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FINAL

CONTROL TECHNOLOGY ASSESSMENT

FOR

COAL GASIFICATION AND LIQUEFACTION PROCESSES

Exxon Coal Liquefaction Pilot Plant (ECLP)
Baytown, Texas

Report for the Site Visit of
September 8-10, 1981

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Submitted to:

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FOREWORD

The Enviro Control Technology Assessment (CTA) team met with representatives of the Exxon Coal Liquefaction Pilot Plant (ECLP) at Baytown, Texas on September 8-10, 1981. At our initial meeting Donato Telesca of Enviro Control explained the purpose of our visit and outlined the type of information Enviro wanted to collect. Based on this discussion, Robert Earhart of ECLP scheduled Enviro to interview appropriate ECLP personnel over the next two days. Those attending this initial meeting were:

<u>ECLP</u>

Jay Cohen	Engineering/Design Section Supervisor
Robert Earhart	Information Systems Section Supervisor
Paul Bucknam	Industrial Hygienist
Richard Brackett	Technical Manager

<u>Enviro Control, Inc.</u>

Donato Telesca	Program Manager
Harvey Epstein	Chemical Engineer
Jan Scopel	Chemical Engineer

<u>NIOSH</u>

Phillip A. Froehlich	NIOSH Project Officer

Without the excellent cooperation of the personnel at the ECLP facility, especially Mssrs. Bob Earhart, Paul Bucknam, and Dick Brackett, this report would not have been possible.

Those interviewed at the ECLP facility were:

Francis Ferraro	Machinery Engineer
Kary Saleeby	Machinery Engineer
Jeffrey Jones	Materials Engineer
Garry Gard	Mechanical Inspector (Safety Valves)
Harry Costner	Project Engineer
Paul Bucknam	Industrial Hygienist
Raymond Parker	Mechanical Supervisor
Robert Acuff	Lab Coordinator
Adolphus Jones	Process Contact Engineer
Wayne York	Process Testing Section Supervisor
Eugene Golebiewski	Mechanical Engineer (Block Valves)
James McGee	Instrument Engineer

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I. INTRODUCTION

A. Background

The objective of the "Control Technology for Coal Gasification and Liquefaction Processes" program is to study the control technologies currently in use for preventing occupational exposure to hazardous agents in the various coal conversion plants. For the purposes of this study the term "control technology" has a very broad meaning. It includes equipment whose specific function is the control of potentially harmful emissions, such as baghouses, dust collection hoods, and thermal oxidizers. It also includes any equipment design or process design change that increases the reliability of the process. Fewer equipment failures result in less worker exposure due to accidental releases and less exposure of the maintenance personnel who must make the repairs. Controls in this category include better metallurgy and improved equipment designs. We also considered the plant's work practices and industrial hygiene program to be part of the control technology.

This report details the control technology and industrial hygiene information gathered at the Exxon Coal Liquefaction Pilot Plant (ECLP) in Baytown, Texas, during the site visit of September 8-10, 1981.

B. Project History

During the period 1966 through 1973 efforts were concentrated on identifying the basic process flow scheme for coal liquefaction. It was very broad in scope and was conducted in experimental equipment ranging in complexity from 100 cubic centimeter batch units to a continuous 1/2-ton-per-day integrated pilot plant.

The reactor configurations evaluated were: stirred bed, tubular reactor (with external and internal solids recirculation), ebullating bed, and tubular reactor (plug flow). Both hydrogenated and unhydrogenated recycle solvents were evaluated for bituminous and subbituminous coals. Process equipment such as distillation columns, centrifuges, filters and hydroclones were evaluated for their ability to separate coal derived liquids from the unreacted coal and ash residue. Wide ranges of temperatures, pressures and residence times were evaluated in both the liquefaction and solvent hydrotreating reactors. Based on these results, a hydrogenated recycle solvent process was selected for further development, and vacuum distillation was identified as the most promising product-separation technique. A noncatalytic tubular plug-flow liquefaction reactor was selected. These choices circumvented the need for ash-tolerant catalysts and mechanical separation devices.

Engineering studies closely paralleled the laboratory effort during this period. These engineering studies concentrated on the following areas:

- Evaluation of laboratory data.
- Development of conceptual commercial plant designs.
- Studies of processing alternatives to define incentives and provide direction to the laboratory effort.
- Development of cost parameters.

During 1974-1975, major efforts were in the following areas:

- The basic design of the 250 ton-per-day Exxon Coal Liquefaction Pilot Plant.
- The construction and initial operation of the one ton-per-day Coal Liquefaction Pilot Plant.
- The supporting laboratory and engineering R&D program.

The laboratory and engineering R&D program more closely defined operating conditions for the process flow scheme selected. This program concentrated on process variable studies of both bituminous and subbituminous coals. In addition, detailed investigations were conducted of solvent hydrogenation in fixed-bed catalytic reactors.

Cooperative agreements were initiated in 1977 between Exxon Research and Engineering (ER&E) and ERDA (now DOE). Also participation agreements were developed between ER&E and Phillips Petroleum Company, and later Japan Coal Liquefaction Development Company, Ltd., ARCO Coal Company, Ruhrkokle AG, AGIP (Italy), and Electric Power Research Institute for continuation of the project. A contract was awarded in September 1977 to Arthur G. McKee Company for engineering and procurement and to Daniels Construction for construction of the 250 ton-per-day Exxon Coal Liquefaction Pilot Plant.

The objective of the ECLP facility is to develop the Exxon Donor Solvent (EDS) process to the point of commercial readiness by 1983 by serving as a test center for the development of a reliable process and mechanical design, and by producing a sufficient quantity of liquefaction products for extensive product testing.

Testing various coals and residual liquefaction bottoms was performed in the one ton per day Coal Liquefaction Pilot Plant and in a 75 pound-per-day Recycle Coal Liquefaction Unit throughout 1978 and 1979. Operation of these pilot plants is continuing as part of the integrated EDS research and development project.

Startup of the Exxon Coal Liquefaction Pilot Plant was achieved in June 1980. During a four month shakedown period, the Pilot Plant ran successfully for 1245 hours and then, following an inspection turnaround, ran successfully for an additional 2,658 hours during a test using Illinois No. 6 coal. The Pilot Plant was intentionally shut-down in June, 1981, to inspect the equipment, make process modificatons, and prepare for the testing of a second coal type. On July 31, 1981, the Pilot Plant operation began on Wyoming Wyodak subbituminous coal.

C. Process Description

The major steps in the Exxon Donor Solvent process, and the relationship of the ECLP facility to the EDS Process is shown in the block flow diagram, Figure 1. A simplified process flow diagram is shown in Figure 2.

Crushed coal is liquefied in a non-catalytic tubular reactor in the presence of molecular hydrogen and the hydrogen-donor solvent. The liquefaction reactor operates at 800-880°F (427-471°C) and 1500-2000 pounds per square inch.

EXXON DONOR SOLVENT PROCESS

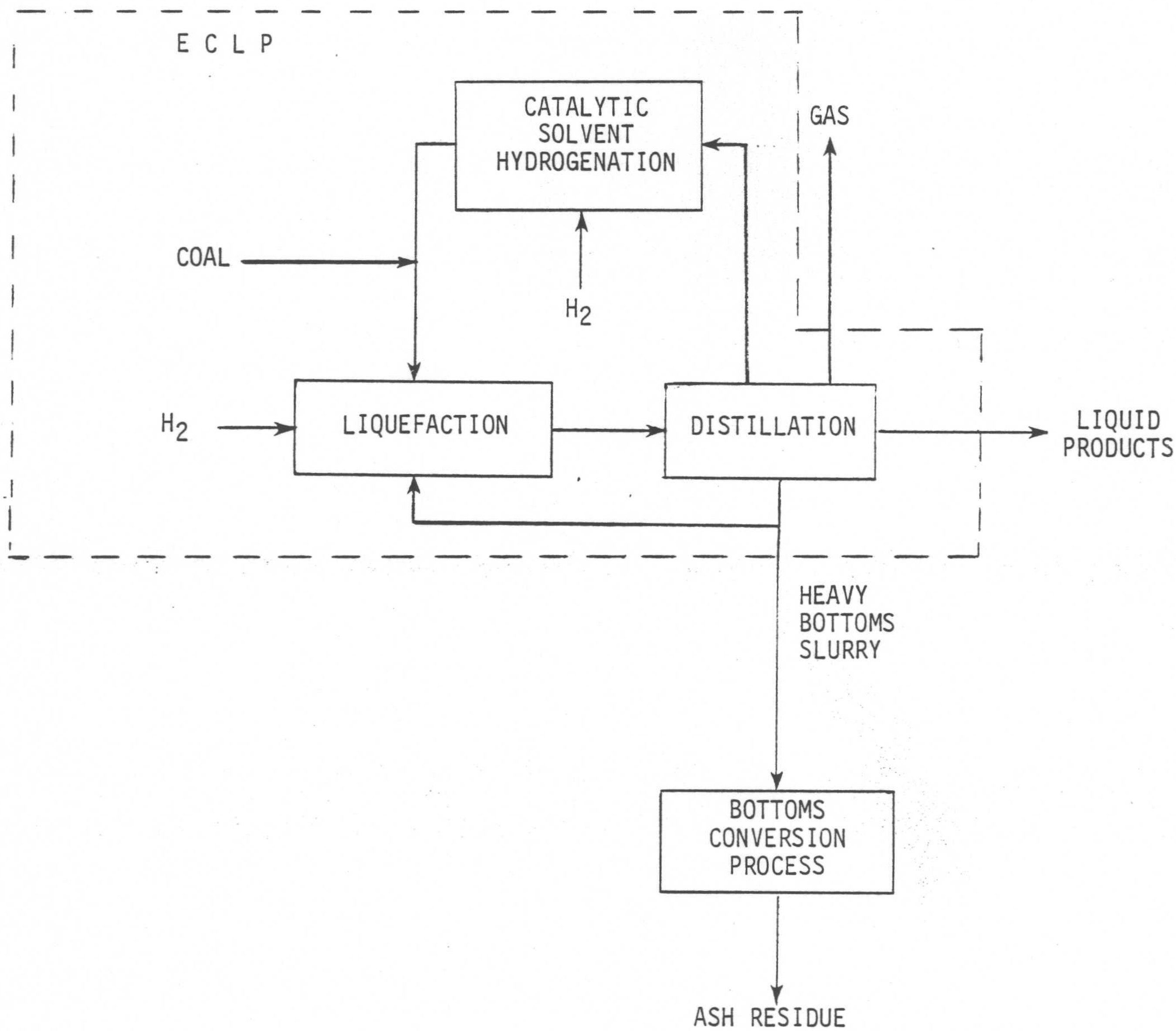

Figure 1. Block Flow Diagram of Exxon Donor Solvent Process

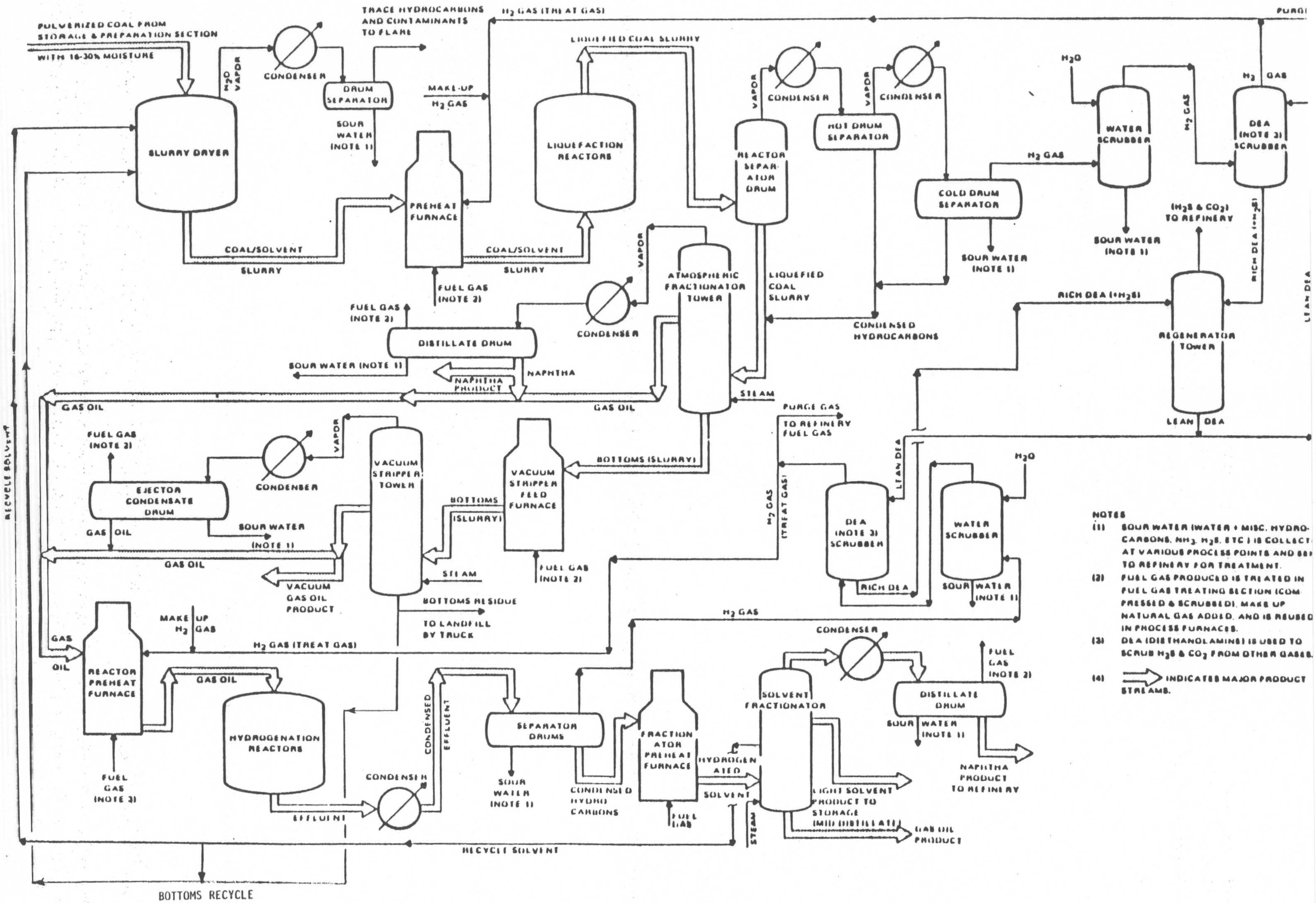

Figure 2. Simplified Process Flow Diagram of ECLP Facility

The hydrogen-donor is a catalytically hydrogenated recycle stream fractionated from the middle boiling range of the liquid product. The solvent is a 400°F-850°F (204-454°C) boiling range material. After hydrogenation, the solvent is mixed with fresh coal feed and pumped through a preheat furnace with the hydrogen treat gas into the liquefaction reactor. Slurry leaving the liquefaction reactor is separated by distillation into gas, naphtha, distillates, and a vacuum bottoms slurry. The vacuum bottoms is solidified on a belt cooler. The Pilot Plant "imports" hydrogen from the adjacent refinery.

The process is simple, and critical processing steps are adaptations of Exxon's petroleum refinery technology. Distinguishing features are the use of a hydrogen donor solvent in the liquefaction reactor, the catalytic hydrogenation of solids free spent solvent, and the use of vacuum distillation for solids/liquid separation. Since the hydrogenation catalyst does not contact coal minerals or high-boiling liquids, long catalyst life at high activity is possible. Hydrogenated solvent produces a greater yield of distillate product than unhydrogenated solvent. The need for mechanical separation devices for solids/liquids separation is avoided.

The process gives high yields of low-sulfur liquids from bituminous and subbituminous coals or lignites. For example, Illinois bituminous coal yields 2.6 barrels of C_4+ liquid per ton of dry coal for once-through operations. Ammonia and elemental sulfur are the only by-products of significance. By varying liquefaction conditions or adjusting solvent properties, product distribution may be varied over a wide range.

D. Pilot Plant Layout

The process equipment is either located on foundations at grade, or housed in open multilevel steel structures. The only enclosed process area is the shed where the coal cars are unloaded. All process areas are paved in concrete. The process areas that comprise the ECLP facility are identified below.

Table 1

Process Areas

Area	Name	Description
CPU	Coal Preparation Unit	Coal unloading, impact mill, gas swept mill
LDU1	Liquefaction Distillation Unit 1	Slurry dryer, slurry feed pumps, liquefaction reactors, high pressure separation drums
LDU2	Liquefaction Distillation Unit 2	Atmospheric and vacuum fractionation towers
LDU3	Liquefaction Distillation Unit 3	Bottoms cooling belt, heat transfer fluid facilities, bottoms recycle facilities
SHU	Solvent Hydrogenation Unit	Solvent hydrogenation reactors, solvent fractionation tower, sour water system, fuel gas scrubbing, acid gas compressors and hydrogen compressors.
OSU	Offsites and Utilities	Tank farm, cooling tower, utility block, wastewater collection system

E. Potential Hazards

Since the Exxon Donor Solvent process generates coal derived liquids, exposure to polynuclear aromatics (PNAs) could occur at many points throughout the process through leaks, spills, and equipment maintenance activities. PNAs, because of their known carcinogenicity, are the hazard of primary concern. The most concentrated PNA containing stream is the vacuum tower bottoms; however, workers are normally exposed to this material only after it has been solidified and thus presents a reduced potential for dermal and inhalation exposure. Table 2 presents the potential hazards by process area.

Table 2
Potential Hazards By Process Area

Area	Hazard
Coal Receipt and Storage	Respirable Coal dust Fire Coal dust explosion
Coal Preparation	Respirable coal dust Fire Coal dust explosion Noise
Slurry Drying	Respirable coal dust Aliphatic and aromatic hydrocarbons Phenols Aromatic amines Hydrogen sulfide Polynuclear Aromatics
Liquefaction	Aliphatic and aromatic hydrocarbons Phenols Aromatic amines Polynuclear Aromatics Hydrogen sulfide Ammonia
Product Distillation	Aliphatic and aromatic hydrocarbons Phenols Aromatic amines Polynuclear Aromatics Organic particulates Hydrogen sulfide
Solvent Hydrogenation	Benzene, Toluene, Xylene Phenols Aromatic amines Polynuclear Aromatics Hydrogen sulfide
Fuel Gas Treating	Hydrogen sulfide Ammonia
Hydrogen Compression	Noise
Utilities and Offsites	Explosive mixtures of hydrocarbon vapors with air Fire Aliphatic and aromatic hydrocarbon vapors

II. ENGINEERING CONTROL TECHNOLOGY

A. Introduction

A two part discussion of each process area in the Exxon Coal Liquefaction 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.

B. Coal Receipt and Storage

1. Process Description

The coal receiving and storage area consists of a 110-ton bottom-dump hopper designed to receive coal delivered by rail. Also provided are feeders, conveyors, and a 5000-ton raw coal storage silo equipped with reclaim feeders. Coal is received and transferred by covered conveyor at an average rate of 300 TPH to the top of the 55-foot diameter, 168 foot high silo (Figure 3).

2. Control Technology

In the coal receiving, storage, and reclaiming operations the following hazardous conditions are found: respirable coal dust, the potential for the spontaneous combustion of coal, and the potential for coal dust explosion.

The following engineering controls are used to mitigate these hazards:

- The railroad cars are covered to prevent coal dust from blowing out.
- There is a water spray dust suppression system at the rail car track hopper.

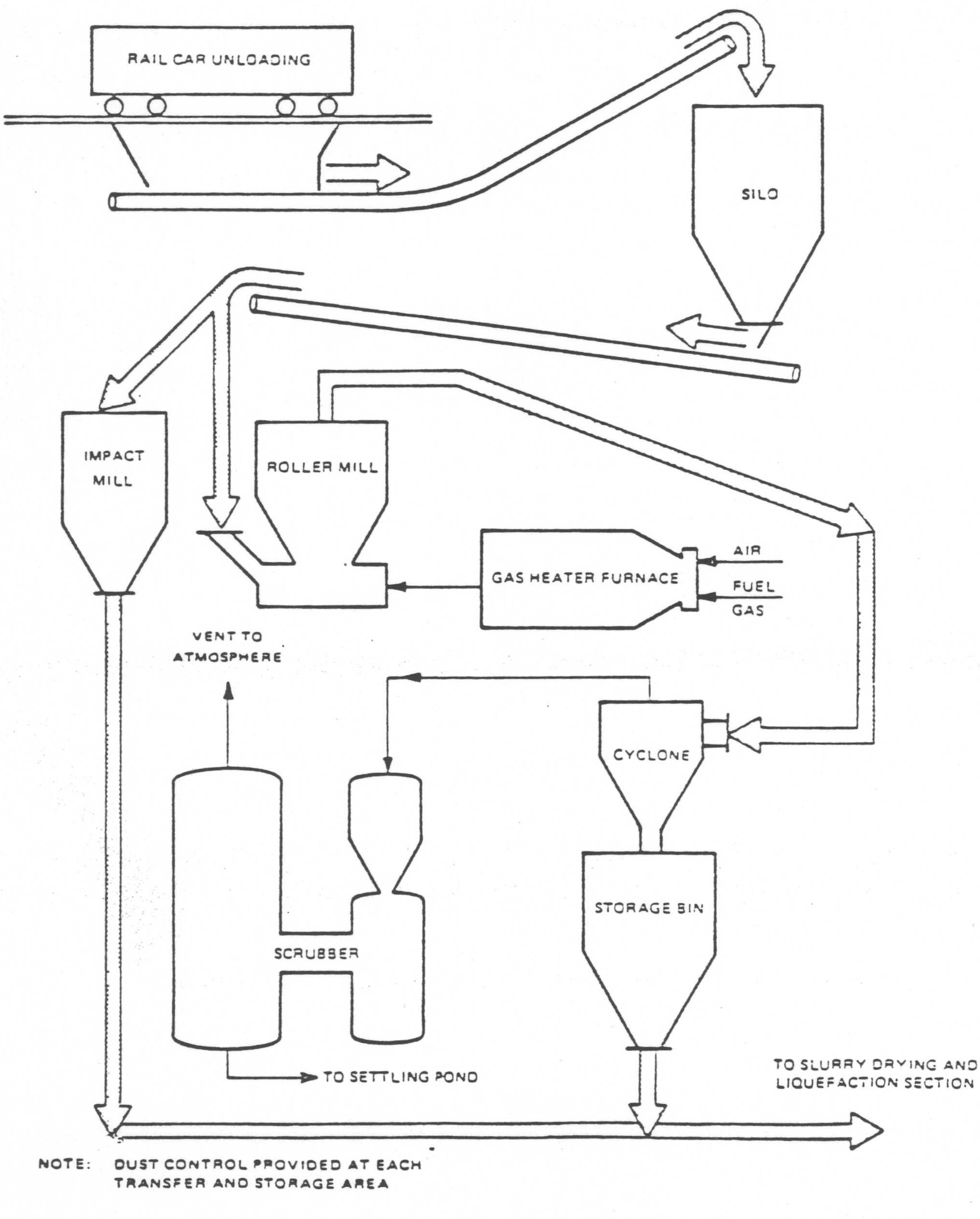

Figure 3. Flow Diagram of Coal Preparation and Storage Area

- There is a bag filter system to filter coal dust from the nitrogen purge gas for the coal silo.

- The conveyor from the track hopper to the coal silo, and the silo reclaim conveyors are covered to prevent coal dust from escaping into the atmosphere.

- The coal silo is nitrogen purged in order to maintain an inert gas atmosphere in the silo and prevent spontaneous combustion of the coal, or a coal dust explosion. The nitrogen is injected with lances in the silo so that the void space between the coal particles is purged as well as the space above the surface of the coal.

C. Coal Preparation

1. Process Description

The coal preparation plant (Figure 3) consists of two parallel equipment trains. In one train coal is fed from the coal storage silo to a dryer-pulverizer system. The coal is ground, classified, and dried with flue gas in a roller mill. The coal is then conveyed with the flue gas stream to cyclones. In the cyclones most of the coal is separated from the gas stream and is discharged through a rotary gas lock to a dried coal storage bin. The gas stream leaving the cyclone goes to a venturi scrubber where the coal fines are removed. The cleaned gas stream leaving the scrubber is split and part of it is recirculated through the drying system heater while the rest is exhausted to the atmosphere.

In the second train, coal from the coal storage silo is fed to a cage mill. The coal is crushed but not dried, and is then fed directly to the slurry dryer.

Only one coal preparation system operates at a time.

2. Control Technology

The hazards associated with the Coal Preparation Area include: respirable coal dust, spontaneous coal combustion, coal dust explosions, and noise.

The following engineering controls are used to mitigate these hazards.

- A venturi scrubber is used to remove coal fines from the roller mill drying gas before discharging it to the atmosphere.
- The crushed coal conveyors are covered to prevent coal dust from escaping into the atmosphere.
- The RPM of the cage mill was reduced for process reasons, however, an advantage of lowering the speed was to reduce noise to an acceptable level.
- The oxygen (O_2) and carbon monoxide (CO) levels in the coal crushing and drying system are monitored in order to prevent coal dust or CO explosions. The amount of oxygen in the system averages 8 to 10-1/2 percent. There is a high O_2 level alarm; however, the alarm does not initiate an automatic shutdown. The system must be shutdown manually. The temperature in the roller mill should be about 300°F. A high temperature in the mill will automatically shutdown the furnace burner. There is also an interlock system that shuts down the coal feed system if the mill stops.
- Dust collection hoods are located over every open coal transfer point. The coal dust is filtered from the collection air by baghouse filters. The nitrogen purge gas from the prepared coal storage bin is also sent to a baghouse filter before being discharged to the atmosphere.
- The prepared coal storage bin is purged with nitrogen in order to maintain an inert gas atmosphere in the bin and prevent spontaneous combustion of the coal or a coal dust explosion.

D. <u>Slurry Drying</u>

1. Process Description

Prepared coal from either the pulverizer-dryer system, or from the impact mill, is conveyed to the slurry dryer. The slurry dryer is an agitated drum that mixes the prepared coal with hot recycle solvent and recycled fluxed vacuum bottoms. The slurry dryer operates in the temperature range of

225-300°F. The coal feed from the impact mill contains moisture which is vaporized in the slurry dryer by hot solvent, vented overhead, condensed, collected in a separator drum, and pumped to the process wastewater treatment area. The slurry dryer operates as a mix tank only for the dry coal from the gas swept mill.

Slurry circulating pumps help mix and heat the slurry by recirculating the contents of the slurry dryer through a steam heated shell and tube type heat exchanger. The slurry circulating pumps also feed the liquefaction reactor charge pumps.

2. Control Technology

The hazards associated with the Slurry Drying Area include the inhalation of coal dust and organic vapors, and dermal contact with process derived coal liquids due to leaks, spills, and equipment maintenance activities.

The following engineering controls are used to mitigate these hazards.

- Coal was originally fed to the slurry dryer through a gate lock valve arrangement. The gate valves were unsatisfactory and were replaced with a rotary valve which has been operating relatively maintenance free since its installation. The valve has Teflon vane tips. The shaft openings in the casing of the valve are nitrogen purged to keep coal dust out of the packing type shaft seals. The rotary valve is vented on its discharge side to a baghouse to control coal dust emissions. A new coal feed system consisting of three screw feeders with the last injecting coal below the liquid level of the dryer will be tested in a future run.

- Vapor emissions from the slurry dryer are controlled by a vent gas system. Light hydrocarbons and water vaporized in the slurry dryer are vented overhead, condensed, and collected in a separator drum. The condensed organics are pumped back to the slurry dryer, the sour water is pumped to the sour water collection drum, and the noncondensible hydrocarbons and other contaminants are sent to the flare.

- To prevent the escape of organic vapors to the atmosphere, the slurry dryer mixer shaft has a double mechanical seal with a self circulating seal oil system. There have been no seal failures through September 10, 1981, the date of our visit.

- The heat exchanger in the recirculation loop of the slurry dryer was originally mounted horizontally and was a U-tube design. The coal particles settled in the channel of the exchanger, blocking the tubes. The plugging problem was solved by replacing the U-tube exchanger with two vertically mounted shell and tube exchanger with a one tube-pass design.

- On one occasion, the slurry dryer overflowed into the overhead vapor condenser and collection drum. This incident occurred when solids settled in the bottom of the dryer and plugged the dip leg of the level recorder differential pressure cell. The reason for the solids settling was too slow a mixing speed. The mixing speed was adjusted and the incident has not recurred.

- Various mechanical design features have reduced the erosion problems in the slurry circulating pumps. The centrifugal pump in use was designed with wider internal flow passages than a pump at similar operating conditions handling clean process fluid (relatively few solids). In addition, the impeller tip speed has been restricted to a maximum of 94 fps, and the volute liner, impeller, and front and back wear plates in the casing are constructed of HC-250, a 28 percent chrome-iron wear resistant material. Because of the slow tip speed, two pumps are operated in series to get the required head. An experimental circulating slurry pump operating at 3600 RPM wore out quickly.

  There are problems maintaining flush oil to the single mechanical seal on the slurry pump and as a result there is a seal failure about every three months. The flowrate of seal fluid is about one gpm. One factor contributing to the seal failures is that fines get into the seal fluid. The ECLP mechanical engineers are currently working on a floating carbon type bushing with a clearance of 0.002 to 0.005 inch that will allow seal fluid flow rates of 3/4 gpm. Seals with this bushing should be more effective.

- The liquefaction reactor high pressure feed pumps are plunger pumps. These pumps are a source of exposure to coal derived process fluid because of packing leakage and frequent packing replacement. A synchronized flush oil system and careful alignment of the plungers in the cylinders have extended packing life to 15 to 20 days.

  Erosive wear of this pump is minimized by the use of a plasma sprayed coating of tungsten carbide in a cobalt-chromium binder on the plungers. Softer sprayed and fused coatings wear too quickly and the very hard ceramic coatings tend to spall. Spalling is undesirable because failure is unpredictable and instantaneous.

  Another problem with the high pressure feed pumps is inadequate dampening of low frequency pulsations. The pulsations shake the piping and can cause flange leaks; however, there have been no significant flange leaks to date.

The check valves in the feed pump have tungsten carbide seats and 440C stainless steel balls. The balls are free floating, not spring loaded. Occasionally coal particles lodged between the ball and the seat or guide cause the check valves to stick open. The closure of the check valve shakes the process piping, accelerates wear on the pump gears, and could potentially break a gear tooth. A solution to this problem has not yet been found.

Exposure to process fluid that leaks past the packing is controlled by a leak-off system. Leak-off lines are sloped to leak-off containers. If the process fluid has a high solidification temperature, the leak-off line is steam traced.

- An attempt was made to protect the pressure safety relief valve on the discharge line of the high pressure slurry pump from contact with the process fluid by using a hydrogen purge. The hydrogen was injected underneath the relief valve and flowed into the discharge line of the slurry pump. The purpose of the purge was to prevent solids from getting into the body of the relief valve and possibly jamming the relief mechanism. The test did not work.

- The block valves on the discharge of the slurry feed pumps must seal tightly in slurry service and contain system pressures of about 2700 psig without leaking. Plug valves are used in this service. The equalizer ring used in these valves was originally made of low-alloy steel and the cut-out for the valve stem had sharp corners. Each corner of the cut-out was a stress point. One of the equalizer rings cracked at a corner of the cut-out. As a result the equalizer rings are now fabricated from 17-4 precipitation hardened stainless steel, and the corners of the cutout are now rounded. Additionally the sealant originally used in the valve body cavity dissolved in the process fluid. The sealant now used, does not dissolve, and is injected once a week.

- The block valves used in low pressure slurry service are through conduit gate valves. These valves are flushed with solvent every time they are used to remove solids from the body cavities.

E. Liquefaction

1. Process Description

Slurry from the high-head slurry feed pumps is mixed with hydrogen recycle gas and is fed to the slurry preheat furnace. From the furnace, the hot slurry is fed to the liquefaction reactors. Nominal reaction conditions for once through operations are 2,000 psig at 449°C and a residence time of 40 minutes. The reactor product consists of light hydrocarbon gases, C_4-540°C boiling range distillate, hydrogen sulfide, water vapor, carbon dioxide, ammonia, and heavy bottoms made up of +540°C boiling range liquids, unreacted coal, and mineral solids. The reactor product is separated into an overhead stream and a bottoms stream in the reactor separator drum. The overhead stream is composed mostly of unreacted hydrogen, with light hydrocarbon gases, condensible organic vapors, water vapor, hydrogen sulfide, and ammonia. The bottoms stream is a slurry composed of high boiling hydrocarbons, unreacted coal, and mineral residue.

The slurry stream is reduced in pressure through a single let-down valve and sent to the atmospheric fractionator. The overhead stream is cooled to recover condensible hydrocarbons, water washed to remove ammonia, and finally scrubbed with diethanolamine (DEA) to remove the hydrogen sulfide. This hydrogen rich gas stream is then recycled to the slurry preheat furnace. The condensed hydrocarbons are sent to the atmospheric fractionator. A portion of the condensed water is used in the water scrubber to remove ammonia, and the excess water is sent to the sour water collection drum.

2. Control Technology

The hazards associated with the Liquefaction Area include inhalation of organic vapors, and dermal contact with process derived coal liquids due to leaks, spills, and equipment maintenance activities, and noise from the furnace burners and the slurry letdown valve.

The following engineering controls are used to mitigate these hazards:

- The slurry letdown valve has an acoustical wrapping, and the process furnace is equipped with burner mufflers to limit noise caused by high air intake volume.

- Because the slurry letdown valve operates at high temperature and high pressure, and handles an erosive slurry, this valve was anticipated to be a potential source of exposure due to process fluid leaks through the valve stem packing, and frequent replacement of the valve trim because of wear. Valve stem leakage has not been a problem, and during the bituminous coal run the valve operated for 128 days without a valve trim failure. At the end of the run the valve showed minor wear. The mechanical design features, and maintenance procedures appear to have overcome these problems.

The slurry letdown valve is a streamlined angle valve. The valve has carbide alloy wear resistant trim, and is tungsten carbide lined below the seat. The pipe after the valve is refractory lined. The valve stem is packed with alternating coils of graphite and braided asbestos packing. Once a week a high temperature lubricant is injected into the packing to keep solids out and prevent sticking.

- Another potential source of exposure is leaking high pressure (2000-2500 psig) flanges. The leaks appear as smoke so they are easy to detect. Metal ring gaskets are used with the high pressure ring-joint flanges. The experience at the ECLP facility has been that leaking flanges have always been the result of poor alignment or poor workmanship in assembling the flanges. Exxon now gives the contract maintenance workers a 3-4 hour training session before allowing them to assemble the high pressure flanges. The following elements are critical for proper assembly: gasket and flange faces must be absolutely clean and unmarred, the flange faces must be properly aligned, and the flange bolts must be tightened in the specified sequence and to the correct torque. Since instituting the training sessions very few flange leaks have occurred at ECLP. If a leak does occur, a sealant is pumped into the leaking flange. However, this is done only as a last resort.

F. Product Distillation

1. Process Description

The slurry stream from the reactor separator drum, and the condensed hydrocarbons from the reactor separator drum overhead, are fed to the atmospheric fractionation tower. Here, the combined stream is separated into fuel gas, naphtha, gas oils, and solids-containing bottoms. The gas oils are pumped to solvent hydrogenation. The naphtha is sent either to the solvent hydrogenation fractionator, or directly to product storage. The atmospheric fractionation tower at ECLP operates with a positive pressure of approximately 21 to 24 psig and at a temperature between 594-649°F (312-343°C). The bottoms from the atmospheric tower are heated in the vacuum stripper feed furnace and fed to the vacuum stripper tower where fuel gas, light vacuum gas oil (LVGO), heavy vacuum gas oil (HVGO), and solids-containing vacuum bottoms are separated. The LVGO and HVGO are combined and pumped to solvent hydrogenation.

A portion of the solids-containing vacuum tower bottoms is fluxed with solvent and recycled to the slurry dryer. The balance is fed to two distributor nozzles which spread the slurry across the width of a steel-belted cooling conveyor. The slurry cools and solidifies on the steel belt into a sheet approximately 1/4" thick. The solidification is accomplished by spraying cooling water on the underside of the cooling belt. The bottoms product solidifies into a brittle sheet which breaks into small pieces as it discharges from the end of the cooling conveyor. The material then falls through a chute onto a conveyor which elevates the material and discharges it into portable steel containers. The material is removed in these containers and stored for future use.

2. Control Technology

The hazards associated with the fractonation section include inhalation of organic particulates and vapors, and dermal contact with process derived coal liquids. The major sources of exposure are: fumes and particulates from the cooling conveyor, vapors from the vacuum tower bottoms pump, and contact with high boiling hydrocarbons in the course of clearing process lines of pluggages. Other sources of exposure are process leaks and spills, and equipment maintenance activities.

The following engineering controls are used to mitigate these hazards.

- When the vacuum tower bottoms product stream is discharged onto the cooling belt, a hydrocarbon aerosol generates. The lightest component of the vacuum bottoms is a hydrocarbon with a boiling range of 750-800°F (399-427°C). The fumes from the cooling belt are withdrawn and sent through a high-energy venturi scrubber. The original scrubber design was inadequate for this service and the bottoms line and demister pad became plugged with tar. These problems were solved by heating the scrubber water, changing to a once-through water operation, and by redesigning the throat of the venturi to get better contact by increased differential pressure.

- The atmospheric tower bottoms pump is a reciprocating pump that originally leaked process fluid through its packing. A redesign of the stuffing box reduced the leakage. In a commercial plant this will probably be a centrifugal pump because of the higher flow rate.

- The pressure safety relief valve on the discharge line of the atmospheric tower bottoms pump is protected from contact with the process fluid by a solvent purge. Clean solvent is injected underneath the relief valve and flows into the discharge line of the bottoms pump. This valve is also steam traced and insulated. This prevents atmospheric tower bottoms material from getting into the body of the relief valve, cooling, and solidifying. In a commercial plant there would be no need for this relief valve because the atmospheric tower bottoms pump would be a centrifugal pump, not a reciprocating pump.

- The vacuum tower bottoms pump is a screw pump that operates at 600°F (316°C). Hydrocarbon fumes escape through the pump packing. Occasionally, operators must wear respirators when working around this pump, depending on pump conditions. The ECLP plant engineers believe that mechanical seals on the pump will reduce the leakage. In a commercial plant this will probably be a centrifugal pump because of the higher flow rate.

- The pressure safety relief valve on the discharge line of the vacuum tower bottoms pump was electric traced and insulated to prevent the vacuum tower bottoms material from getting into the body of the relief valve, cooling, and solidifying. A solvent purge could not be used because this pump conveys material to the solid belt cooler for product solidification. The heat tracing and installation has not been effective in preventing vacuum tower bottoms material from solidifying in the body of the relief valve.

- The vacuum bottoms recycle pumps are centrifugal pumps with double mechanical seals. These are the only pumps in the plant with double mechanical seals. These pumps have their own skid mounted seal oil system. The bottoms recycle pumps have been in service since July 31, 1981, and there have been no seal leakage problems to date (September 10, 1981). An advantage of individual skid mounted seal oil systems is that if a pump leaks solids containing process fluid into the seal oil the entire seal oil system is not contaminated, only that one pump is affected.

- Plugging of the vacuum tower bottoms lines has been a recurring problem. The first method employed to clear the blockage is the use of a ram pump and flush oil. Care must be taken not to exceed the pressure rating of the pipe. If this does not clear the line then the pipe must be disassembled and mechanically cleaned. This is a major source of worker exposure to heavy coal derived process liquids and solids.

Other potential sources of worker exposure are equipment failures from erosion and/or corrosion that result in environmental releases. However, ECLP has experienced only one significant release due to line erosion/corrosion.

o The slurry line between the vacuum tower preheater and the vacuum tower is now lined with castable, 95% alumina refractory, The refractory is reinforced with 304 stainless metal fibers. The elbow between the heater and the tower is a long sweep elbow. Previously, this line was not refractory lined, and the required 90° change in direction was accomplished first with a drilled block. When this eroded through it was replaced with a "flooded-T." The principle behind the flooded-T is that the capped arm of the tee fitting will pack with solids so that the solids rather than the wall of the fitting will take the abrasion from the change in fluid direction. This modification provided longer life than the drilled block, but also failed..

- Corrosion caused a leak in the shell of the atmospheric fractionator. Two of the constituents of the fractionator feed are phenols and organic chlorides. At about 450°F (232°C) HCL is liberated and readily dissolves in the phenols. The organic acid then formed rapidly attacked the carbon steel shell of the tower. The section of the tower where the corrosion took place was lined with type 321 stainless steel. This has minimized the corrosion problem.

- The feed to the vacuum tower enters through a tangential feed nozzle at 200 fps. Centrifugal force separates the solids and liquids in the feed from the vapor that is flashing overhead. An inspection of the flash zone of the vacuum tower revealed that erosion had occurred through a 1/2 inch stainless steel wear plate and through the refractory lining behind to a depth of several inches where the feed impinged on it. The refractory lining was replaced with a wear resistant lining of bricks made of sintered alumina with a ceramic binder.

G. Solvent Hydrogenation

1. Process Description

The solvent hydrogenation section is designed to catalytically hydrogenate oil from the product distillation section. The feed to the hydrogenation unit consists of all the products from the product distillation section except fuel gas and vacuum stripper bottoms. The purpose of the hydrogenation section is to catalytically regenerate the hydrogen depleted solvent from the liquefaction reaction. The hydrogenation facilities are similar to hydrotreating units which are operated in typical refinery services on similar boiling range feedstocks. The liquid feed enters the Solvent Hydrogenation Area at 160°F (71°C) and is stored in a feed surge drum after passing through a feed filter to remove large particulates. It is then pumped to the required process pressure, preheated by heat exchange with reactor effluent, mixed with a hydrogen-rich treat gas, and fed to the reactor preheat furnace. After being heated in the reactor preheat furnace, the feed is pumped to a series of four fixed-bed reactors containing a nickel-molybdate catalyst. The reactor effluent is cooled by heat exchange with the incoming feed and sent to the hot separator drum. The vapor from the hot separator is further cooled by heat exchange against cooling water and fed to the cold separator drum.

The vapor from the cold separator drum is water washed and DEA scrubbed for NH_3 and H_2S removal. A portion of the scrubber gas is withdrawn as a purge and sent to the Exxon Baytown Refinery fuel gas system. The remainder of the scrubbed gas is compressed, make-up hydrogen is added, and the mixture is recycled back to the hydrogenation reactors as treat and quench gas. The quench gas is added between the reactors as required to control reactor temperatures.

The liquid streams from the hot and cold separator drums are combined and sent to the solvent fractionator preheat furnace. The solvent fractionator separates the hydrogenated liquid products into three streams; fresh recycle solvent, off gas, and naphtha. The fresh recycle solvent is cooled and pumped to the slurry dryer via intermediate storage. Excess solvent is pumped to product storage. The off gas is condensed and separated by hot and cold drums into fuel gas, sour water, and a naphtha cut. The naptha product is cooled and pumped to storage.

The hydrogenated solvent required for initial start-up was supplied by hydrogenating raw creosote oil in the solvent hydrogenation section.

2. Control Technology

The hazards associated with the Solvent Hydrogenation Area include inhalation of organic vapors, and dermal contact with process derived coal liquids due to leaks, spills, and equipment maintenance activities.

To date this area of the pilot plant has operated without incident. However, at the time of the visit, specific information on control technology was not available.

H. Fuel Gas Treating Section

1. Process Description

The off gas or fuel gas from the product distillation and solvent hydrogenation sections is sent to the fuel gas treating section where it is compressed, cooled to remove sour water, water scrubbed to remove NH_3, and DEA scrubbed to remove CO_2 and H_2S. The fuel gas treating section is designed to process 1.75 million SCF/SD of feed. The sweetened gas from the fuel gas DEA scrubber is fed to the fuel gas system where it is used to fire the various preheat furnaces. The rich DEA from the DEA scrubbers is stripped of CO_2 and H_2S in the DEA regenerator tower and pumped back to the scrubbers. The stripped CO_2 and H_2S are sent to the Baytown refinery for further processing.

2. Control Technology

The hazards associated with the Fuel Gas Treating Area are exposure to hydrogen sulfide and ammonia gases due to leaks, spills, and equipment maintenance activities.

Because it is 2 miles from the ECLP site to the Baytown Refinery sulfur plant corrosive acid gas condensate would form in this line unless preventive measures are taken. In order to dry the acid gas and thereby eliminate the possibility of corrosion in this line, the gas is compressed and cooled, the condensate is removed, then the gas is depressurized to lower the water dew point sufficiently to ensure that no condensate is formed along the length of the pipeline. In a commercial plant the sulfur recovery plant would be much closer to the DEA scrubbers and the pipeline would be steam or electric-traced and insulated to prevent condensation.

Other engineering controls in this process area include: continuous H_2S monitors with an audible alarm if a leak is detected; appropriate material selection for corrosion resistance; and the use of pulsation dampeners on the high pressure wash water reciprocating pumps to prevent flange leaks or a catastrophic line failure due to vibration.

I. Hydrogen Compression Section

1. Process Description

The hydrogen compression section provides make-up hydrogen to the liquefaction and solvent hydrogenation sections. Hydrogen received from the Baytown Refinery by pipeline is compressed from 555 psia to 2815 psia. Two electric motor driven compressors are provided, with one serving as a spare.

2. Control Technology

The health hazard associated with this process area is noise. Personal protective equipment is used to control exposure.

J. Utilities and Offsites

1. Process Description

a. Cooling Water System

Cooling water is provided via a recirculating cooling water system which consists of a multicell induced-draft cooling tower, distribution and return systems, and chemical addition facilities. A motor driven pump operates under normal conditions, and a steam turbine driven pump serves as a spare. Both pumps have 100 percent circulating capacity.

The cooling water system is designed to supply 8000 gpm of cooling water at 87°F (31°C) to the various ECLP consumers. Make-up water for the cooling tower comes from the industrial water source, which is supplied by the Baytown Refinery, and blowdown from the system is sent to the oily water sewer.

b. Hydrocarbon Flare and Blowdown Systems

Equipment is provided to collect the hydrocarbon releases from safety and control valves, process vents, and the fuel gas compressor suction knockout drum drains. The collected releases are then directed to appropriate disposal facilities.

The flare and blowdown systems consist of:

- flare and blowdown line collection header(s) and associated laterals from individual release sources;
- a noncondensable safety valve release and blowdown drum;
- a flare seal drum; and
- a 150 foot flare stack with a smokeless burning tip.

The noncondensable safety valve release and blowdown drum has been provided with a steam coil to vaporize light hydrocarbon components and send them to the flare. Alternatively, the coil can be used as a cooler for hot, fluxed releases before pump-out to the solvent oil slop tank.

The flare seal drum is provided with a high level seal leg to prevent flooding the flare in the event the liquid level control valve fails in the closed position. Overflow is directed to an open inspection pit pump-out sump from which it is sent to the blowdown drum area drainage sump. Sealing is accomplished by a continual flow of industrial water under level control. The potentially sour sealing water is pumped to the sour water collection facilities.

c. <u>Fire Protection Systems</u>

The fire protection facilities are designed to be compatible with the Baytown Refinery fire fighting equipment. Mobile equipment, such as foam trucks, pumpers, and equipment trucks will be furnished by the refinery should such support equipment be required.

Firewater intake is from the San Jacinto River Canal. Intake is by two 2000 gpm pumps, one driven by an electric motor and one driven by a diesel engine. The intake system specified is similar to the existing Baytown Refinery system and was selected on the basis of its proven reliability.

A looped firewater distribution network is provided. Valving and lines are arranged to permit isolating a ruptured line within the loop system. If a fire should occur, water will be supplied to an emergency area at a minimum pressure of 80 psig and at a flow of at least one-half of the design flow rate.

Hand fire extinguishers of the dry chemical type are placed throughout the plant so that the travel distance from any area to an extinguisher does not exceed 50 feet. A wheeled dry chemical extinguisher is provided for each process unit, and CO_2 extinguishers are provided for the electrical substations.

Two monitor nozzles are located near the coal preparation mill and one near the raw coal silo. If necessary, these monitors are capable of covering the emergency coal dump pits with fog streams, and the bottoms of the raw coal silo and prepared coal storage bin with direct streams. Other fire monitors are located throughout the plant.

d. Tankage

The naphtha products are transported in uninsulated lines at temperatures of about 110°F (43°C). Two 350-bbl intermediate drums provide for gauging naphtha during material balance periods. These drums normally operate at 15 psig under pressure control. Prior to transfer of naphtha to tankage, the light components in the naphtha product drum are vaporized and sent to the fuel gas system to reduce the vapor pressure of the naphtha sufficiently to allow storage in the four ECLP floating roof tanks (two 10,000 barrel tanks, one 750 barrel blend tank, and one 20,000 barrel product tank). Naphtha is shipped to the adjacent Exxon Chemical Plant for use as furnace fuel.

Three types of tankage are required for solvent oil:

- Four 10,000-bbl cone roof tanks are provided to meet various process objectives. They store hydrogenated creosote oil required for start-up, current solvent production for day-to-day operation, and high-quality equilibrium solvent product after the unit has been lined out. These four tanks are manifolded to provide maximum operating flexibility.
- A 350-bbl intermediate cone roof tank for gaging products during material balance periods.
- Two 5500-bbl cone roof tanks are provided for slop oils that may contain unconverted coal fines. The tanks are provided with mixers to maintain these fines in suspension. The contents of the slop tank are rerun periodically using facilities in the liquefaction section.

All gas oil lines are electrically traced and insulated to maintain them at 300°F (149°C). In-tank heaters using 600 psig steam are provided to maintain tank temperatures.

Heavy gas oil may rundown into (1) a 1300-bbl product cone roof tank provided for surge capacity between the plant and refinery slop system, (2) a 300-bbl intermediate cone roof tank for gaging products during material balance periods, or (3) a 3000-bbl heavy slop cone roof tank to receive hot or heavy-oil slurries containing unconverted coal fines. This largest tank is provided with a mixer to maintain the coal fines in suspension and its contents are rerun periodically using facilities in the liquefaction section.

Disposal of gas oil product is to the refinery's fuel oil pool and is done in a batch operation. Each batch is tested to see if it meets refinery specifications before being pumped to the refinery in the transfer line.

e. Sewer Systems and Wastewater Treatment

The ECLP facility has an oily water sewer system, a non-oily water system, and a closed drain system.

The oily water sewer system collects the oily water generated by housekeeping activities, such as hosing down process areas; storm water run-off from the process areas; and scrubber water from the cyclone and the bottoms cooling belt venturi. The oily water sewer system drains to a sump where the floating oil is skimmed off and pumped to the slop tank. Water in the sump that has been skimmed is pumped to the oily water retention tank. From here the water is pumped to the Baytown Refinery for further processing.

Non-oily water from cooling tower blowdown, the flare seal drum, once through cooling water, steam condensate, and storm water run-off from the bottoms cooling and coal preparation areas is pumped to the non-oily water retention ponds where sufficient residence time is provided to settle the solids. The clarified non-oily water is then pumped to the refinery for further processing.

The closed drain system allows residual hydrocarbon liquids left in a piece of equipment after it has been removed from service to be dumped into a closed system, rather than into the open oily-water sewer system. Liquids put into the closed drain system are pumped to the slop tank.

2. Control Technology

a. Cooling Water System

Cooling water treatment requires handling sulfuric acid, caustic, chlorine, and chromate inhibitor. These materials are handled safely using standard refinery or chemical plant practices.

b. Hydrocarbon Flare and Blowdown Systems

The flare and blowdown systems provided at the ECLP facility are standard refinery systems. The primary hazard associated with the flare system is formation of an explosive mixture in the flare header from diffusion of air down the flare stack. A seal drum has been provided, per standard design practice, to prevent this from occurring. The flare stack has a smokeless flare tip. This type of tip improves combustion and therefore decreases the emissions of unburned hydrocarbons.

c. Fire Protection Systems

The fire protection systems provided at the ECLP facility are standard refinery systems. No special considerations beyond standard refinery fire protection systems were installed because ECLP is a coal conversion plant.

d. Tankage

The hazards associated with the tankage area are inhalation of hydrocarbon vapors, and the potential for a fire or explosion. Because the naphtha storage drums operate at pressures up to 15 psig, these tanks are designed to be vapor-tight. Consequently there will be no hydrocarbon emissions from the naphtha storage drums unless the internal pressure exceeds 15 psig and there is a safety valve release. Safety valves release to the closed flare system minimizing hydrocarbon emissions. All naphtha storage tanks are provided with one inch of insulation to reduce safety valve releases during a fire emergency. Emissions from the storage tanks are minimized through the use of floating roofs.

The vapor pressure of solvent and gas oil at storage temperatures is well below 1.0 psia, allowing the use of cone roof tanks. Because cone roof tanks are vented there will be vapor emissions from these tanks; however, the amount of vapor loss will be small due to the low vapor pressure of the materials being stored. Because it was initially suspected that solvent and gas oil vapors would cause an odor problem, activated carbon canisters were installed on the tank vents for odor control. However, this modification has not been required.

e. Sewer Systems and Wastewater Treatment

The hazards associated with the ECLP sewer and wastewater treatment systems are: inhalation of organic vapors, and the possibility of an explosion in the closed drain system due to infiltration of air.

Because the oily water sewer system is an open drain system, organic vapors are released from the drains, from the oily water skimmer sump, and from the oily water retention pond. The emissions from these sources are uncontrolled. The closed drain system is not open to the atmosphere; consequently, the opportunity for organic vapor emissions, or the infiltration of air is minimal.

III. WORK PRACTICES

A. Housekeeping

Housekeeping activities are designed to control worker contact with coal tars by removing coal tar deposits from equipment, flooring, and structures within the process areas, and by keeping tools clean. Exxon uses a mixture of an industrial-strength caustic detergent and either steam or a high-pressure water spray to keep tools and work sites clean. Tools are cleaned by the maintenance laborers in an area designated for this purpose. At least one section of the plant is cleaned each day by field maintenance personnel using the detergent.

The ground level of the process areas is constructed of concrete and diked to contain spills, and washdown water. Drains located in the process areas receive the runoff from clean-up activities.

B. Maintenance

1. Preventive Maintenance

The pressure safety relief valves are critical to the safe operation of the ECLP plant. If, because of a system malfunction, a section of the process becomes overpressured, the relief valve opens and vents the excess pressure to the flare system. This prevents a process vessel or pipeline from bursting. Pressure relief systems are standard for chemical and petrochemical plants.

Six critical safety valves are inspected every three months; all others are inspected at intervals varying from six to twenty-four months. The inspection schedule is computerized to insure that each valve is inspected on schedule.

The inspection procedure involves removing the safety valve, cleaning it, and sending the valve to a contractor who tests the relief pressure, disassembles and inspects the valve, and finally resets and tests it. The valve is returned to the ECLP plant sealed to insure that it was not tampered with after it left the contractor's shop.

Another preventive maintenance program at ECLP is an automatic corrosion monitoring system. Probes have been installed to monitor corrosion continuously at approximately 20 sites where corrosion is likely to be a problem. The probes are tied to a data logger that records measurements from the probes every six minutes and generates a daily printout of corrosion rates. This permits early detection of a corrosion problem, and thus aids in avoiding a potentially catastrophic failure.

2. Maintenance Procedures

To isolate a vessel or tank that must be entered, simply blocking all lines (closing valves) into and out of the equipment is not acceptable. The procedure for preparing a vessel or tank for entry is as follows:

- The remaining contents of the vessel is emptied to the closed sewer system
- All lines must be blinded
- The vessel is chemically cleaned
- The vessel is steamed
- Air is drawn through the vessel with an eductor
- The atmosphere in the vessel is tested for oxygen content, explosivity, and toxic gases (light hydrocarbons, hydrogen sulfide).

Pipelines are cleaned before disassembly by flushing with the EDS Solvent. Pumps are either steamed, water-washed, or detergent-washed before disassembly.

Small equipment, such as valves, are cleaned in degreasing vats before they are worked on.

The maintenance workers are responsible for cleaning up when they have finished a job.

C. Sampling

The sample bottles that come to the laboratory are first wiped down. The technicians wear rubber gloves, and coveralls which are cleaned at the ECLP plant. Samples are handled in hoods. Used samples are poured into a drum. Sample bottles are crushed and put into another drum. The drums are kept under a ventilation hood until they are removed for disposal. It is a company rule that the laboratory technicians must shower before leaving the plant site. A two locker system has been installed. The workers get paid for shower time.

D. Administrative Controls

Entry into the process area by personnel not assigned to the facility is regulated to keep track of the people within the process area. This is accomplished by requiring these persons to sign in at the control room prior to entering the process area, and sign out upon leaving the area. Personnel not familiar with the plant's hazards and safety procedures require an escort.

IV. PROTECTIVE CLOTHING AND EQUIPMENT

The minimum protective equipment required for entering the process area are hard hats, safety glasses, oil-resistant leather safety shoes, and long-sleeves. Coveralls are furnished for employees working in the process area for extended periods. Other protective clothing and equipment is dictated by the activity. The additional equipment available includes:

- PVC slicker suits
- PVC gloves
- PVC boots
- PVC disposable shoe covers
- Respirators

Protective clothing is selected on the basis of its ability to resist aromatic oil penetration. Neoprene does not resist the coal derived aromatic oils typically encountered in the ECLP facility. Safety shoes with neoprene soles disintegrated after one week. Safety shoes with oil-resistant soles are now used. The safety personnel at ECLP also advocate the use of PVC gloves, however leather gloves, or thin latex type rubber gloves are available for times when dexterity is needed. Because leather and rubber gloves are readily available at ECLP, used gloves are discarded before they become saturated with oil or deteriorate. Choosing the proper type of glove for the job and determining when the glove is no longer protecting the worker from contact with process contaminants are problems that may not be dealt with adequately in a commercial facility.

Full face piece respirators with organic vapor/high efficiency cartridges for particulates and a wide-range of organic vapor contaminants, and self-contained breathing equipment are available to trained employees. The maintenance and care of these respirators are under the direction of the industrial hygienist.

The following rules were developed by the safety personnel to insure that the proper protective equipment is used.

- Wear PVC boots and slicker suits when protection by coveralls is inadequate during any activity where contact with coal-tar liquids may occur.
- Wear oil-resistant gloves in handling coal-tar contaminated equipment or tools, and where contact with coal tar liquids may occur.
- Use organic vapor/high efficiency filter cartridge equipped respirators if working around any vapor or fume emissions or in any area where the industrial hygienist indicates such protection is necessary.

V. MONITORING PROGRAM

A comprehensive program of area sampling and personal monitoring has been implemented at the ECLP facility. The program is designed to characterize emissions from all operations, evaluate worker exposure to these emissions, and implement needed controls. The potential hazards selected for study include coal dust, organic vapors, particulates, benzene-soluble fraction, polynuclear aromatics, hydrogen sulfide, and noise. The sampling program includes pre-starting, baseline, and one comprehensive survey during each coal operation.

VI. HEALTH AND SAFETY PROGRAMS

A. Employee Education and Training

All workers at the liquefaction facility have been provided with the details of the occupational health program through group meetings and booklets. A slide/tape program and workbooks were used to provide the employees with an understanding of the contents of the health program. Written tests are used to determine the degree of understanding of the material presented. Outside contractor personnel are also required to take part in this educational program.

Special meetings are held on an as-needed-basis to keep ECLP personnel and outside contractor supervisors abreast of changes in the health program. Contents of the program and any specialized training such as respirator usage are reviewed on an annual basis.

B. Personal Hygiene

Guidelines have been developed to keep worker contact with process constituents to a minimum. These guidelines apply to process and mechanical personnel and include:

- Removal of hard-to-clean jewelry before entering the process area
- Gear such as tools, rags, and slicker suits are not allowed in eating facilities. Hands and face must be washed before entering these areas. Cleanup facilities are provided at the entrance to the lunch area
- Face and hands must be washed before entering smoking and refreshment areas
- Clean hands before and after using rest room facilities
- Wash contaminated skin and change contaminated clothing as soon as possible
- Mandatory showering at the end of each shift
- Use of clean coveralls at the start of each shift

To increase the effectiveness of this hygiene program, signs are used as reminders and to reinforce these guidelines.

A change house equipped with a "clean" and a "dirty" change room is used at ECLP to keep coal tar contaminated material from leaving the work site. In this system the worker enters the clean change room at the start of the shift, places his street clothing in a locker, dons a clean set of coveralls, and passes through the dirty change room to enter the plant. At the end of the shift, the worker removes his used coveralls and places them in a bin for cleaning. He places his hard hat, safety glasses, and safety shoes in the dirty area locker, showers; and enters the clean locker area to don his street clothes.

Contaminated coveralls are dry-cleaned on-site using perchloroethylene. The laundry attendant is informed of the hazards as a participant in the education program.

C. Medical Program

Exxon employees are covered by a medical surveillance program. The program is specifically designed to detect the effects of the polynuclear aromatics found in coal tars. The target organs include the skin, lungs, and urinary tract. The program includes the basic surveillance available to all Exxon employees and special consideration geared to the problems unique to the ECLP facility.

All ECLP employees will undergo the basic examination within one year of plant startup. The basic examination includes:

- medical history and general physical examination
- complete blood count
- urinalysis
- composite of blood chemistries
- chest x-ray

- electrocardiogram
- pulmonary function
- audiogram

This exam is given annually for a minimum of five years after which they will receive their medical examination on the regular Exxon schedule.

The examination for ECLP employees also includes a work and exposure history questionnaire, color photographs of exposed skin surfaces, visual examination of all skin surfaces to identify significant skin lesions, and sputum and urine cytology. All examinations of the skin will be done by the same physicians, while cytological studies will be performed by an outside pathologist. Clinical tests will be conducted on an annual basis.

A control group from the nearby Exxon refinery was selected to provide a base for future epidemiologic studies comparing the hazard of the coal liquefaction unit relative to the petroleum refinery. The controls were matched with ECLP employees with regard to age, race, sex, and smoking habits. The controls will undergo the same physical examinations as the ECLP employees.

Contract employees with 3-months service are given a special examination directed towards the skin, lungs, and urinary tract, and are required to provide a work and exposure history. The special examination includes:

- an examination of the skin for lesions
- chest x-ray
- urinalysis
- complete blood count and differential

Similar evaluations will be conducted annually for the duration of their employment.

VII. CONCLUSIONS AND RECOMMENDATIONS

The following conclusions and recommendations are based upon Enviro's interviews and observations at the Exxon Coal Liquefaction Pilot Plant. The work practices and engineering controls discussed below have helped make the ECLP plant a cleaner and safer place to work, and should be considered for incorporation into the design of future commercial plants.

- The closed drain system allows residual hydrocarbon liquids left in tanks and process vessels to be emptied directly to a closed system. Material sent to the closed drain system is directed to the slop tank. Without the closed drain system, residual liquids could be dumped on the ground where they eventually would be washed into the oily water sewer system. This creates a health hazard due to the inhalation of, and dermal contact with process derived organics. It also results in material loss, places an additional load on the wastewater treatment system and creates a dirty plant. A dirty plant promotes sloppy work habits.

  In order to insure the use of the closed drain system, taps into the system must be conveniently located.

- The importance of following procedures to the letter cannot be overemphasized when bolting up flanges in a high pressure piping system. Exxon has found that the cause of a leak in a high pressure flange can usually be traced to poor workmanship. Exxon now requires that maintenance personnel take a 3-4 hour training course before they are allowed to bolt-up high pressure flanges.

- The slurry dryer system at the ECLP plant removes water from the coal after it has been slurried with recycle solvent. This eliminates the need for a coal drying system that uses hot combustion gases, thus greatly reducing the possibility of coal dust emissions and coal dust explosions. It also decreases the capital investment required for the plant. The slurry dryer system at ECLP is still being evaluated, however, and gas-swept mills may still be the preferred drying system for commercial plants.

- Plug valves receive a weekly injection of sealant to lubricate the plug and to keep solids out of the body cavities.

- A corrosion monitoring system, similar to the one at ECLP, should be used in commercial plants to reduce the potential for a catastrophic equipment or piping failure to supplement ongoing inspection programs.

- There should be a regular inspection schedule for relief valves, especially those in slurry service.

- The seal oil system should be designed to ensure an adequate supply of seal oil, free of contaminants and solids, and with adequate pressure to eliminate reverse flow. For those pumps where there is a significant possibility of reverse flow, an individual seal oil system should be considered. Although individual seal oil systems are expensive, if the seal oil becomes contaminated with solids only one seal is affected rather than every seal.

- Neoprene is not resistant to highly aromatic oils (such as coal derived liquids). Coal liquefaction plants should require the use of safety shoes with oil-resistant soles, PVC gloves, and where the job warrents it, PVC slicker suits.

- There is an established Personal Protective Equipment Program (protective clothing and respirators) at the ECLP plant. 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 is controlled by appropriate equipment such as gloves, slicker suits, rubber boots, and other special work clothing.

  Exposure by inhalation is controlled by the use of respiratory protection. The respiratory protection program at ECLP is based on the regulations contained in the OSHA Safety and Health Standards, 29 CFR 1910. Dust respirators (single-use particulates filter type), chemical cartridge respirators, air-line supplied-air breathing apparatus, and self-contained breathing apparatus are all available at the ECLP plant. Workers receive training in the correct method of donning the masks, selecting the right respirator for the hazard, performing qualitative fit testing, and visual inspection of the respirators for good repair and cartridge expiration dates. The training is repeated annually.

  Although the respirator program at ECLP does not incorporate all the recommendations in 29 CFR 1910 (for example, respirators are not assigned to individual workers for their exclusive use) the program is comprehensive enough to be used as a model for other coal liquefaction plants.

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