119-28a

FINAL

CONTROL TECHNOLOGY ASSESSMENT
FOR
COAL GASIFICATION AND LIQUEFACTION PROCESSES

Rockwell International
Molten Salt Coal Gasification
Process Development Unit
Santa Susana, California

Report for the Site Visit of
September 1981

Contract No. 210-78-0084

April 1982

Submitted to:

Phillip A. Froehlich, Project Officer
National Institute for Occupational
Safety and Health
Division of Physical Sciences and Engineering
Robert A. Taft Laboratories
4676 Columbia Parkway
Cincinnati, Ohio 45226

Submitted by:

Donato R. Telesca, Manager
Engineering Department
Dynamac Corporation
Enviro Control Division
11140 Rockville Pike
Rockville, Maryland 20852

FOREWORD

Personnel from the Enviro Control Technology Assessment (CTA) team met with representatives of the Environmental and Energy Systems Division of Rockwell International at Santa Susana, California on September 15, 1981. The purpose of the visit was to obtain information concerning the engineering controls work practices, and monitoring program used to mitigate the hazards associated with the Molten Salt coal gasification process development unit (PDU). The personnel involved were:

ENVIRO CONTROL, INC.

Jan Scopel, Chemical Engineer
Russell Tanita, Industrial Hygienist

ROCKWELL INTERNATIONAL

Murray Slater, Project Engineer
Charles Trilling, Program Manager
Ray Shah, Technical Staff
Earle Roddy, Industrial Hygienist
Paul Ferry, Manager of Process Development
Richard Rovang, Operating Engineer

TABLE OF CONTENTS

TABLE OF CONTENTS (Continued)

LIST OF FIGURES

LIST OF TABLES

I. INTRODUCTION

A. Background

The objective of the "Control Technology Assessment for Coal Gasification and Liquefaction Processes" program is to study the control technologies that are 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 such as baghouses, dust collection hoods, and thermal oxidizers whose specific function is the control of potentially harmful emissions. 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 their control technology.

This report details the control technology and industrial hygiene information gathered at the Rockwell International Molten Salt Coal Gasification Process Demonstration Unit (MSCG PDU) at Santa Susana, California, during the site visit of September 15, 1981.

B. Project History

The current Molten Salt Gasification program is an outgrowth of work performed by Atomics International, now Energy Systems Group (ESG) of Rockwell International, for the Atomic Energy Commission. Beginning in 1954, Atomic International carried out fundamental studies on molten salts, and tried to develop applications for such purposes as nuclear reactors and decontamination of spent nuclear fuels. The government first expressed an interest in applying the molten salt process to coal gasification in 1964 when the Office of Coal Research (OCR) funded a 3-year study to be performed by the M.W.

Kellogg Company. Between 1964 and 1974 Atomics International, on their own, did experimental work to develop the molten salt combustion and gasification process. Tests were initially conducted in a laboratory-scale unit and then in a bench-scale combustor. In December 1974, a contract was excuted with OCR for the construction and operation of a fully integrated MSCG PDU for conversion of 5 tons of coal an hour to a nonpolluting low-Btu fuel.

The preliminary design of a pilot plant was completed during the third quarter of 1975 and the plant costs were estimated. Because the cost was consideraby higher than the original estimates, alternative approaches were evaluated in order to select a program which would enable the objectives to be met at a lower cost. Atomics International was awarded a contract to construct the one-ton-per-hour plant and the development contract for the five-ton-per-hour facility was terminated.

Phase 1 of this new contract included the design, construction, and initial operation of a PDU to test the Molten Salt Coal Gasification Process. Preliminary engineering was completed in August 1976. Ground breaking for the process development unit occurred on March 8, 1977 and construction of the PDU was completed by mid-1978.

The first low-Btu gas production test was run in November 1978. The first phase was completed June 13, 1980, after five test runs had been performed to demonstrate the basic feasibility of the MSCG Process. A one year, Phase 2 program was initiated on June 25, 1980. The objectives of the Phase 2 program were to conduct extended low-Btu operational testing of the existing PDU to provide reliability and performance data on process systems, components, and materials. Phase 2 testing was completed on June 25, 1981 after four test runs had been performed.

C. Process Description

Figure 1 is a schematic of the MSCG PDU process system. Coal and sodium carbonate are transported by compressed air (10-20 atm) into the bottom of the melt bed in the molten salt furnace. The molten pool is composed of sodium carbonate, with sodium sulfide and other compounds formed during the

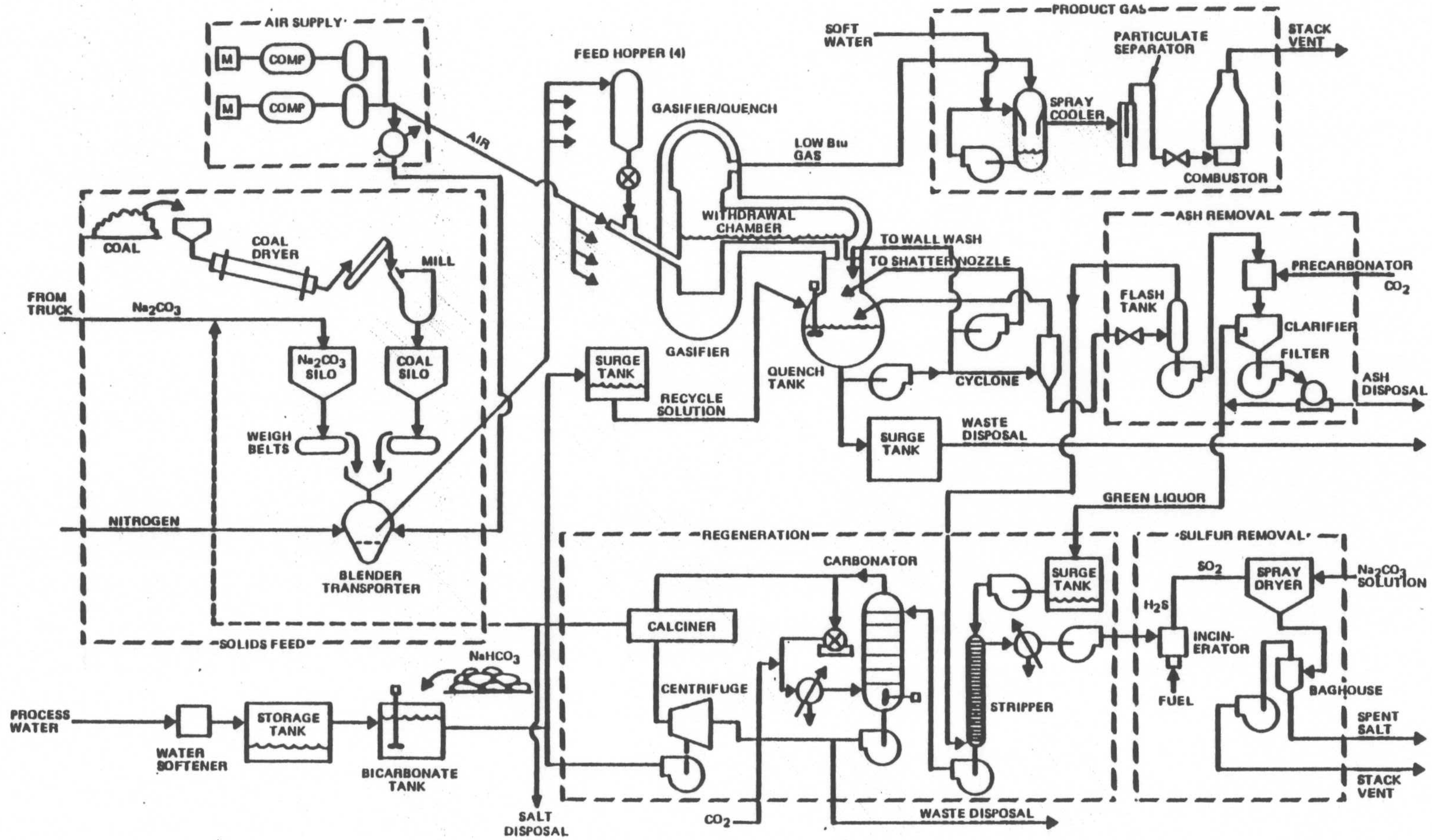

Figure 1. Schematic of the MSCG PDU Process System (source-reference 3)

reaction. The process is designed so that gasification reactions (partial oxidation and pyrolysis) take place at 1800 F (980 C) and 20 atm. The fuel gas produced has a heating value of approximately 150 Btu per standard cubic foot and is predominantly carbon monoxide, hydrogen, and nitrogen. The melt retains the ash and sulfur from the coal, and must be continuously withdrawn from the furnace. Sodium carbonate is subsequently regenerated.

In a commercial power plant installation the hot fuel gas from the molten salt furnace will be burned in a gas turbine to generate electricity. After passing through the turbine, the exhaust gas will produce steam for a steam turbine, producing additional electricity. Flue gas (primarily carbon dioxide) leaving the boiler heats incoming combustion air.

In the regeneration section, the melt is withdrawn from the molten salt furnace into a quench tank and the salt is dissolved in water. The resulting slurry is filtered to remove ash. The filtrate, containing dissolved sodium sulfide, is carried to the stripper where sulfur is stripped off as hydrogen sulfide and incinerated to SO_2. (A commercial plant would use a Claus plant to produce elemental sulfur.) The remaining solution is carbonated, and sodium bicarbonate is crystallized, centrifuged, calcined to sodium carbonate, and recycled.

D. Pilot Plant Layout

The process equipment is either located at grade, or housed in open multi-level steel structures. All process areas are paved with concrete and are diked with concrete curbs to contain spills. There are seven process areas, identified in Table 1. A plot plan of the PDU installation is shown in Figure 2.

E. Potential Hazards

The potential hazards associated with the MSCG process are shown by process area in Table 2.

TABLE 1

Process Areas

Area	Description
100	Solids Feed System
200	Air Compressor System
300	Gasifier/Quench System
400	Product Gas System
500	Ash Removal System
600	Regeneration System
800	Sulfur Removal System
900	Facilities and Services System

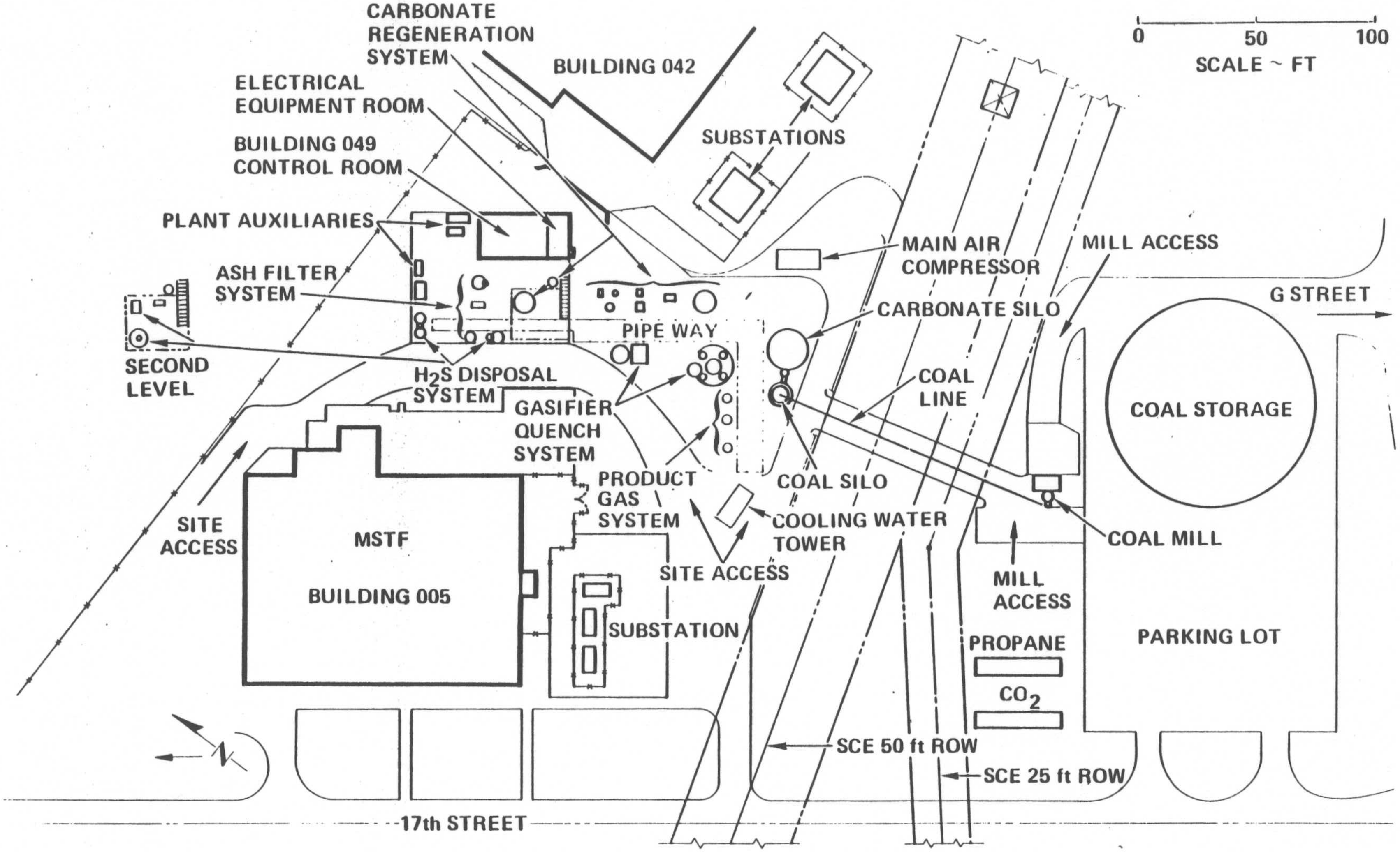

Figure 2. Layout of the PDU Installation (source-reference 2)

TABLE 2

Potential Hazards by Process Area

Process Area	Potential Hazards
Solids Feed System	Respirable coal dust Coal dust explosions Fire Noise Asphyxiation (inerting gas-nitrogen)
Air Compressor System	None
Gasifier/Quench System	High temperatures and pressures Carbon monoxide Hydrogen sulfide Molten sodium carbonate and sulfate Flammable/explosive product gases
Product Gas System	High temperatures and pressures Carbon monoxide Flammable/explosive product gases
Ash Removal System	Hydrogen sulfide Asphyxiation (carbon dioxide)
Regeneration System	Hydrogen sulfide Asphyxiation (carbon dioxide)
Sulfur Removal System	Hydrogen sulfide Sulfur dioxide Respirable Sodium Sulfate dust
Facilities and Services System (Tank Vent Exhaust Subsystem)	Hydrogen Sulfide

II. ENGINEERING CONTROL TECHOLOGY

A. Introduction

A two part discussion of each process area 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 equipmemt, monitoring programs, and health and safety programs as a means of mitigating occupational safety and health hazards are discussed later in the report.

B. Solids Feed System

1. Process Description

A diagram of the Solids Feed System is shown in Figure 3. A front end loader loads coal into a feed hopper. Coal is conveyed to a hammer mill where it is crushed to minus 1/4 inch and pneumatically transported (with nitrogen) to a filter receiver atop the coal silo.

The filter receiver separates the transport gas from the coal. The coal drops through a rotary valve into the coal silo. Nitrogen leaving the filter received is recycled by a blower. The coal storage silo has a capacity of 35 tons of coal.

Sodium carbonate is delivered to the facility by truck and is pneumatically conveyed to the storage silo. Recycle sodium carbonate from the calciner in the Regeneration System is returned to the carbonate storage silo. Coal and carbonate are transported by screw conveyors to an inclined mixing conveyor. The mixed and proportioned coal/carbonate feed empties into the high-pressure transporter. It is then pressurized and transferred to the high-pressure feed subsystem.

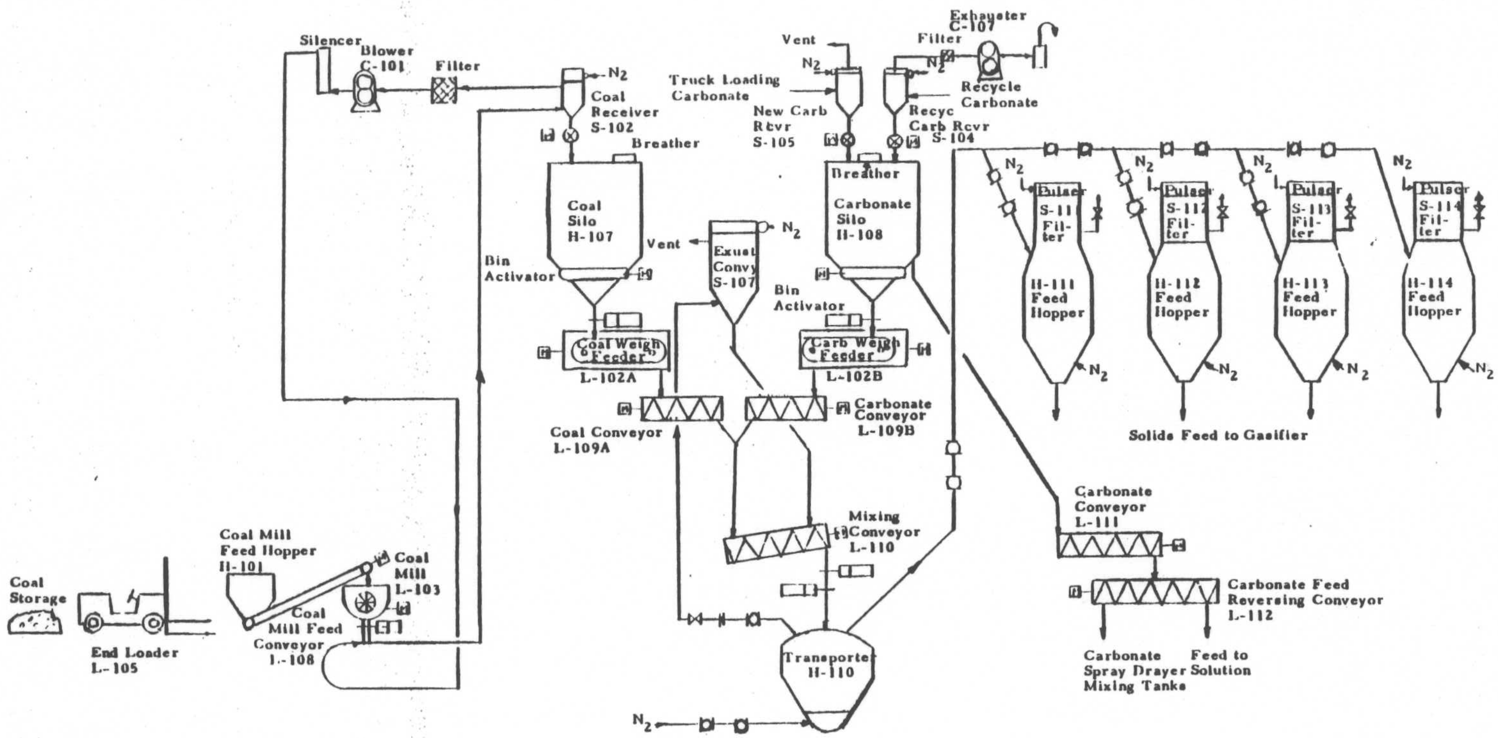

Figure 3. Diagram of the Solids Feed System
(source-reference 2)

The high-pressure solids feed subsystem consists of the high-pressure transporter vessel, four gasifier feed hoppers with rotary feeders, interconnecting and diverter valves, and the electrical and pneumatic control system for operation. The transporter vessel, is filled at atmospheric pressure with coal/carbonate and pressurized. After adequate pressure is attained, the material is transported to one of the four feed hoppers. The transport system maximum design pressure is 375 psig. After a purge cycle, the transporter is vented and refilled. Material is fed from the gasifier feed hoppers to the gasifier via rotary feeders.

The PDU main air supply system is two identical skid-mounted units, each having a first stage rotating screw compressor and a booster stage reciprocating piston compressor. The rated capacity of the system is 2000 cfm at 390 psia. Combustion air is also used to inject coal into the gasifier through feed nozzels. When tests are run at atmospheric pressure compressor output is maintained between 100 and 200 psi.

2. Control Technology Assessment

The hazards associated with the solids feed system include: respirable coal dust, spontaneous coal combustion, coal dust explosions, noise, and asphyxiation.

The following engineering controls are used to mitigate these hazards:

- Coal is conveyed pneumatically from the crusher to the coal storage bin. A silencer has been installed on the blower to reduce excessive noise.
- Nitrogen is used as the coal transport gas to minimize the possiblity of fire or explosion during transport.
- Nitrogen is used to maintain an inert gas blanket to reduce the possiblity of fire or explosion.
- A vibrating bin activator is used on the coal storage bin outlet to ensure that the flow of coal will not be interrupted. The reduces the need for personnel to enter the silo.

The following engineering controls are used to reduce the possiblity of plugging the coal feed nozzles.

- It was ESG's operating experience at the molten salt test facility that individual feeds of cold air or carbonate caused melt freezing and plugging at the point of entry into the melt bed. Either the feed material had to be preheated or fuel had to be injected with the feed material. A lower air velocity limit was established based on a requirement to keep melt out of the nozzle during any gasifier "holding" period. Experience at similar tuyere-fed, high-temperature, molten bed reactors and at the MSTF, indicate that some feed nozzle plugging can be expected. Nozzle drillout devices were developed to clear plugged feed nozzles and to remove protective plugs placed in gasifier drain nozzles when draining the gasifier. With this device it is unnecessary to disassemble other systems prior to drillout mechanism use. A pressure seal, pierced by the rotating drill shaft, isolates the mechanism from the gasifier environment, so the device can be used while the gasifier is at pressure.

- In the event of an electrical power failure, an emergency diesel-powered air compressor substitutes for the PDU air supply system. The emergency air compressor will maintain flow through the feed nozzles, keeping them open, until power can be restored.

- An intercooler is provided with the air compressors to control the temperature of the combustion air provided to the gasifier. If the air is too hot it will cause caking coals to swell, become sticky and plug the gasifier feed nozzles.

C. Gasifier/Quench System

1. Process Description

The key components in the MSCG PDU plant are the gasifier, melt withdrawal chamber, and the quench tank. Each of these vessels was designed for an operating pressure of 20 atmospheres. Figure 4 is a diagram of these vessels.

In the melt region of the gasifier there is a layer of high-alumina refractory cast against the vessel ID, followed by a course of fused cast alumina bricks. The fused cast alumina brick extends about 4 feet above the overflow melt level. Above this the vessel is lined with a layer of the high-alumina castable refractory. There are four 1 inch ID downward-sloping air/solids feed nozzles entering the melt region of the gasifier.

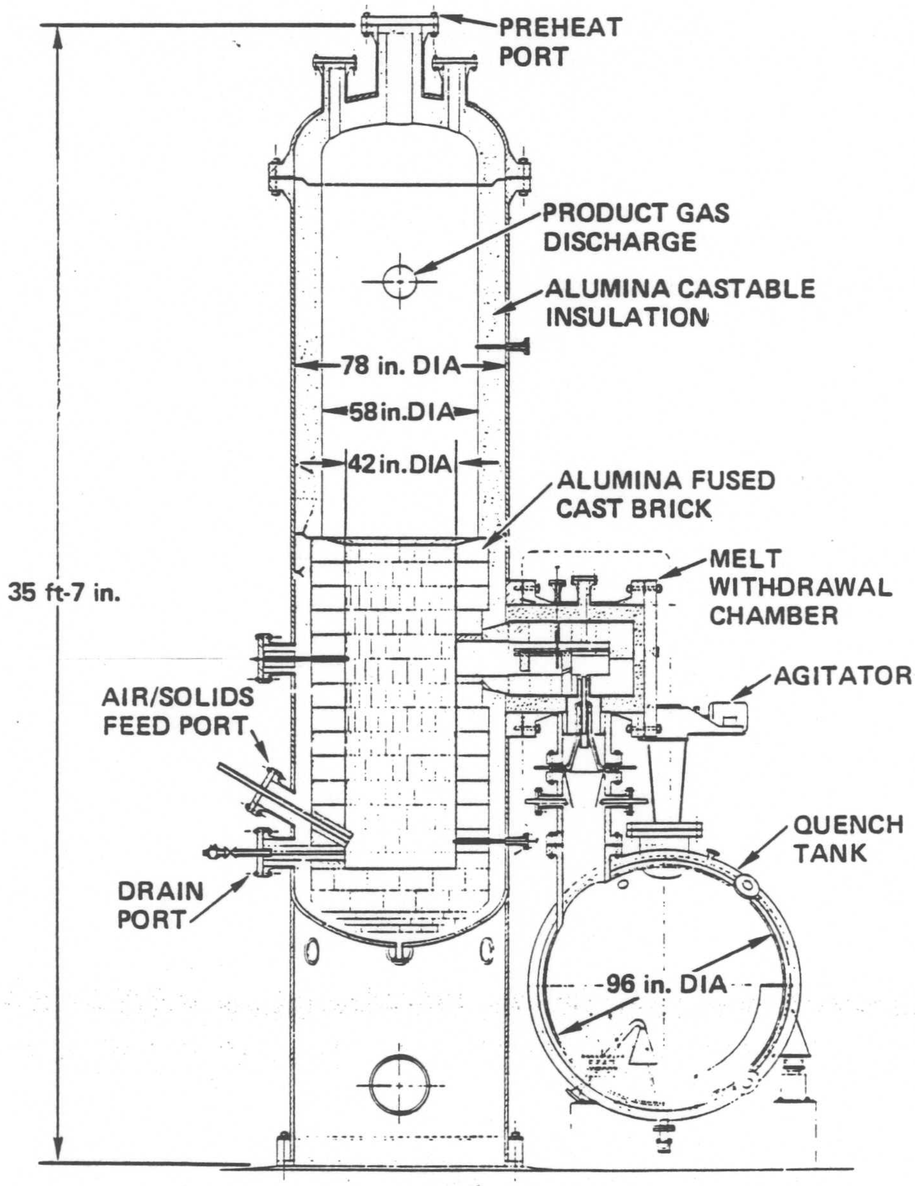

Figure 4. Diagram of the Gasifier/Quench Assembly (source-reference 2)

Overflow melt from the gasifier passes through the melt withdrawal chamber which is lined with high-alumina castable inslulation next to the vessel shell and cast alumina brick as the hot face material. The quench tank is a spherical vessel with a carbon steel shell and a 1/8 inch thick Inconel 600 internal lining.

A diagram of the Gasifier/Quench System is shown in Figure 5. Gasifier melt dissolves in water in the quench tank to produce a slurry of "green liquor" solution and insoluble ash. The slurry is pumped to a hydrocyclone which separates the solids from the liquor solution sending the solids with a portion of the green liquor to the Ash Removal System and the clarified liquor back into the quench tank via the melt shatter nozzles. The liquor makeup pump provides clarified liquor from the recycle liquor storage tank to maintain a constant operating level in the quench tank. This pump can supply either recycled liquor or process water to the quench tank.

The gasifier preheater subsystem was designed to perform the initial liner bakeout and to preheat the gasifier for normal startup from a cold, empty condition. The burner operates at 2000 F (1070 C) to yeild an 1800 F (980 C) refractory wall inner surface temperature and melt the initial charge of sodium carbonate. The burner can be controlled at a set temperature automatically or manually monitored and controlled. An over-temperature automatic cutoff switch is included in the control panel.

2. Control Technology Assessment

The potential hazards associated with the Gasifier/Quench System involve the toxic and flammable/explosive nature of the product gases, the high temperature/high pressure operating conditions, and the corrosive nature of the molten salt. The product gas contains CO, H_2 and trace concentrations of H_2S. The primary engineering control is maintaining a closed system. Sampling activities, maintenance activities, and a once a day blowdown of the quench tank are the only routine activities that break the closed system. Other activities include start-up, snorkel burner change over, and gasifier melt draining on shutdown. The gasifier process is designed so that workers are not needed in the gasification area during operation.

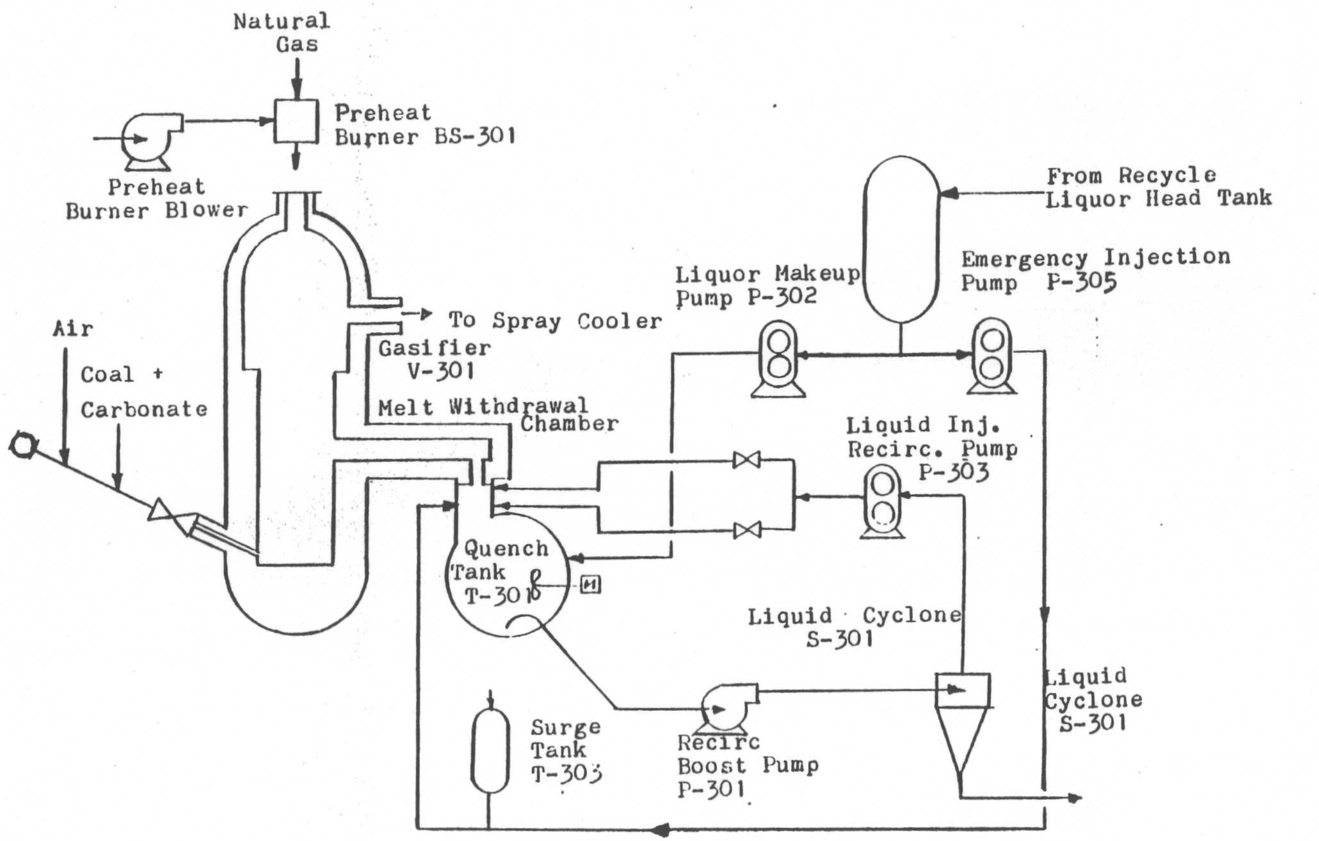

Figure 5. Diagram of the Gasifier/Quench System (source-reference 2)

The following are process-related features of the system which mitigate hazards associated with gasifying coal:

- Approximately 97 to 99 % of the sulfur in the feed coal reacts and is removed with the melt. Sulfur reacts with the melt to form sodium sulfide (Na_2S). Hydrogen sulfide concentrations in the product gas stream and gasifier are approximately 50 to 150 ppm.

- Negligible amounts of tar, heavy hydrocarbons, and ammonia, are produced. Reaction in the melt results in almost complete destruction of these compounds at the 1800 F (980 C) gasifier operating temperature.

- The potential for an explosion to occur when coal feed is stopped is small. A concern with some gasifiers is that when an accidental coal feed stoppage occurs, the momentary continuation of oxygen feeding may cause the reducing atmosphere to an oxidizing atmosphere in the presence of hot flammable/explosive product gases. In the molten salt process, oxygen feed is into the melt pool which contains a considerable inventory of constituents, such as sodium sulfide and residual carbon and these are capable of reacting with excess oxygen until the air/oxygen flow can be stopped.

- The quenching of melt from this gasification operation is similar to quenching smelt in the pulp and paper industry recovery furnaces. An ESG safety review indicated that under gasifier presure, any tendency for explosive interaction between the melt and aqueous solution is inhibited, and that an explosion would not occur under normal gasifier operating conditions. This was borne out during an episode in which an amount of melt approximately five times the design rate was dropped into the quench tank.

ESG anticipated and solved a number of problems to provide safer, continuous and reliable operation of the gasifier/quench system. These difficulties involved the melt withdrawal subsystem, the gasifier refractory, and the thermocouple/thermowell subsystem. Other difficulties involved plugging in the feed nozzles and high pressure quench recirculation loop. The following designs and/or modifications enabled continuous and reliable operation of the gasifier/quench system and maintained the integrity of the closed system.

- The gasifier, melt withdrawal chamber, quench tank, liquid cyclone, and associated systems were designed, fabricated, and inspected in accordance with section 8, division 1 of the ASME Boiler and Pressure Vessel Code for an operating pressure of 20 atmospheres.

- Thermal shock and excessive temperature differentials can be easily imposed on the refractory liner. Slow heatup ramps and controlled dwell times are necessary during preheat and liner bakeout. Flame-outs of the preheat burner were a problem during early PDU startups. Burner controls were designed to automatically hold a manually set temperature, but the system failed due to the slow response time of control thermocouples. A manual control system was installed, which gives full manual control of the fuel gas valve allowing heatup rates as low at 25 F/hr. However, because heatup and dwell time are difficult to control manually, a change to a fully automatic system is being considered.

- The top-mounted, high-velocity preheater system, as designed, was not capable of heating the lower portion of the gasifier. A snorkel, fabricated from thin-wall 304 stainless steel tubing was welded to the lower end of the preheat burners to conduct the hot preheater gases directly to the lower portion of the gasifier.

- During early test runs, when the liquid injector pump was not running, sodium carbonate solidified on the ends of the plungers. When the pump was restarted, the solid material embedded in the pump packing and scored the plungers. The pump is now drained even during short shutdown periods.

- The melt withdrawal chamber underwent numerous modifications in an effort to establish continuous melt overflow into the quench tank. Most of the earlier test runs were terminated as a result of melt plugging in this system. Modifications ranged from the addition of gas-fired burners to changes in the materials of construction and reshaping the chambers.

- The only thermowell material that survived in the molten salt environment is alumina. Thermowells with double alumina tube designs provided the best protection.

- The mounting configuration of the thermowell in the vessel wall is very important to its survival. Following pressure/leak testing prior to one run several thermowells were found protruding several inches into the gasifier. The thermowells apparently slid into the vessel during depressurization. An Alfrax 66 ring was cast on the outer 2 inches of the primary protection tube. This ring butted up againt the refractory backface. Fiberfrax paper was wrapped around the last 6 inches of the thermowell centered in the refractory liner and no mortar was used. This allowed space for radial thermal expansion of the thermowell, thus no stresses were applied to it by the liner. Though three thermowells installed using this method prior to Run No. 5 did not fail, further development is necessary for more reliable designs and materials.

- Standard commercial thermocouples were acceptable for use in thermowells. The expected life of the thermocouples was increased by using larger diameter thermocouples with 16 AWG wire. These thermocouples have a higher maximum operating range. Thermocouple failure was traced to melt corrosion due to failure of the primary and secondary protection tubes. Thermocouple sheath materials of 310 SS, 466 SS, and Inconel 600 failed when exposed to liquid melt.

- The green liquor circulation loop experienced severe plugging problems. The pipelines are electrically traced and insulated, but high concentrations of green liquor solidified in, and plugged entire pipe sections. The plugs occurred only in lines where process flow had slowed appreciably or had stopped. Recirculation loops, fabricated first from hose and later hard-piped in, allowed the green liquor solution to maintain a steady velocity through most of the pipelines. This essentially eliminated plugging.

- In the melt withdrawal nozzle one set of redundant shatter jets is provided as backup in the event the primary set became plugged or eroded. In the event of plugging the primary and the redundant sets of shatter nozzles a pair of backup emergency nozzles was provided and was fed from the recycle liquor storage tank by the emergency injection pump. In the event of a loss of electrical power a surge tank provides a short (15-30 sec.) supply of water to the emergency shatter nozzles. The surge tank is a pressure vessel filled with water and pressurized with nitrogen at a pressure above that of the gasifier/quench system.

ESG has provided the following general engineering controls in this area.

- The gasifier/quench system is housed in an open structure which provides for natural dilution ventilation.

- As designed, most of the flanges on the gasifier vessel were sealed with compressed asbestos gaskets. Some of the larger flanged connections could not be sealed. ESG switched to spiral-wound metal asbestos-filled gasket which resulted in satisfactory sealing.

- The seal water system at the PDU plant provides high pressure water to the seals of process pumps in the gasifier/quench and spray cooler systems. The system has a multi-stage high-pressure pump to maintain a higher pressure on the pump seals than is in the process being pumped. This system was operated during Run No. 5 when the plant was operated at over ten atmospheres pressure. The system operated as designed with no operational problems.

- The gasifier wall configuration in the melt bed region was designed so that in the event of a breach in the protective fused cast alumina liner, the 1800 F melt flowing into the crack or hole would freeze 10 inches from the hot face, where the temperature is ~ 1500 F. This affords a 2 inch safety band before the melt can contact the cast alumina insulation and, subsequently, overheat the carbon steel tank.

- The gasifier is continuously monitored with externally mounted thermocouples, located in a two-way 24 inch grid, which are continuously scanned (and alarmed) by data monitoring equipment in the control room. This allows rapid detection of heat which, for this gasifier, means either excessive internal temperature, failure in the refractory, or failure in a seal. Rapid detection enables precautions to be taken before a hazard develops.

- Two pressure letdown valves are provided in parallel between the liquid cyclone and the flash tank. Being located after the quench tank avoids high temperature service.

- The quench tank discharge flow control valve, a mixed phase valve, controls the green liquor slurry flow from the quench tank to the flash tank. This valve experiences some of the most erosive service in the PDU. Post phase 1 inspection of this angle valve inlet body showed no signs of wear. No corrosion was found in this high velocity mixed phase section.

- A control valve "kicker" was added, which has an adjustable "kick" frequency, duration, and amplitude. The kick has eliminated valve plugging even for extreme green liquor solids concentrations.

- Heat shielding is provided between the gasifier and adjacent equipment. The skin temperature of the gasifier is maintained around 500 F. The aluminum sheet heat shielding provides the necessary reduction in radiant heat transfer to enable proper operation of instrumentation and controls.

- Sodium carbonate dams are used to contain molten salt spills until they solidify. Personnel are warned not to use water to solidify the melt as this can cause steam explosions.

- Chemical seals (diaphrams and fluid) are used to protect and ensure reliable instrumentation transmitter function when used in green liquor-containing streams.

- The increased density of green liquor in the slurry system caused plugging of the sensing taps on two venturi flow elements. Meter operation has improved since the sensing taps were enlarged from 1/16 inch to 1/2 inch pipe diameter and were heat-traced and insulated.

To improve green liquor flow meter operation, ESG suggests that intermittent water purges be added to the vent valves to decrease salt concentrations in the sensor assembly. A magnetic flow meter was tested and worked well, even with highly concentrated green liquor.

D. Product Gas System

1. Process Description

A schematic of the Product Gas System is presented in Figure 6. Gas exiting the gasifier is cooled in the spray cooler, schematically shown in Figure 7. The cooler is a 20-inch diameter Inconel 600 pipe with spray nozzel designed to quench the product gas. There are two levels of spray nozzles with the

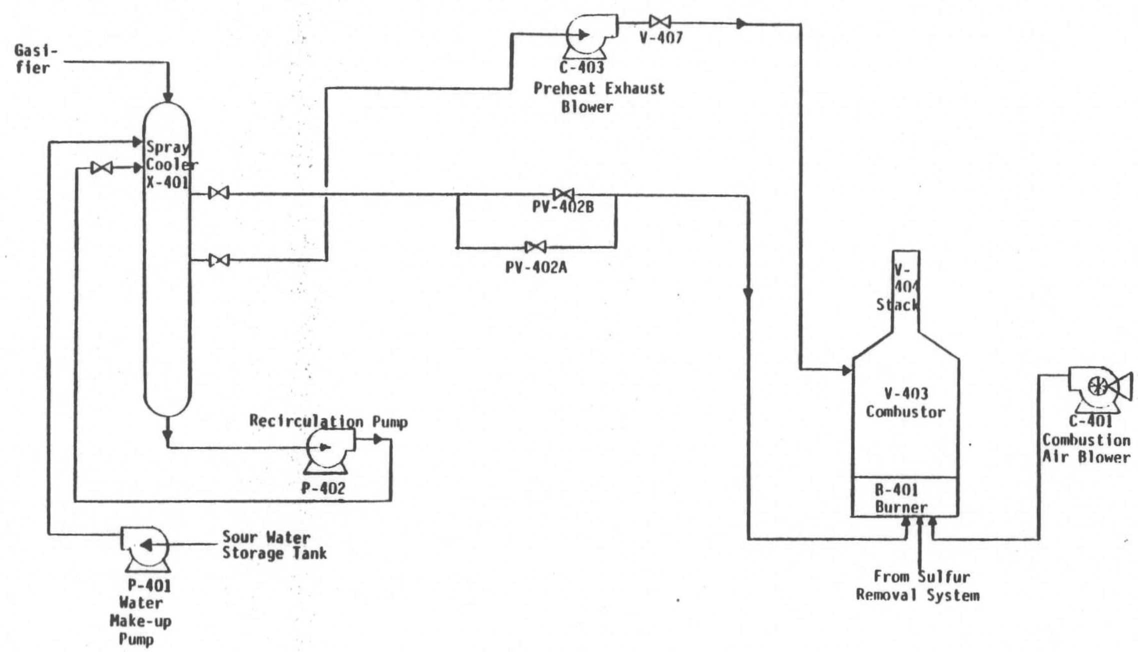

Figure 6. Diagram of the Product Gas System
(source-reference 2)

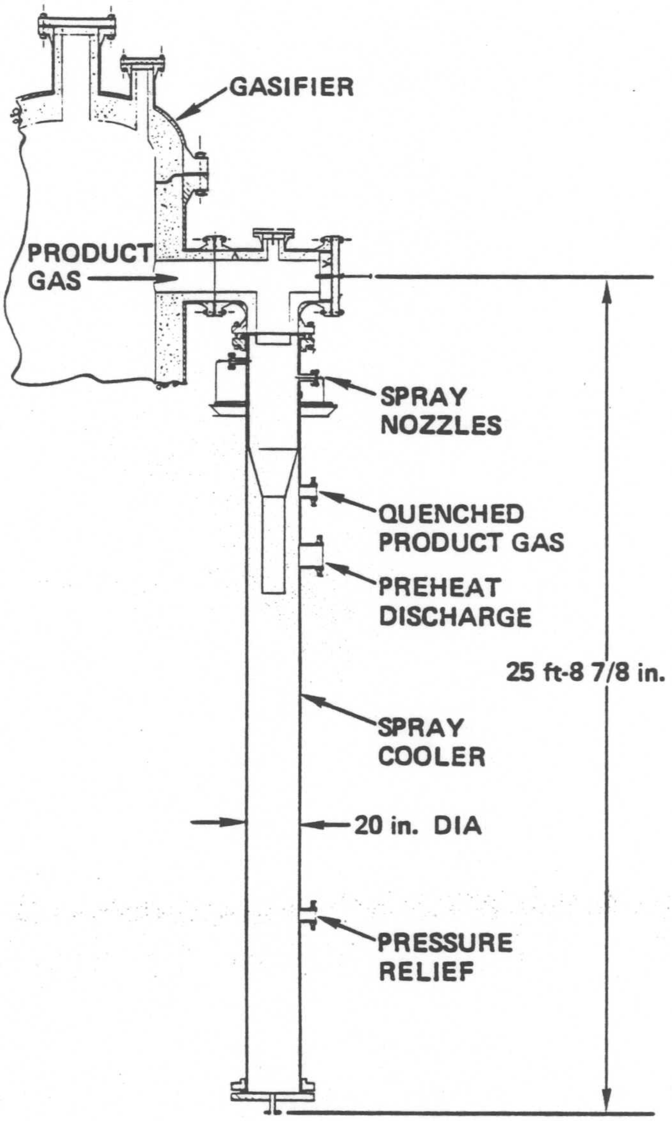

Figure 7. Schematic of the Spray Cooler Assembly (source-reference 2)

upper level used primarily to cool the metal walls above the first level. There are 12 nozzles at each level; half operate continuously with recycled water and the other half are connected to an emergency water supply. Makeup flow is pumped into the spray cooler through a separate set of nozzles. A bleed is provided to avoid sodium carbonate buildup in the spray cooler recirculation loop.

The product gas combustor is a vertical, cylindrical structure approximately 7 ft. in diameter and 28 ft. high with a stack, approximately 23 ft. high, on top of the basic brick-lined incinerator chamber. the unit is designed to incinerate the product gas stream and to accommodate the dispersion of the preheat exhaust gas. The coaxial burner for the unit is fired with supplemental fuel of either natural gas or propane. The combustor is designed for a maximum operating temperature of 2000 F, although the normal operating temperature is 1800 F.

2. Control Technology Assessment

The potential hazards associated with the Product Gas System involve the toxic and flammable/explosive nature of the product gases and the high temperature/high pressure operation conditions. The product gas stream contains CO, H_2 and trace concentrations of H_2S. The primary engineering control is maintaining the closed system. Maintenance work is the only activity that breaks into this system. The following modifications were made to the system which reduced maintenance activities.

- The product gas exits the gasifier through the offgas Tee. Problems with particulate plugging occurred in this area. To clear the offgas Tee during the high-pressure gasifier operation, a high-pressure soot blower was designed. This soot blower uses high pressure streams of nitrogen from nozzles to blow the particulates from the walls of the Tee.

- To avoid valve materials problems related to high temperature use, pressure letdown valves on the product gas stream were installed downstream of the spray cooler.

- Inspection of the balanced plug product gas back pressure control valve, which controls gasifier pressure, revealed little or no wear. Valve erosion problems reported by other coal gasification programs have not been seen at this facility. ESG believes that only normal valve servicing will be required for continuous operation. Post phase 1 inspection showed that four balancing holes in the valve plug contained some soft deposits which did not block the gas passage to the balancing port. The valve cage showed essentially no wear or corrosion and the valve body contained very few deposits.

E. Ash Removal System

1. Process Description

Figure 8 is a diagram of the Ash Removal System. Green liquor slurry from the quench tank recirculation system is removed as underflow from the liquid cyclone. During pressurized plant operation, the green liquor slurry is flashed down to atmospheric pressure through one of two pressure control valves at parallel inlets to the flash tank. Steam generated passes from the tank through an upper outlet nozzle, while the liquid slurry underflow exits through a drain nozzle. The depressurized slurry passes to the precarbonator feed pump. The precarbonator tank, is an insulated, stainless steel cylindrical tank. The green liquor slurry in the tank is sparged with CO_2 to maintain a pH of approximately 9.5

From the precarbonator, green liquor flows by gravity into the clarifier, an insulated, stainless steel, upright, cylindrical settling tank with a conical bottom. Solids settle to the bottom and are moved to the drain by a slowly rotating rake. The clarified liquid is taken off the top of the tank and pumped to the green liquor storage tank.

Underflow from the clarifer is pumped by pneumatic piston pump to the Ash Filter Subsystem. This subsystem consists of a rotary drum filter, a filtrate pump, a filtrate tank, a wash pump, a wash tank, a seal water pump, a seal water tank, and a vacuum pump. The filter is a rotary drum vacuum-type device enclosed in a fumetight hood with a moving cloth belt to collect the filter cake. At the discharge section a hard-rubber edged blade scrapes the ash filter cake from the belt into a conveyor for disposal.

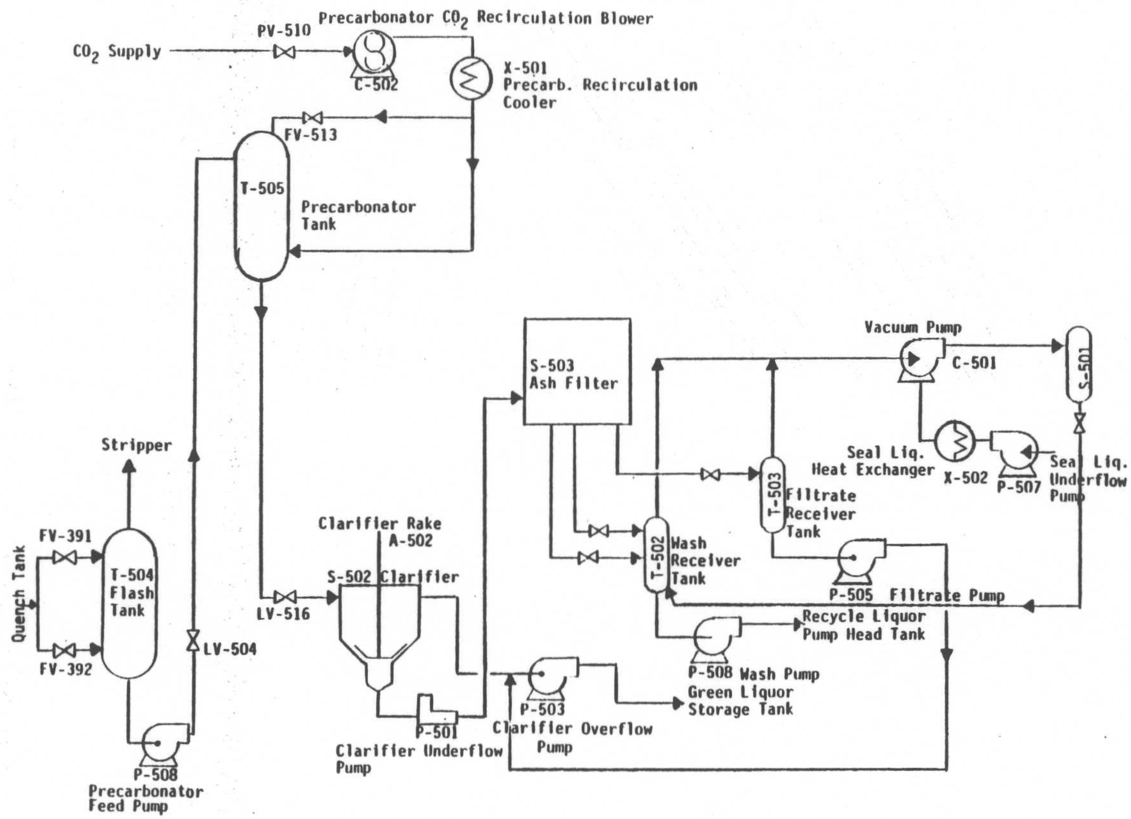

Figure 8. Diagram of the Ash Removal System (source-reference 2)

2. Control Technology Assessment

The potential hazards associated with the Ash Removal System involve the presence of H_2S in the streams containing green liquors and the use of the simple asphyxiant CO_2 in the precarbonator.

The primary engineering control is maintaining a closed system. Except for end of the line ash discharge, maintenance work is the only activity that breaks into this system. The wet ash removal method eliminates ash dust generation. The following engineering controls are used to mitigate the hazards associated with exposure to H_2S.

- Modifications were made to the piping around the flash tank to provide for recirculations of green liquor between the quench tank and the flash tank. The constant flow of green liquor through the lines helped alleviate plugging problems which were very common when the flows were slow. ESG feels that back flushing provisions can improve plant operations.

- In earlier operations, plugging occured frequently in the discharge line from the precarbonator and hoses were connected to sample ports for quick line back flushing when necessary.

- The green liquor storage tank discharge point was raised so solids could settle below the discharge level and not be carried on to the regeneration process during process upsets.

- The major equipment in this area is 304 stainless steel. All vessels are closed and vented to the H_2S vent header for subsequent incineration (see section I.1.a). The ash filter subsystem is enclosed in a fume-tight hood.

- The weir, which decants the clear liquid from the surface of the clarifier, was enlarged to the full 360° circumference of the vessel from the installed 85° arc. This modification was expected to reduce cross currents in the clarifier. Additionally, a 1-ft-thick honeycomb tube arrangement, positioned with the tubes at 60° from the horizontal, was installed across the entire cross section of the upper portions of the clarifier tank. The modifications proved effective under most operating conditions; however, during short periods of high throughput, some solids were still carried through.

F. Regeneration System

1. Process Description

Figure 9 is a diagram of the Regeneration System. This section includes H_2S steam stripping, slurry carbonation, and precipitate calcining. The clarified green liquor produced in the Ash Removal System is stored in the green liquor storage tank, an insulated, heated, stainless steel tank. The vacuum stripper is a stainless steel vessel with 20 equally spaced sieve trays. Green liquor enters the H_2S stripper at the top and is stripped of H_2S by steam.

The H_2S gas exiting the top of the stripper is fed to the H_2S incinerator or to the product gas combustor. The stripped green liquor is pumped from the H_2S stripper sump to the carbonation tower, where sodium carbonate green liquor is converted to a saturated sodium bicarbonate solution. Sodium bicarbonate crystallizes from the solution.

The carbonation tower is a stainless steel cylindrical vessel with 6 evenly spaced sieve trays. Green liquor is fed at the top, while CO_2 gas is recirculated from the bottom to the top of the tower. Sodium bicarbonate crystals are separated from the slurry by a horizontal bowl centrifuge. The cake, containing 10 percent water, drops into the rotary tray calciner.

The calciner is an electriclly heated oven with 24 vertically stacked trays. At the base of the calciner, an air lock receives and discharges the sodium carbonate to a pneumatic piping system for transport to the carbonate silo. Condensate from the calciner off-gas cooler/condenser flows under gravity to the sour water tank.

2. Control Technology Assessment

The potential hazards associated with the Regeneration System involve the presence of H_2S in most process streams and use and production of the simple aphyxiant, CO_2, in the carbonator and the calciner.

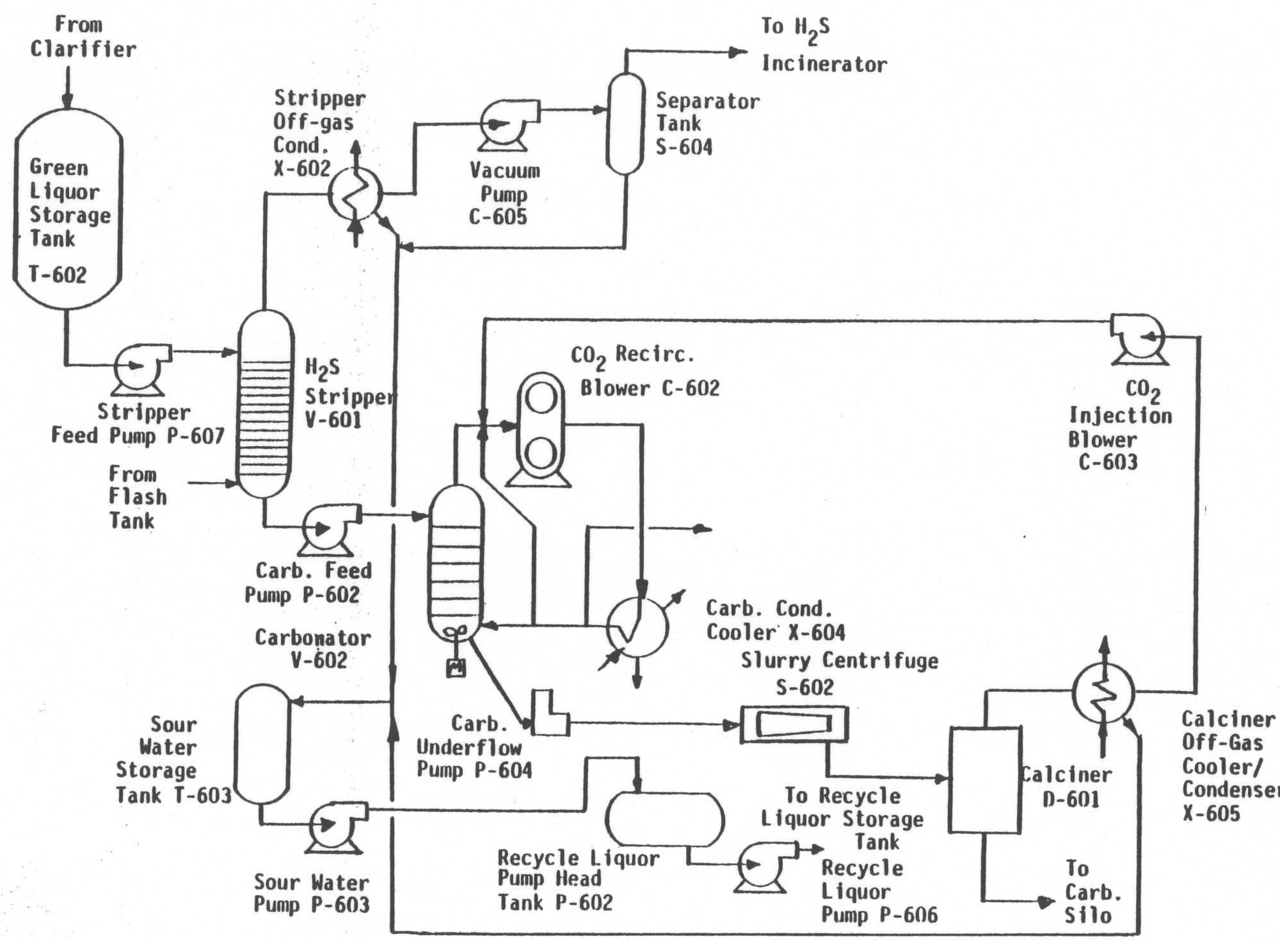

Figure 9. Diagram of the Regeneration System (source-reference 2)

The primary engineering control is maintaining a closed system. Maintenance work is the only activitiy that breaks into this closed operation. The regeneration system is a closed recycle loop with the Sulfur Removal Systems operating essentially as a purge stream.

All process vessels are closed and with the exception of the H_2S stripper are slighty pressurized. A tank vent exhaust system with a blower is used to control the H_2S gas released from various tanks. The H_2S vapors are vented to the H_2S incinerator in the Sulfur Removal System (see section I.1.a). Initially the blower was not generally used because periodic tank overflows flooded the vent system. Experience with the tank level control systems reduced the flooding and the vent exhaust system blower was again put into operation.

The H_2S stripper operates at approximately 6 psia. Air leaks are therefore into the system. The liquid ring vacuum pump has provided for this function.

Most of the tanks and critical piping handling liquids in this section are electrically traced and insulated to avoid heat losses and prevent plugging due to precipitation of $NaHCO_3$ before the carbonator. Generally, the material of construction of the vessels in this system is 304 stainless steel which has given good service. However, for commerical applications, 316 stainless steel probably would be specified.

Maintaining a minimum flow in the carbonation tower is important to prevent plugging the underflow pump feed line. This problem was occurring because when the centrifuge automatically shuts down due to insufficient feed, the carbonator pump cuts off to prevent flooding the centrifuge and calciner. With no flow, the $NaHCO_3$ crystals settle in the pump suction pipe blocking the entire pipe length. Disconnecting the piping was necesary to eliminate the plug. This problem was alleviated by changing the piping configuration and installing a recirculating loop from the pump discharge back to the column.

A number of problems resulted from ash carryover at the clarifier.

- The first component of the regeneration system, the green liquor storage tank, influenced the green liquor physically and chemically affecting its processing downstream. The tank is unagitated; this allows ash carryover from the clarifier to settle out. Originally, the green liquor was withdrawn from the bottom of the tank, as a result, liquor containing ash affected the quality of the centrifuge product cake.

- The centrifuge product cake dryness varies according to the concentration of ash; when the ash content increased, the moisture content of the cake increased. A sodium bicarbonate slurry with a relatively high ash content produced a cake too wet to process easily, forming a hard, brittle sheet of sodium carbonate that was difficult to remove from the calciner.

- The conversion of sodium bicarbonate to sodium carbonate was completed in the calciner, but not at the system's design conditions. The equipment design specifications required a residence time of 45 minutes at 350 F. However, the residence time was increased to one hour and the bottom temperature increased to 400 F to achieve the desired 99 % conversion.

- Sodium carbonate lumps up to 1-1/2 in. in width could not be pneumatically transported to the storage silo. The formation of the lumps was due to the inconsistent centrifuge discharge.

G. Sulfur Removal System

1. Process Description

A diagram of the Sulfur Removal System is shown in Figure 10. It consists of three main pieces of equipment; the H_2S incinerator, the spray dryer, and the filter baghouse. The H_2S from the stripper is pumped to the H_2S incinerator for burning. If the incinerator is down the H_2S is diverted to the product gas combustor.

The H_2S incinerator is a natural-gas fired combustor. After combustion, the product SO_2 gases enter the spray dryer at a temperature of about 1300 F. In the spray dryer, the SO_2 gas is contacted with a fine spray of 10% volume sodium carbonate solution.

Under normal operating conditions. 225 lb/hr of sodium sulfites and sulfates precipitate out in the spray dryer. The precipitate-laden air enters the baghouse at the bottom of the filter bag section, just above the solids

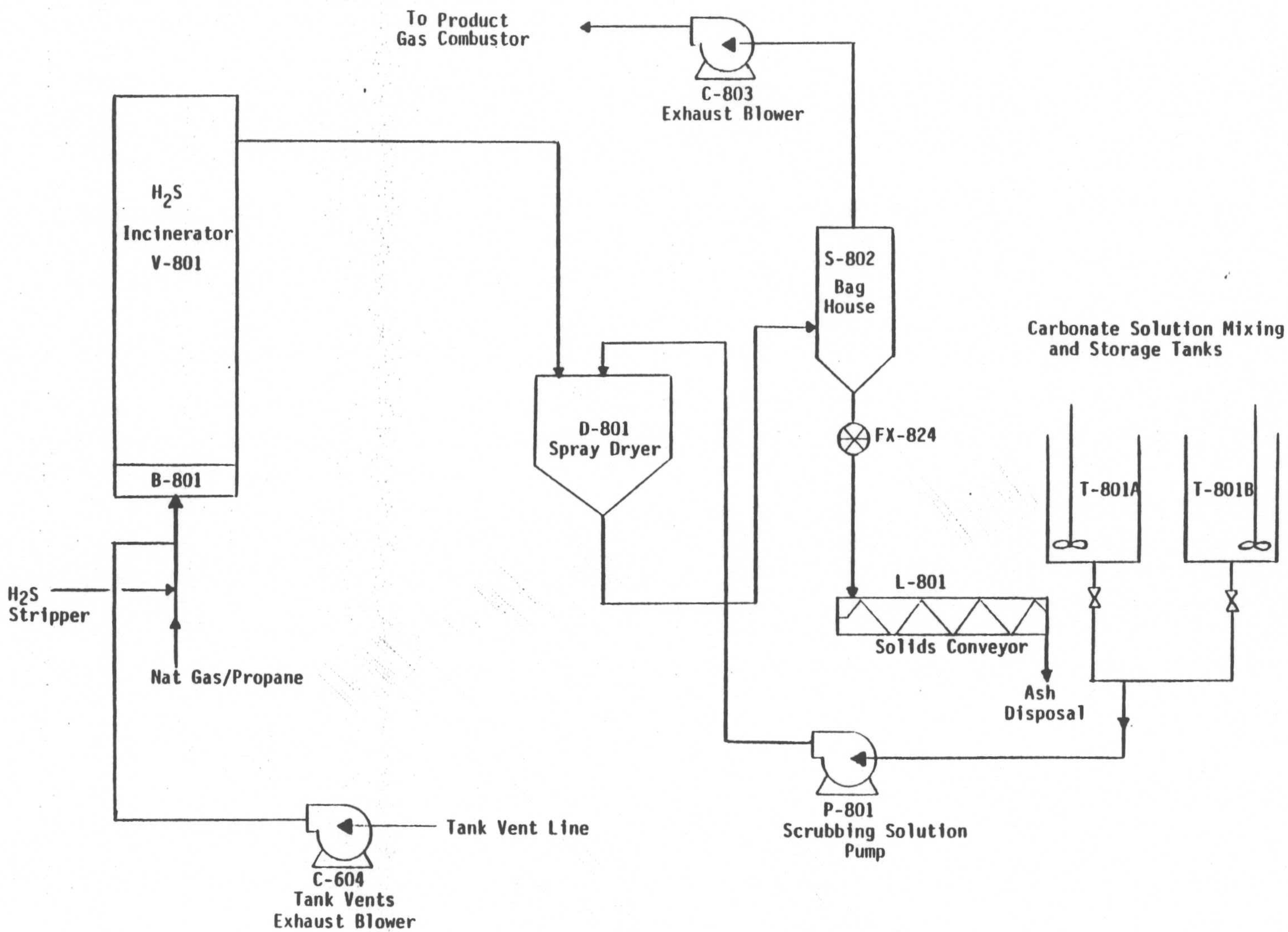

Figure 10. Diagram of the Sulfur Recovery System (source-reference 2)

collecting hopper section in the baghouse. From the baghouse solids collecting hopper, the sulfite and sulfate powder falls through a rotary valve and is transported by a screw conveyor to a receiver for disposal.

2. Control Technology Assessment

The potential hazards associated with the Sulfur Removal System involve the presence of H_2S and SO_2 and Na_2SO_4 dust. The primary control is maintenance of a closed system. This system incinerates H_2S from the H_2S stripper to the less toxic SO_2. The H_2S-containing vent gases from the vent gas header are fed to the H_2S incinerator. The resulting SO_2 is made non-toxic by compounding it with Na_2CO_3 to form Na_2SO_4. The Na_2SO_4 particles are collected in a baghouse. The solids are removed from the baghouse hopper by a rotary feeder.

H. Facilities and Services System

1. Process Description

A diagram of the subsystems which comprise the Facilities and Services System is given in Figure 11.

a. Tank Vent Exhaust Subsystem

An induced-draft header is provided to collect H_2S-containing gases from various storage and hold tanks. This gas is routed to the H_2S incinerator in the Sulfur Removal System for disposal (See Table 3).

b. Instrument Air/Nitrogen Distribution Subsystem

Air for distribution is supplied by an ESG instrument air compressor. This compressor continuously supplies 200 scfm of dry and oil-free air at 110 psig. The air is supplied to various portions of the facility and to the control panels in the plant control room. The air is first filtered and then reduced in pressure to 20 psig.

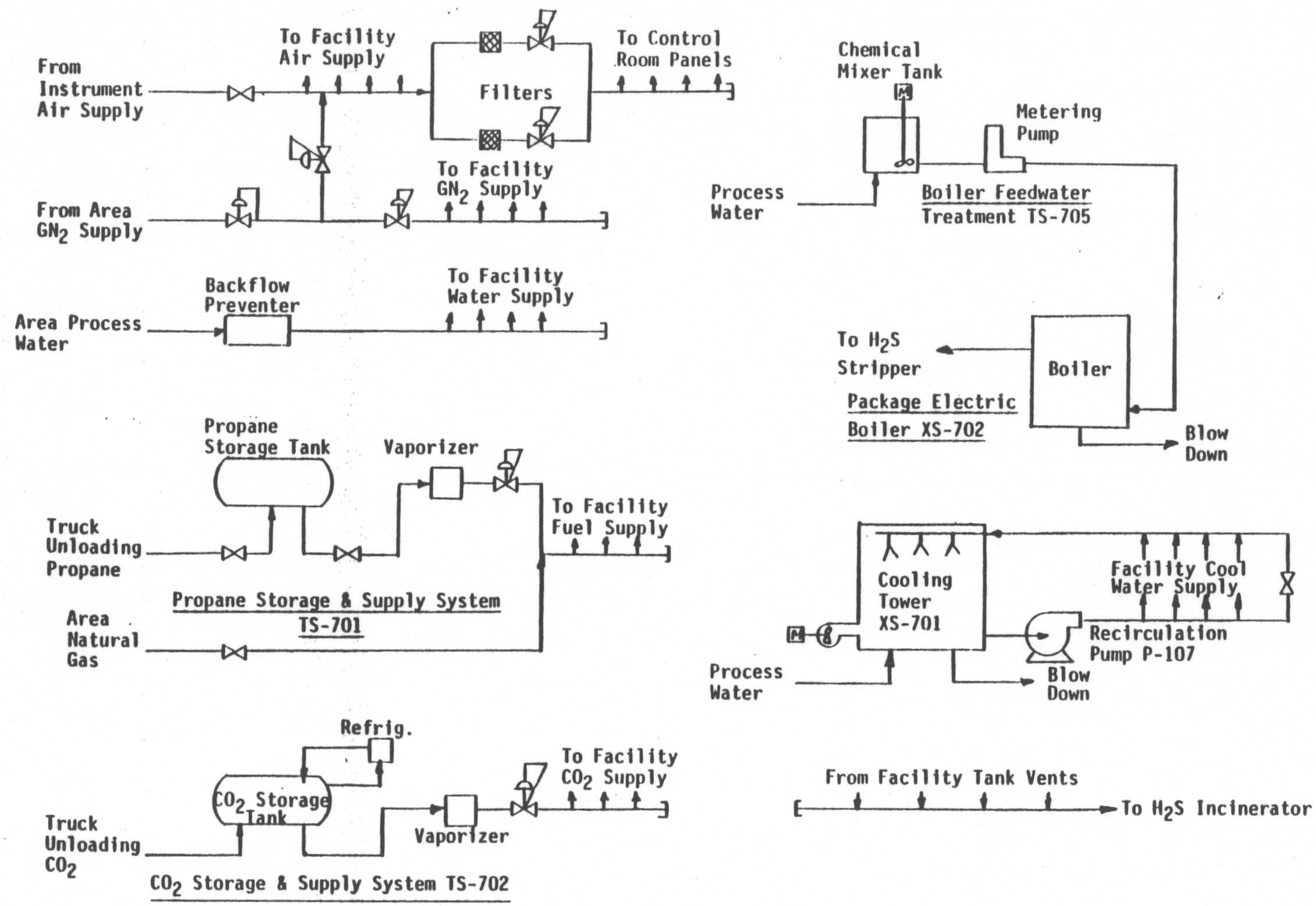

Figure 11. Facility and Services/Subsystem Flow Diagrams (source-reference 2)

TABLE 3

INDUCED DRAFT HEADER TANK VENT LINES

LINES	LOCATION
341-1-XUD	From T-302 Recycle Liquor Storage Tank thru check Valve w/URV
658-1-XUD	From T-604 Recycle Liquor Pump Head Tank
627-1-XUD	On T-603 Sour Water Storage Tank on Line 628-X-HUD three check valve
691-1-XUD	Vent line a V-602 Carbonator, Pressure Safety Relief Valve on line 617-1-LED. Also has a vacuum Relief valve
689-2-XED	Vent line back to vent header
605-1-XUD	From T-602 Green Liquor Storage Tank Thru check valve on line 604
520-1-XED	On S-502 Clarifier thru check valve
515-2-XED	On line 513 from C-502 Precarbonator CO_2 Relief, blower thru PSV
551-2-XUD	From S-501 Seal Liquid vessel thru check valve
526-2-XUD	From S-503 Ash Filter thru check valve
674-3-XUD	To tank vents exhaust blower to H_2S Incinerator

Gaseous nitrogen (GN_2) from the 3500-psig Santa Susana Field Laboratory area distribution system is first reduced in pressure to 1000 psig. The pressure is then further reduced to 350 psig, and the nitrogen is metered and distributed throughout the PDU facility. The GN_2 is also used in the instrument air distribution system as backup to the instrument air compressor.

c. Process Water Distribution Subsystem

Untreated, but potable, site water at 150 psig is distributed to PDU process equipment throughout the facility. It passes through a backflow preventer prior to distribution.

d. Boiler Feedwater Treatment Subsystem

A boiler feedwater treatment system is provided to supply treated water to the package boiler. This consists of a chemical mixing tank and a metering pump. Treatment chemicals are injected into the boiler make-up water.

e. Cooling Water Subsystem

A cooling tower furnishes cooling water to the various heat exchangers in the system.

f. Natural Gas/Propane Supply Subsystem

The Propane Supply Subsystem consists of a storage tank, vaporizer, and pressure regulation station. The storage tank has a capacity of 8000 gal of propane, and the vaporizer has a capacity of 80 scfm. Pressure to the facility services is controlled to 25 psig. The propane system was installed as a backup system in the event the natural gas service was cur- tailed by the supplier utility.

g. CO_2 Storage and Supply Subsystem

The CO_2 Storage and Supply Subsystem is a package unit consisting of a storage tank (with refrigeration system), vaporizer, and pressure let-down station. The storage tank has a capacity of 12 tons of CO_2. The vaporizer is electrically heated (28kW) and has a flow capacity of 350 lb/hr. Pressure to the facility CO_2 supply is controlled at 25 psig.

2. Control Technology Assessment

a. Tank Vent Exhaust Subsystem

A tank vent exhaust system is used to contol the H_2S gas released from the various PDU tanks. The H_2S vapors are fed to the H_2S incinerator by the tank vent exhaust blower. Tank overflows, however, have occasionally caused flooding of the vent system.

b. Instrument Air/Nitrogen Distribution Subsystem

Dry nitrogen was obtained from an ESG 3500 psi header that passes through the site. The plant switched to air when the instrument air compressor became operational. There were no problems with the instrument air/ nitrogen supply system.

c. Process Water Distribution Subsystem

A major problem existed with the process water supply. The water hardness (33 grains/gallon) tended to cause fouling, nozzle plugging, and heat exchanger fouling. A water softener was installed in the makeup water system of the spray cooler and it appeared to prevent fouling of the spray cooler recirculation pump and prevented spray cooler nozzle plugging. Water entered the softener 33 grains/gallon and discharged at 1 grain/ gallon.

d. Boiler Feedwater Treatment Subsystem

Initially the boiler supplied steam at designed conditions, but later its efficiency dropped. The problem was traced to burned-out heater elements. Heater elements were replaced, but continued to fail. The heater failures were apparently due to ineffective water treatment.

e. Cooling Water Subsystem

Minor operational problems were encountered when the cooling water recirculation pump suffered a bearing failure. The problem was corrected, and the cooling water system operated as designed.

f. Natural Gas/Propane Supply

Natural gas is supplied to the plant at 30 psig from an ESG site header. Propane is supplied to the plant in the event of natural gas curtailment.

Natural gas/propane is used primarily for the gasifier preheater, product gas incinerator, and melt withdrawal orifice area burners. A natural gas compressor was installed. This compressor boosts the gas pressure from 30 psig to 300 psig for use in the melt withdrawal chamber burners when operating at 20 atmospheres. Other than minor piping leaks, the natural gas/propane supply operated very well.

g. Carbon Dioxide Storage and Supply Subsystem

Gaseous carbon dioxide is used for sodium carbonate regeneration in the calciner, precarbonator, and carbonator. The carbon dioxide system was activated during regeneration system checkout activities. The system operated as designed with no operational problems.

III. WORK PRACTICES

Work practices for the Molten Salt Facility supplement engineering controls to provide worker protection against hazards identified in the industrial hygiene monitoring program. The California Occupational Safety and Health Administration standards and occupational health and safety requirements of th Department of Energy were followed in the development of these guidelines. The Department of Energy requirements paralled those of the Federal Occupational Safety and Health Administration.

A. Guidelines

Guidelines which are intended to maximize the health and safety of workers while performing standard operations are placed in the operations manual as they are developed. Modifications will be made to these basic guidelines to meet the requirements of each test run. Worker familiarization with these guidelines is met through training sessions held prior to the test runs. Jobs of a more variable nature are handled on a case by case basis using a permit system to insure maximum safety for work involved. A sample permit shown in Figure 12 is completed by the originator of the task outlining special procedures required to safely complete the task. This is reviewed by the Safety Staff and other supervisory personnel for completeness and effectiveness of the described procedures as they relate to the job on hand.

B. Administrative Controls

Work practice procedures and other health and safety guidelines are reinforced by administrative controls serving as a check upon the safety status of the facility and personnel. These controls provide a means of ensuring that the necessary guidelines are being followed and that the workers involved have the necessary training and equipment. These controls include management review, a certification program, and control of access to the facility.

UNIT AUTHORIZING OR PERFORMING WORK

Requested By: ______________________ Dept: __________

Job Location ______________________

Job Description ______________________

Before starting work, safety Supervision of group authorizing or performing work and supervision of work area must be notified.

Reference Procedure, Work Request, Job Order, Etc ______________________

Date of Request __________ Work to Begin __________ Work to End __________

SAFETY AND ORIGINATOR

NAME AND IDENTIFICATION OF PERSONS COVERED BY THIS FORM

NAME	NON-ROCKWELL AFFILIATION	INITIAL	NAME	NON-ROCKWELL AFFILIATION	INITIAL

SAFETY

PROTECTIVE EQUIPMENT REQUIRED

HANDS
- ☐ Canvas Gloves
- ☐ Neoprene Gloves
- ☐ PVC Gloves
- ☐ Surgeon's Gloves
- ☐ Leather Gloves
- ☐ Gauntlet Type
- ☐

BODY
- ☐ Coveralls
- ☐ Lab Coat
- ☐ Surgeon's Cap
- ☐ Hood

- ☐ Acid Apron
- ☐ Gonad Shield
- ☐ Hard Hat
  - ☐ Phenolic
  - ☐ Face Shield
- ☐ Eye Protection
  - ☐ Safety Glasses
  - ☐ Jones Goggles
- ☐ Ear Protection
  - ☐ Ear Plugs
  - ☐ Ear Muffs
- ☐ Safety Harness
- ☐ Safety Belt

FEET
- ☐ Toe Guards
- ☐ Canvas Covers
- ☐ Plastic Covers
- ☐ Boots
- ☐ Leggings
- ☐

RESPIRATORY PROTECTION
- ☐ SCBA
- ☐ Airline Respirator

- ☐ Full-Face Respirator
- ☐ Half-Face Respirator
- ☐ Ultra Filter
- ☐ Combination Canister
- ☐ Organic Vapor
- ☐ Acid Gas
- ☐

PERSONNEL MONITORING EQUIPMENT -
- ☐ Beta-Gamma Film Badge
- ☐ Neutron Film Badge
- ☐ Beta-Gamma Dosimeter
- ☐ Neutron Dosimeter
- ☐ Extremity Monitoring
- ☐ Personal Air Sampler
- ☐ Survey Meter

SPECIAL REQUIREMENTS -
- ☐ Personal Survey
- ☐ Tool Survey
- ☐ Welding Permit
- ☐ Confined Space Procedures
- ☐ Oxy. Deficiency Test
  - ________ % O_2
- ☐ Combustible Atmosphere
  - ________ % LEV
- ☐ Toxic Atmosphere Test
  - ________ % TLV
- ☐ Standby Required
- ☐ Fire Protection

RADIATION MEASUREMENTS

Beta __________ mrem/hr

Gamma __________ mrem/hr

Neutron __________ mrem/hr

Total __________ mrem/hr

Surface Contamination

__________ dpm/100 cm^2

Airborne Radioactivity Concentration

__________ μCi/ml

Special Instructions ______________________

APPROVALS

APPROVALS FOR PERFORMING WORK

Supervisor of Area Where Work Will be Performed ______________________ Date __________

Supervisor of Group Authorizing or Performing Work ______________________ Date __________

Safety ______________________ Date __________ Permit Expires __________

ALL PERSONS COVERED BY THIS PERMIT MUST INITIAL AFTER SAFETY INSTRUCTIONS HAVE BEEN GIVEN

ORIGINATOR

Figure 12. Restricted Access Area Entry Permit

C. Management Review

Manager review is held prior to each test run and on each major change in plant operation. Depending on the nature of the test, the requirements, and the risks, the facility manager may hold one or more meetings with the section engineers where the safety and readiness status of the facility is discussed to ensure that the necessary safety controls are in place and functional. These meetings may be followed by sessions in which the workers are present. The engineers describe the tasks that the workers will be required to perform and the associated hazards. The correct work procedure for the safe completion of each task is covered at this time.

Each major change in plant operation requires a review by upper management before implementation. The project manager and appropriate staff members present the proposed changes, the risks that are involved, and the safety precautions needed to protect the affected workers. These sessions and those pertaining to the test runs are attended by the manager of the industrial hygiene program to ensure that risks involved have been identified and properly evaluated.

D. Controlled Access to Facility

Access to the process area is regulated only while the plant is in operation. During this period the stairwell is chained and no one is allowed in the upper levels near the reactor unless they have specific duties.

Personnel who are not assigned to the facility on a full-time basis must obtain the permission of the project manager and must sign in prior to entering the facility which is fenced in. For activities involving special requirements and safety measures, Rockwell employees must present the types of training they have had and training status; if their training status is considered deficient, they can enter the process area only under escort. Other visitors can only enter the facility under escort.

IV. PERSONAL PROTECTIVE CLOTHING AND EQUIPMENT

At Rockwell, protective clothing and equipment needs are determined on a case-by-case basis by the work area and by the type of operation. The criteria used in making these determinations are based on industrial hygiene monitoring data which was used to identify the potential presence or possible occurrence of the following:

- High operating temperatures: above 1700 F (930 C)
- High operating pressures: 5 atm - 20 atm
- Hydrogen sulfide
- Carbon monoxide
- Thermal stress
- Dust
- Fire and explosion

These hazards are controlled principally by engineering design. However, there are activities which can lead to worker exposure to these hazards. Worker protection is afforded in these cases by the use of protective clothing and equipment.

The basic protective clothing and equipment requirements are dictated by the type of hazard involved and include:

- hard hat in process area
- eye protection (chemical goggles or face shield) for work on pressurized systems
- asbestos gloves for work involving hot surfaces
- aluminized coat for work on high-temperature systems
- dust respirator for coal handling activities
- respirators for on-line equipment containing product gas

Exact specifications are determined prior to each job and recorded on a job permit (Figure 12). This is reviewed by the Industrial Hygiene and Safety Staff, area supervisor, and job supervisor. The workers performing the activity are also required to initial the completed form indicating that they were aware of the necessary precautions.

Canvas gloves are available for use at the worker's descretion. Surgical gloves covered by canvas gloves are used with coveralls in the coal handling area during hopper loading activities and in cleaning char vessels. These activities are extremely dusty and these protective clothing were recommended for personal hygiene reasons. Respiratory protection is provided by the use of a full-face hood with supplied-air.

General equipment for the collection of process stream samples are respirators, gloves, and face shield and/or chemical goggles. The type of respirator required is dependent upon the sample being collected. Hydrogen sulfide is the contaminant of major concern. Both supplied-air and air-purifying respirators are available with choice being determined by the supervisor and safety office on the potential levels that may be encountered.

Hard hat, face shield, and asbestos gloves are required for the collection of a melt sample at the gasifier. Aluminized insulated coats are also recommended for personal comfort.

The operators are provided with shoes and work clothing as needed to replace that damaged by the molten salt. Maintenance personnel working around the gasifier may wear coveralls to provide some degree of protection from the salts.

There are no provisions for the protection of workers from exposures to coal tars because the molten salt process is not considered a tar-producing process.

Personal hygiene requirements such as a daily change of clothing, daily showers, and the use of a clean room/dirty room system that play a critical role in other gasification programs are neither mandatory nor emphasized at this plant.

General health precautionary measures have been developed for upset conditions involving carbon monoxide or sulfur dioxide. These provisions will be modified as needed to meet the needs of each job. For hydrogen sulfide, protective clothing is expected to include full-face shield or nonventilated chemical goggles, chemically resistant rubber gloves, apron or jacket, long sleeves and trousers. Open shoes or sneakers are prohibited. Either air-purifying respirators or self-contained breathing appartus (SCBA) should be used depending upon expected level.

Area monitors are located throughout the process area. At 5 ppm hydrogen sulfide, a warning buzzer is activiated. Workers properly attired are required to find and repair the leak. Respirators are not required at this stage. At 15 ppm an alarm is activated. Anyone remaining in the area must be equipped with an SCBA.

Any work involving opening and entering the regeneration tank requires the use of a supplied-air respirator in addition to the other mandatory clothing. Hydrogen sulfide is present in this tank at a concentration of 2000 ppm by volume. In comparison, the gasifier and product gas has a hydrogen sulfide level of 110 ppm to 200 ppm by volume.

For carbon monoxide, either an SCBA or supplied-air respirator must be used. Carbon monoxide levels range from 29% to 57% in the product gas stream. Personal protection against sulfur dioxide includes full face shield or nonventilated chemical goggles, chemically resistant rubber gloves, apron or jacket, and long sleeve shirt and trousers. Open shoes and sneakers are not allowed. SCBAs or air-purifying respirators may be used depending upon the work involved.

Other respirators used at this facility include the air-purifying and single-use respirator for dust exposure at the coal yard and coal dryer. Chemical canisters providing protection against other contaminants are available at the Respirator Laboratory but have not been used at the Molten Salt Facility. The Respirator Laboratory is the central storage area for respirators and accessories. The Laboratory stores, issues, cleans, and maintains all respirators used by the Energy Systems Group following ANSI Z88.2-1969.

V. MONITORING PROGRAM

ESG used literature information to select the chemical and physical agents for evaluation at the Molten Salt Facility. These agents included total dust, benzene soluble material, benzene, toluene, xylene, naphthalene, hydrogen sulfide, sulfur dioxide, nitrogen dioxide, carbon monoxide, and thermal stress. Items sampled at each test run were determined by test parameters and requirements.

Both personal and area samples were taken. Total dust levels were reported as excessive in coal handling operations including hopper loading. Controls in the form of supplied-air respirators, coveralls, and gloves were imple- mented to reduce exposures in these activities.

Hydrogen sulfide levels up to 90 ppm and carbon monoxide levels of 1000 ppm were obtained at the gasifier sample port. Upset conditions involving liquid waste spill resulted in a hydrogen sulfide level of up to 2000 ppm in areas where no personal were exposed; the breathing zone concentration for personnel was only about one half the TLV. During normal operations a hydrogen sulfide level of 2 ppm was obtained. Results indicated potential problems with hydrogen sulfide and carbon monoxide during upset conditions when spills can occur and in activities at the gasifier. Control was initiated through the use of respirators.

Thermal stress is reported to be a potential problem at the gasifier. Control was handled at the training session level by identifying exposure areas and symptoms of overexposure. Other measured agents were reported to be below the TLV and precautionary measures were not considered necesary.

VI. HEALTH AND SAFETY PROGRAMS

A. Certification Program

The certification program is used to track the status of Rockwell personnel with regards to the different training programs given in the Energy Systems Group. This information is stored in a computerized personnel file and on a card carried by each worker, and can be rapidly used to spot training difficulties. This system is important because workers are not permanently assigned to the Molten Salt facility but are commonly rotated among the different projects managed by this division.

The Molten Salt Coal Gasification project has a nucleus of key personnel including supervisors, engineers and lead operators. During test runs additional personnel will be brought in to run the process. These new personnel are screened and any training deficiencies are corrected prior to the test run. Two types of certification required at this gasification facility include the emergency reentry team certification and respirator training.

B. Training

Work practice procedures are tailored to the needs of each test run. All workers involved in the test run are expected to participate in training sessions to obtain hands-on experience in the performance of the tasks required by the run. These sessions are a continuation of the safety/readiness review held by the facility manager in which the engineers verbally discuss the potential hazards of the test run, the symptoms of overexposures, and the protective measures required. During these sessions the workers become familiar with the facility, and learn the correct ways of performing the tasks. Retraining is provided annually for the duration of the test.

Air-purifying and supplied-air respirators are for use at the gasification facility. Workers at this facility must have a current certification in the use of respirators indicating that they have participated in a respirator training program within the past 12 months. The training session follows the requirements of the American National Standards Institutes ANSI Z88.2 - 1969 using videotapes and practical demonstration to train workers in the use and maintenance of these respirators.

Workers who are members of the emergency reentry team must undergo additional training to familiarize them with the potential problems that may arise during a test run. Training is tailored to the requirements of the individual test run and includes rehearsals in the steps to be followed for a given emergency situation. Team members are certified at the successful completion of the training program with certification being renewed every 6 months for the duration of the test. The use and maintenance of the self-contained breathing apparatus is also a part of this training program.

C. Medical Surveillance Program

All Rockwell personnel who work in the Molten-Salt facility on a regular basis are required to participate in a medical surveillance program. The program includes a complete work and medical history, and an annual physical examination. The physical consists of a complete blood work, chest x-ray, audiogram, eye test, hearing test, EKG, and pulmonary function test. Since these medical requirements are the same for all personnel in the Energy Systems Group, the primary concern is that the information available is current with respect to the individual.

Two additional tasks specifically included in the medical program for the Molten Salt facility personnel include sputum and urine cytology. Skin examinations are not provided because the process is not considered a source of PNAs, which are potential skin carcinogens.

Each worker has a physical capability profile outlining job restrictions including limitations on respirator usage because of medical disabilities. These profiles are distributed to the employee, his supervisor, and the Industrial Hygiene Officer.

VII. CONCLUSIONS

Information on the potential hazards and the control technologies applicable to the operation of the MSCG PDU was presented in this report. The potential hazards are due to the use of high operating temperatures (1800 F) and pressures (20 atm), the generation of coal dust, and the production of toxic and flammable/explosive gases such as CO, H_2S and H_2.

The primary method used to minimize worker exposure to these potential hazards in each process area is by maintaining closed system operations. Because the facility is housed in open structures, natural dilution ventilation provides some dissipation of process emissions entering the workplaces.

Maintaining the closed systems involves both inherent process features as well as a wide range of design and materials of construction modifications. While the later is attempted for reliable, continuous operation, the changes reduce maintenance-related activities and exposures where the maintenance involved breaking into the process streams containing harmful or toxic agents. Where there are emissions into the workplace, such as vent gas streams, equipment has been provided to reduce emissions of agents such as coal dust, noise, and CO and H_2S. The potential for fire and/or explosion is minimized throughout the system by using GN_2 as a cover gas, ASME Section VIII Standards for pressure vessel design, explosion-proof electical systems, and proper process design and review.

These engineering controls are supplemented by work practices and personal protective equipment on a case-by-case basis. Results of in-house monitoring surveys have indicated the need for such activities as gasifier stream sampling and maintenance and housekeeping activites.

REFERENCES

1. Kohl, A.L., Rockwell International, Molten Salt Coal Gasification Process Development Unit, Phase 1 Final Report, Volume 2, Commercial Plant Study, May 1980, U.S. Department of Energy, DOE/ET/10296-66 (Vol. 1).

2. Kohl, A.L., Rockwell International, Molten Salt Coal Gasification Process Development Unit, Phase 1 Final Report, Volume 1, PDU Operations, May 1980, U.S. Department of Energy, DOE/ET/10296-66 (Vol 1).

3. Slater, M.H., A.L. Kohl, Molten Salt Coal Gasification Process Development Unit, Phase 2, Quartely Techniucal Progress Report No. 4, For April-June, 1981, July 21, 1981, U.S. Department of Energy, DOE/ET/10296-194.

4. Dravo Corporation, Handbook of GAsifiers and Gas Treatment Systems, Final Report, February 1976. U.S. Department of Energy. FE-1772-11.

5. National Institute for Occupational Safety and Health, Criterial for Recommended Standard...Occupational Exposures in Coal Gasification Plants, September 1978, U.S. Department of Health, Education and Welfare. DHEW (NIOSH) Publication No. 78-191.

6. National Institute for Occupational Safety and Health, Recommended Health and Safety Guidelines for Coal Gasification Pilot Plants, Enviro Control, Inc., U.S. Department of Health, Education and Welfare. January 1978. DHEW (NIOSH) Publication No. 78-120.

7. U.S. Department of Energy, Coal Gasification, Quarterly Report, July-September 1979. DOE/FE-00-2/70/3. Publication Date: July, 1980.