Section 9

COST COMPARISONS OF ALTERNATIVE ROUTES FOR CONVERTING SRC-II OIL-TO-DISTILLATE FUELS

by

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I. Summary

The net whole liquid process product from the SRC-II coal liquefaction process (SRC-II syncrude) was refined in pilot plant facilities at Chevron Research Company. Advanced commercial petroleum processing technology was employed to produce distillate fuels: gasoline, kerosene jet fuel, diesel, and heating fuel. Six alternate refining routes were evaluated, each involving hydrotreating at one of several severities, followed by either hydrocracking or fluid catalytic cracking when further reduction of boiling point was needed.

SRC-II syncrude presents unusual refining problems. It is notable for high nitrogen and oxygen contents and is composed mainly of cyclic compounds.

The key to the successful refining of SRC-II syncrude is an effective initial hydrotreating step. This removes the contaminants, increases the hydrogen content, and permits the use of conventional hydrocracking or fluid catalytic cracking for further conversion.

Refining costs were estimated for each of the six processing routes based on producing 50 MBPCD of transportation or heating fuels from a "grass roots" refinery, that is, a complete new refinery which includes all of the necessary supporting facilities, such as utility plants, tankage, and required environmental control equipment. In addition, a number of variations on the six basic cases were explored.

Typical yields of finished products ranged from 88 to 91 liquid volume percent of feed.

Refining costs to convert SRC-II syncrude to transportation fuels were estimated to be $14 per barrel of product for a product slate of both motor gasoline and jet fuel or $16 per barrel to produce motor gasoline only. Costs would drop significantly if products other than transportation fuels are to be produced. Processing cost would be about $10 per barrel if No. 2 furnace oil is the major product.

These costs are exclusive of any cost for the SRC-II oil itself. Partial integration with an SRC-II plant could result in reductions of the above costs, as could integrating the facilities with an existing petroleum refinery. Both of these alternatives are worth further study.

The desired product slate was the main factor causing differences in refining costs. A given product slate can often be made by different refining routes at nearly the same costs. One exception is that for making all gasoline, hydrocracking is significantly more efficient than catalytic cracking, mainly because the catalytic cracking feed must be more severely hydrotreated to attain sufficient conversion to desired products.

The total cost of producing finished liquid fuels from coal would include the processing costs mentioned above and also the following additional costs: resource acquisition, coal mining, handling, liquefaction, waste disposal, transportation of raw SRC-II oil and finished products, and community and support facilities.

II. Introduction

This work was done for the Department of Energy under Contract No. EF-76-C-01-2315. Results are reported in

File EF-2315-47, Distribution Category UC-90D. Also included in this file are the results of the laboratory and pilot plant studies which form the basis for the work presented here.

The refining cost of a crude oil can vary widely, depending on many factors, such as crude oil properties, refinery capacity, type of processing, desired products, and refinery location, among others. To estimate the possible range of SRC-II oil refining costs, a series of refining plans was developed based on the different initial hydrotreating severities demonstrated in the pilot plant studies. Hydrotreating severity can be defined in a number of ways. For this study, it was defined by hydrogen consumption and arbitrarily classified into three levels as shown in Figure 1 (horizontal axis).

In broad outline, the refinery plans consist of:

Case	Major Processing	Desired Products
1	High Severity Hydrotreating	Motor Gasoline Kerosene Jet Fuel
2	Intermediate Severity Hydrotreating Plus Further Downstream Hydrotreating	Motor Gasoline Kerosene Jet Fuel
3	High Severity Hydrotreating Plus Fluid Catalytic Cracking	Motor Gasoline
4	Intermediate Severity Hydrotreating Plus Recycle Hydrocracking	Motor Gasoline
5	Moderate Severity Hydrotreating	Motor Gasoline No. 2 Oil
6	Moderate Severity Hydrotreating Plus Fluid Catalytic Cracking	Motor Gasoline No. 2 Oil

The refinery plans are based on the use of advanced, state-of-the-art, commercially proven technology. At the heart of each processing plan are Chevron-licensed processes well suited to refining this feedstock. The hydrotreating and hydrocracking plants are based on the Chevron hydrotreating and Isocracking processes, catalytic reforming on the Rheniforming process, and waste water processing for hydrogen sulfide and ammonia recovery on the Chevron WWT process. Process conditions and yields for the various refinery units are based directly on the laboratory and pilot plant data obtained for this project, as well as on general petroleum processing correlations.

The primary basis is to produce 50,000 BPCD of the desired products in a "grass roots" refinery; that is, a complete new refinery which includes all necessary supporting facilities such as utility plants, tankage, and required environmental control equipment. This product rate was selected because the SRC-II oil feed rate would be close to the maximum size SRC-II plant as the process is presently conceived. The desired products were transportation fuels (motor gasoline, kerosene jet fuel, and/or diesel fuel) for the main cases in the study (1-4). Production of No. 2 oil was allowed for Cases 5 and 6 to explore cost sensitivity.

A number of variations on the basic six cases were explored:

. Single versus two-stage hydrocracking.

- Burning SRC-II oil versus hydrotreated products in refinery furnaces.

- Hydrogen production by partial oxidation of SRC-II oil versus steam reforming of refinery gases and naphtha.

- Separate naphtha and middle distillate versus whole oil initial hydrotreating.

- Partial integration with the SRC-II process versus grass roots facilities.

III. Processing Plans

Figures 2-6 show the refinery plans in the form of block flow diagrams. These diagrams are meant to point out differences in the overall refinery arrangements and, hence, do not show details within the process plants. Different refining plans were developed to best utilize the different initial hydrotreating severities demonstrated in the pilot plant work.

The first plan (Figure 2) is centered around high severity hydrotreating of the whole SRC-II oil. Specification kerosene jet fuel and naphtha suitable for single-stage reforming are produced in a single step. The middle distillate produced here could also be used as diesel fuel. The greatest advantage of this plan is its simplicity.

Case 2 (Figure 3) uses intermediate severity hydrotreating, followed by separate downstream hydrotreating of naphtha and middle distillate to produce reformer feed and jet fuel. This case was included to see if "tailored" processing could reduce costs enough to justify the added complication.

Figure 4 shows the processing arrangement for Cases 3 and 6 in which fluid catalytic cracking is used to reduce the boiling range of the hydrotreated SRC-II oil. One object of Case 3 was to produce all motor gasoline, for which severe hydrotreating is necessary to allow high enough catalytic cracking conversion. Case 6, on the other hand, uses moderate hydrotreating, allowing lower conversion in the catalytic cracker and some production of No. 2 oil. The use of alkylation is marginal in either case under the ground rules of the study. It was used in the low conversion case to increase the ratio of gasoline to No. 2 oil. A comparison of Cases 3 and 6 will show the effect of changing hydrotreating severity and, hence, attainable cracking conversion.

Case 4 (Figure 5) uses a recycle hydrocracker to produce motor gasoline as the only desired product. This case will show whether the large liquid volume expansion resulting from hydrocracking can reduce overall refinery cost compared to the jet fuel cases because of the ground rule to make a constant amount of desired products while letting feed rate vary. By producing all gasoline, it will also show one extreme in defining the effect of required product distribution on refinery costs. For this case, the initial hydrotreating severity, selected to provide essentially complete nitrogen removal, fell at the high end of the intermediate range. Different hydrotreating severities were examined, and it was found that there was little to choose economically between one- and two-step hydrotreating ahead of the Isocracker. The case presented here was chosen because it was the simplest.

Case 5 (Figure 6) uses a similar refinery arrangement to Case 1, except that the initial hydrotreating severity is now moderate and further naphtha hydrotreating is now required. The middle distillate product is now No. 2 oil instead of jet fuel. This case was included to give some idea of the effect on refinery cost of relaxing the ground rule to make only transportation fuels.

Each plan represents a completely feasible and reasonably efficient refinery arrangement. A more detailed optimization of conditions, cut points, and other factors, while not within the scope of this study, would be carried out in the course of a normal refinery design.

Simplified flow diagrams for the hydrotreating, hydrocracking, and WWT plants are shown in Figures 7, 8, and 9. The diagrams are provided for readers unfamiliar with these Chevron-licensed processes. WWT plants are included in the processing schemes not only to allow recycling of most of the process water for use within the process plants but also to produce about 100 tons per day of salable ammonia from the large quantity of nitrogen removed by hydrotreating SRC-II oil.

Complete feed properties are given in Table 7. One assumption in these studies is that the feed properties will be typical of actual operation of a full-scale SRC-II plant. Although only time will tell whether this assumption is completely valid, there was concern about whether handling and storage of the feed sample had resulted in a significant loss of lower boiling material. Figure 10 compares the boiling point curve of the actual feed sample with an estimate for the full-scale process received from the contact office. Although the curves obviously differ, the lower boiling portions would be almost identical if the amount of butanes given for the full-scale estimate (4.6 LV %) were added to the actual feedstock. With the permission of the contact officer, the assumption was made for the engineering studies that the SRC-II oil would contain that amount of butanes.

Tables 1-6 show yields and product qualities for the hydrotreaters and hydrocrackers used in each of the processing arrangements. This information is based directly on the laboratory results (Reference 1) with some minor adjustments to represent average yields over an entire operating cycle.

IV. Stock Balances

Detailed stock balances were developed for each refining arrangement using different sets of assumptions, explained below. Estimates of finished gasoline production were made by using correlations for catalytic reforming of naphtha and blending of gasoline components. Correlations could be used in this case because the properties of the reformer feeds distilled from the pilot plant hydrotreater products were well wihin Chevron's range of experience on petroleum stocks. Reforming was remarkably mild compared to petroleum stock because of the exceptionally high ring content of the feeds. Gasoline blending objectives were to make a single unleaded pool meeting accepted industry specifications for quality with minimum octane numbers of 93 Research (F-1 clear), 84 Motor (F-2 clear), and 89 (Research + Motor)/2. These octane numbers are typical of those projected for the average market during the early 1980's. Table 15 lists the refinery product inspections and specifications. Properties of the middle distillates are discussed in Reference 1. Both kerosene jet fuel and No. 2 heating oil meet all specifications except density, not a critical specification in either case.

One series of detailed stock balances is shown in Tables 8-12 and summarized in Table 14 designated by the letter A. This series was based on the requirement to meet refinery furnace fuel and hydrogen plant feed requirements with internally supplied clean fuels, ensuring minimum air emissions. Boiler plants, however, were assumed to be coal-fired in compliance with present DOE regulations.

In examining this series of stock balances, it was apparent that stocks which could be used as transportation fuels were being consumed in the refinery furnaces. Another set of stock balances was, therefore, developed based on burning untreated SRC-II oil instead. The detailed balances are not included here, but the results are summarized in Table 14 (designated by the letter B). SRC-II oil has been tested as a burner fuel with encouraging results (Chemical and Engineering News, January 1979).

Comparing the stock balance results shows that burning untreated SRC-II oil instead of hydrotreated products can save about 1% of the feedstock at constant product rate.

Another alternative suggested itself in examining the stock balances. Potential transportation fuels were also being used as hydrogen plant feed. Partial oxidation of SRC-II oil was, therefore, included in the studies. Yield and cost estimates for partial oxidation were obtained from Texaco Corporation. A stock balance showing this alternative for Case 1 is shown in Table 13. Stock balance results for this alternative on other refining arrangements are summarized in Table 14 (designated by the letter C). The savings in feed can be 3% to 6%, depending on the case examined.

Although this work was mainly directed toward examining grass roots refineries, it seemed worthwhile to gain some idea of how much benefit there could be in integrating with the SRC-II plant. Stock balances were, therefore, developed for Cases 1, 4, and 5 in which gas from the SRC-II process is used as refinery fuel and hydrogen plant feed.

Results from these stock balances are included in Table 14, designated by the letter D. As would be expected, this alternative allowed a larger saving of feed, amounting to 10-15% over the base.

The following table gives an overall summary of the stock balance results:

Volume Percent Yield of Desired Products on SRC-II Oil Feed

Refinery Fuel:		Hydro-treated Product	SRC-II Oil Feed		
Hydrogen Plant Feed:		Refinery Gas and Naphtha	Refinery Gas and Naphtha	SRC-II Oil Feed	Outside Gas
Desired Products	Major Processing				
Motor Gasoline	Hydro-treating Plus Hydro-cracking	88.5	89.2	91.8	95.3
	Hydro-treating Plus Fluid Catalytic Cracking	84.3	84.3	88.3	-
Motor Gasoline Plus Kerosene Jet Fuel	Severe Hydro-treating	83.5	84.1	88.3	97.7
	Inter-mediate Plus Downstream Hydro-treating	84.7	84.7	88.6	-
Motor Gasoline Plus No. 2 Oil	Moderate Hydro-treating	87.4	88.3	90.0	94.8
	Moderate Hydro-treating Plus Fluid Catalytic Cracking	-	-	90.2	-

Using the overall yield criteria, some further observations can be made about the efficiency of the different processing arrangements. Under the ground rules, hydrocracking yields 3% to 4% more gasoline than fluid catalytic cracking without alkylation. (Adding alkylation to the high conversion fluid catalytic cracking case improves the overall gasoline yield by about 0.5%.) When making gasoline and jet fuel, two-step hydrotreating improves the yield by about 0.5% over one-step hydrotreating. Requiring jet fuel as a product will drop the yield efficiency by about 3% or 4% compared to either motor gasoline plus No. 2 oil or all gasoline, which give about the same yield.

In judging a refining plan, the yield efficiency needs to be combined with cost information, discussed below, as well as other factors such as flexibility, product demands and values, and smoothness of operation.

V. Cost Estimates

Investment costs and utility requirements for the whole oil and middle distillate hydrotreaters and hydrocrackers are given in Table 16. These were estimated from cost correlations of actual plants constructed by Standard Oil of California. Sizing of reactors was based directly on the bench-scale demonstrations discussed in Reference 1 along with petroleum processing correlations where appropriate. Overall plant investment costs for some of the refineries are broken down and detailed in Tables 18-23. Reforming costs reflect both the mild conditions required because of the high ring content of these stocks and the potential for catalyst fouling resulting from the bicyclic naphthene contents. (Reformer design, however, has not been optimized with reformer feed end point, a possible subject for further study.) Refining plans which use clean hydrotreated products as fuel are emphasized here. The same type of detailed estimates were carried out on all the options discussed. Results are summarized and compared in the next section.

Again, these estimates were developed using cost correlations based on actual plants constructed by Standard Oil of California during the period from the 1960's through the mid-1970's. The important bases for these estimates are summarized in Table 17. In addition to adjustments for inflation, plant capacity, and location, the base estimates include allowances for other factors. These are:

- Estimated accuracy of the cost correlations themselves.

- A less favorable field labor productivity and materials purchasing situation--likely to be experienced if the U.S. enters into a significant program of synthetic fuels construction.

- Changes in plant design philosophy to provide for improved operating efficiency, better reliability, increased safety, additional energy conservation, and stricter environmental requirements.

Also shown separately are allowances to cover the cost of items which the history of major projects show are encountered as the detailed project engineering proceeds. Investments are categorized as "onplot," those directly concerned with the individual refinery process plants, and "offplot" for auxiliary or supporting facilities such as utility plants and tankage. The investments are based on First Quarter 1980 costs, excluding escalation for the planning, design, and construction period.

The boiler plant estimates are based on coal-fired burners with attendant stack gas sulfur dioxide removal facilities. Where SRC-II oil is burned directly in refinery furnaces, extra facilities were included for reduction of nitrogen oxides in the emitted gases. As indicated in Table 17, no allowance is included for (a) coal resource costs, (b) mining and handling of coal, (c) conversion of coal to oil by the SRC-II process, and (d) refined product distribution and transportation from the refinery. These additional costs are not required to evaluate refinery processing costs. However, they should be included if it is desired to determine the overall economics of a specific coal oil refining project.

The allowance for "infrastructure" is for roads, power lines, water supply, and effluent water disposal lines outside the refinery. It assumes that these services can connect to existing facilities within a few miles from the site. It does not include community facilities or electric power generation, which are also assumed to be existing.

As mentioned previously, most of the estimates assumed that complete new refining facilities would be constructed. Estimates were also developed for Cases 1, 4, and 5 which assumed partial integration with the SRC-II plant, e.g., sharing of the offplot boiler plant and office buildings. Further study along this line might be desirable because integration could proceed to sharing of the partial oxidation plant already in the SRC-II complex.

VI. Cost Comparison

Tables 24, 25, and 26 summarize the cost estimates and compare the results in a standard manner. Factors used for labor, maintenance, taxes, and insurance are typical of those used in analyzing long-term, large-scale commercial projects. The capital charge factor, the yearly rate at which the investment is charged to the project, was chosen to provide about a 15% aftertax discounted cash flow rate of return on investments based on reasonable and commonly used assumptions for projects of this type and magnitude. These assumptions are summarized in Table 17.

Table 24 compares the cost of different refining arrangements making different product slates but with the common basis that refinery furnace fuel and hydrogen plant feed are supplied by internally generated hydrotreated products. Product distribution is by far the most important factor in determining refining cost of SRC-II oil. For the same product distribution, the effects of markedly different refining facilities are almost insignificant. Table 24 could be further summarized as follows:

Product Slate	Motor Gasoline and Heating Oil	Motor Gasoline and Jet Fuel	Motor Gasoline
Minimum Total Investment, $MM	500	700	800
Minimum Processing Cost, $/Bbl Product	10	14	16

As mentioned previously, the processing cost is exclusive of any cost for the SRC-II oil itself.

The table also shows that lower severity initial hydrotreating followed by separate downstream hydrotreating of naphtha and middle distillate can save a half dollar per barrel over one-step severe hydrotreating. This difference is marginally significant within the accuracy of the study.

Considering this result, it is natural to ask whether splitting the naphtha and middle distillate before hydrotreating rather than after would be a better choice. Based on cost alone and at intermediate or high severity, it is not. A brief comparison of these two options at intermediate severity follows:

Distillate Hydrotreater	Whole Oil	400°F+
Bbl/Operating Day	62,000	44,000
Onplot Investment, $MM	63	57
Naphtha Hydrotreater	Hydrotreated	Raw
Onplot Investment, $MM	14	23
Total Onplot Investment, $MM	77	80

The difference between the options is greater at high severity. The option of separate naphtha hydrotreating was not studied for the situations where only moderate distillate hydrotreating severity is required. It is likely to be more economical in those cases and would be worth further study if transportation fuels were not the primary objective.

Another observation from Table 24 is that for making all gasoline, catalytic cracking is significantly more expensive than hydrocracking. The main reason for this is that catalytic cracking requires high severity hydrotreating of the feed to reach high enough conversion, whereas hydrocracking requires only intermediate severity hydrotreating. Also, while hydrocracking to gasoline does reduce the required capacity of the initial hydrotreater compared to the jet fuel cases (refer back to Table 14), the cost of the extra processing far overwhelms this effect.

Costs were also estimated for the same refining plans when burning untreated SRC-II oil in the refinery furnaces. Results, not included here, show no significant differences from those in Table 24. As mentioned previously, there is about 1% less feed required for the same product when burning SRC-II oil instead of refinery products.

Table 25 compares the costs of the different refining arrangements with the common basis that refinery fuel and hydrogen plant feed are supplied by SRC-II oil. In these cases, the costs include nitrogen oxide reduction facilities on the refinery furnace gases and partial oxidation rather than steam reforming for hydrogen production. Overall costs are again not significantly different from those in Table 24, although there is 3% to 6% less feed required.

Costs are shown on Table 25 for one scheme which was not shown on the previous table, that is, moderate hydrotreating plus fluid catalytic cracking. Its only possible advantage is that it reduces the amount of No. 2 oil from that produced by moderate hydrotreating but at a cost almost as high as the all-gasoline cases.

Table 26 summarizes the results of cost estimates for refineries assumed to be integrated with the SRC-II plant to the extent that they would share offplot facilities and use the SRC-II gas as refinery fuel and hydrogen plant feed. Comparing the results with those on the previous table shows that most of the savings are in the offplot costs. Onplot costs are also lower because gas-fed hydrogen plants are less expensive per unit of capacity. Of course, further savings are possible by more complete integration of the two refining complexes. While outside the scope of this work, this is a likely area for future study.

Cost savings could also result if the facilities were integrated with an existing petroleum refinery because onplot and offplot equipment could be shared. Also, the low paraffinicity of coal-derived stocks compared to petroleum could be beneficial to reforming and both gasoline and distillate blending if the two oil types were refined together. While beyond the scope of this study, Co-Refining of coal and petroleum oils in existing refineries is the most likely path for growth for an oil-from-coal industry and is a highly promising area for future work.

The costs discussed here are all based on refineries producing 50,000 barrels per day of finished products. Required feed rate would about match the output of a single maximum size SRC-II plant. Although detailed estimates were not carried out in this study for other throughput capacities, general experience indicates that the effect of capacity on total cost can be estimated fairly accurately. Total investment for a refinery producing 100,000 barrels per day of finished products would be about 160% of that for 50,000 barrels per day products, while cost per barrel would be about 80% of that for the lower rate.

VII. Conclusions

A "grass roots" refinery in a midcontinent location producing 50,000 BPCD of finished motor gasoline and high quality jet fuel from SRC-II oil would cost at least $700 MM to build now (First Quarter 1980) and would result in a minimum total processing cost of about $14 per barrel of products. This is exclusive of any cost for the SRC-II oil itself.

The main factor causing differences in refining costs was found to be the product slate desired. A given product slate can be made by different refinery routes at nearly the same costs.

Producing all gasoline would add about $100 MM investment and about $2 per barrel to the costs for a gasoline plus jet fuel product slate.

Costs would drop significantly if all transportation fuels were not required: Investment would be about $500 MM and processing cost about $10 per barrel is production of No. 2 furnace oil were allowed.

For making all gasoline, hydrocracking is significantly more efficient than catalytic cracking, mainly because the catalytic cracking feed must be more severely hydrotreated to attain sufficient conversion.

Producing hydrogen by partial oxidation of SRC-II oil results in about the same overall cost as does steam reforming of internally generated gas and naphtha.

Overall costs would be lower if the refining facilities were integrated with the SRC-II plant. There could be cost savings and additional refinery benefits if the SRC-II oil were processed along with petroleum at the site of an existing refinery.

VIII. References

1. "Refining and Upgrading of Synfuels from Coal and Oil Shales by Advanced Catalytic Processes--Third Interim Report; Processing of SRC-II Syncrude," R. F. Sullivan, H. A. Frumkin; April 30, 1980; U.S. Department of Energy Contract No. EF-76-C-01-2315; File FE-2315-47; Distribution Category UC-90D.

COST COMPARISONS OF ALTERNATIVE ROUTES FOR CONVERTING SRC-II TO DISTILLATE FUELS

Index of Enclosures

Tables	Title	Drawing No.
1	Yields and Product Inspections; High Severity Hydrotreating of Whole SRC-II Oil; Cases 1 and 3	RD 793135-2
2	Yields and Product Inspections; Intermediate Severity Hydrotreating of Whole SRC-II Oil; Case 2	RD 793136-2
3	Yields and Product Inspections; Hydrotreating of 300-550°F Product from Intermediate Severity Hydrotreating; Case 2	RD 793137-2
4	Yields and Product Inspections; Intermediate Severity Hydrotreating of Whole SRC-II Oil, Case 4	RD 793141-2
5	Yields and Product Inspections; Single-Stage Recycle Isocracking of 300°F+ Product from Intermediate Severity Hydrotreating of SRC-II Oil; Case 4	RD 793142-2
6	Yields and Product Inspections; Moderate Severity Hydrotreating of Whole SRC-II Oil; Cases 5 and 6	RD 793138-2
7	Properties of Whole SRC-II Oil	RE 794998-1
8	Stock Balance - Case 1A; Refining SRC-II Oil by High Severity Hydrotreating to Produce 50,000 Barrels per Calendar Day of Motor Gasoline Plus Jet Fuel	RD 793389-3
9	Stock Balance - Case 2A; Refining SRC-II Oil by Intermediate Severity Hydrotreating to Produce 50,000 Barrels per Calendar Day of Motor Gasoline Plus Jet Fuel	RD 793390-3
10	Stock Balance - Case 3A; Refining SRC-II Oil by High Severity Hydrotreating and Fluid Catalytic Cracking to Produce 50,000 Barrels per Calendar Day of Motor Gasoline	RD 793391-3

COST COMPARISON OF ALTERNATE ROUTES
FOR CONVERTING SRC-II TO DISTILLATE FUELS

Index of Enclosures

Tables	Title	Drawing No.
11	Stock Balance - Case 4A; Refining of SRC-II Oil by Intermediate Severity Hydrotreating and Single-Stage Isocracking to Produce 50,000 Barrels per Calendar Day of Motor Gasoline	RD 804941
12	Stock Balance - Case 5A; Refining of SRC-II Oil by Moderate Severity Hydrotreating to Produce 50,000 Barrels per Calendar Day of Motor Gasoline Plus No. 2 Oil	RD 793393-3
13	Stock Balance - Case 1C; Refining of SRC-II Oil by High Severity Hydrotreating to Produce 50,000 Barrels per Calendar Day of Motor Gasoline Plus Jet Fuel	RD 796618-1
14	Stock Balance Summary; Refining of SRC-II Oil to Produce 50,000 Barrels per Day of Desired Products	RB 794999-1
15	Refinery Product Inspections; Refining of SRC-II Oil	RC 793394-2
16	Investment and Utility Summary; Hydrotreaters and Isocrackers; Refining of SRC-II Oil	RL 804942
17	Bases for Cost Estimates and Comparisons; Refining of SRC-II Oil	RL 793395-4
18	Estimates of Investments and Utilities - Case 1A; Refining of SRC-II Oil by High Severity Hydrotreating to Produce 50,000 Barrels per Calendar Day of Motor Gasoline Plus Jet Fuel	RC 793396-1
19	Estimates of Investments and Utilities - Case 2A; Refining of SRC-II Oil by Intermediate Severity Hydrotreating to Produce 50,000 Barrels per Calendar Day of Motor Gasoline Plus Jet Fuel	RC 793397-1

COST COMPARISONS OF ALTERNATE ROUTES FOR CONVERTING SRC-II OIL TO DISTILLATE FUELS

Index of Enclosures

Tables	Title	Drawing No.
20	Estimates of Investments and Utilities - Case 3A; Refining of SRC-II Oil by High Severity Hydrotreating and Fluid Catalytic Cracking to Produce 50,000 Barrels per Calendar Day of Motor Gasoline	RC 795001
21	Estimates of Investments and Utilities - Case 4A; Refining of SRC-II Oil by Intermediate Severity Hydrotreating and Single-Stage Isocracking to Produce 50,000 Barrels per Calendar Day of Motor Gasoline	RC 804943
22	Estimates of Investments and Utilities - Case 5A; Refining of SRC-II Oil by Moderate Severity Hydrotreating to Produce 50,000 Barrels per Calendar Day of Motor Gasoline Plus No. 2 Heating Oil	RC 793400-1
23	Estimates of Investments and Utilities - Case 1C; Refining of SRC-II Oil by Moderate Severity Hydrotreating to Produce 50,000 Barrels per Calendar Day of Motor Gasoline Plus Kerosene Jet Fuel	RC 796614-1
24	Comparative Cost Summary; Refining of SRC-II Oil; Grass Roots Refineries Producing 50,000 BPCD of Desired Products; Refinery Furnace Fuel and Hydrogen Plant Feed Supplied by Internally Generated Hydrotreater Products	RC 804944
25	Comparative Cost Summary; Refining of SRC-II Oil; Grass Roots Refineries Producing 50,000 BPCD of Desired Products. Refinery Furnace and Hydrogen Plant Feed Supplied by SRC-II Oil Feedstock	RC 804945
26	Comparative Cost Summary; Refining of SRC-II Oil; Refineries Partially Integrated with SRC-II Process; 50,000 BPCD of Desired Products; Refinery Fuel and Hydrogen Plant Feed Supplied by Gas from SRC-II Process	RD 804946

COST COMPARISONS OF ALTERNATE ROUTES
FOR CONVERTING SRC-II OIL TO DISTILLATE FUELS

Index of Enclosures

Figures	Title	Drawing No.
1	Characterization of Severities - Initial Hydrotreating of SRC-II Oil	RE 796680
2	Schematic Flow Diagram; Refining of SRC-II Oil by High Severity Hydrotreating; Case 1	RD 796681
3	Schematic Flow Diagram; Refining of SRC-II Oil by Intermediate Severity Hydrotreating; Case 2	RD 796682
4	Schematic Flow Diagram; Refining of SRC-II Oil by Hydrotreating and Catalytic Cracking; Cases 3 and 6	RD 796683
5	Schematic Flow Diagram; Refining of SRC-II Oil by Hydrotreating and Hydrocracking; Case 4	RD 804940
6	Schematic Flow Diagram; Refining of SRC-II Oil by Moderate Severity Hydrotreating; Case 5	RD 796685
7	Simplified Flow Diagram of Chevron First-Stage Hydrotreating	RE 796686
8	Simplified Flow Diagram of Chevron Recycle Isocracking	RE 796687
9	Simplified Flow Diagram of Chevron WWT Process	RE 796688
10	Comparison of SRC-II Oil Boiling Curves: Actual Samples Versus Commercial Estimate	RE 796689

TABLE 1

YIELDS AND PRODUCT INSPECTIONS
HIGH SEVERITY HYDROTREATING OF
WHOLE SRC-II OIL - CASES 1 AND 3
DOE CONTRACT EF-76-C-01-2315

Process Yields				
		Raw Feed Basis		
	Weight Percent of Input Hydrocarbon	Pounds per 100 Barrels	Barrels per 100 Barrels	Chemical Consumption, SCF/Barrel
H_2				2950
H_2S	0.31	102		
H_2O	4.25	1,401		
NH_3	1.03	340		
C_1	0.2	66		
C_2	0.3	99		
C_3	0.4	132		
iC_4	0.01	3		
nC_4	0.2	66		
C_5-180°F	5.2	1,714	6.65	
180-300°F	26.8	8,836	32.6	
300-550°F	61.05	20,128	67.2	
550°F+	5.0	1,649	5.25	
Total	104.75	34,532	111.7	

Inspections						
		Products				
Stock	Raw Feed	C_5^+	C_5-180°F	180-300°F	300-550°F	550°F+
Gravity, °API	18.6	39.6	60	51	34	26.2
Aniline Point, °F		110		100	115	150
ASTM Distillation, °F	D 86/1160		D 86	D 86	D 86	
St/5	155/215		120/145	210/215	345/355	
10/30	280/380		155/160	220/225	360/380	
50	440		175	235	400	
70/90	485/595		180/185	245/265	425/475	
95/EP	700/850		190/210	275/315	490/530	
Composition, LV %						
Paraffins			28	8	4	13
Naphthenes			66	85	86	78
Olefins			-	-	-	-
Aromatics		9	6	7	10	9
Sulfur, ppm	2,900	5		1		
Total Nitrogen, ppm	8,500	0.2		<0.1		
Total Oxygen, ppm	37,900	50		20		
Bromine Number	70	1				
Neutralization Number						
Pour Point, °F	<-80				0.02	
Refractive Index	1.5073	1.4272			1.4385	1.4642
Freeze Point, °F					-90	
Smoke Point, °F					21	
Flash Point, TCC, °F					130	
Viscosity at -40°F/-4°F, cSt					12/6	
Octane Numbers						
F-1 Clear			81.5	67		
F-2 Clear			77.5	66.5		

TABLE 2

YIELDS AND PRODUCT INSPECTIONS
INTERMEDIATE SEVERITY HYDROTREATING OF
WHOLE SRC-II OIL - CASE 2
DOE CONTRACT EF-76-C-01-2315

Process Yields				
		Raw Feed Basis		
	Weight Percent of Input Hydrocarbon	Pounds per 100 Barrels	Barrels per 100 Barrels	Chemical Consumption, SCF/Barrel
H_2				1980
H_2S	0.31	102		
H_2O	4.25	1,401		
NH_3	1.03	340		
C_1	0.1	33		
C_2	0.2	58		
C_3	0.2	68		
iC_4	0.02	7		
nC_4	0.1	35		
C_5-180°F	5.25	1,731	6.7	
180-300°F	24.95	8,226	29.95	
300-550°F	58.73	19,347	62.3	
550°F+	8.05	2,654	8.05	
Total	103.19	34,022	107.0	

Inspections						
		Products				
Stock	Raw Feed	C_5^+	C_5-180°F	180-300°F	300-550°F	550°F+
Gravity, °API	18.6	34.1	59.9	48.7	27.9	19
Aniline Point, °F		65		80	50	95
ASTM Distillation, °F	D 86/1160		D 86	D 86		
St/5	155/215		120/145	210/215	345/360	
10/30	280/380		155/160	220/225	365/390	
50	440		175	235	410	
70/90	485/595		180/185	245/265	440/480	
95/EP	700/850		190/210	275/315	495/530	
Composition, LV %						
Paraffins			32	10	4	10
Naphthenes			60	73	42	52
Olefins			-	-	-	-
Aromatics		40	8	17	54	38
Sulfur, ppm	2,900	10		1	10	20
Total Nitrogen, ppm	8,500	40	1	5	50	100
Total Oxygen, ppm	37,900	850	20	100	1200	2000
Bromine Number	70	10				
Neutralization Number					0.04	
Pour Point, °F	<-80					
Refractive Index	1.5073				1.464	
Freeze Point, °F					-76	
Smoke Point, MM					11	
Flash Point, TCC, °F					140	
Viscosity at -40°F/-4°F, cSt					13/6	
Octane Numbers						
F-1 Clear			81	71		
F-2 Clear			77	68		

TABLE 3

YIELDS AND PRODUCT INSPECTIONS
HYDROTREATING OF 300-550°F PRODUCT FROM
INTERMEDIATE SEVERITY HYDROTREATING - CASE 2
DOE CONTRACT EF-76-C-01-2315

Process Yields				
	Weight Percent of Input Hydrocarbon	Raw Feed Basis		
		Pounds per 100 Barrels	Barrels per 100 Barrels	Chemical Consumption, SCF/Barrel
H_2	-			1150
C_1	0.02	6		
C_2	0.05	15		
C_3	0.20	62		
iC_4	0.06	19		
nC_4	0.06	19		
C_5-300°F	8.0	2,484	9.3	
300°F+	93.58	29,057	96.8	
Total	101.97	31,662	106.1	

Inspections			
Stock	Raw Feed	Products	
		C_5-300°F	300°F+
Gravity, °API	27.9	53	33.4
Aniline Point, °F	50		105
ASTM Distillation, °F	D 86		D 86
St/5	345/360		340/355
10/30	365/390		360/380
50	410		390
70/90	440/480		410/455
95 EP	495/530		475/525
Composition, LV %			
Paraffins	4		4
Naphthenes	42		80
Olefins	-		-
Aromatics	54		16
Sulfur, Wt %			
Total Nitrogen, ppm	50		
Total Oxygen, ppm	1200		
Refractive Index	1.464		
Pour Point, °F			
Freeze Point, °F	<-76		<-76
Smoke Point, mm	11		20
Flash Point, TCC, °F	140		140

TABLE 4

YIELDS AND PRODUCT INSPECTIONS
INTERMEDIATE SEVERITY HYDROTREATING OF
WHOLE SRC II OIL - CASE 4
DOE CONTRACT EF-76-C-01-2315

Process Yields

	Weight Percent of Input Hydrocarbon	Raw Feed Basis: Pounds per 100 Barrels	Raw Feed Basis: Barrels per 100 Barrels	Raw Feed Basis: Chemical Consumption, SCF/Barrel
H_2				2500
H_2S	0.31	102		
H_2O	4.25	1,401		
NH_3	1.03	340		
C_1	0.1	33		
C_2	0.2	63		
C_3	0.2	81		
iC_4	0.02	7		
nC_4	0.1	40		
C_5-180°F	5.3	1,747	6.8	
180-350°F	37.0	12,199	44.1	
350°F$^+$	55.52	18,286	59.2	
180-300°F	26.0	8,572	31.4	
300°F$^+$	66.52	21,913	71.9	
Total	104.03	34,299		

Inspections

Stock	Raw Feed	Products: C_5^+	Products: C_5-180°F	Products: 180-350°F	Products: 350°F$^+$	Products: 180-300°F	Products: 300°F$^+$
Gravity, °API	18.6	37.5	60	47.4	28.7	49.8	30.8
Aniline Point, °F		95		90	100	90	100
ASTM Distillation, °F	D 86/1160		D 86	D 86	D 1160	D 86	D 1160
St/5	155/215		120/145	220/230	385/395	210/220	330/350
10/30	280/380		155/160	235/245	400/415	225/230	360/390
50	440		175	260	435	235	420
70/90	485/595		180/185	285/310	470/535	245/270	465/535
95/EP	700/850		190/210	320/360	590/660	280/310	590/660
Composition, LV %							
Paraffins			20	7	7	8	6
Naphthenes			62	80	65	79	66
Olefins			-	-	-	-	-
Aromatics		21	8	13	28	13	28
Sulfur, ppm	2,900	10		1	12		10
Total Nitrogen, ppm	8,500	0.3		<0.1	0.35		0.32
Total Oxygen, ppm	37,900	80		50	120		100
Bromine Number	70						
Pour Point, °F	<-80						
Refractive Index	1.5073						
Octane Numbers							
F-1 Clear			81	65		70	
F-2 Clear			77	63		68	

TABLE 5

YIELDS AND PRODUCT INSPECTIONS
SINGLE-STAGE RECYCLE ISOCRACKING OF
300°F+ PRODUCT FROM INTERMEDIATE SEVERITY
HYDROTREATING OF SRC II OIL - CASE 4
DOE CONTRACT EF-76-C-01-2315

Process Yields				
	Weight Percent of Input Hydrocarbon	Raw Feed Basis		
		Pounds per 100 Barrels	Barrels per 100 Barrels	Chemical Consumption, SCF/Barrel
H_2				1520
C_1	0.05	9		
C_2	0.11	34		
C_3	3.6	1,104		
iC_4	10.9	3,330	16.9	
nC_4	2.9	887	4.3	
C_5^+	85.1	25,935		
C_5-180°F	26.75	8,150	33.1	
180-300°F	58.35	17,785	66.7	
Total	102.65	31,298	121.1	

Inspections				
		Products		
Stock	Raw Feed	C_5^+	C_5-180°F	180-300°F
Gravity, °API	30.8	58.8	69.7	54.1
Aniline Point, °F	100			115
ASTM Distillation, °F	D 1160		D 86	D 86
St/5	330/-		100/120	190/215
10/30	360/390		125/135	220/230
50	420		145	245
70/90	465/535		150/160	255/270
95/EP	-/660		165/185	280/305
Composition, LV %				
Paraffins	6			21.5
Naphthenes	66			71.5
Olefins	-			-
Aromatics	28			7
Sulfur, ppm	10			
Oxygen, ppm	100			
Total Nitrogen, ppm	0.32			
Octane Numbers				
F-1 Clear			86	74
F-2 Clear			87	68

TABLE 6

YIELDS AND PRODUCT INSPECTIONS
MODERATE SEVERITY HYDROTREATING OF
WHOLE SRC-II OIL - CASES 5 AND 6
DOE CONTRACT EF-76-C-01-2315

	Process Yields			
		Raw Feed Basis		
	Weight Percent of Input Hydrocarbon	Pounds per 100 Barrels	Barrels per 100 Barrels	Chemical Consumption, SCF/Barrel
H_2				1750
H_2S	0.30	99		
H_2O	4.21	1,388		
NH_3	0.97	320		
C_1	0.09	30		
C_2	0.17	56		
C_3	0.18	59		
iC_4	0.02	7		
nC_4	0.08	26		
C_5-180°F	4.5	1,484	5.8	
180-350°F	32.4	10,682	38.3	
350°F+	59.9	19,749	60.65	
180-300°F	26.5	8,737	31.9	
300°F+	65.8	21,694	67.05	
Total	102.82	33,900		

	Inspections						
		Products					
Stock	Raw Feed	C_5^+	C_5-180°F	180-350°F	350°F+	180-300°F	300°F+
Gravity, °API	18.6	30.9	60.9	46	20.5	49	21.5
Aniline Point, °F		40		80		85	
ASTM Distillation, °F	D 86/1160		D 86	D 86	D 1160	D 1160	D 1160
St/5	155/215		120/145	210/220	365/385	210/220	315/340
10/30	280/380		155/160	230/240	390/485	225/230	350/400
50	440		175	265	455	235	440
70/90	485/595		180/185	290/325	490/580	245/270	485/580
95/EP	700/850		190/210	335/355	645/760	285/310	645/760
Composition, LV %							
Paraffins			32	9	5	12	4
Naphthenes			60	70	28	68	33
Olefins			-	-	-	-	-
Aromatics			8	21	67	20	63
Sulfur, ppm	2,900	10		1	20		
Total Nitrogen, ppm	8,500	350		115	530	100	450
Total Oxygen, ppm	37,900	3000		1000	4500		
Bromine Number	70						
Pour Point, °F	<-80						
Refractive Index	1.5073	1.4608					
Octane Numbers							
F-1 Clear			82	70		71	
F-2 Clear			78	67		68	

TABLE 7

PROPERTIES OF WHOLE SRC-II OIL
DOE CONTRACT EF-76-C-01-2315

Gravity, Degrees API	18.6
Sulfur, Weight Percent	0.29
Total Nitrogen, Weight Percent	0.85
Basic Nitrogen, Weight Percent	0.7
Oxygen, Weight Percent	3.79
Carbon, Weight Percent	84.61
Hydrogen, Weight Percent	10.46
Hydrogen/Carbon Atom Ratio	1.47
Chlorine, Parts per Million	50
Ramsbottom Carbon, Weight Percent	0.70
Hot Heptane Asphaltenes, Parts per Million	468
Benzene Insolubles, Weight Percent	<0.03
Ash, Parts per Million	40
Molecular Weight	132
Bromine Number	70
Pour Point, Degrees Fahrenheit	Below -80
Refractive Index at 80 Degrees Centigrade	1.5073
Viscosity, Centistokes at 100 Degrees Fahrenheit	2.196
Viscosity, Centistokes at 130 Degrees Fahrenheit	1.617
Maleic Diene Value, Centigrams per Gram	30.7
Water by Distillation, Volume Percent	0.06
ASTM D 86/D 1160 Distillation, Degrees Fahrenheit at Liquid Volume Percent Distilled:	
Start/5	154/217
10/30	281/382
50	438
70/90	484/597
95/End Point	699/850
Percent Overhead	98

TABLE 8

STOCK BALANCE - CASE 1A
REFINING SRC-II OIL BY HIGH SEVERITY HYDROTREATING TO PRODUCE
50,000 BARRELS PER CALENDAR DAY OF MOTOR GASOLINE PLUS JET FUEL
DOE CONTRACT EF-76-C-01-2315

		Processing					Products			
Feeds and Products, Barrels per Calendar Day	Refinery Input	High Severity Hydrotreating	Catalytic Reforming	Hydrogen Manufacture	H_2S Recovery and Sulfur Plant	Offplot Boiler Plant	Refinery Fuel	Motor Gasoline	Kerosene Jet Fuel	By-Products
Whole SRC II Oil*	59,860	(59,860)								
Coal, Equivalent Fuel Oil	1,870					(1,870)				
Fuel Gas, Equivalent Fuel Oil		795	115				910			
Isobutane		1,380	15	(510)			160	725		
Normal Butane		1,410	10	(520)			160	740		
C_5/C_6 Light Gasoline		3,795						3,795		
180-300°F Heavy Gasoline		18,615	(10,070)	(8,545)						
300-550°F Kerosene		38,370					2,570		35,800	
550°F+ Bottoms		3,000					3,000			
Reformate (97.5 F-1 Clear)			8,940					8,940		
Total Liquid Product		67,365	9,080	–			6,800	14,200	35,800	
Total Liquid Feed		(59,860)	(10,070)	(9,575)						
Liquid Gain (Loss)		7,505	(990)	(9,575)			(105)			
Fuel		(625)	(545)	(5,525)			6,695			
Hydrogen, Millions of Standard Cubic Feet Per Calendar Day		(174.9)	17.0	157.9						
Tons Per Calendar Day										
Hydrogen Sulfide		29.1			(29.1)					
Sulfur		-			26.2					26.2
Ammonia		96			-					96

*Including 4.6 LV % Butanes
Note: Parentheses () Denote a Negative Quantity, i.e., Consumption

1-15-80

TABLE 9

STOCK BALANCE - CASE 2A
REFINING OF SRC-II OIL BY INTERMEDIATE SEVERITY HYDROTREATING TO PRODUCE
50,000 BARRELS PER CALENDAR DAY OF MOTOR GASOLIN. PLUS JET FUEL
DOE CONTRACT EF-76-C-01-2315

Feeds and Products, Barrels per Calendar Day	Refinery Input	Processing: Intermediate Severity Hydrotreating	Middle Distillate Hydrotreating	Naphtha Hydrotreating and Catalytic Reforming	Hydrogen Manufacture	H_2S Recovery and Sulfur Plant	Offplot Boiler Plant	Products: Refinery Fuel	Motor Gasoline	Kerosene Jet Fuel	By-Products
Whole SRC II Oil*	59,020	(59,020)									
Coal, Equivalent Fuel Oil	1,250						(1,250)				
Fuel Gas, Equivalent Fuel Oil		645	205	145				995			
Isobutane		1,360		25	(735)				650		
Normal Butane		1,360		20	(730)				650		
C_5/C_6 Light Gasoline		3,775									
180-300°F Heavy Gasoline		16,860	3,170	(13,100)	(6,930)				3,775		
300-550°F Kerosene		35,075	(34,115)					960			
550°F+ Bottoms		4,535						4,535			
Hydrotreated Kerosene			33,025							33,025	
Reformate (97 F-1 Clear)				11,900					11,900		
Total Liquid Product		63,616	36,400	12,090	-			6,490	16,975	33,025	
Total Liquid Feed		(59,620)	(34,115)	(13,100)	(8,395)						
Liquid Gain (Loss)		4,590	2,285	(1,010)	(8,395)						
Fuel		(530)	(250)	(770)	(4,940)			6,490			
Hydrogen, Millions of Standard Cubic Feet Per Calendar Day		(117.1)	(41.5)	18	140.9						
Tons Per Calendar Day											
Hydrogen Sulfide		28.7				(28.7)					
Sulfur						26					26
Ammonia		96				-					96

*Including 4.6 LV % Butanes

Note: Parentheses () Denote a Negative Quantity, i.e., Consumption

1-15-80

TABLE 10

STOCK BALANCE - CASE 3A
REFINING SRC-II OIL BY HIGH SEVERITY HYDROTREATING AND FLUID CATALYTIC CRACKING
TO PRODUCE 50,000 BARRELS PER CALENDAR DAY OF MOTOR GASOLINE
DOE CONTRACT EF-76-C-01-2315

Feeds and Products, Barrels per Calendar Day	Refinery Input	Processing							Products		
		High Severity Hydrotreating	Fluid Catalytic Cracking	Light Ends Recovery	Catalytic Reforming	Hydrogen Mfg.	H_2S Recovery and Sulfur Plant	Offplot Boiler Plant	Refinery Fuel	Motor Gasoline	By-Products
Whole SRC II Oil*	59,130	(59,130)									
Coal, Equivalent Fuel Oil	1,890							(1,890)			
Fuel Gas, Equivalent Fuel Oil		785	310	1,910	260				3,265		
Propylene			1,575	(1,515)							
Propane			1,130	(1,130)	220	(220)					
Isobutane		1,365	1,800	(1,800)/1,300	65	(500)				2,230	
Butylene			745	(745)/535						535	
Normal Butane		1,395	720	(720)/525	60	(510)				1,470	
C_5/C_6 Light Gasoline		3,750								3,750	
180-400°F Heavy Gasoline		33,560			(27,230)	(6,330)					
FCC Light Gasoline			11,665							11,665	
FCC Heavy Gasoline			6,295							6,295	
400°F+ Bottoms		25,690	(25,690)								
FCC Cycle Oil			3,415						3,415		
Reformate (98.5 F-1 Clear)		-	-		24,055					24,055	
Total Liquid Product		66,545	27,595	4,270	24,660	-			6,680	50,000	
Total Liquid Feed		(59,130)	(25,690)	(5,910)	(27,230)	(7,560)					
Liquid Gain (Loss)		7,415	1,905	(1,640)	(2,570)	(7,560)					
Fuel		(625)	(385)	-	(1,470)	(4,400)			6,680		
Hydrogen, Millions of Standard Cubic Feet per Calendar Day		(172.7)			47.0	125.7)					
Tons Per Calendar Day											
Hydrogen Sulfide		28.8					(28.8)				
Sulfur							25.9				25.9
Ammonia		96									96

*Including 4.6 LV % Butane

Note: Parentheses () Denote a Negative Quantity, i.e., Consumption

TABLE 11

STOCK BALANCE - CASE 4A
REFINING OF SRC-II OIL BY INTERMEDIATE SEVERITY
HYDROTREATING AND SINGLE-STAGE ISOCRACKING TO PRODUCE
50,000 BARRELS PER CALENDAR DAY OF MOTOR GASOLINE
DOE CONTRACT EF-76-C-01-2315

		Processing						Products		
Feeds and Products, Barrels per Calendar Day	Refinery Input	Intermediate Severity Hydrotreating	Hydrocracking	Naphtha Hydrotreating and Catalytic Reforming	Hydrogen Manufacture	H_2S Recovery and Sulfur Plant	Offplot Boiler Plant	Refinery Fuel	Motor Gasoline	By-Products
Whole SRC II Oil*	56,520	(56,520)								
Coal, Equivalent Fuel Oil	1,110						(1,110)			
Fuel Gas, Equivalent Fuel Oil		675	470	475				1,620		
Isobutane		1,320	5,235	100	(3,325)			85	3,245	
Normal Butane		1,320	1,335	85	(1,546)				1,200	
C_5/C_6 Light Gasoline		3,700	10,795						14,494	
180-300°F Heavy Gasoline		17,085	21,755	(34,515)	(4,325)					
300°F+ Bottoms		38,615	(32,625)					5,990		
Reformate (96 F-1 Clear)				31,060					31,060	
Total Liquid Product		62,715	39,590	31,720	-			7,695	50,000	
Total Liquid Feed		(56,520)	(32,625)	(34,515)	(9,910)					
Liquid Gain (Loss)		6,195	6,965	(2,795)	(9,190)					
Fuel		(570)	(230)	(1,880)	(5,015)			7,695		
Hydrogen, Millions of Standard cubic Feet Per Calendar Day		(142.0)	(52.5)	49.0	145.5					
Tons Per Calendar Day										
Hydrogen Sulfide		27.7				(27.7)				
Sulfur						25				25
Ammonia		92								92

*Including 4.6 LV % Butanes.

Note: Parentheses () Denote a Negative Quantity, i.e., Consumption

◇ Revised 8-28-80

TABLE 12

STOCK BALANCE - CASE 5A
REFINING SRC-II OIL BY MODERATE SEVERITY HYDROTREATING TO PRODUCE
50,000 BARRELS PER CALENDAR DAY OF MOTOR GASOLINE PLUS NUMBER TWO HEATING OIL
DOE CONTRACT EF-76-C-01-2315

Feeds and Products	Refinery Input	Processing					Products			
Barrels per Calendar Day		Moderate Severity Hydrotreating	Naphtha Hydrotreating and Catalytic Reforming	Hydrogen Manufacture	H_2S Recovery and Sulfur Plant	Offplot Boiler Plant	Refinery Fuel	Motor Gasoline	Number Two Oil	By-Products
Whole SRC II Oil*	56,200	(57,200)								
Coal, Equivalent Fuel Oil	860					(860)				
Fuel Gas, Equivalent Feed Oil		490	215				705			
Isobutane		1,320	35	(260)			220	875		
Normal Butane		1,320	30	(260)			215	875		
C_5/C_6 Light Gasoline		3,165						3,165		
180-300°F Heavy Gasoline		17,405	(12,800)	(4,605)						
300°F+ Bottoms		36,585					3,090		33,495	
Reformate (96.5 F-1 Clear)			11,590					11,590		
Total Liquid Product		60,285	11,870	-			4,230	16,505	33,495	
Total Liquid Feed		(57,200)	(10,800)	(5,125)						
Liquid Gain (Loss)		3,085	(930)	(5,125)			(145)			
Fuel		(410)	(740)	(2,945)			4,095			
Hydrogen, Millions of Standard Cubic Feet Per Calendar Day		(101.1)	17.0	84.1						
Tons Per Calendar Day										
Hydrogen Sulfide		26.7			(26.7)					
Sulfur					24.0					24.0
Ammonia		88								88

*Including 4.6 LV % Butanes

Note: Parentheses () Denote a Negative Quantity, i.e., Consumption

TABLE 13

STOCK BALANCE - CASE 1C
REFINING SRC-II OIL BY HIGH SEVERITY HYDROTREATING TO PRODUCE
50,000 BARRELS PER CALENDAR DAY, OF MOTOR GASOLINE PLUS JET FUEL
DOE CONTRACT EF-76-C-01-2315

Feed and Products Barrels per Calendar Day	Refinery Input	Processing: High Severity Hydrotreating	Processing: Catalytic Reforming	Processing: Hydrogen Manufacture, Partial Oxidation	Processing: H_2S Recovery and Sulfur Plant	Processing: Offplot Boiler Plant	Products: Refinery Fuel	Products: Motor Gasoline	Products: Kerosene Jet Fuel	Products: By-Products
Whole SRC II Oil*	56,625	(48,940)		(7,685)		(1,270)				
Coal, Equivalent Fuel Oil	1,270									
Fuel Gas, Equivalent Fuel Oil		650	150				800			
Isobutane		1,170	30	(400)				800		
Normal Butane		1,260	20	(410)				870		
C_5/C_6 Light Gasoline		3,105						3,105		
180-275°F Heavy Gasoline		12,000	(12,000)							
275-550°F Kerosene		34,605							34,605	
550°F+ Bottoms		2,450		(115)			2,335			
Reformate (97 F-1 Clear)			10,620					10,620		
Total Liquid Product		55,240	10,820	-			3,135	15,395	34,605	
Total Liquid Feed		(48,940)	(12,000)	(8,610)						
Liquid Gas (Loss)		6,300	(1,180)	(8,610)						
Fuel		(520)	(645)	(1,970)			3,135			
Hydrogen, Millions of Standard Cubic Feet per Calendar Day		(143)	20.0	123						
Tons per Calendar Day										
Hydrogen Sulfide		23.5			(23.5)					
Sulfur		-			22					22
Ammonia		79			-					79

*Including 4.6 LV % butanes.
Note: Parentheses ( ) denote a negative quantity, i.e., consumption.

1-15-80

TABLE 14

STOCK BALANCE SUMMARY
REFINING OF SRC-II OIL TO PRODUCE 50,000
BARRELS PER DAY OF DESIRED PRODUCTS
DOE CONTRACT EF-76-C-01-2315

Case	1A	1B	1C	1D	2A + 2B	2C	3A + 3B	3C	4A	4B	4C	4D	5A	5B	5C	5D	6C
Input, Barrels Per Calendar Day																	
Whole SRC II Oil	59,860	59,425	56,625	49,045	59,020	56,410	59,130	56,610	57,030	56,535	54,945	46,920	57,200	56,635	55,580	49,935	55,460
Coal, Equivalent Fuel Oil	1,870	1,800	1,270	1,580	1,230	760	1,890	1,310	1,110	1,140	710	990	860	820	620	780	990
Outside Gas, Equivalent Fuel Oil				7,100								7,960				5,375	
Processing, Barrels Per Operating Day																	
Whole Oil Hydrotreating																	
High Severity	63,000	60,000	52,000	52,000			63,000	55,000									
Intermediate Severity					62,500	53,000			60,000	54,000	49,000	49,000					
Moderate Severity													61,000	57,000	53,000	53,000	59,000
Fluid Catalytic Cracking							29,000	25,000									36,000
(Conversion, Liquid Volume Percent)							(87.4)	(87.4)									(64)
Single Stage Hydrocracking									36,000	38,500	35,000	35,000					
Middle Distillate Hydrotreating					38,000	34,000											
Naphtha Hydrotreating					15,000	18,000			38,000	38,000	39,000	39,000	14,000	14,000	16,000	16,000	23,000
Catalytic Reforming	11,000	11,000	13,000	13,000	15,000	18,000	29,000	12,000	38,000	38,000	39,000	39,000	14,000	14,000	16,000	16,000	23,000
(F-1 Clear Octane)	(97.5)	(98)	(97)	(97)	(97)	(95.6)	(98.5)	(98)	(96)	(96)	(98.5)	(96)	(96.5)	(96.5)	(96)	(96)	(97)
Hydrogen Manufacturing, Millions of Standard Cubic Feet Per Operating Day																	
Steam Reforming	176	170		137	156		140		162	148		132	94	86		77	
Partial Oxidation			137			125		111			130				77		80
Alkylation																	3,000
Light Ends Recovery							6,600	6,500									
Products, Barrels Per Calendar Day																	
Motor Gasoline	14,200	13,580	15,395	15,395	16,975	20,015	50,000	50,000	50,000	50,000	50,000	50,000	16,505	15,805	16,995	16,995	36,435
Kerosene Jet Fuel	35,800	36,420	34,605	34,605	33,025	29,985											
Number Two Heating Oil													32,495	34,195	33,005	33,005	13,565
Refinery Fuel, Barrels Per Calendar Day																	
Outside Gas, Equivalent Fuel Oil				2,220								5,825				2,925	
Refinery Gas, Equivalent Fuel Oil	1,125	1,055	800	800	995	890	3,265	2,425	1,695	1,600	1,340	1,450	995	645	660	660	1,950
Hydrotreated Liquid Products	5,570	2,845	2,335	2,450	5,495	2,560	3,415	1,630	6,500				3,090				1,280
SRC-II Oil Feed		2,625								5,935	3,535			3,165	1,615		

Case Designations and Bases:

Numerical

1. High severity hydrotreating to motor gasoline and jet fuel.
2. Intermediate severity hydrotreating and separate downstream hydrotreating to motor gasoline and jet fuel.
3. High severity hydrotreating and high conversion fluid catalytic cracking to motor gasoline.
4. Intermediate severity hydrotreating and single-stage recycle hydrocracking to motor gasoline.
5. Moderate severity hydrotreating to motor gasoline and number two heating oil.
6. Moderate severity hydrotreating and moderate conversion fluid catalytic cracking to motor gasoline and number two heating oil.

Alphabetical	Refinery Fuel	Hydrogen Manufacture
A	Hydrotreated Product	Steam Reforming of Refinery Gas and Product Naphtha
B	SRC-II Oil, if Necessary	Steam Reforming of Refinery Gas and Product Naphtha
C	SRC-II Oil, if Necessary	Partial Oxidation of SRC-II Oil
D	Refinery and Outside Gas	Steam Reforming of Outside Gas

1-15-80

TABLE 15

REFINERY PRODUCT INSPECTIONS
REFINING OF SRC-II OIL
DOE CONTRACT EF-76-C-01-2315

	ASTM Method	1978 Specifications	Case 1	Case 2	Case 3	Case 4	Case 5	Case 6
Inspections of Motor Gasoline								
Reid Vapor Pressure, Pounds	D 323	-	10	10	10	10	10	10
Doctor Test	D 484	Negative	Negative	Negative	Negative	Negative	Negative	Negative
Sulfur, Weight Percent	D 1266	0.03 Max	<0.03	<0.03	<0.03	<0.03	<0.03	<0.03
Octane Number,								
Research Unleaded	D 2699	93 Min.*	94	94	95.3	93.3-94	94-94.5	94.8
Motor Unleaded	D 2700	84 Min.*	84	84	84	84.6-85	84	84
Distillation Temperature, °C								
At 50% Distilled	D 86	116 Max.	102-107	112-116	112	96-104.5	113	116
End Point		215.5 Max.	215.5	215.5	215.5	215.5	215.5	215.5
Inspections of Kerosene Jet Fuel								
Specific Gravity, Relative to Water at 15.5°C	D 287	0.8398-0.7753	0.845-0.855	0.855-0.858	-	-	-	-
Aromatics, Volume Percent	D 1319	20 Max.	10	16	-	-	-	-
Flash Point, °C	D 56	37.8 Min.	38-54	49-54	-	-	-	-
Freezing Point, °C	D 2386	-40 Max.	-70	-60	-	-	-	-
Smoke Point, Millimeters	D 1322	20 Min.	21	20	-	-	-	-
Mercaptan Sulfur, Weight Percent	D 1323	0.003 Max.	<0.001	<0.001	-	-	-	-
Distillation Temperature, °C	D 86							
At 10% Recovered		204.4 Max.	170-182	175-182	-	-	-	-
At 20% Recovered		-	182-188	184-188	-	-	-	-
At 50% Recovered		-	204	202-204	-	-	-	-
At 90% Recovered		-	246	246	-	-	-	-
Final Boiling Point		300	277	277	-	-	-	-
Viscosity, Centistokes at -20°C	D 445	8 Max.	5.2-5.7	5.5	-	-	-	-
Net Heat of Combustion, Btu/Pound	D 1405	18,400 Min.	18460-18570	18,375-18,400	-	-	-	-
Copper Strip Corrosion after Two Hours at 100°C	D 130	No.1 Max.	No. 1A	No. 1A	-	-	-	-
Naphthalenes, Volume Percent	D 1840	3 Max.	0.15	0.25	-	-	-	-
Existent Gum, Milligrams per Hundred Milliters	D 381	7 Max.	0	0	-	-	-	-
Thermal Stability, Jet Fuel Thermal Oxidation Test, Rating at 280 °C	D 1660	(See Text)	No. 1	No. 1	-	-	-	-
Inspections of No. 2 Heating Oil								
Specific Gravity, Relative to Water at 15.5°C	D 287	0.8762 Max.	-	-	-	-	0.919-0.925	0.947
Flash Point, °C	D 93	38 Min.	-	-	-	-	43-47	38
Pour Point, °C	D 97	-6 Max.	-	-	-	-	-50	-30
Water and Sediment, Volume Percent	D 1796	0.05 Max.	-	-	-	-	<0.01	<0.01
Carbon Residue on 10% Bottoms, Weight Percent	D 524	0.35 Max.	-	-	-	-	<0.05	0.1
Distillation Temperature at 90% Recovered, °C	D 86	282-338	-	-	-	-	304	321
Viscosity, Saybolt Seconds Universal at 38°C	D 445	32.6-97.9	-	-	-	-	33	31
Kinematic Viscosity, Centistokes at 38°C	D 445	2.0-3.6	-	-	-	-	2	1.6
Copper Strip Corrosion after Two Hours at 100°C	D 130	No. 3 Max.	-	-	-	-	No. 1A	No. 4
Sulfur, Weight Percent	D 2662	0.5 Max.	-	-	-	-	<0.001	<0.01
Thermal Stability, Percent Reflectance after 90 Minutes at 150°C	(See Text)		-	-	-	-	90	-

Average Market Projections for the Early 1980's

.-15-80

TABLE 16

INVESTMENT AND UTILITY SUMMARY
HYDROTREATERS AND HYDROCRACKERS
REFINING OF SRC-II OIL
DOE CONTRACT EF-76-C-01-2315

Case		Feed Rate, Barrels Per Operating Day (Excluding Butanes)	Investment,[1] Millions of Dollars: Total Onplot	Investment,[1] Millions of Dollars: Initial Catalyst	Utility Consumptions[2]: Fuel, Barrels Per Operating Day	Utility Consumptions[2]: Power, Mega-Watts[3]	Utility Consumptions[2]: 150 psig Steam Thousands of Pounds Per Hour	Utility Consumptions[2]: Water, Thousands of Gallons Per Minute: Cooling[4]	Utility Consumptions[2]: Water, Thousands of Gallons Per Minute: Process[4]	Hydrogen Required Millions of Standard Cubic Feet Per Operating Day	Catalyst Replacement, Millions of Dollars Per Year	Labor, Shift Positions	Estimating Bases: Catalyst Type	Estimating Bases: Reactor Trains/Reactors Per Train	Estimating Bases: Catalyst Life, Months: To First Regeneration	Estimating Bases: Catalyst Life, Months: Total
1A	Whole Oil Hydrotreating	63,000	169	12	690	10.2	140	12	0.5	192	5	2	ICR 106	4/2	-	24
1B		60,000	165	12	660	9.7	130	11	0.5	183	5	2	ICR 106	4/2	-	24
1C+D		52,000	141	10	570	8.4	110	9	0.4	158	5	2	ICR 106	3/2	-	24
2A+B		62,500	111	4	590	7.5	55	6	0.5	131	4	2	ICR 106	3/1	-	12
2C		53,000	100	3	500	6.0	45	5	0.4	111	3	2	ICR 106	3/1	-	12
3A+B		63,000	165	12	690	10.2	140	12	0.5	192	5	2	ICR 106	4/2	-	24
3C		55,000	138	11	630	9.2	120	10	0.5	174	5	2	ICR 106	4/2	-	24
4A		60,000	125	6	600	8.6	80	8	0.6	158	3	2	ICR 106	3/1	-	24
4B		54,000	117	5	520	7.7	80	7	0.5	142	2.5	2	ICR 106	3/1	-	24
4C+D		49,000	109	5	500	7.0	75	6	0.3	129	2.5	2	ICR 106	3/1	-	24
5A		61,000	81	2	460	5.1	30	5	0.5	112	4	2	ICR 113	1/2	-	6
5B		57,000	76	2	430	4.8	30	5	0.5	105	3.5	2	ICR 113	1/2	-	6
5C+D		53,000	71	2	400	4.5	30	5	0.5	98	3	2	ICR 113	1/2	-	6
6C		59,000	79	2	450	5.0	30	5	0.5	108	4	2	ICR 113	1/2	-	6
2A+B	Middle Distillate Hydrotreating	38,000	41	2	280	1.8	10	3	-	46	0.4	2	ICR 106	1/1	24	40
2C		34,000	38	2	250	1.6	10	2	-	42	0.4	2	ICR 106	1/1	24	40
4A	Hydrocracker	36,000	50	4	255	1.4	70	5	-	57	1	1	ICR 202	2/1	24	40
4B		38,000	54	4	280	1.3	80	6	-	62	1	1	ICR 202	2/1	24	40
4C+D		35,000	48	4	240	1.3	70	5	-	56	1	1	ICR 202	2/1	24	40

[1] Estimated for U.S. Mid-Continent location as of first quarter, 1980.
[2] Operating day basis.
[3] Gross consumptions: overall refinery requirements in later tables are net considering steam turbine usage.
[4] Cooling water is recycled to cooling tower. Process water is recycled to WWT plant.

◈ Revised 8-28-80

TABLE 17

BASES FOR COST ESTIMATES AND COMPARISONS
REFINING OF SRC-II OIL
DOE CONTRACT EF-76-C-01-2315

General

Estimated processing costs include annual capital charges and operating costs required to refine SRC-II oil using conventional refining processes. No allowance is included in these estimates for (a) coal resource costs, (b) mining or handling of coal, (c) conversion of coal to oil by the SRC-II process, (d) SRC-II oil transportation to the refinery, (e) refined product distribution and transportation from the refinery, or (f) community facilities, electric power generation or other support facilities (except for a small "infrastructure" allowance for roads, power lines, water supply, and disposal lines from the refinery to connect to existing services a few miles away). Notes apply to all subsequent cost tables. Item numbers are keyed to comparative cost summaries.

Investment Costs

Investment estimates are based on:

1. First quarter, 1980 costs. (Excludes escalation during planning, design, and construction periods.)
2. Mid-Continent refining location.
3. Tankage equivalent to ten days of SRC-II oil feed, fifteen days of motor gasoline blend components, fifteen days of light products, and ten days of intermediate products.
4. Cost correlations based on actual plants constructed by Standard Oil Company of California from the 1960's through mid-1970's. In addition to adjustments for inflation, size and known differences in plant location, the base estimates include allowances for:
   a. Accurancy of the cost correlations.
   b. A less favorable field labor productivity and materials purchasing situation that will likely be experienced if the U.S. enters into a significant program of synthetic fuels plant construction.
   c. Changes in plant design philosophy to provide for improved operating efficiency, better reliability, increased safety, additional energy conservation, and stricter environmental requirements.
5. Adding an estimating allowance of about 10% of total onplot and offplot investment to account for the cost of additional items which the history of major projects shows are encountered as the detailed project engineering proceeds.

Working Capital Includes

6. Value of feed and product inventories in storage, assuming tanks are half full.
7. Estimated value of spare catalyst and spare parts.
8. Estimated value of accounts receivable less accounts payable for thirty days.

Capital Charge Factor

9. Overall processing costs are based on a capital charge equal to 30% of total investment (including working capital and initial catalyst costs) per year. This capital charge factor is approximately equivalent to a 15% after tax discounted cash flow rate of return on investment based on:
   a. 51% income tax.
   b. Four-year construction period.
   c. Investment payments equal to 10%, 15%, 25%, and 50% of total investment during the four years of construction.
   d. 50% of design capacity during first year of operation; 100% in second year and thereafter.
   e. 10% investment tax credit.
   f. Sum of the years' digits depreciation; 13-year tax life of refining equipment.
   g. 20-year project life.

Utilities and Operating Costs

10. Refinery fuel and steam are internally supplied. Boiler plant fuel is purchased coal (amounts shown on stock balances).
11. Process water is conserved by treatment in the WWT plants and then returned to the refining units. Net make-up water cost estimated at $300 per million gallons.
12. Maintenance cost estimated at 2-1/2% of onplot plus offplot per year.
13. Property taxes and insurance estimated at 2-1/2% of onplot plus offplot per year.
14. Operating labor cost estimated at 110,000 dollars per shift position per year. Sixty-five percent is then added to cover support labor (technical service, administration, security, etc.) and supplies.
15. Power cost estimated at three cents per kilowatt-hour.
16. Coal cost estimated at eight dollars per equivalent fuel oil barrel. (Net heating value of six million British thermal units.)

TABLE 18

ESTIMATES OF INVESTMENTS AND UTILITIES: CASE 1A
REFINING OF SRC-II OIL BY HIGH SEVERITY
HYDROTREATING TO PRODUCE 50,000 BARRELS PER
CALENDAR DAY OF MOTOR GASOLINE PLUS JET FUEL

	Size	Investment, Millions of Dollars	Initial Catalyst, Millions of Dollars	Net Power Required, Megawatts	Catalysts and Chemicals, Millions of Dollars per Year	Labor, Shift Positions
Onplot Facilities						
High Severity Whole Oil Hydrotreater	63,000 Barrels per Operating Day	169	12	6.5	5	2.5
Hydrogen Manufacture	2 x 88 Million of Standard Cubic Feet per Operating Day	161	2	1	1	6
Reformer	11,000 Barrels per Operating Day	17	3	-	-	2
WWT Plant	500 Gallons per Minute	12	-	0.5	-	1
Hydrogen Sulfide Recovery	2,700 Pounds per Hour	4	-	-	-	0.5
Sulfur Production and Tail Gas Treating	30 Tons per Operating Day	6	-	-	-	1
Subtotal		369	17	8	6	12.5
Estimating Allowance		37				
Offplot Facilities						
Boiler and Miscellaneous Utility Plant	780,000 Pounds per Hour Steam	89	-	-	-	
Cooling Tower	36,000 Gallons per Minute	6	-	0.5	-	
Electrical Distribution	30,000 Kilovolt-Amperes	9	-	-	-	
Feed and Product Storage Tanks	1.7 Million Barrels	31	-	-	-	
Interconnecting and Tankfield Pipeways Plus Blending Facilities	-	36	-	0.5	-	
Site Development	110 Acres	6	-	-	-	
Relief and Flare System	-	7	-	-	-	
Buildings and Maintenance Equipment	-	17	-	-	-	
Waste Disposal	-	18	-	-	-	
Land Purchase and Infrastructure Allowance	-	7	-	-	-	
Subtotal		226	-	1	-	8
Estimating Allowance		23				
Working Capital						
Feed Inventory	Half Full	20				
Intermediate and Finished Product Inventory	Half Full	29				
Spare Catalyst and Parts	-	10				
Accounts Receivable Minus Payable	30 Days	1				
Subtotal		60				

Note: No allowance is included in these estimates for (a) coal resource costs, (b) mining or handling of coal, (c) conversion of coal to oil by the SRC-II process, (d) SRC-II oil transportation to the refinery, or (e) refined product distribution and transportation from the refinery.

See Table 17 for estimating bases.

1-15-80

TABLE 19

ESTIMATES OF INVESTMENTS AND UTILITIES: CASE 2A
REFINING OF SRC-II OIL BY INTERMEDIATE SEVERITY
HYDROTREATING TO PRODUCE 50,000 BARRELS PER
CALENDAR DAY OF MOTOR GASOLINE PLUS JET FUEL
DOE CONTRACT EF-76-C-01-2315

	Size	Investment, Millions of Dollars	Initial Catalyst Millions of Dollars	Net Power Required, Megawatts	Catalysts and Chemicals, Millions of Dollars per Year	Labor, Shift Positions
Onplot Facilities						
Intermediate Severity Whole Oil Hydrotreater	62,500 Barrels per Operating Day	111	4	6	4	2.5
Hydrogen Manufacture	2 x 78 Millions of Standard Cubic Feet per Operating Day	147	2	1	0.5	6
Middle Distillate Hydrotreater	38,000 Barrels per Operating Day	41	2	1	0.5	2
Naphtha Hydrotreater	15,000 Barrels per Operating Day	15	-	0.5	-	1
Reformer	15,000 Barrels per Operating Day	22	3	0.5	-	2
WWT Plant	500 Gallons per Minute	12	-	0.5	-	1
Hydrogen Sulfide Recovery	2,500 Pounds per Hour	4	-	-	-	0.5
Sulfur Production and Tail Gas Treating	30 Tons per Operating Day	6	-	-	-	-
Subtotal		358	11	9.5	5	15.5
Estimating Allowance		36				
Offplot Facilities						
Boiler and Miscellaneous Utility Plant	510,000 Pounds per Hour Steam	66	-	-	-	
Cooling Tower	30,000 Gallons per Minute	5	-	1	-	
Electrical Distribution	30,000 Kilovolt-Amperes	9	-	-	-	
Feed and Product Storage Tanks	2.1 Million Barrels	38	-	-	-	
Interconnecting and Tankfield Pipeways Plus Blending Facilities	-	36	-	0.5	-	
Site Development	130 Acres	7	-	-	-	
Relief and Flare System	-	6	-	-	-	
Buildings and Maintenance Equipment	-	18	-	-	-	
Waste Disposal	-	19	-		-	
Land Purchase and Infrastructure Allowance	-	8	-	-	-	
Subtotal		211	-	1.5	-	9
Estimating Allowance		21				
Working Capital						
Feed Inventory	Half Full	9				
Product Inventory	Half Full	31				
Spare Catalyst and Parts	-	7				
Accounts Receivable Minus Payable	30 Days	1				
Subtotal		68				

Note: No allowance is included in these estimates for (a) Coal Resource Costs, (b) Mining or handling of coal, (c) conversion of coal to oil by the SRC-II process, (d) SRC-II oil transportation to the refinery, (e) refined product distribution and transportation from the refinery.

See Table 17 for estimating bases.

1-15-80

TABLE 20

ESTIMATES OF INVESTMENTS AND UTILITIES: CASE 3A
REFINING SRC-II OIL BY HIGH SEVERITY
HYDROTREATING AND FLUID CATALYTIC CRACKING TO PRODUCT
50,000 BARRELS PER CALENDAR DAY OF MOTOR GASOLINE
DOE CONTRACT EF-76-C-01-2315

	Size	Investment, Millions of Dollars	Initial Catalyst, Millions of Dollars	Net Power Required, Megawatts	Catalysts and Chemicals, Millions of Dollars per Year	Labor, Shift Positions
Onplot Facilities						
High Severity Whole Oil Hydrotreater	63,000 Barrels Per Operating Day	165	12	6	5	2
Fluid Catalytic Cracker	29,000 Barrels Per Operating Day	89	-	1	1	4.5
Hydrogen Manufacture	2 x 70 Million of Standard Cubic Feet per Operating Day	135	2	1	1	6
Chevron Rheniformer	29,000 Barrels per Operating Day	33	7	0.5	-	1.5
Light Ends Recovery	6,000 Barrels per Operating Day	11	-	-	-	1.5
Chevron WWT Plant	500 Gallons per Minute	12	-	0.5	-	1.0
Hydrogen Sulfide Recovery	2,700 Pounds per Hour	4	-	-	-	0.5
Sulfur Production and Tail Gas Treating	30 Tons per Operating Day	6	-	-	-	1.0
Subtotal		455	21	9	7	18
Estimating Allowance		46				
Offplot Facilities						
Boiler and Miscellaneous Utility Plant	790,000 Pounds per Hour Steam	89	-	0.5	-	
Cooling Tower	36,000 Gallons per Minute	6	-	1	-	
Electrical Distribution	30,000 Kilovolt-Amperes	9	-	-	-	
Feed and Product Storage Tanks	2.6 Million Barrels	45	-	-	-	
Interconnecting and Tankfield Pipeways Plus Blending Facilities	-	46	-	0.5	-	
Site Development	140 Acres	8	-	-	-	
Relief and Flare System	-	9	-	-	-	
Buildings and Maintenance Equipment	-	19	-	-	-	
Waste Disposal	-	20	-			
Land Purchase and Infrastructure Allowance	-	8	-	-	-	
Subtotal		259	-	2	-	9
Estimating Allowance		26				
Working Capital						
Feed Inventory	Half Full	31				
Product Inventory	Half Full	44				
Spare Catalyst and Parts	-	13				
Accounts Receivable Minus Payable	30 Days	1				
Subtotal		89				

Note: No allowance is included in these estimates for (a) Coal Resource Costs, (b) Mining or handling of coal, (c) conversion of coal to oil by the SRC-II process, (d) SRC-II oil transportation to the refinery, and (e) refined product distribution and transportation from the refinery.

See Table 17 for estimating bases.

1-15-80

TABLE 21

ESTIMATES OF INVESTMENTS AND UTILITIES: CASE 4A
REFINING OF SRC-II OIL BY INTERMEDIATE SEVERITY
HYDROTREATING AND SINGLE-STAGE ISOCRACKING
TO PRODUCE 50,000 BARRELS PER CALENDAR DAY OF MOTOR GASOLINE
DOE CONTRACT EF-76-C-01-2315

	Size	Investment, Millions of Dollars	Initial Catalyst, Millions of Dollars	Net Power Required, Megawatts	Catalysts and Chemicals Millions of Dollars per Year	Labor, Shift Positions
Onplot Facilities						
Intermediate Severity Whole Oil Hydrotreater	60,000 Barrels per Operating Day	125	6	7.5	3	2.5
Hydrocracking	36,000 Barrels per Operating Day	50	4	1	1	1
Hydrogen Manufacture	2 x 81 Millions of Standard Cubic Feet per Operating Day	151	2	1	0.5	6
Naphtha Hydrotreater	38,000 Barrels per Operating Day	25	-	1.5	-	1
Reformer	38,000 Barrels per Operating Day	39	9	1	-	1.5
WWT Plant	500 Gallons per Minute	12	-	0.5	-	1
Hydrogen Sulfide Recovery	2,600 Pounds per Hour	4	-	-	-	0.5
Sulfur Production and Tail Gas Treating	28 Tons per Operating Day	6	-	-	-	1
Subtotal		412	21	12.5	4.5	14.5
Estimating Allowance		41				
Offplot Facilities						
Boiler and Miscellaneous Utility Plant	540,000 Pounds per Hour Steam	67	-	-	-	
Cooling Tower	37,000 Gallons per Minute	6	-	1	-	
Electrical Distribution	30,000 Kilovolt-Amperes	9	-	-	-	
Feed and Product Storage Tanks	2.6 Million Barrels	45	-	-	-	
Interconnecting and Tankfield Pipeways, Blending Facilities	-	44	-	0.5	-	
Site Development	140 Acres	7	-	-	-	
Relief and Flare System	-	9	-	-	-	
Buildings and Maintenance Equipment	-	18	-	-	-	
Waste Disposal	-	19	-	-	-	
Land Purchase and Infrastructure Allowance	-	8	-	-	-	
Subtotal		232	-	1.5	-	9
Estimating Allowance		23				
Working Capital						
Feed Inventory	Half Full	34				
Product Inventory	Half Full	41				
Spare Catalyst and Parts	-	13				
Accounts Receivable Minus Payable	30 Days	1				
Subtotal		89				

Note: No allowance is included in these estimates for (a) coal resource costs, (b) mining or handling of coal, (c) conversion of coal to oil by the SRC-II process, (d) SRC-II oil transportation to the refinery, or (e) refined product distribution and transportation from the refinery.

See Table 17 for estimating bases. ◈ Revised 8-28-80

8-28-80

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TABLE 22

ESTIMATES OF INVESTMENTS AND UTILITIES: CASE 5A
REFINING OF SRC-II OIL BY MODERATE SEVERITY
HYDROTREATING TO PRODUCE 50,000 BARRELS PER CALENDAR DAY OF
MOTOR GASOLINE PLUS NUMBER TWO HEATING OIL
DOE CONTRACT EF-76-C-01-2315

	Size	Investment, Millions of Dollars	Initial Catalyst, Millions of Dollars	Net Power Required, Megawatts	Catalysts and Chemicals, Millions of Dollars per Year	Labor, Shift Positions
Onplot Facilities						
Moderate Severity Whole Oil Hydrotreater	61,000 Barrels per Operating Day	81	2	4	4	2.5
Hydrogen Manufacture	94 Millions of Standard Cubic Feet per Operating Day	91	1	0.5	0.5	3
Naphtha Hydrotreater	14,000 Barrels per Operating Day	15	-	0.5	-	1
Reformer	14,000 Barrels per Operating Day	21	3	0.5	-	1.5
WWT Plant	500 Gallons per Minute	12	-	0.5	-	1
Hydrogen Sulfide Recovery	2,600 Pounds per Hour	4	-	-	-	0.5
Sulfur Production and Tail Gas Treating	28 Tons per Operating Day	6	-	-	-	1
Subtotal		230	6	6	4.5	10.5
Estimating Allowance		23				
Offplot Facilities						
Boiler and Miscellaneous Utility Plant	350,000 Pounds per Hour Steam	51	-	-	-	
Cooling Tower	23,000 Gallons per Minute	4	-	0.5	-	
Electrical Distribution	20,000 Kilovolt-Amperes	7	-	-	-	
Feed and Product Storage Tanks	1.8 Million Barrels	33	-	-	-	
Interconnecting and Tankfield Pipeways Plus Blending Facilities	-	25	-	0.5	-	
Site Development	110 Acres	6	-	-	-	
Relief and Flare System	-	5	-	-	-	
Buildings and Maintenance Equipment	-	17	-	-	-	
Waste Disposal	-	18	-		-	
Land Purchase and Infrastructure Allowance	-	7	-	-	-	
Subtotal		173	-	1	-	8
Estimating Allowance		17				
Working Capital						
Feed Inventory	Half Full	19				
Product Inventory	Half Full	34				
Spare Catalyst and Parts	-	5				
Accounts Receivable Minus Payable	30 Days	2				
Subtotal		60				

Notes: No allowance is included in these estimates for (a) coal resource costs, (b) mining or handling of coal, (c) conversion of coal to oil by the SRC-II process, (d) SRC-II oil transportation to the refinery, or (e) refined product distribution and transportation from the refinery.

See Table 17 for estimating bases.

1-15-80

TABLE 23

ESTIMATES OF INVESTMENTS AND UTILITIES: CASE 1C
REFINING OF SRC-II OIL BY HIGH SEVERITY
HYDROTREATING TO PRODUCE 50,000 BARRELS PER
CALENDAR DAY OF MOTOR GASOLINE PLUS JET FUEL

	Size	Investment, Millions of Dollars	Initial Catalyst, Millions of Dollars	Net Power Required, Megawatts	Catalysts and Chemicals, Millions of Dollars per Year	Labor, Shift Positions
Onplot Facilities						
High Severity Whole Oil Hydrotreater	52,000 Barrels per Operating Day	141	10	6	5	2.5
Hydrogen Manufacture (Partial Oxidation)	2 x 69 Million of Standard Cubic Feet per Operating Day	180	5	4	2	5
Reformer	13,000 Barrels per Operating Day	20	3	-	-	1.5
WWT Plant	500 Gallons per Minute	12	-	1	-	1
Hydrogen Sulfide Recovery	2,300 Pounds per Hour	4	-	-	-	0.5
Sulfur Production and Tail Gas Treating	25 Tons per Operating Day	6	-	-	-	1
Selective Catalytic NO_x Reduction	-	5	-	-	-	-
Subtotal		368	18	11	7	11.5
Estimating Allowance		37				
Offplot Facilities						
Boiler and Miscellaneous Utility Plant	530,000 Pounds per Hour Steam	68	-	-	-	
Cooling Tower	90,000 Gallons per Minute	12	-	2	-	
Electrical Distribution	30,000 Kilovolt-Amperes	9	-	-	-	
Feed and Product Storage Tanks	1.9 Million Barrels	30	-	-	-	
Interconnecting and Tankfield Pipeways Plus Blending Facilities	-	33	-	0.5	-	
Site Development	110 Acres	6	-	-	-	
Relief and Flare System	-	7	-	-	-	
Buildings and Maintenance Equipment	-	17	-	-	-	
Waste Disposal	-	18	-	0.5	-	
Land Purchase and Infrastructure Allowance	-	7	-	-	-	
Subtotal		207	-	3	-	8
Estimating Allowance		21				
Working Capital						
Feed Inventory	Half Full	23				
Intermediate and Finished Product Inventory	Half Full	29				
Spare Catalyst and Parts	-	11				
Accounts Receivable Minus Payable	30 Days	1				
Subtotal		64				

Note: No allowance is included in these estimates of (a) coal resource costs, (b) mining or handling of coal, (c) conversion of coal to oil by the SRC-II process, (d) SRC-II oil transportation to the refinery, or (e) refined product distribution and transportation from the refinery.

See Table 17 for bases.

1-15-80

TABLE 24

COMPARATIVE COST SUMMARY
REFINING OF SRC-II OIL
"GRASS ROOTS" REFINERIES PRODUCING
50,000 BARRELS PER CALENDAR DAY OF DESIRED PRODUCTS
DOE CONTRACT EF-76-C-01-2315

Refinery Furnace Fuel and Hydrogen Plant Feed Supplied by Internally Generated Hydrotreated Products

Case		1A	2A	3A	4A	5A
Desired Products		Motor Gasoline Plus Kerosene Jet Fuel		Motor Gasoline		Motor Gasoline Plus No. 2 Oil
Major Processing		Severe Hydrotreating	Intermediate Plus Downstream Hydrotreating	Severe Hydrotreating Plus Fluid Catalytic Cracking	Intermediate Severity Hydrotreating Plus Hydrocracking	Moderate Hydrotreating
Investment Costs, Millions of Dollars	Notes (See Table 17)					
Onplot Investment	(1), (2), (4)	370	360	460	410	230
Offplot Investment	(1), (2), (3), (4)	230	210	260	230	170
Estimating Allowance	(5)	60	60	70	70	40
Initial Catalyst		20	10	20	20	10
Working Capital	(6), (7), (8)	60	70	90	90	60
Total Investment Costs		740	710	900	820	510
Operating Costs, Millions of Dollars Per Year						
Catalysts and Chemicals	-	6	5	7	5	5
Maintenance	(12)	15	14	18	15	10
Taxes and Insurance	(13)	15	14	18	16	10
Labor	(14)	4	4	5	4	3
Power	(15)	2	3	3	4	2
Boiler Plant Coal	(16)	5	4	6	3	2
Total Operating Costs		47	44	57	47	32
Total Processing Cost, Dollars Per Barrel of Desired Products*	(9)	14.5	14	18	16	10
Volume Ratio of Desired Products to SRC-II Feed		0.835	0.847	0.843	0.885	0.874

*Based on a Capital Charge at 15% Value of Money and Rounded to the Nearest Half Dollar Per Barrel

◇ Revised 8-28-80

TABLE 25

COMPARATIVE COST SUMMARY
REFINING OF SRC-II OIL
"GRASS ROOTS" REFINERIES PRODUCING
50,000 BARRELS PER CALENDAR DAY OF DESIRED PRODUCTS
DOE CONTRACT EF-76-C-01-2315

Refinery Furnace Fuel and Hydrogen Plant Feed Supplied by SRC-II Oil Feedstock

Case		1C	2C	3C	4C	5C	6C
Desired Products		Motor Gasoline Plus Kerosene Jet Fuel		Motor Gasoline		Motor Gasoline Plus No. 2 Oil	
Major Processing		Severe Hydrotreating	Intermediate Plus Downstream Hydrotreating	Severe Hydrotreating Plus Fluid Catalytic Cracking	Intermediate Severity Hydrotreating Plus Hydrocracking	Moderate Hydrotreating	Moderate Hydrotreating Plus Fluid Catalytic Cracking
Investment Costs, Millions of Dollars	Notes (See Table 17)						
Onplot Investment	(1),(2),(4)	370	380	460	420	240	390
Offplot Investment	(1),(2),(3),(4)	210	190	240	210	160	220
Estimating Allowance	(5)	60	60	70	70	40	60
Initial Catalyst		20	10	20	20	10	10
Working Capital	(6),(7),(8)	60	70	100	100	60	90
Total Investment Costs		720	710	890	820	510	770
Operating Costs, Millions of Dollars Per Year							
Catalysts and Chemicals	-	7	5	7	5	4	6
Maintenance	(12)	14	14	17	15	10	15
Taxes and Insurance	(13)	15	14	18	16	10	15
Labor	(14)	4	4	5	4	4	5
Power	(15)	4	4	4	5	3	4
Boiler Plant Coal	(16)	4	2	4	2	2	3
Total Operating Costs		48	43	55	47	33	48
Total Processing Cost, Dollars Per Barrel of Desired Products*	(9)	14.5	14	17.5	16	10	15.5
Volume Ratio of Desired Products to SRC-II Feed		0.883	0.886	0.883	0.920	0.900	0.902

*Based on a Capital Charge at 15% Value of Money and Rounded to the Nearest Half Dollar per Barrel

TABLE 26

COMPARATIVE COST SUMMARY
REFINING OF SRC-II OIL
REFINERIES PARTIALLY INTEGRATED WITH SRC-II PROCESS
50,000 BARRELS PER CALENDAR DAY OF DESIRED PRODUCTS
DOE CONTRACT EF-76-C-01-2315

Refinery Fuel and Hydrogen Plant Feed Supplied by Gas from SRC-II Process
Partial Sharing of Offplot Facilities Assumed

Case		1D	4D	5D
Desired Products		Motor Gasoline Plus Kerosene Jet Fuel	Motor Gasoline	Motor Gasoline Plus No. 2 Oil
Major Processing		Severe Hydrotreating	Hydrotreating Plus Hydrocracking	Moderate Hydrotreating
Investment Costs, Millions of Dollars	Notes (See Table 17)			
Onplot Investment	(1),(2),(4)	300	360	210
Offplot Investment	(1),(2),(3),(4)	140	150	110
Estimating Allowance	(5)	50	50	30
Initial Catalyst		10	20	10
Working Capital	(6),(7),(8)	60	90	60
Total Investment Costs		560	670	420
Operating Costs, Millions of Dollars Per Year				
Catalysts and Chemicals	-	6	5	4
Maintenance	(12)	11	12	8
Taxes and Insurance	(13)	11	13	8
Labor	(14)	3	4	3
Power	(15)	2	3	2
Boiler Plant Coal	(16)	5	3	2
Total Operating Costs		38	40	27
Total Processing Cost, Dollars Per Barrel of Desired Products*	(9)	11.5	13	8.5
Volume Ratio of Desired Products to SRC-II Feed		0.977	0.961	0.948

*Based on a Capital Charge at 15% Value of Money and Rounded to the Nearest Half Dollar Per Barrel

◇ Revised 8-28-80

8-28-80

FIGURE 1

CHARACTERIZATION OF SEVERITIES -
INITIAL HYDROTREATING OF SRC-II OIL
DOE CONTRACT EF-76-C-01-2315

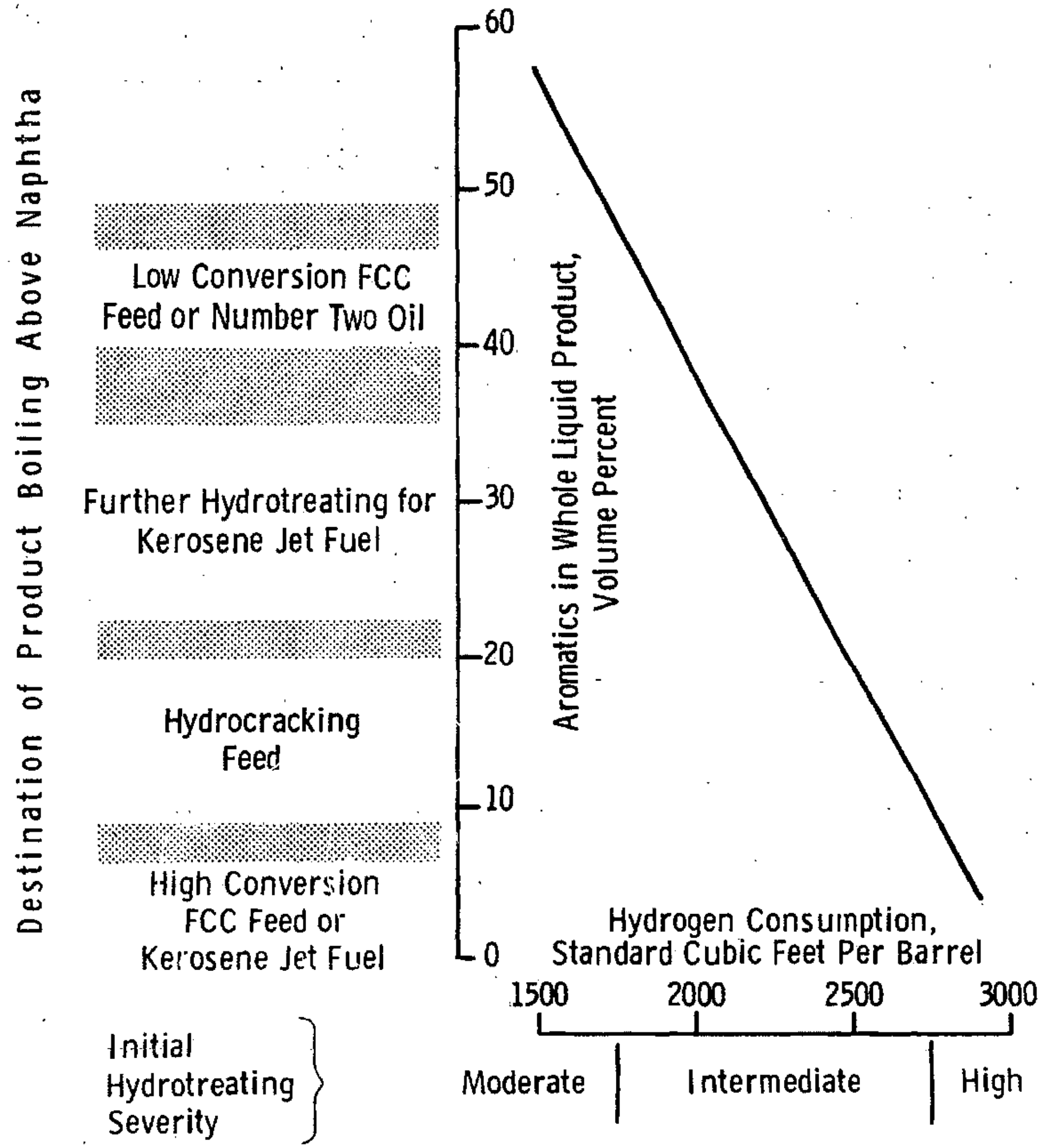
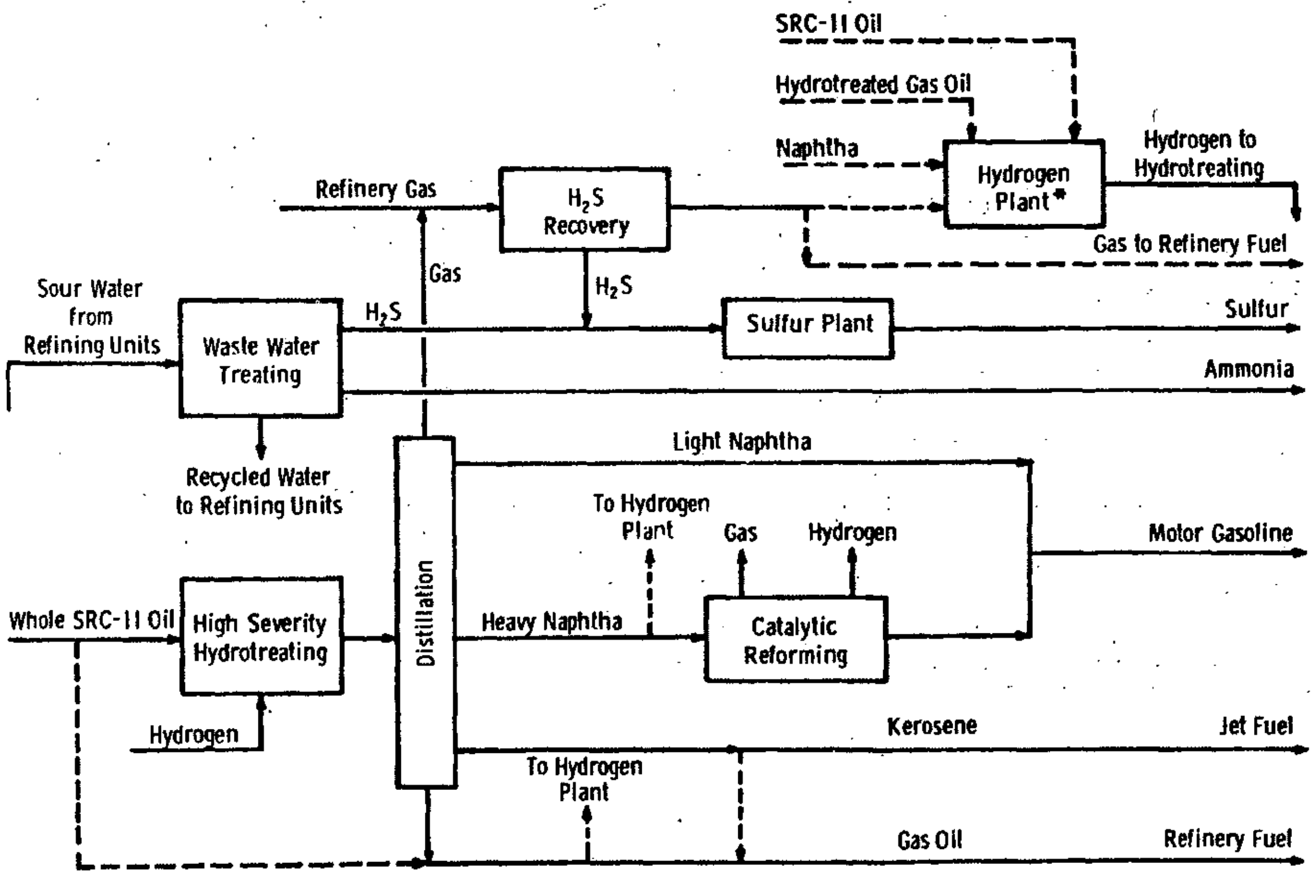


FIGURE 2

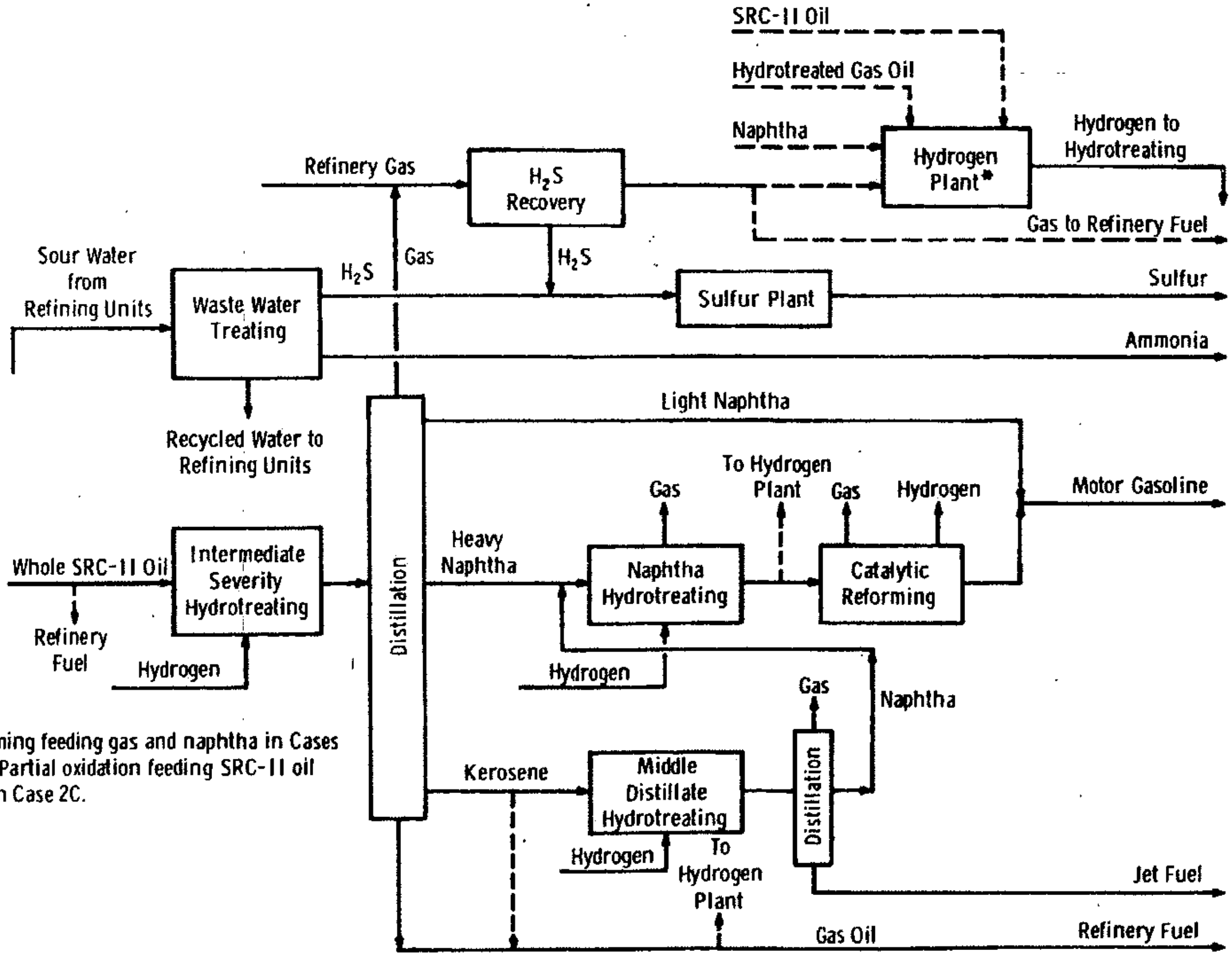
SCHEMATIC FLOW DIAGRAM
REFINING OF SRC-II OIL BY
HIGH SEVERITY HYDROTREATING - CASE 1
DOE CONTRACT EF-76-C-01-2315



*Steam reforming feeding gas and naphtha in Cases 1A, 1B, and 1D.
Partial oxidation feeding gas oil and SRC-II oil in Case 1C.

FIGURE 3

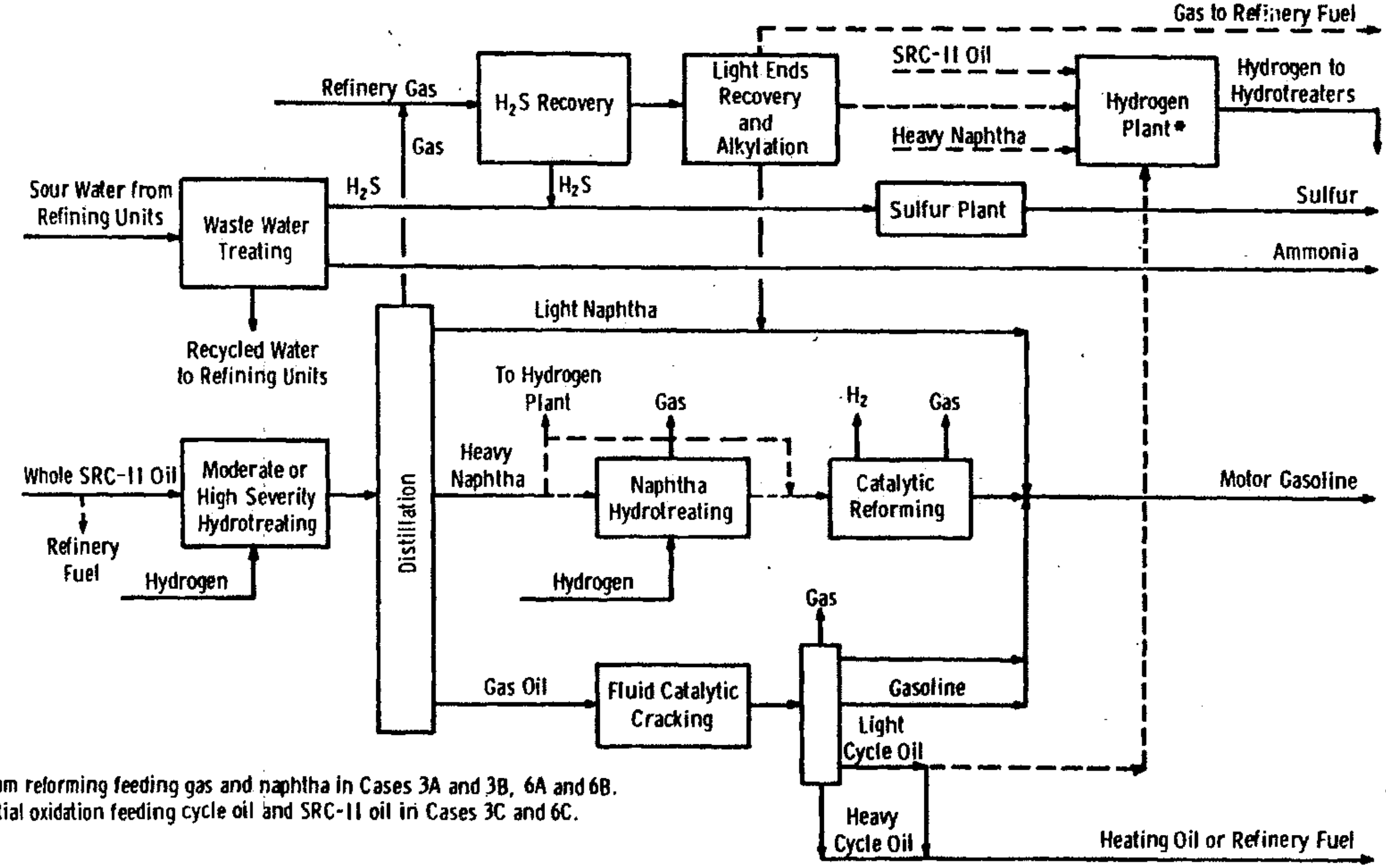
SCHEMATIC FLOW DIAGRAM
REFINING OF SRC-II OIL BY
INTERMEDIATE SEVERITY HYDROTREATING - CASE 2
DOE CONTRACT EF-76-C-01-2315



* Steam reforming feeding gas and naphtha in Cases 2A and 2B. Partial oxidation feeding SRC-II oil and gas oil in Case 2C.

FIGURE 4

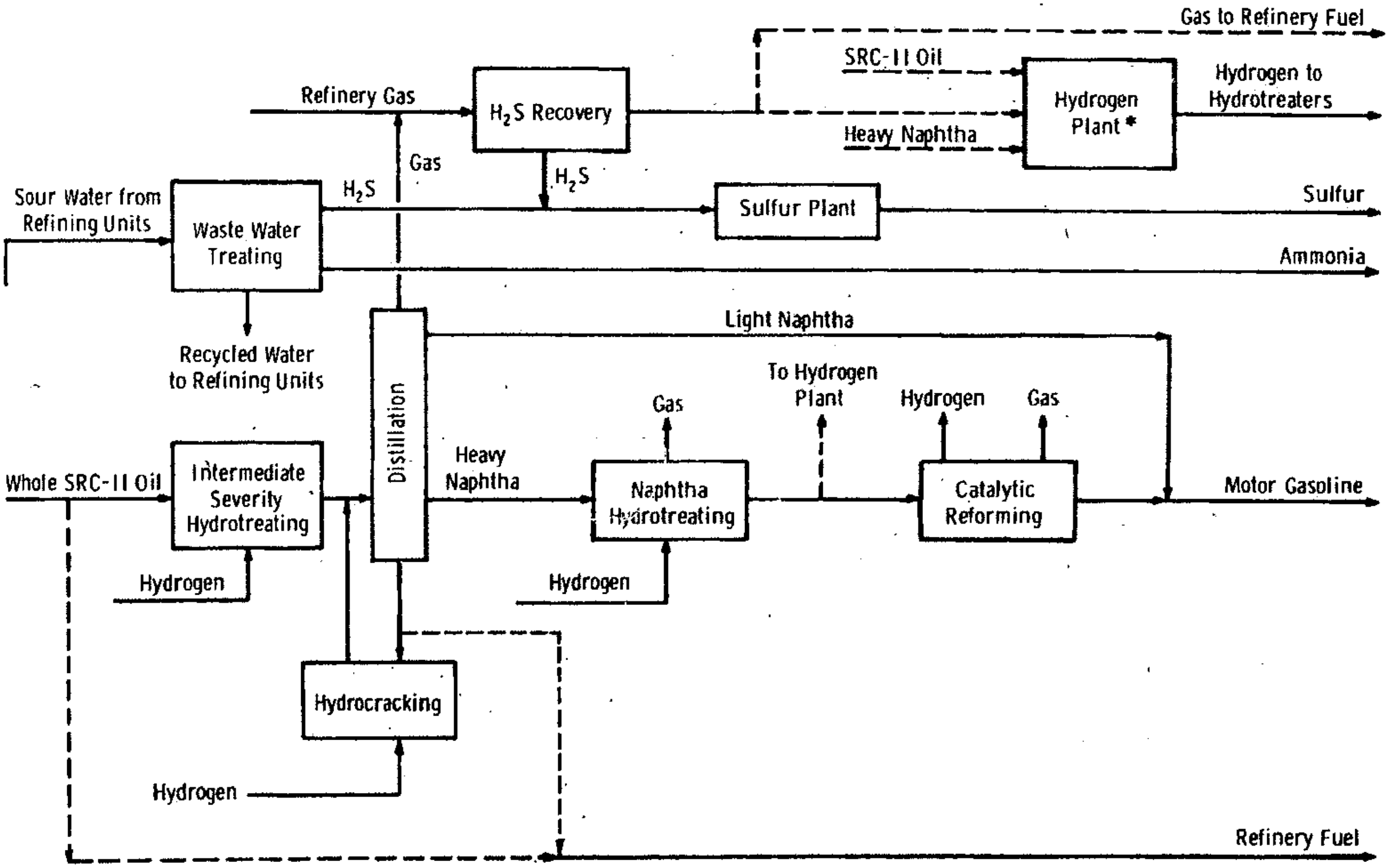
SCHEMATIC FLOW DIAGRAM
REFINING OF SRC-II OIL BY
HYDROTREATING AND FLUID CATALYTIC CRACKING - CASES 3 AND 6
DOE CONTRACT EF-76-C-01-2315



* Steam reforming feeding gas and naphtha in Cases 3A and 3B, 6A and 6B.
Partial oxidation feeding cycle oil and SRC-II oil in Cases 3C and 6C.

FIGURE 5

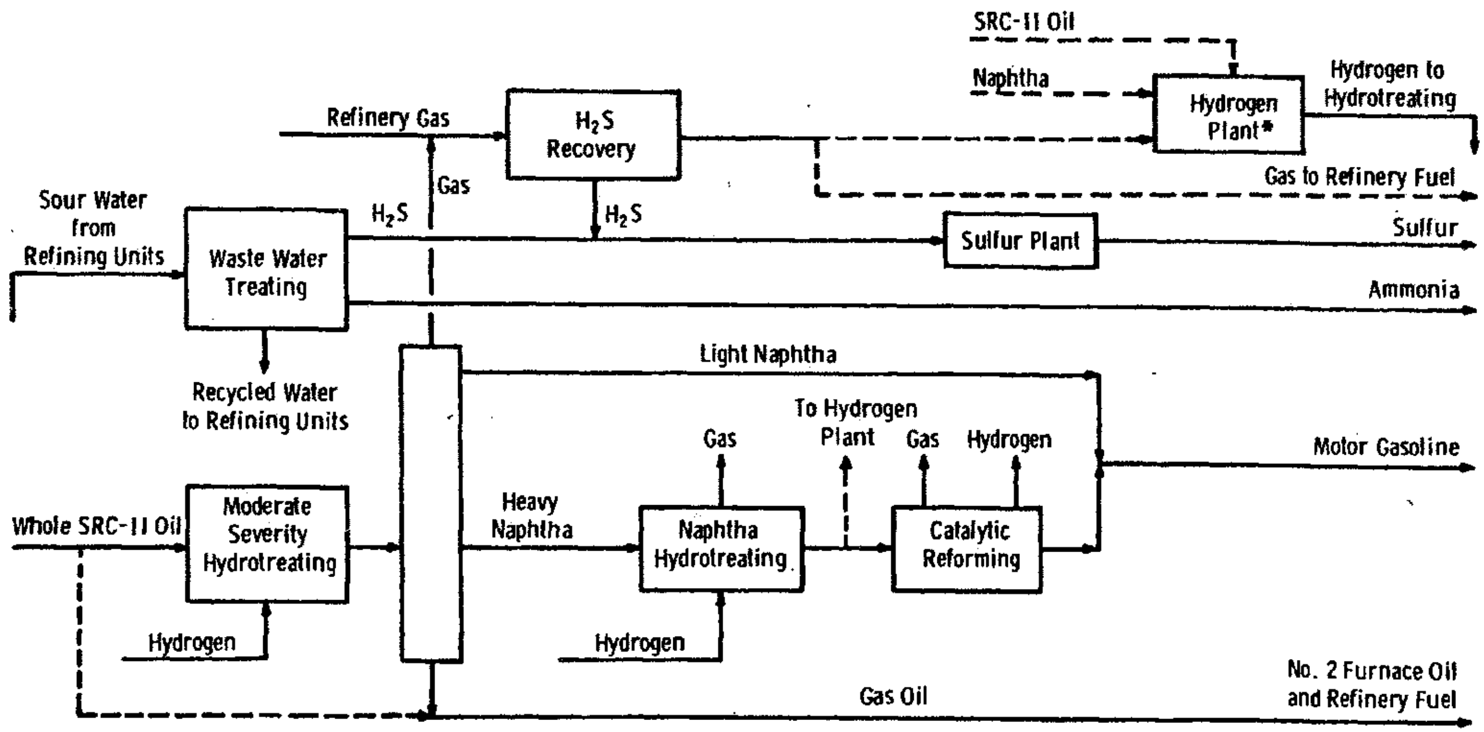
SCHEMATIC FLOW DIAGRAM
REFINING OF SRC-II OIL BY
HYDROTREATING AND HYDROCRACKING - CASE 4
DOE CONTRACT EF-76-C-01-2315



* Steam reforming feeding gas and naphtha in Cases 4A, 4B, and 4D.
Partial oxidation feeding SRC-II oil in Case 4C.

FIGURE 6

SIMPLIFIED FLOW DIAGRAM
REFINING OF SRC-II OIL BY
MODERATE SEVERITY HYDROTREATING - CASE 5
DOE CONTRACT EF-76-C-01-2315



* Steam reforming feeding gas and naphtha in Cases 5A, 5B, and 5D.
Partial oxidation feeding SRC-II oil in Case 5C.

FIGURE 7

SIMPLIFIED FLOW DIAGRAM OF
CHEVRON FIRST STAGE HYDROTREATER
REFINING OF SRC-II OIL
DOE CONTRACT EF-76-C-01-2315

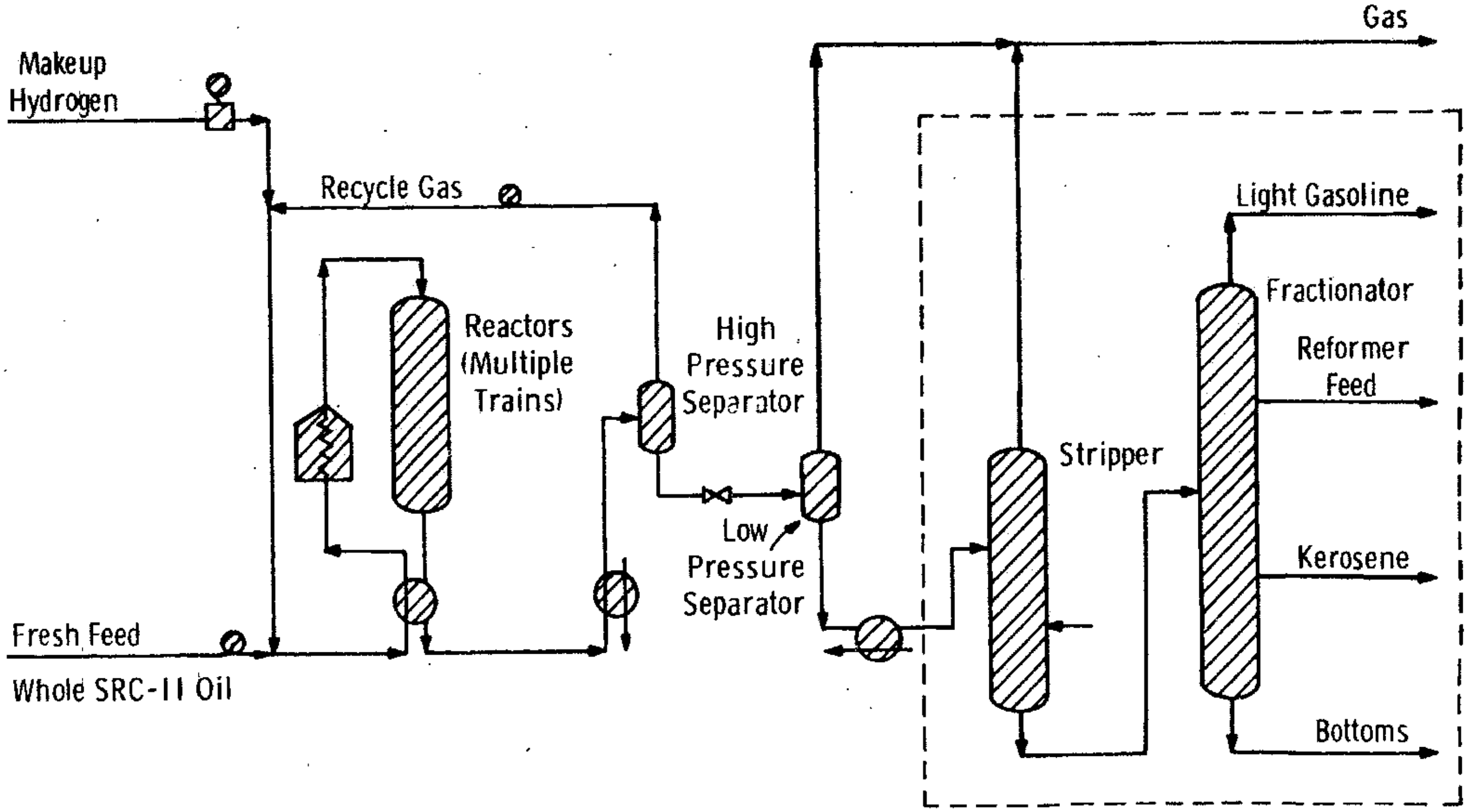


FIGURE 8

SIMPLIFIED FLOW DIAGRAM OF
CHEVRON SINGLE STAGE RECYCLE ISOCRACKER
REFINING OF SRC-II OIL
DOE CONTRACT EF-76-C-01-2315

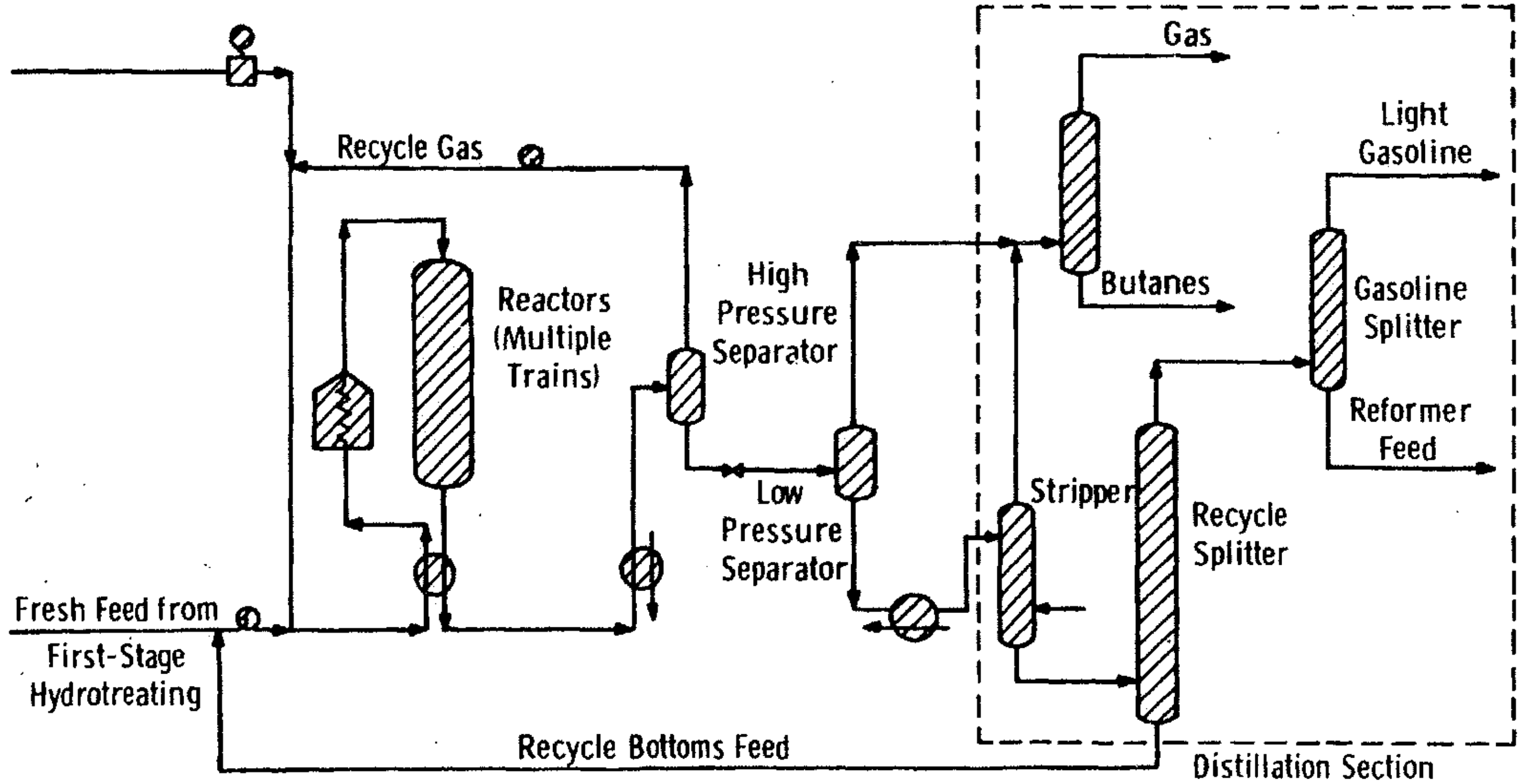


FIGURE 9

SIMPLIFIED FLOW DIAGRAM OF
CHEVRON WWT PROCESS
REFINING OF SRC-II OIL
DOE CONTRACT EF-76-C-01-2315

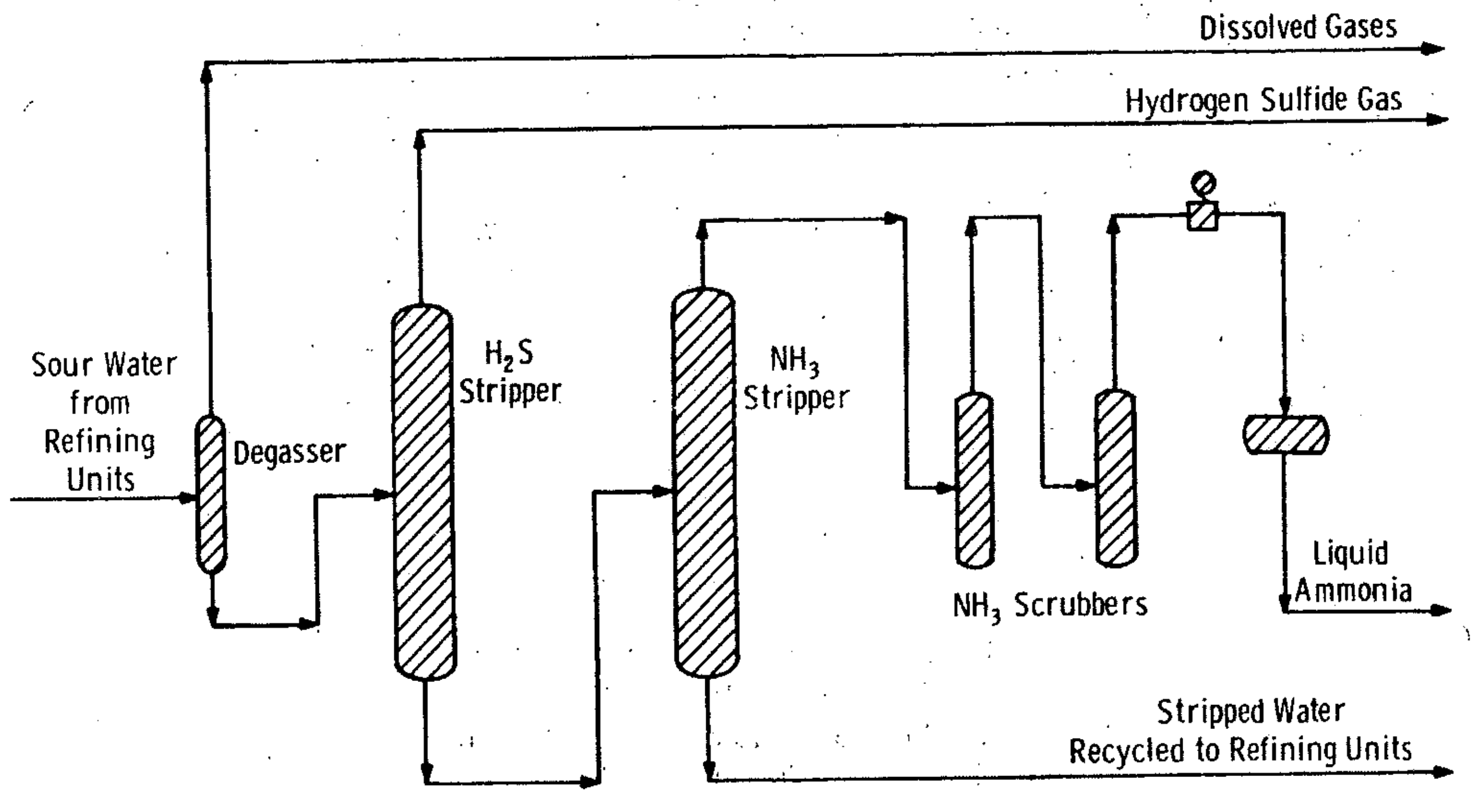


FIGURE 10

COMPARISON OF SRC-II OIL BOILING CURVES
DOE CONTRACT EF-76-C-01-2315