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SRC-I QUARTERLY TECHNICAL REPORT

Supplement for the Period October—December 1980

Work Performed Under Contract No. AC05-78OR03054

International Coal Refining Company
Allentown, Pennsylvania

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SRC-I

QUARTERLY TECHNICAL REPORT

SUPPLEMENT

OCTOBER-DECEMBER 1980

Prepared by

INTERNATIONAL COAL REFINING COMPANY
P.O. Box 2752
Allentown, Pennsylvania 18001

for the

UNITED STATES DEPARTMENT OF ENERGY
Office of Solvent-Refined Coal Products
under Contract DE-AC05-78-OR-03054

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TABLE OF CONTENTS

	<u>Page no.</u>
CHARACTERIZATION OF ASH CONCENTRATE SOLIDS: DESIGN OF SOLIDS HANDLING EQUIPMENT J. R. O'Leary	1
EFFECT OF FEED COAL VARIATION ON DEMONSTRATION PLANT PERFORMANCE D. S. Hoover, S. V. Joshi, E. N. Givens, A. Bland, B. Davis, J. Hower, D. Koppenaal, and D. Pollock	19
EFFECTS OF ACCUMULATED SOLIDS ON DISSOLVER PERFORMANCE R. W. Skinner and E. N. Givens	43
IMPACT OF SRC RECYCLE ON COMMERCIAL DESIGN D. Kang and E. N. Givens	107

Note

Articles in this Supplement were previously withheld from publication to avoid premature disclosure of inventions. Two of the articles in this volume were published prior to June 1984 and are not republished here. The article on page 19 was included in the January-March 1982 Quarterly Technical Report (DOE/OR/03054-7), and the article on page 43 was published in the April-June 1981 Quarterly Technical Report (DOE/OR/03054-4). Pagination has not been altered, since this could invalidate any cross-references.

CHARACTERIZATION OF ASH CONCENTRATE SOLIDS:

DESIGN OF SOLIDS HANDLING EQUIPMENT

J. R. O'Leary*

Temperature, hold time, SRC content and deashing solvent content may affect the flowability of the ash concentrate solids. To better understand the effects, flow characterization studies were made by Jenike & Johanson, Inc. The results form the basis for the design of the Ash Concentrator and storage facilities for the Demonstration Plant.

The flow characteristics of solids are measured in a shear cell by applying a force to the sample and recording the resistance to slide. Material strength, determined by measuring the resistance of the material to slide over itself, is used to calculate the critical opening required for flow; the resistance of the material to slide over stainless or carbon steel is used to determine the critical angles required for flow.

Ash concentrate samples, consistent with SRC recoveries ranging from 65% to 80% in the Critical Solvent Deashing (CSD) Process, were tested at temperatures from ambient to 550°F and at storage times up to 3 days. The flowability tests showed that the ash concentrate is sensitive to temperature and storage time when the SRC content of the solids is high (i.e., low SRC recovery in CSD Process). Increasing either the temperature or the storage time will increase the strength of the material, consequently requiring larger critical openings to assure solids flow. The critical angles required for flow are very steep at all temperatures. Ash concentrate samples corresponding to 80% SRC recovery were more free-flowing and much less sensitive to temperature.

*ICRC

Jenike & Johanson, Inc. (J&J) strongly recommend that the ash concentrate be handled in mass flow bins regardless of the temperature or storage time. This means that the bins should be designed so that the entire contents is in motion whenever any material is withdrawn from the outlet. The critical openings and angles required to maintain mass flow in a hopper were determined at all the conditions tested. Hopper designs for the Ash Concentrator and storage vessels were recommended based on the results for the high SRC samples.

The design of the Ash Concentrator will be tested at Wilsonville under actual operating conditions.

INTRODUCTION

The ash concentrate solids, as processed in the Ash Concentrator, may reach temperatures as high as 500°F, and contain high levels of SRC, as well as varying amounts of deashing solvent. These factors may affect the stickiness of the solids and consequently the solids flowability from the Ash Concentrator. Once the solids discharge from the Ash Concentrator, they are conveyed either to short-term storage (up to 8 hr) or long-term storage (up to 1 day). These facilities must be designed for temperatures that assure solids flowability throughout the range of SRC content, deashing solvent content and hold time anticipated.

ICRC contracted with Jenike & Johanson, Inc. to determine the flow characteristics of the ash concentrate at the process conditions expected in the Demonstration Plant, and to recommend functional designs for the Ash Concentrator and storage bins based on the flow characterization studies.

Of three samples of Kerr-McGee ash concentrate sent to J&J, two were obtained at conditions consistent with low SRC recovery (65 to 70%) in the Critical Solvent Deashing (CSD) unit, i.e., high SRC content in samples. It was felt that these samples would exhibit poor flow characteristics, requiring a conservative design for the Demonstration Plant. To support this assumption, the third ash concentrate sample was obtained at conditions consistent with approximately 80% SRC recovery in

the CSD unit. Because at times coal will have to be added to the Gasification unit, samples of coal and coal/ash mixtures were also tested by J&J as part of the contract. Sample behavior was tested as a function of temperature and storage time at rest.

BIN DESIGN

It is important that fine powders such as ash concentrate be handled in a mass flow bin, the entire contents of which are in motion whenever any material is withdrawn from the outlet. This is in contrast to a funnel flow bin in which the solids flow down the center of the bin while material along the walls remains stationary. In a funnel flow bin, ratholing will occur, and because the ash concentrate fluidizes easily, flooding and flushing combined with starvation of the feeder will be the mode of operation. Figures 1 and 2 depict a funnel flow bin and a mass flow bin, respectively. Notice that the only difference between the two is a much steeper hopper angle in the mass flow bin.

TESTING TECHNIQUE

Two main considerations in the design of a mass flow bin are the size of the outlet required to prevent arching, and the smoothness and steepness of the hopper walls required to force flow along the walls. These critical dimensions are determined by performing standard tests on a "Direct Shear Tester." The tests are conducted by placing a sample of the ash concentrate in a shear cell as shown in Figure 3, and applying force. The resistance of the material to slide over itself is used to calculate the strength of the material, which is a function of temperature, hold time at rest, SRC content and possibly deashing solvent content. Material strength under a given set of conditions is compared to the stresses required to form an arch over an opening. If the strength is greater than the stress, a stable arch will form. Conversely, if the stresses acting on the arch are greater than the strength of the material, an arch will not form. Using the knowledge that stress on an arch increases as the opening increases, J&J

determined the critical opening required to prevent a stable arch from forming.

J&J used the resistance of the material to slide over stainless or carbon steel to determine the critical angles required for mass flow, as shown in Figure 4. Theta C is the maximum recommended angle (from the vertical) for conical hoppers and end walls of transition hoppers, and Theta P is the maximum angle of side walls of transition hoppers.

SOLIDS CHARACTERIZATION RESULTS

The two high-SRC samples of ash concentrate sent to J&J were labeled #163 (65% SRC recovery) and #165 (70% SRC recovery). At all temperatures tested, Sample #163 was more difficult to handle than Sample #165. In general, both samples were temperature-sensitive, especially with respect to their tendency to cake with time. Table 1 tabulates the Critical Openings required to prevent stable arch formation, and Table 2 lists the Critical Angles required to maintain mass flow.

The results show that the ash concentrate can be handled at 500°F, provided that a mass flow bin with a 2.7-ft-wide, 8-ft-long slotted outlet is used (Figure 5). This will be large enough to overcome bridging provided the storage time at rest is less than 12 min. At 500°F, the ash has a high coefficient of friction on steel, even if that steel is smooth 2B finish stainless steel sheet. At temperatures below 500°F, the material is more easily flowing with less tendency to cake. For example, the outlet dimensions given above are sufficient at 400°F to overcome bridging after up to 8 hr at rest. At 550°F the ash is much more difficult, if not impossible, to handle by gravity; severe sticking to steel occurs, and the ash concentrate's cohesion is increased considerably, even at short storage times at rest.

The sample of ash concentrate corresponding to high SRC recovery in the CSD unit (low SRC sample) was much easier to handle than the other samples. It was insensitive to temperatures up to 500°F and had no bridging tendencies. This confirmed the assumption that the high SRC

samples are more difficult to handle and require more conservative designs for the Ash Concentrator and storage bins.

RECOMMENDATIONS

J&J recommended the design shown in Figure 5 for the solids storage section of the Ash Concentrator. This design is based on the following criteria:

1. An ash inlet temperature of 500°F or less.
2. Less than 5-min retention time at 150,000 lb/hr in the hopper section. This hopper has a retention time of 2.5 to 4.0 min at the expected densities of 16 to 24 lb/ft³.
3. Surge capacity in the event of downstream stoppages through the placement of an 8-ft diameter cylindrical section between the hopper and the conical chute. The height of the cylinder should not be increased because this would cause an increase in gas pressure and, therefore, screw-sealing capability requirements. The normal ash level should be maintained in the hopper, leaving the cylinder for surge.

The design includes the following specifications:

1. The hopper slope angle, θ_p , has been increased to 15° from the value in Table 2 of 8° using 2B finish stainless steel sheet since $\theta_c = 0$, i.e., no convergence on the end walls.
2. The outlet slot has dimensions of 34 in. by 8 ft because of feeder limitations.
3. The conical chute has a slope of 20° from the vertical and is constructed of 2B finish stainless steel sheet. If the operating temperature is reduced to 400°F or below, a 30° carbon

steel chute is recommended. Material should not be allowed to accumulate in the conical chute because the ash will rathole causing buildup in the chute.

4. As shown in Figure 5, vibrator mounting plates should be installed to restart flow in the event of a stoppage lasting more than 12 min.

There is no difficulty in achieving the desired flow rate of 150,000 lb/hr during normal operation. Two-phase flow computer simulation using the physical geometry shown in Figure 5, as well as the properties of the material, showed during continuous flow within the hopper, the material will essentially be in a fluidized state and pose no problem in attaining the rate desired. However, if material rises into the cylinder, flow may become erratic.

If the material is allowed to sit and deaerate in the hopper and/or cylinder, a reduced flow rate can be expected on startup unless a nitrogen permeation system is added between the hopper and screw to keep the material fluidized. This system is composed of a nitrogen supply, pressure regulator, gauge, rotometer and piping. The rotometer should be adjusted so that the minimum gas flow rate is 102 scfh with the pressure regulator set for 4.2 psig and the bin empty. This pressure regulator setting accomodates a maximum pressure of 2 psig at the top of the flash hopper; if this pressure varies, the regulator pressure should be adjusted to be at least 2.2 psi greater than that at the top of the surge cylinder. During normal operation of the bin, the gas permeation system should be shut off. However, when solids flow stops, the nitrogen should be turned on and maintained to ensure immediate flow of solids at the required rate when the feeder is restarted.

Ash Concentrator and Sealing Screw

The screw feeding from the ash concentrator must operate under two flow situations. The most difficult requires that it prevent flushing while sealing against an internal gas pressure of 2 psig maximum plus 1.1 psi for every 10-ft head of material above the hopper outlet. The second situation would require that it feed a deaerated material from an

extended shutdown during which the nitrogen permeation system may have been inadvertently turned off.

The feeder should consist of:

1. Twin 15-in. diameter mass flow screws extending at full pitch through two distinct barrels.
2. Two screen compacting barrels, each of which will effectively deaerate the material, seal against the internal gas pressure and provide controlled feeding of the material in conjunction with a constant pressure plate at the end.

The design of these screws is critical in terms of plate pressure, screen barrel length, screen size, etc. Further work must be done before the design can be finalized.

8- and 24-Hour Capacity Bins

The recommended design of these bins is shown in Figures 6 and 7. The wall angles in Table 2 indicate no significant difference between 400°F and 200°F, temperatures at which the 8- and 24-hr bins, respectively, will operate. Because arching dimensions are similar for the two temperatures, J&J recommends a common design with maximum wall angles of $\Theta P = 20^\circ$ and $\Theta C = 8^\circ$ using 2B finish stainless steel sheet. Such angles are adequate provided the bin temperature is not allowed to drop below 200°F, when solvent migration and condensation on the walls may cause a reduction of 7° in each angle.

Because of feeder and overall bin geometrical limitations, two in-line 33-in. by 8-ft slots are required for each bin. To reduce head room and maximize capacity, a square to round transition from the hopper to the circular cylinder is accomplished with carbon steel plates sloping at 30° from the vertical. The flat-sided hopper has corner plates to eliminate sharp corners, thereby maintaining material flow in the corners.

Two-phase flow modeling of the bins shows that two nitrogen permeation levels are required and placed as shown in Figure 6, to

achieve the desired flow rate. Since the material must be maintained in an inert environment, this system will also provide the necessary purge.

The nitrogen permeation control system shown in Figure 8 is based on the 8-hr bin with a 25-ft tall cylinder section (Figure 6). The rotometers should be adjusted so that the maximum gas flow rate is 10 and 2.6 scfm in top and bottom levels, respectively, with the pressure regulators set for 1.1 psig and the bin empty. This pressure regulator setting accomodates a maximum feed rate of 75 tph, but some field adjustment may be necessary if fluctuations in flow rate are observed. It should be noted that if the geometry is changed substantially, the stated values will change.

J&J recommends that a second pressure gauge be mounted near the top of the screw feeder trough. For best control of the feed rate, the pressure regulator should be adjusted so that this gauge indicates atmospheric pressure during steady-state flow. However, as the feed rate varies, the regulator pressure required to achieve this will vary. In practice, the reading on the screw gauge can be allowed to vary by several inches of water (either positive or negative) and still maintain good accuracy on the volumetric feed. Although it is hoped that only one regulator setting will be needed for the required range of feed rates, wide variation in material properties may require field adjustment of the pressure and maximum flow rate.

During operation of the bin, the pressure regulator maintains a constant pressure. The gas flow rate then adjusts automatically between zero and the maximum set by the rotometer. When operating with a low head of solid, the gas flow rate will be consistently at the maximum allowed by the rotometer and the gas pressure will adjust to accomodate this flow rate between the maximum pressure set on the regulator and zero psig. When a pressure drop occurs, the maximum allowable solids rate may decrease.

If the solids flow is to be stopped for less than a day, gas permeation should be maintained to ensure immediate flow of solids at the required rate when the feeder is started. If solids flow is to be stopped for several days, the gas may be turned off but should be turned on again several hours before solids flow resumes.

Table 1

Ash Concentrate Tests: Critical Openings Required for Flow

Time/temperature	Critical slot width (ft)	
	#163	#165
12 min/400°F	0.9	0.7
12 min/500°F	2.5	0.8
12 min/550°F	>25.	-
8 hr/400°F	2.7	-
65 hr/200°F	-	0.9

Table 2

Ash Concentrate Tests: Critical Angles Required for Flow

Temperature (°F)	Theta C ^a	Theta P	Theta Chute ^b
72	13	24	47
200	13	24	49
400	13	25	-
500	0	8	25
550	0	7	-

^aTheta = Degrees from vertical; Theta C and Theta P - based on 304 stainless steel

^bTheta Chute - based on aged carbon steel

Figure 1
Funnel Flow

SOME MATERIAL IS STATIONARY WHILE THE REST IS MOVING.

CHARACTERISTICS

- LOW HEADROOM
- FIRST-IN-LAST-OUT
- RATHOLES MAY DEVELOP
- FLOW MAY BE ERRATIC
- POWDERS WILL FLUSH
- SEGREGATION PROBLEMS ARE MADE WORSE

Figure 2
Mass Flow

ALL THE MATERIAL IS IN MOTION WHENEVER ANY IS WITHDRAWN

CHARACTERISTICS

- **SMOOTH STEEP HOPPER**
- **FIRST-IN-FIRST-OUT**
- **FINE POWDERS DEAERATE**
- **SEGREGATION PROBLEMS ARE MINIMIZED**
- **MATERIAL IS FED UNIFORMLY AT CONSTANT DENSITY**

Figure 3
Wall Friction Test

DIRECT SHEAR TESTER

Figure 4
Mass Flow Bins

TRANSITION HOPPER

CONICAL HOPPER

Figure 5
Recommended Design for Ash Concentrator

Figure 6
Eight and Twenty-four Hour Storage Capacity Bin Elevations

Figure 7
Eight and Twenty-four Hour Storage Capacity Bin Plan View

Figure 8
Nitrogen Permeation Control System

	PRESSURE REGULATOR SETTING (PSIG)		ROTOMETER AIR FLOW SETTING (CFM)	
	NOMINAL VALUE	RANGE*	NOMINAL VALUE	RANGE*
UPPER LEVEL	1.1	0 – 5	10.0	2 – 20
LOWER LEVEL	1.1	0 – 5	2.6	1 – 10

*ANTICIPATED MAXIMUM RANGE OF ADJUSTMENT REQUIRED FOR SIZING GAUGE, ROTOMETER AND REGULATOR. THE ROTOMETER SHOULD BE SET WITH THE BIN EMPTY AND THE PRESSURE REGULATOR SET FOR THE REQUIRED PRESSURE.

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IMPACT OF SRC RECYCLE ON COMMERCIAL DESIGN

D. Kang and E. N. Givens*

This program was initiated to answer questions regarding recycle of SRC in the SRC-I Demonstration Plant. The major objective was to determine if, when necessary, solvent yield could be increased by recycling SRC to keep the plant in solvent balance. In this program the impact of SRC recycle on the SRC-I plant design has been studied using Air Products' Coal Process Development Units (CPDU).

Three quarterly reports have been issued that partially covered the study of both light and heavy SRC (LSRC and HSRC) recycle using Kentucky #9 coal and two types of process solvents, creosote oil (CO) and hydro-treated creosote oil (HTCO), since systematic study of SRC recycle required the use of solvents with varying properties. This report covers a part of the work conducted on both light and heavy SRC recycle at varying concentrations using a Wilsonville recycle solvent (WRS) derived from coal during the SRC-I pilot plant operation at Wilsonville, Alabama. Light and heavy SRC used in this program were produced from the third and second stage settler of the Kerr-McGee Critical Solvent Deashing Unit at Wilsonville.

In this program, mixtures of coal, SRC and solvent were processed under simulated Demonstration Plant conditions--840°F, 2000 psig, 40-min residence time and 20 M scf feed hydrogen gas rate per ton of coal--as well as at 780°F. Results have shown that the presence of both light and heavy SRC in the feed increased the oil formation from Kentucky #9 coal at the expense of SRC products. Increasing the concentration of either light or heavy SRC in the feed solvent from 15% to 25% further increased the oil yield. The presence of either LSRC and HSRC

*APCI

in the feed drastically decreased the optimal process temperature and enhanced the uptake of molecular hydrogen, reducing the importance of hydrogen content in the feed solvent. However, at Demonstration Plant conditions (840°F), hydrogen consumption was higher with addition of LSRC and HSRC because of the increased light gas formations.

All the results from the SRC recycle study thus far have been based on single pass runs in the CPDU, although actual plant conditions will involve continuous recycle of SRC/solvent in a closed loop. Most of FY '81 process runs are programmed to evaluate the recycling of SRC materials based on multiple passes of solvent/SRC materials to reduce or eliminate uncertainties associated with the transient single pass run conditions.

EXPERIMENTAL PROGRAM

Process Runs

Process runs covered in this quarterly report were made with 38 wt % Kentucky #9 coal slurry using Wilsonville recycle solvents blended with 15% and 25% of light or heavy SRC. Previous reports covered the study of 15% light or heavy SRC in CO and HTC0. Process conditions for the present runs (BCL-29) were:

Temperature (°F):	780/840
H ₂ pressure (psig):	2000
H ₂ rate (M scf/ton of coal):	20
Nominal residence time (min):	40
Slurry space rate (lb/ft ³ /hr):	106
SRC to solvent ratio:	15:85/25.75
Coal to blended solvent ratio:	38:62

MATERIALS

Coals

The BCL-29 run used Kentucky #9 coal ground, dried, and sized to minus 150 mesh in air to bring the moisture content of the coal below

2%. Typical proximate and ultimate analyses of the coal are given in Table 1.

Solvents

Process solvent was a Wilsonville recycle solvent (WRS) produced during Wilsonville Run 179. For these runs, 15% and 25% of light or heavy SRC were blended with this solvent. The WRS contained 8.5% hydrogen, which was considerably higher than that of the HTC0 (7.5%), and C0 (6.4%) used in earlier experiments. Hydrogen content alone, however, is not sufficient to scale solvent quality. As shown in Table 2, WRS yielded a much higher ratio of alpha and other protons to aromatic protons (i.e., $(H_a + H_o)/H_{ar} = 1.82$) compared with those of HTC0 and C0, 1.06 and 0.44, respectively, indicating that a large portion of hydrogen in Wilsonville solvent was incorporated as non-donatable hydrogen such as alkyl side chains. Gas chromatography data for the solvent support this interpretation. WRS contained 1.25% hydroxyl groups, which was 18-fold greater than the hydroxyl content of HTC0.

Four distillate cuts of WRS presented in Table 2 show that the hydroxyl functional groups were more enriched in the IBP-450°F cut with a minimum level in the 550-650°F cut. The higher boiling 650-1010°F cut showed a greater hydroxyl content than the 550-650°F cut. Hydroxyl groups in coal-derived solvents are known to enhance solubility characteristics of the solvents by their ability to hydrogen bond with other nucleophilic groups. Although the chemical role of hydroxyl groups in coal liquefaction is not yet well understood, they appear to function both as hydrogen donors in hydrogen-starved reaction environments and as hydrogen consumers in hydrogen-sufficient environments.

SRC Composition

Light and heavy SRC used in this run were produced from third- and second-stage settlers in the Kerr-McGee Solvent Deashing Unit during Wilsonville Runs 167 and 203, respectively, while that plant was operating with Kentucky #9 coal. The properties of LSRC and HSRC, discussed in previous reports, are summarized in Table 3.

RESULTS AND DISCUSSION

Oil yields given in this report were determined by a distillation method, whereas, earlier data were based on pentane solubility of product slurry. The final cut point in the distillation was determined by the onset of still bottom product decomposition under less than a few millimeters of mercury, which indicates a cut point close to 1000°F at atmospheric pressure.

In Table 4, yield data of Kentucky #9 coal reacted with WRS containing 15% and 25% Kerr-McGee LSRC or HSRC is compared with yield data for WRS alone. The data reveal that 15% LSRC addition to the feed solvent increased oil yield slightly, but that 25% LSRC addition increased yield as much as two-fold. Distillation data (to be supplied in a later report) showed that oils produced at a higher process temperature (840°F) contained more lighter end products than those at a lower process temperature (780°F). Increasing temperature from 780 to 840°F reduced the yields, especially the 450 to 1000°F cut, with 25% LSRC recycle. Although the addition of 15% HSRC showed a decrease in oil yield at 780°F, HSRC addition in all other cases yielded an even more pronounced increase than did LSRC addition. It should be noted that increase of process temperature from 780 to 840°F decreased oil yield at the higher HSRC concentration, reflecting the highly temperature-sensitive nature of HSRC material.

Excepting 15% HSRC at 780°F, the addition of either LSRC or HSRC resulted in decreased SRC yield.

Although LSRC additions always decreased asphaltene yield, HSRC addition increased asphaltene yield at 780°F, especially at the 15% concentration. LSRC yielded increases in preasphaltenes, except at 780°C, and HSRC always decreased preasphaltene yields.

Data in Table 5 show that, in all but one case, LSRC and HSRC recycle increased the asphaltenes to preasphaltenes ratio in the feed to the Kerr-McGee unit. LSRC (but not HSRC) recycle substantially decreased asphaltene/preasphaltene ratios in the net SRC product.

Coal conversions appeared to be slightly enhanced by 15% LSRC addition. However, further addition of LSRC to 25% showed a trend of

slightly reduced conversion. On the other hand, at both concentrations and temperatures, HSRC always increased conversion. The conversion increases may result from changes in the solubility characteristics of product liquid caused by SRC addition. However, SRC addition can affect conversion by chemical interaction with the solvent and/or reactants, as well as by altering the physical solubility characteristics of the solvent.

Although sulfur contents in SRC were substantially reduced in the presence of 15% LSRC at both 780 and 840°F, an increase to 25% concentration reduced the efficiency of sulfur removal. Similarly, sulfur was reduced with 15% HSRC at both temperatures, but increased concentration and temperature reduced the effectiveness of removal to the point that a decrease in sulfur content (compared with the base case) could be achieved only at 780°F.

In the presence of both light and heavy SRC, light hydrocarbon gases (C_1 to C_4) and other gaseous products consistently increased. However, gas yields were not appreciably different between LSRC and HSRC addition.

Although hydrogen consumption decreased at 780°F with 15% addition of either LSRC or HSRC, it increased with increasing temperature and concentration.

CONCLUSIONS

SRC recycle in Wilsonville recycle solvent:

- ° Increased oil yield at certain favorable reaction conditions.
- ° Increased the sensitivity of yields to reaction temperature and decreased the optimum reaction temperature (as a function of increasing SRC concentration in feed).
- ° Decreased SRC yield at the favored reaction conditions.

- Decreased asphaltene yield with LSRC addition, but increased asphaltene yield with HSRC addition.
- Appeared to enhance conversion at the design temperature (840°F).
- More efficiently reduced sulfur content at the lower concentration (15%).
- Increased the formation of light gaseous products.
- Increased hydrogen consumption compared with equivalent conditions with no SRC recycle.

FUTURE WORK

Continuous SRC recycle runs using 15% LSRC/85% solvent mixture with Kentucky #9 coal are in progress. Including base-line runs with coal only, this run will require 1-1/2 months to achieve at least four to five passes of recycle solvent through Air Products' CPDU. In this experiment, performance quality of steady-state recycle LSRC/solvent will be evaluated and compared with conventional solvent.

Table 1

Analyses of Kentucky #9 Coal^a

Analysis	wt %
Proximate	
Moisture	1.93
Volatile matter	35.11
Fixed carbon	49.59
Ash	13.37
Ultimate (dry basis)	
Carbon	70.31
Hydrogen	4.72
Oxygen	6.04
Nitrogen	1.50
Sulfur	3.19
Ash	13.63

^aGround and dried in air.

Table 2
Properties of Solvent

	WRS (900-1)	HTCO (M-97)	CO (F-223)
Hydrogen (wt %)	8.5	7.5	6.4
H _{ar} (%) ^a	35.4	48.1	69.6
H _a (%)	27.7	26.1	20.2
H _o (%)	36.9	25.1	10.2
Aromaticity	0.63	0.74	0.87
H _a /H _{ar} or H _o /H _{ar}	0.78 (1.04)	0.54 (0.52)	0.29 (0.15)
MW	186	175	180
Boiling range (°F)	403-1010	306-850	414-999
Wt % cuts: IBP-450°F	6.0	--	--
450-550°F	46.3	--	--
550-650°F	14.4	--	--
650-1010°F	31.4	--	--
Residue	1.3	--	--
% OH as oxygen in cuts			
IBP-EP	1.25	0.07	0.43
IBP 450°F	2.59	--	--
450-550°F	1.55	--	--
550-650°F	0.71	--	--
650-1010°F	1.12	--	--

^aH_{ar} - Aromatic hydrogen
H_a - Alpha hydrogen
H_o - Other hydrogen

Table 3

Properties of Light and Heavy SRC

Analysis	LSRC	HSRC
Carbon (wt %)	85.4	87.0
Hydrogen (wt %)	6.8	6.3
Oxygen (wt %)	4.3	3.6
Nitrogen (wt %)	1.7	2.1
Sulfur (wt %)	1.0	1.1
Ash (wt %)	0.1	0.3
Oils (wt %)	--	1.2
Asphaltenes (wt %)	--	58.6
Preasphaltenes (wt %)	--	40.2
MW	--	1290
Molecular formula	--	$C_{93.4}H_{80.6}O_{2.9}N_{1.9}S_{0.4}$
Softening point (°F)	--	--
OH in asphaltenes (wt % OH as O)	--	1.35
NH in asphaltenes (wt % NH as N)	--	0.25

Table 4

Yield Data Summary for SRC Recycle Run

Sample no.	BCL-29-9	BCL-29-13	BCL-29-51	BCL-29-62	BCL-29-80	BCL-29-72	BCL-29-117	BCL-29-108	BCL-29-126	BCL-29-137
Coal	Ky #9	KY #9	KY #9	Ky #9	Ky #9	Ky #9	Ky #9	Ky #9	Ky #9	Ky #9
Solvent	WRS	WRS	WRS/LSRC	WRS/LSRC	WRS/LSRC	WRS/LSRC	WRS/HSRC	WRS/HSRC	WRS/HSRC	WRS/HSRC
SRC in solvent (wt %)	0	0	15	15	25	25	15	15	25	25
Temperature (°F)	784	841	783	840	779	846	782	841	779	842
Conversion (wt %)	<u>92.2</u>	<u>88.4</u>	<u>92.6</u>	<u>92.4</u>	<u>92.0</u>	<u>91.6</u>	<u>92.7</u>	<u>91.5</u>	<u>93.9</u>	<u>96.0</u>
C ₁ -C ₄	1.48	4.23	1.53	5.59	1.85	5.76	1.92	5.28	2.36	5.69
CO + CO ₂	0.56	0.89	0.48	1.06	0.59	0.95	0.55	0.86	0.63	0.89
H ₂ S + NH ₃	1.05	1.54	0.99	2.06	0.21	2.08	0.93	1.40	0.94	1.11
H ₂ O	1.76	4.31	1.94	5.43	3.94	8.86	2.62	2.41	3.55	5.57
Oils	9.0	10.2	10.3	11.5	18.8	16.3	7.6	23.2	21.1	19.2
116 28 SRC ^a	<u>78.4</u>	<u>67.3</u>	<u>77.3</u>	<u>66.8</u>	<u>65.6</u>	<u>57.6</u>	<u>79.1</u>	<u>58.4</u>	<u>65.4</u>	<u>63.5</u>
Asphaltenes	12.6	24.0	-5.7	14.8	9.9	10.7	25.2	20.1	14.7	22.7
Preasphaltenes	65.7	43.2	83.0	52.0	55.7	46.9	53.9	38.2	50.7	40.8
UCC ^b	9.7	13.8	9.3	10.5	9.9	11.1	9.2	10.7	7.5	6.2
Sulfur in SRC (wt %)	1.50	1.09	1.36	0.94	1.21	1.15	1.20	0.93	1.40	1.24
Solvent hydrogen (wt %)										
Start	8.47	8.47	8.24	8.24	8.08	8.08	8.21	8.21	8.03	8.03
Finish	8.30	8.01	8.20	7.95	7.86	7.60	8.06	8.09	7.68	7.69
Hydrogen consumption (wt % as maf coal)										
Total	<u>0.74</u>	<u>1.04</u>	<u>0.32</u>	<u>1.52</u>	<u>1.35</u>	<u>1.83</u>	<u>0.72</u>	<u>1.48</u>	<u>1.18</u>	<u>1.58</u>
Gas	0.41	0.17	0.24	0.97	0.92	0.89	0.43	1.24	0.51	0.93
Solvent	0.33	0.87	0.08	0.55	0.43	0.93	0.29	0.24	0.68	0.65

^aAsphaltenes + preasphaltenes.^bUnconverted carbon.

Table 5

Asphaltene/Preasphaltene Ratio in the Product Slurry With and Without SRC Recycle

Sample no.	BCL-29-9	BCL-29-18	BCL-29-51	BCL-29-62	BCL-29-80	BCL-29-72	BCL-29-117	BCL-29-108	BCL-29-126	BCL-29-137
Solvent	WRS	WRS	WRS/LSRC	WRS/LSRC	WRS/LSRC	WRS/LSRC	WRS/HSRC	WRS/HSRC	WRS/HSRC	WRS/HSRC
% SRC in solvent	0	0	15	15	25	25	15	15	25	25
Temperature (°F)	784	841	783	840	779	846	782	841	779	842
Asphaltene/Preasphaltene ratio										
K-MAC feed	0.22	0.58	0.20	0.69	0.80	1.00	0.65	0.78	0.60	0.80
Product (ratio based on net yields)	0.19	0.56	-0.07	0.29	0.18	0.23	0.47	0.53	0.29	0.56