

SRC-II PRODUCT APPLICATIONS - RECENT DEVELOPMENTS

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INTRODUCTION

The SRC-II process utilizes direct hydrogenation, coal liquefaction technology and has been described previously.¹ SRC-II converts high-sulfur and high-ash coal principally to liquid fuels along with light hydrocarbons and other by-products. Coal is first dissolved in a solvent slurry recycled from the process, then hydrogenated and hydrocracked at elevated temperature and pressure. The hydrogenation and hydrocracking reactions are enhanced by the catalytic activity of the inorganic matter contained in the recycle slurry, as well as the inorganic matter in the feed coal. Molecular hydrogen is supplied directly under pressure in the hydrogenation step. Non-distillables, after separation of the liquid products, can be used as a feed to an auxiliary gasifier to generate the required hydrogen for SRC-II.

The Pittsburg & Midway Coal Mining Co. (P&M), a wholly owned subsidiary of Gulf Oil Corporation, has been working on development of Solvent Refined Coal technology for 19 years, primarily under sponsorship of the United States' Department of Energy and its predecessor agencies. Last year P&M joined Ruhrkohle AG affiliates and Mitsui & Co., Ltd. in forming a joint venture, SRC International, to further SRC technology development, and licensing.

During the last four years a major part of the SRC-II development effort has involved operation of a 30 ton per day SRC-II Pilot Plant at Ft. Lewis, Washington. Approximately 20,000 barrels of SRC-II distillates have been produced there, which are being utilized in product development and applications testing. This paper provides a brief review of the status of that effort.

CHARACTERISTICS OF SRC-II PRODUCTS COMPARED TO PETROLEUM

Typical yields from the SRC-II process are given in Table 1. The co-products, methane, propane and butane are, of course, traditional products of the petroleum and natural gas industries, and it is expected that they will be produced to normal industry specifications. Likewise, by-product ammonia and sulfur are conventional products which will meet industry specifications. The liquid SRC-II product is not similar to conventional liquid fuels now derived from petroleum.

The properties of liquid hydrocarbon fuels are determined by two principal factors, the range of temperature over which they boil (volatility) and their chemical make-up.

Figure 1 compares the volatility of the SRC-II liquid product with a mixed base Texas crude oil. The SRC-II process recovers only atmospheric and vacuum distillates, (residuum is recycled), and most of the liquid boils below 700°F. Some 50% of the crude oil boils above this temperature. Volatility of SRC-II liquids is comparable to that of the higher quality petroleum distillate fuels.

Chemically, they are significantly different. Table 2 compares chemical analyses of SRC-II fuel oil (350°F+) with typical data for No. 2 and No. 5 fuel oils. The SRC-II product is more aromatic, and therefore has a lower hydrogen/carbon ratio. It is also substantially higher in nitrogen and oxygen.

RAW FUEL OIL PRODUCT SLATE

SRC-II liquids can be upgraded to conventional products, as will be shown later. Studies conducted for the DOE in 1979², however, suggested that substantial markets could be developed for raw SRC-II fuel oil. It was projected that SRC-II fuel oil could be used as an industrial and electric utility fuel thereby freeing petroleum products for higher value applications, including refining.

However, the naphtha produced by the SRC-II process is expected to be refined, first hydrotreating to remove heteroatoms, then reforming to a high octane gasoline blendstock.

Naphtha Disposition

The yield of naphtha (C₅ - 380°F) from the SRC-II process comprises about one-third of the total liquid product. Most petroleum naphtha is catalytically reformed to manufacture gasoline. The catalysts cannot tolerate significant nitrogen, oxygen or sulfur levels. SRC-II naphtha contains appreciable levels of each of these catalyst poisons, and thus requires hydrotreating to reduce them to acceptable levels. Gulf has evaluated the use of SRC-II naphtha as a reformer feedstock. In these evaluations, various hydrotreated SRC-II naphthas were produced and analyzed for composition and properties pertinent to use as a reformer feedstock. A single, optimized hydrotreated naphtha was then used in reforming studies.

Properties of raw and hydrotreated SRC-II naphtha are shown in Table 3. Total cycloparaffins and aromatics are much higher than in most petroleum naphthas, indicative of a feedstock which should yield a high octane reformat with relative ease. This has been borne out by the preliminary reforming studies. Figure 2 compares the performance of Kuwait and SRC-II derived naphthas in a conventional reforming operation. The SRC-II naphtha yields equivalent Research Octane Number at

substantially lower reforming temperatures and with much improved reformate yields. Reforming catalyst aging studies have shown no problems with catalyst aging.

It is noteworthy that more hydrogen is produced during reforming than is consumed during hydrotreating, i.e., SRC-II naphtha refining results in net hydrogen production.

The reformate produced in the aging study has been used to prepare gasoline blends consisting of base unleaded regular gasoline stock and SRC-II reformate. These gasolines will be tested for stability, corrosion characteristics and volatility. Engine and vehicle tests will be conducted to evaluate exhaust emissions, fuel economy and carburetor cleanliness.

Universal Oil Products has studied the production of reformate from SRC-II naphtha. Their conclusions³ confirm the technical feasibility of this strategy.

SRC-II Fuel Oil Disposition

The market application studies conducted during 1979² suggested that the use of raw SRC-II fuel oil in steam boilers, industrial direct heat applications and stationary engines would be economically attractive. To substitute SRC-II products for petroleum fuel oils in applications such as these, two different sets of criteria must be satisfied. The first relates to the ability to handle, transport and store the fuel by conventional means. SRC-II fuel oil measures up well in many respects. As shown in Table 2, it has low viscosity, high flash point and low pour point. Gulf has conducted studies of product stability, stability of blends with petroleum fuel oils and compatibility with fuel system components. Typical results on the properties of blends of SRC-II fuel oil with No. 6 fuel oils are given in Table 4. Little or no oxidized sludge precipitated during extended storage (5 months at 118°F) in either the SRC-II fuel oil (350° - 950°F) or its blends with petroleum residual oils.

SRC-II fuel oil was somewhat corrosive to lead and zinc, but in general, metal corrosion seems unlikely to be a problem (Table 5). Many elastomers commonly used in fuel handling systems are rapidly destroyed, however, as shown by simple swelling tests (Table 6). Exceptions are viton and nylon 6/6.

The second set of performance criteria determining the quality of SRC-II fuel oils is their combustion performance. As we have seen, SRC-II fuel oils have a substantially lower hydrogen content and thus higher content of aromatics than petroleum fuel oils. Fuels of high aromaticity burn with a more luminous (hotter) flame and have a greater tendency to produce smoke. The high nitrogen content of SRC-II fuel oil raises the possibility that NO_x emission regulations might not be met.

Realization of these potential problems, not just for SRC-II, but for a variety of synthetic liquid products, led DOE, the Environmental Protection Agency (EPA) and the Electric Power Research Institute (EPRI) to undertake programs to assess the problem and to seek solutions. These programs are ongoing but sufficient progress has been made to suggest that control capability can be developed.

In general, the aromaticity of the fuel does not cause a particular problem. Excessive smoke formation can be prevented under proper combustion conditions.^{4, 5} Flame luminosity is not found to be a problem in most applications, and may even be advantageous in some industrial uses where high radiant heat transfer is desirable. Flame luminosity did create problems for Westinghouse in an EPRI-funded study, which used coal liquids in a conventional type gas turbine combustor. Combustor overheating occurred and projected combustor life was unacceptable.⁶ But Westinghouse concluded that a modified combustor design should avoid such problems. Brown-Boveri, with a different turbine design which uses only one large combustor, recently burned highly aromatic fuels without problems, and in fact guarantees performance for fuels with hydrogen contents similar to SRC-II fuel oil. Maintaining nitrogen oxide emissions within acceptable limits is therefore the major issue affecting combustion performance.

STEAM BOILERS Conventional combustion of SRC-II fuel oil leads to high emissions of nitrogen oxides (NO_x) in boilers⁵ and other applications. "Rich/lean" or staged combustion looks promising as a solution. A short full-scale test of this concept, sponsored by Consolidated Edison of New York, was carried out in a 450,000 lb./hr. steam electric utility boiler in the fall of 1978.⁷ Performance with the SRC-II fuel oil met all applicable emission regulations, including NO_x.^{1, 7}

The Consolidated Edison unit is a tangentially fired, low heat release (coal designed) boiler, ideally suited to take maximum advantage of the staging concept, (a well-mixed flame in the fuel rich zone, and adequate space for soot burn-out in the fuel lean zone).

The degree of success which may be anticipated in other types of electric utility boiler with more intense flames is not certain, but EPRI has ongoing programs to develop these data. Future tests of coal liquids will likely involve single wall-fired, low heat release units, moving eventually to high heat release (oil and gas designed) units of both the tangential and wall-fired types.⁸ Also worthy of note are EPRI's fundamental combustion studies at Massachusetts Institute of Technology which recently focused on defining minimum NO_x emissions from SRC-II fuel oil during staged combustion. Values less than 100 ppm NO_x were obtained.⁹ This low value may not be attainable in a practical boiler design, or by retrofitting an existing boiler; but it does provide a reference point.

The precise strategy used for rich/lean firing may differ, but fundamentally, there is no reason to suppose that the success occurring in utility boiler applications cannot be extended to industrial steam raising and a variety of industrial direct fired heater applications.

Several NO_x reducing techniques have been tested on industrial sized oil fired boilers including the use of low excess air (LEA) and staged combustion.

LEA firing can be implemented now in most industrial boilers. The level of implementation depends on many factors such as flame stability and excursions in CO and particulate emissions.

Staged combustion has been demonstrated successfully in several larger industrial boilers with multiple burners. Staged combustion in such units has been achieved by rearranging burner firing patterns to create fuel-rich primary zones in the rear burner regions.¹⁰ This practice of redistributing fuel and air to various burners, (the method used in the Consolidated Edison electric utility boiler), usually requires a reduction in firing rate potential. However, a slight derating of a large industrial unit can normally be tolerated since most industrial plants have boiler over-capacity.

Smaller watertube packaged units usually have only one burner and no provisions for secondary air injection. Several successful tests of staged combustion have been performed in such units where secondary air capacity has been added through the use of air lances.¹¹ Single burner equipment may also be staged by retrofitting a low-NO_x burner which aerodynamically provides the necessary rich/lean zones.^{12,13}

STATIONARY COMBUSTION TURBINES The stationary combustion turbine has also been identified as a potential market for SRC-II fuel oil. NO_x emissions from turbine combustors can be controlled by staged combustion. However, the dimensions and firing rates of most existing combustor designs allow little opportunity for engineering a rich-lean flame. Retrofit of new combustor designs is feasible, and a number of manufacturers are working towards this end.

The EPA funded pioneering work in this field in which United Technologies developed a rich/quick-quench/lean bench-scale combustor which met NSPS limits on NO_x firing SRC-II fuel oil.¹⁴ More recently, the DOE undertook a major effort to develop low-NO_x turbine combustors. This program, managed by NASA-Lewis, has been using SRC-II product as a baseline fuel. In Phase I several U.S. turbine manufacturers have been funded to develop and test their individual designs. Results will be used to focus future efforts on the best concepts, leading to a single design which may be field tested around 1984. Early results from this program were presented in a series of papers by DOE's contractors earlier this year.¹⁵ In general, the preliminary data were encouraging, one contractor reporting NO_x emissions of 60-80 ppm with acceptable smoke emissions while firing SRC-II product.

Another consideration in qualifying alternate fuels for stationary combustion turbines is their ash content and potential for causing corrosion or erosion of the turbine blades. Gulf has conducted laboratory distillations of SRC-II fuel oil which indicate that the entire product can be obtained satisfactorily clear of ash and trace metals known to cause corrosion, i.e., the contained ash is almost wholly involatile. However, some ash carry-over does occur in the vacuum separation at the Fort Lewis pilot plant, and metal contaminant levels to be expected in the overhead from the fractionation system of a commercial plant are uncertain at this time. For this and other reasons, it is expected that a commercial fractionation system would be designed to produce two distillate fuel oil streams, a middle distillate boiling from about 380° to 600°F, and a heavy distillate boiling from about 600° to 900°F. A commercial SRC-II plant could have the flexibility to store and market either stream or to reblend in various proportions depending on product application requirements. The middle distillate would meet required trace metal levels for turbine use and is currently projected as the most likely product for that application.

DIESEL ENGINES The modern diesel engine is an extremely efficient power plant. Stationary diesels have thermal efficiencies of over 40% in simple cycle and more than 56% in steam cogeneration mode. They also have an excellent reliability record, and are a logical target for the use of synthetic fuels. Stationary diesel engines are not a major prime mover in the U.S. electric utility industry, but are of interest to many smaller utilities.

Large diesel engines have varying fuel requirements. Low speed (300 rpm) two-stroke engines used commonly for power generation and heavy marine applications have been operated reliably on residual fuels. Medium speed (300 - 1200 rpm) two-stroke and four-stroke engines, used in stationary, marine and railroad locomotive applications have also operated on heavy fuels, although U.S. manufacturers have very limited experience with such fuels.

Sulzer Brothers Incorporated of Switzerland, the major manufacturer of low speed diesels, has tested SRC-II fuel oil in a single-cylinder, two-stroke cycle test engine operating at a speed of 120 rpms. Due to SRC-II fuel oil's high aromaticity, auto-ignition was too slow to permit satisfactory engine performance. Blends with conventional fuels (80% SRC-II product) performed well however; and in tests with two injectors per cylinder, only 3.5% diesel fuel was required in the pilot injector to permit smooth burning of the remaining 96.5% SRC-II fuel. 16

A DOE program, "Coal Liquid Fuel/Diesel Engine Operating Compatibility," includes medium-speed engine testing by various U.S. manufacturers. One objective is to evaluate the suitability of raw SRC-II product for domestic engines with minimum engine modifications. Because of poor auto ignition qualities SRC-II fuels will be used in mixtures with high cetane number conventional fuels. Two of the engine

models included can operate with advanced timing pilot injection which reduces the auto-ignition requirement of the primary fuel. Verbal reports from one of these DOE contractors indicates successful operation with blends containing up to 80% SRC-II fuel.

The DOE has also made SRC-II fuel oils available for medium-speed diesel engine tests in laboratories in France, Japan and Norway. Each confirms acceptable operation with fuel blends containing SRC-II products. Engines were generally found to be clean and there was no evidence of unusual wear after these tests.

HEALTH EFFECTS

The liquid products produced by processes which directly hydrogenate coal, including the SRC-II process, are suspected carcinogens.¹⁷ Such products produce skin tumors in rodents subjected to regular skin painting and display mutagenic activity in the Ames test.¹⁸

The DOE has initiated a major effort to quantify the toxicity of coal liquids and identify its molecular source. Progress in pin-pointing the genotoxic components of SRC-II fuel oil has been encouraging.

Early studies employed the Ames test and other in-vitro bioassays to screen the three liquid products obtained from the fractionation system at the Fort Lewis pilot plant, naphtha (C₅ - 350°F), middle distillate (350° - 550°F) and heavy distillate (550° - 950°F). Only the heavy distillate was mutagenic.¹⁷

Subsequently, various laboratories used chemical and physical separations to fractionate heavy distillate and employed the Ames test to bioassay the resulting fractions. Not all fractions were active. Chemical analyses of the active fractions implicated nitrogen containing compounds as major contributors to mutagenic activity.¹⁹ High molecular weight primary aromatic amines have been suggested as the most important source of genotoxicity in SRC-II fuel oil.^{20, 21}

If nitrogen containing molecules are largely responsible for mutagenic activity in the Ames test, then their removal, (eg. by hydrogenation), should reduce this activity. Two recent papers confirm this hypothesis.^{22, 23} As shown in Table 7, when full range SRC-II fuel oil is hydrotreated to remove some 70% of the fuel bound nitrogen, it displays no detectable activity in the Ames test.

In other recent work, SRC International prepared 50°F cuts of SRC-II fuel oil from 350° - 950°F. Ames tests of these fractions were carried out at Battelle Pacific Northwest Laboratory under DOE contract. Mutagenic activity was absent in fractions boiling below about 720°F.²⁴ Approximately 10% of the overall SRC-II liquid yield boils above this temperature.

The Ames test is an important screening procedure, but lengthy animal testing is necessary to establish the presence or absence of various genotoxic effects in an acceptable way. Directionally, however, the Ames test results are important. They suggest that elimination of genotoxic components from SRC-II liquids may require special processing of only a small fraction of the total product. A variety of ways in which this might be accomplished are under study.

REFINED PRODUCT SLATE

The properties of SRC-II liquids seem unsuited for the production of conventional fuels. Fuel bound nitrogen is deleterious to most petroleum refining catalysts and is more difficult to remove by hydrogenation than sulfur. Additionally, highly aromatic streams have traditionally been a bane to the petroleum refiner.

A DOE program carried out by Chevron Research, however, suggests that hydrotreating SRC-II liquids to manufacture transportation fuels is a viable option. Chevron showed that the key to successful SRC-II refining is an effective initial hydrotreating step which removes heteroatoms, increases hydrogen content, and permits the use of conventional processes for further conversion to high-value products.²⁵

Chevron hydrotreated the complete SRC-II product to various degrees, then distilled the hydrogenated product into the volatility ranges of three major transportation fuels -- diesel fuel, jet fuel, and gasoline. If the initial hydrotreating was severe, the resultant naphtha was sufficiently pure to permit direct charging to a conventional naphtha reformer to make gasoline. Jet fuel was produced directly and met all Jet-A specifications except density. The density disparity is caused by high naphthene content which may be advantageous in practice.²⁶ When the initial hydrotreating was less severe, additional downstream processing was required to attain various product slates of gasoline, jet and diesel fuels.

The Chevron authors defined severity in terms of hydrogen requirements, which were high (2000 - 3000 SCF/bbl). The catalyst and reaction conditions, however, fall within the scope of advanced petroleum refining technology. Moreover, hydrogen requirements appear to be little different than in the case of other potential syncrudes, i.e., raw shale oil.²⁶

As shown in Figure 3, some 85% of SRC-II liquid falls within the volatility range of transportation fuels, so that extensive hydrocracking is not required to make such products. This is in keeping with the low gas make and relatively modest change in boiling-point range (Figure 3) described in the Chevron work. Hydrogen is used quite selectively to remove heteroatoms and saturate aromatics.

Because of the high percentage of cyclic paraffins which results from such hydrotreating, the refined SRC-II products have some

unusual properties compared to transportation fuels derived from petroleum. Hydrotreated SRC-II naphthas make exceptionally fine reformer feeds for high octane gasoline as discussed earlier. The SRC-II derived jet fuel meets smoke point and stability specifications, has a high heating value per unit weight, and has an unusually low freezing point. This is in agreement with theory that cycloalkanes as a class make ideal jet fuel components.²⁷ Cycloalkanes, however, do not have the rapid autoignition properties desired for automotive diesel fuels, and the SRC-II derived diesel fuel produced by Chevron had relatively poor cetane number.

Chevron calculated refining costs based on producing 50,000 barrels per calendar day of transportation or heating fuels from a "grass roots" refinery; (that is, a completely new refinery which includes all of the necessary supporting facilities, such as utility plants, tankage, and required environmental control equipment). Calculated upgrading costs included \$10 per barrel of product for a two-product slate of gasoline and heating oil and \$14 per barrel for gasoline and jet fuel (\$1980). More than 40% of the cost was due to hydrogen requirements in each case.

These incremental costs are substantial, and continued emphasis on the raw fuel oil product slate seems warranted. It is noteworthy, however, that the refining costs are on a par with those expected for other syncrudes and that they could potentially be lowered by partial integration of product refining with the SRC-II plant or with an existing petroleum refinery.

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TABLE 1
TYPICAL YIELDS FROM SRC-II PROCESS

<u>PRODUCT</u>	<u>WT % MOISTURE FREE COAL CHARGE</u>
Heavy Distillate (600 ^o -950 ^o F)	7.9
Middle Distillate (380 ^o -600 ^o F)	17.9
Naphtha (C ₅ -380 ^o F)	10.2
Butanes	2.2
Propane	4.1
Ethane	4.4
Methane	5.8

TABLE 2

PROPERTIES OF SRC-II FUEL OILS AND COMPARABLE PETROLEUM PRODUCTS

	SRC-II MIDDLE DISTILLATE (350°-550°F)	NO. 2 FUEL OIL	SRC-II HEAVY DISTILLATE	NO. 5 FUEL OIL
ANALYSIS (DRY): % BY WT.				
CARBON	86.0	87.0	89.1	88.3
HYDROGEN	9.1	12.8	7.5	10.7
NITROGEN	0.9	<0.2	1.2	<0.3
SULFUR	<0.2	0.04-0.48	0.37	0.07-1.9
OXYGEN	3.6	<0.09	1.4	<0.4
SATURATES: % BY VOL.	35	>65	-	-
AROMATICS: % BY VOL.	62	<32	-	-
DENSITY	0.974	<0.876	1.072	0.940
VISCOSITY: SUS @ 100°F, 38°C	36.3	32.6-37.9	231	124-900
FLASH POINT: °F	>160	>130	-	-
POUR POINT: °F	<-45	<+5	<+45	<+80
NICKEL: ppm	<0.1	<0.1	<0.3	45
VANADIUM: ppm	<0.1	<0.1	<0.1	180
SODIUM: ppm	-	<0.5	2-11	2-20

TABLE 3
PROPERTIES OF RAW AND HYDROTREATED SRC-II NAPHTHA

	<u>STABILIZED & UNHYDROTREATED</u>	<u>STABILIZED & HYDROTREATED</u>
Approximate Distillation Range	100°F, 38°C IBP 150°F, 66°C 10% 290°F, 143°C 50% 350°F, 176°C 90% 380°F, 193°C End Point	(1)
Nitrogen, PPM	4,500	Less than 0.2
Sulfur, PPM	1,900	Less than 0.5
Oxygen, Wt. %	3.5	
Hydrocarbon Analysis (Vol. %)		
Aromatics	34	14
Cycloparaffins	45	62
Paraffins	21	24

(1) End point established to meet reformer specifications.

TABLE 4

	SRC-11 FUEL OIL	LOW SULFUR NO. 6 (0.05% S)	LOW SULFUR NO. 6 and SRC-11 50% BLEND	VENEZUELA NO. 6	VENEZUELA and SRC-11 50% BLEND
VISCOSITY, KIN, D445, CS					
100°F	6.64	1158	45.62	875	40.19
122°F	4.48	417	25.11	362	23.18
210°F	1.57	35.69	5.49	33.83	5.22
POUR POINT: OF	-50	+75	+50	+30	-5
ASPHALTENES, IP 143: WT. %	0.04	0.07	1.28	-	3.35
SEDIMENT, D473: WT. %	0.03	0.06	0.04	0.05	0.21
INSOLUBLES, PROCEDURE B, D893: WT. %					
N-PENTANE	0.05	3.33	0.95	9.89	5.92
TOLUENE	0.05	0.29	0.35	1.50	0.09
RESINS	0.00	3.04	0.60	6.39	5.83
			-AFTER 5 MONTHS STORAGE AT 118°F-		
VISCOSITY, KIN, D445, CS					
100°F	6.85	1194	54.66	1064	37.29
122°F	4.55	397	28.23	413	20.63
210°F	1.61	35.97	5.93	37.86	4.92
POUR POINT: OF	-45	+80	+60	+35	+10
ASPHALTENES, IP 143: WT. %	0.46	-	1.63	7.20	3.92
SEDIMENT, D473: WT. %	0.02	0.03	0.03	0.04	0.03
PUMPABILITY TEST, IP 230/69					
6 POISE: OF	BELOW +39	110.0	66.5	106.5	50.5
10 POISE: OF	BELOW +39	99.5	61.5	97.5	BELOW +39
25 POISE: OF	BELOW +39	87.0	48.0	80.5	BELOW +39
INSOLUBLES, PROCEDURE B, D893: WT. %					
N-PENTANE	0.23	3.64	1.99	10.00	4.46
TOLUENE	0	0.13	0.45	0.10	0
RESINS	0.23	3.51	1.54	9.90	4.46

TABLE 5

METAL CORROSION - SCREENING TESTS (a)

<u>Specimen</u>	<u>Calculated Thickness Loss/Year (Mils)</u>	
	No. 6 Fuel Oil	SRC-II Fuel Oil
Copper	1.36	1.95
Zinc	0.83	15.45
Aluminum 2024	1.49	1.59
Bronze	0.99	1.83
Lead	1.78	6.59
Brass	1.18	2.30
Cadmium	1.15	1.35

(a) 72 hours @ 120°F in autoclave; stirring rate 500 RPM.

TABLE 6

ELASTOMER COMPATIBILITY - SCREENING TESTS

<u>Elastomer</u>	<u>Size Increase (%)</u>	<u>Weight Increase (%)</u>	<u>Test Conditions</u>
Nylon 6/6	0	0	a
Fuorocarbon P0652	123	92	a
Viton E430	0	0	a
Fluorasilicone	185	14	a
Butyl Rubber	43	21	a
Neoprene	118	84	a
PVC Vinyl	Destroyed	Destroyed	b
Nitrile Rubber	199	356	b
Urethane	517	188	b

(a) 45 days at ambient temperature

(b) 30 days at 120°F

TABLE 7
AMES TEST DATA FOR RAW AND HYDROTREATED SRC-II FUEL OIL

<u>SRC-II Test Material</u>	<u>Hydrogen Consumed in Hydrotreating (SCF/bbl.)</u>	<u>Nitrogen Content (Wt. %)</u>	<u>Revertants/mg (Ames Test)</u>	<u>Ref. No.</u>
SRC-II Fuel Oil	0	0.81-0.90	2.54	22
Same: Hydrotreated	1290	0.55	Background	22
Same: Hydrotreated	1870	0.19	Background	22
SRC-II Fuel Oil	0		11.22	23
Same: Hydrotreated	1270	0.631	1.78	23
Same: Hydrotreated	1930	0.352	Background	23
Same: Hydrotreated	2670	0.033	Background	23

FIGURE 1

**BOILING POINT CURVES
for SRC-II LIQUIDS
and TYPICAL CRUDE OILS**

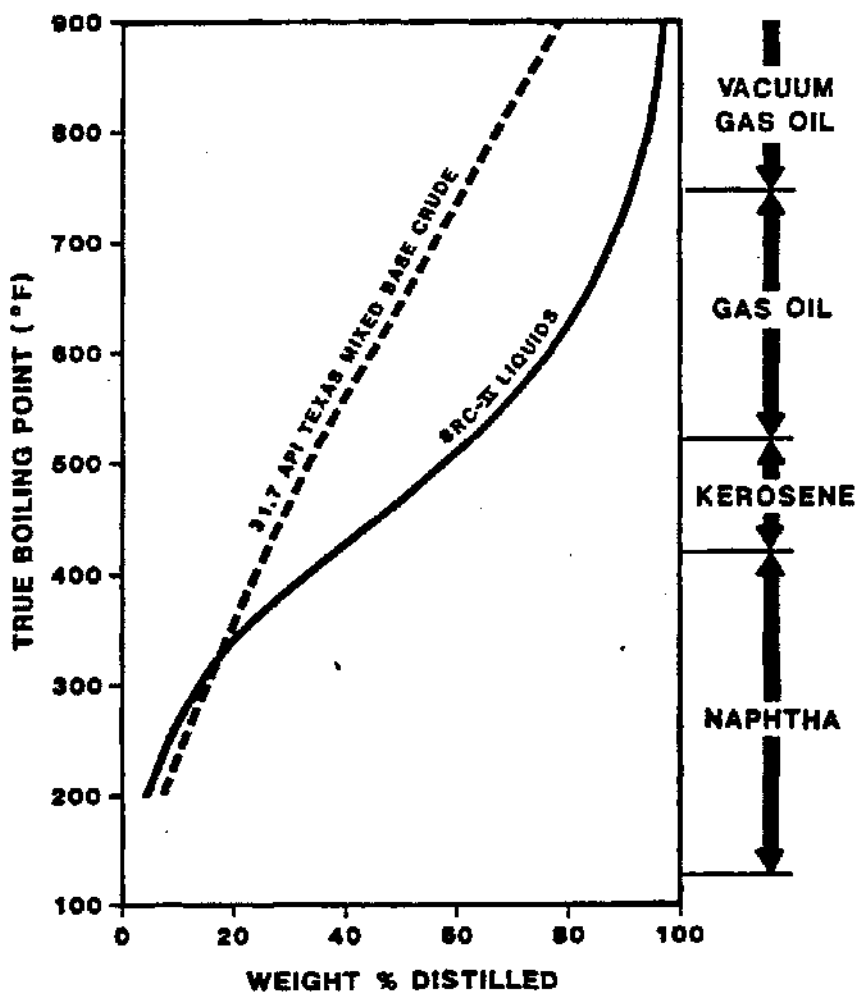


FIGURE 2

**CATALYTIC REFORMING EXPERIENCE WITH
PETROLEUM AND COAL DERIVED NAPHTHAS**

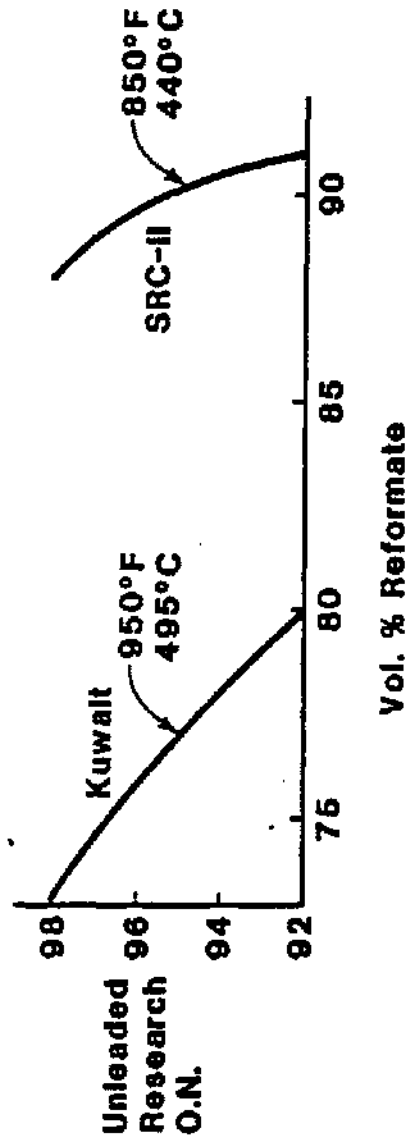


FIGURE 3

BOILING POINT CURVE FOR SRC-II LIQUIDS

