Department of the Army

THE SYNTHETIC LIQUID FUEL POTENTIAL
OF
KANSAS

PRINCIPAL ELECTRIC UTILITY
GENERATING STATIONS AND TRANSMISSION LINES
IN AND AROUND THE COAL-PRODUCING AREA

Ford, Bacon & Davis
Incorporated
Engineers

NEW YORK · CHICAGO · PHILADELPHIA · LOS ANGELES

Exhibit No. 24

Population, Labor Force, and Employment in Kansas in 1940 and Population in 1950

County	Area (Square) Miles	1950 Census Preliminary Count	Civilian Population - 1940				Labor Force 1940	Numbers Employed - 1940					
			Total	Urban	Rural Nonfarm	Rural Farm		Total	Agri-culture	Mining	Construc-tion	Manufac-turing	Service
Coal Counties													
Bourbon	639	19,121	20,944	10,557	2,040	8,347	7,620	6,583	2,481	63	223	440	3,376
Cherokee	587	25,053	29,817	12,698	8,317	8,802	10,318	7,790	2,183	1,671	266	497	3,173
Crawford	598	40,199	44,191	20,125	14,842	9,224	16,612	12,543	2,396	1,687	421	965	7,074
Total Coal Counties	1,824	84,373	94,952	43,380	25,199	26,373	34,550	26,916	7,060	3,421	910	1,902	13,623
Total Other Counties	80,289	1,810,017	1,706,076	710,561	417,110	578,405	635,265	556,910	176,303	11,790	23,957	51,169	293,691
Total State	82,113	1,894,390	1,801,028	753,941	442,309	604,778	669,815	583,826	183,363	15,211	24,867	53,071	307,314
Percentages Showing Composition of Population and Numbers Employed in Coal Counties and in Entire State													
Coal Counties:													
Total Population			100.0%	45.7%	26.5%	27.8%	-						
Total Employed								100.0%	26.2%	12.7%	3.4%	7.1%	50.6%
Entire State:													
Total Population			100.0%	41.9%	24.5%	33.6%	-						
Total Employed								100.0%	31.4%	2.6%	4.3%	9.1%	52.6%
Percentages of Classified Populations in Coal Counties in Relation to Entire State													
Coal Counties		4.5%	5.3%	5.8%	5.7%	4.4%	5.2%	4.6%	3.9%	22.5%	3.7%	3.6%	4.4%
Other Counties		95.5	94.7	94.2	94.3	95.6	94.8	95.4	96.1	77.5	96.3	96.4	95.6
Entire State		100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%

Exhibit No. 25

Manufacturing Workers Covered by Old-Age and Survivors Insurance by Industry Groups

Industry Group Mid-March 1948	Number of Employes	Percent of Total
Food and Kindred Products	27,159	35.70%
Textile Mill Products	75	.10
Apparel, Fabric Products, etc.	1,970	2.59
Lumber and Wood Products	893	1.17
Furniture and Fixtures	1,338	1.76
Paper and Allied Products	1,224	1.61
Printing, Publishing, etc.	6,646	8.74
Chemicals and Allied Products	4,839	6.36
Products of Petroleum and Coal	4,431	5.82
Leather and Leather Products	178	.23
Stone, Clay, and Glass Products	4,129	5.43
Primary Metal Industries:		
Iron and Steel Foundries	1,689	2.22
Nonferrous Foundries	145	.19
Misc. Primary Metal Industries	31	.04
Total, Primary Metal Industries	1,865	2.45
Fabricated Metal Products:		
Cutlery, Hand Tools, Hardware	287	.38
Heaters, Plumbers' Supplies, etc.	2,167	2.85
Fabricated Structural Metal Products	1,529	2.01
Metal Stamping, Coating, Engraving	160	.21
Fabricated Wire Products	40	.05
Miscellaneous Fabricated Metal Products	60	.08
Total Fabricated Metal Products	4,243	5.58%
Machinery (except electrical)	5,023	6.60
Electrical Machinery, etc.	795	1.04
Transportation Equipment:		
Motor Vehicles and Equipment	3,140	4.13
Aircraft and parts	5,681	7.47
Transportation Equip. n.e.c.	133	.17
Total Transportation Equipment	8,954	11.77%
Instruments, etc.	159	.21
Miscellaneous Manufacturing Industries	751	.99
Unaccounted for and added to balance total	1,407	1.85
Total Manufacturing	76,079	100.00%

EXHIBIT NO. 26

REPORT

Corps of Engineers
Department of the Army

THE SYNTHETIC LIQUID FUEL POTENTIAL
OF

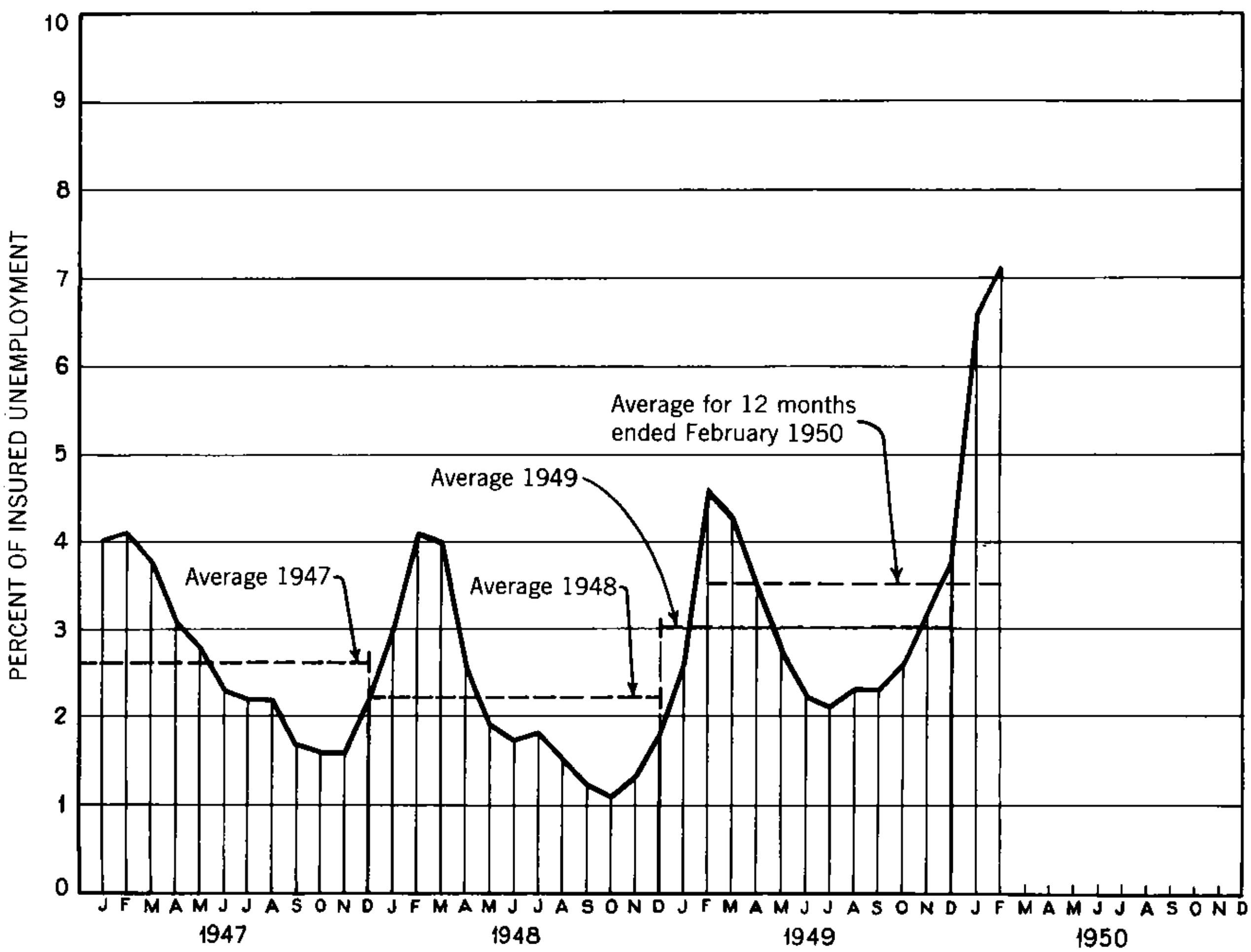
KANSAS

PERCENT OF
INSURED UNEMPLOYMENT
OF
AVERAGE MONTHLY COVERED EMPLOYMENT

1947-1950

Ford, Bacon & Davis
Incorporated
Engineers

NEW YORK CHICAGO PHILADELPHIA LOS ANGELES



SF-740 1-19-51

Exhibit No. 27

Number of New Coal Mine Employes Necessary to Produce Fuel Requirement of a Typical Unit Plant after Diversion of a Portion of Present Production Capacity in the General Area to the Unit Plant

	Coal Production (Tons)	Average Number of Working Days	Average Productivity per Man-Day (Tons)	Number of Men Working Daily
Before Introduction of Unit Plant (1948)				
Total 3 Counties (One General Area):				
At present conditions	2,222,410	187	11.10	1,071
Production capacity at 240 working days per year	2,853,144	240	11.10	1,071
Increase in capacity at 240 days over present	630,734			
After Introduction of Coal Hydrogenation Unit Plant				
Fuel requirement of unit plant	1,432,519			
Less increase in present capacity, 240-day basis	630,734			
Balance, production required of associated mine	801,785			
Number of new operational workers		240	8.50	393
Vacations, illness, etc. (10%)				39
Total operational employes				432
Administrative employes (5%)				22
Total new coal mine employes required				454
After Introduction of Coal Synthine Unit Plant				
Fuel requirement of unit plant	1,841,810			
Less increase in present capacity, 240-day basis	630,734			
Balance, production required of associated mine	1,211,076			
Number of new operational workers		240	8.50	594
Vacations, illness, etc. (10%)				59
Total operational employes				653
Administrative employes (5%)				33
Total new coal mine employes required				686

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SF-552 8-2-50

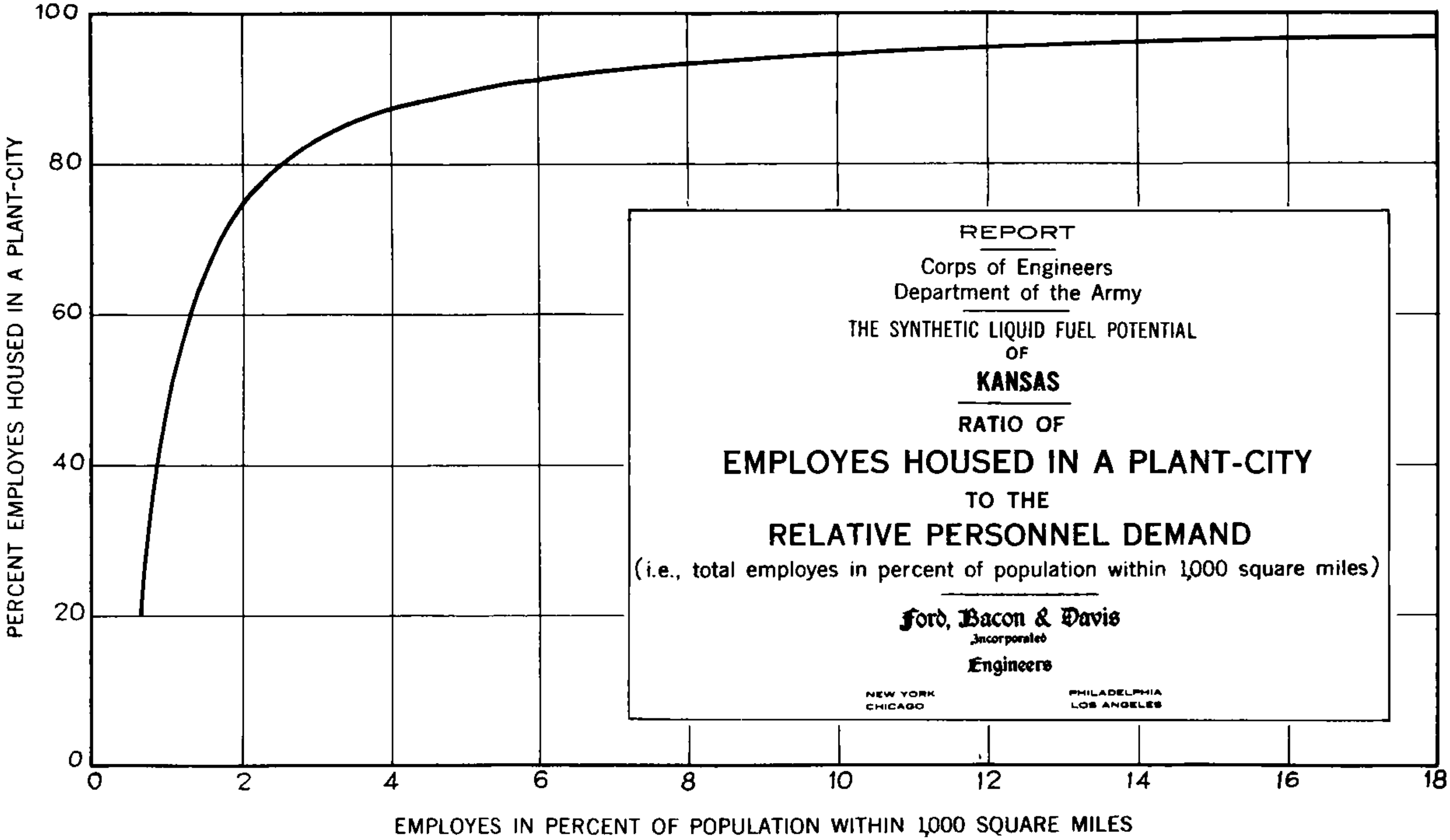


EXHIBIT NO. 28

KAN.

SF-329 8-2-50

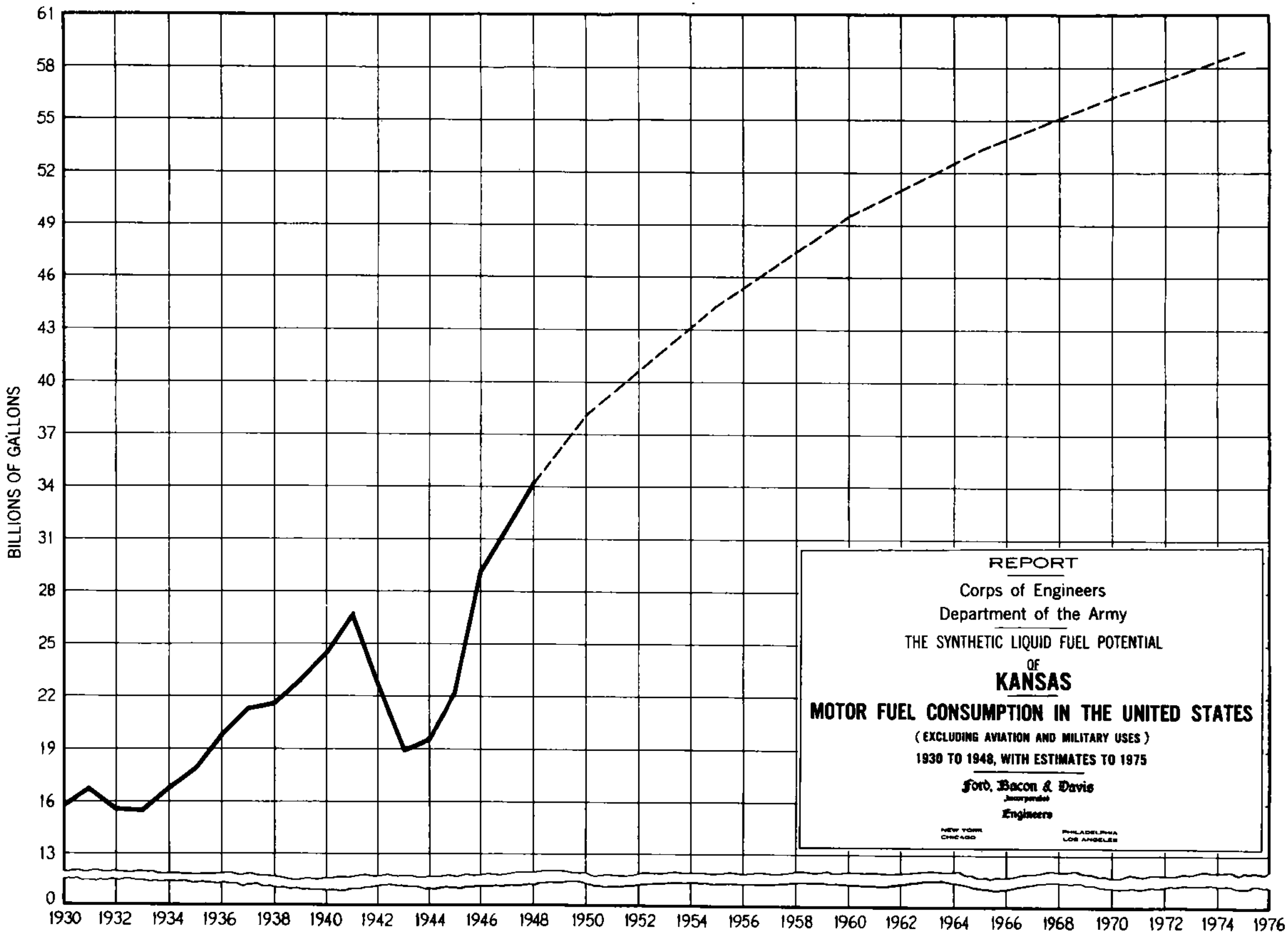


EXHIBIT NO. 29

KAN.

SF-351 8-2-50

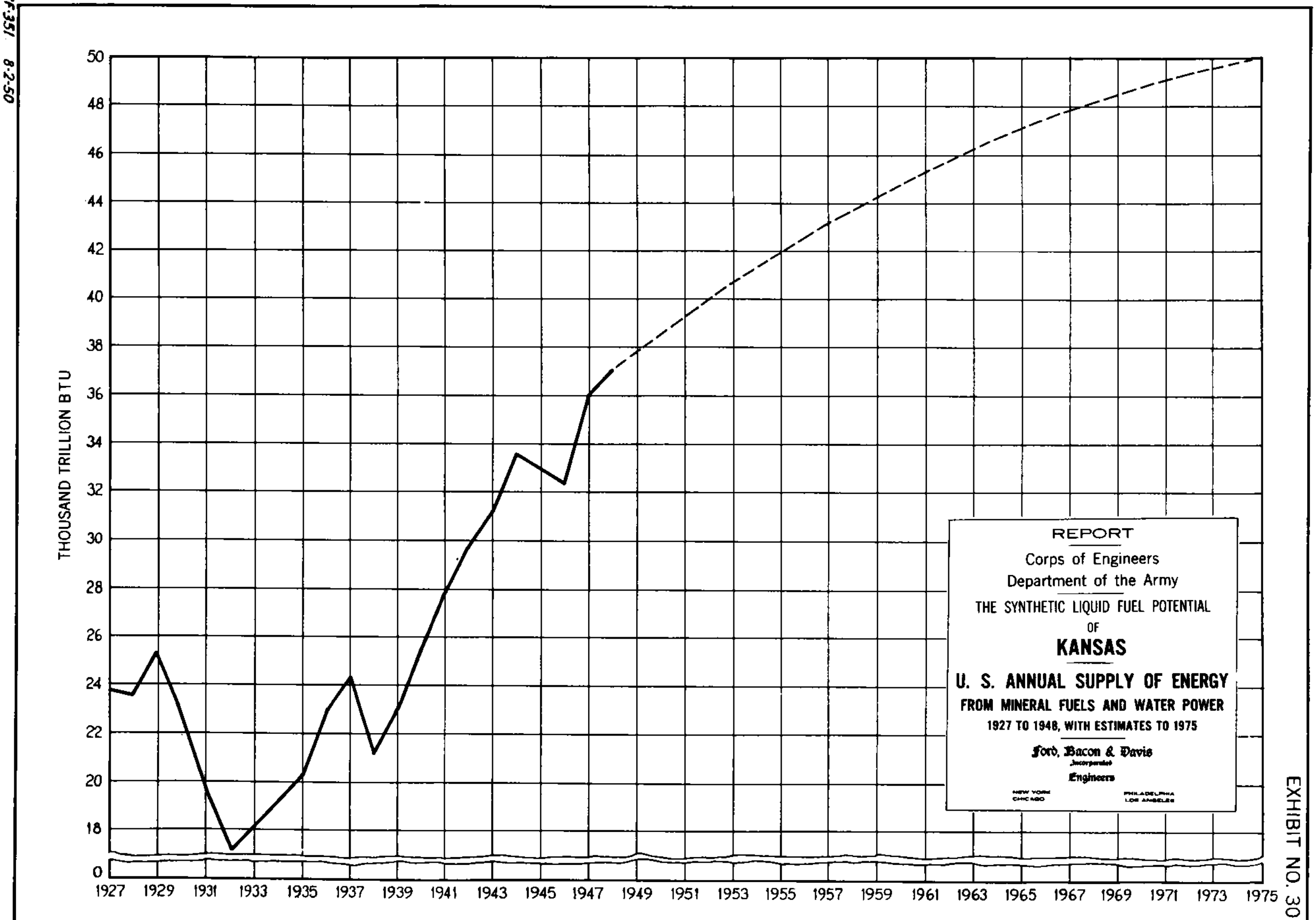


EXHIBIT NO. 30

KAN.

SF-373 8-2-50

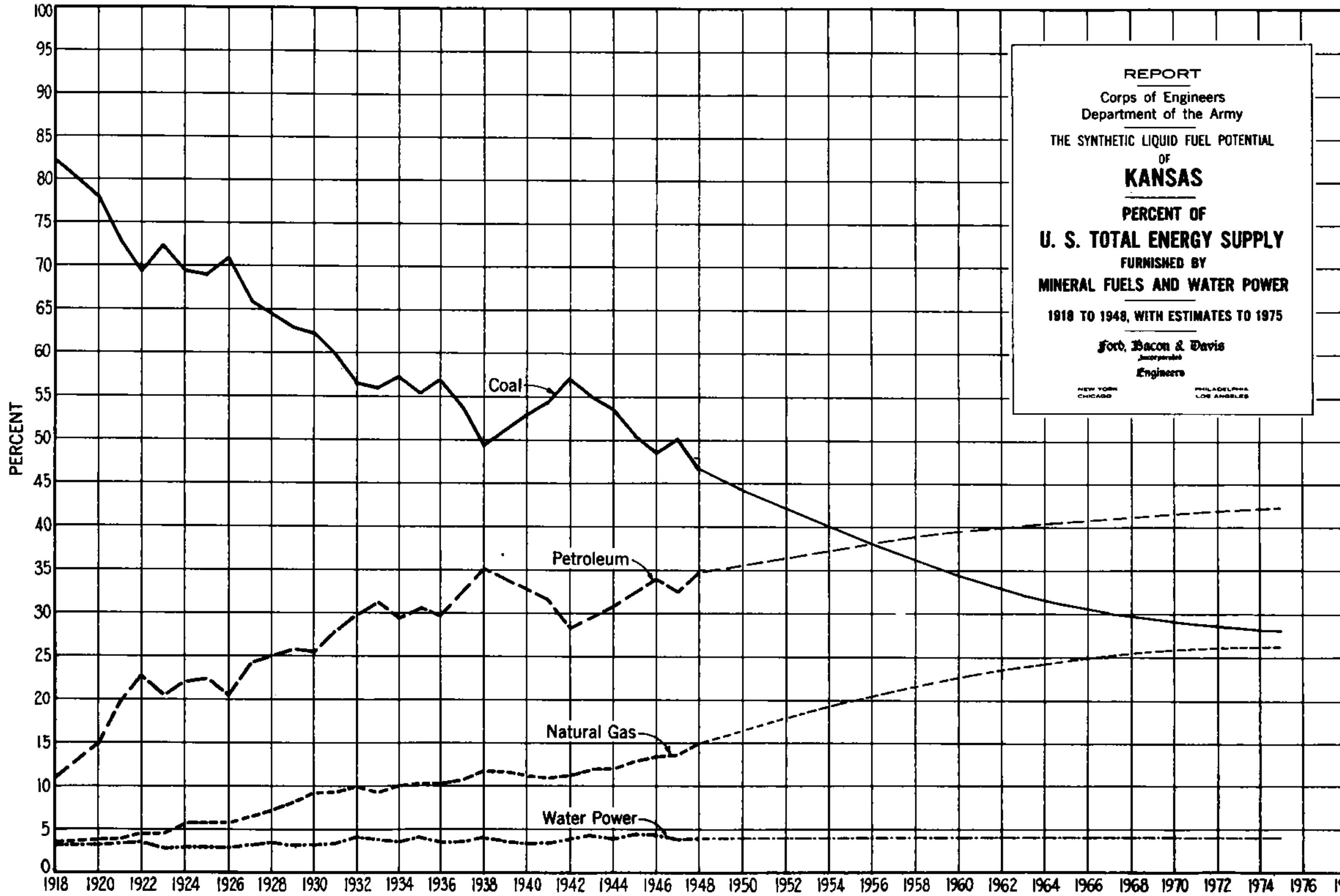


EXHIBIT NO. 31

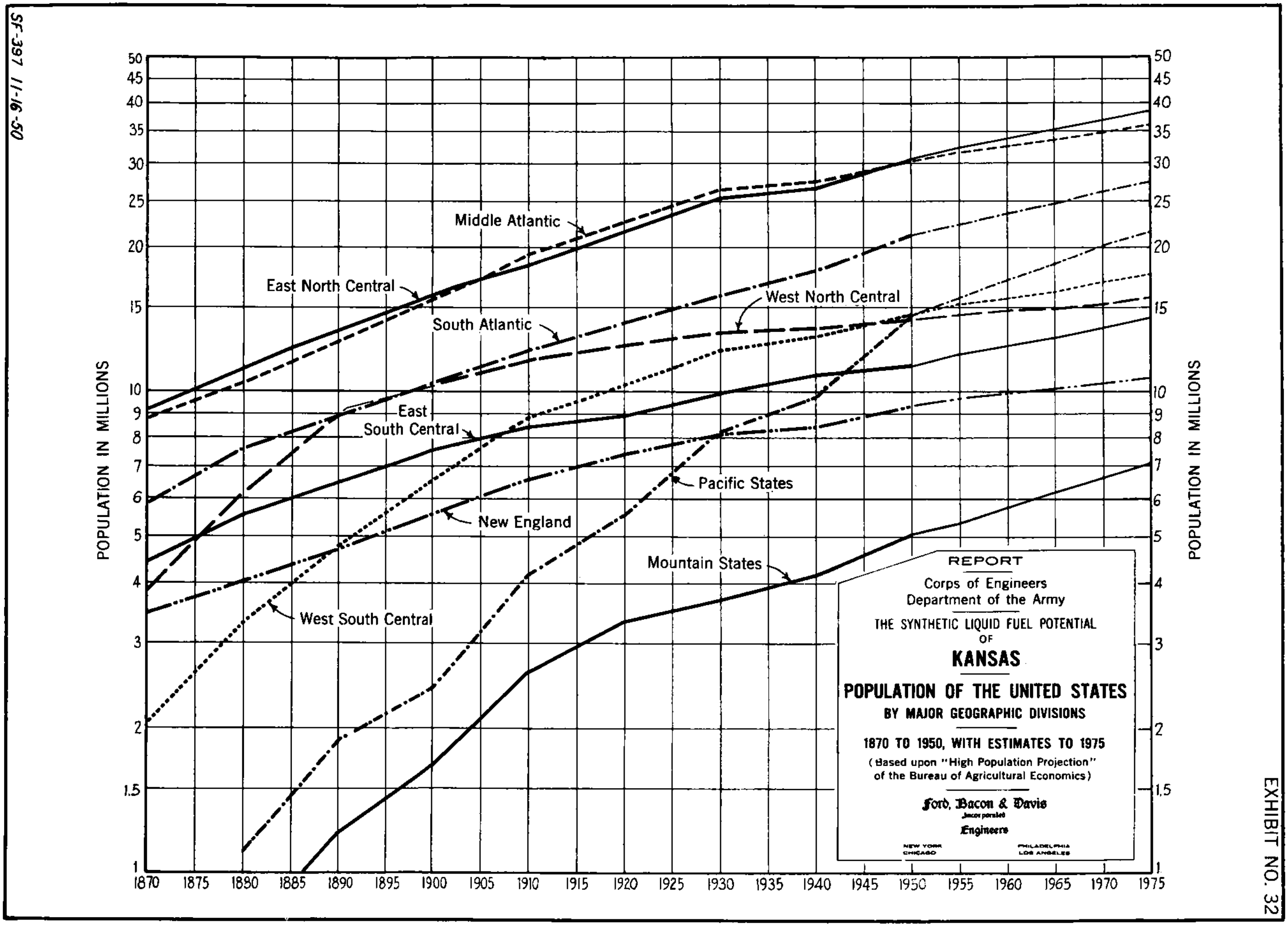


EXHIBIT NO. 32

KAN.

SF-701 12-15-50

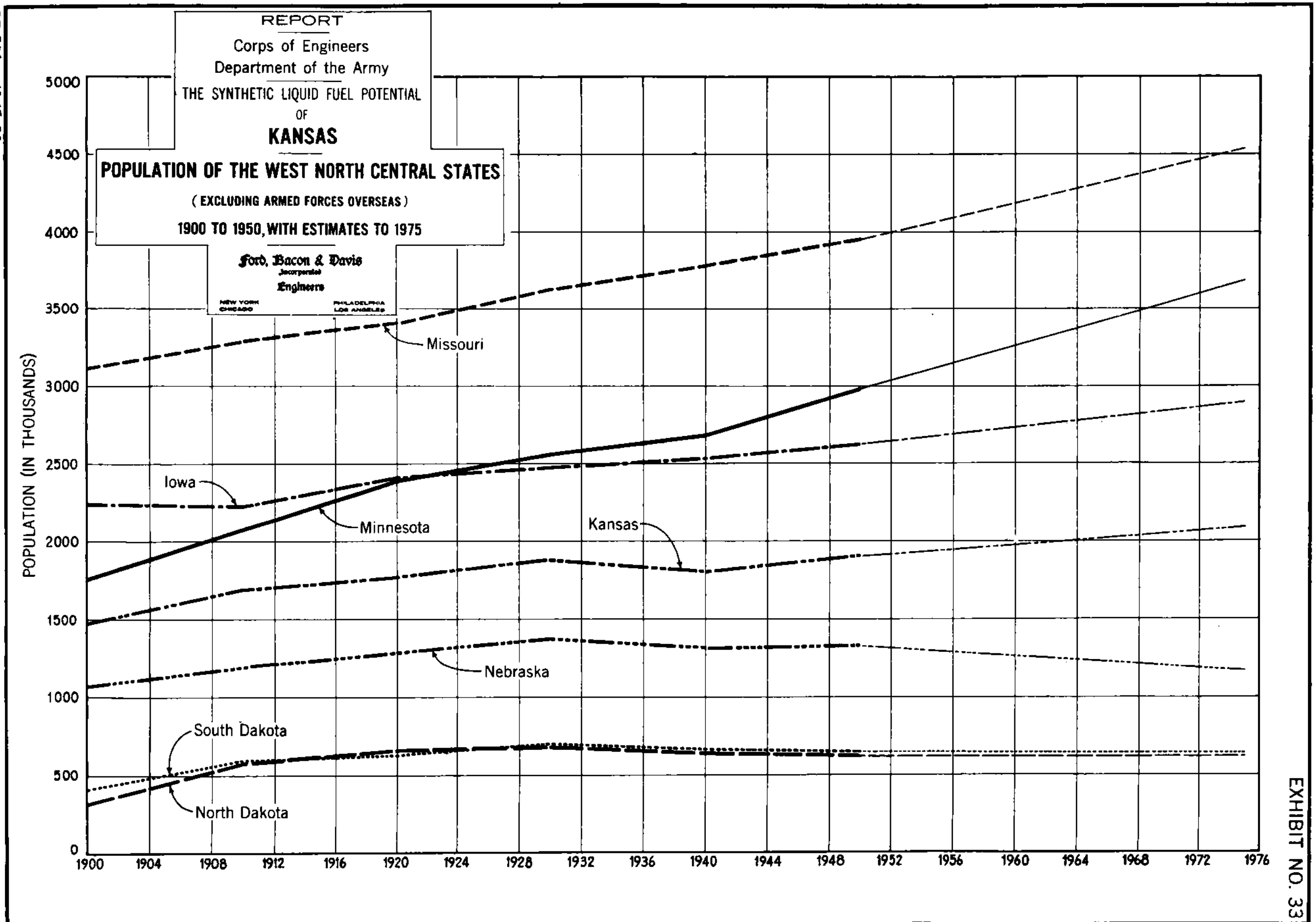


EXHIBIT NO. 33

KAN.

SF-419 1-15-51

REPORT

Corps of Engineers
Department of the Army

THE SYNTHETIC LIQUID FUEL POTENTIAL OF

KANSAS

PERSONS PER PRIVATE AND COMMERCIAL AUTOMOBILE VS. PER CAPITA INCOME PAYMENTS FOR EACH STATE

1948

Ford, Bacon & Davis
Incorporated
Engineers

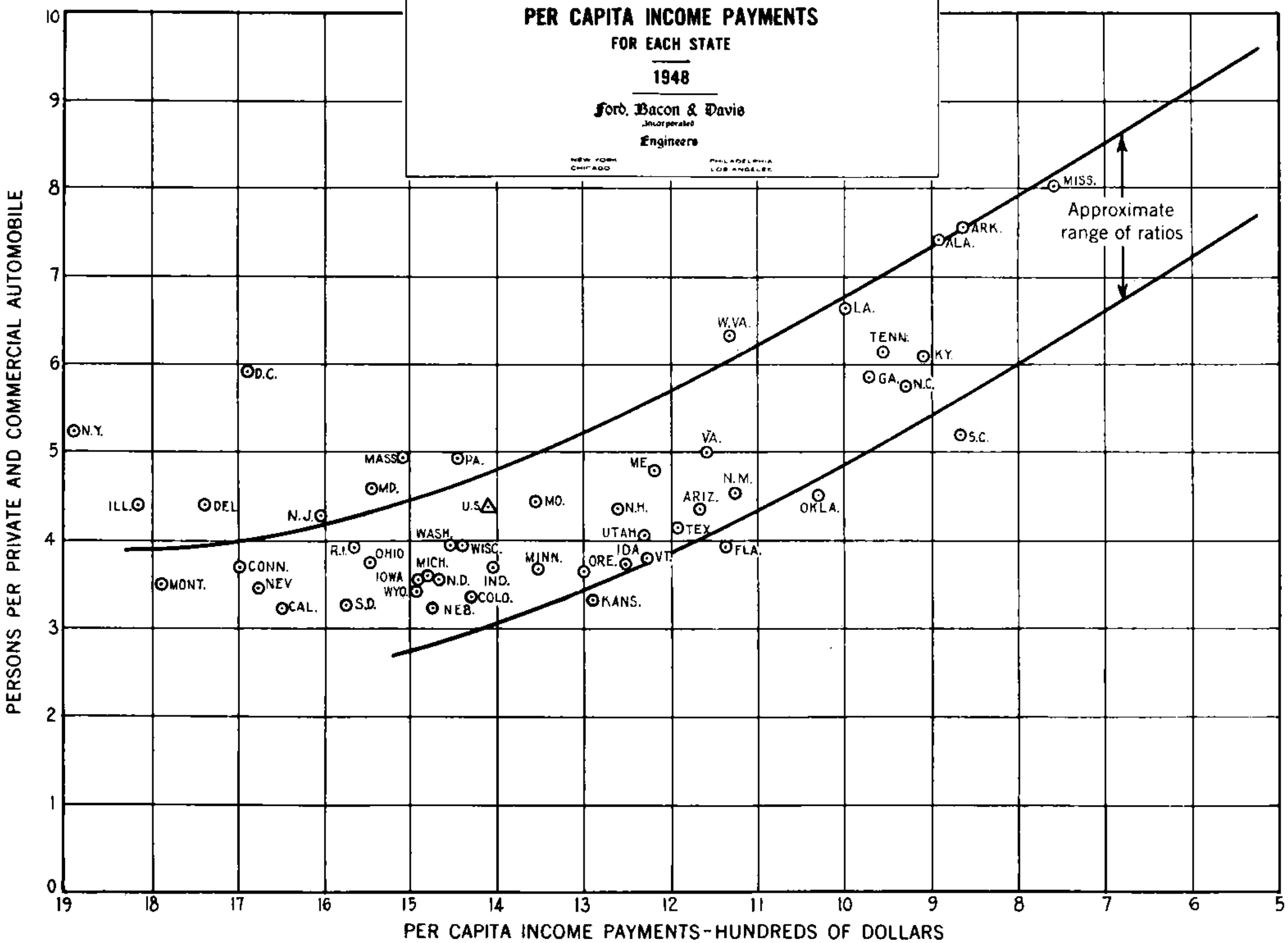


EXHIBIT NO. 34

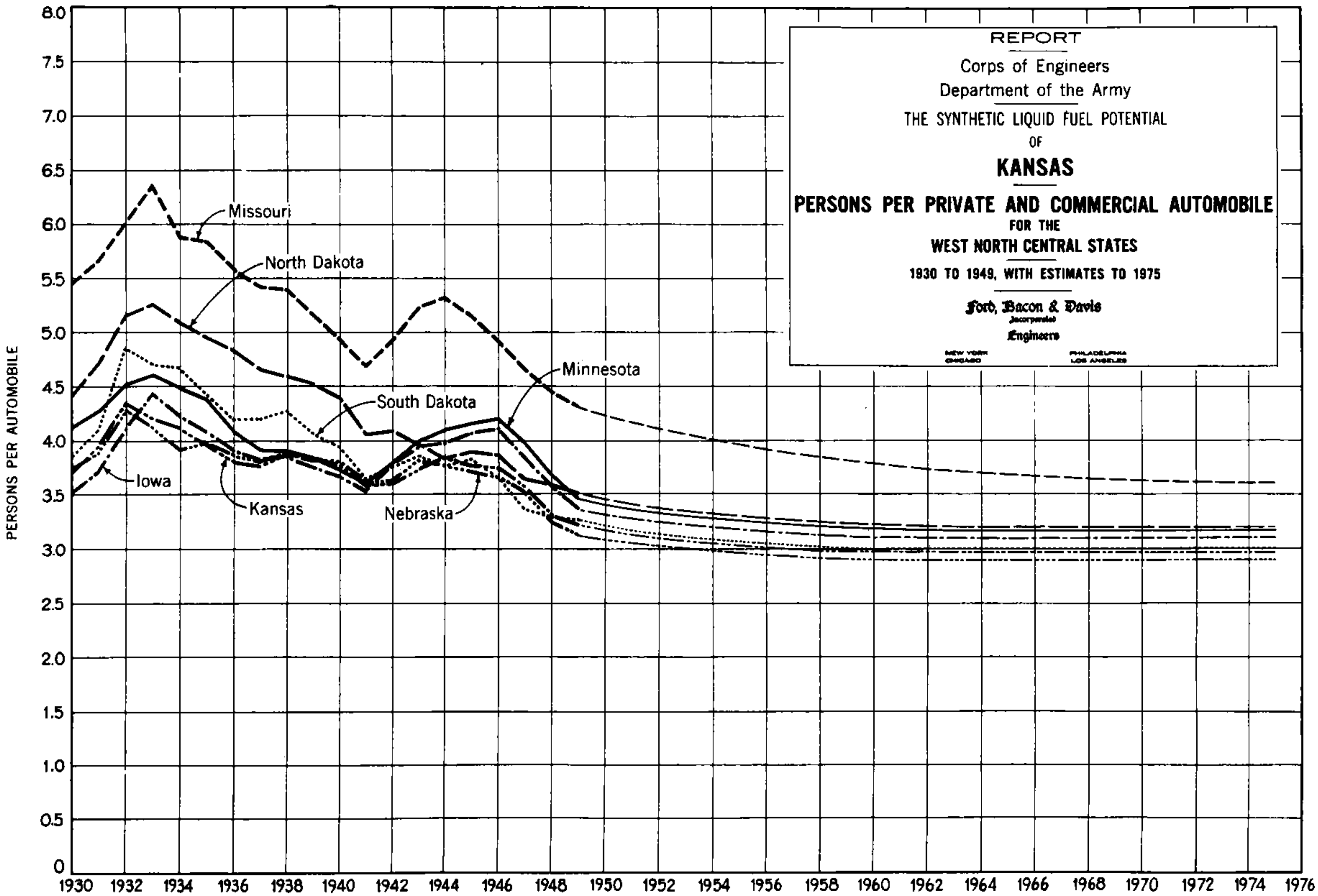
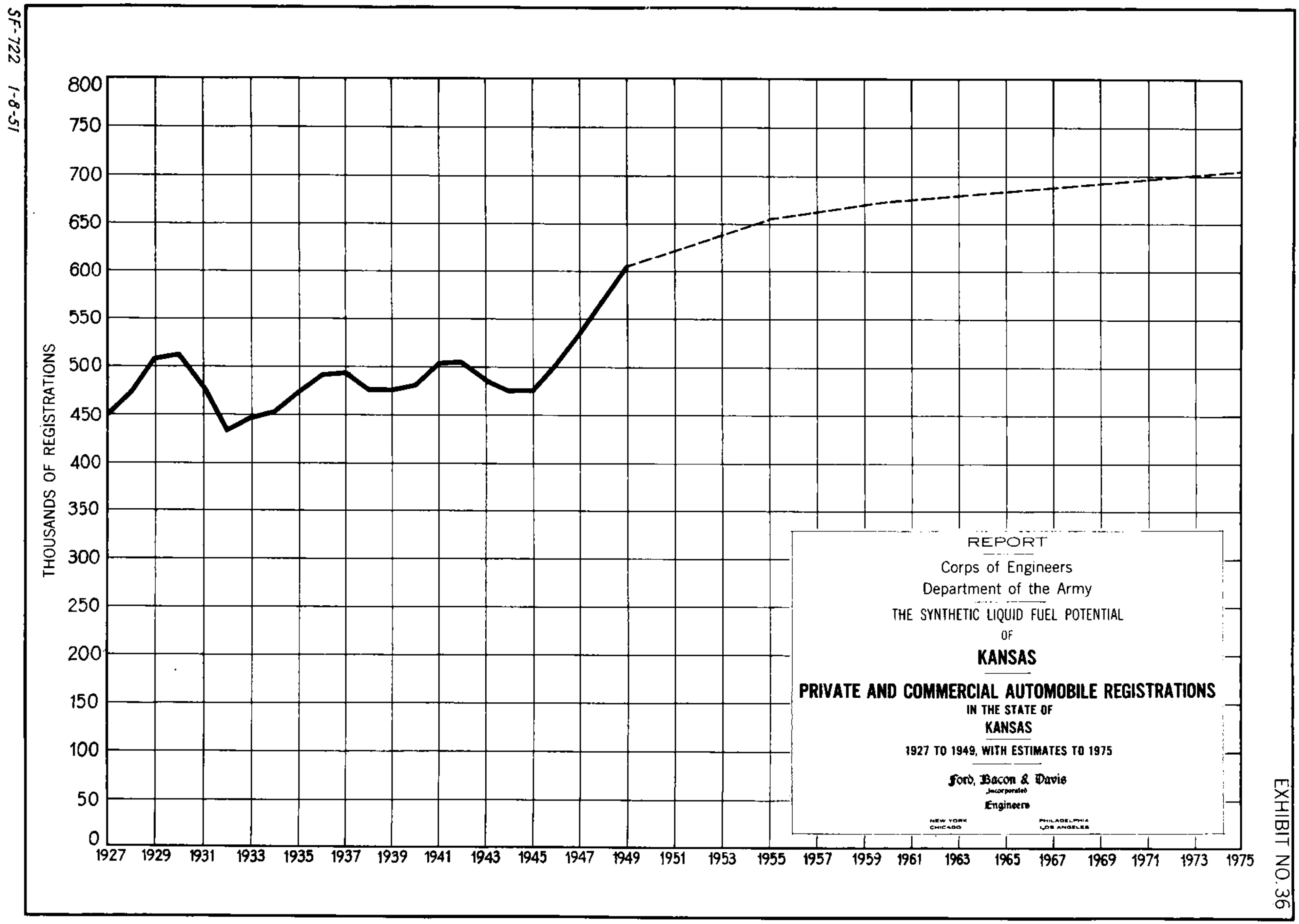


EXHIBIT NO. 35


SF-722 1-8-51
THOUSANDS OF REGISTRATIONS
800
750
700
650
600
550
500
450
400
350
300
250
200
150
100
50
0
1927
1929
1931
1933
1935
1937
1939
1941
1943
1945
1947
1949
1951
1953
1955
1957
1959
1961
1963
1965
1967
1969
1971
1973
1975
REPORT
Corps of Engineers
Department of the Army
THE SYNTHETIC LIQUID FUEL POTENTIAL
OF
KANSAS
PRIVATE AND COMMERCIAL AUTOMOBILE REGISTRATIONS
IN THE STATE OF
KANSAS
1927 TO 1949, WITH ESTIMATES TO 1975
Ford, Bacon & Davis
Incorporated
Engineers
NEW YORK
CHICAGO
PHILADELPHIA
LOS ANGELES
EXHIBIT NO. 36

SF-709 12-14-50

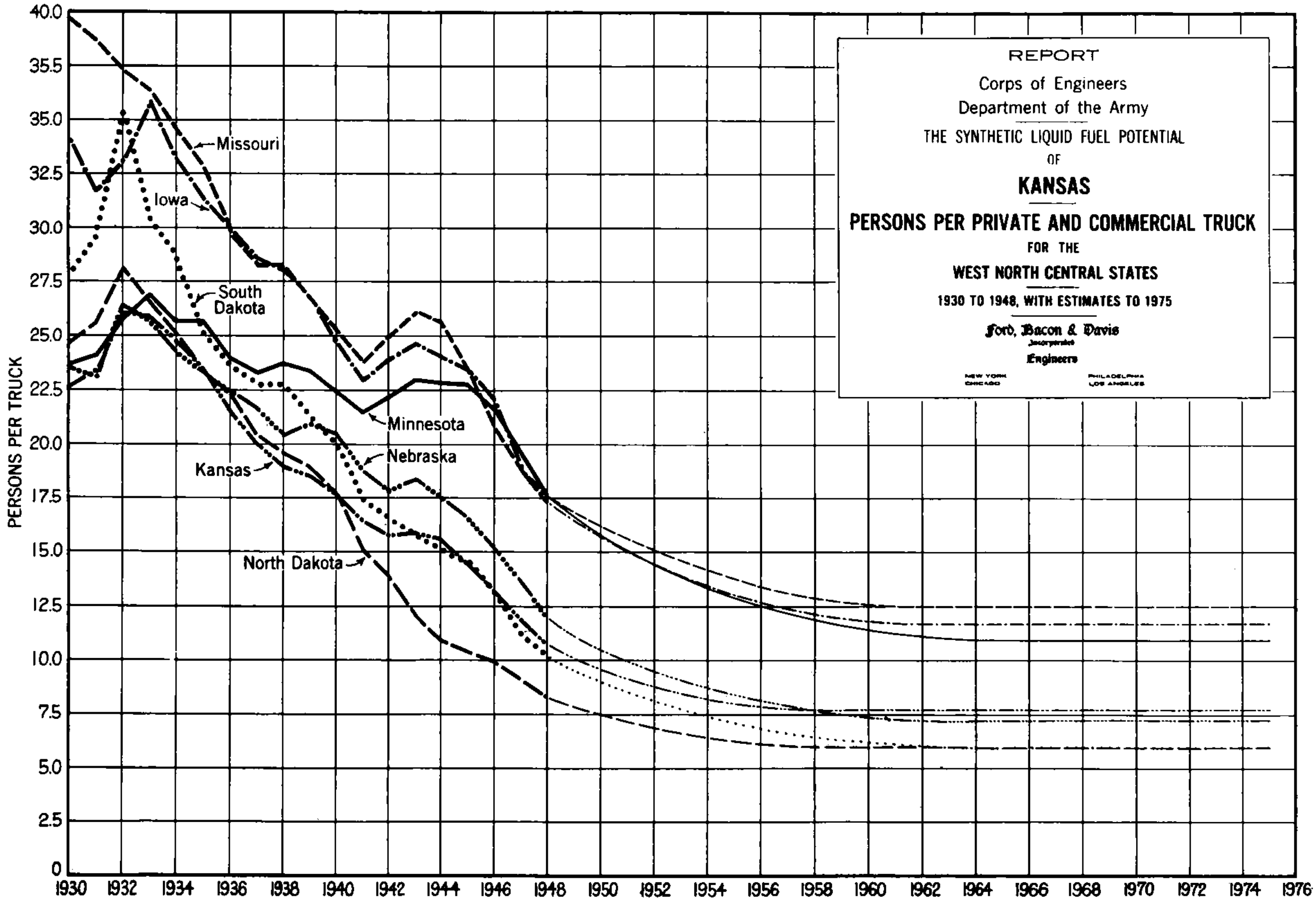


EXHIBIT NO. 37

KAN.

SF-446 8-2-50

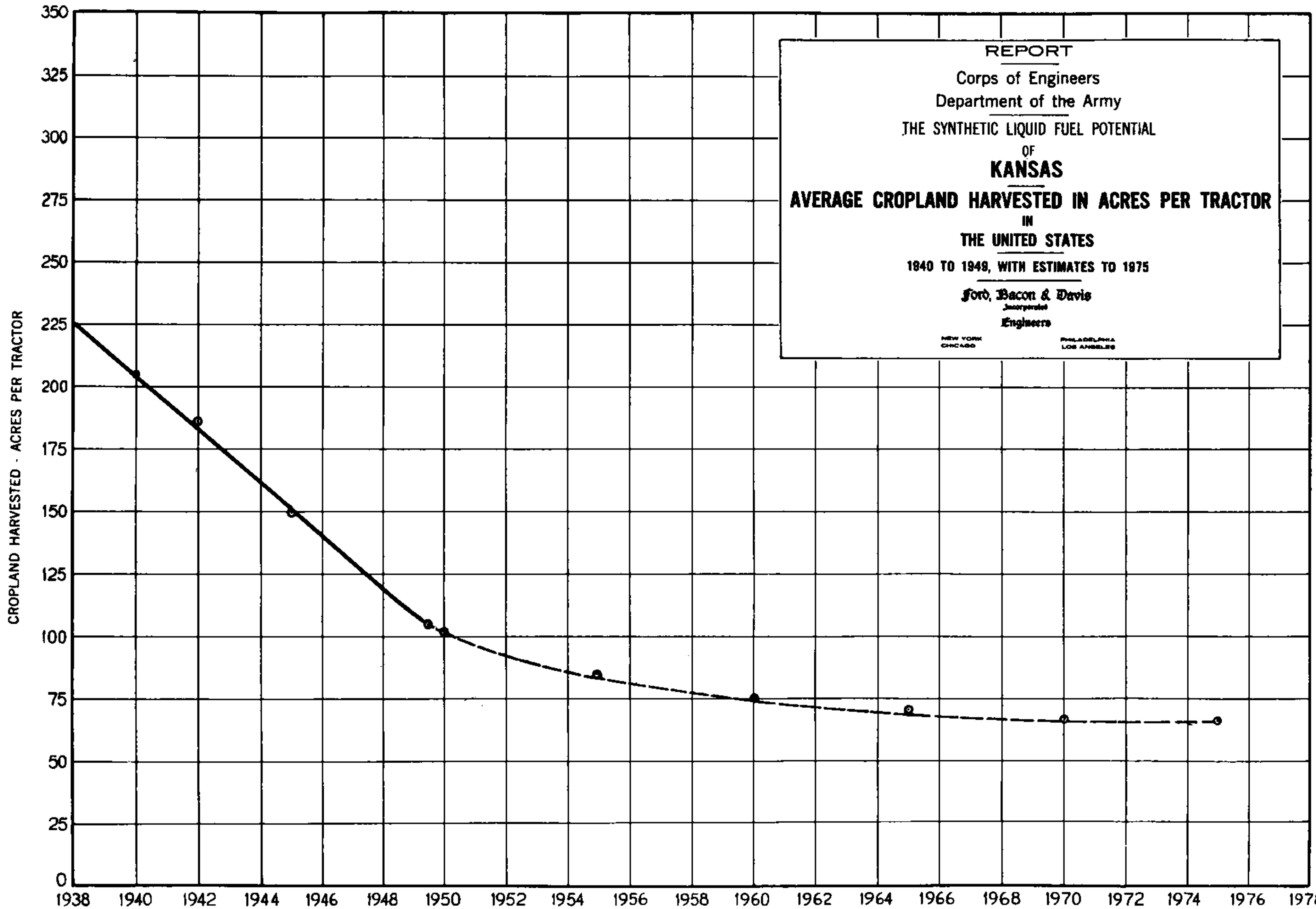
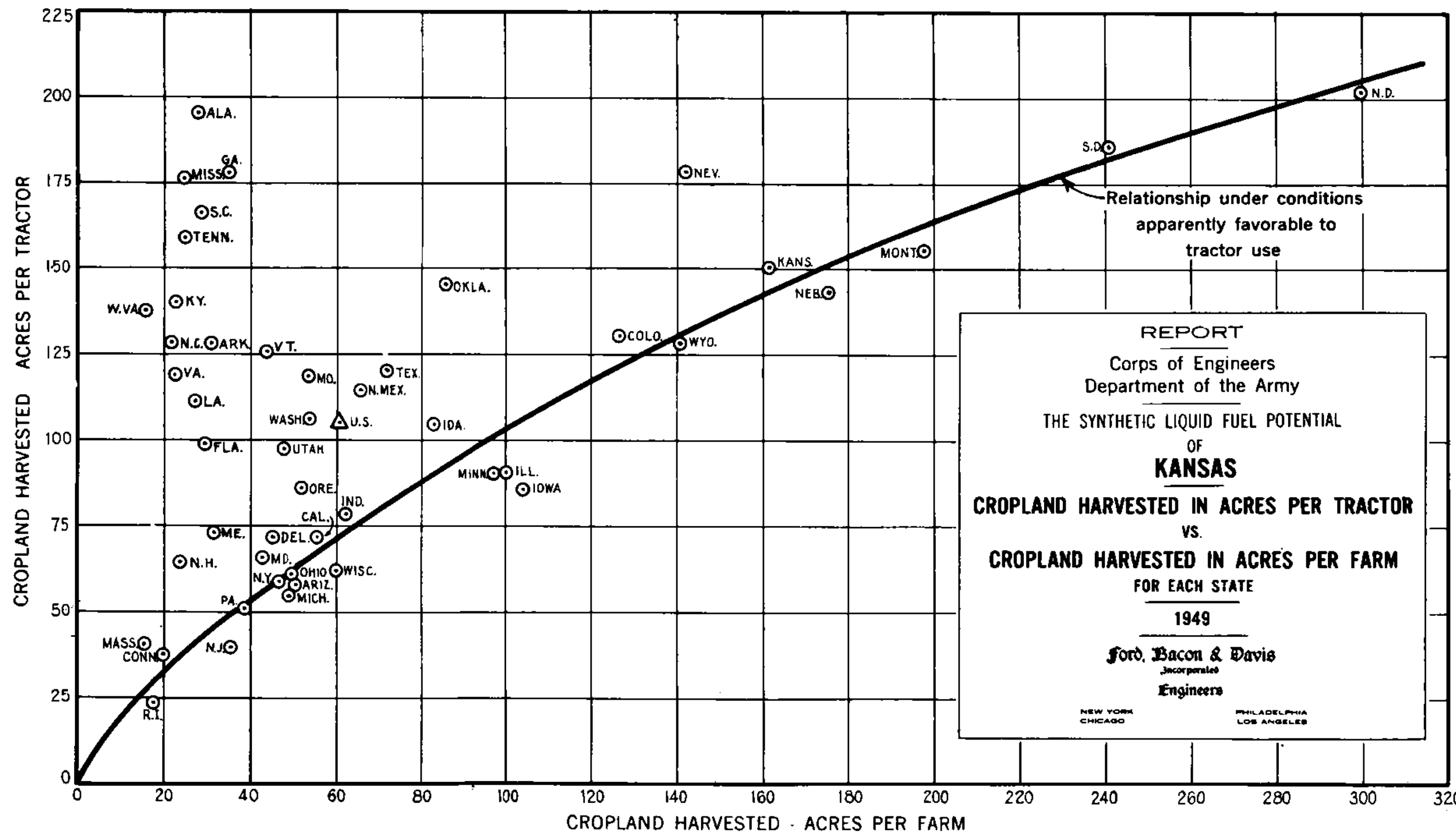


EXHIBIT NO. 38

KAN.

SF-463 8-2-50



REPORT

Corps of Engineers
Department of the Army

THE SYNTHETIC LIQUID FUEL POTENTIAL
OF
KANSAS

CROPLAND HARVESTED IN ACRES PER TRACTOR
VS.
CROPLAND HARVESTED IN ACRES PER FARM
FOR EACH STATE

1949

Ford, Bacon & Davis
Incorporated
Engineers

NEW YORK CHICAGO PHILADELPHIA LOS ANGELES

EXHIBIT NO. 39

KAN.

SF-485 8-2-50

REPORT

Corps of Engineers
Department of the Army

THE SYNTHETIC LIQUID FUEL POTENTIAL
OF
KANSAS

ESTIMATED CROPLAND HARVESTED IN ACRES PER TRACTOR
VS.
CROPLAND HARVESTED IN ACRES PER FARM
FOR EACH STATE

1975

Ford, Bacon & Davis
Incorporated
Engineers

NEW YORK CHICAGO PHILADELPHIA LOS ANGELES

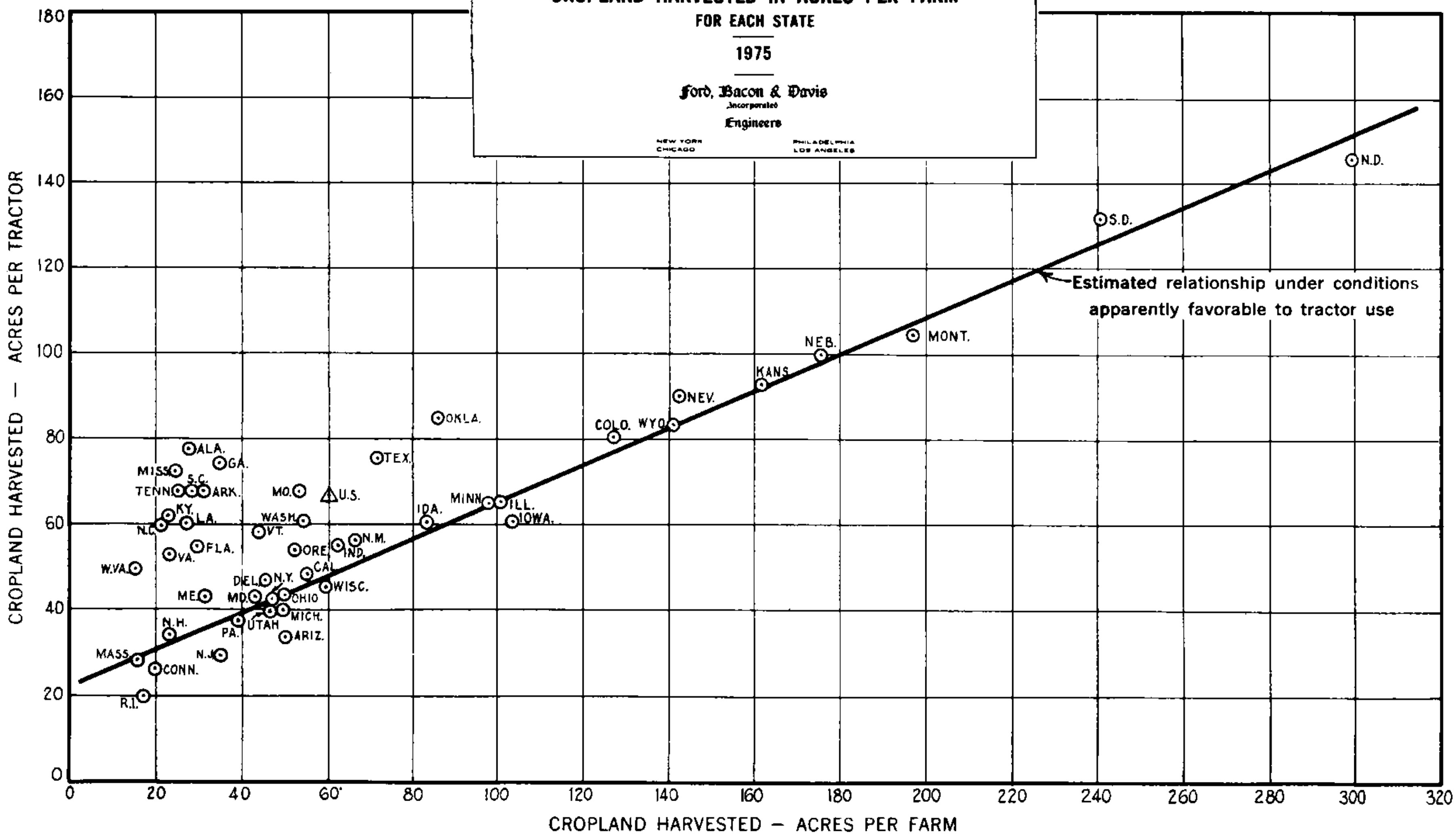
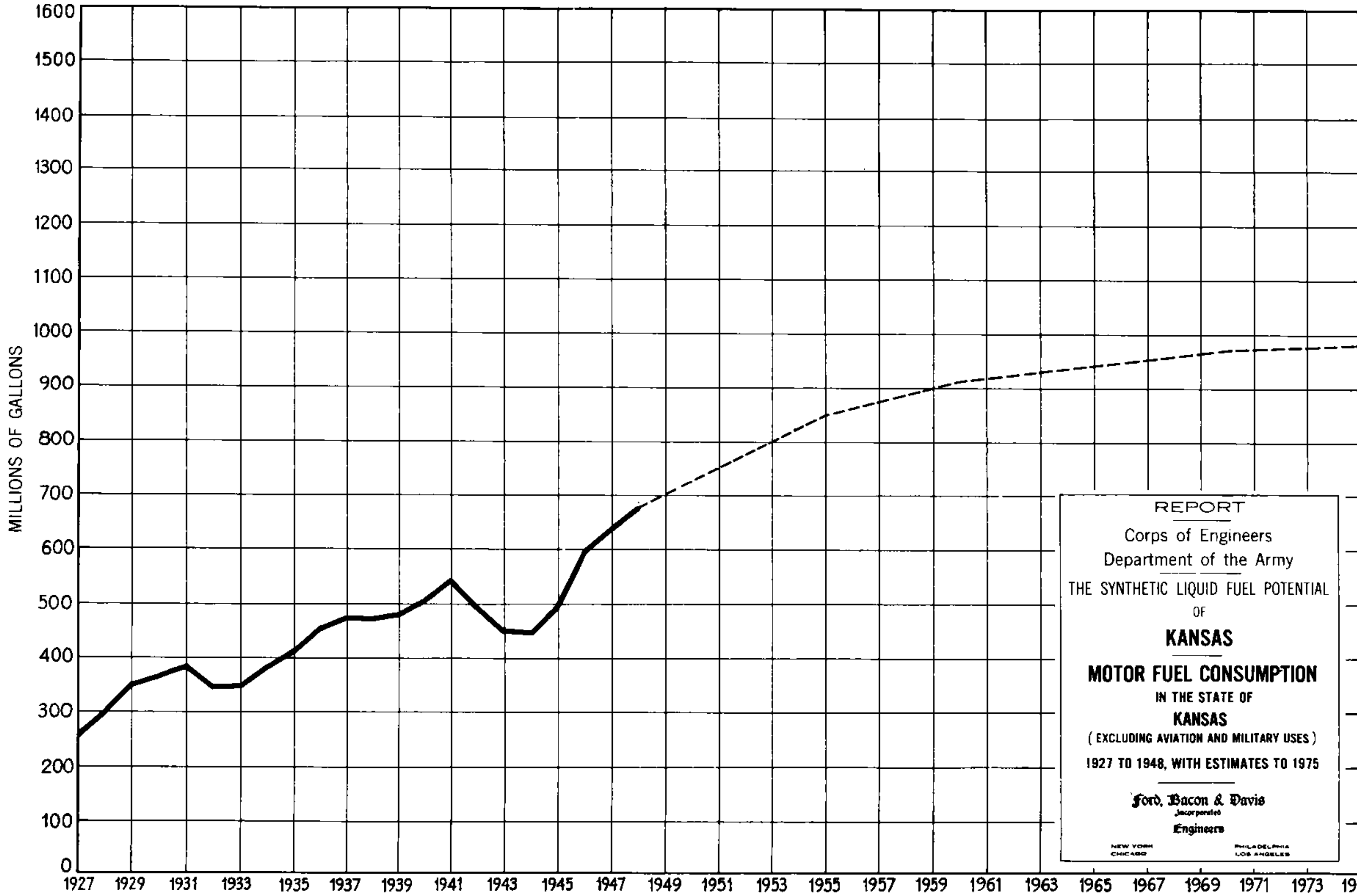


EXHIBIT NO. 40



SF-721 1-8-51

EXHIBIT NO. 41

EXHIBIT NO. 42

REPORT

Corps of Engineers
Department of the Army

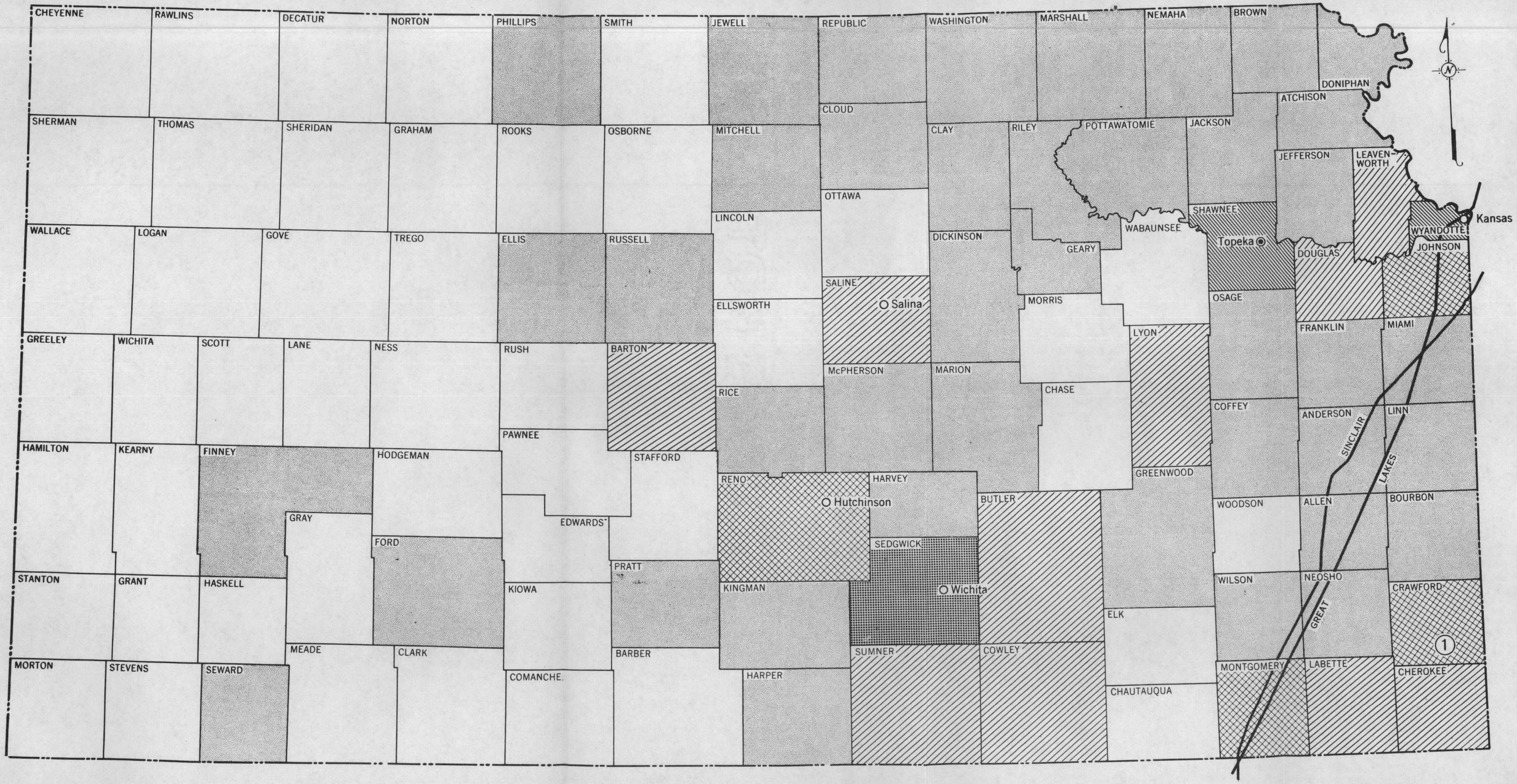
THE SYNTHETIC LIQUID FUEL POTENTIAL
OF

KANSAS

ESTIMATED POPULATION OF COUNTIES IN KANSAS
BY SIZE GROUPS
AS OF JANUARY 1, 1949
AND APPROXIMATE CENTER OF THE GENERAL AREA

Ford, Bacon & Davis
Incorporated
Engineers

NEW YORK CHICAGO PHILADELPHIA LOS ANGELES



SCALE OF MILES
10 0 10 20 30 40

LEGEND

Products pipe line

(1) etc. Center of General Area of Coal and Water Availability

IDENTIFICATION

Approx Center	General Area
(1)	Crawford-Cherokee

POPULATION

0 to 10,000
10,001 to 25,000
25,001 to 50,000
50,001 to 100,000
100,001 to 200,000
OVER 200,000

SF-214A 4-27-51

KAN

Estimated Plant Construction Cost and Initial Capital Investment Required for a 10,000-barrel-per-day Coal Hydrogenation Plant at Rock Springs, Wyo., as of First Quarter of 1948 (Based on Estimates by U.S. Bureau of Mines (R.I. No. 4564) for a 30,000-barrel Plant)

Subdivisions of Total Plant	Estimated Initial Capital Investment (As of First Quarter of 1948)	
Gas Production Section (including recovery and compression):		
Low-temperature Off-gas Separation	$ 1,922,000	
Hydrocarbon Steam Cracking	2,389,000	
Coal Gasification	3,066,000	
Oxygen Plant	3,673,000	
Hydrogen Purification and Compression	7,200,000	
Total Gas Production		$18,250,000
Hydrogenation Section (including product distillation and separation):		
Coal Preparation	$ 2,327,000	
Paste Preparation	930,000	
Liquid Phase Hydrogenation	14,967,000	
Delayed Coking	2,122,000	
Vapor Phase Hydrogenation	8,400,000	
Product Distillation	3,017,000	
Phenols Recovery	668,000	
Total Hydrogenation		32,431,000
General and Auxiliary Plants Section:		
Tankage	$ 1,670,000	
Power Plant	12,083,000	
Plant Utilities	8,573,000	
General Plant Facilities	7,967,000	
Total General and Auxiliary Plants		30,293,000
Total Plant Construction Cost		$80,974,000
Interest during Construction		3,037,000
Depreciable Investment		$84,011,000
Operating Capital		4,608,000
Total Investment entitled to Return		$88,619,000

Estimation of Operating Capital
Coal Hydrogenation Unit Plants in Kansas
(As of March 31, 1950)

	Crawford-Cherokee General Area of Coal and Water Availability
Costs per Calendar Day	
Coal:	
Mine Investment (thousands)	$ 6,432 (B)
Daily Plant Consumption (tons)	3,927 (B)
Cost per Ton	$ 4.37 (B)
Daily Cost excluding Return	$ 17,161
Daily Return on Investment @ 4%	705
Daily Coal Cost including Return	$ 17,866
Water:	
Water Investment (thousands)	$ 5,848
Annual Cost	$ 264,160
Daily Cost excluding Return	$ 724
Daily Return on Investment @ 5%	801
Daily Cost including Return	$ 1,525
Catalysts	$ 1,293
Total Raw Material (C)	$ 20,684
Total Direct and Indirect Costs excluding Raw Material (A)	$ 18,688
Operating Capital	
Cost of 30 days' coal supply at rated capacity operation	$ 535,980
Cost of direct materials and water for one-half year operation at average 25 percent capacity	943,708
All other operating costs for one-half year (except fixed costs)	3,410,560
Total	$4,890,248

Note:

(A) From Contractor's Estimate of Processing Costs -

Total Direct and Indirect Costs	$ 37,866
Less Direct Materials (Coal and Catalysts)	18,454
Less Make-up Water	724
Balance, Direct and Indirect Costs excluding Raw Material	$ 18,688

(See Page 2 of this Exhibit for balance of Footnotes)

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70021

Estimation of Operating Capital
Coal Hydrogenation Unit Plants in Kansas
(As of March 31, 1950)

Note:

(B) Assumed equal amounts of primary underground and secondary strip coal used over 40 years' life of plant:

	Daily Plant Consumption (Tons)	Cost per Ton	Mine Investment (Thousands)
Underground	3,837	$5.19	$7,000
Strip	4,016	3.55	5,864
Average	3,927	$4.37	$6,432

(C) Cost of Coal, Water, and Catalysts

Methods Used in Preparation of Estimates of Daily Operating Costs For a Typical Coal Hydrogenation Unit Plant in Continental United States

Direct Labor:

Direct labor 1 man per shift per $1,000,000 of plant cost erected (cost as of first quarter 1948) (A) (B)

Supervisory personnel 10 percent of direct labor personnel (B)

Total labor personnel 4.5 times personnel per shift (B)

Direct labor wage rate (at Rock Springs, Wyo., first quarter 1948)- average, all classifications, $1.75 per hour (A)

Cost of supervision 15 percent of labor cost (A)

Plant Maintenance Labor and Supervision:

Total annual cost of maintenance labor and supervision 2 percent of plant cost erected (cost as of first quarter 1948) (A)

Maintenance labor personnel 1.18 times direct labor personnel (B)

Supervisory personnel 10 percent of maintenance labor personnel (B)

Total maintenance labor personnel 4.5 times average personnel per shift (B)

Maintenance labor wage rate (at Rock Springs, Wyo., first quarter 1948) - average, all classifications, $1.68 per hour (B)

Cost of supervision 15 percent of labor cost (A)

Plant Maintenance Materials:

Per year, 1 percent of plant cost erected (A)

Payroll Overhead:

12-1/2 percent of direct labor and supervision and maintenance labor and supervision (A)

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70021 20 percent of maintenance labor, supervision, and materials (A)

Methods Used in Preparation of Estimates of Daily Operating Costs For a Typical Coal Hydrogenation Unit Plant in Continental United States

Total Indirect Costs (general administrative, office overhead, and indirect operating costs):

50 percent of direct labor and supervision, plant maintenance labor, supervision and materials, and operating supplies (A)

Indirect Labor:

Total indirect labor personnel (wage earners), as estimated in detail by individual functions (B) - actually amounting to 11-1/2 percent of total wage earners (including indirect labor)

Indirect labor wage rate, (at Rock Springs, Wyo., first quarter 1948) - average, all classifications, $1.58 per hour (B)

Total daily cost of indirect labor, 1/365 of annual cost, at 2,080 hours per year, per man (C)

Cost of supervision, none (supervision provided by salaried personnel) (C)

Indirect Salaried Personnel:

Total indirect salaried personnel, as estimated in detail by individual functions (B)

Average salary $3,600 per year (B)

Other Indirect Costs:

Balance remaining after deducting from total indirect costs (as above) the sum of payments to indirect labor and indirect salaried personnel (also as above)

Local, County, and State Taxes:

Per year, 1 percent (A) of depreciable investment (plant cost erected, plus interest during construction)

Depreciation:

15-year, straight line; per year, 6-2/3 percent (A) of depreciable investment

Methods Used in Preparation of Estimates of Daily Operating Costs For a Typical Coal Hydrogenation Unit Plant in Continental United States

References:

(A) R.I. No. 4564, U.S. Bureau of Mines, August 1949: "Estimated Plant and Operating Costs for Producing Gasoline by Coal Hydrogenation."

(B) Memorandum, U.S. Bureau of Mines Synthetic Oil Plant, Louisiana, Mo., February 3, 1950: "30,000-barrel-per-day Coal Hydrogenation Plant - Labor Classification and Hourly Rates" (Transmitted to F.B. & D., Inc. by Corps of Engineers, February 17, 1950)

(C) Memorandum, U.S. Bureau of Mines Synthetic Oil Plant, Louisiana, Mo., March 8, 1950: "Fischer-Tropsch Commercial Liquid Synthetic Fuel Plant - 10,000 Barrels per Day Estimate."

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Methods Used in Preparation of Estimates of Daily Operating Costs For Coal Hydrogenation Unit Plants in Kansas as of March 31, 1950

Direct Materials:

Coal, from section of report entitled "Coal"; 3,927 tons at $4.37 per ton, assuming equal amounts of underground and strip coal used over 40-year life of plant.

Catalysts and chemicals as estimated by Bureau of Mines.

Direct Labor:

Wage earners, daily cost estimated by Bureau of Mines multiplied by ratio of $1.62 over $1.70. $1.62 represents estimated average straight-time hourly wage rate payable to wage earners (exclusive of supervisors) in synthetic liquid fuels plants in Kansas as developed in the section of this report entitled "Labor". $1.70 represents the weighted average hourly wage rate of wage earners (exclusive of supervisors) as used in the Bureau of Mines estimate of operating costs in a typical coal hydrogenation unit plant.

Supervisors, 15 percent of daily cost of wage earners.

Plant Maintenance Labor and Supervision:

Wage earners, daily cost estimated by Bureau of Mines multiplied by ratio of $1.62 over $1.70, as developed under direct labor.

Supervisors, 15 percent of daily cost of wage earners.

Plant Maintenance Materials:

Per year, 1 percent of plant construction cost.

Payroll Overhead:

12-1/2 percent of direct labor and supervision and maintenance labor and supervision.

Operating Supplies:

20 percent of maintenance labor, supervision, and materials.

Total Indirect Costs (general administrative, office overhead, and indirect operating costs):

50 percent of direct labor and supervision, plant maintenance labor, supervision and materials, and operating supplies.

Methods Used in Preparation of
Estimates of Daily Operating Costs
For Coal Hydrogenation Unit Plants
in Kansas as of March 31, 1950

Indirect Labor:
Daily cost estimated by Bureau of Mines multiplied by ratio of $1.62 over $1.70 as developed under direct labor.

Indirect Salaried Personnel:
As estimated by Bureau of Mines.

Other Indirect Costs:
Balance remaining after deducting from total indirect costs (as above) the sum of payments to indirect labor and indirect salaried personnel (also as above).

Local, County, and State Taxes:
Per year, 1 percent of depreciable investment (plant construction cost plus interest during construction).

Depreciation:
15-year, straight line; per year, 6-2/3 percent of depreciable investment.

Estimated Coal Synthine Unit Plant Construction Costs
and Required Total Initial Investment
Plant near Caseyville, Ky., using
W. Kentucky Bituminous Coal
(Based on Preliminary Estimates by U.S. Bureau of Mines)

Subdivisions of Total Plant	10,000-barrel-per-day Plant Using Coal (as of March 1, 1950)	
Synthesis Gas Production Section:		
Coal Preparation	$ 2,995,000	
Gas Generation	8,330,000	
Gas Purification	3,780,000	
Oxygen Production and Compression	21,700,000	
Total Synthesis Gas Production Section		$36,805,000
Synthesis and Other Processing Section:		
Synthesis	$11,100,000	
Catalyst Preparation and Coolant Oil Clean-up	250,000	
Distillation and Gas Recovery	7,350,000	
Polymerization	875,000	
Catalytic Reforming and Cracking	1,365,000	
Waste Recovery and Disposal	1,000,000	
Total Synthesis and Other Processing		$21,940,000
General and Auxiliary Plants Section:		
Tankage	$ 2,100,000	
Power Plant	3,570,000	
Plant Utilities	9,660,000	
Plant Facilities	7,730,000	
Total General and Auxiliary Plants		$23,060,000
Total Plant Construction Cost		$81,805,000
Interest during Construction		2,455,000
Depreciable Investment		$84,260,000
Operating Capital		4,000,000
Total Investment entitled to Return		$88,260,000

Estimation of Operating Capital
Coal Synthine Unit Plants in Kansas
(As of March 31, 1950)

	Crawford-Cherokee General Area of Coal and Water Availability
Costs per Calendar Day	
Coal:	
Mine Investment (Thousands)	$ 8,270(B)
Daily Plant Consumption (Tons)	5,049(B)
Cost per Ton	$ 4.37(B)
Daily Cost excluding Return	$ 22,064
Daily Return on Investment @ 4%	906
Daily Coal Cost including Return	$ 22,970
Water:	
Water Investment (Thousands)	$ 5,848
Annual Cost	$ 264,160
Daily Cost excluding Return	$ 724
Daily Return on Investment @ 5%	801
Daily Cost including Return	$ 1,525
Catalysts	$ 1,200
Total Raw Material (C)	$ 25,695
Total Direct and Indirect Costs excluding Raw Material (A)	$ 17,625
Operating Capital	
Cost of 30 days' coal supply at rated capacity operation	$ 689,100
Cost of direct materials and water for one-half year operation at average 25 percent capacity	1,172,334
All other operating costs for one-half year (except fixed costs)	3,216,563
Total	$5,077,997

Note:

(A) From Contractor's Estimate of Processing Costs -

Total Direct and Indirect Costs	$ 41,613
Less Direct Materials (Coal and Catalysts)	23,264
Less Make-up Water	724
Balance Direct and Indirect Costs excluding Raw Material	$ 17,625

(See Page 2 of this Exhibit for balance of Footnotes)

Estimation of Operating Capital
Coal Synthine Unit Plants in Kansas
(As of March 31, 1950)

Note:

(B) Assumed equal amounts of primary underground and secondary strip coal used over 40 years' life of plant:

	Daily Plant Consumption (Tons)	Cost per Ton	Mine Investment (Thousands)
Underground	4,933	$5.19	$9,000
Strip	5,164	3.55	7,540
Average	5,049	$4.37	$8,270

(C) Cost of Coal, water and catalysts.

Exhibit No. 49

Methods Used in Preparation of Estimates of Daily Production Costs For a Typical Coal Synthine Unit Plant in Continental United States

(Based on Preliminary Data from U.S. Bureau of Mines)

Direct Labor:

Direct labor (75 men per shift), as estimated in detail by individual functions (A)

Supervisory personnel 10 percent of direct labor personnel (A)

Total labor personnel 4.5 times (average) personnel per shift (A)

Direct labor wage rate (at Caseyville, Ky., first quarter 1950) - average, all classifications, $1.75 per hour (A)

Cost of supervision 15 percent of labor cost (A)

Plant Maintenance Labor and Supervision:

Total annual cost of maintenance labor and supervision 2 percent of plant cost, erected (cost as of March 1, 1950) (A)

Maintenance labor personnel 420 men, approximately 5/4 of direct labor personnel (A)

Supervisory personnel 10 percent of maintenance labor personnel (A)

Total maintenance labor personnel 4.5 times (average) personnel per shift

Total maintenance labor cost 100/115 of total daily cost (1/365 of annual cost) of maintenance labor and supervision (as above)

Cost of supervision 15 percent of labor cost (A)

Plant Maintenance Materials:

Per year, 1 percent of plant cost erected (A)

Payroll Overhead:

12-1/2 percent of direct labor and supervision and maintenance
Kan labor and supervision (A)

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Operating Supplies:

70021 20 percent of maintenance labor, supervision, and materials (A)

Methods Used in Preparation of Estimates of Daily Production Costs For a Typical Coal Synthine Unit Plant in Continental United States
(Based on Preliminary Data from U.S. Bureau of Mines)

Total Indirect Costs (general administrative, office overhead, and indirect operating costs):
50 percent of direct labor and supervision, plant maintenance labor, supervision and materials, and operating supplies (A)

Indirect Labor:
Total indirect labor personnel (wage earners) 12 percent of total wage earners (including indirect labor) (A)

Indirect labor wage rate (at Caseyville, Ky., first quarter 1950) - average, all classifications, $1.64 per hour (A)

Total daily payments to indirect labor, 1/365 of annual cost at 2,080 hours per year, per man (B)

Cost of supervision, none (supervision provided by salaried personnel)

Indirect Salaried Personnel:
Average salary rate $3,600 per year (A)

Total indirect salaried personnel, number of employes at $3,600 per year payable from a sum equal to 50 percent of total indirect costs less payments to indirect labor (A)

Other Indirect Costs:
Balance remaining after deducting from total indirect costs (as above) the sum of payments to indirect labor and indirect salaried personnel (also as above)

Local, County and State Taxes and Insurance:
Per year 1 percent (A) of depreciable investment (plant cost erected plus interest during construction)

Depreciation:
15-year straight line; per year 6-2/3 percent (A) of depreciable investment

References:

Kan (A) Memorandum, U.S. Bureau of Mines Synthetic Oil Plant, Louisiana, Mo., March 8, 1950:
3 "Fischer-Tropsch Commercial Liquid Synthetic Fuel Plant - 10,000 Barrels per Day Estimate".

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(B) R. I. No. 4564, U. S. Bureau of Mines, August 1949: "Estimated Plant and Operating Costs for Producing Gasoline by Coal Hydrogenation".

Methods Used in Preparation of Estimates of Daily Operating Costs For Coal Synthine Unit Plants in Kansas as of March 31, 1950

Direct Materials:

Coal, from section of report entitled "Coal"; 5,049 tons at $4.37 per ton, assuming equal amounts of underground and strip coal used over 40 years' life of plant.

Catalysts and chemicals, same cost as estimated by Bureau of Mines.

Direct Labor:

Wage earners, daily cost estimated by Bureau of Mines multiplied by ratio of $1.62 over $1.73. $1.62 represents estimated average straight-time hourly wage rate payable to wage earners (exclusive of supervisors) in synthetic liquid fuels plants in Kansas as developed in the section of this report entitled "Labor". $1.73 represents the weighted average hourly wage rate of wage earners (exclusive of supervisors) as used in the Bureau of Mines estimate of operating costs in a typical coal synthine unit plant

Supervisors, 15 percent of daily cost of wage earners.

Plant Maintenance Labor and Supervision:

Wage earners, daily cost estimated by Bureau of Mines multiplied by ratio of $1.62 over $1.73, as developed under direct labor.

Supervisors, 15 percent of daily cost of wage earners.

Plant Maintenance Materials:

Per Year, 1 percent of plant construction cost.

Payroll Overhead:

12-1/2 percent of direct labor and supervision and maintenance labor and supervision.

Operating Supplies:

20 percent of maintenance labor, supervision, and materials.

Total Indirect Costs (general administrative, office overhead, and indirect operating costs):

50 percent of direct labor and supervision, plant maintenance labor, supervision and materials, and operating supplies.

Indirect Labor:

Daily cost estimated by Bureau of Mines multiplied by ratio of $1.62 over $1.73 as developed under direct labor.

Methods Used in Preparation of Estimates of Daily Operating Costs For Coal Synthine Unit Plants in Kansas as of March 31, 1950

Indirect Salaried Personnel:
As estimated by Bureau of Mines.

Other Indirect Costs:
Balance remaining after deducting from total indirect costs (as above) the sum of payments to indirect labor and indirect salaried personnel (also as above).

Local, County, and State Taxes:
Per year, 1 percent of depreciable investment (plant construction cost plus interest during construction).

Depreciation:
15-year, straight-line; per year 6-2/3 percent of depreciable investment.

Summary of Capital Investment, Operating Costs, and Requirement for Each Percent of Gross Return on Investment for One 10,000-barrel-per-day Coal Hydrogenation Plant in Kansas (As of March 31, 1950)

Capital Investment ($1,000's)

Raw Material (Coal) (A)	$ 6,432
Water, Process	5,848
Other Processing (B)	99,402
Access Transportation	130
Product Transportation	(G)
Waste Disposal (Solids)	493
Subtotal	$112,305
Housing	12,960
Total (C)	$125,265

Operating Costs, exclusive of Return on Investment, in Dollars per Barrel of Products (D)

Raw Material (Coal) (A)	$1.716
Water, Process	.073
Other Processing (E)	3.983
Access Transportation	.001
Product Transportation	(G)
Waste Disposal (Solids)	.030
Subtotal	$5.803
Housing	(H)
Total (F) - per barrel	$5.803
- per gallon	13.82¢

Dollars per Barrel Required for Each Percent of Gross Return on Capital Investment (D)

Raw Material (Coal)	$0.018
Water, Process	.016
Other Processing	.272
Access Transportation	(I)
Product Transportation	(G)
Waste Disposal (Solids)	.001
Subtotal	$0.307
Housing	.036
Total - per barrel	$0.343

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(See following page for footnotes)

Summary of Capital Investment, Operating Costs, and Requirement for Each Percent of Gross Return on Investment for One 10,000-barrel-per-day Coal Hydrogenation Plant in Kansas
(As of March 31, 1950)

Note: (A) Assumed equal parts of primary underground and secondary strip coal used over 40 years' life of plant.
(B) Includes plant erection cost, interest during construction, and operating capital.
(C) Exclusive of capital invested in commercial facilities, one-half of residential housing assumed sold to employes, and domestic water supply.
(D) Individual costs sometimes adjusted in last digit to agree with total.
(E) See text of "Processing Costs" for details of items included.
(F) Exclusive of domestic water supply and housing, assumed offset by a portion of water rents and residential housing rents.
(G) Product transportation, i.e., the cost of moving products to distant markets, has not been considered for those General Areas with adjacent local marketing territory capable of absorbing the output of a unit plant.
(H) Operating costs offset by a portion of rentals paid by occupants of dwelling units.
(I) Less than 0.5 mills.

Summary of Capital Investment, Operating Costs and Requirement for Each Percent of Gross Return on Investment for One 10,000-barrel-per-day Coal Synthine Plant in the Crawford-Cherokee General Area of Kansas
(As of March 31, 1950)

Capital Investment ($1,000's)	
Raw Material (Coal) (A)	$ 8,270
Water, Process	5,848
Other Processing (B)	89,338
Access Transportation	130
Product Transportation	(C)
Waste Disposal (Solids)	839
Subtotal	$104,425
Housing (D)	14,654
Total	$119,079
Operating Costs, exclusive of Return on Investment, in Dollars per Barrel of Products (E)	
Raw Material (Coal) (A)	$ 2.206
Water, Process	.073
Other Processing (F)	3.652
Access Transportation	.002
Product Transportation	(C)
Waste Disposal (Solids)	.051
Subtotal	$ 5.984
Housing	(G)
Total - per barrel	$ 5.984
- per gallon	14.25¢
Dollars per Barrel Required for Each Percent of Gross Return on Capital Investment	
Raw Material (Coal)	$ 0.023
Water, Process	.016
Other Processing	.245
Access Transportation	(H)
Product Transportation	(C)
Waste Disposal (Solids)	.002
Subtotal	$ 0.286
Housing	.040
Total - per barrel	$ 0.326

(See following page for footnotes)

Summary of Capital Investment, Operating Costs and Requirement for Each Percent of Gross Return on Investment for One 10,000-barrel-per-day Coal Synthine Plant in the Crawford-Cherokee General Area of Kansas
(As of March 31, 1950)

Note:
(A) Assumed equal parts of primary underground and secondary strip coal used over 40 years' life of plant.
(B) Includes plant erection cost, interest during construction, and operating capital.
(C) Product transportation, i.e., the cost of moving products to distant markets, has not been considered for those General Areas with adjacent local marketing territory capable of absorbing the output of a unit plant.
(D) Does not include commercial facilities and one-half of residential units assumed as sold to employes.
(E) Individual costs may be adjusted in last digit to agree with total.
(F) See text of "Processing Costs" for details of items included.
(G) Operating costs offset by a portion of rentals paid by occupants of dwelling units.
(H) Less than 0.5 mills.

Costs Reflecting Exclusive Use of Secondary (Strip) Coal in Unit Plant in Suitable General Area in Kansas (As of March 31, 1950)

	Crawford-Cherokee General Area	
	Hydrogenation Process	Coal Synthine Process
Initial Capital Investment ($1,000's)		
Total Capital Investment Specified Plant (A)	$125,265	$119,079
Coal Investment in Alternate Plant(B)	$ 5,864	$ 7,540
Coal Investment in Specified Plant	$ 6,432	$ 8,270
Decrease in Investment in Alternate Plant	$ 568	$ 730
Decrease in Operating Capital (Processing)	$ 224	$ 288
Total Capital Investment in Alternate Plant	$124,473	$118,061
Operating Costs, exclusive of Return on Investment, in Dollars per Barrel of Products		
Total Operating Cost in Specified Plant (A)	$5.803	$5.984
Raw Material (Coal) Alternate Plant (B)	$1.426	$1.833
Raw Material (Coal) Specified Plant	$1.716	$2.206
Decrease in Operating Cost in Alternate Plant - per barrel	$0.290	$0.373
Total Operating Cost, Alternate Plant:		
Per barrel	$5.513	$5.611
per gallon	13.13¢	13.36¢
Dollars per Barrel Required for Each Percent of Gross Return on Initial Capital Investment		
Total per Barrel, Specified Plant (A)	$0.343	$0.326
Total per Barrel, Alternate Plant (B)	$0.341	$0.323

Note: (A) Plant using coal as specified for synthetic liquid fuels manufacture, all primary reserves, or 50 percent primary and 50 percent secondary. For Costs see Exhibit No. 51 for Hydrogenation and No. 52 for Synthine.
(B) Plant using all Strip (secondary) reserves.

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APPENDIX A

REASONS FOR ELIMINATION OF 23 COUNTIES NOT MEETING SURVEY REQUIREMENTS AS TO COAL RESERVES

APPENDIX A

REASONS FOR ELIMINATION OF 23 COUNTIES NOT MEETING SURVEY REQUIREMENTS AS TO COAL RESERVES

The 23 counties eliminated from further study, after preliminary consideration, because of isolated or insufficient reserves may be discussed as follows:

Allen County
(See Exhibit No. 5 for references A below)

Allen County is located in the south-central portion of the coal-bearing area of Kansas. The Thayer coal bed outcrops in a few scattered localities across the central part of the county, in a general north-south direction. This bed does not exceed 0 ft 9 in. in thickness, and averages less than 0 ft 6 in. within the county. There is no evidence from available information that sufficient coal reserves are available in Allen County to warrant further consideration as synthetic liquid fuels plant supply.

Anderson County
(See Exhibit No. 6 for references B below)

Anderson County is located in the central portion of the coal-bearing area of Kansas. Except in the extreme northwest corner of this county, the Williamsburg coal horizon is represented by an impure coal bed measuring from 1 ft 0 in. to 1 ft 6 in. in thickness. The available information indicates that reserves of this bed, where present as a portion of the field which has been extensively mined in Franklin and Osage counties to the north, are insufficient in amount to warrant further consideration. Although the Thayer coal horizon outcrops within the county, there is no information concerning locations or thickness of reserves.

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Atchison County
(See Exhibit No. 5 for references C below)

Atchison County lies in the northeastern portion of the coal-bearing area of Kansas and is bordered by the Missouri River

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(References A: 18, 27)
(References B: 18, 24)
(References C: 18, 31)

on the east. This portion of Kansas has been glaciated to the extent that outcrops are obscured. The Nodaway and Elmo coal horizons have been recognized within the county limits, but apparently average less than 1 ft 0 in. in thickness.

A northward extension of the deep coal beds mined in Leavenworth County has also been mined in southeastern Atchison County. These operations were conducted at depths greater than 1,000 feet below the surface. Information concerning the possible extent, thickness, and continuity of such coal beds is insufficient to warrant estimates of reserves as potential synthetic liquid fuels plant supply.

Brown County

(See Exhibit No. 5 for references A below)

Brown County is located at the center of the northern line of counties, in the coal-bearing area of Kansas. The Elmo coal forms the principal coal bed within the county and outcrops with measurements ranging from 0 ft 10 in. to 2 ft 2 in. in thickness. Thin coals have been reported to outcrop both east and west of the Elmo bed outcrop, but have not been extensively prospected. Where opened they seldom exceed 1 ft 0 in. in thickness. The available information pertaining to coal beds in Brown County is insufficient to permit a basis for estimates of reserves.

Chautauqua County

(See Exhibit No. 5 for references A below)

Chautauqua County is situated in the southwestern corner of the coal-bearing area of Kansas. The Nodaway coal bed crosses the western part of the county in a general north-south direction, with thicknesses ranging from 1 ft 4 in. to 1 ft 6 in. The bed has been operated locally for domestic consumption by both strip and slope operations. There is no evidence from the available information of sufficient reserves to warrant further consideration to this report.

Coffey County

(See Exhibit No. 5 for references B below)

Coffey County is located in the west-central portion of the coal-bearing area of Kansas. The Williamsburg coal outcrops across the eastern portion of the county. The Nodaway coal outcrops in the extreme northwestern corner of the county. These beds represent a continuation of the Osage field, which is located north of Coffey County, but range only from a few inches to approximately 1 ft 0 in.

(References A: 18, 31)
(References B: 18, 24, 31)

in thickness. Small strip and shallow underground operations have been opened in a few localities. The available information indicates that the reserves in Coffey County are insufficient in quantity and discontinuous in extent to warrant further study.

Doniphan County
(See Exhibit No. 5 for references A below)

Doniphan County is located in the extreme northeastern corner of the coal-bearing area of Kansas. The area is heavily covered by glacial deposits and only a few outcrops of the Nodaway coal have been reported in the western part of the county. This bed measures from a few inches to 1 ft 0 in. in thickness and has been opened in a few places along the outcrop for local use. The available information indicates that there are insufficient reserves in Doniphan County to warrant further consideration.

Douglas County
(See Exhibit No. 5 for references B below)

Douglas County is located in the north-central portion of the coal-bearing area of Kansas. The Blue Mound coal has been opened at a few localities in the north-central portion of the county, where it measures from 1 ft 0 in. to 2 ft 2 in. in thickness. The Williamsburg coal bed outcrops in the southwestern portion of the county, but commonly measures less than 1 ft 0 in. in thickness. Elsewhere within the county, these two beds, as well as others, seldom attain a thickness greater than 0 ft 8 in. There is no evidence from available information that the coal beds of this county are suitable for further consideration.

Elk County
(See Exhibit No. 5 for references A below)

Elk County is located in the southeastern portion of the coal-bearing area of Kansas. Outcrops of the Nodaway and Elmo beds cross the county in a general north-south direction, and apparently attain a thickness of from 1 ft 4 in. to 1 ft 6 in. at irregular occurrences. The available information indicates that these beds are discontinuous in nature and further consideration does not appear to be warranted.

Greenwood County
(See Exhibit No. 5 for references A below)

Greenwood County is located in the southwest-central
ans portion of the coal-bearing area of Kansas. The Nodaway and Lortin

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(References A: 18, 31)
(References B: 18, 24, 31)

beds have been reported in this county, but do not exceed 0 ft 10 in. in thickness. The available information indicates that the coals of this county are insufficient in extent to warrant further consideration.

Jackson County
(See Exhibit No. 5 for references A below)

Jackson County is located in the northwestern portion of the coal-bearing area of Kansas. The Elmo coal forms the principal coal horizon in the eastern and southeastern portions of the county, but is not known to be of minable continuity and thickness. The maximum reported thickness is 1 ft 0 in. The available information indicates that the coals of Jackson County are insufficient in extent to warrant further consideration.

Jefferson County
(See Exhibit No. 5 for references A below)

Jefferson County is located in the north-central portion of the coal-bearing area of Kansas. The Nodaway coal occurs widely within this county, with a relatively uniform thickness ranging from 0 ft 8 in. to 1 ft 2 in. The Elmo coal, also found within the county, has not been developed by even local mining. The available information indicates that reserves are insufficient in extent to warrant further consideration in this report.

Johnson County
(See Exhibit No. 5 for references A below)

Johnson County is located in the northeast-central portion of the coal-bearing area of Kansas. No minable coals are known to occur within this county and further consideration is unwarranted.

Labette County
(See Exhibit No. 5 for references B below)

Labette County is located in the central part of the southern tier of counties in the coal-bearing area of Kansas. This county forms the western part of the southern portion of the southeastern Kansas coal district, and contains the Mineral, Crowsburg, and Bevier beds, which are extensively mined in Cherokee and Crawford Counties to the east. These beds in Labette County measure less than 2 ft 0 in. in thickness and have been mined by a number

(References A: 18, 31)
(References B: 4, 6, 14, 16, 17, 22, 28, 30, 33)

of small strip operations in the southeastern quarter of the county. The Weir-Pittsburg bed is located at shallow depths in this same area and has been worked by shallow shaft operations.

Bureau of Mines data on bituminous coal production in 1948 indicate that 3,700 tons were produced in that year from two strip operations in Labette County. The available information indicates that the minable areas of the coal beds in this county have been extensively depleted and that the remaining reserves are too discontinuous in location and insufficient in amount to warrant further consideration as potential synthetic liquid fuels plant supply.

Leavenworth County
(See Exhibit No. 5 for references A below)

Leavenworth County is located in the northeastern portion of the coal-bearing area of Kansas and is bordered on the northeast by the Missouri River. While a number of beds outcrop at the surface in Leavenworth County, the beds are thin and discontinuous in occurrence, with the outcrops being frequently obscured by deep glacial deposits. The Sibley bed ranges from 1 ft 4 in. to as much as 2 ft 0 in. in thickness in the southern portion of the county, but is erratic in occurrence and appears to decrease rapidly in thickness in all directions.

During former years a number of deep shaft mines were opened near the city of Leavenworth and it is reported from the evidence of underground operations in these shafts that 5 coal beds, having a total coal thickness of 9 ft 0 in., occur at depths ranging from 600 to 1,000 feet below the surface. The principal bed mined by such operations has been correlated with the Bevier bed and is reported to range in thickness from 1 ft 7 in. to 1 ft 10 in. The most recent deep-mining operation in this field was the Kansas State Penitentiary mine, which in 1945 produced 49,039 tons. While it is believed that large reserves of these deep beds underlie a substantial area in Leavenworth and adjoining counties, the available information is insufficient to permit the estimating of reserves. It appears that most, if not all, of these beds are under 2 ft 0 in. in thickness, which represents the minimum thickness for secondary coal reserves of bituminous rank to be considered, under the definitions and procedures employed in this report.

Kans Lyon County
(See Exhibit No. 5 for references B below)

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Lyon County is located in about the middle of the western edge of the coal-bearing area of Kansas. A number of coal

(References A: 14, 18, 24)
(References B: 18, 31)

beds are present, of which the Nodaway, Nyman, and Lortin beds have been mined by scattered local operations. These beds rarely exceed 1 ft 0 in. in thickness, although the Lortin bed has been reported to attain a maximum thickness of 1 ft 8 in. in a few localities. The available information is insufficient to permit estimates of possible reserves in this county.

Miami County
(See Exhibit No. 5 for references A below)

Miami County is located in the east-central portion of the coal-bearing area of Kansas. This county is largely underlain by glacial material which makes the coal bed outcrops over substantial areas. The Thayer bed has been observed in a few scattered outcrops in the central part of the county, where it measures 0 ft 9 in. in thickness. There is no evidence from available information that coal reserves in this county are sufficient in extent or continuity to warrant further consideration.

Nemaha County
(See Exhibit No. 5 for references B below)

Nemaha County is located in the northwestern corner of the coal-bearing area of Kansas. The Nyman and Nodaway beds have been locally operated within this county and, while the Nyman bed is persistently thin in occurrence, the Nodaway bed occasionally increases to from 1 ft 4 in. to 2 ft 4 in. in thickness. Such areas of thickening, however, are local in extent. The available information indicates that the coal beds in this county are too discontinuous in extent, and insufficient in amount, to warrant further investigation.

Pottawatomie County
(See Exhibit No. 5 for references B below)

Pottawatomie County is located in the northwestern portion of the coal-bearing area of Kansas. The Elmo and Lortin beds outcrop within the county, with the Elmo bed attaining a maximum thickness of 0 ft 10 in. The available information indicates that the coal reserves in this county are insufficient in amount to warrant further consideration.

Shawnee County
(See Exhibit No. 5 for references B below)

Shawnee County is located in the northwest-central portion of the coal-bearing area of Kansas. The Nodaway coal outcrops ir-

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(References A: 18, 24, 27)
(References B: 18, 31)

regularly from the northeastern part of the county to the south-central portion, measuring 0 ft 5 in. to 1 ft 0 in. in thickness within the area of occurrence. The Elmo bed outcrops in a parallel line a short distance west of the Nodaway bed, measuring from 0 ft 4 in. to 1 ft 4 in. in thickness. Both of these beds have been opened by small strip and drift operations, for domestic use. The available information indicates that coal reserves in Shawnee County are insufficient in amount and extent to warrant further consideration.

Wabaunsee County
(See Exhibit No. 5 for references A below)

Wabaunsee County is located in the northwest-central portion of the coal-bearing area of Kansas. Indications of coal are limited to the eastern tier of townships within this county, where the Nyman coal bed outcrops at a few scattered locations, reaching a maximum thickness of 0 ft 8 in. It is from Wabaunsee County that a minor amount of coal has been obtained from a thin coal bed of local extent, which occurs in the basal Permian formation overlying the Pennsylvanian coal-bearing formation. There is no evidence from available information that sufficient reserves are present to warrant further consideration.

Woodson County
(See Exhibit No. 5 for references B below)

Woodson County is located in the southwest-central portion of the coal-bearing area of Kansas. The Upper Williamsburg bed outcrops in scattered areas within this county, but ranges in thickness from 0 ft 5 in. to only 0 ft 10 in. It has been stripped at a few localities for local use. The available information indicates that potential reserves are too limited in amount for further consideration as synthetic liquid fuels plant supply.

Wyandotte County
(See Exhibit No. 5 for references A below)

Wyandotte County is located in the northeastern portion of the coal-bearing area of Kansas and is bordered on the northeast by the Missouri River. This county is underlain by glacial material and no information is available regarding surficial coal occurrences. Since this county adjoins Leavenworth County, it is
Kans probable that some of the deep coal horizons present in the latter

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(References A: 18, 31)
(References B: 18, 24)

county extend under Wyandotte County. The available information on potential coal reserves in Wyandotte County is insufficient to permit the estimates of any reserves.

Miscellaneous

(See Exhibit No. 5 for references A below)

In addition to, and separate from, the principal Pennsylvanian coal-bearing areas of eastern Kansas, a number of outcrops of thin lignite beds have been reported in the north-central portion of Kansas, in areas where the Dakota sandstone of Cretaceous age forms the principal bedrock formation. The coal beds occur near the top of these sandstones and are highly discontinuous in nature and contain many impurities. Most of the reported outcrops are located in Republic, Cloud, Mitchell, Osborne, Russell, Lincoln, and Ellsworth counties. A 2 ft 6 in. coal bed was operated by a deep shaft mine in Jewell County in 1902 and 1906. This bed probably represented the down-dip extension of coal beds outcropping at the surface in Republic County, toward the east. Most of the known production of these lignites has been obtained in Ellsworth County, where the beds measure from 1 ft 1 in. to 1 ft 6 in. in thickness. Occasional measurements in other portions of the lignite-bearing area indicate a maximum thickness of 3 ft 6 in. at a single location in Lincoln County. The available information indicates that all of these lignite beds are below the minimum thickness of lignite stipulated for consideration by the definitions and procedures established for this report.

(References: 6, 7, 8, 18, 33)

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APPENDIX B

REPORT BY DeGOLYER and MacNAUGHTON
ON
NATURAL GAS IN KANSAS
AS OF JANUARY 1, 1949

APPENDIX

REPORT BY DeGOLYER and MacNAUGHTON
ON
NATURAL GAS IN KANSAS
AS OF JANUARY 1, 1949

Summary of Estimated Recoverable Natural Gas Reserves in Kansas
(in Mcf under Standard Conditions)

As of January 1, 1949 (A)

Total		15,654,009,000
Commercial Requirements:		
Contract	14,678,380,000	
To Be Used in Field	791,179,000	
Total Commercial Requirements		15,469,559,000
Undedicated Reserves:		
Proved Drilled	32,580,000	
Proved Undrilled	13,730,000	
Probable	138,140,000	
Total Undedicated Reserves as of January 1, 1949		184,450,000

Note: (A) Modified by interim reserve dedications

As shown by the above table, essentially all of the available gas reserves are under contract to gas pipe lines for domestic, commercial, and industrial use. The available volume of gas is dominantly in the probable classification, and the total Btu content approximates 175 trillion units.

The weighted average field price for gas under contract in Kansas during 1948 ranged from 3.5 to 12 cents per Mcf, with the average being on the order of 6 cents per Mcf. However, any appreciable volume of reserves cannot be acquired under present conditions for less than 12 cents to 14 cents per Mcf.

None of the gas deposits could be considered an available reserve as defined herein because the available information gave no indication that the undedicated deposits within a radius of 40 miles contained at least 225 trillion Btu with a heating value of at least 400 Btu per cubic foot at standard conditions. This reserve would be equal to 236,840,000 Mcf of 950-Btu gas.

It is, therefore, concluded that there are insufficient undedicated reserves of natural gas in Kansas presently available to support a unit synthetic liquid fuels plant. Discoveries of new fields and extensions of old fields from January 1, 1949 to the date of this report warrant no changes in this conclusion.

PART I - INTRODUCTION

Authorization

This investigation and report on natural gas deposits in Kansas have been made as a part of that authorized by a contract, dated June 1, 1949, between Ford, Bacon and Davis, Inc. (called the Contractor) and DeGolyer and MacNaughton (called the Subcontractor). The contract is identified as Subcontract No. 2 of the Principal Contract No. W 49-129 eng-137, dated May 3, 1949, between the United States of America (called the Government) and the Contractor. The subcontract was duly approved by a Representative of the Contracting Officer for the Government.

Purpose

The purpose of this investigation and report is to present an inventory of natural gas reserves or deposits that meet minimum standards as to quantity, quality, and occurrence, as later defined herein, and which might provide a source of raw materials for synthetic liquid fuels manufacture, and to determine General Areas suitable for the location of synthetic liquid fuels plants. An investigation of this type is required for a state in which it was considered that a review of available information might indicate that production of synthetic liquid fuels would be feasible, either at the present time or in the near future.

Scope of Report

Since this investigation determined that there were insufficient natural gas reserves, this report is confined to a general review of the nature and extent of the natural gas deposits and conclusions as to their suitability or unsuitability for the manufacture of synthetic liquid fuels. The reserve data in this report are subdivided into three areas: Eastern Kansas, Western Kansas, and Western Kansas - Hugoton Field.

The study included the collection of basic data, the preparation of maps and the determination of factors necessary to estimate the gas reserves in the oil and gas fields of the State of Kansas; the estimation of the reserves, and the determination of the suitability and availability of the reserves for synthetic liquid fuels manufacture.

PART II - GENERAL

Definitions Relating to Natural Gas and Gas Reserves

Natural Gas - Natural deposits of a combustible gas that occur in porous strata of the earth and consist of a mixture of hydrocarbon gases composed principally of methane, small quantities of ethane, and which very often contain small quantities of other heavier hydrocarbon gases such as propane, butane, pentane, and hexane; usually having a heating value of about 1,000 Btu per cubic foot at standard conditions, which value may vary considerably depending upon the contained percentage of nitrogen and other inert gases.

Heating (or Calorific) Value - Heat (gross) resulting from combustion of fuel, expressed for natural gas as Btu per cubic foot at standard conditions.

Standard conditions - For natural gas, commonly 14.65 pounds per square inch absolute pressure and 60° F temperature.

Minimum Gas Reserves - Deposits of natural gas are not considered reserves for the purpose of this study unless they contain at least 225 trillion Btu in natural gas producible within a radius of 40 miles and with a heating value of not less than 400 Btu per cubic foot at standard conditions.

Estimates of Natural Gas Reserves - The quantities in each of the categories of "proved drilled", "proved undrilled", and "probable" are calculated assuming standard conditions.

(a) Proved drilled reserves - Those reserves of natural gas which will be produced from existing wells.

(b) Proved undrilled reserves - Those reserves of natural gas proved by existing wells and other data, but which will be produced from new wells as yet undrilled.

(c) Probable Reserves - Those reserves of gas indicated to be present by existing wells and other data, and which are classified as probable rather than proved due to the nature or scarcity of the data, or the inability to reach definite conclusions from the available data.

Non-Associated Gas - Free gas not in contact with crude oil.

Associated Gas - Free gas in contact with crude oil.

Dissolved Gas - Gas in solution in crude oil.

Availability of Natural Gas Reserves - From the viewpoint of availability of natural gas reserves, the quantity remaining after allowance for present commercial and industrial requirements. Available reserves are considered sufficient for one or more plants when there is a recoverable amount sufficient to supply a natural gas synthine plant with a capacity of 5,000 barrels of synthetic liquid fuels per day for a period of 20 years of which 10 years' supply is from primary reserves and the additional 10 years' supply is from either primary or secondary reserves.

(a) Primary Reserves - Deposits containing at least 225 trillion Btu producible from gas wells within a rdaius of 20 miles, with a minimum heat value of 700 Btu per cubic foot at standard conditions.

(b) Secondary Reserves - Deposits containing at least 225 trillion But producible from gas wells within a radius of 40 miles, with a minimum heat value of 400 Btu per cubic foot at standard conditions.

Unit Plant or Unit Capacity - A synthetic liquid fuels plant for processing natural gas by the synthine process with a production capacity of 5,000 barrels of liquid fuel products per day. Such a plant would require 55,000,000,000 Btu daily or 55,000 Mcf of 1,000-Btu gas. It would consume 20,075,000 Mcf of 1,000-Btu gas annually and would require a reserve of such natural gas of 401,500,000 Mcf over a 20-year period. The estimated cost of a 5,000-barrel plant (taken at one-half the amount estimated by the U.S. Bureau of Mines for a 10,000-barrel plant) is $30,000,000. Such a plant size is adopted in the survey for comparative purposes and is not necessarily the most efficient size for an independent plant.

A Suitable General Area as considered herein will not be larger than a county or 1,000 square miles, depending on local conditions, with adequate raw materials and water supply and other satisfactory qualifications as to labor and housing, power supply, and transportation.

Available Sources of Information

Data for this study were obtained from files of the Subcontractor, from public records of the Federal Power Commission, from oil and gas companies operating in the State, and from records of the Kansas State Geological Survey.

Reference has been made to principal publications on natural gas in Kansas with particular attention to publications of Federal and State authorities. Important publications consulted are listed in Exhibit No. B-5.

Personnel of oil and gas companies and geologists familiar with gas-bearing formations in Kansas were interviewed. The cooperation and assistance of individuals listed in Exhibit No. B-6 are gratefully acknowledged.

PART III - STUDY OF SURVEY DATA

History of the Natural Gas Industry in Kansas

The search for oil and gas in Kansas began when oil was occasionally observed in wells being drilled for salt water at Osawatomie, Paola, and other places in Miami County, Eastern Kansas. The first successful well in Kansas was drilled by Dr. G. W. Brown of Conneautville, Pa., early in 1860, on the Lykens farm one mile east of Paola, Miami County. This well was credited with a flow of one barrel per day from 275 feet, but water production was so great that the well was soon abandoned.

Further development was interrupted by the Civil War and the Reconstruction Period. However, early in 1882, the first reported commercial gas field was discovered in Kansas 7 miles northeast of Paola, Miami County. Sufficient volume was developed in this pool to supply the local city's needs for a number of years.

The first reported commercial oil well in the State was completed October 4, 1893, near Neodesha, Kans. This well produced initially 12 barrels of oil per day and was called the Guffey and Galey No. 1 Norman. The ensuing years saw great development in Kansas and by 1907 a total of 18 major oil and gas pools had been developed, among which were the Coffeyville, Chanute, and Peru fields. The great Hugoton gas field was discovered in 1922 by the completion of the Defenders and Traders Oil Company No. 1 well on the Boles lease in Seward County.

It is estimated as of January 1, 1949, that some 66,000 wells had been drilled for oil and gas in Kansas; that there were some 27,000 wells producing oil and gas; and that the recorded cumulative gas production was on the order of 2,609,000,000 Mcf. This recorded volume does not include a large volume of gas estimated to have been produced with oil and vented or flared.

General Geology and Natural Gas Reservoirs

The topography of Kansas is marked by a gentle monoclinal slope toward the east, which is interrupted by the valley of the Arkansas River in central Eastern Kansas, and with the extreme eastern part of the State characterized by a west dipping surface of irregular hills and valleys that lie on the western flank of the Ozark Mountains.

The main structural uplifts of Kansas can be roughly divided into three parts, namely: the Chautauqua Arch which is a wide anticlinorium running in a northwest-southeast direction in the southeast corner of the State; the Nemaha uplift, a submerged mountain range trending in a northeasterly direction through Eastern Kansas; and the Central Kansas uplift, extending into Kansas from southwestern Nebraska and covering the east central part of northwestern Kansas. The main basin structural features flank the Central Kansas uplift. The Hugoton embayment of the Anadarko Basin of Oklahoma and Texas is to the southwest, the Salina Basin is to the northeast, and the Forest City Basin is to the northeast, being north of the Chautaqua Arch and east of the Nemaha uplift.

The dominant oil productive formations in Kansas are the Lansing and Kansas City limestones of Pennsylvanian age, the Upper Mississippian sands and limestones, the Hunton limestone of Siluro-Devonian ages, and the Viola and Arbuckle limestones of Ordovician age. These latter two formations underly in excess of 60 percent of the State. Extensive gas production has been developed from shallow Pennsylvanian sands in Eastern Kansas, from Mississippian limestones west of the Nemaha uplift, and from the Permian dolomites and limestones in the Hugoton field in Western Kansas. Depths of production range from 100 to 6,500 feet.

Extensive production will continue to be developed in Kansas by the extensions and development of the presently known producing areas. Also, production will be developed from stratigraphic traps occurring on the flanks of the main buried structural features.

Gas Well and Production Data

During 1948, natural gas in commercial quantities was produced from about 2,850 gas wells at an estimated average daily rate of 703,974 Mcf.

Gas Purchase Contract Data

Essentially all of the commercial gas produced in Kansas is under contract, with the major portion being under contract for a term ranging from 20 years to the life of production. The average price paid for gas in the field varies from 3.5 to 12 cents per Mcf with the average being on the order of 6 cents per Mcf. Gas purchase contract data including purchasers, terms, and prices are presented in Exhibit No. B-7.

Estimation of Natural Gas Reserves

Natural gas reserves of the various gas fields have been estimated for the most part on the basis of reservoir pressure-cumulative production decline curves. Abandonment pressures were estimated on the basis of the deliverability characteristics of the wells, the size of the gas field, and the demand for the gas. Natural gas reserves of the various oil fields have been estimated on the basis of the future producing gas-oil ratio in each field, with consideration being given to the primary type of energy mechanism responsible for production of the oil from the reservoir.

The Eastern Kansas gas reserves are entirely controlled by contract or field uses. The reserves are widely scattered, many wells serving to supply small local communities and farms. The average daily well production is small and delivery pressures are low.

The Western Kansas gas reserves, omitting the Hugoton field, are dominantly associated and dissolved gas reserves scattered through many counties and fields. Although some reserves are available, the impracticability of gathering a sufficient daily average volume within a reasonable radius precludes their utilization for a synthetic fuels plant.

The undedicated available gas reserves in the Hugoton field are in the probable classification and are not in sufficient volume to serve as either primary or secondary reserves as of the present time (see Exhibit No. B-3). The period from January 1, 1949 to September 1, 1950 was marked by the contracting of all of the proved undedicated gas reserves in this field that were available as of January 1, 1949.

The estimates are divided into categories of "proved drilled", "proved undrilled", and "probable". All reserves were calculated assuming standard conditions of 14.65 pounds per square inch at 60° F.

The following table is summarized from Exhibit No. B-2:

Classification of Estimated
Recoverable Gas Reserves in Kansas
As of January 1, 1949 in Mcf

	Total	Undedicated and Available for Synthetic Liquid Fuels Manufacture
Reserves		
Proved Drilled	8,678,278,000	32,580,000
Proved Undrilled	6,776,511,000	13,730,000
Probable	199,220,000	138,140,000
Total	15,654,009,000	184,450,000
Type of Gas		
Non-Associated	15,198,923,000	154,230,000
Associated	309,883,000	30,220,000
Dissolved	145,203,000	0
Total	15,654,009,000	184,450,000

Undedicated Natural Gas Reserves

As of January 1, 1949, there were 184,450,000 Mcf of natural gas reserves available for the manufacture of synthetic liquid fuels. However, this volume of gas available does not meet the minimum requirements set forth for a synthetic fuels plant, taking into consideration both the "probable" classification of such reserves and their scattered areal distribution. Therefore, under the conditions of this requirement, it is concluded that there are insufficient undedicated reserves of natural gas in Kansas presently available for synthetic liquid fuels plants.

PART IV - CONCLUSIONS

Data relating to remaining available reserves of natural gas in Kansas which have an average heating value of 950+ Btu under standard conditions are briefly summarized in the following table:

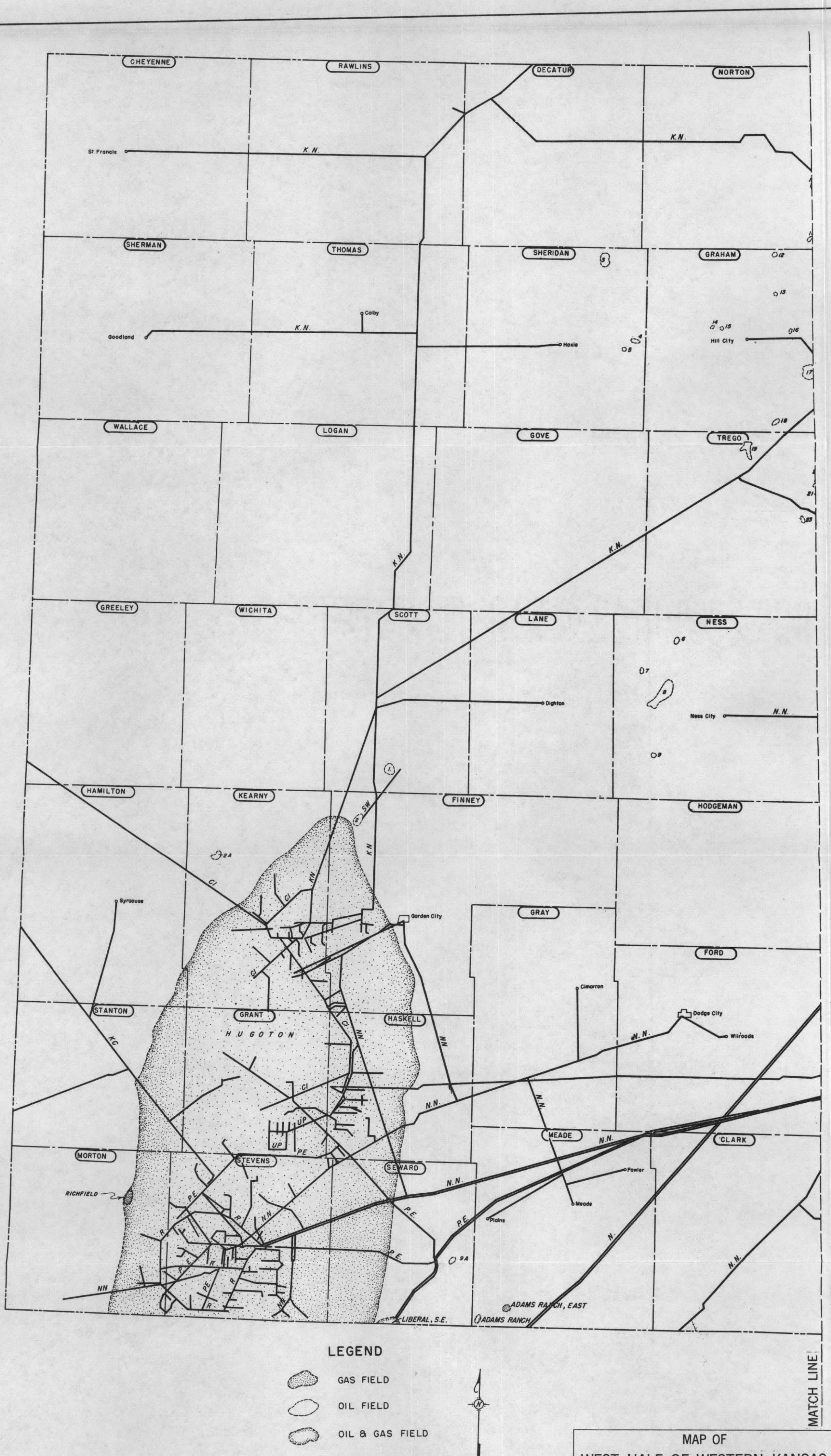
Summary of Estimated
Recoverable Natural Gas Reserves
in Kansas
(In Mcf under Standard Conditions)

As of January 1, 1949 (A)		
Total		15,654,009,000
Commercial Requirements:		
Contract	14,678,380,000	
To Be Used in Field	791,179,000	
Total Commercial Requirements		15,469,559,000
Undedicated Reserves:		
Proved Drilled	32,580,000	
Proved Undrilled	13,730,000	
Probable	138,140,000	
Total Undedicated Reserves as of January 1, 1949		184,450,000

Note: (A) Modified by interim reserve dedications.

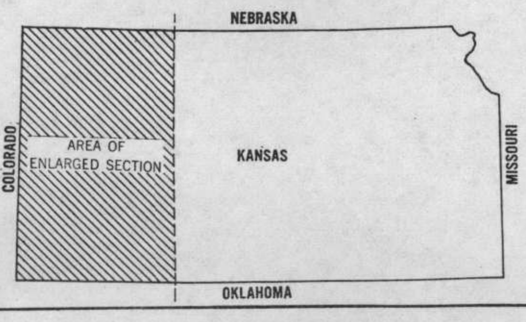
The average field price for gas under contract ranges from 3.5 to 12 cents per Mcf, depending upon the field and contract under consideration. The reserves of natural gas in Kansas have an average heating value of 950+ Btu per cubic foot.

For the purposes of this study, there are no gas reserves in the State of Kansas that can be considered as suitable for synthetic fuels manufacture because of the insufficient volume of undedicated reserves, the "probable" classification of available gas reserves, and the scattered areal distribution of those reserves available. Discoveries of new fields and extensions of old fields from January 1, 1949, to the date of this report warrant no changes in this conclusion.



LEGEND

- GAS FIELD
- OIL FIELD
- OIL & GAS FIELD
- GAS PIPE LINES



PIPE LINE LEGEND

CI	Colorado Interstate Gas Company
KC	Kansas - Colorado Utilities , Inc.
KN	Kansas - Nebraska Natural Gas Company, Inc
N	Natural Gas Pipeline Company of America
NN	Northern Natural Gas Company
PE	Panhandle Eastern Pipeline Company
R	Republic Natural Gas Company
UP	United Producing Company

MAP OF

WEST HALF OF WESTERN KANSAS

SHOWING

OIL AND GAS FIELDS AND MAIN GAS PIPE LINES

AS OF JANUARY 1, 1949

SCALE OF MILES

0 10 20 30 40

DEGOLYER AND MACNAUGHTON DALLAS, TEXAS

EXHIBIT NO. B-1

Page 1 of 36

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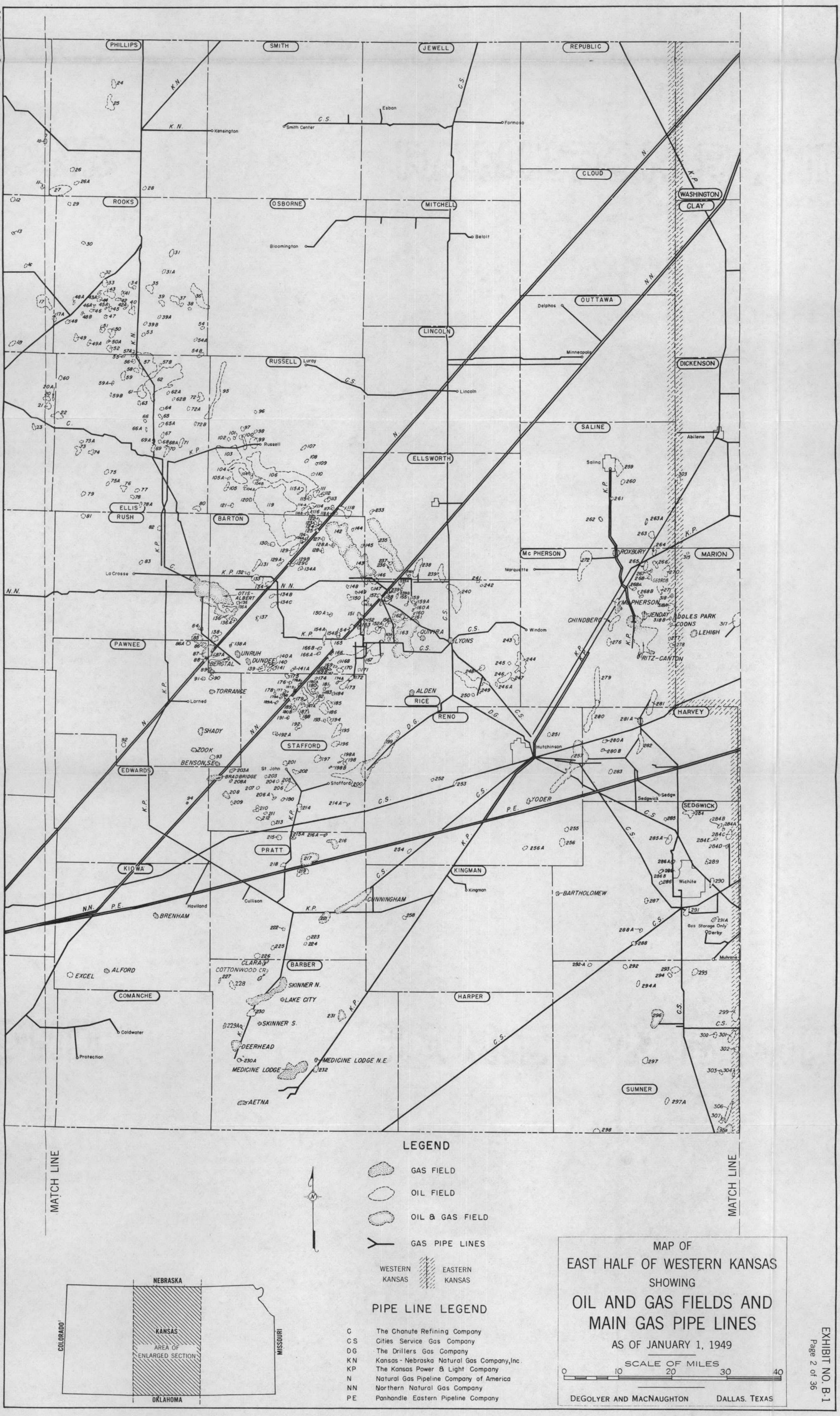

EXHIBIT NO. B-1
Page 2 of 36

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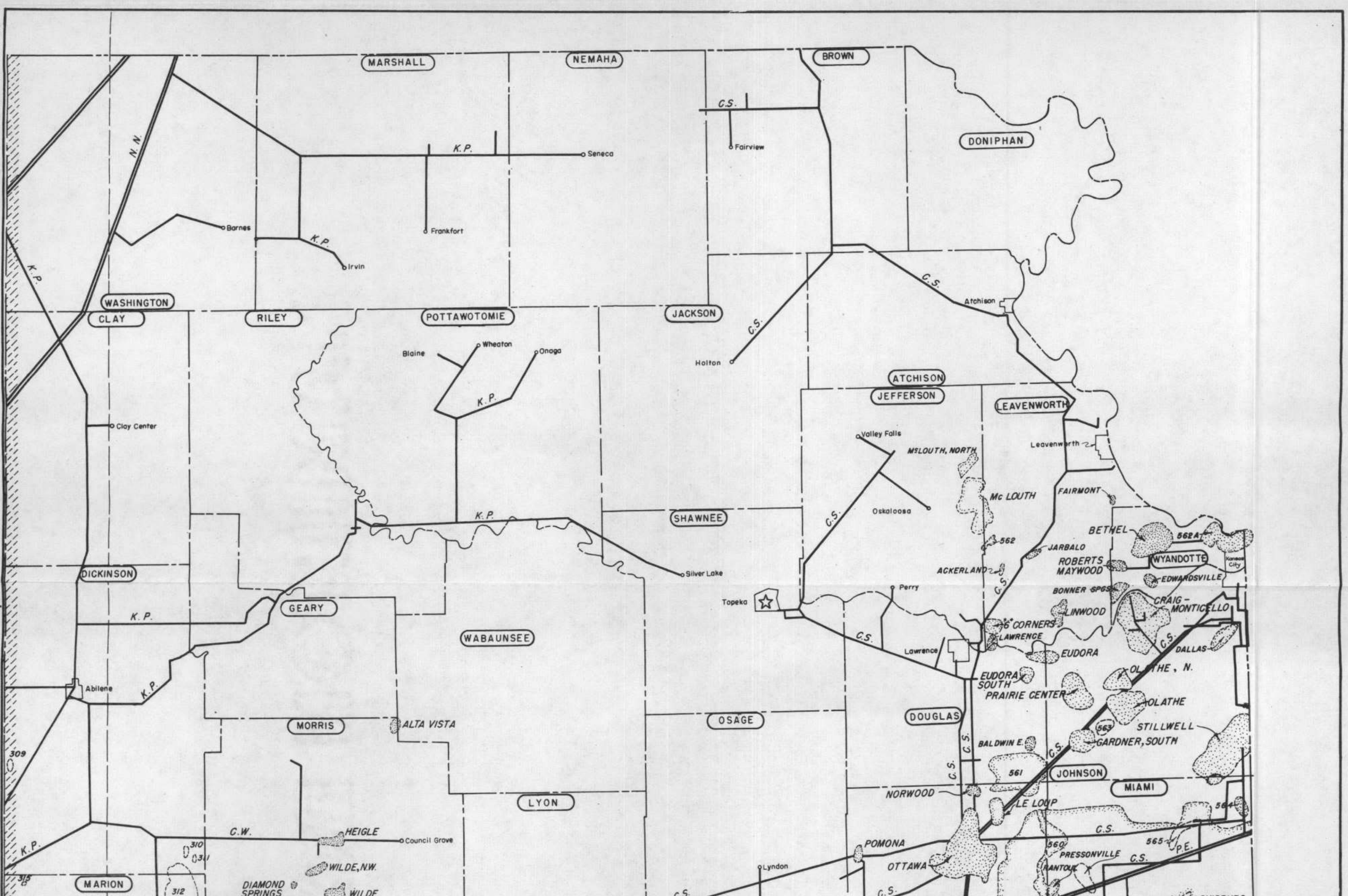

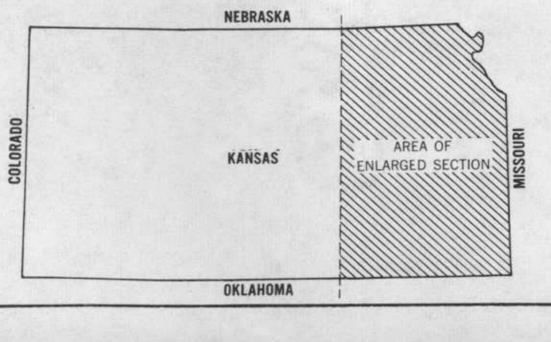

LEGEND

GAS FIELD

OIL FIELD

OIL & GAS FIELD

GAS PIPE LINES

WESTERN KANSAS | EASTERN KANSAS

PIPE LINE LEGEND

CW	Central West Utility Company
CS	Cities Service Gas Company
CPC	The Commercial Gas Pipeline Company
KP	The Kansas Power & Light Company
NN	Northern Natural Gas Company
PE	Panhandle Eastern Pipeline Company
UG	Union Gas System, Inc.

MAP OF EASTERN KANSAS SHOWING OIL AND GAS FIELDS AND MAIN GAS PIPE LINES

AS OF JANUARY 1, 1949

SCALE OF MILES

0 10 20 30 40

DeGOLYER AND MacNAUGHTON DALLAS, TEXAS

List of Oil and Gas Fields in Kansas (A)

Key to Map Numbers

EASTERN KANSAS

County	Gas	Gas and Oil	Oil
Allen			Bayard (547)
		Bronson-Zenia (548)	
		Davis-Bronson (549)	
		Elsmore, West	
			Elsmore Shoestring
		Humboldt-Chanute	
		Iola (546)	
		Iola, Northeast	
	Jonestown		
		Moran	
		Neosho Falls	
	Savonburg, West		
		Seibert (573)	
	Seibert, North		
Anderson			Bush City Shoestring (554)
			Cedar Creek (551)
		Colony, West	
		Colony-Welda	
	Garnett, West (557)		
		Garnett Shoestring (556)	
			Graves (555)
			Greeley (558)
			Kincaid (550)
			Northcott (552)
			Parks (571A)
			Scipio (558A)
			Selma (571)

Note: (A) The classification of fields into "gas", "oil and gas", and "oil" is based primarily upon the original association of the hydrocarbons in all of the productive zones. The current status of a field, as shown on Exhibit No. B-2 by the types of wells now producing, may not correspond to the original classification shown in this exhibit, due to the depletion or inactivity of one or more of the producing zones.

EASTERN KANSAS (Cont'd)

County	Gas	Gas and Oil	Oil
Bourbon			Bronson, Southeast (572)
	Devon		
	Fulton		
	Garland		
			Hepler (544)
	Irish Valley		
	Irish Valley, South		
	Lost Creek		
	Mapleton		
	Mapleton, Southwest		
		Savonburg	
	Schlegel		
Butler			Allen (333)
			Allen, North (333A)
		Augusta (347)	
		Augusta, North (337)	
			Bausinger (336A)
			Benton (334)
			Blankenship (355)
			Brandt-Sensebaugh (359)
			Combs (370)
			Combs, Northeast (370A)
		DeMoss (351)	
			Dixon (343)
		Douglas (365)	
			Dunns Mill (344)
			Eckel (341)
			Elbing (324)
		El Dorado (332)	
			Ferrell (372)
			Fox-Bush (363)
			Garden (339)

EASTERN KANSAS (Cont'd)

County	Gas	Gas and Oil	Oil
Butler (Cont'd)			Gelwick (336)
			Guyot (363A)
			Hannah (375)
			Hannah, North (374)
			Haverhill (346)
			Hazlett (327)
			Hickory Creek (363B)
			Joseph (328)
			Keighley (352)
			King (326)
	Knox (341A)		
			Kramer-Stern (349)
			Kramer-Stern, South (361)
			Leon (345)
			Lucas (354)
			McCaig (360)
			McCann (329A)
			McCullough (350A)
			Marnane (335)
	Pettit (362)		
			Pierce (331)
			Pontiac (342A)
			Potwin (329)
			Potwin, South (330)
			Powell (326A)
			Reynolds-Schaffer (340)
			Salter (364)
			Semisch (368)
			Seward (353)
			Shinn (373)
			Smock-Sluss (338)
			Snowden-McSweeney (367)
			Steinhoff (369)
			Thompson (325)
			Towanda (331A)

EASTERN KANSAS (Cont'd)

County	Gas	Gas and Oil	Oil
Butler (Cont'd)			Vandenberg (350)
			Weaver (348)
	Womack (366)		
			Young (342)
Chase	Altemus		
	Davis		
	Elk		
	Elmdale		
	Hymer (425)		
	Lipps		
	Littler		
	Neva		
	Strong City		
Chautauqua		Berlin (511)	
		Brown-Sturgis (516)	
		Elgin (519)	
		Frazier	
		Hale-Inge (508)	
			Hewins (520)
			Hoover (508A)
	Hylton		
			Kingston (509)
			Landon-Floyd (510)
			Leniton (515)
			Lowe (517)
			McAllister (512)
			McGlasson (514A)
			McNoun (514)
			Malone (512A)
	Mantanzas		
		Niotaze (522)	

EASTERN. KANSAS (Cont'd)

County	Gas	Gas and Oil	Oil
Chautauqua (Cont'd)			Oliver (510A)
		Peru-Sedan	
		Wauneta & Borroum (518)	
		Wayside-Havana (526)	
		Wiggam (513)	
Coffey	Carter (475)		
		Hatch	
			LeRoy (477)
			LeRoy, North (476)
			Van Noy (478)
Cowley	Arkansas City		
			Baird (418)
			Baird, East (419)
		Biddle (396)	
			Box (376A)
		Brown (400)	
		Burden (398)	
			Clark (384)
			Clover (399)
			Combs (370)
			Couch (378)
			Countryman (405)
			Daniels (379)
			Darien (385)
			David (381)
			David, South (381A)
			Deichman (389)
	Denton		
		Dexter (408)	
			Doane (410)
			Dunbar (386)
		Eastman	

EASTERN KANSAS (Cont'd)

County	Gas	Gas and Oil	Oil
Cowley (Cont'd)		Elrod-Tisdale	
			Enterprise (423B)
			Esch (409)
	Estes (402A)		
		Falls City	
			Ferguson, West (377)
			Frog Hollow (393)
			Frog Hollow, East (397)
			Geuda Springs (416)
			Geuda Springs, West (417)
			Gibson (420)
			Graham (422)
	Guthrie		
			Henderson (394)
			Hittle (390)
			Hower (305A)
	Jarvis		
			Mahannah (376)
	Millett		
			Murphy (414)
		Olsen	
			Otter Creek (413)
		Otto	
	Pudden		
			Rahn (411)
			Rainbow Bend (423)
			Rainbow Bend, Northeast (423A)
			Rainbow Bend, West (305)
			Reidy (402)
			Rock and Rock, East (380)
			Rock, North (371)
			Seacat (424)
			School Creek (404)

EASTERN KANSAS (Cont'd)

County	Gas	Gas and Oil	Oil
Cowley (Cont'd)			Silverdale (411A)
			Slick-Carson (395)
			Smith (391)
		State	
			Thurbow (421)
		Tisdale	
			Trees (382)
			Turner (406)
			Turner, North (403)
			Udall (383)
	Vestal (415)		
	Walnut Bend		
			Weathered (392)
	Werner		
		Wilmot-Floral (388)	
			Wilson (407)
		Winfield (397A)	
			Winfield, South (393A)
Crawford			Brazilton (542)
			Fair Oak (541)
			Girard (543)
		Hepler (544)	
		Green Elm (574)	
		McCune (575)	
		McCune Townsite (576)	
		Monmouth (577)	
			Walnut, Southeast (540)

EASTERN KANSAS (Cont'd)

County	Gas	Gas and Oil	Oil
Dickinson			Bonaccord (309)
			Lost Springs, North (310)
			Lost Springs, Northeast (311)
Douglas		Baldwin (561)	
	Baldwin, East		
	Eudora		
	Eudora, South		
	Lawrence		
Elk	Adams		
		Arbuckle (507)	
		Bunyard	
		Bush-Denton	
		Clear Creek	
			Collyer (504)
			Dory (502)
			Dunkleberger (499)
	Elk Falls		
	Ewers		
		Ferguson, East (503)	
			Fleak (505)
			Fleming (496)
		Grand Summit (401)	
	Heck		
	Hinderliter (497)		
		Key (506B)	
	Kimzey (493)		
			Kipfer (498A)
			Liscoe (506A)
			Logsden
		Longton	
		Longton, North	

EASTERN KANSAS (Cont'd)

County	Gas	Gas and Oil	Oil
Elk (Cont'd)		Love	
			Mills (501)
		Moline	
	Moline, South (506D)		
			New Albany (498)
		Oak Valley	
		Oak Valley, South (494)	
		Oliver (506C)	
			Porter (495)
			Preston (500)
			Rettig (506)
		Schade	
		Schrader	
		Shambaugh	
		Starr	
			Upola (492)
			Walker
		Webb	
			Youngmeyer (495A)
Franklin			Lane (559)
		LeLoup	
	Norwood		
	Ottawa		
		Paola-Rantoul (560)	
	Pomona		
Greenwood		Beaumont	
			Beaumont, South
		Beaumont, North	
			Blackwell (462)
		Brinegar	

EASTERN KANSAS (Cont'd)

County	Gas	Gas and Oil	Oil
Greenwood (Cont'd)			Brinegar, North
			Browning (429)
			Burkett (432)
			Climax
			Demalorie-Souder (428)
			Dunaway (456)
			Eureka (443)
			Fankhouser (451)
			Ferrell, North (372A)
			Gaffney (436)
			Gilroy (464)
			Hamilton (459)
			Hinchman (460)
			Hollis (434)
			Hubbard (453)
			Jackson (358)
			Jobes (461)
			Lamont (455)
			Madison (449)
	Neal		
			Ott (454)
			Parks (435)
			Petterson (446)
			Pixlee (429A)
			Polhamus (439)
			Quincy (465)
		Reese	
			Sallyards (357)
			Scott (430)
			Seeley-Wick (431)
			Severy (448)
		Severy, North (447)	
			Stanhope (356)
			Teeter (430A)

EASTERN KANSAS (Cont'd)

County	Gas	Gas and Oil	Oil
Greenwood (Cont'd)			Teichgraber (441)
			Thrall-Aagard (433)
		Tonovay	
	Tucker		
			Utopia (438)
			Virgil (458)
			Virgil, North (457)
			Wiggins (437)
			Wilkerson (440)
			Willard (444)
Jefferson		McLouth	
		McLouth, North	
Johnson	Craig-Monticello		
		Dallas	
			Gardner (563)
	Gardner, South		
	Olathe		
	Olathe, North		
	Prairie Center		
	Stillwell		
Labette	Altamont		
	Angola		
	Banzet		
	Bartlett		
		Chetopa	
	Chetopa Townsite		
	Country Club		

EASTERN KANSAS (Cont'd)

County	Gas	Gas and Oil	Oil
Labette (Cont'd)		Dartnell	
	Dennis		
	Edna		
	Gossard		
	Idenbro		
	Lake Creek		
		Mound Valley	
	Mound Valley, South		
	Oswego		
	Powers		
		Price	
	Valeda		
	Tomey		
Leavenworth		Ackerland	
		Bankers Life (562)	
	Fairmont		
	Jarbalo		
	Lawrence		
	Linwood		
	Six Corners		
Linn		Blue Mound	
		Centerville (570)	
	Critzer		
		Goodrich-Parker (568)	
		LaCygne-Cadmus (569)	
		Mound City	
	Prescott		

EASTERN KANSAS (Cont'd)

County	Gas	Gas and Oil	Oil
Lyon			Atyeo (426)
			Bradfield
			Ritchey-Moore
			Rock Creek (427)
Marion			Antelope (316)
			Antelope, North (316A)
			Covert-Sellers (320)
	Doles Park		
			Elbing, North (323)
			Fanska (315)
			Florence (321)
			Hillsboro (317)
		Lehigh	
			Lost Springs (312)
			Lost Springs, East (313)
			Lost Springs, South (314)
			Lost Springs, Southeast (314A)
			Peabody (322)
		Propp	
	Robinson		
			Wenger (319)
Miami		Beagle (567)	
			Big Lake (565)
		Black	
	Block		
	Fontana		
	Fontana, South (566)		
		Louisburg	
	Louisburg, Northeast (564)		
		Osawatomie	

EASTERN KANSAS (Cont'd)

County	Gas	Gas and Oil	Oil
Miami (Cont'd)		Paola-Rantoul (560)	
			Pressonville
		Rantoul	
			Stanton
Montgomery		Brewster (529)	
		Caney (528)	
			Caney, West (523)
		Coffeyville-Cherryvale	
		Coleman	
		Elk City	
		Jefferson-Sycamore (527)	
		Sorghum Hollow	
		Tyro (524)	
		Wayside-Havana (526)	
Morris	Alta Vista		
	Diamond Springs		
	Heigle		
			Nelson
	Wilde		
	Wilde, Northwest		
Neosho		Altoona, East (536)	
	Canville Creek (537)		
	Dennis		
		Erie (538)	
	Galesburg		
		Hertha	
		Humboldt-Chanute (545)	
	Kimball		

EASTERN KANSAS (Cont'd)

County	Gas	Gas and Oil	Oil
Neosho (Cont'd)			Ladore (533)
			Ladore, North (532)
			Morehead (531)
		St. Paul-Walnut	
			Thayer (535)
		Thayer, East (534)	
	Trent		
		Urbana	
Wilson		Altoona (489)	
		Altoona, East (536)	
		Benedict (490)	
	Buxton		
		Coyville	
		Fall River	
		Farmdale	
		Fredonia	
		Lafontaine	
		Neodesha (491)	
	Neodesha, East		
		New Albany Townsite	
		Vilas (474)	
			Wiggins (489A)
Woodson			Batesville (466)
		Big Sandy (467)	
		Buffalo (473)	
			Evans (479)
			Halligan (472)
			Hoagland (480)
			Laidlow (480A)
		Neosho Falls	

EASTERN KANSAS (Cont'd)

County	Gas	Gas and Oil	Oil
Woodson (Cont'd)			Perry (471)
			Piqua (487)
		Rose (470)	
			Silver City (468)
	Strang (485)		
	Stephenson		
	Teichnor (482)		
		Toronto	
			Vernon (483)
			Weide (481)
		Winterscheid (463)	
			Wissman (484)
		Yates Center (469)	
Wyandotte	Bethel		
	Bonner Springs		
	Edwardsville		
	Roberts-Maywood		
	Welborn-Fairfax (562A)		

WESTERN KANSAS

County	Gas	Gas and Oil	Oil
Barber	Aetna		
		Boggs (232)	
		Clara	
	Cottonwood Creek		
		Deerhead	
			DeGeer (230A)
	Donald (229A)		
		Lake City	
	Medicine Lodge		
	Medicine Lodge, Northeast		
			Skinner (230)
	Skinner, North		
	Skinner, South		
			Sun City (228)
			Turkey Creek (227)
		Whelan (231)	
Barton	Adolph (138A)		
			Ainsworth, South (129)
		Albert (136)	
			Ames (150)
			Ames, Northwest (148)
		Ash Creek (89)	
			Bahr (135)
			Barrett (130)
			Beaver (125)
			Beaver, North (122)
			Beaver, Northwest (123)
			Beaver, South (127)
		Behrens (138)	
		Bergtal	
			Bird (135A)
			Bloomer (146)

WESTERN KANSAS (Cont'd)

County	Gas	Gas and Oil	Oil
Barton (Cont'd)			Boyd (133)
			Breford, Southwest (143)
			Bryant (166A)
			Carroll (131)
			Carroll, Southwest (132)
			Davidson (118)
		Dundee	
		Eberhardt (153)	
			Ellinwood, North (154B)
			Esfeld (144)
			Eveleigh (134)
			Feltes, North (124)
			Feltes, Northwest (124)
			Hagan (168)
			Hammer (154A)
			Heizer (137)
			Hiss (141)
			Hiss, Southeast (140)
			Hiss, West (140A)
			Hoisington (129A)
			Homestead (134A)
			Kaufman (116)
			Klug (129C)
			Klug, North (129B)
			Kowalsky (170)
			Kowalsky, Northwest (169)
		Kraft-Prusa (142)	
			Kraft-Prusa, Northeast (145)
	Krier (128A)		
			Lake Barton (134B)
			Lanterman (154)
			Laudick (126A)
			Marchand, West (166B)

WESTERN KANSAS (Cont'd)

County	Gas	Gas and Oil	Oil
Barton (Cont'd)			Merten, Northeast (136A)
			Mue-Tam (171)
			Odin (128)
		Otis-Albert	
		Pawnee Rock (87)	
			Pawnee Rock, East (87A)
			Pritchard (139)
			Reif (126)
		Rick (151)	
			Roesler (149)
			Rolling Green (141A)
			St. Peter (150A)
			Silica (165)
			Silica, South (166)
			Trapp (119)
		Unruh	
			Workman (169A)
			Workman, Southeast (169B)
			Yeakley (134C)
Edwards	Belpre (94)		
	Bradbridge		
Ellis			Antonino (75A)
			Beeching (80)
			Bemis-Shutts (62)
			Bemis, South (62A)
			Blue Hill (72)
			Burnett (57)
			Burnett, Northwest (57A)
			Burnett, Southwest (58)

WESTERN KANSAS (Cont'd)

County	Gas	Gas and Oil	Oil
Ellis (Cont'd)			Canyons (62B)
			Catharine (65A)
			Catharine, Northwest (65)
			Catharine, South (67)
			Ellis (22)
			Emmeram (72B)
			Fairport (95)
			Haller (56)
			Herzog (71)
			Irvin (74)
			Koblitz (63)
			Kraus (75)
			Kureger (54B)
			Leiker (77)
			Madden (78A)
			Nicholson (60)
			Penny-Wann (79)
			Pleasant (73)
			Pleasant, North (73A)
			Polifka (66A)
			Richards (55)
			Riverview (59)
			Ruder (76)
			Schmeidler (64)
			Schoenchen (78)
			Solomon (59B)
			Solomon, Northeast (59A)
			Sugarloaf (68)
			Sugarloaf, Southeast (68A)
			Toulon (70)
			Ubert (66)
			Upper Turkville (57B)
			Walter (61)
			Weigel (72A)
			Younger (69)
			Younger, North (69A)

WESTERN KANSAS (Cont'd)

County	Gas	Gas and Oil	Oil
Ellsworth County			Bloomer (146)
			Edwards (239)
			Heiken (236)
			Heiken, North (237)
			Lorraine (238)
		Stoltenberg (235)	
			Vacek (233)
			Wilkens, Southeast (238A)
Finney	Hugoton		
			Nunn (2)
Graham			Alda (13)
			Faulkner (18)
			Gettysburg (15)
			Gra-Rook (17A)
			Houston (12)
			Luck (16)
			Morel (17)
			Penokee (14)
Grant	Hugoton		
Hamilton	Hugoton		
Harvey			Brandenberger (283)
		Burrton (257)	
			Graber (281)
			Halstead (282)

WESTERN KANSAS (Cont'd)

County	Gas	Gas and Oil	Oil
Harvey (Cont'd)			Hollow-Nikkel (280)
		Sperling (281A)	
			Stucky (280A)
	Stucky, South (280B)		
Haskell	Hugoton		
Kearny	Hugoton		
			Patterson (2A)
Kingman		Cunningham	
			Pat Creek (258)
Kiowa	Alford Brenham		
			Excel
McPherson			Battle Hill (318A) Battle Hill, North (318) Bitikofer (278) Bitikofer, North (277) Bornholdt (244) Burk (268A) Canton, North (318B) Chindberg
	Coons		
			Crowther (270)
	Doles Park		
			Georob Graber (281)

WESTERN KANSAS (Cont'd)

County	Gas	Gas and Oil	Oil
McPherson (Cont'd)			Gypsum Creek (264)
			Henne (266)
			Hoffsommer (268)
			Jenday
			Johnson (276)
			Lindsborg (272)
		McPherson	
			Maxwell (268B)
			Paden (271)
		Ritz-Canton	
			Roxbury
			Roxbury, South (265)
			Roxbury, Southeast (267)
			Twin Mounds (269A)
			Voshell (279)
Meade		Adams Ranch	
	Adams Ranch, East		
Morton	Hugoton		
	Richfield		
Ness			Aldrich (8)
			Arnold (6)
			Kansada (7)
			Manteno (9)
Norton			Hewitt (10)
			Ray, West (11)

WESTERN KANSAS (Cont'd)

County	Gas	Gas and Oil	Oil
Pawnee		Ash Creek (89)	
			Ash Creek, South (90)
			Ash Creek, Southwest (91)
			Benson (93)
	Benson, Southeast		
			Garfield (92)
		Pawnee Rock (87)	
			Pawnee Rock, South (88)
			Rutherford (86A)
		Ryan (85)	
			Ryan, Southeast (86)
		Shady	
	Torrance		
		Zook	
Phillips			Bow Creek (28)
			Dayton (25)
			Dayton, North (24)
			Hansen (26A)
			Logan (26)
			Ray (27)
Pratt		Carmi (217)	
			Chance (218)
		Chitwood (221)	
		Clara	
			Coats (225)
		Cunningham	
			Frisbie (215)
			Frisbie, Northeast (215A)
			Iuka (219)

WESTERN KANSAS (Cont'd)

County	Gas	Gas and Oil	Oil
Pratt (Cont'd)			Ludwick (222)
			Shriver (226)
		Stark (216)	
			Stoops (223)
			Stoops, Southwest (224)
	Ward (216A)		
Reno			Abbyville (253)
			Albion (256A)
			Buhler (251)
		Burrton (257)	
			Hilger (256)
			Hilger, North (255)
			Lerado, Southwest (254)
			Morton (252)
		Yoder	
		Zenith-Peach Creek (199)	
Rice	Alden		
			Bloomer (146)
			Bowman, North (152A)
			Bornholdt (244)
			Bredfeldt (239B)
			Bredfeldt, West (239C)
		Chase (163)	
			Click (241)
			Click, Southeast (242)
			Cow Creek (155)
			Doran-Doran, West (156)
			Edwards (239)
			Gemeinhardt (147A)
			Geneseo (240)
		Haferman (162)	

WESTERN KANSAS (Cont'd)

County	Gas	Gas and Oil	Oil
Rice (Cont'd)			Heinz (147)
			Keller (160)
	Lyons		
		Orth (158)	
			Orth, West (157)
			Pioneer (163A)
			Ploog (160A)
			Ponce (250)
			Prosper (239A)
	Quivira		
			Raymond (167)
			Rick (151)
			Rick, Southeast (152)
			Rickard (159)
			Silica (165)
			Smyres (243)
			Soeken (161)
			Volkland (159A)
			Welch (246)
			Welch, East (247)
			Welch, North (245)
			Welch, West (246A)
			Wherry (249)
			Wherry, North (248)
Rooks			Alcona (30)
			Barry (43)
			Barry, East (41)
			Barry, Southeast (42)
			Barry, West (43A)
			Baum (54A)
			Berland (49A)
			Burnett (57)

WESTERN KANSAS (Cont'd)

County	Gas	Gas and Oil	Oil
Rooks (Cont'd)			Burnett, Northwest (57A) Chandler (45A) Dopita (35) Dorr (38) Erway (54) Finnesy (53) Gick (46) Gra-Rook (17A) Hobart (34) Jelinek (45) Krueger (54B) Laton (36) Lone Star (31A) McClellan (44) McHale (42A) Marc (46A) Marcotte (49) Nettie (39A) Northampton (48B) Nyra (39) Palco (48) Palco Townsite (48A) Paradise Creek (40) Plainville (39B) Ray, Southeast (29) Silvers (32) Stockton (31) Vohs (50) Vohs, Northwest (51) Vohs, South (50A) Webster (33) Westhusin (37) Zurich (52) Zurich Township (47)

WESTERN KANSAS (Cont'd)

County	Gas	Gas and Oil	Oil
Rush		Otis-Albert Ryan (85)	Loretto (82) Rush Center (83) Tammen (84) Weitzel (81)
Russell			Atherton (100) Atherton, North (97) Atherton, West (101) Beisel (109) Big Creek (104) Boxberger (121) Bunker Hill (107) Claussen (96) Davidson (118) Dillner, Northwest (102) Donovan (105) Donovan, North (105A) Driscoll (117) Dubuque (118A) Fairport (95) Forest Hill (114) Forest Hill, North (115) Gideon (104A) Gorham (103) Gustason (112) Gustason, Northwest (111) Hall-Gurney (106) Janne (113) Jerry (104C) Kaufman (116)

WESTERN KANSAS (Cont'd)

County	Gas	Gas and Oil	Oil
Russell (Cont'd)			Lewis (110) Mahoney (108) Meier (114A) Ney (114B) Parker (115A) Russell (99) Russell, North (98) Smoky Hill (104B) Strecker (120) Trapp (119)
Saline			Hunter (263) Hunter, North (263A) Mentor (261) Olsson (262) Salina (259) Salina, South (260)
Scott			Shallow Water (1)
Sedgwick		Bartholomew	
			Chambers (288A) Clearwater (288) Cross (285) Curry (286B)
	Derby (291A)		
			Eastborough (290) Fairview (284A) Fairview, North (284B) Goodrich (284) Greenwich (284C)

WESTERN KANSAS (Cont'd)

County	Gas	Gas and Oil	Oil
Sedgwick (Cont'd)			Greenwich, South (284D) Hinkle (289) Hohn (286) Petrie (286A) Robbins (291) Schulte (287) Valley Center (285A) White Cotton (284E)
Seward	Hugoton		
			Kismet (9A)
		Liberal, Southeast	
Sheridan			Adell (3) Studley (4) Studley, Southwest (5)
Stafford			Ahnert (192) Bedford (197)
	Bradbridge		
			Brock (196) Byron (174) Cadman (190) Copeland (206A) Curtis (189A) Drach (187) Drach, Northwest (189) Drach, West (188)
		Farmington (208)	
			Fischer (187A)

WESTERN KANSAS (Cont'd)

County	Gas	Gas and Oil	Oil
Stafford (Cont'd)			Fischer, Northwest (187B)
			Gates (179)
			Gray (202)
			Grunder (209)
			Hazel (177)
			Heyen & Heyen, West (194)
	Hildebrand (198B)		
			Hufford (179B)
			Jordan (210)
			Kelly (198A)
			Kenilworth (191)
			Kipp (212)
			Kipp, Northeast (211)
			Leesburgh (214)
			McCandless (213)
	Macksville (203A)		
			Max (185)
			Moon (179A)
			Mueller (180B)
			Nellie (192A)
			Neola (214A)
		O'Connor (208A)	
			Pundsack (178)
			Rattlesnake (204)
			Rattlesnake, West (203)
			Richardson (195)
			Richland (207)
			Riley (198)
			Rothgarn (176)
			Rothgarn, East (176A)
			St. John (206)
			St. John Townsite (201)
			Sandago (174A)

WESTERN KANSAS (Cont'd)

County	Gas	Gas and Oil	Oil
Stafford (Cont'd)			Sand Hills (184) Saundra (181) Saundra, South (183) Shaeffer (175) Sittner (182) Sittner, South (186) Snider (172) Snider, South (173) Spangenberg (193) Stafford (200) Syms (180) Syms, East (180A) Van Lieu (205)
		Zenith-Peace Creek (199)	
Stanton	Hugoton		
Stevens	Hugoton		
Sumner			Anness (292A) Anson (294A) Bellman (295) Caldwell (298) Chandler (307) Churchill (299) Corbin (297A) Latta (292) Margaret (302) Oxford (301) Oxford, West (300)
		Padgett (306)	

WESTERN KANSAS (Cont'd)

County	Gas	Gas and Oil	Oil
Sumner (Cont'd)			Perth (297)
			Rainbow Bend, West (305)
			Rutter (303)
			Val Verde (304)
		Vernon, North (308)	
		Wellington (296)	
			Zyba (293)
			Zyba, Southwest (294)
Trego			Cotton (20)
			Cotton, East (20A)
			Ellis (22)
			Ellis, Northwest (21)
			Riga (23)
			Wakeeney (19)

STATE of KANSAS
SUMMARY CONCERNING NATURAL GAS RESERVES
as of
JANUARY 1, 1949

Location	Number of Wells as of 1-1-49: Producing		Shut-In		Estimated Additional Required for Development		Estimated Daily Average Gas Production, 1948, Mcf	Estimated Remaining Recoverable Gas Reserves in Million Cu Ft as of 1-1-49						Estimated Remaining Recoverable Gas Reserves Available in Million Cu Ft as of 1-1-49			
	Gas	Oil	Gas	Oil	Gas	Oil		Proved Drilled	Proved Undrilled	Probable	Total	Under Contract	To be Used in Field	Proved Drilled	Proved Undrilled	Probable	Total
EASTERN KANSAS	1,191(A)	12,643	-	4	31	512	14,853	37,048	900	8,650	46,598	17,435	29,163	0	0	0	0
Non-Associated (A)	893	0	-	0	6	0	6,932	16,128	100	7,100	23,328	12,335	10,993	0	0	0	0
Associated (A)	298	0	-	0	25	0	4,421	17,820	500	1,050	19,370	4,600	14,770	0	0	0	0
Dissolved (A)	0	12,643	0	4	0	512	3,500	3,100	300	500	3,900	500	3,400	0	0	0	0
WESTERN KANSAS	320	11,952	17	2	30	1,652	177,516	501,705	67,636	31,670	601,011	390,945	153,116	32,580	13,730	10,640	56,950
Non-Associated	101	0	10	0	21	0	44,319	138,195	10,360	20,640	169,195	136,815	5,650	12,850	3,240	10,640	26,730
Associated	219	0	7	0	9	0	89,152	254,713	24,800	11,000	290,513	240,641	19,652	19,730	10,490	0	30,220
Dissolved	0	11,952	0	2	0	1,652	44,045	108,797	32,476	30	141,303	13,489	127,814	0	0	0	0
WESTERN KANSAS-HUGOTON FIELD																	
Non-Associated	1,342	0	261	0	1,830	0	511,605	8,139,525	6,707,975	158,900	15,006,400	14,270,000 (B)	608,900	0(B)	0(B)	127,500	127,500
TOTAL KANSAS	2,853(A)	24,595	278	6	1,891	2,164	703,974	8,678,278	6,776,511	199,220	15,654,009	14,678,380	791,179	32,580	13,730	138,140	184,450
Non-Associated	2,336	0	271	0	1,857	0	562,856	8,293,848	6,718,435	186,640	15,198,923	14,419,150	625,543	12,850	3,240	138,140	154,230
Associated	517	0	7	0	34	0	93,573	272,533	25,300	12,050	309,883	245.241	34,422	19,730	10,490	0	30,220
Dissolved	0	24,595	0	6	0	2,164	47,545	111,897	32,776	530	145,203	13,989	131,214	0	0	0	0

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Note; (A) Estimated

(B) Adjusted for proved drilled reserves totaling 58,600 million cubic feet and proved undrilled reserves totaling 1,655,200 million cubic feet available as of January 1, 1949, contracted for after that date.

Data Concerning Natural Gas Reserves in the Hugoton Field as of January 1, 1949

Location	Year of Discovery	Name of Producing System	Depth of Production (Feet)	Kind of Gas	Average Wellhead Reservoir Pressure, Psia		Average Heating Value (Btu per Cu Ft (A)	Analysis of Gas (Per Cent) (B)			Number of Wells as of 1-1-49					
											Producing		Shut-In		Estimated Additional Required for Development	
					Original	As of 1-1-49		Methane	Ethane+	Other	Gas	Oil	Gas	Oil	Gas	Oil
WESTERN KANSAS																
Hugoton Field																
Finney County	1936	Permian	2,200-2,700	Non-Associated	458	411	925	61.9	18.4	19.7	60	0	20	0	300	0
Grant County	1930	Permian	2,200-2,700	Non-Associated	458	410	1,005	69.2	15.8	15.0	318	0	20	0	225	0
Hamilton County	1946	Permian	2,200-2,700	Non-Associated	451	451	965	65.0	13.0	22.0	0	0	4	0	35	0
Haskell County	1936	Permian	2,200-2,700	Non-Associated	458	412	920	64.6	11.7	23.7	161	0	3	0	265	0
Kearny County	1936	Permian	2,200-2,700	Non-Associated	455	404	970	66.7	13.8	19.5	147	0	64	0	350	0
Morton County	1930	Permian	2,200-2,700	Non-Associated	450	372	985	69.0	12.0	19.0	35	0	52	0	140	0
Seward County	1922	Permian	2,200-2,700	Non-Associated	455	406	990	69.2	17.5	13.3	52	0	0	0	225	0
Stanton County	1944	Permian	2,200-2,700	Non-Associated	456	422	995	62.5	21.1	16.4	69	0	57	0	90	0
Stevens County	1927	Permian	2,200-2,700	Non-Associated	458	381	1,035	75.8	12.4	11.8	500	0	41	0	200	0
Total Hugoton Field				Non-Associated							1,342	0	261	0	1,830	0

Note: (A) Btu Averages represent many more determinations than were available from the fractional analyses utilized.

(B) Representative of currently produced gas and does not correspond directly to Btu averages, primary source Bureau of Mines analyses prior to 1945.

(C) Open flow potentials not measured. Deliverability factor used for proration of production.

(D) Adjusted for proved drilled reserves totaling 58,600 million cubic feet and proved undrilled reserves totaling 1,655,200 million cubic feet available as of January 1, 1949 contracted for after that date.

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Data Concerning Natural Gas Reserves
in the Hugoton Field as of
January 1, 1949

Gas Production Statistics in Thousand Cu Ft				Estimated Remaining Recoverable Gas Reserves in Million Cu Ft as of 1-1-49						Estimated Remaining Recoverable Gas Reserves Available in Million Cu Ft As of 1-1-49			
Estimated Average Daily Rate, 1948	Estimated Daily Allowable Productive Capacity of Shut-In Wells	Estimated Total Open Flow Capacities of All Wells in Field	Estimated Daily Gas Production Available for a Synthetic Fuel Plant, 1-1-49	Proved Drilled	Proved Undrilled	Probable	Total	Under Contract	To be Used in Field	Proved Drilled	Proved Undrilled	Probable	Total
22,033	7,000		0	407,592	890,308	0	1,297,900	1,291,900	6,000	0	0	0	0
94,899	6,000		0	1,764,370	1,406,730	0	3,171,100	2,949,100	222,000	0	0	0	0
0	800		0	20,000	112,000	0	132,000	131,800	200	0	0	0	0
43,619	0		0	748,595	1,081,805	0	1,830,400	1,825,400	5,000	0	0	0	0
67,152	25,600		0	1,083,230	875,470	69,400	2,028,100	1,860,700	101,400	0	0	66,000	66,000
13,992	16,900		0	393,484	274,016	33,500	701,000	665,500	2,000	0	0	33,500	33,500
11,924	0		0	223,197	893,603	28,000	1,144,800	1,112,800	4,000	0	0	28,000	28,000
852	17,100		0	631,597	233,703	28,000	893,300	891,800	1,500	0	0	0	0
257,134	18,450		0	2,867,460	940,340	0	3,807,800	3,541,000	266,800	0	0	0	0
511,605	91,850	-(C)	0	8,139,525	6,707,975	158,900	15,006,400	14,270,000(D)	608,900	0(D)	0(D)	127,500	127,500

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Exhibit No. B-4

Depositories for Detailed Data Relating to Estimated Natural Gas Reserves in Kansas

The Bureau of Mines has informed the Office of Chief of Engineers, Department of the Army, that it will furnish the following depository libraries with bound copies of the "Estimated Natural Gas Reserves in Kansas", where they will be available for public inspection:

Central Library
Department of the Interior
Washington 25, D.C.

Library of Congress
Washington, D.C.

Bureau of Mines Library
4800 Forbes Street
Pittsburgh 13, Pennsylvania

Bureau of Mines Library
Bartelsville, Oklahoma

Bureau of Mines
810 Barfield Building
Amarillo, Texas

Bureau of Mines Library
Petroleum Field Office, Rm.1909
1114 Commerce Street
Dallas 2, Texas

Bureau of Mines Library
Petroleum and Oil Shale Experiment Station
University of Wyoming
Laramie, Wyoming

Bureau of Mines Library
1415 Appraisers Building
630 Sansome Street
San Francisco 11, Calif.

Bibliography

1. Committee, Petroleum Industry, "Report on Natural Gas Production and Reserves, District 2", Petroleum Administration for War, 1943.

2. DeGolyer and MacNaughton, Twentieth Century Petroleum Statistics, Dallas, Texas, 1949.

3. Jewett, John Mark, "Oil and Gas in Eastern Kansas", Bulletin 77, Kansas State Geological Survey, University of Kansas, Lawrence, 1949.

4. Morgan, T.A., "The Oil and Gas Industry in Kansas", Oil and Gas Conservation Division, Kansas State Corporation Commission, Wichita, Kansas, 1943.

5. Ver Wiebe, W.A., "Western Interior Province - Kansas", North American and Middle East Oil Fields, University of Wichita, 1950. pp 63-72.

6. Ver Wiebe, W.A., Jewett, J.M., and Nixon, E.K., "Oil and Gas Developments in Kansas During 1948", Bulletin 78, Kansas State Geological Survey, University of Kansas, Lawrence, 1949.

7. Certain public records of the Federal Power Commission, Washington, D.C.

In addition, all publications of the Kansas State Geological Survey relating to oil and gas resources were consulted in the preparation of this report.

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Exhibit No. B-6

Acknowledgments

1. Camp, R.H., Vice President, Consolidated Gas Utilities Company, Oklahoma City, Oklahoma.

2. Dickinson, J.G. Jr., Vice President, Texoma Natural Gas Company, Amarillo, Texas.

3. Hinton, C.H., Superintendent of Production and Reserves, Panhandle Eastern Pipe Line Company, Liberal, Kansas.

4. Hirshfield, Norman, President, Consolidated Gas Utilities Company, Oklahoma City, Oklahoma.

5. Hoffman, C.C., Superintendent of Land and Geological Department, Cities Service Gas Company, Oklahoma City, Oklahoma.

6. Morgan, Bernie, Gas Engineer, Canadian River Gas Company, Amarillo, Texas.

7. Page, J.H., General Manager, Eastern Kansas Gas Company, Iola, Kansas.

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State of Kansas
Gas Purchase Contract Data (A)

Location	Name of Gas Purchaser	Term of Contract (Years)	Price per Mcf, 1948 (Cents) (B)	Range in Price per Mcf for Contract Term (Cents)
EASTERN KANSAS				
Various Fields and Cities Service Gas	Union Gas System, Inc.	-	8.8¢	-
Johnson County				
Gardner Field	Cities Service Gas Co.	-	11.19	-
Marion County				
Various Fields	Kansas Power and Light Co.	-	6.71	-
WESTERN KANSAS				
Various Counties				
Hugoton Field	Cities Service Gas Company	20	6.72	6.72 - 8.95¢
		20	7.05	-
	Colorado Interstate Gas Co.	20	-	5.0 - 6.5
	Kansas-Colorado Utilities Co.	Life of Production?	-	4.48 - 8.96

Note: (A) State Kansas Law setting minimum wellhead price at 8 cents per Mcf at 16.4 psi under litigation at present time.
(B) Prices calculated at 14.65 psi and 60° Fahrenheit.

The tabulation gives representative gas purchase contract data for certain fields and/or purchasers where the details were available.

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State of Kansas
Gas Purchase Contract Data (A)

Location	Name of Gas Purchaser	Term of Contract (Years)	Price per Mcf, 1948 (Cents) (B)	Range in Price per Mcf for Contract Term (Cents)
WESTERN KANSAS				
Various Counties				
Hugoton Field (Cont'd)	Kansas-Nebraska Natural Gas Co.	Life of Production	-	6.71 till 1972, then 2.24 plus royalties
		5 to 20	3.9 - 5.0	-
	Kansas Power and Light Co.	15	-	12.20 Minimum
	Northern Natural Gas Pipe Line Co.	20	6.72	6.72 - 11.19
		20	5.93	5.93
		Life of Production	-	11.75 Minimum
		Various Terms	-	4.48 - 7.84
		15	7.6	-
	Panhandle Eastern Pipe Line Co.	5 to Life of Production	4.0	3.5 - 5.0
Barber County				
Boggs Field	Kansas Power and Light Co.	-	6.71	-
Deerhead Field	" " " " "	-	6.71	-
Lake City Field	" " " " "	-	6.71	-
Whelan Field	" " " " "	-	6.71	-
Barton County				
Eberhart Field	Cities Service Gas Co.	Life of Production	4.48	-
Otis Field	Northern Natural Gas Co.	" " "	4.81	-
Silica Field	Cities Service Gas Co.	-	5.60	-
Edwards County				
Various Fields	Kansas Power and Light Co.	-	4.48	-

Exhibit No. B-7
Page 2 of 3

State of Kansas
Gas Purchase Contract Data (A)

Location	Name of Gas Purchaser	Term of Contract (Years)	Price per Mcf, 1948 (Cents) (B)	Range in Price per Mcf for Contract Term (Cents)
WESTERN KANSAS				
Harvey County				
Burrton Field	Cities Service Gas Co.	Life of Production	6.71	-
McPherson County				
Various Fields	Kansas Power and Light Co.	Various Terms	4.48 - 8.95	-
Pawnee County				
Pawnee Rock Field	Northern Natural Gas Co.	Year to year	7.61	-
Various Fields	Kansas Power and Light Co.	-	5.6 - 6.71	-
Various Fields	Kansas-Nebraska Natural Gas Co.	Life of Wells	3.35	-
Pratt County				
Coats Field	Kansas Power and Light Co.	-	6.71	-
Various Fields	" " " " "	-	5.59	-
Chitwood Field	Cities Service Gas Co.	Life of Production?	5.04	-
Cunningham Field	" " " "	" " "	6.49	-
Rice County				
Haferman Field	Cities Service Gas Co.	-	4.48	-
Lyons Field	" " " "	-	3.36	-
Orth Field	" " " "	-	4.48	-
Rush County				
Various Fields	Kansas Power and Light Co.	-	8.95	-
Various Fields	" " " " "	-	12.17	-
Sedgwick County				
Schulte Field	Cities Service Gas Co.	-	5.82	-
Stafford County				
Various Fields	Kansas Power and Light Co.	-	6.71	-

We, the undersigned subcontractors have read and are severally familiar with the over-all contents of this report on The Synthetic Liquid Fuel Potential of Kansas. Each of us individually approves, by his appended signature, of the report as written, insofar as it relates to conditions, conclusions, and recommendations with respect to the raw material forming his responsibility under his subcontract.

COAL

Paul Weir Company

Paul Weir Company, Incorporated

NATURAL GAS

De Golyer and MacNaughton

DeGolyer and MacNaughton

OIL SHALE

De Golyer and MacNaughton

DeGolyer and MacNaughton

WATER

Malcolm Pirnie Engineers

Malcolm Pirnie Engineers

OIL-IMPREGNATED STRIPPABLE DEPOSITS

Max W. Ball

Max W. Ball