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CONTROL TECHNOLOGY ASSESSMENT
FOR COAL GASIFICATION AND LIQUEFACTION PROCESSES

Solvent Refined Coal Pilot Plant

Ft. Lewis, Washington

February 1979
Site Visit Report

Contract No. 210-78-0084

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Submitted to:

National Institute for Occupational
Safety and Health
Division of Physical Sciences and Engineering
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FORWARD

The Enviro Control Technology Assessment (CTA) Team met with representatives of the Solvent Refined Coal (SRC) Pilot Plant at Ft. Lewis, Washington, and the Pittsburg & Midway Coal (P&M) Company on February 5, 1979 to discuss the purpose of the visit. Attending this meeting were:

Solvent Refined Coal

James Smith	Plant Nurse
John Segerson	Technical Relations Coordinator

Enviro Control, Inc. - CTA Team

James Evans	Project Manager
Donato Telesca	Principal Investigator
Russell Tanita	Senior Industrial Hygienist

Others attending the meeting were:

Enviro Control, Inc.

Dewey Cubit	Senior Industrial Hygienist
Edward Haggerty	Industrial Hygienist
Carl Bailey	Industrial Hygienist

National Institute for Occupational Safety and Health (NIOSH)

Barry Pallay	NIOSH Project Officer for the Industrial Hygiene Characterization of Liquefaction Plants
Dr. William McKay	NIOSH Physician and Observer

The CTA assessment spanned a period of two weeks. Techniques used for the study included detailed inspections of plant equipment, review of equipment drawings and interviews with personnel in maintenance, operations, safety, and engineering and planning. In addition, daily operating reports prepared by the plant were supplied by DOE. Information was obtained from various papers given by personnel from P&M.

Without the excellent cooperation of the personnel at the SRC Ft. Lewis, Washington Facility and Mr. Harold Fisher, DOE Project Manager, this report would not have been possible.

Those interviewed at the Solvent Refined Coal Pilot Plant at Ft. Lewis Washington were:

David Williams	Staff Process Engineer
Carl Ackerman	Chemical Engineer, P.E., Engineering Department
Fred Von Bargen	General Maintenance Foreman
Duane Konen	Day Process Supervisor
Dennis Canfield	Corrosion Engineer
Donald Vollentine	Pump Shop Foreman
Robert Ward	Instrument Supervisor
James Smith	Plant Nurse
John Segerson	Technical Relations Coordinator
Thomas Visaya	Technical Specialist
Russell Perrussel	Chief Chemist
John Ward	Plant Manager

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Control Technology Assessment
of the
Solvent Refined Coal Pilot Plant
Ft. Lewis, Washington

I. SUMMARY

A control technology assessment (CTA) of the Solvent Refined Coal (SRC) process was conducted during the period of February 5-14, 1979 at the pilot plant facility in Ft. Lewis, Washington. Although the plant was operating in the SRC-II mode, which is the process for producing liquid fuel from coal, the assessment included equipment used for the SRC-I mode, which is the process for producing low ash, low sulfur solid fuel from coal. During the period a complete qualitative survey was conducted by the team industrial hygienist. Details of the process and plant operating history were examined by site inspection and detailed interviews of plant personnel. The assessment was broadened by being conducted simultaneously with the comprehensive industrial hygiene survey. In addition, the scope of the assessment was widened through a review of SRC literature.

The CTA survey showed that progress has been made in the selection and use of equipment for the control of emissions from coal liquefaction processes. However, there are unit operations where improvements in the design and/or materials of construction are required, such as letdown valves, relief valves, pump impellers and casings, seals, mineral separation equipment and solvent recovery equipment. There is a need for reliable process equipment and for fast response instrumentation for industrial health and safety measurements.

Personnel associated with the SRC process have done a good job in adapting off-the-shelf equipment to the requirements of the pilot plant, but more specifically designed equipment is required for the demonstration and commercial installations.

II. INTRODUCTION

A. Background

The objective of the "Control Technology Assessment for Coal Gasification and Liquefaction Processes" program is to study the control technology that is available to prevent occupational exposure to hazardous agents in coal conversion plants. This report details the control technology and industrial hygiene information gathered at the Solvent Refined Coal (SRC) Pilot Plant at Ft. Lewis, Washington during the site visit of February 5-14, 1979.

The SRC pilot plant at Ft. Lewis is being operated by Pittsburg and Midway Coal Mining Company (P&M), a subsidiary of Gulf Oil Corporation, under the sponsorship of DOE. The objectives of the operation are to obtain technical and economic data necessary for the scale-up of the pilot plant to a commercial size facility and to provide large samples of solvent refined coal and process by-products for market development studies.

The SRC-I process produces a low ash, low sulfur, solid product. The SRC-II process is a second-generation technology for deriving hydrocarbon liquids from coal, and one of the processes most likely to compete with the commercially proven Fischer-Tropsch indirect coal liquefaction process.

B. Project History

The Solvent Refined Coal (SRC) project began in 1962 when Spencer Chemical Company was awarded a research contract by the Office of Coal Research (OCR) to study the technical feasibility of a coal de-ashing process. In 1965, the process was successfully demonstrated in a 50-lb/hr continuous-flow unit. During the term of the contract, Gulf Oil Corporation acquired Spencer Chemical Company. After reorganization, the contract was assigned to the research department of the Pittsburg and Midway Coal Company (P&M).

In 1969, Stearns-Roger Corporation completed the design for a pilot plant processing 50 tons of coal per day. Rust Engineering Company began constructing the pilot plant in July 1972 at Fort Lewis, Washington. The plant became fully operational in October 1974.

Test runs during 1975 at Fort Lewis were designed to study the effects of different coal feed rates and dissolver temperatures. A 3,000 ton run was conducted during 1975 and 1976 to produce specification SRC for use in combustion testing by Georgia Power Company. Filtration tests were conducted following the production run. The plant was shut down in January 1977 for a major maintenance turnaround and piping tie-in for SRC-II (slurry recycle) operation. Modifications were completed in May 1977 and testing began with a blend of Kentucky No. 9 and No. 14 coals. Operability and yields were explored with emphasis on conditions yielding organic residues compatible with hydrogen generation needs. Testing with Illinois No. 6 coal began in September 1977, and Pittsburg seam coal was used for testing during November and December 1977. In June 1978, processing was started in the SRC-I mode with Kentucky coal. The period between June through September 1978 was devoted to testing of the Johns-Manville filter. In January and February 1979, the plant was operating in the SRC-II mode.

C. Process Description

The Solvent Refined Coal (SRC) process is used to convert high-sulfur, high-ash coals to an environmentally and commercially acceptable fuel low in sulfur and ash. There are two variations of the SRC process. The SRC-I process produces a solid fuel. The SRC-II process produces a liquid fuel. Although the pilot plant was operating in the SRC-II mode at the time of the visit, the control technology assessment included equipment and unit operations used in the SRC-I configuration, for example, the precoat filters and Sandvik solid belt cooler.

A schematic of the SRC-I process is given in Figure 1. In this process pulverized coal is mixed with process-derived solvent in a slurry mix

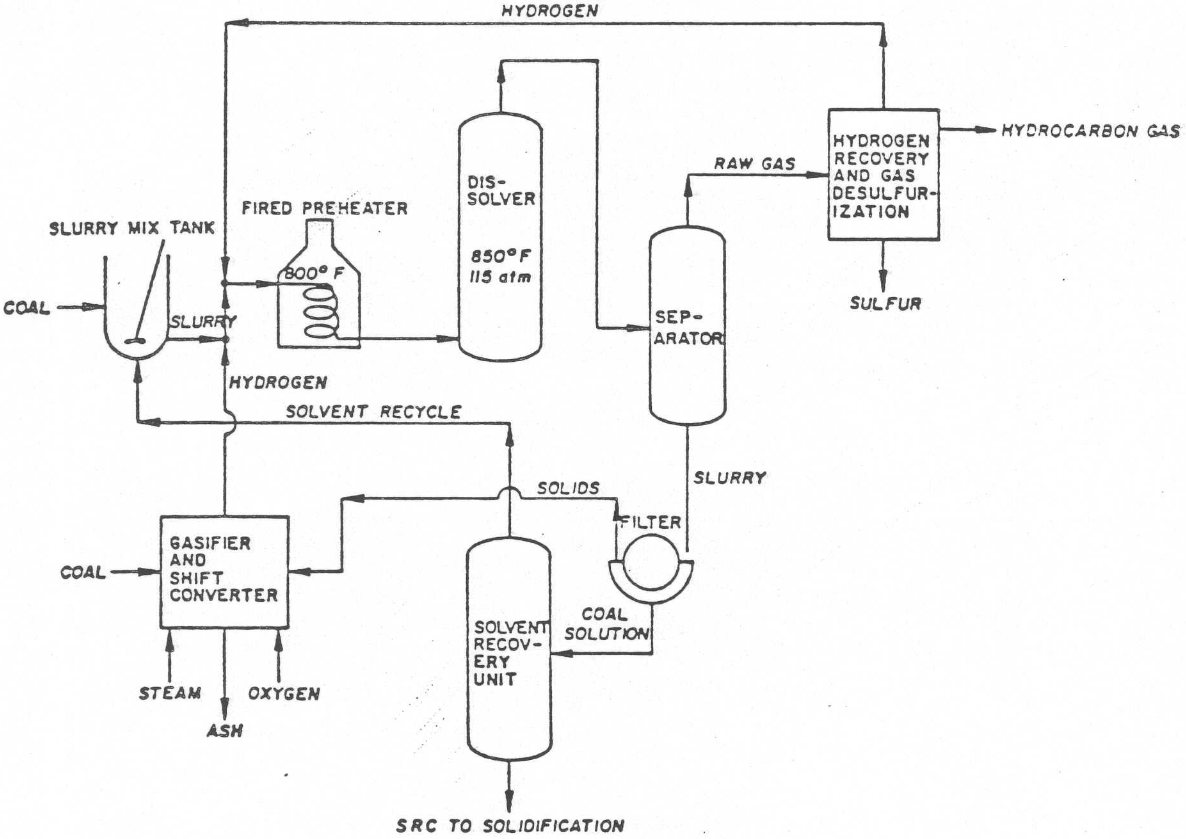


Figure 1. SRC-I PROCESS SCHEMATIC[a]

Solvent Refined Coal Pilot Plant
Fort Lewis, Washington

[a] Adapted from Reference 1.

tank. The slurry is combined with hydrogen and pumped through a preheater and into a dissolver which operates at 425 to 467 C (800 to 875 F), and a total pressure of approximately 1500-2000 psig. The residence time in the dissolver is 30 minutes. At these operating conditions, the carbonaceous material in the coal is dissolved, hydrogenated, and depolymerized; the process-derived solvent is hydrocracked, yielding low molecular weight hydrocarbons; and organic sulfur compounds in the coal are hydrogenated to hydrogen sulfide.

After the dissolver, the mixture passes through a gas-liquid separator. The raw gas is sent to the hydrogen recovery and gas desulfurization units. The liquid slurry is treated in a solids separation unit, which was a filtration system at the time of the visit. After solids removal, the coal solution is sent to a solvent recovery unit where the process-derived solvent is recovered for recycle to the slurry mixing unit. The SRC product from the solvent recovery unit is solidified by cooling on a Sandvik belt. The solid fuel produced had a solidification point of 177 to 205 C (350 to 400 F) and a heating value of approximately 16,000 Btu per pound.

Generally, the SRC I and II processes are the same through the dissolver. However, in the SRC-II process (Figure 2) the slurry exiting the dissolver is split. One portion is recycled to provide solvent for the coal slurry mixing operation, and the other portion is fractionated. The fractionation products are naphtha, low sulfur fuel oil, and a residue of heavy oil, ash, and undissolved organic material from the coal. The increased severity of operating conditions in the dissolver (i.e., the increased residence time, operating pressure, and hydrogen concentration) results in the majority of the coal being converted to a liquid fuel resembling No. 2 fuel oil with a 175-455° C (350-850° F) boiling range.

D. Pilot Plant Layout

The Solvent Refined Coal Pilot Plant at Fort Lewis, Washington, is laid out in a rectangular grid with a panhandle which contains the tank farm

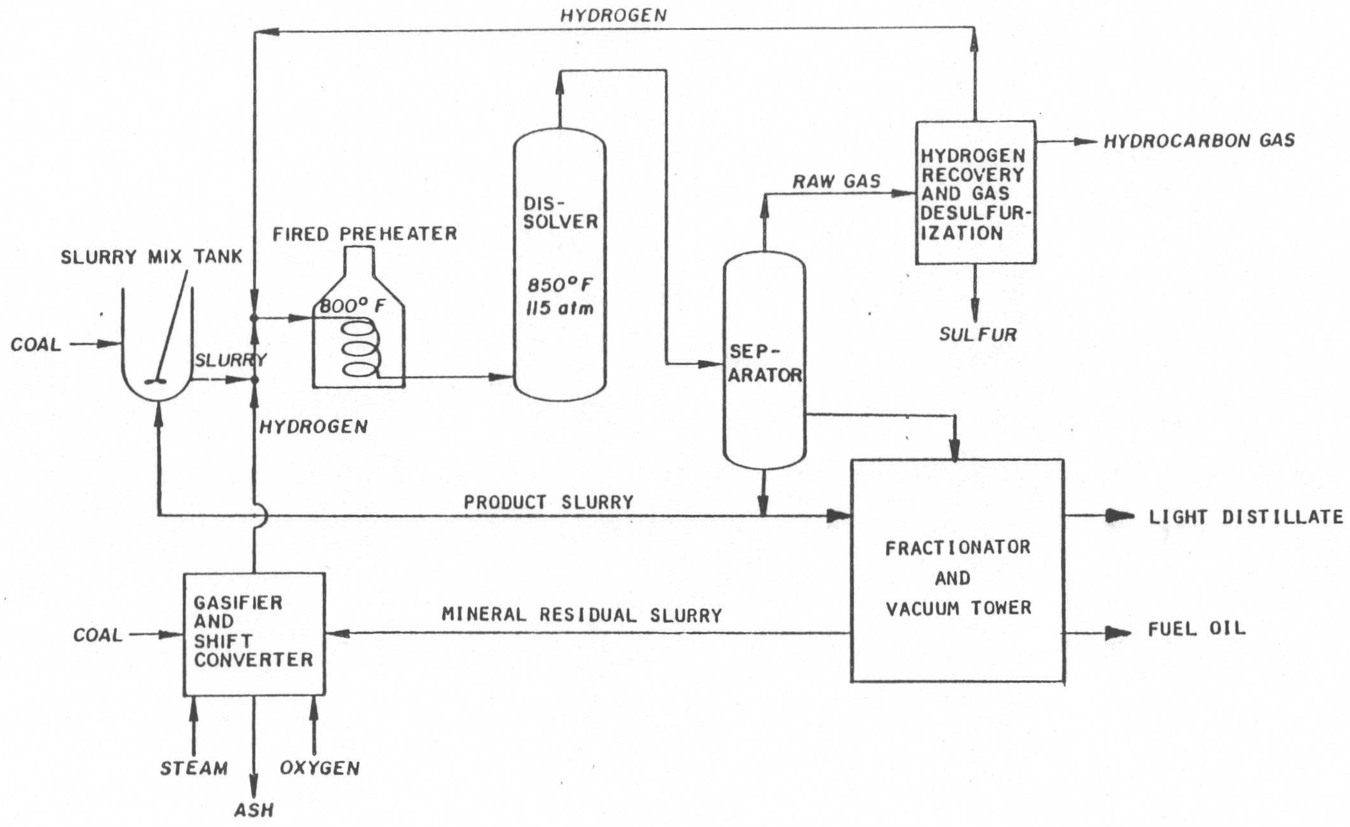


Figure 2. SRC-II PROCESS SCHEMATIC[a]

Solvent Refined Coal Pilot Plant
Fort Lewis, Washington

[a] Adapted from Reference 1.

and waste treatment facilities. The layout of the plant is shown in Figure 3. The unit processes are housed in open, multilevel structures with the exception of the coal grinding, slurry mixing, filtration and Sandvik belt operations, which are in enclosed structures.

E. Potential Hazards

Since the SRC process utilizes coal derived liquids (recycle solvent) throughout the process, exposure to these contaminants could potentially occur anywhere in the process through leaks and other emission sources. The possibility of exposure to these contaminants is higher in the coal preparation and product solidification areas where several processing steps are not performed in a closed system.

A brief summary of the potential hazards associated with each unit area is presented in Table 1.

III. ENGINEERING CONTROL TECHNOLOGY

A. Introduction

A two part discussion of each process area in the Fort Lewis Pilot Plant is presented. The first part consists of an area process description. The second part is a discussion of the potential hazards associated with that process area, and the engineering controls used to mitigate those hazards. The term engineering control means the use of hardware (e.g., ventilation systems, mechanical seals, or special metallurgy) to eliminate or reduce an occupational safety or health hazard. Work practices, protective equipment, monitoring programs, and health and safety programs as a means of mitigating occupational safety and health hazards are discussed later in the report.

AREA	DESCRIPTION
01	Coal preparation area
02	Preheater and dissolver area
03	Mineral separation area
04	Solvent recovery area
05	Gas recovery and recompression area
06	Partially paved storage area
07	Paved storage area
08.1	Product solidification area
08.2	Solid product storage area
09.1	Process waste water disposal system
09.2	Tank farm
09.3	Cooling water
09.4	Boilers
09.5	Hydrogen/synthesis gas and inert gas generation and desulfurization units
09.6	Control building
09.7	Shop and warehouse building
09.8	Dowtherm system
09.9	Dry chemical storage building
10.0	Solvent deashing area

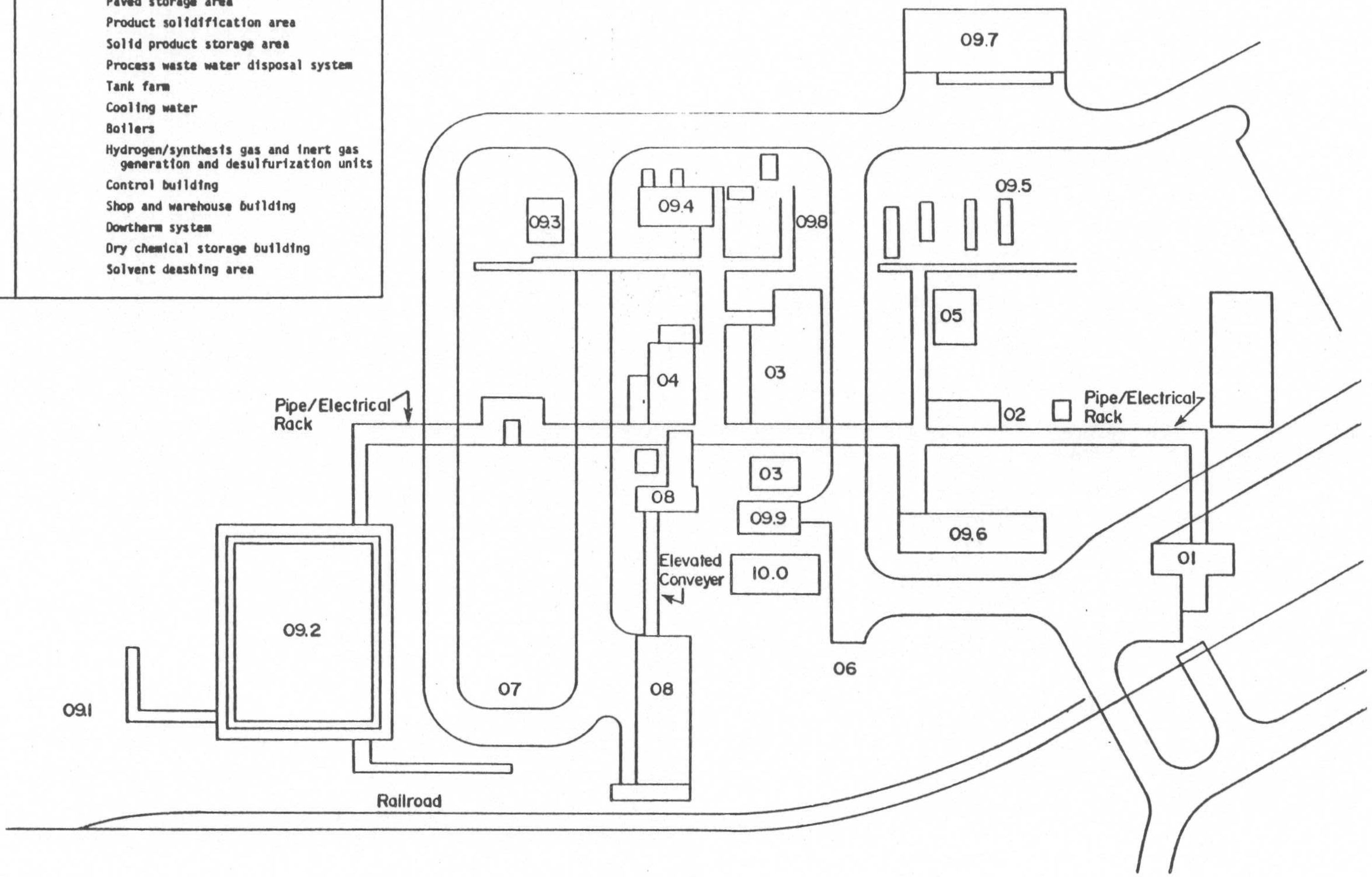


Figure 3. Layout of Solvent Refined Coal Pilot Plant
Fort Lewis, Washington

Table 1

POTENTIAL HAZARDS BY PROCESS AREA

Solvent Refined Coal Pilot Plant
Fort Lewis, Washington

Unit Operation	Hazard
Coal Preparation	Polynuclear aromatics (PNAs) Aromatic amines Benzene, toluene, and xylene Carbon monoxide Coal dust Noise Ionizing radiation Trace elements
Dissolver/Preheater	PNAs Aromatic amines Benzene, toluene, and xylene Carbon monoxide
Mineral Separation	PNAs Aromatic amines Benzene, toluene, and xylene
Solvent Recovery	PNAs Aromatic amines Benzene, toluene, and xylene Noise
Product Solidification	PNAs Aromatic amines Benzene, toluene, and xylene Particulates Noise
Environmental Units	Hydrogen sulfide Mercaptans Noise

B. Coal Preparation (01 Area)

(1) Process Description

The coal preparation area capacity is limited to about 6,000 lb/hr of coal feed by the drying and conveying capabilities of the pulverizer gas loop.

The coal preparation (01) area is shown in Figure 4. Coal may be brought into the SRC plant by rail or by truck. The coal is dropped into a hopper located at ground level. A vibrating feeder located at the bottom of the hopper transfers coal from the bin to a conveyor which carries the coal to a crusher. The crusher empties into a bucket elevator that conveys the coal to the top of either of two 300-ton crushed coal storage bins. Coal from the storage bins is then transferred into either the surge bin bucket elevator for conveying to the pulverizer surge bin, or into the reclaim bucket elevator for removal from the plant.

Coal flows from the surge bin into a Wallace & Tiernan gravimetric feeder, and then into the pulverizer. The pulverizer is designed to grind the coal to 100 percent minus 20 mesh, 70 percent minus 200 mesh. An attempt is being made to grind the coal to 100 percent minus 30 mesh but as of the date of our visit this attempt had not been successful. Hot, 93 C (200 F), inert gas dries the pulverized coal to approximately 1 to 2 percent free moisture, and conveys it to a baghouse. Moisture laden 66 C (150 F) recycle gas is discharged from the pulverized coal dust collector into a scrubber. Water scrubs the inert gas and dehumidifies it by cooling it. The scrubbed recycle gas is reheated in the pulverizer gas preheater and returned to the pulverizer. The inert recycle gas preheater is natural gas fired.

Pulverized coal is dropped from a small collection bin under the baghouse into a venturi-type nozzle. In the SRC-I configuration it is mixed in the venturi scrubber with fresh solvent and slurry recycling from the slurry blend tank. The venturi effect injects the coal from the weighbelt coal

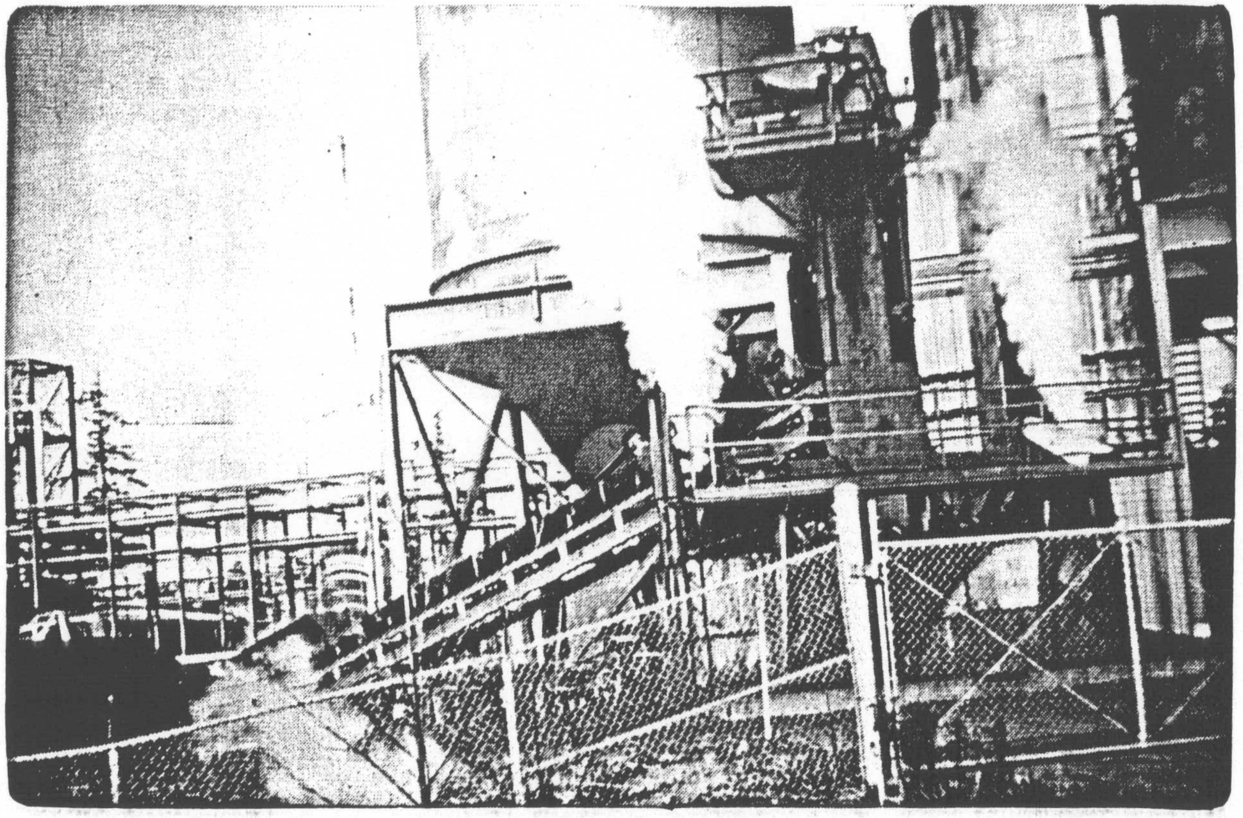


Figure 4. Coal Preparation (01 Area) Coal Loading Into Steam Heater

chute into the solvent and induces mixing without the formation of dust or scum. In the SRC-II mode the coal is fed to a small mix tank rather than the venturi to facilitate mixing at the high solids concentration.

The coal slurry blend tank operates continuously. Coal slurry from the venturi or mix tank is continuously fed into it and continuously removed by the preheater charge pump. The blend tank has a centrifugal pump which recycles the slurry through the venturi, and also feeds the Wilson-Snyder preheater charge pump. The recycle pump has two spares. The slurry mixing system normally operates at approximately atmospheric pressure and about 66 C (150 F) in the SRC-I mode. In the SRC-II mode the slurry mixing system operates at 177 to 232 C (350 to 450 F). The system is designed for 50 psig and 343 C (650 F) to accomodate both modes of operation. No maximum slurry solids concentration has been established. In SRC-I operations, the coal concentration has normally been abut 40 percent, but concentrations up to 45 percent have been handled successfully. The Wilson-Snyder reciprocating triplex preheater charge pump which is spared, feeds the preheater at 1500 to 2500 psig.

The slurry-preparation area as described above is shown schematically by Figure 5.

(2) Control Technology Assessment

Several fires have occurred in the coal storage bins when coal has been stored for several months at a time.

An inert gas generator produces carbon dioxide for use in purging the coal storage bins, and for use in conveying and drying pulverized coal. Because of deficiencies in the inert gas generator, carbon monoxide is present in the inert gas due to incomplete combustion.

Coal from the bins passes over the weigh feeder to a feed chute and is fed into the pulverizer via a rotary feeder. The inert gas used for pneumatic

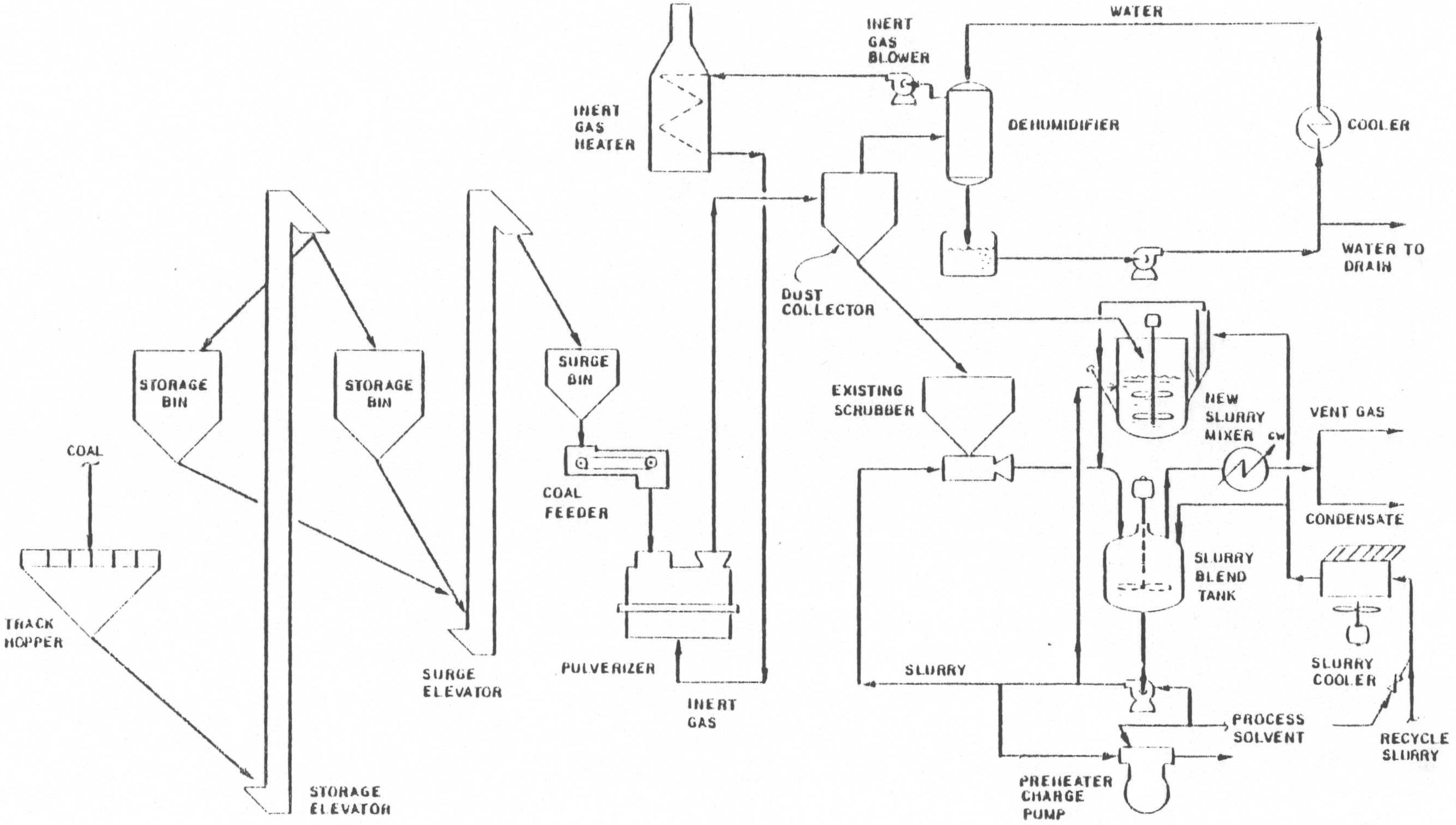


Figure 5. Area 01 Coal Receiving and Preparation Flow Scheme

conveying and drying of the pulverized coal leaks back through the rotary feeder into the work area near the weigh feeder. This presents a danger of asphyxiation from carbon monoxide and other inert gases in the work area.

The coal dust and inert gas that blow back through the rotary feeder can be minimized by providing the rotary valve with adjustable vane tips. This rotary valve was also a severe maintenance problem because the shaft packing was wearing out in minutes. To increase the service life, a heavy duty valve with purged packing should be used and the valve should have a hard chrome plated bore and plate. The Fort Lewis plant made these changes and reported longer valve life and greatly reduced emissions from the valve.

In order to prevent fires or explosions, the coal pulverizing and drying system was designed to limit the oxygen content of the pulverizer recycle gas to 0.5 percent. However SRC has been unable to maintain the oxygen content of the recycle gas at 0.5 percent or less due to deficiencies in the inert-gas equipment. Use of a pressurized pulverizing system and nitrogen as the recycle gas, planned for the SRC commercial plant design, should eliminate these problems.

Because the inert gas contains a large percentage of carbon dioxide and is wet, it can cause severe corrosion problems. The dehumidifier demister pad in the inert gas recycle stream has a tendency to become partially plugged with rust, which results in water carryover to the inert gas blower. Such carryover can cause excessive wear and pitting of the blower impeller, which in turn causes excessive vibration. Periodic checking of the demister pad and replacement when required has eliminated the problem. For the commercial plant careful selection of materials of construction (e.g., stainless steel and plastic) and the use of pure nitrogen as the inert gas will eliminate this problem.

The Wallace and Tiernan gravimetric feeder is the primary control for measuring coal addition rate to the Fort Lewis SRC pilot plant. To insure that it is accurate to within 1 percent, timed samples are taken on an hourly basis by diverting the entire flow into a sample holder and then weighing it. This procedure results in exposure to coal dust and vapors from the mixer located on the floor below. At the pilot plant, the problem can be reduced by enclosing the sampling system and/or providing a local exhaust system. The coal preparation and feed system used at the pilot facility will be replaced with more sophisticated commercially available equipment at the demonstration plant.

A capacitance-type level indicator has been suggested for use in the coal storage bins; however, this type instrument would work only until coated with dust and would require extensive maintenance with potentially high exposure to coal dust. Pressure differential type level instruments are used to control liquid levels. During operation solids in the vessel plug the lower tap rendering the instrument inoperable. Inert gas or nitrogen is used to purge the pressure differential level indicators. When inert gas is used at the pulverizer, an oxygen analyzer is also used to warn the operator of the level of oxygen in the recycling inert gas system. Although there are no plans to use a shutdown interlock system between the oxygen analyzer and the pulverizer at the pilot plant, such an interlock system should be included in the design at demonstration or commercial facilities. The pulverizer system at the pilot plant includes blow-out panels to direct any explosions away from the process area. The SRC plant has a shutdown interlock between the rotary feeder, the baghouse, and the pulverizer.

A capillary viscometer is used to measure the flow of material into the slurry blend tank. Stellite-coated valve internals have reduced erosion of the valve seating in the viscometer. Orifice plates are used to measure flow in some areas, however, erosion is a problem. The erosion problems may be reduced by using harder materials of construction, such as tungsten carbide. At the 01 area a purge venturi is being used to measure the slurry, but plugging of the purges causes problems. The use of purge fluids, liquid or gaseous, should be used to keep the lines clear of solids.

Mixing coal with solvent and/or slurry is difficult because of problems with wetting the coal fines. Partially wet coal dust agglomerates causing line pluggages.

The slurry mixing system used in the SRC-II mode consists of the pulverizer-dust collector which feeds coal through a rotary valve into the coal dust scrubber. From there, coal is educted by the slurry recycle stream flowing through a venturi and is fed to the slurry blend tank. Vapors from the slurry mix tank are controlled by directing them through a slurry mix tank vapor scrubber in which the scrubbing fluid is a slurry. Although agitator shafts are potential emissions sources, especially as the seals wear, there are no problems with the mix or blend tank agitator shafts. The lack of fume emissions may be attributed to the vacuum eductor system in use on these tanks. In addition, the flow of clean air past the seals may contribute to seal life. Equipment associated with coal preparation is located in a two-level pit. In a commercial plant, this area should be raised so that all equipment will be positioned above ground in order to avoid the collection of toxic gases in the area around the equipment.

There is some difficulty with plugging of the slurry pumps in this area. The pulverizer currently produces feed that is 98 percent through 16 mesh. SRC is attempting to grind to a minus 30 mesh, but to date this grind has not been attained. The smaller size coal particles will wet more readily, reducing the tendency of the particles to agglomerate and cause pluggages. Plugging also occurs when the slurry becomes too viscous. If viscosity could be measured continuously with a reliable instrument, the amount of plugging could be reduced along with the attendant worker exposure that occurs in cleaning the plugged line.

At present the plant has three slurry blend tank circulating pumps. The first is a Morris pump which operates at 1700 rpm and a temperature of 177 C (350 F); the other two are Durco pumps which have a single seal and are flushed continuously. One Durco pump operates at 1700 rpm and the other operates at 3500 rpm. The combined flush is maintained at 300-1000 lb/hr for the circulating and the charge pumps. The downstream pump is normally operated to avoid plugging the lines between the operating pump and those on standby. In order to extend the life of the pumps in the 01 section, the Fort Lewis plant has flame-sprayed tungsten carbide on the inside of the pump casing and on the impeller. Low-cobalt binder is used because it is harder, resists erosion better, and is resistant to ammonia which may be present in the process stream. See Figures 6, 7, 8, and 9 for examples of erosion problems experienced at the pumps.

The preheater charge pumps are plunger-type pressure pumps which use a stuffing box with a flush and a free-floating ball check. By nature of construction, a certain amount of potentially toxic vapors are emitted to the area. This creates a hydrocarbon emission problem in the pump shed which can be corrected by installing a localized ventilation system. Although ball check valves performed well in the discharge line of the high-pressure slurry pumps, most of the swing check valves, even those located in vertical lines, did not function in slurry service.

Although the pumps with Chesterton Seals work well, they cannot be used in hot service because they contain o-rings. This limits the use of these pumps to the water systems or any low-temperature system in the plant. Many pumps in the plant are run at 3600 rpm. It has been suggested that a lower rotating speed might reduce the erosion and wear around the pump shaft and impeller. This procedure was implemented at Sasol and reports indicate that this reduction in rotational speed reduced wear on pumps. The flowrate can be maintained at the lower rotational speed by increasing the diameter of the pump impeller. The SRC plant has a Lawrence pump on which the pump liner and stuffing box may be removed by removing pump bearing housing only. Plant personnel are able to change both the linings and the impeller without disturbing the alignment of the piping system around the pump, thereby reducing the time required for maintenance and reducing worker exposure. Another possibility for reducing some of the problems around the pumps is to raise the temperature of the flush to the

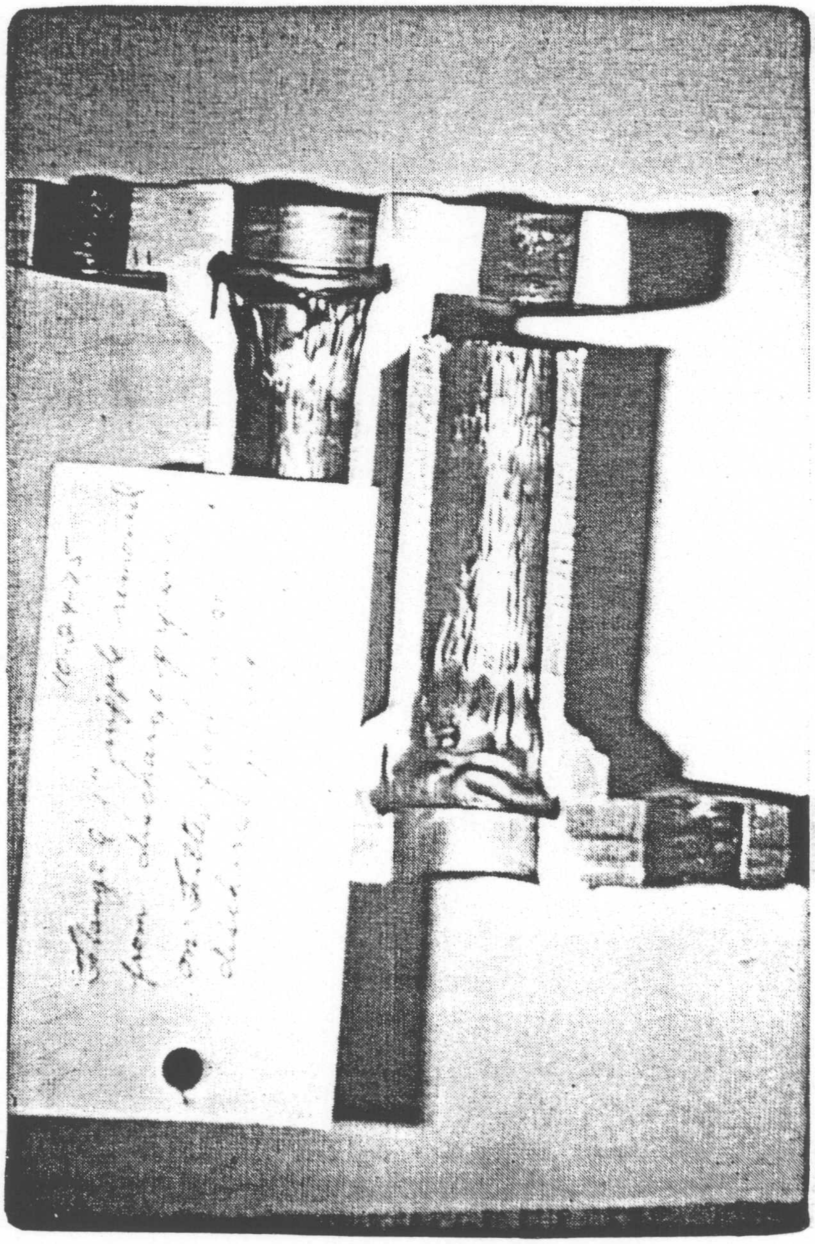


Figure 6. Flash Feed Pump Erosion

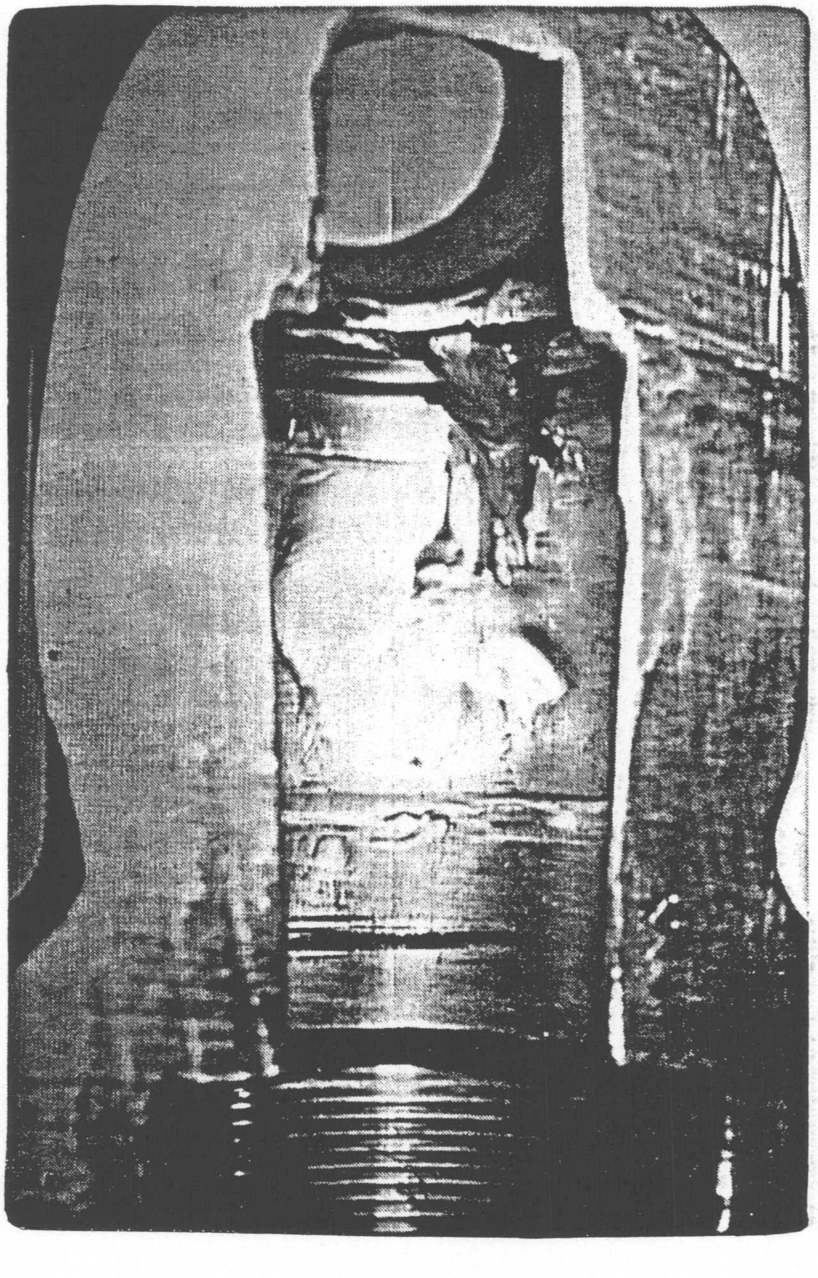


Figure 7. Pump Erosion

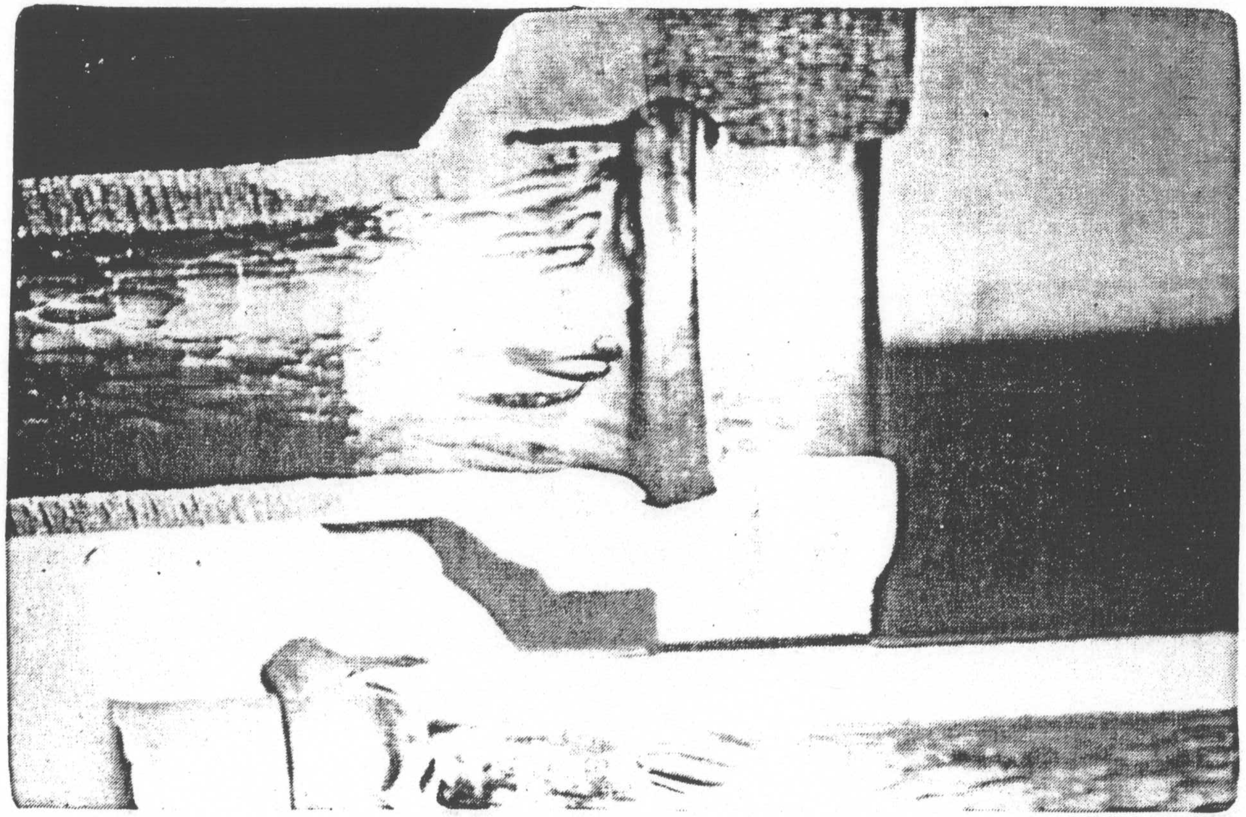


Figure 8. Pump Erosion

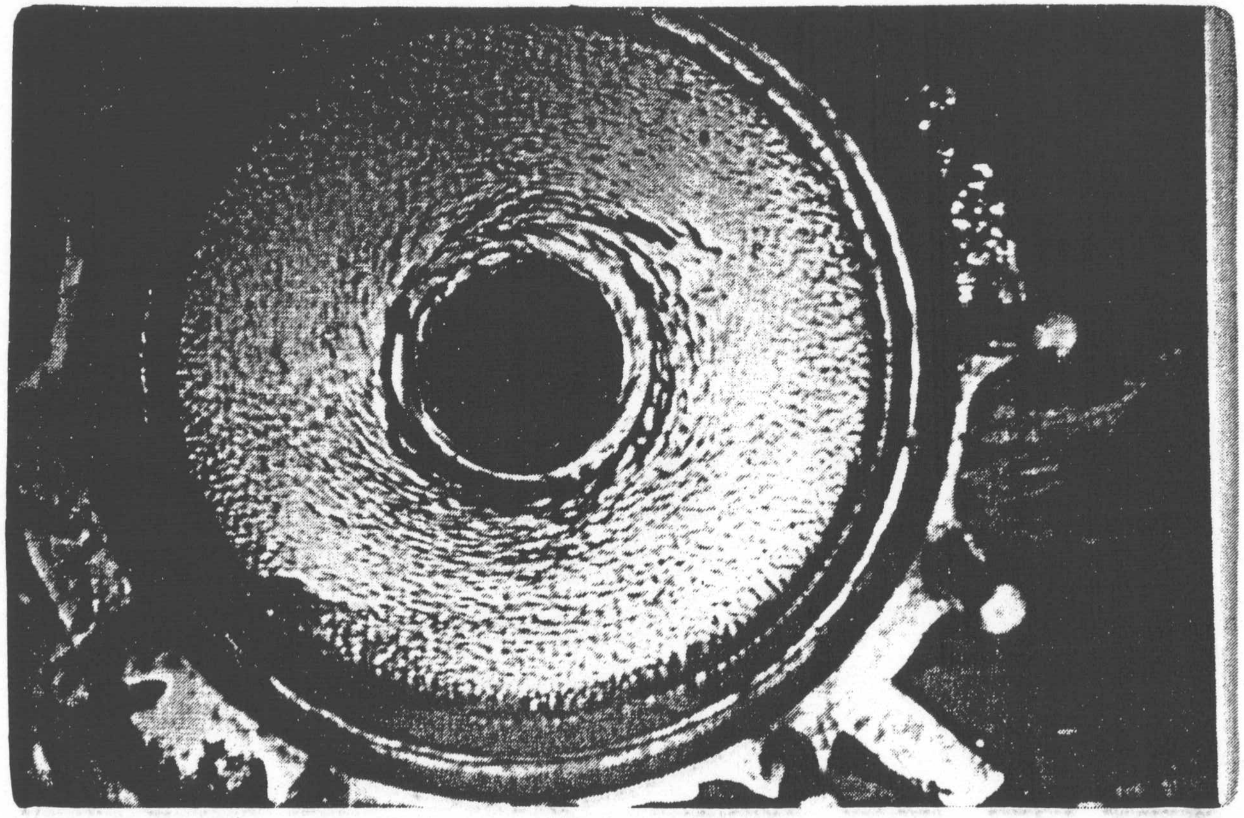


Figure 9. Filter Feed Discharge Erosion

seals to 120 C (250 F). Flush for the process lines should be operating at a higher temperature, probably 149 to 177 C (300 to 350 F). Adoption of these temperatures for the flushing liquids would reduce the precipitation of tars on the seals, impellers, etc., and thereby reduce the amount of wear. In order to reduce wear on the shafts of the various pumps, the SRC plant is using Mobiloid lubricating oils.

Many new pumps coming into the plant are flame sprayed with tungsten carbide without undercutting any metal from the pumps. When the pumps are eroded and require rebuilding, they are sent out to a contractor who flame sprays them with tungsten carbide and resurfaces them to proper clearances. Occasionally, when a new pump comes to the plant, wear rings are removed and the openings are filled to size by flame spraying with tungsten carbide. In some cases, depending upon the erosion problem, SRC personnel prefer stellite replacement parts rather than flame spraying. These procedures have resulted in longer intervals between repairs, thereby reducing worker exposure.

During repairs of a pump, seals are completely replaced. Pumps are not repaired in situ. The impeller and casing are inspected each time a pump is down for maintenance to determine whether or not it can continue in use. If not, the pump is thoroughly cleaned and sent out to a contractor for major rebuilding. On return, the pump is inspected; any flaws result in returning the pump to the contractor for rework.

In order to minimize problems with the various pumps in the plant, the pump mechanics are sent to "pump school" in order to learn the details concerning pumps that are being used in the areas for which they are responsible. As new pumps are brought in, the pump mechanics return to school for refresher courses.

A new disc-type pump from the Eureka Pump Company was demonstrated to the personnel at SRC. This pump is designed to pump slurries. The demonstrator used marbles to indicate the capability of the pump to move solids under high pressures. According to the salesman, the pump should be available shortly. Until the pump characteristics are known and tested in a pilot plant, there is some question about the use of this pump in a coal conversion plant.

Flanges are raised-face, ring-joint type with Flexitallic gaskets. To prevent leakage at this gasket, care must be used to avoid scoring the face during mantenance. The opinion of the plant personnel was that the Gray Tool Company flanges (Grayloc) are the best for use in the SRC service because they are the easiest to assemble and maintain. The mechanics must be properly trained to work on the Grayloc flanges when reassembling in order to avoid scoring at the flat flange surface.

In order to reduce damage to the 01 pumps, the plant has installed a pressure damper which consists of a bottle that is pressurized with hydrogen.

C. Slurry Preheat and Dissolving (02 Area)

(1) Process Description

Figures 10 and 11 are photographs of the slurry preheat and dissolving area. The coal slurry is transferred from the coal preparation area to the preheater by reciprocating pumps. Cold high-pressure gas, containing 50 to 90 moles/hr of hydrogen is added to the slurry feed which is fed to the preheater at a rate of 12,000 to 16,000 lb/hr for the SRC-I mode and 6,000 to 8,000 lb/hr for the SRC-II mode. The preheater is a vertical coil furnace with gas burners located at the bottom of the unit. The slurry is fed at the bottom of the preheater. Slurry exit temperature from the preheater is 400 to 427 C (750 to 800 F). Pressure drop across the preheater is typically 100 psig. Problems encountered with the preheater are minimal.

The preheater is adjacent to two dissolvers which can be operated in series. Each dissolver is 24 inches in inner diameter by 30 feet tall, and

Figure 10. Slurry Preheat and Dissolving (02) Area Preheater

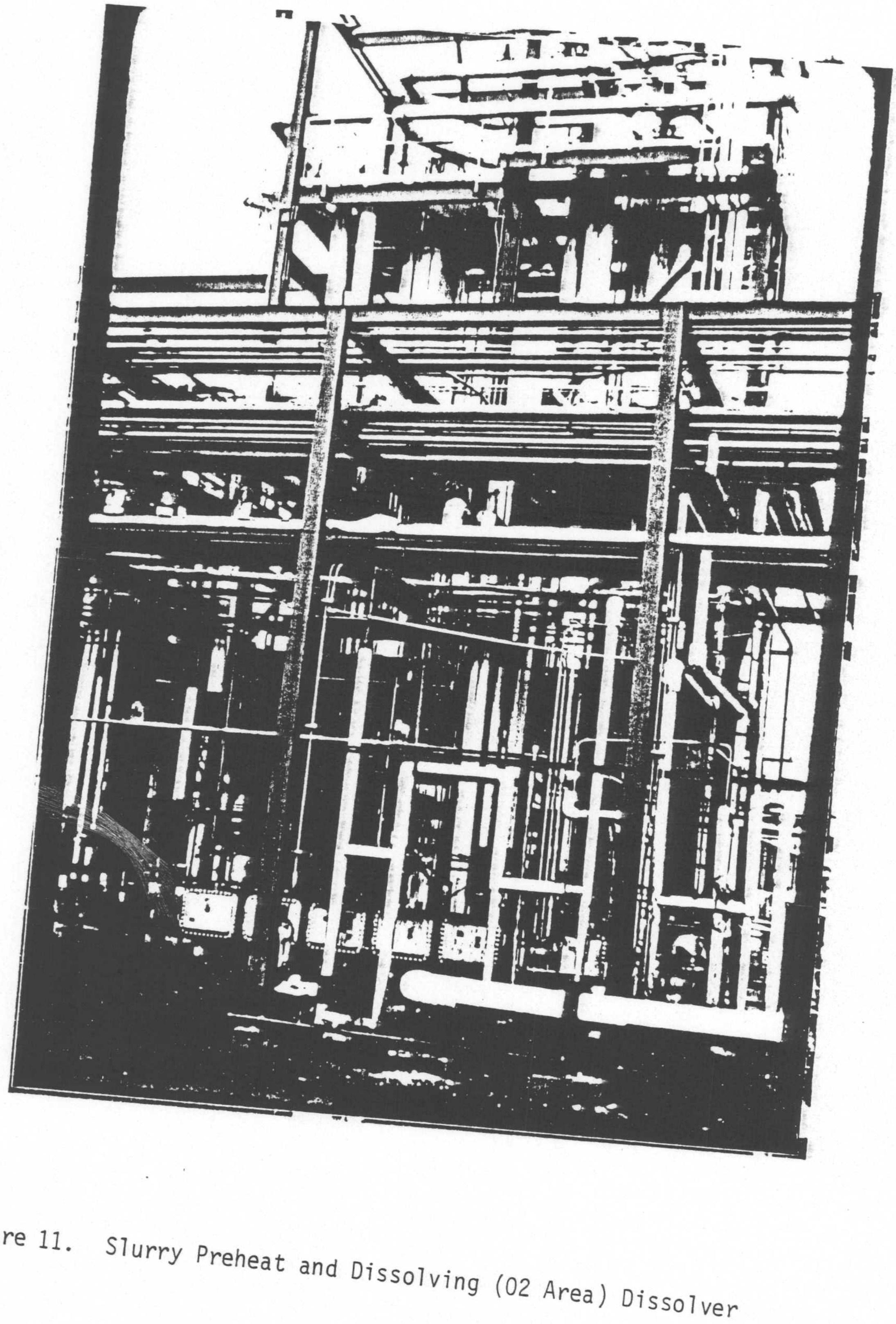


Figure 11. Slurry Preheat and Dissolving (02 Area) Dissolver

is designed for 2400 psig at 510 C (950 F). Dissolver flow is from bottom to top of dissolver No. 1, then bottom to top of dissolver No. 2. Normally only one dissolver is onstream at any given time. The dissolvers are designed for a residence time of approximately 30 minutes for SRC-I at a coal feed rate of 4,000 lb/hr and a solvent feed rate of 12,000 lb/hr. If desired, hydrogen can be added upstream of the first dissolver and between the first and second dissolvers. Cold hydrogen can also be added internally to the dissolvers for temperature control. The exothermic reaction can result in a temperature increase of about 28 C (50 F). Typical dissolver operating conditions in the SRC-I mode are 455 C (851 F) and 1500 psig. For the SRC-II mode the temperature is 460 C (860 F), the pressure is 1900 to 2000 psig, the residence time is approximatey 1 hour, and the coal feed rate is 2,000 lb/hr with a solvent feed rate of 6,000 lb/hr. With the exception of valves, and fans on the air coolers, the preheater, the dissolvers, and the downstream letdown systems have no rotating or moving equipment.

From the dissolver, the product moves to a high-pressure flash drum. At the high-pressure flash drum, gas and light hydrocarbons are flashed from the liquid and taken overhead, while the remaining slurry is taken off the bottom of the flash drum at approximately 288 C (550 F). The overhead gas passes through an air-cooled heat exchanger and a water-cooled condenser into a recycle condensate separator. The 38 C (100 F) gas is sent to gas recycle (05 Area), while the condensate is sent to the #3 water separator.

In the SRC-II mode of operation the slurry taken off the bottom of the high pressure flash drum flows through a letdown valve into the intermediate pressure flash drum. At the intermediate pressure flash drum hydrocarbons flashed from the liquid are taken overhead, while a slurry stream is taken off the bottom of the drum. The overhead vapors are condensed and collected in the #3 water separator. The bottoms slurry stream is fed to the slurry recycle stripper. The condensed hydrocarbons from the #3 water separator are normally pumped through a heater that raises the temperature of the oil to 500-500°F, and into the slurry recycle stripper. This oil is added to control the solids content of the stripper bottoms which is recycled to Area 01 for slurry mixing. If the solids content of the stripper bottoms does not require adjusting, this oil is pumped to the wash solvent accumulator.

The slurry recycle stripper operates at about 100-150 psig and has no reboiler. The major source of heat for the column is the hot feed from the intermediate pressure flash drum. Inert gas is introduced into the stripper to stir the stripper bottoms and strip out the water and light oil. The slurry bottoms from the stripper is split into two streams. One stream goes to the 01 Area where it is used for slurrying the coal. The second stream flows to the 04 Area vacuum flash drum.

A side draw from the stripper is collected in an accumulator drum. The side draw flows by pressure from the accumulator through a cooler into the suction of a gear pump. This pump distributes the side draw to the 01 Area pumps where it is used as seal flush fluid.

The overhead from the stripper is condensed, collected, and recycled to the stripper as reflux.

Water collected in the #3 water separator and in the stripper reflux drum flows by pressure to the recycle process water tank. Water from this tank is normally sent to the wastewater treatment area; however, in the event of a process upset it can be used as quench water to control temperature excursions in the dissolver.

In the SRC-I mode of operation the bottoms from the slurry recycle stripper is also split into two streams. As in the SRC-II mode, one stream is recycled to the 01 Area where it is used for slurrying the coal. However, the second stream flows to either the filter feed flash tank or the filter feed surge tank in the 03 Area. Except for this difference, and the fact that generally throughput is higher and pressure is lower, the operation of the 02 Area is identical in either the SRC-I or SRC-II mode.

(2) Control Technology Assessment

Figure 12 is a simplified flow sheet of the slurry Preheating and Dissolving area. The preheating and dissolving section of the SRC pilot plant has operated very reliably in comparison to other plant areas. This reliability resulted from conscientious attention to details during the design phase, use of correct construction materials and the company's experience in designing equipment for use in similar company operations. This section has forced a general plant shutdown only three times during the entire operating period.

The slurry preheater has a backflow preventer valve at the entry which actuates the shutoff valve to prevent material from flowing back through the pumps into the slurry blend tank located in the 02 Area. This backflow-preventer valve is automatic and goes into operation when the temperature on the twentieth coil reaches 288 C (550 F).

In addition, there are two backflow check valves in the hydrogen line to the slurry. The first one is soft-seated and goes into operation in the event of backflow in the system. If the soft-seated valve does not close properly, the second valve goes into operation automatically; it is hard-seated and can shut off the slurry system.

A diaphragm seal is placed between the instrument and the process stream in order to reduce blockage of pressure gauges. This diaphragm combined with cushioning gas should further reduce the blockage problems.

Control valves are Fisher globe angle valves. These valves are installed in a "backwards" mode to avoid the impingement of slurry on the packing and on the seals. This installation has reduced the maintenance and replacement rate of these control valves. The controls on the globe valves are a stem type, which have been hardened to reduce erosion. This stem has been shortened to reduce breakage, but this has reduced the control capabilities of the valve. At the Wilsonville SRC plant, a fluted-type

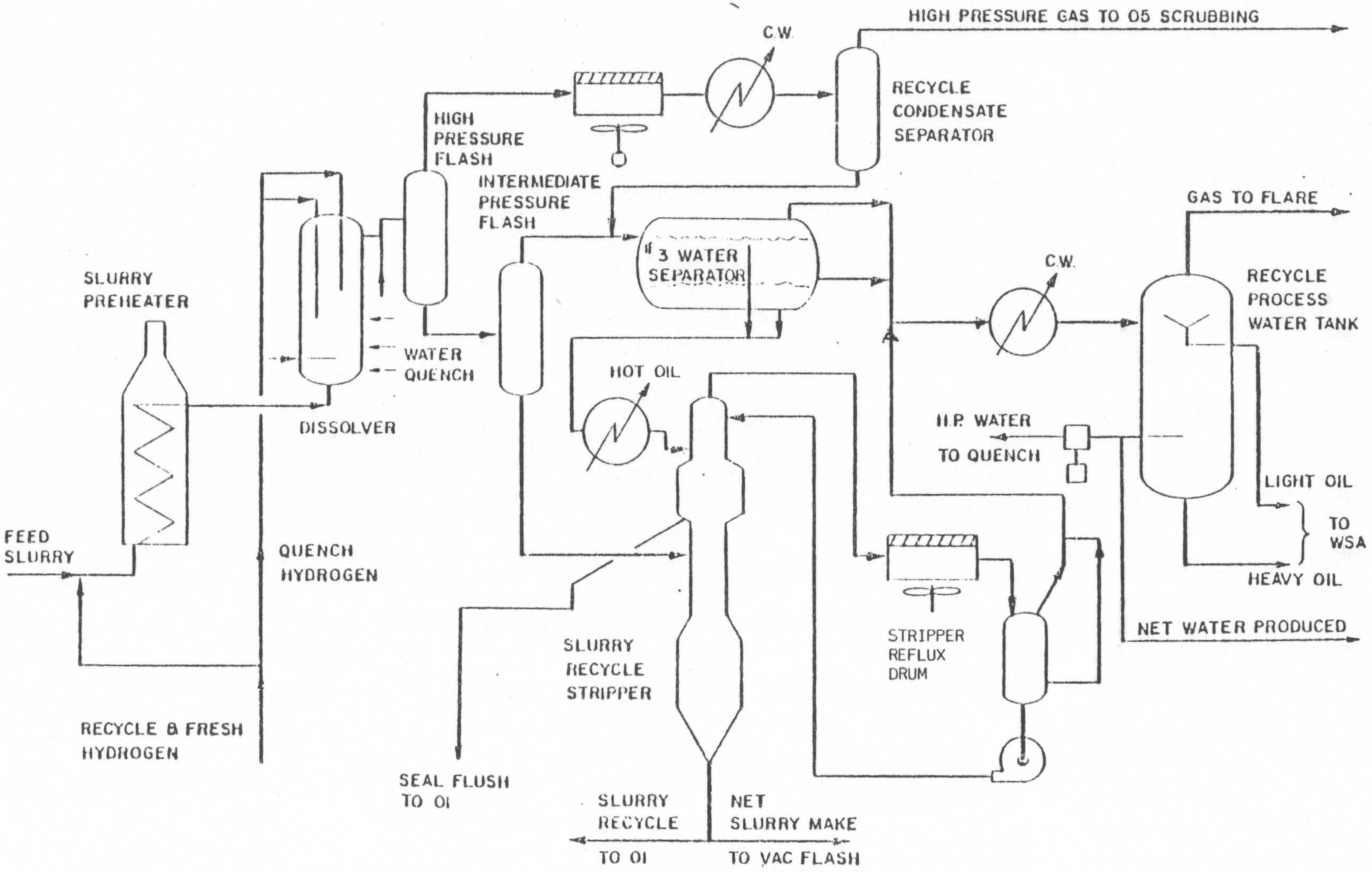


Figure 12. SRC-II Simplified Flow Sheet of the 02 Area Preheating, Dissolving, and Water-Oil Separation

control valve is being used with satisfactory results. In a demonstration or commercial plant, large diameter globe valves will require larger diameter stems. As a result, there should be less stem breakage.

A series of velocity, heat flux, and corrosion studies are being run in order to design a new slurry preheater which will have a pipe diameter that is smaller than the present unit. With the smaller pipe diameter the velocity of the slurry through the line will be higher with higher heat transfer rate.

The Willis valve, which handles a differential pressure from 2000 psig down to 900 psig, is used to control the flow of slurry from the high pressure flash tank to the intermediate pressure flash tank. If the Willis valve must be removed from service, the plant can switch over to a Fisher model DBAQ globe type letdown valve. A procedure has been developed for testing the integrity of the block valve so that the Willis control valve can be maintenanced while the plant is still operating. This Willis valve is designed so that there is a wiping action between the two plates that control the flow through the valve. These plates are optical finish flat with orifices that operate on a counter-rotation system to control the flow. Because of the close fit, there is little or no opportunity for the slurry to damage the faces of this type control valve.

However, the Willis valve operation is dependent upon the opening of orifices which are located in the sliding sections of the valve. Because of the hardness of coal, these orifices wear quite rapidly. Two additional valves which are being considered for use as control valves are: (1) a microfluted trim valve and (2) a solid tungsten carbide control valve which uses a special grade of carbide with a binder as low as 1.5 percent. No final decision has been made on either valve. Examples of valve stem and valve body erosion are shown in Figures 13 and 14.

Letdown valves, which have to be replaced periodically mainly because of erosion, also have a potential for cavitation which would further deteri-

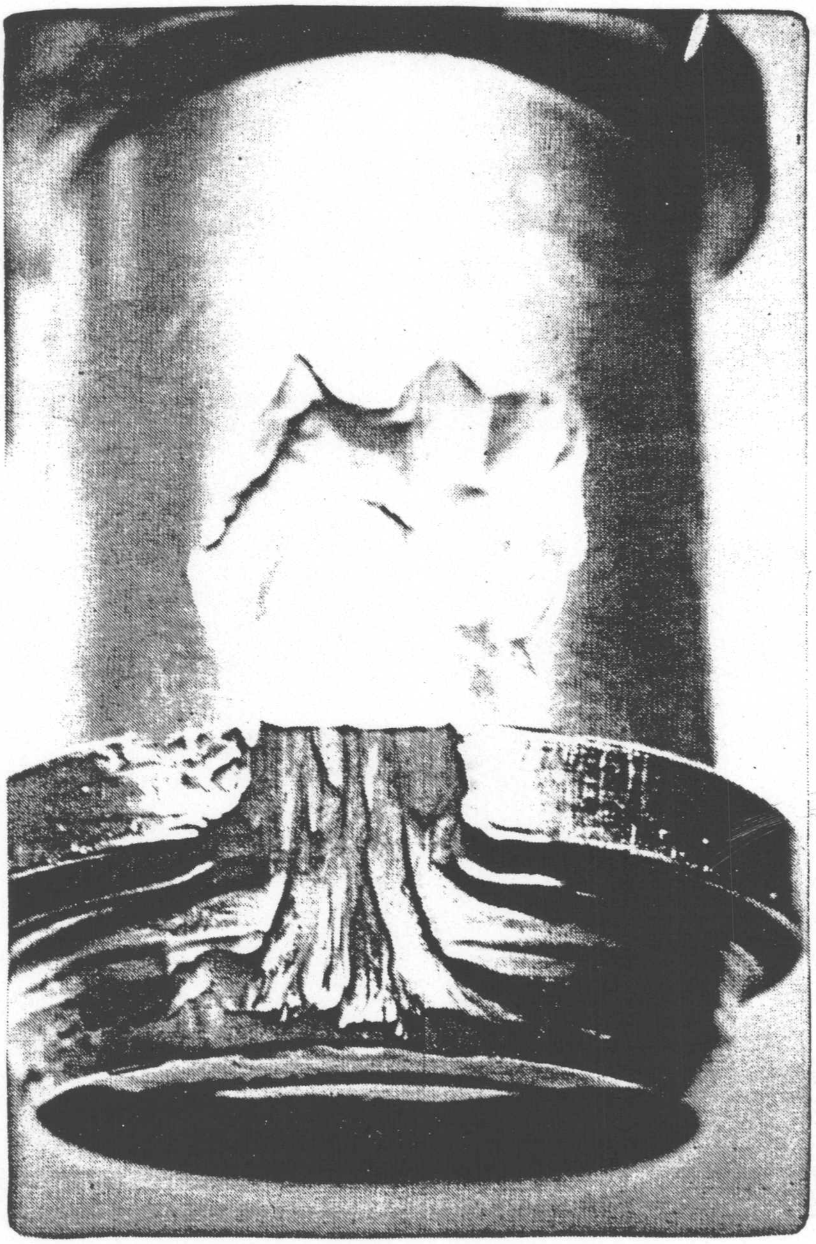


Figure 13. Valve Stem Erosion

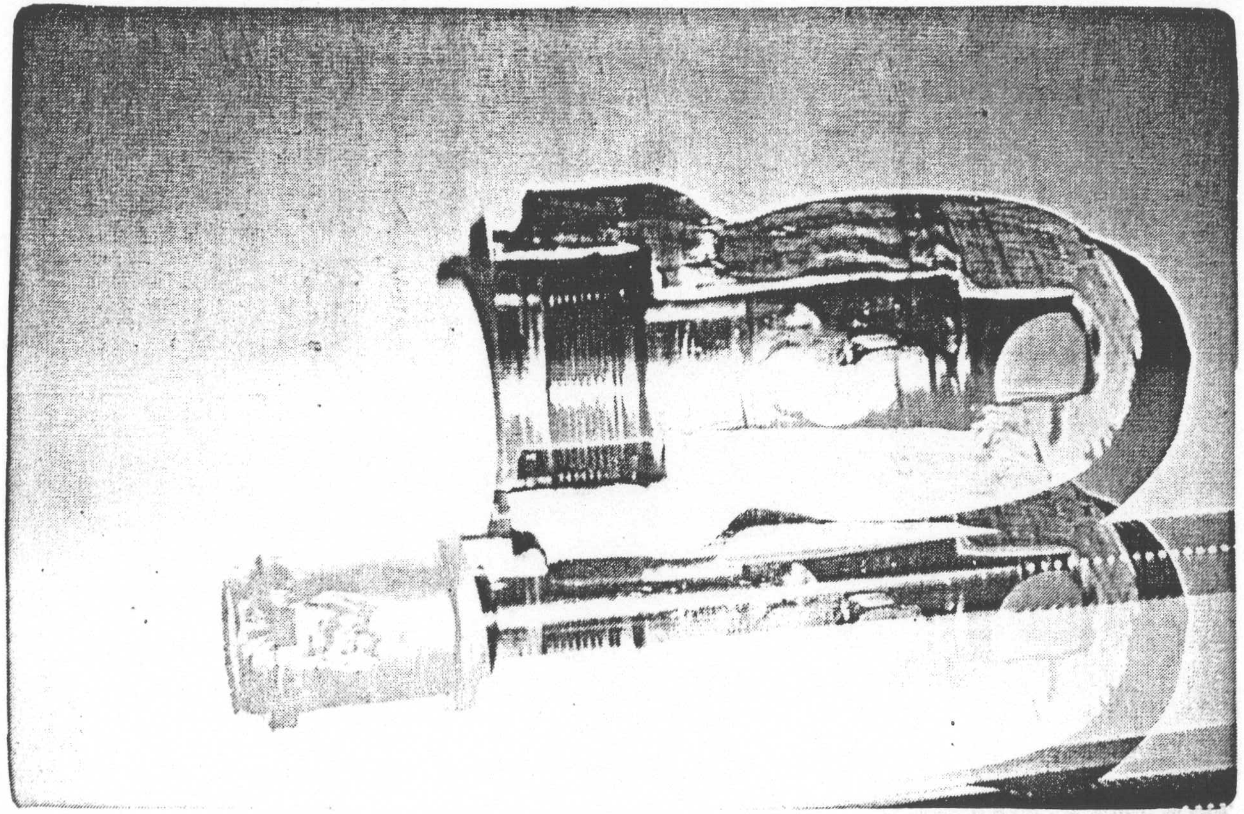


Figure 14. Hole Through Valve Body Caused by Seat Erosion

orate the valve. However, there has been no evidence of cavitation at the SRC plant.

The SRC plant is designed with two dissolvers. Most of the operation is through dissolver A, with dissolver B on standby. Takeoff lines for dissolver A are located at the top of the dissolver and approximately midway in the dissolver. With this configuration, the pressure differential at the dissolver is measured with a purge line that frequently plugs thereby reducing the reliability of control of the purge and resulting in erratic pressure drop indication.

The use of single pass multi-tube air exchangers for slurry cooling was unsuccessful at the Fort Lewis pilot plant. The slurry containing gas, liquids and solids apparently separates in the feed plenum so that the lower tubes contain more solids. The velocities through the lower tubes are not sufficient to suspend the slurry which settles and hardens, causing plugs. In the tubes with plugs the flow of hot material stops causing these tubes to cool, thereby setting up severe non-uniform thermal stresses which cause the plugged tubes to shrink and buckle and in some cases pull from the tube sheet. The air cooler was replaced with a water quench, which is working well. A concentric pipe-within-a-pipe construction is being considered for use as a single line cooler, but at the time of this assessment had not been included in the operation.

The valve PCV-216, which was a globe valve, was not designed to permit the passage of ash. PCV-216 was used as a control valve on the vacuum flash drum inlet. However, analysis of the materials that have been handled at this valve indicate a high-ash slurry, with high erosion rates (4 days wear out time per body). It was replaced by PCV-216A, an angle valve in "backward" configuration. As a result, wear has been very slow even during high ash operation. Trim life is still limited to approximately 90 days. Larger valves with the same design used commercially could be expected to have a longer trim life.

The successful modifications for control valves have been: the use of angle valves; the use of downward flow along the axis of the plug through the orifice; and the use of tungsten carbide tubes (chokes) beyond the orifice to conduct the high-speed stream beyond the valve body into an enlarged pipe as a deceleration chamber.

D. Mineral Separation (03 Area)

The mineral separation section is not used in the SRC-II process except to provide surge capacity between the dissolver and the solvent recovery areas. Because solids separation is an important process step for the production of SRC-I material, it will be discussed as a part of this report.

(1) Process Description

The mineral separation section is in a three-story structure with an entirely enclosed third story (see Figure 15). The two Goslin-Birmingham filters and the new Johns-Manville filter are located on the third floor. The rotary-drum calcining kiln is located on the second floor. Some tanks are located within this building and some are located outside adjacent to it. All centrifugal pumps for the mineral separation area are located on the bottom, or ground, floor.

Slurry from the high-pressure flash tank is sent to the filter-feed surge vessel, which is a stirred vessel with centrifugal pump recycle. The surge vessel is designed for 175 psig at 343 C (650 F).

Under normal operation, slurry from the filter-feed flash vessel or from the filter-feed surge vessel is pumped to the Goslin-Birmingham filters. If the filtration rate is not sufficiently high, the filter feed overflows. Overflow is returned to the filter-feed flash vessel. This procedure prevents cooling of the slurry as well as settling and consequent blinding of the filter screen.

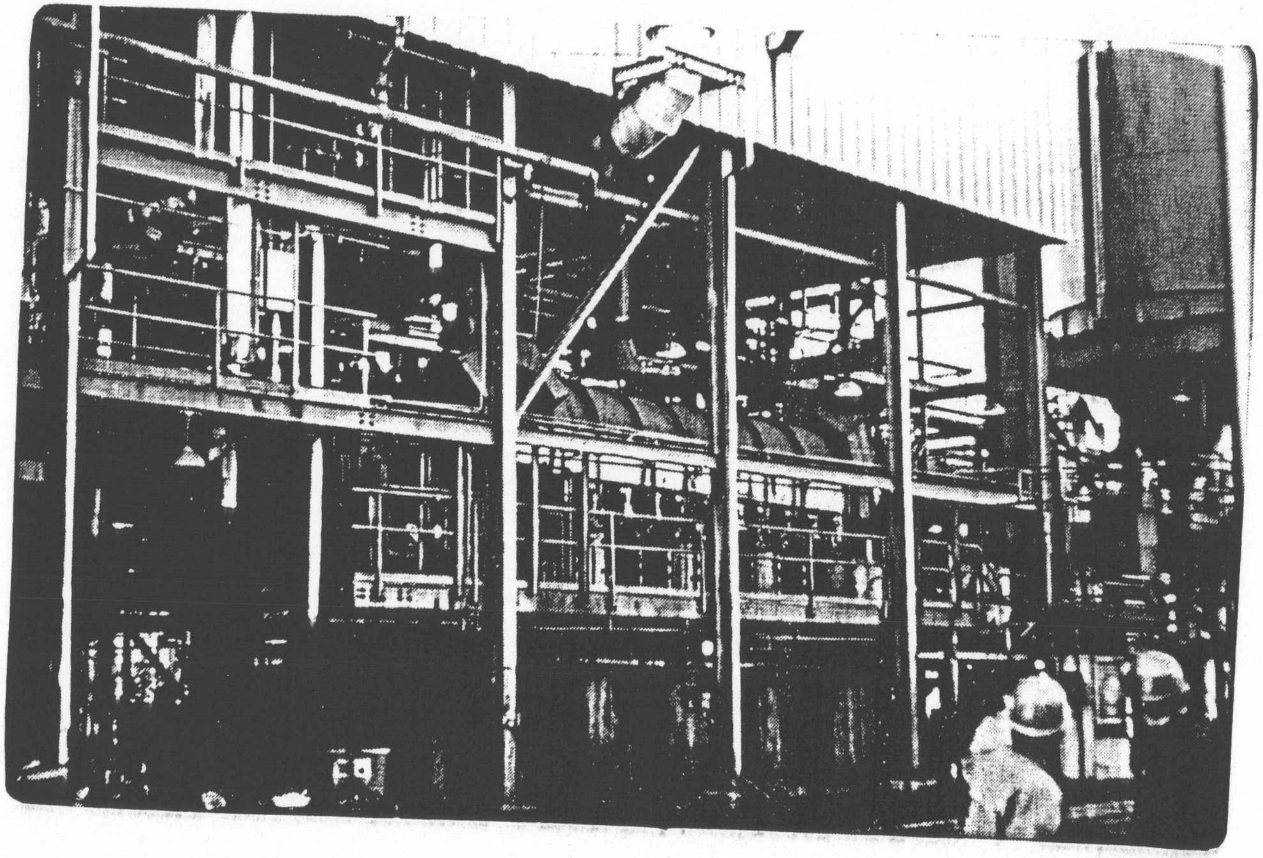


Figure 15. Mineral Separation Section (Area 03) Showing Rotary Kiln

The Goslin-Birmingham filters are rotary-drum precoat filters with the filter cake on the outside of the drum. One drum has 80 square feet of surface, while the second drum has 40 square feet. Each rotary filter is completely enclosed. Entry into the drum can be accomplished only by depressurizing and cooling the filter and removing the entire head. Normal operating conditions for the filters are about 316 C (600 F) and 150 psig with approximately 20-45 psi pressure drop across the filter cake.

Three operations are performed during the filter cycle. During the filtration portion of the filter cycle most of the dissolved coal is filtered from the undissolved coal and mineral residue. Filtration is followed by a solvent wash to remove the dissolved coal from the filter cake. The filter cake is then removed with a knife, and sluiced to an 8-inch pipe hopper. Filter cake is removed continuously from the pipe hopper with a gear pump and a 2.5-inch Rockwell valve. The pump and valve allow filter cake to be removed with depressurizing the filter.

Filtrate (dissolved coal and wash solvent) goes to the filtrate receiver and is then pumped to the vacuum flash preheater, which is located in the solvent recovery area. The filtrate contains approximately 0.1 percent ash.

Under normal conditions, the filter cake goes into the rotary kiln calcining drum where it is heated sufficiently to drive off any solvent in the residue. The solvent is condensed and recovered in the solvent recovery section. The mineral residue is cooled and stored in a bin until it can be trucked from the plant.

The filter is pressurized with inert gas. The inert gas supply and recycle system for the filter was not studied during this visit.

(2) Control Technology Assessment

During SRC-I production, the Goslin-Birmingham filters are operated at 150 psig and approximately 260 C (500 F). The Johns-Manville filter is operated at 150 psig and approximately 316 C (600 F). At the time of the site visit the plant was in the SRC-II mode and the filters were not in operation.

The bearings on the Goslin-Birmingham filters (A & B units) are internal, and it is difficult to keep them properly lubricated. On the Johns-Manville (C unit) filter the bearings are external and easier to reach, but it is still difficult to maintain proper lubrication. Another difficulty at each of the filters was that the pre-coat occasionally dropped off and caused the agitator to bind. As a result, uneven layers of material were deposited on the filters. In addition, there were leaks into the filter through the screens, which required that the screen covers be removed and the entire screen replaced. Some of the bypass leaks were eliminated by soldering or brazing the screens to the drums rather than bolting them on. All these problems lead to a high level of maintenance and worker exposure. For example, during the production of the 3000 ton SRC-I test material, the head of the "A" filter had to be removed thirty-three times and the head of the "B" filter was opened twenty-three times.

Another problem at the filters was leakage which occurred around the sight glasses because of difficulty in maintaining integrity at these pressures and temperatures. On one occasion, a sight glass blew out. The use of quartz sight glass was suggested, but they are brittle and the suggestion was not used. Another suggested solution was the use of a closed circuit television, although it would still be necessary to clean the optics, which would be a very difficult problem.

A high volume of feed slurry is circulated through the filter and back to the filter feed surge vessel in an attempt to reduce sludge buildup. This procedure decreases the buildup but does not eliminate it.

Process derived oil will ignite spontaneously if it soaks into calcium silicate insulation. This is because calcium silicate acts like a wick for the process derived oil, and catalytically promotes its oxidation. In order to eliminate this fire hazard, the insulation on the filter feed surge vessel was replaced with a non-absorbant inert insulation called Foamglas (PPG Industries).

Asbestos plus diatomaceous earth was successfully used as a precoat for the filters, but because of the danger of asbestos to the workers, diatomaceous earth alone is now used as the precoat material. This diatomaceous earth lasts from 12 to 60 hours before replacement is necessary. The mixing of the diatomaceous earth should be automated in order to reduce worker exposure to the high silica content of this material.

The residue from the filters after drying is pyrophoric, and if a fire occurs large volumes of sulfur dioxide are released.

One difficulty in the SRC plant is the plugging of lines. In an effort to prevent lines from plugging, each line is flushed before it is taken out of service. For the SRC-I process, process solvent is used as the flush. In the SRC-II process, heavy solvent is used as the line-flush material.

If pluggages occur, they can often be removed without having to break into the line. Most of the material that causes plugging in the lines is a meltable material; high-pressure steam in many cases will successfully remove it from the pipelines. A second method is to pump solvent at high pressure into the line to break through the pluggage.

In order to reduce the chances of complete shutdown because of plugging, the plant will occasionally use a temporary bypass consisting of a corrugated stainless steel line which can be used during the repair of a plugged line (up to 1 inch in diameter). During this temporary operational period, the plant must reduce pressure and, because of the difference in size of the pipes, reduce the total capacity of the plant. More plugs will occur in the SRC pilot plant than in a normal commercial plant primarily because of the small pipe sizes which are used to transport the various products during the processing of coal. Greater worker exposure may result because of the additional maintenance required.

One of the great difficulties for the plant is that the tacky, semi-solid process material may interfere with the operation of the safety valves, i.e., they will be blocked off and not function when needed. To minimize this possibility, a hydrogen gas cushion is used under the safety valves. On the new Lummus unit, a nitrogen purge under the safety valve is being used. In most situations, the preferred cushion material is flush solvent, which is used as much as possible. The use of rupture discs beneath the safety valves has been considered, but to date no such installation has been made.

The rotary dryer has not been used because of difficulty in maintaining the integrity between the dryer and the letdown valves into the dryer. In addition, manual control must be used to optimize output, causing difficulty with feed rate changes, and flow of gases from the unit.

A Lummus antisolvent unit is being installed to take the place of the filters. With the use of the Lummus unit, up to 20 percent of the SRC product will be discharged with the bottoms, which contain the ash. In a commercial plant, these bottoms could be pumped into a gasifier and used for the generation of hydrogen, thus eliminating the problems associated with the filters and pre-coat materials. The maintenance requirements for the antisolvent unit should be much lower than for the filters, thereby reducing worker exposure to coal liquefaction products.

An instrument to determine the density of a stream by absorbtion of radiation has been used at the filters in the 03 Area. This device was never successful because of difficulties with the filter equipment and in determining the density of the material at the filter. Additional work with this instrument may result in a successful calibration of the unit, which could be used in a number of locations. Fewer line pluggages will occur if the plant is able to adjust and maintain the proper slurry density in various process lines and equipment. This should result in less maintenance and lower worker exposure.

The use of strain gauges to indirectly control density, although not precise, should be investigated. There was one strain gauge in the plant. However, the tank to which it was attached was securely fastened, so that the strain gauge could not function properly. The successful use of the strain gauge would be an indirect way of measuring density.

If density could be successfully controlled, process upsets and maintenance would be reduced, resulting in less worker exposure. A double seal was used with a middle distillate for seal flush. This did not work and the system was returned to single-seal units. In the 03 area the differential pressure across the seals is 60 psi, but there is no problem in the solvent-recovery area except as noted above with pumps and the corrosion at the vacuum-flash tanks.

E. Solvent Recovery (04 Area)

(1) Process Description

The solvent recovery section is adjacent to the mineral separation section and consists of seven levels. All rotating and moving equipment in this section are located on the ground floor; reflux drums and air coolers are located on the top levels; and feed points are located on the middle levels. Most valving in this section is located on the first and second levels.

The solvent plus dissolved coal from the filtrate receiver is pumped to the vacuum flash feed accumulator drum and from there it is pumped to the vacuum flash preheater, where the material is heated to approximately 316 C (600 F). It is then flashed across valve PCV-216 into the vacuum flash drum. Normal operating pressure of the vacuum flash drum is 4 psig at 316 C (600 F). Product from the vacuum flash drum is pumped with a gear pump either back to the vacuum flash preheater, to the prilling tower, or to the Sandvik belt. The vapor from the vacuum flash drum is cooled with an air-cooler, then sent to the light-ends removal column which is designed to operate at 40 psig and 343 C (650 F). The overhead light oil is separated from the water, and the light oil is sent to the light oil product storage tank. Water is processed for discharge. Bottoms from the light-ends removal column are treated in the wash solvent fractionator.

Overhead from the wash solvent fractionator is condensed and collected in the wash solvent accumulator and recycled back to the mineral separation section. Bottoms from the fractionator are pumped to the process solvent accumulator and then are either pumped back to the slurry preparation section or sent to the tank farm.

(2) Control Technology Assessment

The problems in this section include coking, Dowtherm leaks, electric tracing problems, inability to control leaks, erosion and corrosion.

Figure 16 is a schematic of the solvent recovery area as originally designed. Operation in this mode provided good separation into specification cuts of SRC, process solvent, wash solvent and light oil. However, coking of the vacuum flash preheater coil occurred frequently resulting in maintenance worker exposure. In December 1975, the solvent recovery area was modified as shown in Figure 17. While this mode of operation eliminated much of the coking problem in the vacuum flash preheater, reducing worker exposure, it was not possible to produce light oil and wash solvent in the desired boiling point ranges.

The changes included:

- Removal of the light oil and wash solvent with an atmospheric preflash tower.

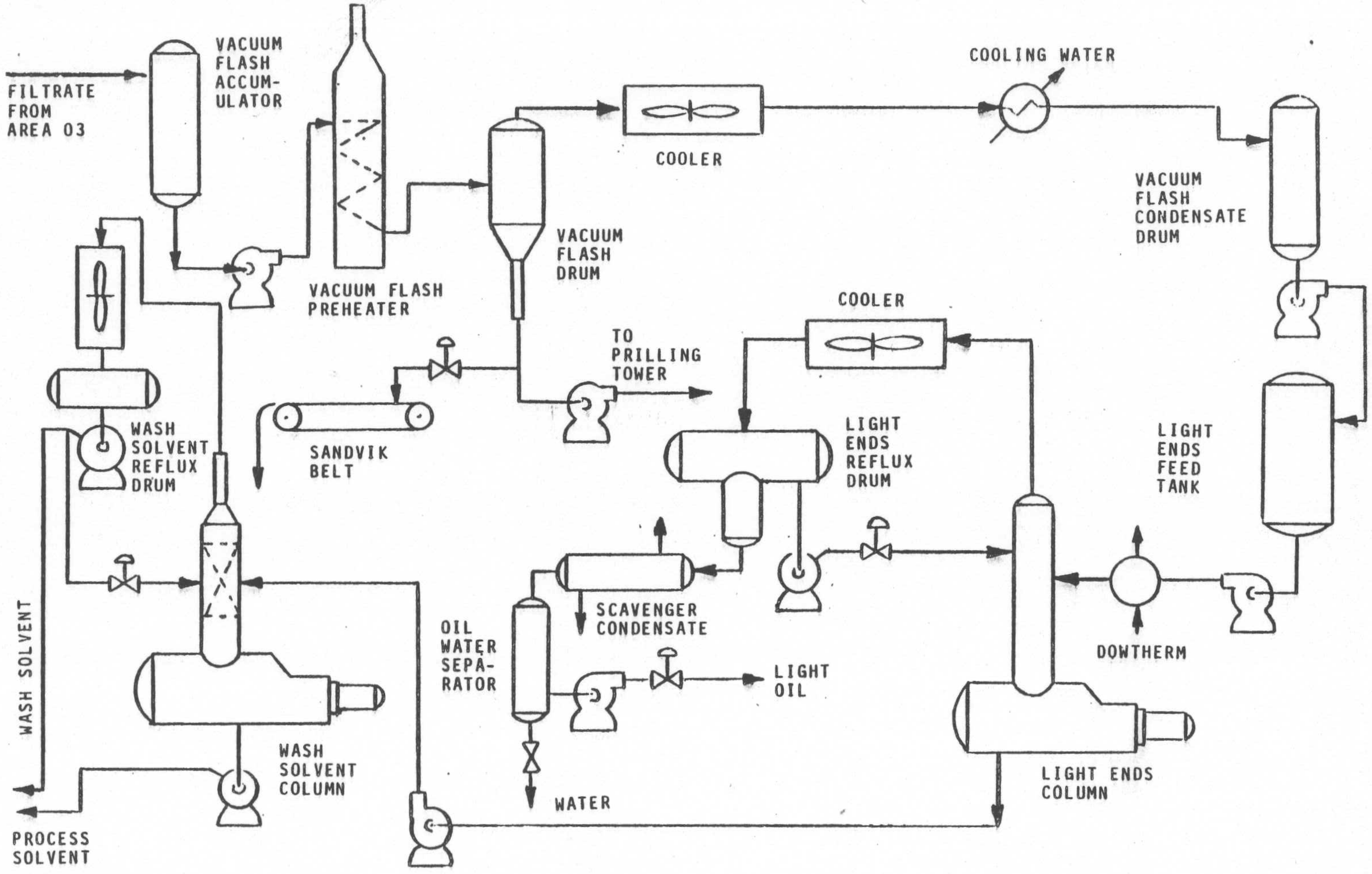


Figure 16. Area 04 Solvent Recovery Flow Scheme

- Installation of a recirculation system to move the vacuum flash drum bottom back to the inlet of the vacuum flash preheater coil.

The results of the changes were a decrease in vapor pressure of material flowing through the coil; a reduced outlet temperature of the coil, and increased back pressure on the coil to minimize two phase flow.

Flow problems through valves were reduced by installing angle valves in parallel, and by installing special tungsten carbide valve seats with an integral extension nozzle in each pressure control valve.

Corrosion problems have been quite severe in the solvent recovery area. The bottom of the light-ends columns, and the top of the wash-solvent columns, show more corrosion than the rest of the units. The corrosion is associated with the presence of chlorides. The main replacement metal for the corroded parts is stainless 316 and the use of this alloy has resulted in vastly improved operating life. There are some data indicating that stainless 316L may be superior to stainless 316. Also being considered as a replacement metal for equipment in this area are the various Hastelloys® and Incoloys®.

Coking is a problem because of the heat sensitivity of coal derived liquids. Equipment must be designed to avoid coking by maintaining turbulent flow, by avoiding localized overheating, and by avoiding dead spots where solids can collect.

At the oil-water separators, the primary health/environmental considerations relate to the high concentrations of hydrogen sulfide in the process streams. Considerations for new facilities should address pump seal and packing selections, clean-up and disposal of leaks, spills, and blowdowns, and adequate ventilation.

F. Product Solidification (08 Area)

(1) Process Description

SRC-I product solidification consists of two separate areas: the prilling tower, which has never been used, and the Sandvik belt. Product underflow from the vacuum flash drum is sprayed onto the water-cooled steel Sandvik belt where is solidifies into a glassy friable solid approximately 1/4- to 3/8-inch thick. The Sandvik belt carries this material to a series of conveyors which deliver it to product storage bins for bagging or loadout to trucks or railroad cars.

In the SRC-II mode of operation, the vacuum flash drum bottoms stream, which contains high boiling hydrocarbons and mineral residue from the coal, is sent to the Sandvik belt for solidification. After solidification the material is trucked to a disposal site. In a commercial plant the vacuum bottoms would be pumped to a gasifier for the production of hydrogen.

(2) Control Technology Assessment

The prilling tower has not been used. Appreciable quantities of hot hydrocarbon fumes, liquid product carry over, and solid SRC buildup on the tower walls are expected should the unit be operated.

The area in this plant where the greatest potential for exposure to toxic fumes occurs is at the Sandvik product belt. There is a hood over the Sandvik belt, and a steam eductor is used to remove the fumes. These controls are inadequate. Fumes still escape into the workplace and operators who work near the belt are not required to wear respirators.

G. Product Storage and Shipping (08.2 Area)

(1) Process Description

The SRC solids from product solidification are stored in bins in the storage building, or on open air concrete pads. This product may be loaded into railroad cars or trucks from the storage building. A payloader is used to load product from the storage pads into trucks.

(2) Control Technology Assessment

The SRC-I low ash product is very friable and dusty. A dust collection and baghouse system solved this problem.

The transport of SRC-I product in coal carrier type railroad cards resulted in a dusting problem. A minor loss of product was experienced when the material was shipped to Georgia for a test burn. The best method to date for reducing railroad car losses is to spray the SRC-I with a wetting agent (such as Johnson-March MC) during loading, and then spraying the top of the load with a latex crusting agent (such as Dowell M166).

Laboratory tests have shown that water containing a wetting agent suppresses SRC dust by 30%. The addition of 0.4 to 1% process derived solvents and petroleum derived oil also suppresses dusting; however, the resultant material is somewhat sticky.

H. Hydrogen Plant (09.5 Area)

(1) Process Description

There are four locations where hydrogen is added to the system:

- Quenches on the dissolvers;
- Hydrogen purge at the pressure transmitters;

Figure 18. Sandvik Belt Cooler

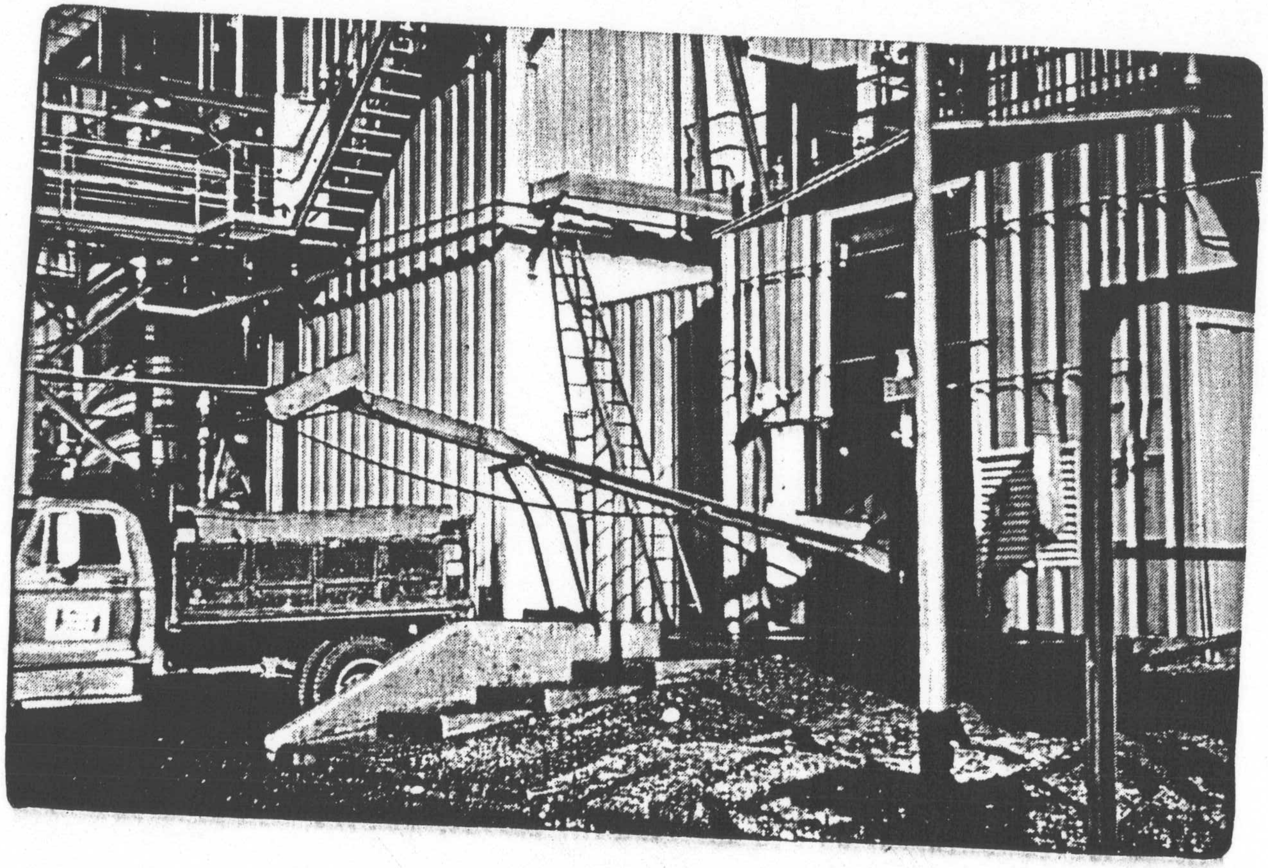


Figure 19. Product Solidification (08 Area) Loading Area for Sandvik Belt Product

- Transmitters for the letdown-valve controls; and the
- Level transmitter

(2) Control Technology Assessment

Loss of hydrogen pressure causes fouling from the process liquids. In a commercial plant, the hydrogen source would be more uniform and more reliable so that much of this problem would be eliminated. In the gas recycle system, three-stage compressors are used to bring the recycled hydrogen up to a final pressure of 1200 psig. Compressor corrosion has caused some problems at the compressors. Moisture is picked up in the process causing corrosion. The hydrogen gas generator is an off-the-shelf unit. Methane and steam are reformed and the resulting mixture of hydrogen and carbon dioxide is passed to the MEA solution yielding high-purity hydrogen, which then goes to the syngas compressor.

The Stretford unit has caused many problems. Feed to the Stretford unit is 80 to 90 percent hydrogen sulfide gas; however, the unit is designed for 10 percent hydrogen sulfide content of the gas flow. As a result the unit is overloaded. Additional problems may have resulted from the fact that the Stretford unit was originally designed for short-term use. The materials of construction may be unsuited for continuous use.

Failure of the hydrogen compressors is in part due to the failure of the gas drying system which allowed passage of trace amounts of wet carbon dioxide or hydrogen sulfide. These gases caused corrosion cracking of the heel springs. Another problem was traced to the square cross section of the spring material. As a result, stresses are intensified at the corners of the cross section resulting in spring failures. The bronze packing in the recycle gas compressors was also attacked by the wet hydrogen sulfide; however, the use of carbon filled Teflon packing has proven superior.

The naphtha circulation pumps experienced excessive vibration problms and frequent packing failures. The excessive vibration problem was eliminated by:

- The installation of a hydrogen purged gas compression pocket on the discharge of each pump; and
- The installation of a hydraulic accumulator on the suction of each pump.

The packing problem was solved by the substitution of two rings of Teflon-impregnated asbestos packing with Anchor-rad moldable packing in-between for the original Teflon impregnated asbestos.

I. Wastewater Treatment (09.1 Area)

(1) Process Description

The wastewater treatment system is shown schematically in Figure 20. It was designed to process 150 gallons per minute (gpm). Treating rates during the winter months average 100 gpm, due to the nearly constant rainfall, and 50 gpm during summer months.

This unit receives process wastewater containing MEA, DEA, ammonia, sodium hydroxide, sulfuric acid, Stretford solution, aromatic coal solvents and pulverized coal.

(2) Control Technology Assessment

The treating units have done an outstanding job in removing contaminants, the only exception being during infrequent periods when the biological unit was experiencing an upset. The lack of a proper oil/water separation system has presented some difficulty at the waste treatment system. A horizontal steel unit (Phoenix tank) has been jury-rigged, which removes some of the oil from the water. At times this system is upset, allowing oils to get into the charcoal and biological filter treatment systems. Upsets in any single unit in the chain causes upsets throughout the remainder of the system.

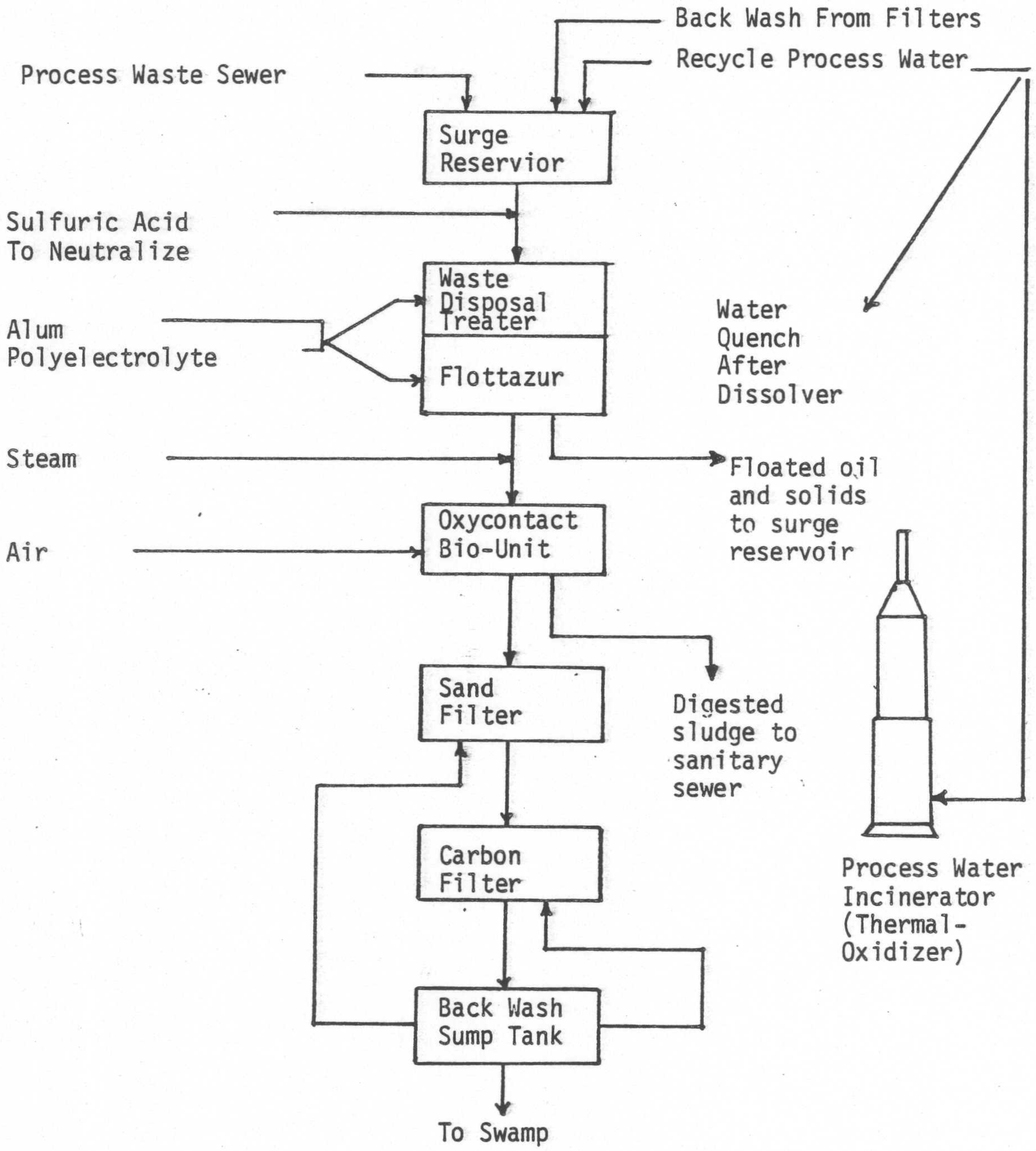


Figure 20. Wastewater Treatment System

The "biomass" for the biological unit was grown from a commercially prepared vacuum dried bacterial preparation. The biological treatment unit is an aerated tank in which bacteria feed on the organic components of the process wastewater. The biological treatment normally works well, but upsets in pH have "shocked" the biomass. When this happens additional vacuum dried bacteria are added.

The biomass loading in the bio-unit aeration section was increased from 20 to a nominal 30 percent loading, to more easily withstand shock loadings of phenols to the system.

J. Tank Farm (09.2 Area)

(1) Process Description

The tank farm consists of a number of large storage tanks in an earthen wall diked area. The tanks are used for storage of startup, in process, and SRC-II final product.

(2) Control Technology Assessment

The pressure-vacuum valve on one of the raw solvent tanks was plugged with naphthalene. As a result, when the tank cooled the vacuum created caused a partial collapse of the tank. Steam tracing of the pressure-vacuum valves has prevented a recurrence.

Material from the filtration area has at times been pumped to the heavy oil tanks to allow maintenance in the filtration area to proceed. A heavy tarry material which is extremely difficult to remove has accumulted in these tanks. This tank is unsatisfactory because cleaning may require worker entry and exposure to these materials.

The drains on the tanks are inadequate. As a result there is more exposure to PNAs, naphtha, etc., because of the additional maintenance and operating labor to clean tanks.

The naphtha tank requires daily draining to remove water. As a result, the area around the naphtha tank is saturated with oil. This condition is unsatisfactory because of worker exposure and the fire hazard. The situation was being studied by plant personnel to determine the best method of solving the problem.

IV. WORK PRACTICES

A. Housekeeping

Coal derived liquids contain volatile components such as benzene. When these liquids leak or spill, the volatiles evaporate leaving behind a tacky, tar-like, semi-solid material. This material may be carried on shoes, gloves, or clothing from the process area to "clean" areas such as the control room, lunch room, or wash room.

The spills and leaks may occur from a break in the equipment, from shaft seals, flanges and valves, from the sampling of process streams, or from scheduled maintenance.

It is recognized that changes in equipment for research and development purposes have created more problems at the Fort Lewis Pilot Plant than would be experienced at a commercial plant; but the problem of leaks is nevertheless of concern because of worker exposure by the inhalation of vapors and by dermal contact with PNA containing leaks and spills.

Housekeeping is an important practice in limiting this contact. Housekeeping activities are performed on an as-time-permits basis by the field operators. Surfaces are cleaned with steam lances after gross material has been removed by shovels. The steam line is arranged with a venturi which draws a combination solvent-detergent (NUVAT), which combined with steam is used in dislodging and dissolving material from the concrete floors and other surfaces. The next step in the procedure is to wash the removed material into the drain system which goes to the treatment plant.

Although the Health and Safety Office of the plant stresses housekeeping in order to keep the process areas free of potentially toxic materials; deposits of coal tar products, which contain PNAs, were observed throughout the process area and were especially heavy in the product solidification area.

A new method of cleaning is being designed by Browning and Ferris which will use high-pressure water and solvent mix in a cleaning wand. The equipment is in the process of being constructed and will be put into operation when it is received. Plant personnel believe that the new system will do a better job of cleaning spills then the present lance which uses steam because of the force of the water jet. In addition to this operators will be in a better position to observe the work because there will be no steam clouds, and there should be less inhalation exposure to the tars because hydroblasting does not aerosolize tars as readily as steam cleaning.

Some of the tacky semi-solid material settles and hardens in the plant drain system. The preferred method for cleaning the drains is with a hydroblaster; however, the present design restricts the movement of the hydroblaster through the system. Future designs should include long radius bends, and pipe diameters large enough throughout the drain system to allow passage of commercial hydroblaster equipment. The design should allow access to the drains at every point from entry to discharge.

Adsorbent material should be provided at easily accessible locations throughout the plant. This material should be applied to oil spills immediately after occurrence to reduce worker exposure which would result from fumes and "tracking" of the spill. The adsorbent can be easily removed, thereby reducing housekeeping problems and worker exposure by contact or inhalation. Spills of tarry materials are usually not cleaned up with an adsorbent because the material hardens too quickly. Steam or high pressure water with a solvent-detergent is used to remove tarry materials.

B. Administrative Controls

Administrative controls are procedures designed to reduce a worker's exposure to potentially hazardous substances by limiting the amount of time the worker spends in process areas or work situations where exposure is most likely to occur. Limiting exposure in this way may be accomplished by regular work scheduling, i.e., planned rotation of workers to different work assignments; and/or by rotation only after a large non-routine exposure, such as from an accidental release.

Administrative controls are not part of the SRC plant's overall strategy for controlling worker exposure.

V. PROTECTIVE CLOTHING AND EQUIPMENT

The work practice program emphasizes the use of protective clothing and equipment whenever there is a potential for skin contact with PNAs. The type of clothing and equipment used is dependent upon the potential degree of exposure associated with the job. Generally, gloves are required in the process areas. One type is a rubber, solvent-resistant glove, and a second type is the "nitty-gritty" glove, a plastic or solvent resistant rubber on cloth. The "nitty-gritty" glove is normally worn by the field operators. Rubber gloves are needed for jobs requiring the handling of contaminated equipment or material. In addition, faceshields are required where splashing may occur. Full protection consisting of rubber gloves, faceshield, raingear, and rubber boots are used in jobs where spills or drenching of the worker can occur. These jobs include breaking into process lines and removal of equipment from service.

Because of the generally cool weather at Ft. Lewis, wearing protective equipment has not presented a heat stress problem. The worker's uniforms and cotton coveralls are dry cleaned and their underwear are laundered by an outside contractor. The contractor has been warned in writing of the potential hazards associated with the contaminants on the clothing by the

Ft. Lewis Health and Safety Office. The outer clothing was originally laundered, but the clothes still fluoresced under u.v. light after being washed so the plant changed to dry cleaning. The rain suits and rubber gloves are not cleaned. They are reused until the worker decides that they are contaminated. The discarded equipment is disposed of by the plant. The "nitty-gritty" gloves are usually discarded after one day of use.

Respirators will not be used for PNA exposure control unless data from the monitoring program indicates that high concentrations of PNAs are associated with particular work activities or plant areas. Respirators are used primarily for controlling the inhalation of coal dust in the coal preparation area and for controlling hydrogen sulfide exposure in such areas as the environmental units. Single-use respirators and half-mask respirators equipped with the proper cartridge are used to protect workers from these contaminants.

VI. MONITORING PROGRAM

Of the 184 workers at the Fort Lewis plant, 133 were identified as having potential exposure to process contaminants because of their job assignments. The 133 workers consist of 41 non-shift, day only workers and 92 shift workers. Non-shift personnel include the plant supervisor and 40 maintenance workers. The shift workers include 4 shift supervisors, 16 laboratory technicians, 16 technical specialists and 56 operators. The technical specialists are the field supervisors with responsibility for assigned unit operations. The operators are under the technical specialists and monitor their assigned area.

Broad spectrum monitoring was initiated to identify the types of compounds to which these workers may be exposed. In this program selected compounds, representing chemical groups that may be formed by the process, were studied using both area and personal monitoring.

Monitoring of these workers by SRC Health and Safety Office personnel have indicated that workers are being exposed to organic contaminants in the parts-per-billion and microgram-per-cubic meter range (see Appendix A). At these levels it is believed that the studied contaminants would not pose a health problem on the basis of current federal health standards. A possible exception is exposure to PNAs because of the absence of information to assess the hazards of long term PNA exposures at the observed levels. Enviro performed a comprehensive study industrial hygiene survey concurrently with the control technology assessment. The results obtained by the Enviro industrial hygiene survey team essentially confirmed the SRC data. The Enviro data also included the aromatic amines, a chemical group which was not included in the pilot plant program (see Appendix B). The results of the Enviro monitoring program indicates minimum levels of exposure to aromatic amines.

A relationship between the benzene soluble fraction of particulate samples and the amount of PNAs in the sample has been established for the coke oven industry. An attempt to find a similar relationship at the SRC plant was made by both SRC Health and Safety Office personnel and by the Enviro industrial hygienists. No relationship was observed between the benzene-soluble fraction and PNA levels; therefore, the soluble fraction could not be used to evaluate PNA exposure. The lack of adequate exposure data and the suspected carcinogenic nature of the PNAs were the major reasons for classifying the PNAs as the principle hazard.

VII. HEALTH AND SAFETY PROGRAMS

A. Employee Education and Training

The Fort Lewis plant maintains an employee education and training program to promote safety and industrial hygiene.

An orientation program for new employees is given which stresses work environment and hazards, and worker protection practices and equipment. The plant also maintains a continuing health-education program to reinforce the importance of good industrial hygiene practices.

All new SRC employees receive an intensive health-protection orientation. This includes an 18-minute audiovisual presentation with test questions, a manual, a tour of the locker/change house, a visit with the company nurse, and the signing of a statement acknowledging the worker has completed the orientation. To further insure that the worker has received the orientation, the company uses a checklist for each employee.

The audiovisual presentation was established to maintain quality and uniformity in the program. The presentation shows the facility's hazards, protective measures used by the company, and protective measures available to each employee. Included are the following:

Plant processes
Skin conditions (including cancer)
Hazardous compounds
Midshift clothing change following excessive contamination
Footwear
Gloves
Skin barriers and emollients
Ear protection
Air monitoring
Skin-wipe samples
Animal toxicity studies
Reporting skin abnormalities and injuries
Respirators
U.V. skin photographs
First-aid equipment

After the presentation, the employee reads a Health Protection Manual, and signs an acknowledgment statement.

The new employee is then shown the locker/change house and the procedures for entering and leaving the plant. Locations of lockers, clean and dirty clothing and soap and towels are identified.

To reinforce health protection, all workers periodically attend classes presented by the following personnel:

Director of Health Protection
SRC Industrial Hygiene Technician
Gulf Regional Medical Director
Gulf Regional Senior Industrial Hygienist

Classes and courses presented to date include the following:

Industrial first-aid
Cardiopulmonary resuscitation
Shock
Burns
Trauma orientation
Red Cross multimedia first aid
Health and Hygiene
Toxic gases (sulfur dioxide, hydrogen sulfide, carbon monoxide)
SRC health protection slide presentation

Two important aspects of health protection have been the transfer of education to the workplace and close supervision to insure compliance. Work supervisors are encouraged to participate in health-protecton classes and to set good examples on the job. However, supervision is still required to insure the compliance of some individuals.

B. Safety

The Ft. Lewis SRC pilot plant maintains a Health and Safety Office which has the responsibility of providing workers with a safe work environment. Their efforts are supplemented by a medical program and a monitoring program in order to detect illnesses and determine whether they are occupationally related. The medical program and monitoring program are discussed later under their own headings.

The potential hazards of hydrogen sulfide and carbon monoxide are recognized, however the major emphasis of the health and safety program is the control of PNA exposure due to its suspected carcinogenicity. The control of inhalation exposure is primarily by the use of the previously mentioned engineering controls. Work practice requirements supplement the existing engineering controls and are intended to keep skin contact with PNAs at a minimum.

There are "catch basins" at the several areas in the plant to contain spills. The smooth cement combined with recurring oil spills and the use of rubber footware results in a slippery condition. At the SRC plant the floor was roughed-up with a special machine. Although housekeeping will be more difficult because of the rougher surface, a serious safety hazard was minimized.

The work performed by maintenance personnel and by field operators engaged in sampling process streams presents special safety problems.

Maintenance personnel may experience a high level of exposure to potentially toxic chemicals because their job requires removal of equipment, cleaning of plugged equipment, replacement of eroded and/or corroded equipment and miscellaneous repairs.

In order to reduce the potential for exposure, when a pipeline or piece of equipment is to be repaired, it is cleaned before maintenance personnel begin working. The equipment is flushed with solid free solvent (process or heavy) to remove process material to prevent plugging. The equipment is then flushed with light solvent and then steamed. This procedure, although effective does not guarantee that all coal derived materials have been removed. The maintenance department tries to work on the pumps while they are hot so that the material does not harden and require being chipped out of the pump casing and other areas. Sometimes a flame is used to heat the material so that it can be removed from the pump casings and from around the impeller. This procedure should be done in a well ventilated area with appropriate respirator protection to reduce inhalation exposure.

One area requiring frequent maintenance is in the maintenance of let-down control valves. Wherever possible, attempts are made to prepare the equipment by flushing with solvent, followed by steam. An area that is being steamed is roped off, and the process is steamed to the atmosphere. The practice of "steaming to atmosphere" is a work practice which should be investigated to determine the amount of solvents and/or other toxic agents being emitted. Based on the levels of contamination, the commercial plant may have to install local units which would remove the steaming products to a scrubber system.

Sampling is very difficult at this plant because of the high pressures and high temperatures.

Because of the nature of the material, elaborate sampling points have been established in which hydrogen gas is trickled back through the "dead points" to avoid a buildup of material and blockage of the lines. A system of block valves is used before and after the control valves and sampling points. After the sample is taken, the line is flushed out through the various valve systems and back into the vessel from which the sample is taken. The final flushing, which is done into a pot that is open to the atmosphere is a point at which some exposure to toxic materials can be expected. In a commercial plant the pot should be sealed to minimize worker exposure and vented to a scrubbing system to reduce emissions to the atmosphere.

C. Industrial Hygiene

The intent of the industrial hygiene program is to insure that prolonged skin contact with PNAs does not occur because of poor hygiene practices, and that PNA-contaminated clothing and material are kept within the plant. In this program all workers entering the process area must change into clean work uniforms including underclothing at the beginning of the shift. A locker room is provided for this purpose. At the end of the work day these workers enter a change room and remove all their work clothing. The dirty uniforms are deposited in a dirty-clothes bin and the underclothing in a mesh bag in the change house. The employees shower and then enter the connecting locker room and don their street clothing.

Periodic long wavelength ultraviolet examination of the skin by the plant nurse has demonstrated the effectiveness of showering with soap and water for removal of most of the fluorescing compounds. During periods of gross contamination such as a spill, workers are encouraged to shower and change as soon as possible. Also, for exceptionally dirty jobs, such as entering vessels, workers don rain suits, coveralls, appropriate gloves, and other equipment needed for added protection.

D. Medical Program

The medical program provides for a pre-employment and annual physical examination. Examinations are extensive, including a medical history, blood count and blood chemistry measurements, urinalysis, chest x-rays, and pulmonary functon tests. These examinations provide a broad base for monitoring worker health with regard to occupationally related illnesses.

Two aspects of this program have been instituted particularly for monitoring PNA exposures. These include skin and longwave ultraviolet examinations. The skin examination entails a careful examination for lesions and other unusual skin conditions because of the suspected skin carcinogenicity characteristics of the PNAs. Examinations are conducted on an annual basis by a Board-certified dermatologist with supplemental quarterly examinations by the plant nurse. Employees are also asked to report any unusual skin conditions or lesions.

Long wavelength ultraviolet light has been used on a periodic basis to check for skin contamination. Since ultraviolet light is a co-carcinogen its use should be carefully regulated until additional information is obtained on the combined effect of exposure to ultraviolet light and PNAs. Until this information is available, emphasis should be placed on thorough cleaning with soap and water.

VIII. CONCLUSIONS AND RECOMMENDATIONS

- There should be catch basins with cleanouts in all areas in order to facilitate cleaning and to avoid plugging of drains. This will allow the water to go to the waste treatment plant and prevent solids from getting past the catch basin into the drain system. Although personnel in operations expressed the opinion that the grating should be removable so that it could be cleaned by dipping, maintenance personnel felt that it is safer and better to clean the gratings in place. Equipment was suggested that is similar to hydroblasting. Periodically, special plant crews should clean the various spills which may occur.

- Throughout the plant, greater emphasis should be placed on housekeeping. It is the responsibility of the individual operators and/or the assigned maintenance personnel to keep the various areas clean. It is recognized that this is an R&D plant, with constant changes being made in the equipment in order to run tests; as a result the spills will probably be greater than in a normally operating demonstration or commercial plant.

- At present at the SRC Fort Lewis plant, accessibility around pumps for maintenance is limited; as a result, maintenance personnel often work for longer periods of time and thereby increase their exposure for each job. In new plants, there should be better provision for cleaning pump areas to prevent material from going to the waste treatment plants. Working space around the pumps should be increased to facilitate maintenance.

- A central control area for thermostat, junction boxes, etc., is recommended in the design of demonstration and commercial plants, so that the thermostat controls for the heat tracing of the pipelines would not be in areas where fouling occurs and in which excessive maintenance is required.

- In measuring tank levels, it is suggested that the indicators, both liquid and direct-reading, be purged. Liquid and direct-reading indicators give better results than any of the other equipment used in the plant.

- There should be an established procedure for handing down changes in procedure from shift to shift.

- One of the difficulties with the nuclear density-measuring equipment is that the equipment was designed for a different vessel from the one which it is currently installed. Readings are inaccurate because of the difference in wall thickness between the two vessels. An adjustment, based on the thickness of the tank, should be made to the response time. SRC personnel believe that with proper adjustment a tank using this equipment will give accurate readings.

- The flow of hot slurry between the 01 and the 02 areas is not being measured because of lack of equipment. The density of effluents is dependent upon the accuracy of the weighbelt which feeds the coal into the slurry tank. The plant instrument staff have been having difficulty maintaining the calibration this weighbelt which requires an accuracy within one percent of the capacity. It has been suggested that a nuclear weighbelt might be more effective than the present piece of equipment.

- There should be an established personal protective equipment (protective clothing and respirators) program. During normal operations, such as housekeeping, and preparation of vessels for maintenance, workers may be exposed to various hazardous substances by inhalation and dermal exposure. Skin exposure may be controlled by appropriate equipment such as gloves, coveralls, shields, and special work clothing. At present, recommendations for providing worker respiratory protection are inadequate. NIOSH suggests that respirators be provided for three functions. First, escape type respirators should be conveniently stationed around the coal conversion facility for workers to wear during emergencies or process upsets. Second, half-mask respirators with disposable particulate filters/ cartridges should be used by workers in the coal preparation area. Finally, and most importantly workers involved in cleaning and maintaining process vessels should wear a combination supplied-air respirator with full-face piece and auxiliary SCBA, operated in pressure demand or other positive pressure mode.

- The Sandvik belt should be ompletely enclosed and an eductor installed to remove the fumes to either a flare stack or a high-energy venturi scrubber. If the belt enclosure must be opened, workers should wear respirators.

Appendix A

SUMMARY OF SRC MONITORING PROGRAM DATA

Solvent Refined Coal Pilot Plant
Fort Lewis, Washington

APPENDIX A

Summary of SRC Monitoring Program Data

An extensive industrial hygiene monitoring program is being conducted by the Pittsburg and Midway (P&M) Coal Mining Company at the Fort Lewis plant. The project is conducted from the Gulf Oil Company San Francisco office which was assigned responsibility for developing a sampling program. The actual sampling is performed by personnel from the SRC Health and Safety Office. Samples are sent to the Gulf Oil Industrial Hygiene Laboratory for analysis.

Since the plant was started in 1974, personal monitoring and area sampling have been conducted to assess the extent and nature of exposure, and to identify specific areas needing additional controls. Sampling results for the SRC-I process for the period January 1, 1974, through June 30, 1977, have been reported in the Department of Energy publication FE/496-T15, "Solvent Refined Coal (SRC) Process: Health Programs."[1] These published results for the SRC-I process have been summarized in the preliminary walk-through report prepared by Enviro and submitted to NIOSH in July 1979.[2] Results characterizing the SRC-II process are reported in DOE publication FE/496-T19 "Solvent Refined Coal (SRC) Process: Health Programs."[3]

These publications contain a detailed description of the sampling and analytical procedures and of the industrial hygiene sampling results. Publication FE/496-T19 also presents an in-depth comparison of the SRC-I and SRC-II processes. Because of the availability of this information, sampling results from the P&M survey will only be presented in summary from in this report. The summarization of results are given in Tables A-1 to A-7. The sampling procedures followed by P&M are discussed below.

Benzene, toluene, xylene, and hexane (Table A-1) were sampled using 20/40 mesh activated charcoal and a flow rate of 200 milliliters/minute (ml/min). Gas chromatography was used in the analysis of these samples following NIOSH methods in P&CAM No. 127.[7]

Particulate samples (Table A-2) were collected using a high volume sampler and 8 inch by 10 inch fiberglass filters for area samples and glass fiber/silver membrane filters in 37 mm field monitor cassettes for personal samples. Total particulate concentrations were determined gravimetrically. The benzene soluble fraction (BSF) of area samples were determined by soxhlet extraction of the filter with benzene followed by gravimetric determination of total weight loss. The difference in weights represented the BSF level. Personal sample filters were extracted ultrasonically with benzene followed by evaporation in a tared dish for weighing. Benzo(a)pyrene was determined following methods described in PCAM No. 251.[7]

A midget impinger containing an alkaline suspension of cadmium hydroxide was used for the collection of hydrogen sulfide samples (Tables A-3, A-4). A flow rate of 1.5 liters per minute (lpm) was used with spectrophotometric analysis following the procedure described in NIOSH P&CAM No. 126.[7] NIOSH method P&CAM No. 160[7] was followed for the sampling and analysis of sulfur dioxide. This method involves the use of a midget impinger containing sodium tetrachloromercurate and a sampling rate of 1 lpm with spectrophotometric analysis. Phenols were collected and analyzed by two methods. One procedure involved the collection of samples on silica gel using a flow rate of from 200 to 800 ml/min. Analysis used gas chromatography. In the second procedure samples were collected using a midget impinger containing sodium hydroxide solution and a flow rate of 2 lpm. Analysis was by spectrophotometry.

Carbon monoxide (Table A-5) measurements were made using Draeger detector tubes certified by NIOSH. Noise measurements were taken with either the Scott 452 or General Radio 1565A sound level meter.

Tapered polyethylene cylinders mounted on collecting jars were used for dustfall measurements (Table A-6). Collectors were located six feet above ground level in six different locations. The locations are shown in Figure A-1. Collecting jars were gathered every 30 days and total weight and benzene solubles were determined by the same methods described for Table A-2.

In summarizing the P&M data, results were averaged by process area for area and personal samples. In calculating averages the following steps were taken to simplify calculations:

1. ND (not detected) values were equated to zero.
2. Samples above the detection limit but not quantifiable were given values equal to the detection limit.
3. Trace samples were set at the level of sensitivity of the analytical method.
4. Less than signs were dropped and only magnitude was considered.
5. Sample volumes were assumed to approximate 8-hour samples.

The effect of these steps is to maximize the data so values given in the tables are higher than actual values.

Table A-1

AVERAGE AIRBORNE CONCENTRATION OF ORGANICS BY PROCESS AREA

Solvent Refined Coal Pilot Plant
Fort Lewis, Washington

Area and Sample Type	SRC Process	Benzene		Toluene		Xylene		Hexane	
		No. of Samples	Average (Range) ppm	No. of Samples	Average (Range) ppm	No. of Samples	Average (Range) ppm	No. of Samples	Average (Range) ppm
COAL PREPARATION Area	I	-		-		-		-	
	II	16	0.06 (0.01 - 0.51)	16	0.07 (0.01 - 0.79)	16	0.08 (0.01 - 0.79)	16	0.04 (0.01 - 0.32)
Personal	I	1	ND[a]	1	ND	1	ND	1	ND
	II	6	0.01 (0.01 - 0.02)	6	0.02 (0.01 - 0.05)	6	0.02 (0.01 - 0.05)	6	0.03 (0.01 - 0.05)
PREHEATER/DISSOLVER Area	I	-		-		-		-	
	II	7	0.02 (0.01 - 0.05)	8	0.02 (0.01 - 0.05)	8	0.04 (0.01 - 0.05)	8	0.04 (0.01 - 0.05)
Personal	I	-		-		-		-	
	II	5	0.02 (0.01 - 0.03)	5	0.01 (0.01)	5	0.02 (0.01 - 0.05)	5	0.02 (0.01 - 0.05)
MINERAL SEPARATION Area	I	3	0.03 (0.02 - 0.03)	3	0.02 (0.02 - 0.03)	3	0.03 (0.02 - 0.05)	3	0.01 (0 - 0.02)
	II	21	0.02 (0.01 - 0.05)	22	0.02 (0.01 - 0.05)	22	0.03 (0.01 - 0.05)	21	0.03 (0.01 - 0.05)
Personal	I	4	0.16 (0 - 0.50)	4	0.04 (0 - 0.07)	4	0.01 (0 - 0.04)	4	0.02 (0 - 0.05)
	II	7	0.02 (0.01 - 0.05)	7	0.01 (0.01 - 0.02)	7	0.02 (0.01 - 0.05	7	0.04 (0.01 - 0.05)
SOLVENT RECOVERY Area	I	3	0.06 (0.02 - 0.13)	3	0.05 (0.02 - 0.11)	3	0.01 (0 - 0.03)	3	ND -
	II	76	0.03 (0.01 - 0.39)	77	0.03 (0.01 - 0.13)	77	0.04 (0.01 - 0.05)	77	0.04 (0.01 - 0.05)
Personal	I	2	0.04 (0.04)	2	0.05 (0.04 - 0.06)	1	ND -	2	0.02 (0 - 0.03)
	II	19	0.02 (0.01 - 0.05)	19	0.02 (0.01 - 0.1)	19	0.02 (0.01 - 0.05)	19	0.04 (0.01 - 0.05)
GAS RECOVERY Area	I	-		-		-		-	
	II	34	0.04 (0.01 - 0.37)	35	0.03 (0.02 - 0.22)	35	0.04 (0.01 - 0.39)	35	0.03 (0.01 - 0.15)
Personal	I	-		-		-		-	
	II	1	0.04 -	1	0.02 -	1	0.05 -	1	0.05 -
PRODUCT SOLIDIFICATION Area	I	9	0.02 (0 - 0.05)	9	0.003 (0 - 0.03)	8	ND -	9	ND -
	II	38	0.03 (0.01 - 0.17)	39	0.04 (0.01 - 0.02)	38	0.05 (0.01 - 0.2)	39	0.04 (0.01 - 0.05)
Personal	I	4	0.002 (0 - 0.01)	4	0.002 (0 - 0.01)	4	0.003 (0 - 0.01)	4	0.002 (0 - 0.01)
	II	8	0.03 (0.01 - 0.05)	8	0.05 (0.02 - 0.23)	8	0.04 (0.01 - 0.17)	8	0.04 (0.01 - 0.05)
UTILITIES/SUPPORT Area	I	-		-		-		-	
	II	29	0.04 (0.01 - 0.29)	29	0.17 (0.01 - 2.6)	30	0.14 (0.01 - 1.6)	30	0.03 (0.01 - 0.09)
Personal	I	2	0.02 (0 - 0.05)	2	0.06 (0.04 - 0.08)	2	ND -	2	ND -
	II	18	0.02 (0.01 - 0.11)	18	0.02 (0.01 - 0.05)	18	0.03 (0.01 - 0.05)	18	0.03 (0.01 - 0.05)

[a] Not detected.

Table A-2

AVERAGE PARTICULATE CONCENTRATION BY PROCESS AREA

Solvent Refined Coal Pilot Plant
Fort Lewis, Washington

Area and Sample Type	SRC Process	Total Particulates No. of Samples	Total Particulates Average (Range) $[mg/m^3]$	Benzene Solubles No. of Samples	Benzene Solubles Average (Range) $[mg/m^3]$	Benzene Solubles No. of Samples	Benzene Solubles Average (Range) [%]	Benzo(a)Pyrene No. of Samples	Benzo(a)Pyrene Average (Range) $[mg/m^3]$
COAL PREPARATION									
Area	I	73	4 (0.01 - 82)	71	0.2 (0.001 - 3.1)	71	13 (0 - 75)	31	0.001 (0 - 0.001)
	II	21	1.4 (0.01 - 6.3)	20	0.04 (0.01 - 0.13)	18	7 (1 - 25)	-	[a]
Personal	I	9	2.3 (0.01 - 5.6)	9	0.3 (0.01 - 1.7)	8	12 (1 - 55)	4	ND[b] -
	II	30	2.1 (0.01 - 5.2)	23	0.10 (0.01 - 0.60)	29	5 (1 - 34)	4	0.03 (0.01 - 0.09)
SOLVENT RECOVERY									
Area	I	34	0.20 (0.01 - 0.60)	34	0.08 (0.01 - 0.41)	33	50 (3 - 100)	17	0.005 (0 - 0.01)
	II	24	0.11 (0.01 - 0.55)	24	0.03 (0.01 - 0.07)	24	38 (7 - 100)	-	[a]
Personal	I	11	4 (0.15 - 29)	11	0.21 (0.01 - 0.78)	11	22 (1 - 100)	4	ND -
	II	7	0.4 (0.01 - 1.3)	7	0.2 (0.01 - 1.2)	6	30 (2 - 92)	1	0.57 -
PRODUCT SOLIDIFICATION									
Area	I	81	1.3 (0.07 - 7.5)	81	0.7 (0.01 - 6.0)	81	56 (2 - 100)	30	0.3 (0 - 2.2)
	II	36	0.13 (0.02 - 0.73)	36	0.04 (0.01 - 0.13)	36	34 (13 - 70)	1	0.41 -
Personal	I	9	5 (0.54 - 14)	9	2.6 (0.23 - 7.3)	9	48 (10 - 82)	4	ND -
	II	29	2 (0.07 - 28)	29	1 (0.01 - 10)	29	22 (2 - 65)	11	0.32 (0.01 - 0.99)

[a] No analysis done.

[b] Not detected.

Table A-3

AVERAGE CONCENTRATION OF AIRBORNE CONTAMINANTS BY PROCESS AREA

Solvent Refined Coal Pilot Plant
Fort Lewis, Washington

Area	SRC Process	Hydrogen Sulfide		Sulfur Dioxide		Phenol	
		No. of Samples	Average (Range) [ppm]	No. of Samples	Average (Range) [ppm]	No. of Samples	Average (Range) [mg/m³]
COAL PREPARATION	I	1	ND[a] -	1	0.01 -	-	b
	II	12	0.68 (0.01 - 8)	7	0.01 (0.01)	-	b
PREHEATER/DISSOLVER	I	4	ND -	8	0.12 (0.01 - 0.50)	4	0.005 (0 - 0.01)
	II	7	0.17 (0.01 - 1.1)	6	0.01 (0.01)	1	0.01[c] -
MINERAL SEPARATION	I	7	0.10 (0 - 0.37)	9	0.02 (0.01 - 0.04)	17	0.01 (0 - 0.02)
	II	3	3.2 (0.09 - 7.5)	2	0.01 (0.01	10	0.01[d] (0.01)
SOLVENT RECOVERY	I	8	0.11 (0 - 0.47)	11	0.01 (0.01 - 0.03)	23	0.01 (0 - 0.04)
	II	11	0.07 (0.01 - 0.27)	5	1 (0.01 - 3)	16	0.01[e] (0.01)
GAS RECOVERY	I	1	ND -	1	0.01 -	-	b
	II	6	0.04 (0.01 - 0.17)	4	0.01 (0.01)	9	0.01[f] (0.01)
PRODUCT SOLIDIFICATION	I	3	0.003 (0 - 0.01)	4	0.01 (0.01)	-	b
	II	3	0.01 (0.01)	2	0.01 (0.01)	3	0.01[g] (0.01)
ENVIRONMENTAL/SUPPORT	I	7	0.03 (0 - 0.16)	6	0.01 (0.01)	18	0.01 (0 - 0.01)
	II	10	0.16 (0.01 - 0.74)	6	0.01 (0.01)	11	0.01[h] (0.01)

[a] Not detected.

[b] No analyses.

[c] 6 Samples had levels belows detection limits. Samples not included in table.

[d] 12 Samples below detection limits, 5 with traces. These samples not included in tables

[e] 14 Samples below detection limits. These samples not included in table.

[f] 11 Samples below detection limits. These samples not included in table.

[g] 10 Samples below detection limits. These samples not included in table.

[h] 17 Samples below detection limits. These samples not included in table.

Table A-4

HYDROGEN SULFIDE CONCENTRATION AT POTENTIAL SOURCES

Solvent Refined Coal Pilot Plant
Ft. Lewis, Washington

LOCATION	CONCENTRATION (ppm)
COAL PREPARATION	
1 inch from hot well tank drain	8
PREHEATER/DISSOLVER	
4 feet from sight-glass area	40
SOLVENT RECOVERY	
Hot well tank drain area - first floor	26
Hot well tank vent on 6th floor 2 feet from vent	15,000
Hot well tank vent - 6th floor	1,800
Hot well vent - top floor 1 inch from vent	20
Hot well vent - top floor 1 inch from vent	5
TANK CAR/TRUCK LOADING ENTRY PORT OF CAR FOR NAPHTHA LOADING[a]	
3 inches inside	42,000
2 feet outside and below	16,000
3 feet outside (5 samples)	17
Top of port	93,000
5 feet outside (2 samples)	60
Top of ladder going to top of tank car	80
Catwalk level on tank car edge	10
Stationary part of loading platform	1
5 feet above ground beside track (4 samples)	82

[a] Loading through open hatch.

Table A-5

CARBON MONOXIDE LEVELS BY PROCESS AREA

Solvent Refined Coal Pilot Plant
Fort Lewis, Washington

AREA	SRC PROCESS	RANGE (ppm)	LOCATION OF SOURCE OF HIGH LEVELS (50+)
Coal Preparation	I	ND[a]-10,000	Inside gravimetric feeder chute - (5,000-10,000) 3 feet of feeder-(70-350) 6 feet of feeder-(50-70) Roof vent-60
	II	ND-5,000	Inside gravimetric feeder chute - (ND-5,000) 3 feet from feeder-3rd floor-(ND-200) 6 feet from feeder-3rd floor-(5-100) 12 feet from feeder-(trace-90)
Preheater/ Dissolver	I	ND(1 sample)	
	II	b	
Mineral Separation	I	ND-5	
	II	b	
Solvent Recovery	I	ND(7 samples)	
	II	b	
Gas Recovery	I	ND-4,000	Inside cabinet of east panel in control shack-(3,000-4,000)
	II	b	
Product Solidification	I	ND(2 samples)	
	II	b	
Environmental/ Support	I	ND(4 samples)	
	II	b	

[a] Not detected.

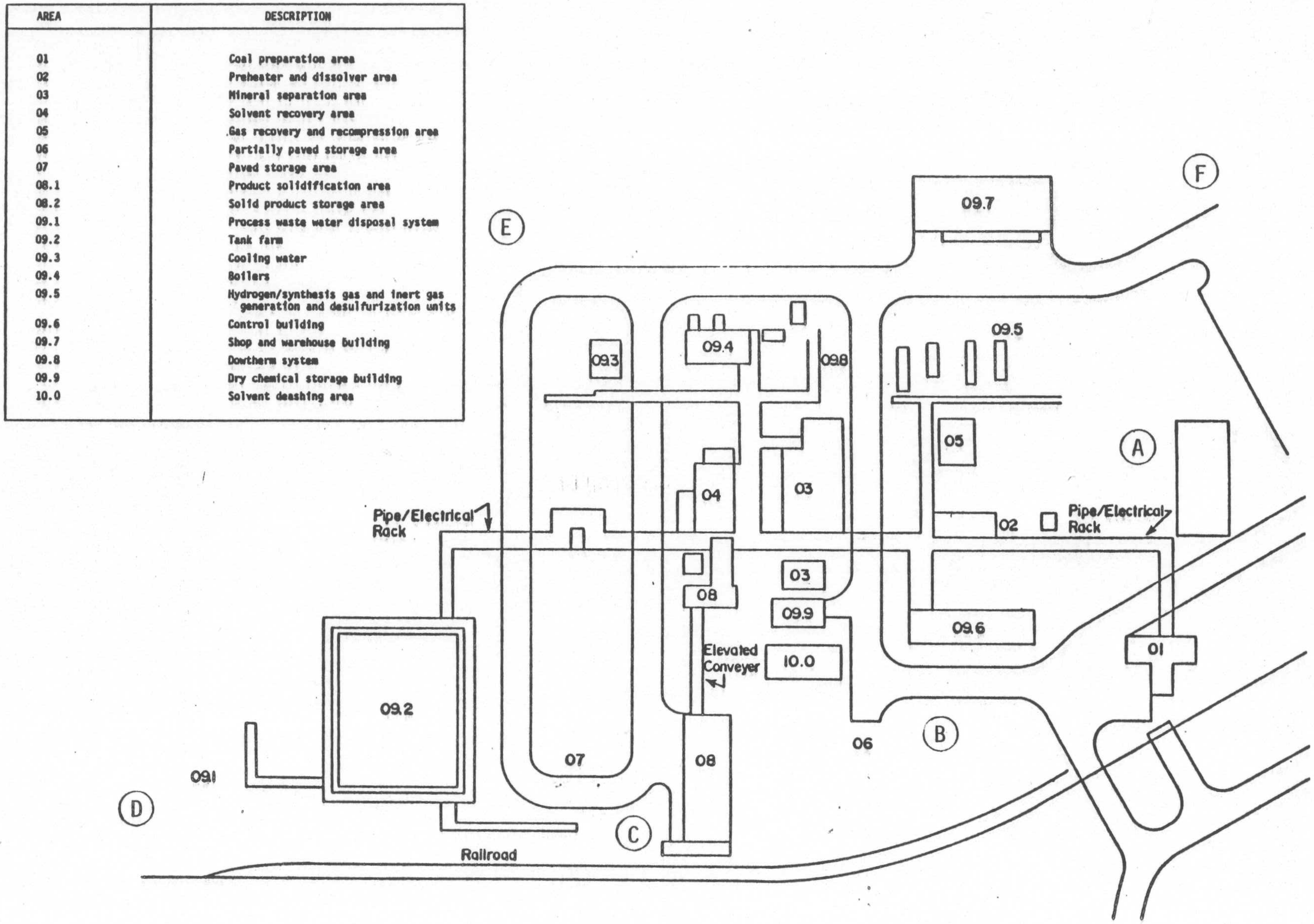
[b] Samples not taken.

Table A-6

AVERAGE DUSTFALL CONCENTRATIONS AT SIX STATIONS

Solvent Refined Coal Pilot Plant
Fort Lewis, Washington

		Dustfall		Benzene Solubles		
Station	SRC Process	No. of Samples	Average (Range) [gm/m^3/mo]	No. of Samples	Average (Range) [gm/m^3/mo]	Average (Range) [%]
A	I	4	2.4 (0.35 - 6.7)	4	0.3 (0.01 - 1.0)	5 (1 - 15)
	II	10	4.2 (2.9 - 6.0)	10	0.05 (0.01 - 0.12)	2 (1 - 3.4)
B	I	7	3.2 (0.16 - 5.9)	7	0.2 (0.01 - 1.5)	5 (1 - 31)
	II	10	9.6 (1.9 - 40)	10	0.08 (0.01 - 0.11)	1 (1 - 2.2)
C	I	6	6 (0.1 - 23)	6	2 (0.01 - 12)	10 (1 - 52)
	II	11	4.1 (2 - 9.5)	11	0.12 (0.03 - 0.55)	2.5 (1.3 - 5.8)
D	I	6	1.4 (0.1 - 3.4)	6	0.12 (0.01 - 0.95)	6 (1 - 28)
	II	11	2.5 (1.3 - 3.4)	11	0.04 (0.01 - 0.12)	2 (1 - 4)
E	I	7	1.4 (0.12 - 3.5)	7	0.09 (0.01 - 0.55)	4 (1 - 16)
	II	10	2.4 (1.2 - 3.3)	10	0.04 (0.01 - 0.07)	2 (1 - 3.8)
F	I	7	1.7 (0.44 - 4.0)	7	0.13 (0.01 - 0.85)	4 (1 - 21)
	II	10	3.4 (2.0 - 6.1)	10	0.05 (0.01 - 0.14)	2 (1 - 2.3)



AREA	DESCRIPTION
01	Coal preparation area
02	Preheater and dissolver area
03	Mineral separation area
04	Solvent recovery area
05	Gas recovery and recompression area
06	Partially paved storage area
07	Paved storage area
08.1	Product solidification area
08.2	Solid product storage area
09.1	Process waste water disposal system
09.2	Tank farm
09.3	Cooling water
09.4	Boilers
09.5	Hydrogen/synthesis gas and inert gas generation and desulfurization units
09.6	Control building
09.7	Shop and warehouse building
09.8	Dowtherm system
09.9	Dry chemical storage building
10.0	Solvent deashing area

Figure A-1. Location of Dustfall Sampling Stations Fort Lewis, Washington

Table A-7

NOISE LEVELS BY PROCESS AREA

Solvent Refined Coal Pilot Plant
Ft. Lewis, Washington

AREA	Noise Level SRC-I (dBA)	Noise Level SRC-II (dBA)
COAL PREPARATION	90 - 124	86 - 115
PREHEATER/DISSOLVER	-[a]	82 - 96
MINERAL SEPARATION	85 - 110	90 - 107
SOLVENT RECOVERY	90 - 100	78 - 93
GAS RECOVERY	-[a]	87 - 100
PRODUCT SOLIDIFICATION	90 - 105+	80 - 106
ENVIRONMENTAL/SUPPORT	85 - 95	81 - 116
TANK FARM	-[a]	65 - 70

[a] No readings taken.

Appendix B

COMPREHENSIVE SURVEY RESULTS FOR THE SRC-II PROCESS

Solvent Refined Coal Pilot Plant
Fort Lewis, Washington

Appendix B

COMPREHENSIVE SURVEY RESULTS FOR THE SRC-II PROCESS

Solvent Refined Coal Pilot Plant
Fort Lewis, Washington
February 5-18, 1979

The following tables give the analytical results for the samples taken at the Solvent Refined Coal Pilot Plant, in Fort Lewis, Washington. Tables are arranged by compound groups as represented by the sampling media used. For these tables, a blank space indicates that the compound was not detected in the sample. The less than (<) sign denotes that the compound was present but at levels below the quantifiable limits of the analytical method. The numerical value following the less than sign represents the quantifiable limits for the given sample volume.

Details of the analytical procedure followed in the analysis of these samples are given in "Sampling and Analytical Procedures for the Industrial Hygiene Characterization of Coal Gasification and Liquefaction Pilot Plant" which was prepared by Enviro in May 1979.

Table B-1

PNA ANALYTICAL RESULTS FOR PERSONAL AND AREA SAMPLES--SRC-II PROCESS[a]

Solvent Refined Coal Pilot Plant
Fort Lewis, Washington

	Coal Preparation									Dissolver Preheater	Mineral Separation			
	Area			Welder	Operator			Mechanic	Tech Spec	Area	Area	Operator		
Sample Number	006	007	010	003	011	020	103	073	012	040	041	033	088	090
Sample Volume (ℓ)	3312	3146	3395	220	352	243	275	182	245	5051	5078	439	242	438
Sample Time	0820-1420	1230-1812	1306-1813	0955-1335	1233-1825	0821-1627	0837-1312	0856-1400	1234-1824	1827-0336	1829-0341	0816-1624	0834-1637	0838-1645
Naphthalene	5.7	0.3	5.2	76.1	0.1	0.2	7.1	36.02	8.2	5.3	8.9	6.6	6.5	9.3
Quinoline	13.7	0.6	0.5	4.9	3.6				0.2	6.4	14.5	0.1	0.04	0.2
2-Methylnaphthalene	8.1	0.7	4.6	13.8	9.4		18.9	15.2	31.7	2.0	34.9			45.06
1-Methylnaphthalene	1.01	0.2	0.6	2.3	1.03	0.4	0.8	1.2	0.4	0.3	1.1	5.1	3.8	1.0
Acenaphthalene	0.6			3.9	26				0.02					
Acenaphthene		0.4	1.0		0.07	0.07	1.3	2.4	1.7	0.06	4.9	0.01	0.9	1.9
Fluorene	4.4	4.0	1.6	8.9	0.6	0.8	4.0	8.0	7.4	0.6	8.5	6.2	0.3	4.4
Phenanthrene, Anthracene	13.7	19.6	26.6	15.8		2.0	6.1	17.8	6.6	3.03	43.3	12.7	2.2	7.8
Acridine	1.8			0.06	0.06	0.01		0.04	0.07			0.08		
Carbazole	3.8	0.2	4.6		0.1			1.0		0.2	28.9	1.0		0.3
Fluoranthene	1.7	0.5	2.7	0.9	1.3			0.8	0.1	0.2	23.0	0.6		0.2
Pyrene	1.5	0.2	1.6	0.2		0.07	0.2	2.2	0.3	0.2	24.9	2.3	0.1	0.8
Benzo(a)fluorene	0.3	0.1	0.4	0.04	0.1			0.2		0.07	10.6	1.0		0.2
Benzo(b)fluorene		0.6	0.4								13.7			
Benz(a)anthracene	0.02		0.4				0.2			0.3	3.8			
Chrysene, Triphenylene	0.01		0.4								2.0			
Dimethylbenz(a)anthracenes														
Benzo(e)pyrene											1.3			
Benzo(a)pyrene														
Perylene														
Dibenz(a,j)acridine														
Dibenz(a,i)carbazole														
Indeno(1,2,3-cd)pyrene														
Dibenzanthracenes														
Benzo(g,h,i)perylene														
Anthanthrene														
Coronene														
Dibenzpyrenes														
TOTAL	56.3	17.4	50.6	127	19.0	3.5	38.6	84.9	56.7	18.7	224	33.7	13.8	71.2

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[a] Results are given in $\mu g/m^3$.

Table B-1 cont'd

	Solvent Recovery					Gas Recycle	Product Solidification				Laboratory			Blanks[a]			
	Area	Operator			Tech Spec	Area	Area	Operator			Laboratory Technician						
Sample Number	025	016	021	035	023	066	026	013	022	034	053	054	055	029	030	077	082
Sample Volume (ℓ)	4407	227	242	300	378	4269	4361	202	483	287	304	251	450				
Sample Time	0912-1711	1303-1821	0824-1630	0814-1634	0838-1630	1847-0231	0910-1704	1246-1822	0823-1626	0817-1615	0828-1653	0831-1658	0830-1650				
Naphthalene	10.6		17.6	19.6	21.7		0.8		14.09	38.9		2.7	0.4	0.1		0.3	
Quinoline	40.0		0.3	0.3	0.6		1.8		0.2	0.9							
2-Methylnaphthalene	10.5	4.3	69.8	63.3	76.1		0.6		48.2	180.0		13.1	0.8	0.09		0.2	
1-Methylnaphthalene	6.7	0.8			0.8	0.02	0.2	0.06	0.5	0.02		1.3	1.0	0.03		0.05	
Acenaphthalene	0.1																
Acenaphthene	1.2	0.6	4.2	2.4	2.9		0.2	0.03	1.9	8.4		0.4					
Fluorene	3.6	2.5	7.1	3.2	5.7	0.1	0.4		4.3	16.3		1.2	0.6			0.04	
Phenanthrene, Anthracene	16.1	4.6	7.2	5.8	7.1	0.4	1.8	8.2	5.2	19.8	1.0	3.4	0.6	0.2	0.2		0.01
Acridine		0.04	0.03	0.02	0.01			0.1				0.2					
Carbazole	0.2			0.04		0.02	0.04	0.4	0.09							0.02	
Fluoranthene	0.6	0.06				0.02	0.07	1.0	0.1					0.08		0.03	
Pyrene	0.7	0.4	0.1	0.5	0.3	0.02	0.1	4.5	0.07			0.1		0.06		0.04	
Benzo(a)fluorene	1.2							3.4	0.1								
Benzo(b)fluorene	1.4																
Benz(a)anthracene				0.08					0.02				0.09				0.1
Chrysene, Triphenylene																	
Dimethylbenz(a)anthracene									<0.01								
Benzo(e)pyrene									<0.01								
Benzo(a)pyrene									0.01								
Perylene									0.02								
Dibenz(a,j)acridine																	
Dibenz(a,i)carbazole																	
Indeno(1,2,3-cd)pyrene																	
Dibenzanthracene									0.04								
Benzo(g,h,i)perylene																	
Anthanthrene																	
Coronene																	
Dibenzpyrene																	
TOTAL	92.9	13.3	106	95.2	115	0.6	6.0	17.7	74.8	264	1.0	22.4	3.5	0.6	0.2	0.7	0.1

[a] Results are given in $\mu g/m^3$.

Table B-2

CHARCOAL TUBE ANALYTICAL RESULTS FOR PERSONAL AND AREA SAMPLES--SRC-II PROCESS

Solvent Refined Coal Pilot Plant
Fort Lewis, Washington

Sample Number	Sample Volume (ℓ)	Sample Time	Unit Operation	Type Sample[a]	Compound		
					Benzene (ppm)	Toluene (ppm)	Xylene (ppm)
042	55.1	1842-0355	01 Area	Area	0.02	0.03	0.03
043	53.4	1856-0352	01 Area	Operator	0.02	0.06	0.04
062	41.3	1908-0200	01 Area	Operator	< 0.02	0.02	0.02
046	53.3	1909-0400	01 Area	Tech Spec	< 0.01	< 0.01	< 0.01
083	47.8	0844-1642	03 Area	Area	0.04	0.09	0.06
064	43.9	1908-0226	03 Area	Operator	< 0.02	0.01	< 0.01
115	48.3	0839-1643	03 Area	Operator	< 0.01	< 0.01	< 0.01
065	42.5	1918-0224	04 Area	Area	0.02	0.08	0.1
044	53.9	1900-0401	04 Area	Operator	< 0.01	0.03	0.04
063	43.9	1900-0220	04 Area	Operator	< 0.02	0.02	0.04
110	49.6	0835-1650	04 Area	Operator	< 0.01	0.1	0.01
001	7.8	1344-1505	04 Area	Millwright	0.08	0.4	0.07
002	13.3	1347-1601	04 Area	Millwright	0.07	0.2	0.06
004	36.8	0853-1500	04 Area	Pipefitter	< 0.02	0.08	0.04
117	47.3	0846-1638	08.1 Area	Area	< 0.01	< 0.01	< 0.01
069	48.3	0824-1628	Laboratory	Technician	< 0.01	< 0.01	< 0.01
070	48.9	0827-1630	Laboratory	Technician	< 0.01	< 0.01	< 0.01
071	48.0	0828-1628	Laboratory	Technician	< 0.01	< 0.01	< 0.01
014	33.3	1248-1820	All	Shift Supervisor	< 0.02	0.06	< 0.02
015	32.8	1254-1823	All	Plant Supervisor	< 0.02	< 0.01	< 0.02
027[b]	-	-	-	Blank	< 2	< 1	< 2
081[b]	-	-	-	Blank	< 2	< 1	< 2

[a] Samples numbered 042, 083, 065, and 117 are area samples; samples numbered 027 and 081 are blanks; the remainder are personal samples.

[b] Values are given in nanograms.

Table B-3

AROMATIC AMINE ANALYTICAL RESULTS FOR PERSONAL AND AREA SAMPLES--SRC-II PROCESS

Solvent Refined Coal Pilot Plant
Fort Lewis, Washington

	Coal Preparation						Mineral Separation					Solvent Recovery			
	Area	Operator			Tech Spec	Mech	Area	Operator			Tech Spec	Area	Operator		
Sample Number	097	056	093	116	060	072	084	019	045	105	057	108	061	085	092
Sample Volume	47.5	48.7	47.1	48.5	47	30.4	47.7	47.2	54.5	50	47.4	46.9	42.1	47.6	48.3
Sample Time	0857-1651	0834-1642	0844-1638	0836-1644	0832-1623	0855-1400	0845-1641	0835-1630	1901-0404	0831-1650	0839-1636	0853-1643	0932-1630	0839-1634	0841-1645
Compound (in ppm)															
Aniline	<0.02	<0.02	<0.02	<0.02	<0.02	0.3	<0.02	<0.02	<0.01	<0.02	<0.02	<0.02	<0.02	0.02	<0.02
N,N-Dimethylaniline	<0.01	<0.01	<0.01	<0.01	<0.01	<0.02	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
2,4-Dimethylaniline	<0.01	<0.01	<0.01	<0.01	<0.01	<0.02	<0.01	0.04	0.01	<0.01	<0.01	<0.01	<0.01	0.03	<0.01
o-Toluidine	<0.01	<0.01	<0.01	<0.01	<0.02	<0.02	<0.01	<0.02	<0.01	<0.01	<0.02	<0.01	<0.02	<0.01	<0.01
o-Anisidine	<0.02	<0.02	<0.02	<0.02	<0.02	<0.03	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02
p-Anisidine	<0.02	<0.02	<0.02	<0.02	<0.02	<0.03	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02

	Product Solidification					Laboratory			Supervisor		Blank	
	Area	Operator			Tech Spec	Technician			Plant	Shift		
Sample Number	036	058	086	091	059	074	075	076	017	018	028	080
Sample Volume	49.8	47.1	48.2	48.4	46.7	48.6	47.7	47.5	48	48.7		
Sample Time	0823-1640	0842-1634	0832-1635	0839-1644	0846-1632	0915-1720	0919-1721	0925-1721	0812-1613	0813-1621		
Compound (in ppm)												
Aniline	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	ND[a]	ND
N,N-Dimethylaniline	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	ND	ND
2,4-Dimethylaniline	<0.01	<0.01	<0.01	<0.01	<0.01	<0.02	<0.01	<0.01	0.01	0.02	ND	ND
o-Toluidine	<0.01	<0.02	<0.01	<0.01	<0.02	<0.01	<0.01	<0.01	<0.01	<0.01	ND	ND
o-Anisidine	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	ND	ND
p-Anisidine	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	ND	ND

[a] ND = Not detected.

Table B-4

ANALYTICAL RESULTS OF QUALITATIVE SCREENING[a] FOR PNA WIPE SAMPLES

Solvent Refined Coal Pilot Plant
Fort Lewis, Washington

COAL PREPARATION AREA

Sample Number 089

Acridine
Pyrene

Sample Number 113

1-Methylnaphthalene
1,7-Dimethylnaphthalene
1,1'-Oxybisbenzene
1,6,7-Trimethylnaphthalene
1,2-Dihydroacenaphthalene
Dibenofuran
Xanthene
1-Methylfluorene
Dibenzothiophene
Phenanthrene
3-Methylphenanthrene
2-Methylphenanthrene
1-Phenylnaphthalene
2-Phenylnaphthalene
Fluoranthene
Pyrene
1-Methylpyrene
Triphenylene
Chrysene
Benz(a)anthracene

MINERAL SEPARATION AREA

Sample Number 112

Fluorene
Phenanthrene
9-Methylphenanthrene
Fluoranthene
Pyrene
Benzo(a)fluorene
1-Methylpyrene
Triphenylene
Chrysene
Benz(a)anthracene

SOLVENT RECOVERY AREA

Sample Number 100

Not detected

Sample Number 101

1-Butylnaphthalene
Fluorene
2-Ethyl-1,1'-biphenyl
2,7-Dimethylnaphthalene
3,4-Dimethyl-1,1'-biphenyl
Phenanthrene
Thioxanthene
9-Methylphenanthrene
2-Methylphenanthrene
Xanthene
2,3,5-Trimethylphenanthrene
Fluoranthene
Pyrene
9-Butylanthracene
Benzo(a)fluorene
Triphenylene
Chrysene
Benz(a)anthracene
1-Methylbenzo(c)phenanthrene
Benzo(a)pyrene
Benzo(e)pyrene
Perylene

Sample Number 111

Naphthalene
2-Methylnaphthalene
1,1'-Biphenyl
1,1'-Oxybisbenzene
Acenaphthene
Dibenzofuran
2-Butylnaphthalene
1-(2-Propenyl)-naphthalene
4-Methyldibenzofuran
9-Methylfluorene
3,4'-Dimethyl-1,1'-biphenyl
Dibenzothiophene
Phenanthrene
9-Methylphenanthrene
2-Methylphenanthrene
1-Phenylnaphthalene
Fluoranthene
Pyrene
Benzo(a)fluorene
Benzo(b)fluorene
1-Methylpyrene
Triphenylene
Chrysene
Benzo(a)anthracene

PRODUCT SOLIDIFICATION AREA

Sample Number 102

Phenanthrene
Anthracene
9-Methylphenanthrene
Pyrene

CONTROL ROOM

Sample Number 098

Not detected

Sample Number 099

4-Ethenyl-1,2-dimethylbenzene
1,2,3,4-Tetrahydronaphthalene
2,3-Dihydro-1,1-dimethylindene
Naphthalene
6-Ethyl-1,2,3,4-tetranaphthalene
2-Methylnaphthalene
1-Methylnaphthalene
1,7-Dimethylnaphthalene
1,1'-Oxybisbenzene
2,2'-Bipyridine
2-(1-Methylethyl)naphthalene
1,2-Dihydroacenaphthylene
Dibenzofuran
2-Butylnaphthalene
1-(2-propenyl)naphthalene
2-Ethyl-1,1'-biphenyl
2,6-Dimethylnaphthalene
9-Methylfluorene
Phenanthrene
3-Methylphenanthrene
2-Methylphenanthrene
9-Methylcarbazole
Fluoranthene
Pyrene
1-Methylpyrene
Benzo(a)fluorene
Benz(a)anthracene
Triphenylene
Chrysene

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[a] Compounds were identified by computer match with library containing more than 25,000 chemical entries.

Table B-5

ANALYTICAL RESULTS OF QUALITATIVE PNA SCAN[a] BULK PROCESS SAMPLES--SRC-II PROCESS

Solvent Refined Coal Pilot Plant
Fort Lewis, Washington

Naphtha (Sample Number 120)	Middle Distillate (Sample Number 121)	Heavy Distillate (Sample Number 122)	Stripper Bottom (Sample Number 123)
1,2,3,4-Tetrahydronaphthalene	Naphthalene	Naphthalene	Naphthalene
Naphthalene	Methyltetrahydronaphthalene	Quinoline	Quinoline
Methyltetrahydronaphthalene	C_1-Naphthalene	C_1-Naphthalene	C_1-Naphthalene
Dimethyltetrahydronaphthalene	Dimethyltetrahydronaphthalene	Acenaphthalene	Acenaphthalene
C_2-Napthalene	C_2-Naphthalene	Acenaphthene	Acenaphthene
Quinoline	Phenylether	Fluorene	Fluorene
Acenaphthalene	C_4-Naphthalene	Phenanthrene Anthracene	Anthracene Phenanthrene
Fluorene	Quinoline	Acridine	Acridine
Phenanthrene Anthracene	Acenaphthalene	Carbazole	Carbazole
Acridine	Acenaphthene	Fluoranthene	Fluoranthene
Carbazole	Fluorene	Pyrene	Pyrene
Fluoranthene	Phenanthrene Anthracene	Benzfluorene	Benzfluorene
Pyrene	Acridine	Benz(a)anthracene Chrysene Triphenylene	Chrysene Triphenylene Benz(a)anthracene
Benzofluorene	Carbazole	C_2-Benzanthracene	C_2-Benzanthracene
Chrysene Triphenylene Benz(a)anthracene	Fluoranthene	Benzopyrene	Benzopyrene
Benzopyrene	Pyrene	Dibenzcarbazole	Perylene
Dibenzo(a,j)acridine	Benzofluorene	Indeno(1,2,3-cd)pyrene	Dibenzacridine
	C_2-Benzanthracene	Dibenzanthracene	Dibenzcarbazole
	Dibenz(a,i)carbazole	Benzo(g,h,i)perylene	Indeno(1,2,3-cd)pyrene
		Anthanthrene	Dibenzanthracene
			Benzo(g,h,i)perylene
			Anthanthrene

[a] Compounds were identified by computer match with library containing more than 25,000 chemical entries.

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