SYNFUELS R&D STATUS AND PROJECTIONS

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INTRODUCTORY REMARKS

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Presumably, I have been asked to serve as moderator of this session on "Industrial Synfuels R & D Status", because I have little to contribute but questions. At the outset, let me make it perfectly clear that neither I nor the company I represent are engaged in any activity that could pass for "Synfuel R & D". I am here to learn, not to teach.

Having set the record straight on my credentials and objectives, let me now tell you about some of my concerns. I cannot assure you that they accurately portray all of the engine industry's concerns, but I believe they hit the high points.

First Concern

I am convinced that this country and the rest of the non-communist world will enter a new era of petroleum insufficiency within the next 15 years. I also believe that the doubting Thomases will fall silent and begin to bid the price of oil up through the ceiling even sooner---probably starting in the 1985-1987 period---when it becomes inescapably obvious that a crunch cannot be avoided.

My concern, then, is for the availability of gap-fillers (Synfuels) when the petroleum shortage materializes. An ERDA study suggests that the U. S. could experience a petroleum shortfall of 18 MMBD by the year 2000. The same study projects our maximum Synfuel capability---assuming a "no-holds-barred" crash program---at 10 MMBD and a "reasonable" maximum of 3 MMB by 2000.

Accepting the shaky nature of these estimates, the picture still emerges of a very small boy (the Synfuel industry) trying to shoulder an impossibly large burden.

The question to my colleagues then is this: Is the Synfuel industry going to be able to rise to the occasion, or are we talking about bailing a torpedoed ship with a teaspoon?

Second Concern

Given the declining availability of petroleum and the rising availability of Syncrudes, it appears that we are headed for a period of increasingly unsettled fuel specifications. This is a matter of considerable importance to the engine industry not only with respect to the operating characteristics of newly manufactured engines, but also to the operability of millions of engines already in the field, from which their owners expect many years of satisfactory service.

Will the Synfuel industry be able to maintain fuel specifications within current limits as the percentage of Syncrude rises?

Third Concern

Perhaps as a corollary to the previous concern is the question of ultimate Synfuel specifications. If we derive fuels conforming to traditional specifications from our Syncrudes, are we making the best possible use of those crudes? Or should an optimization of the crude-refinery-fuel-engine system be undertaken to insure that we are getting the maximum useful work from our resources? And if such an optimization is to be performed, how should it be organized?

Proposal

After so many questions, let me propose a way to bring our Synfuel future into focus.

Right now, the engine industry has only a vague concept of what is meant by the word "Synfuel". The fuel industry must begin to define what Synfuel is. Assuming that it is an "umbrella" name for a broad range of possible fuels, we need to know how that range differs from today's.

The sooner the fuel industry can define specific candidate Synfuels, the sooner we will be able to develop a meaningful dialogue between the engine builders and the fuel suppliers.

I expect that we will find that Syncrude is sufficiently different from the petroleum crudes of today to make it difficult, and perhaps uneconomic, to produce fuels which are precisely like today's fuels.

I suggest that candidate fuels for spark and compression ignition engines should be made available to the engine industry as soon as possible. They should be representative of the specifications which would seem to make the most economical use of our combined resources.

The engine industry, for its part, should experiment with these candidate fuels in order to define the kind of engine modifications which would be necessary to adapt to these fuels while retaining acceptable power, economy and emissions characteristics.

I anticipate a long period of iteration before we agree on what are acceptable Synfuel specifications from both the supplier's and the user's points of view. But, it is important that we begin the process soon if we hope to make a smooth transition to that brave new world in which Synfuels are expected to satisfy an increasing share of our energy needs.

BROADCUT FUELED ENGINES USING NON-HYDROCRACKED SHALE OR COAL PYROLYSIS LIQUIDS AS FUELS — AN ALTERNATIVE ENGINE/FUEL STRATEGY

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Broadcut Fueled Engines Using Non-Hydrocracked Shale or Coal Pyrolysis Liquids as Fuels--An Alternative Engine/Fuel Strategy

An alternative to hydrocracking crude shale oil and coal to refinable liquids of compositions nearly identical to gasoline and diesel fuel is needed. One approach is to develop engines which work on hydrocarbon liquids derived by simple processing steps from shale oil or coal pyrolysis liquids. This paper discusses this alternative and why we believe its a valuable program to pursue.

Energy Costs

At the heart of this proposal is the search for ways to use coal and shale oil which on a BTU basis are no more costly than oil at today's world oil price.

Continually rising oil demand and rising cost in the face of limited production is at the heart of the energy problem. Forecasts of world oil supply and demand indicate a high probability that oil will become more scarce and more expensive during the late 1980's. At present, world oil production is about 60 million barrels/day. It is not likely to exceed 70 million b/d in the future.*

Over the past 15 months, a variety of industrial, governmental and academic groups have assessed the world oil outlook. The results demonstrate a high degree of uncertainty. Nevertheless, these studies indicate a high probability that world demand for OPEC oil will meet or exceed OPEC production sometime during the 1980's. Any shortfall of OPEC production compared to demand will make world oil markets tighten and oil prices rise. How much tightening and how much price rises is highly uncertain.

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* Draft of the National Energy Supply Strategy, D.O.E. document, April, 1978

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In the internal D.O.E. document drafted for the House Science and Technology Committee on a National Energy Supply Strategy, the authors state that if "prices alone are relied upon to trim growing consumption to match static OPEC capacity, oil prices must rise sharply for a number of years. World oil prices could double sometime between 1985 and 1990".

U.S. Energy Picture

Our forecast of the U.S. energy picture is summarized in Table 1:

TABLE 1. ENERGY USE

(Expressed in Million Barrels/Day Crude Equivalent)

	1978	2000
Oil	18	23
Gas	10.5	10
Coal	6.5	13
Hydro/Geothermal	1.5	2.5
Nuclear	1.5	15
Solar	-	1
Total	38	64.5

Of particular interest is the forecast liquid hydrocarbon supply-demand picture. Table 2 summarizes our best guess for the year 2000. We have assumed strong conservation moves and shifts to coal for utility and industrial boilers. We believe legislative action and government pressures will be a major force in directing energy developments along the lines shown in Table 2.

TABLE 2. LIQUID H/C SUPPLY-DEMAND

YEAR = 2000

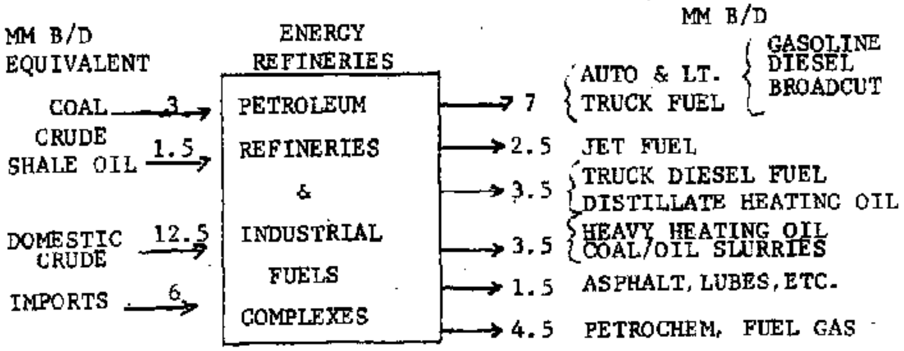

Table 2 needs some explanation. We believe that the petroleum industry will lead the nation in energy advances through expansion into "energy refineries". These refineries will process coal and crude shale oil as well as conventional petroleum.

To meet the liquid hydrocarbon demand in the year 2000, we believe that coal and shale oil will be required. Domestic crude production is forecast at 12.5 million barrels/day. We believe imports will be limited to 6 million barrels/day--either by U.S. government limitation or by world competition for limited OPEC oil. This shortfall--4.5 million barrels per day--will have to be made up by coal and shale oil.

The challenge facing us is to develop technology to convert shale oil and coal to meet this growing liquid hydrocarbon shortfall at costs nearly competitive with the world oil price as it is today. Prices of $25 per barrel for synthetic oil (in 1978 dollars) to meet this shortfall will have significant negative effect on our economy.

The conventional approach to synthetic fuels production is hydrocracking. Shale oil requires about 2000 scf/bbl and coal in excess of 5000 scf/bbl. Current H_2 costs of $2.20/bbl add $4.40/barrel to crude shale oil cost and $11/barrel to coal costs. And we see no real hope for lower cost hydrogen. Using hydrocracking for upgrading shale and coal to refinable liquids almost inevitably leads to prices in the range $20/barrel shale syncrude and $25/barrel coal derived syncrude. While these syncrudes may be higher quality than typical crudes, this is not nearly sufficient to make up for the large differences in prices.

We are proposing an alternative approach. Our approach is to use simple processing steps, without hydrocracking, to produce acceptable fuels to meet this shortfall. But the fuels are obviously going to be different and would generally be considered of lower quality. Thus, special engines or burners need to be developed for these fuels. And there needs to be an incentive to do so.

To understand this approach, I refer again to table 2. An opportunity to use low cost processing of shale oil and coal hinges on three developments: (1) An engine which can operate on a broadcut IBP-700° non-hydrotreated shale or coal pyrolysis liquid, (2) the wide spread use of coal/oil mixtures for industrial and certain utility boilers, and (3) fluid bed combustion of coal or char for refinery process heat.

The basic approach is to:

1) Split shale oil into two roughly equal fractions--a IBP-700°F distillate cut and a 700°F+ bottoms cut for coal/oil mixtures.

2) Pyrolyze coal into a IBP-700°F pyrolysis liquid and char.

3) Use char for coal/oil mixtures and for refinery heat via fluid bed combustion.

The IBP-700°F shale and coal pyrolysis distillates would be combined and stabilized for use as a broadcut fuel. The properties are given in Table 3.*

TABLE 3

Possible Range of Properties of a Reference Broadcut Fuel From Shale and/or Coal Syncrude

Property	Value
Specific gravity	0.85 to 0.93
Distillation, D-86, °F	
IBP	100 min.
50%	200 to 400
90%	550 to 650
EP	750 max.
Residue, vol%, max.	1
Aromatics, vol%	30 to 50
Olefins, vol%	10 to 25
Sulfur, wt%, max.	0.50
Nitrogen, ppm, max.	100
Trace metals, ppm, max.	
Na+K	10
V	5
Ca	20
Ash, wt%, max	0.03
Viscosity, cSt at 100°F	1.4 to 6.0
Pour Point, °F, max	10
Flash Point, °F, min.	100

Such a fuel presents several problems for engine combustion, e.g.: (1) need to stabilize, (2) high nitrogen content giving NOx in exhaust, (3) volatilization problems in combustion. Yet, it is technically feasible

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*Reference. Identification of Probable Automotive Fuels Compositions. 1985-2000. Contract EY-76-C-04-3684. D.O.E.

to solve all these in relatively low cost ways. Embarking upon such a program could lead to a significantly lower cost way to meet our energy needs.

This approach does require new engines. One promising engine is the direct-injected stratified charge (DISC) engine. Such an engine can, in principle, operate on the fuel described in table 3, provided chemical treatments are developed to stabilize the fuel. A way to control fuel contributed NOx will also have to be developed. One possible approach is simple extraction of nitrogen compounds via solvent extraction. KVB, for example, has such a process in development.

Referring again to table 3, the targeted coal and shale oil use would yield about 1.5 million barrels per day of this broadcut fuel. The remainder of the coal and shale oil bottoms could be consumed in fluid bed combustion for process heat, coal/oil mixtures for industrial & utility burners and for chemicals. These levels of usage seem feasible for the year of 2000.

PRODUCTION OF LIQUID FUELS FROM OIL SHALE

S.K. Alley
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"PRODUCTION OF LIQUID FUELS FROM OIL SHALE"

S. K. Alley

INTRODUCTION

The United States is richly endowed with fossil fuel resources recoverable using today's technology (Figure 1). The largest of these resources is in the form of coal, but oil shale constitutes a significant resource, comparable to conventional crude oil in terms of the rate at which it could be produced to help satisfy our energy needs.

Oil shale is found in several areas of the United States (Figure 2); however, considering size, quality and accessibility, the only deposit suitable for development with present technology is the Green River formation underlying 16,000 square miles in Colorado, Utah, and Wyoming. (Figure 3).

"Oil Shale" is a term used to cover a wider range of materials than are properly classified as true shales. The organic component of oil shale, known as "kerogen," occurs in combination with a variety of sedimentary minerals. The kerogen consists of complex, high molecular weight compounds which are rich in carbon and hydrogen. Kerogen undergoes destructive distillation when heated to between 700°F and 900°F to yield a crude oil rich in hydrocarbons and containing many sulfur, nitrogen, and oxygen compounds. The process of obtaining the hydrocarbons from oil shale is known as "retorting." Oil shales being considered for development contain 30-45 gallons/ton, but shales range from 10-70 gallons/ton.

SOME CURRENT RETORTING CONCEPTS

Because oil shale has very low permeability, it must be broken up to permit retorting. Both "in place" and surface operations are contemplated for commercial recovery of oil from shale. For above-ground retorting, the shale is mined and crushed. In-situ processes involve blasting, hydraulic fracturing, or leaching to prepare the shale for the retorting operation.

The three major concepts in above-ground retorting utilize (1) gravity flow of shale down through a vertical vessel; (2) upflow of shale moved by a solids pump; and (3) circulation of an inert solid heat carrier.

Four retorting processes currently under consideration are: (1) The Petrosix process, developed by Petrobras, the Brazilian national oil company, is a downflow process using gas combustion: (2) The Paraho kiln is another modification of the gravity flow concept. Heat required for retorting comes from combustion of recycle gas, carbon residue or externally heated recycle gas. (3) The Tosco II process which uses an inert solid heat transfer medium. In this process, crushed raw shale is preheated with hot flue gas and then fed to a horizontal, rotating pyrolysis drum where it is contacted with hot ceramic balls and heated to retorting temperature. (4) The Union Oil Company retorting process utilizes the upflow of solids. Shale is pumped upward through an expanding cone as shown in Figure 4. A countercurrent stream of gas heats the rising bed of shale to the temperature necessary for retorting. The upflow technique achieves several very important objectives, as follows:

(a) Oil liberated from the shale is quickly forced downward by the gas, toward cooler shale. This quenches the polymerization reactions which form heavy residues that are difficult to refine. (b) Oil condensing in the bed of cooled shale drains away from the retorting zone. This eliminates any chance of refluxing and coking of the product oil as in a downflow retort. (c) Finally, retorting takes place near the top of the retort. Here, the pressure between shale particles is at a minimum. With the rich Colorado shale, a plastic condition exists under certain retorting conditions. If the particle contact pressures are too high, agglomeration occurs (1, 2, 3, 4).

UPGRADING OF SHALE OIL TO LIQUID FUELS

Shale oil can be processed, using existing petroleum refining technology, into a full slate of fuels and/or petrochemical feedstocks. Shale oil does have some properties which differ significantly from petroleum crudes, and which require special technology in refining. Figure 5 lists properties of crude shale oils made in Union Oil's retorting operations. Compared to petroleum crudes, the shale oil is markedly higher in ash, nitrogen and arsenic content. Thus, in a sense, crude shale oil is closer to coal than to petroleum.

The liquid product from retorting shale contains up to 2000 ppm of shale fines and other solids, and from 20 to 50 ppm of arsenic in the form of organic compounds. Union Oil has developed proprietary technology to remove solids and arsenic to any desired level consistent with use of the product as fuel oil or as a refinery feedstock.

Removal of Solids and Arsenic

Figure 6 shows a schematic flow diagram for the refining of shale oil. The pretreatment steps involve first the removal of the bulk of the solids, and then a special step for the removal of arsenic. The removal of solids is necessary to prevent plugging of the downstream reactors. Arsenic deactivates the hydrotreating catalyst and markedly affects catalyst regenerability. Union Oil's proprietary arsenic removal process (5) operates at moderately low pressure, considerably lower than the pressure of the hydrotreating section. Figure 7 shows a simplified flow diagram of the arsenic removal system which contains both guard chambers and absorbent reactors. This system is capable of reducing the arsenic content of the oil to less than 1 ppm. After gas separation, the treated oil is ready for hydrotreating.

Hydrotreating of Shale Oil

The objective of shale oil refining work has been the production of a high-quality syncrude which can be further processed into transportation fuels using conventional refining technology. A typical shale oil may contain 1.8% nitrogen, 0.75% sulfur and 0.9% oxygen. This level of nitrogen is about ten times that of normal crude oils. Because nitrogen is a poison for many downstream catalytic processes, reduction of the nitrogen content is necessary to make shale oil compatible with the processing capabilities of most existing refineries. Such hydrotreating can be carried out in moderately high pressure, but using conventional equipment. Proper reactor design is important however, because of 1) the high heat release from the hydrogenation reactions, 2) the high conversion required, and 3) the high cost per unit of reactor volume. With present technology, a high quality syncrude, with a product nitrogen of about 500 ppm, can be produced with a hydrogen consumption of about 1500 scf/bbl (0.29 Nm^3/kg) of shale oil. In such a system, hydrotreating catalyst cycle life of 1.5 years is expected.

Properties of Hydrotreated Shale Oil and Fractions Therefrom

Some properties of a raw and a hydrotreated full range shale oil are shown in Figure 8. This particular treating operation has produced a 35.2°API gravity oil with 500 ppm nitrogen, 14 ppm sulfur and <50 ppm oxygen with nil arsenic. Substantial mid boiling point reduction is seen for this hydrotreated product.

In Figure 9 a comprehensive, crude assay-type analysis is shown for a full-range product sample hydrotreated to 670 ppm nitrogen. The naphthas, after additional hydrotreatment to lower the nitrogen and sulfur content, make good reforming stocks on the basis of the moderately high ring content. The turbine and diesel fuel stock show properties which make them valuable blending components. The diesel-free gas oil can be used for charge stock to a fluid cat cracker. Thus, it is seen that shale oil can be treated to produce good feedstocks for making finished transportation fuels with modern refining technology.

Some Possible Schemes for Upgrading Shale Oils

As shown above, full range raw shale oil can be de-ashed, dearsenited and hydrotreated to produce intermediate streams for further processing in a conventional refinery. There are other options for upgrading shale oil, some of which are shown below. All these upgrading schemes involve to a greater or lesser degree, removal of unwanted contaminants (i.e., water, ash, arsenic, nitrogen, sulfur, oxygen) and increase of hydrogen content of the hydrocarbons.

Basically, one can coke the shale oil directly and treat the resulting liquids, or hydrotreat the raw shale to provide feed for further downstream conversion units. These two routes are summarized below, along with a minimum upgrading case:

I – Raw Shale Oil ⟶ Coking ⟶ Hydrotreating ⟶ Distillation ⟶
⟶ Liquids for Further Processing

II – Raw Shale Oil ⟶ Solids Removal ⟶ Hydrotreating ⟶ Distillation ⟶
⟶ (a) Hydrocracking of 650°F+ Fraction or
⟶ (b) Fluid Catalytic Cracking of 650°F+ Fraction
Both (a) and (b) produce liquid fuels for further upgrading.

III – Direct Utility Fuel
Raw Shale Oil ⟶ Solids Removal ⟶ Feed to Power Plants

The particular upgrading scheme employed will be determined by the intended use of the finished fuel, the quality of the raw shale feed, and nearness of retorting site to refining facilities, and other factors (7, 9).

Use of Catalysts in Refining of Shale Oils

In most proposed schemes for shale oil upgrading, catalysts which are other than conventional are needed for only two operations. The arsenic removal step is best carried out with a long-lived, efficient catalyst (and absorbent), and the hydroprocessing of raw shale oil for deep nitrogen removal requires a rugged catalyst. Such catalysts have already been developed by those active in oil shale upgrading technology (1, 7, 8, 9). Downstream processing of coker liquid fractions or of fractions from hydrotreated whole shale oil can be carried out with conventional refining catalysts, and at more or less conventional operating conditions.

HISTORY AND CURRENT STATUS OF THE SHALE OIL INDUSTRY

Although there has been research and development activity in the oil shale field since the early 1920's, the shale oil industry has yet to reach commercial importance. The shale oil deposits have been well defined, analyzed, characterized and evaluated for mining and retorting ease. Various demonstration plants have been constructed and operated to demonstrate technical feasibility (9, 11). An experimental retort was built and operated over 25 years ago by the Bureau of Mines in Colorado. In the late 1950's, Union Oil Company of California constructed and operated a 1200 tons/day plant near the same area in Colorado (10). Laramie Energy Research Center has operated a 150-ton batch unit at their Laramie, Wyoming facilities. The Colony Shale project (Tosco-II process) was operated for several years and produced many thousands of barrels of shale oil (11). Occidental Petroleum has been conducting in-situ retorting studies for several years (12). There are various other in-situ operations being conducted on U.S. government leases. The Paraho demonstration plant in Colorado has operated for several years to produce ~100,000 barrels of raw shale oil. This oil has been shipped to Sohio's Toledo Refinery for preparation of fuels for testing by the U.S. Navy.

Union Oil Company of California has announced plans to construct, with its own funds, a $100 million experimental oil shale project if Congress creates the necessary investment and regulatory climate for the oil shale industry (9). This plant would be located on Union Oil lands in Grand Valley, Colorado and would process 10,000 tons/day of 41 gallons/ton oil shale (~9,000 barrels/day of raw shale oil). This shale oil would be used directly as boiler fuels in electrical generating plants.

FUTURE OF FUELS FROM SHALE OIL

As indicated in the foregoing text, serious entries into oil shale development are being made. The success of these ventures is quite dependent on evolution of the proper political climate to get the shale oil industry competitive. Once the prototype plants are operating, evolutionary improvements will increase the efficiency of this technology and make it even more competitive. However, it must be emphasized that the outlook for the oil shale industry is uncertain at this time. The large capital investments required, the availability of foreign oil, the environmental hurdles and the emergence of competitive energy sources (nuclear, solar, coal, etc.) all contribute to this uncertainty. Official projections of the size of the shale oil industry in 1985 have declined in magnitude over the past three years (13). However, considering the size of our oil shale reserves, our growing dependence on non-domestic oil sources and the slowness of development of other energy sources, it is simply a matter of time until the U.S. must develop a viable oil shale industry. The exact path that this development will take is not certain at this time, but Union Oil's announced prototype plant represents a giant first step towards evolving a sound shale oil industry. Whatever ultimate path is established for production of liquid fuels from shale oils, all indications are that the quality of these shale-derived fuels will be such that they will present no insurmountable problems for current and projected engines and lubrication systems.

REFERENCES

1. Hartley, F. L., "Oil Shale: Another Source of Oil for The United States," Oil Daily's Third Annual Synthetic Energy Forum, New York, New York, June 10, 1974.

2. Baral, W. J. and C. P. Reeg, "Liquid Fuels from Oil Shale," presented to the 106th Annual Meeting, Am. Inst. of Mining Metallurgical and Petroleum Engineers, March 6-10, 1977, Atlanta, Georgia.

3. Hopkins, J. M., H. C. Huffman, A. Kelley and J. R. Pownall, "Development of Union Oil Company Upflow Retorting Technology," Presented at 81st National Meeting, American Inst. of Chemical Engineers, April 11-14, 1976, Kansas City, Missouri.

4. Duir, J. F., R. F. Deering and H. R. Jackson, "New Developments in Oil Shale Retorting by Union Oil Company." Presented at the API Refining Department 42nd Midyear Meeting, Update of Alternate Fossil Fuel Technology, May 10, 1977, Chicago, Illinois.

5. Young, D. A., U. S. Patent No. 4,046,674, September 6, 1977. Assignee: Union Oil Company of California.

6. Sullivan, R. F. and B. E. Stangeland, "Catalytic Hydroprocessing of Shale Oil to Produce Distillate Fuels," Symposium on Refining of Synthetic Crudes, Petroleum Division, 174th National American Chemical Society Meeting, Chicago, Illinois, 8/28-9/2/77. (Preprints, Div. of Petroleum, Inc. 23, (1), pp. 322-342, March 12-14, 1978).

7. Sullivan, R. F., B. E. Stangeland, C. E. Rudy, D. E. Green and H. A. Frumkin, "Refining and Upgrading of Synfuels from Coal and Oil Shales by Advanced Catalytic Processes; First Interim DOE Report, Processing of Paraho Shale Oil," Contract No. EF-76-C-01-2315, July 1978.

8. Sullivan, R. F., B. E. Stangeland, H. A. Frumkin and C. W. Samuel, "Refining Shale Oil," 1978 Proceedings of the 43rd Midyear American Petroleum Institute Meeting - Refining Department, pp. 199-210, May 8-11, 1978, Toronto.

9. Synder, G. B. and J. R. Pownall, "Union Oil's Long Ridge Experimental Shale Oil Project," Presented at Colorado School of Mines Oil Shale Symposium, April 13, 1978.

References, cont'd.

10. Hartley, F. L. and C. S. Brinegar, "Oil Shale - Energy of the Future," Fifth World Petroleum Congress, Section II, Paper No. 4, 1959.

11. Yen, T. F., Science and Technology of Oil Shale. Chapter 4, "The Tosco-II Oil Shale Process," Whitcombe, J. A. & R. G. Vawter, pp. 47-64, Ann Arbor Science Publishers, Inc., 1976.

12. ibid., Chapter 6, "Operations and Environmental Considerations, Occidental Petroleum Corp. - In-Situ Operations," Chew, III, R. T., pp. 73-81.

13. (a) Project Independence, ERDA, Federal Energy Administration Independence Blueprint, Final Task Force Report, November 1974.
(b) ERDA Report #1547, Final Environmental Impact Statement, September 1977.

FIGURE 1

UNITED STATES FOSSIL ENERGY RESOURCES

(1973)

	RESOURCE IN PLACE	RECOVERABLE BY TODAY'S TECHNOLOGY	ESTIMATED 1973 PRODUCTION	YEARS OF SUPPLY AT 1973 RATES
	QUADRILLION BTU			
COAL	74,400	3,600	15	240
OIL SHALE		424	—	21 *
CRUDE OIL	4,100	415	20	21
NAT. GAS	1,510	295	23	13
TAR SANDS	162	29	—	1 *
U.S. TOTAL	90,000	4,800	58	82 *

*BASED ON PRODUCING SYNCRUDE FROM SHALE AT U.S. 1973 CRUDE OIL PRODUCTION RATE OF 10 MM B/D.

**BASED ON TOTAL 1973 YEARLY PRODUCTION OF COAL, CRUDE OIL AND NATURAL GAS.

FIGURE 2

LOCATION OF U.S. OIL SHALE DEPOSITS AND TYPES

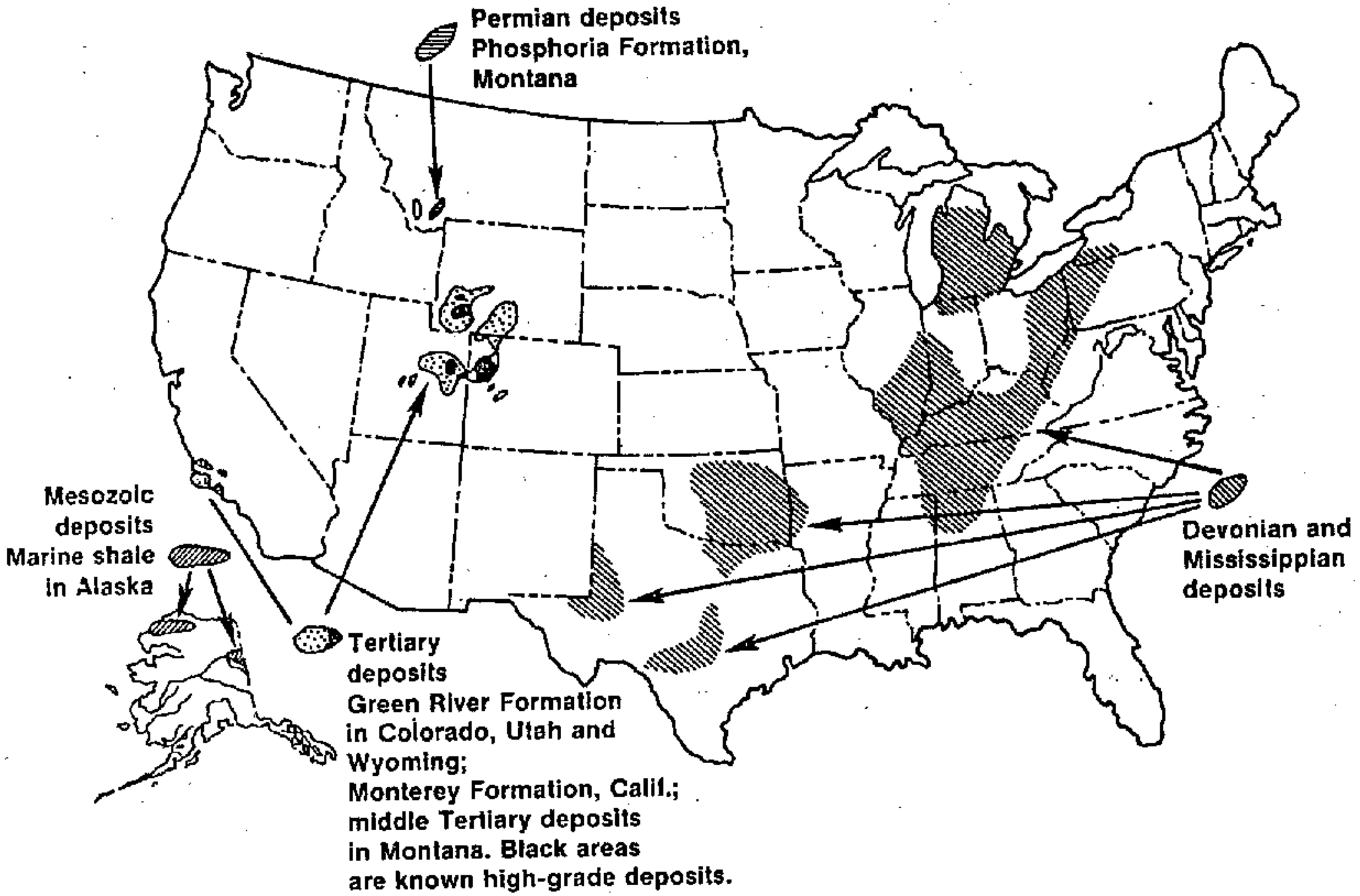

FIGURE 3

THE GREEN RIVER SHALE FORMATION

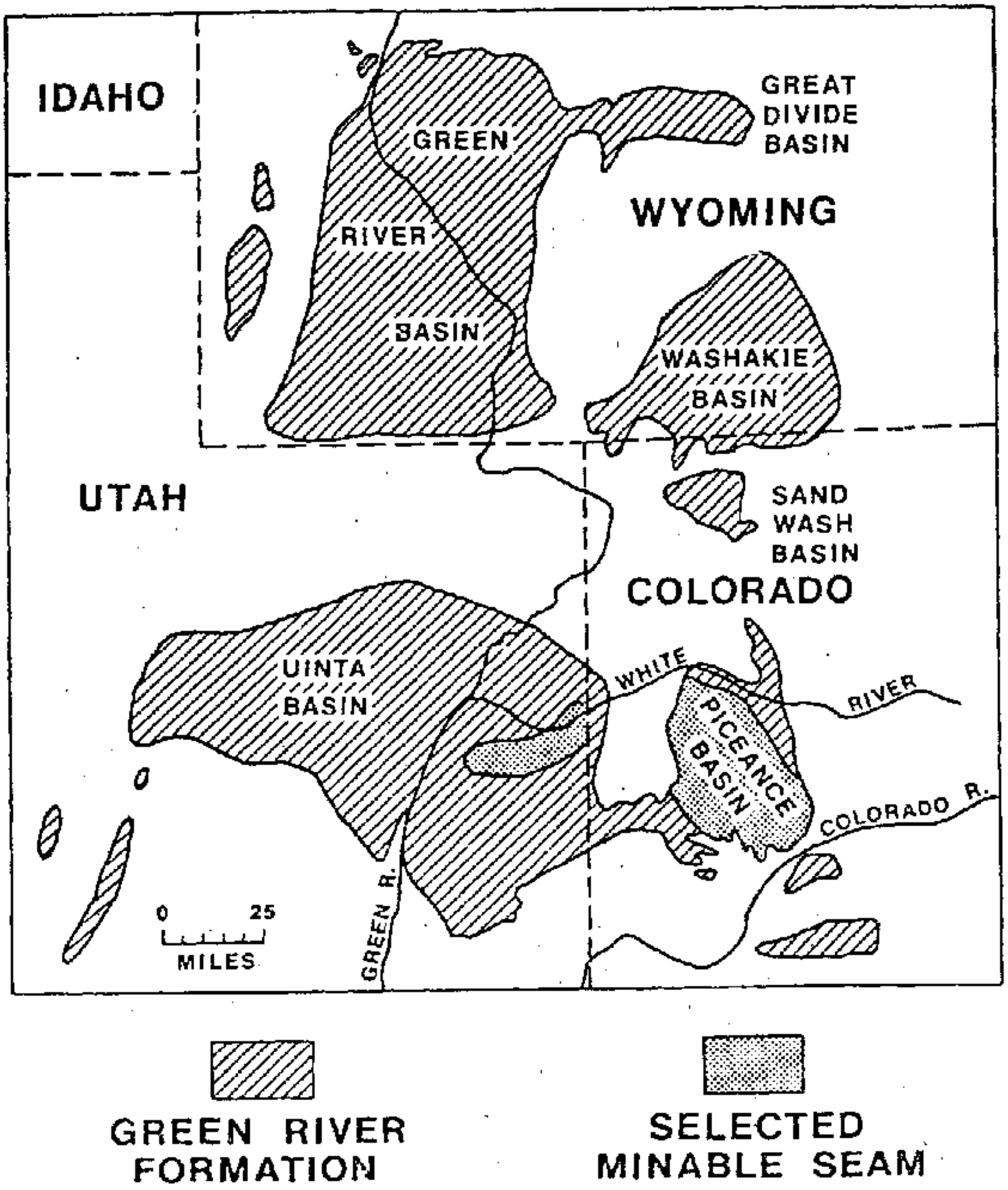

FIGURE 4

RETORT B

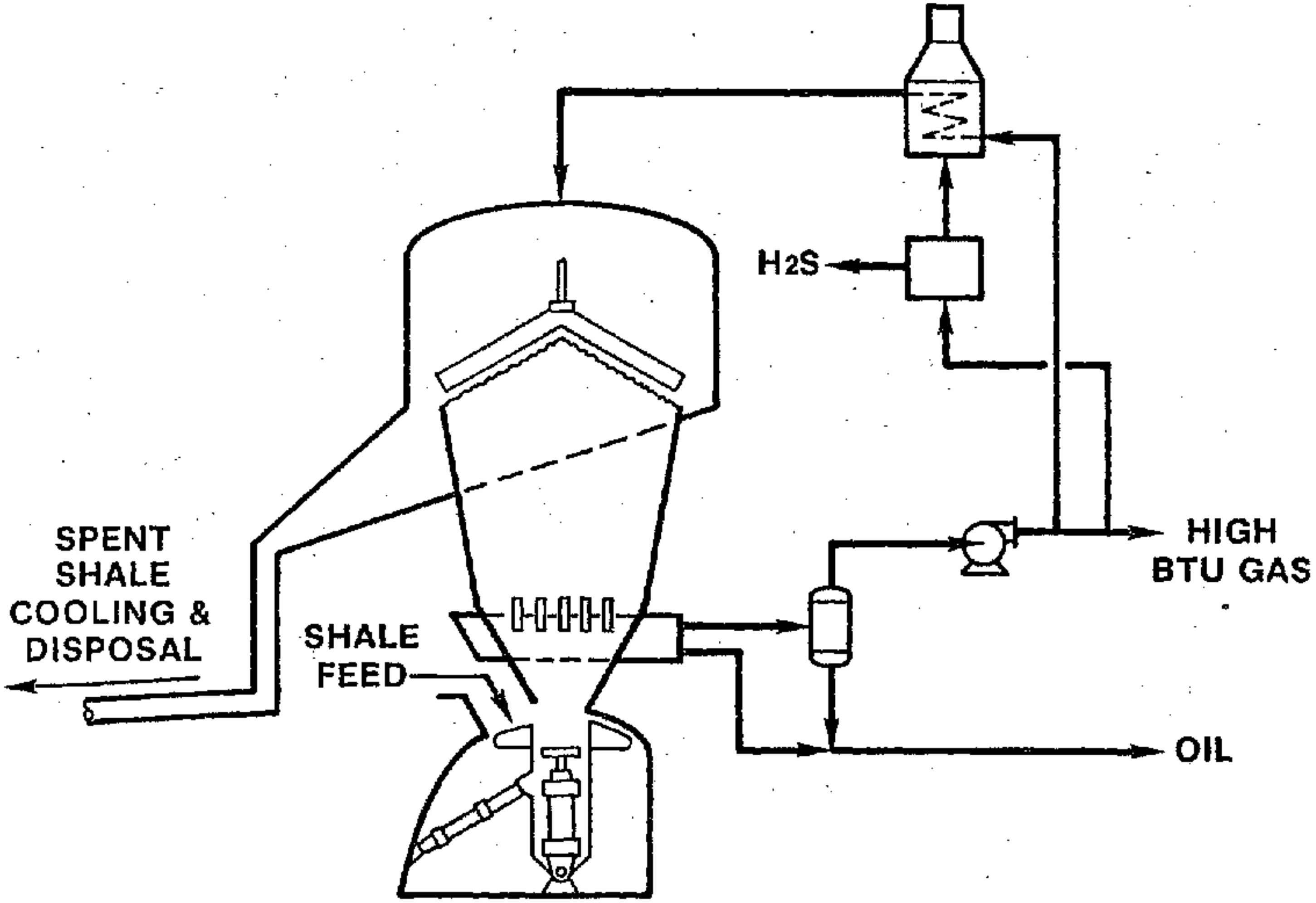

FIGURE 5

PROPERTIES OF CRUDE SHALE OIL

	FISCHER ASSAY	UNION OIL	
		RETORT A	RETORT B
GRAVITY, °API	24.2	19.7	21.5
DISTILLATION, D-1160, °F			
IBP		250	173
10%		500	410
50%		770	772
90%		1011	982
MAXIMUM		1071	1063
SULFUR, WT%	0.7	0.9	0.74
NITROGEN, WT%	1.6	2.0	1.76
CONRADSON CARBON, WT%	2.5	4.0	1.73
POUR POINT, °F	70	80	60
ASH, WT%		0.1	0.06
ARSENIC, PPM		60	36

FIGURE 6

SCHEME FOR REFINING SHALE OIL

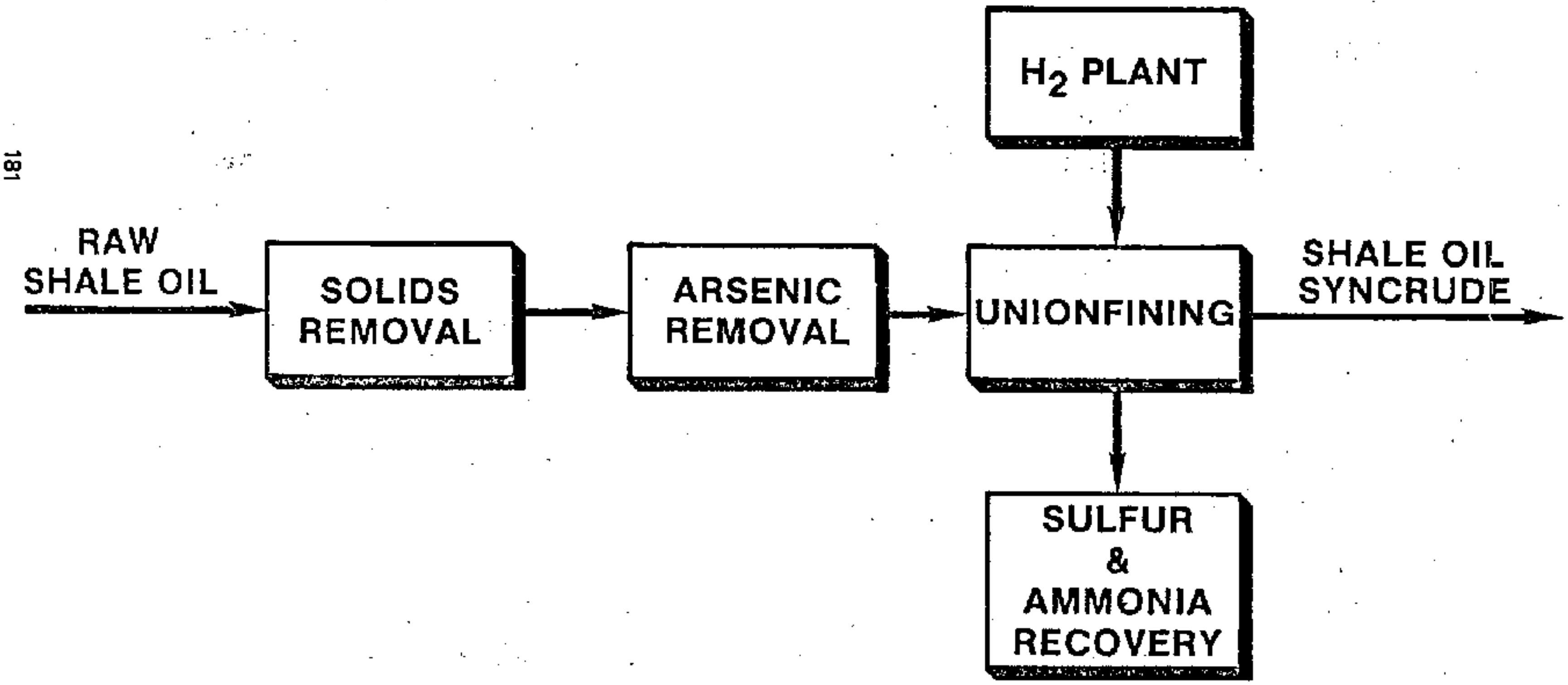

FIGURE 7

SHALE OIL ARSENIC REMOVAL SYSTEM

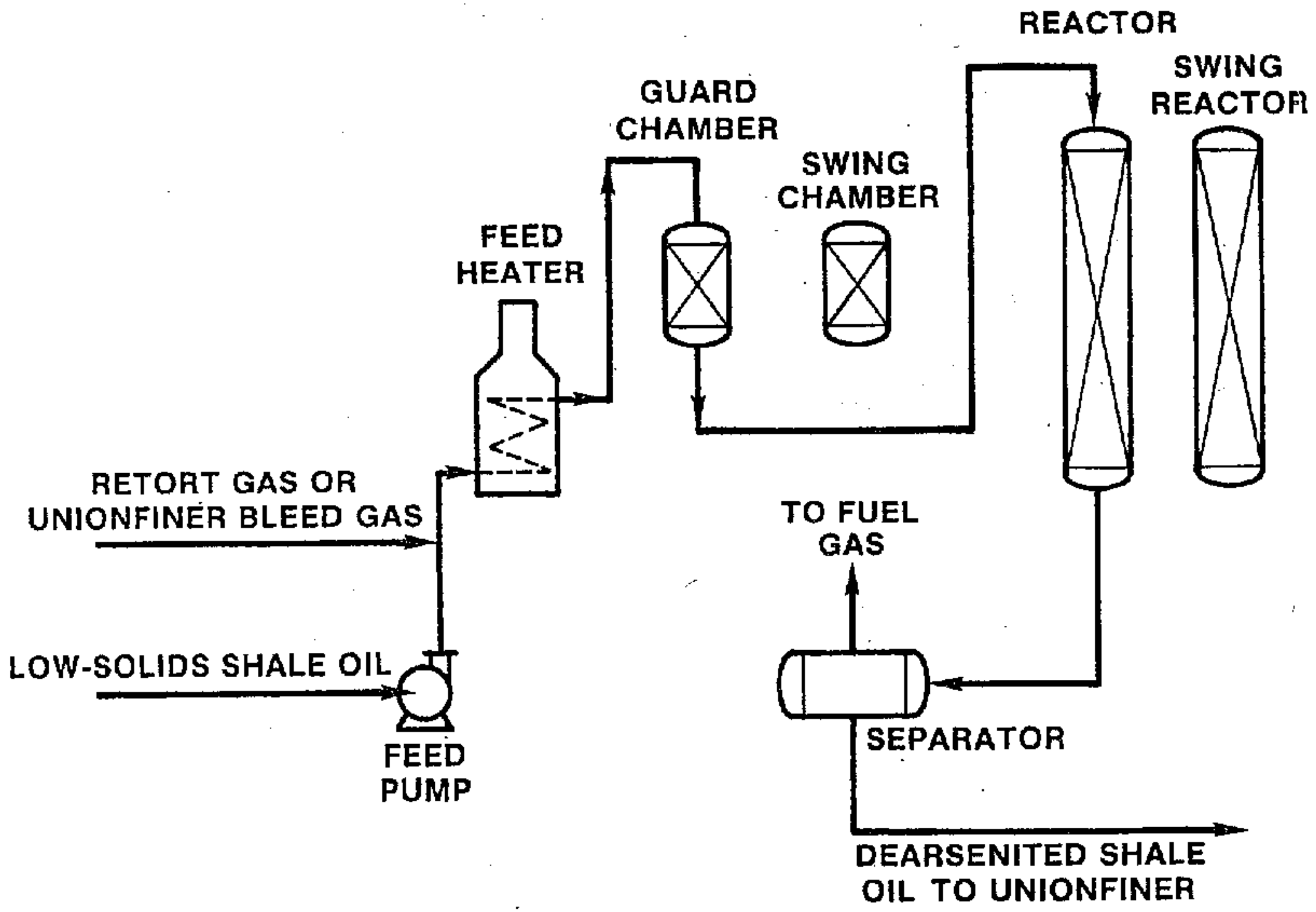

FIGURE 8

PROPERTIES OF RAW AND TREATED FULL-RANGE SHALE OIL

	FROM RETORT	AFTER ARSENIC REMOVAL	AFTER UNIONFINING
YIELD, BASED ON RAW SHALE OIL, VOL%	100	101.0	103.6
WT%	100	100.0	96.4
GRAVITY, °API	21.6	22.5	35.2
GM/CM	0.924	0.919	0.849
ASTM DIST., °F (°C)			
IBP	175 (79.4)	-----	176 (80.0)
50%	778 (414.4)	-----	602 (316.7)
MAX.	1086 (585.6)	-----	1093 (589.4)
NITROGEN, WT%	1.8	1.8	0.0501
SULFUR, WT%	0.85	0.74	0.0014
OXYGEN, WT%	1.41	1.26	<0.0050
ARSENIC, PPM	50	0.7	NIL

FIGURE 9

PRODUCT PROPERTIES AFTER HYDROTREATING

LABORATORY DISTILLATION OF FULL-RANGE PRODUCT (0.067 WT% NITROGEN)

CUT POINT, °F (°C)	NAPHTHA 200-300 (93-149)	NAPHTHA 300-380 (149-193)	TURBINE STOCK 380-500 (193-260)	DIESEL STOCK 500-650 (260-343)	DIESEL-FREE 650-PLUS (343-PLUS)
YIELD, VOL% RAW SHALE OIL	3.2	6.2	16.4	26.3	50.9
GRAVITY, °API	57.3	49.4	41.3	35.1	28.4
GM/CM^3	0.750	0.782	0.819	0.849	0.885
ASTM DIST., °F (°C)					
IBP	209 (98)	315 (157)	420 (216)	525 (274)	----
10%	238 (114)	326 (163)	425 (218)	546 (286)	----
50%	262 (128)	338 (170)	442 (228)	564 (296)	----
90%	287 (142)	357 (181)	472 (245)	601 (316)	----
MAX.	311 (155)	376 (191)	492 (256)	619 (326)	----

FIGURE 9 (CONTINUED)

PRODUCT PROPERTIES AFTER HYDROTREATING

LABORATORY DISTILLATION OF FULL-RANGE PRODUCT (0.067 WT% NITROGEN)

CUT POINT, °F (°C)	NAPHTHA 200-300 (93-149)	NAPHTHA 300-380 (149-193)	TURBINE STOCK 380-500 (193-260)	DIESEL STOCK 500-650 (260-343)	DIESEL-FREE 650-PLUS (343-PLUS)
NITROGEN, PPM	1	4	61	310	1140
SULFUR, PPM	25	35	12	9	200
FREEZE POINT, °F	--	--	-40.9	--	--
, °C	--	--	-40.5	--	--
POUR POINT, °F	--	--	-45	+20	+105
, °C	--	--	-42.8	-6.6	40.6
ANILINE POINT, °F	--	--	146.5	165.3	--
, °C	--	--	63.6	74.1	--
SMOKE POINT, MM	--	--	23.4	--	--
LUMINOMETER NUMBER	--	--	54	--	--
CETANE NUMBER	--	--	--	53.4	--
HYDROCARBON TYPE, WT%					
I-PARAFFINS	19.3	26.7	36.4	34.9	30.0
N-PARAFFINS	33.9	17.8			
NAPHTHENES	39.4	43.6	43.0	38.7	32.8
AROMATICS	7.4	12.0	20.6	26.4	37.2

COMPOSITION OF TRANSPORTATION SYNFUELS

R.G. Jackson
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COMPOSITION OF TRANSPORTATION SYNFUELS

Synfuels R&D Status and Projections Panel Contribution

R. G. Jackson

"Synfuels" for transportation are potentially available from a variety of sources such as oil shale and coal. Processes exist for transforming coal to alternative fuels, and what is needed today is a way of relating their use to the supply of transportation fuels for the next twenty years or so.

There is little difference between coal gasification and coal liquefaction from an economic viewpoint, and there is a surprising amount of technical overlap in the leading gasification and liquefaction schemes. The most striking difference lies in the markets they satisfy and in the degree and method of regulatory control present in these markets, difference which may be crucial to the strategy for introducing coal-based alternative fuels.

The current energy problem predates the oil embargo and popularization through the media. Indeed I was asked to come to the U.S. to work on energy problems in 1970, agreed to come in 1971, and arrived in 1972. My experience since then seems to indicate that R&D programs have become bigger, but not necessarily better, and have been dedicated more toward creating problems rather than solving them. It is time to put engineers, blue collar workers, and white collar employees to work building

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plants with present day technology, and producing measurable quantities soon of fuels that may be desperately needed in large quantities within a generation.

Private industry and the free market system have difficulty doing this job as soon as required because the magnitude of each individual investment, delays in obtaining regulatory approvals, the long lead-times before production, and the inability of the market system to monetize the value of protection against foreign supply disruption are barriers requiring federal assistance to insure timely penetration. The key issue is to determine what the federal government can do better than anyone else and then to convince the government to do only what it must do, and leave the rest to industry.

In the civilian economy the federal government does two things more effectively than any other organization:

1. It redistributes money.
2. It molds public opinion directly and indirectly.

Marginal sources of refined products cost about $3.00 per MMBtu in bulk ready for distribution. Typical sources are foreign oil, Alaskan gas and oil, etc, but while there is a substantial spread in the cost of these sources, $3.00 per MMBtu is a workable average. Unconventional supplies of liquid and gas from coal or oil shale would cost about $4.50 per MMBtu at today's prices. Present imports of foreign oil are roughly equivalent to 8 MMBpd of oil or about 45 million MMBtu, and cost about $35 billion per year. Their replacement by synfuel would cost about $75 billion per year, a difference equal to about 50 cents per person per day.

How do we try to achieve this? First I think by establishing an attainable goal, say the production of the equivalent of one MMBpd of oil by 1990.

The federal government cannot unilaterally award projects or major subsidies to individual companies no matter how meritorious. Also, since direct government management should be limited as much as possible and because the whole economy would benefit from a synfuels capability, then the government should look toward creating a limited market in which the various forms of unconventional energy could compete on an equal footing with each other. It would be unwise to try to do this by mandating energy companies to produce a fixed percentage of their output as synthetics. Doing this could cause complexity in administration, political manipulation to provide exceptional relief, and difficulty in scheduling synfuel plant development. There is one limited market, however, where the federal government can do as it likes — that is its own use. Thus, if the government were to say that all civil and military transportation fuel paid for by the federal government must include 10 percent from non-petroleum sources by 1985, 20 percent by 1990, and maybe 50 percent by 2000, the basic problem of creating a market could be solved.

In these circumstances what should R&D do in the future?

Because the automobile is the largest transportation energy consumer and because transportation consumes about 50 percent of the crude oil used, I think the first priority should be given to developing an engine (or engines) which is not fuel sensitive. Fortunately, support is already being given both by DOE and industry to engines which are capable of achieving this end. As Serge Gratch said at Santa Clara, the direct injection stratified charge engine, for small vehicles, and the gas turbine, for larger ones, are already almost with us, and the stirling engine may be not too far away. Only an extra push is needed to make these engines able to digest either narrow or broad cut distillate of any composition from any source. When that is achieved it should be straight forward to provide part of the fuel as a synfuel, maybe as methanol through gasification of coal or biomass, maybe from shale oil or tar sands, maybe from liquefaction or extrative distillation of coal. Whichever will not be important if the product can be used without too much further processing.

And where do we stand today? There are two oil shale projects in the commercial demonstration stage which potentially, and with the right support, could be providing synfuel by 1985.

There are a number of coal gasification processes which could be built starting tomorrow, and others which could move into the commercial demonstration stage. Unfortunately almost all of them were conceived to produce gas rather than liquid fuel so that today liquid fuel, such as methanol, can be produced at a reasonable efficiency only if it is a co-product with SNG. Perhaps, therefore, the transportation synfuels effort should be directed towards those processes which can, with minimum modification, most readily produce liquids without too much loss of energy.

Coal liquefaction technology needs to be further developed, and commercial demonstration plants are still needed to establish more definitive economics and reliability.

For some time to come, therefore, I can only see synfuels for transportation coming from oil shale or from coal through gasification or displacement of oil fuels, for instance, in boilers.

R. G. Jackson
October 4, 1978

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