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HAZARD ANALYSIS REPORT

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ALLEGANY BALLISTICS LABORATORY

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HERCULES AEROSPACE DIVISION
HERCULES INCORPORATED
ALLEGANY BALLISTICS LABORATORY
CUMBERLAND, MARYLAND

SAFETY ANALYSIS
of the
1000 LB/DAY COAL-
LIQUEFACTION PDU

MAY 1981

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Conclusions presented in this hazards analysis report are based upon the hardware (or design), materials of construction, operating conditions, process materials and procedures as they existed at the time of the analysis (or as they were presented to Hercules for analysis). If changes in any of these parameters occur in the future, the conclusions of the current hazard analysis may be invalidated.

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I. SUMMARY

A. OBJECTIVE

The objective of the program reported herein was to provide a Safety Analysis of the 1000 lb/day PDU located in Building 83 at the Pittsburgh Energy Technology Center. This Safety Analysis conforms to DOE Order 5481.1(1) and was performed in accord with the "Management Implementation Plan for a Safety Analysis and Review System"(2) developed as a separate task under the same contract, with one exception: an audit of the unit to demonstrate conformance with all guides, codes, and standards was excluded as being out of scope of the present contract. A Level 1 Safety Analysis is reported herein.

B. CONCLUSIONS

Risks to personnel from potential process hazards are largely controlled by installation of a major portion of the unit within a "hot cell". This segregates and isolates personnel from a majority of potential equipment rupture and fire/explosion hazards. Equipment within the cell is subject to potential risks associated with overpressurization or excessively high temperature, and fire/explosion due to ignition of leaking flammable gas (i.e. H_2). There are some existing safeguards designed to protect against overpressure or high temperature. Additional safeguards are offered to minimize these risks. The hot cell is provided with general dilution ventilation and hydrogen monitoring. However, confinement effects and potential ignition sources are such that avoidance of formation and ignition of flammable mixtures cannot be assured.

Potential health hazards relate to contact with coal-derived liquids or inhalation of irritant or toxic gases, vapors, or dusts, associated with slurry preparation, sampling, draw down of catch-pots, or cleaning of centrifuge bowls.

No particularly serious workplace safety hazards were identified, and environmental concerns are largely limited by the relatively low throughput for the unit.

No specific risk criteria were provided by PETC for the conduct of this analysis. The Implementation Plan (2) specifies mandatory recommendations for any hazards meeting Recommendation Guidelines based on likelihood and severity as shown in the matrix in Table I. No hazards meeting these requirements were identified, primarily because consequences to personnel are controlled and limited by location of the high pressure-high temperature equipment within the hot cell. A number of Category I hazards with 'Remote' likelihood, and Category II hazards with 'May Occur' likelihood, were identified. Recommendations were developed for these hazards. Implementation of these recommendations will materially reduce the overall risk level of the operation.

TABLE I
RECOMMENDATION GUIDELINES*

<u>Likelihood Ranking</u>	<u>Hazard Category</u>			
	<u>I</u>	<u>II</u>	<u>III</u>	<u>IV</u>
Frequent	PF	PF	P	-
Probable	PF	P	-	-
May Occur	P	-	-	-
Remote	-	-	-	-

Codes

- P: Recommendation required if consequence to people involved
- PF: Recommendation required if consequence to people or facilities involved
- : Recommendation optional

Likelihood Rankings

- Frequent - Likely to occur often
- Probable - Likely to occur occasionally
- May Occur - Unlikely, but may occur at some time
- Remote - Unlikely to occur at any time

Hazard Categories

- I - Catastrophic: Death or permanent total disability; or loss of large, expensive operation or building or off-site structure.
- II - Critical: Permanent partial disability; or loss of major equipment item, some damage to adjacent units, or loss of entire small operation.
- III - Marginal: Temporary disability; or moderate damage to major equipment, but repairable.
- IV - Negligible: First aid case or no injury; or minor damage to major equipment, or loss of minor equipment, or no damage.

*Based on Reference (2).

C. RECOMMENDATIONS

The following specific recommendations are made to aid in assuring a remote likelihood of occurrence for the Category I or Category II hazards, as identified.

1. Establish and follow a preventive maintenance and inspection program for H₂ compressors.

Compressor rupture is a Category I hazard, based on pressure at rupture and location of compressors. Following a good maintenance and inspection program will aid in assuring the likelihood of compressor rupture remains 'Remote'.

2. Provide the following safeguards against high system pressure:
 - a) Re-set make-up H₂ compressor relief valve to 5000 psig.
 - b) Provide high pressure cutoff switch for compressor set at ~ 4500 psig.
 - c) Provide high pressure cutoff switches on system pressure transducers (PT3-PT8) to shutdown compressors and feed pump at ~ 4500 psig.
 - d) Relocate PT-10 or V-41 on discharge of recycle H₂ compressor so that PT-10 is between compressor and valve.

Rupture of system vessel due to overpressurization is classified as 'Category II hazard with 'May Occur' likelihood. Recommended safeguards will reduce likelihood to 'Remote'.

3. Establish program for monitoring metallurgical condition of vessels

The 316SS material of construction is notably resistant to most forms of gaseous attack. However, the synergistic effects of the process material constituents is not understood. Therefore, the likelihood of vessel rupture due to metallurgical change (Category II hazard) has been ranked as 'May Occur'. Closely monitoring system vessels will aid in assuring that progressive or incipient metallurgical change is detected before an incident occurs. Likelihood can then be ranked as 'Remote'.

4. Provide relief valves on all steam jackets

Failure of steam pressure regulator can result in overpressurization of the jacket. Relief valves will reduce the likelihood of this Category II incident from 'May Occur' to 'Remote'.

5. Provide independent high-temperature switches for reactor heaters

Rupture of a reactor due to loss of material strength at high temperature is classified as a 'Category II - May Occur' incident. Providing an independent high temperature switch to shut off power in the event of temperature control failure will reduce likelihood to 'Remote'.

6. Re-qualify reactors to ASME code

There were indications that modifications involving cutting and welding have been made on the reactors. Since these are not documented, the current pressure capability of the vessel is uncertain. Therefore, likelihood was ranked as 'May Occur'. The generic failure rate for coded vessels corresponds to a likelihood of 'Remote'. This recommendation applies to any other vessels which may have been modified.

7. Provide inerting system for vacuum still, interlocked to vacuum pump

The ignition temperature of the heavy oil which is vacuum distilled was not among the material properties provided in the technical data package. The still operating temperature of 300°C. is above the ignition temperature of some hydrocarbon compounds. Ignition of the vacuum still contents on admission of air may therefore be a credible scenario. Failure of the vacuum pump, followed by backflow of air into the still is the most plausible mode of air inflow. Consideration should be given to providing a system to fill the still with nitrogen in the event of vacuum pump failure, unless it can be determined the auto-ignition scenario is not credible.

8. Provide nitrogen purge for Light Oil Receiver D-14

This is the only receiver for which the process flow diagram does not indicate inclusion of a nitrogen purge. Provision of the nitrogen purge, if not now present, would result in a 'Remote' likelihood of internal fire/explosion (a Category II hazard).

The following general recommendations are made to further minimize the likelihood or severity of identified hazards in the operation of the 1000 lb/day PD-U.

1. Institute and follow a pressure vessel history log system to document and record history of use, inspections, tests, and modifications for each pressure vessel.
2. Develop written operating manual for the unit containing formalized operating procedures, personal protective equipment, etc.
3. Check all nitrogen lines connected to unit and provide check valves to prevent backflow, if not now provided.
4. Conduct monitoring program to determine concentrations of airborne contaminants present for each manual operation.
5. Consider feasibility of incineration of waste materials as alternate to landfill.

II. INTRODUCTION

A. BACKGROUND

The 1000 lb/day PDU is a continuous-flow coal liquefaction unit installed in Building 83 at the Pittsburgh Energy Technology Center. DOE Order 5481.1 requires that DOE Operations with hazards of a type or magnitude not routinely encountered and/or accepted by the public be analyzed to assure that potential hazards are systematically identified, potential impacts are analyzed, and that reasonable measures to eliminate, control, or mitigate the hazards have been taken. The Safety Analysis reported herein was conducted to meet these objectives. Work was carried out under Contract DE-AC22-80PC 30198. This report completes Task No. 3 of this contract.

B. SCOPE OF THE ANALYSIS

The scope of the analysis reported herein was the 1000 lb/day coal liquefaction PDU, consisting of the subsystems identified in Table II. Most of the high-pressure, high-temperature sections of the process are located in a concrete 'hot cell' and personnel are thus protected from potential hazardous incidents. This fact, combined with the general informal and broad nature of the documentation available for the analysis, was the determinant of a Level 1 Safety Analysis as being the most appropriate for the unit.

Bounds of the analysis with respect to the slurry feed subsystem is the point at which pulverized coal is added to the slurry preparation tank. Boundary for the make-up hydrogen subsystem is the suction of the hydrogen compressor. The bounds for liquid 'product' streams were the respective receivers, from which material is removed from the unit. Off-gases boundaries were the points at which the streams enter the flare system from individual equipment items.

Testing of product or samples and ultimate disposal was not in scope. Analysis of the building in which the unit is housed was not in scope. Interfacing of the unit with building systems such as ventilation and fire protection was considered, however.

The Safety Analysis reported herein conforms to DOE 5481.1 and the Implementation Plan ⁽²⁾ developed under Task No. 4 of this contract with the one exception that an audit to demonstrate conformance to applicable guides, codes, and standards is not included. While this provision of DOE 5481.1 was noted, the vast number of applicable regulations was not evident until midway through the development of the Implementation Plan when the document specifying prescribed standards was identified and requested from PETC. The number of guides, codes, and standards which would have to be checked for applicability and then audited against is far beyond what anyone envisioned and is clearly beyond the scope of the present contract. A listing of prescribed standards is presented in Appendix D for reference.

C. BASIS OF THE ANALYSIS

The Safety Analysis as reported herein was based on a site visit, the process flow diagrams, material balance, equipment data, and operating procedures provided to Hercules or as represented to Hercules by the Pittsburgh Energy Technology Center. A detailed listing of the data and information package which was used as the basis of the analysis, is documented in Appendix A.

III. DISCUSSION

This section of the report contains a description of the 1000 lb/day PDU and a discussion of the safety analysis of the unit. The section consists of five subsections: A - Description of the Operation, B - Process Hazards Analysis, C - Workplace Health Analysis, D - Workplace Safety Analysis, and E - Environmental Analysis. A Level 1 safety analysis is reported herein.

A. DESCRIPTION OF THE OPERATION

The 1000 lb/day coal liquefaction PDU is designed to process coal slurry (up to 40% coal) at a rate of 45 lb/hr. Design operating conditions are 2000 psig and 455°-460°C. Natural catalytic constituents of the coal (ash) or disposable catalysts are generally used. The unit consists of slurry and hydrogen feed, reaction and separation, and equipment to purify and recycle liquid products and off-gas. A functional block diagram of the unit is shown in Figure III-1.

Pulverized coal is slurried in recycle oil in a slurry preparation tank on a batch basis and transferred to a slurry feed tank. Slurry is fed to the unit at the desired rate by a metering feed pump. The slurry feed subsystem is kept at 200°-250°F for viscosity control, and circulation and agitation are provided to maintain a uniform coal suspension.

Make-up hydrogen is compressed in a five-stage compressor to provide hydrogen make-up to the unit. The compressor is driven by a variable speed drive which is set to deliver the desired flow of make-up hydrogen. Recycle hydrogen (purified off-gas) is pressure boosted in a recycle compressor. The flow of recycle hydrogen is controlled by a flow controller fed by a flow transmitter and modulating a flow control valve. Excess recycle hydrogen is recycled around the compressor by a pressure control valve which is modulated by the compressor discharge pressure. A back pressure regulator on the system directs the excess off-gas to a flare system.

The coal slurry, make-up hydrogen, and recycle hydrogen are fed through a common line to a preheater where temperature is raised to 350°-400°C. The combined stream then passes through three reactors in series, each of which has four temperature-controlled heating zones. The reacted mixture then passes through a cooler to the primary separator where initial liquid-vapor (gas) separation occurs. The vapor (gas) passes through a second cooler (condensor) to the light oil separator. Water may be injected if desirable to remove NH_3 or further cool the vapor. Off-gas from the light oil separator may optionally be passed through an amine absorber (for removal of H_2S) and/or through a kerosene absorber (for removal of CH_4). It then passes either to the recycle compressor or through the back pressure controller to the flare system.

III-2

Figure III-1. 1000 Pound/Day PDU Block Diagram

Heavy oil is let down from the primary separator through a let down valve which operates on a timed cycle sequence designed to maintain level within the separator in a controlled range. Heavy oil may be directed to either the centrifuge subsystem or vacuum distillation subsystem for 'purification' prior to being recycled back to the slurry feed system.

The centrifuge subsystem consists of tankage, pumps and centrifuge used to clean up the heavy oil. By contrast, vacuum distillation is used in the alternate clean-up scheme.

Light oil is let down from the light-oil separator similarly to heavy oil in the primary separator. It is directed to one of two light oil receivers, from which it is removed from the unit as light oil product.

B. PROCESS HAZARDS ANALYSIS

The process hazards analysis is a constituent analysis of an overall safety analysis and considers the hazard consequences of fire/explosion, material release, and vessel failure due to component failure(s), operator error(s), process upset, procedural deficiency, or design characteristics. A discussion of the process hazards analysis of the 1000 lb/day PDU is presented in the paragraphs which follow. The discussion is accompanied by hazards analysis fact sheets which document the individual identified process hazards.

1. General Process Concerns

Concerns in the operation of the 1000 lb/day PDU relate to: 1) the high operating pressures and temperatures, 2) the severity of service posed by the process materials, 3) the extent and nature of operating procedures for the unit, and 4) electrical equipment classification. Each of these is discussed in general below.

a. High Pressure and Temperature

The stated design conditions for the unit are an operating pressure of 2000 psig at an operating temperature of 460°C (in preheater and reactor). The system is normally cold tested at 4000-4500 psig and tested at operating temperature at 2000 psig. A pressure test is conducted with nitrogen before testing with hydrogen.

A review of equipment specifications and ratings indicates that the equipment, as originally purchased, was adequate for the service conditions. The history of system vessels, however, with regard to inspections, hydrostatic tests, or possible modifications, is not well documented. Therefore, the current status of system vessels cannot be stated with

certainty. It is recommended that a pressure vessel history log system be implemented and that the provisions of the ASME Code for periodic testing and inspection be followed. A summary of the PDU vessel data is presented in Table III.

b. Metallurgical Considerations

Materials of construction in the high pressure - high temperature sections of the PDU is 316 SS. Tanks in the low pressure ancillary areas are either 304 SS or carbon steel. The 300 series SS are particularly resistant to most forms of attack by gases (such as H₂, H₂S, CO, CH₄) at the system operating temperatures. However, the effects of elevated pressure and possible synergistic effects of the process material constituents are not well understood. Furthermore, composition of the gaseous phase may vary from feedstock to feedstock or run to run. Therefore, it is advisable that close attention be paid to the metallurgical condition of the system vessels as an aid to preventing possible vessel failure due to metallurgical change.

c. Operating Procedures

Current operating procedures are informal, and quite general in nature. There is therefore no basis for presuming with any certainty that standard and 'safe' procedures are being followed in the conduct of the operation (although this may nonetheless be true). Development of, and adherence to, a formal set of standard operating procedures would enhance the level of assurance that safe practices are being followed.

d. Electrical Equipment

System documentation did not include the designation of classifications of hazardous areas or of electrical equipment specifications. The likelihood and severity of potential incidents originating with leaking of hydrogen would be minimized by the use of equipment and wiring in the hot cell and immediate vicinity of the hydrogen compressors, which meet the requirements for Class I, Division 2, Group B.

2. Results and Recommendations

A number of potential hazards were identified in the PDU system. These were evaluated for both likelihood of occurrence and severity in the event of occurrence. Likelihood and severity codes were assigned to each hazard in accord with the definitions in Table III-1. The highest risk levels identified are represented by 1) "Catastrophic" Consequence with "Remote" Likelihood (I - Remote), and 2) Critical Consequence with "May Occur" Likelihood (II - May Occur). No specific risk criteria were provided for use in the conduct of the analysis. The Implementation Plan⁽²⁾ specifies mandatory recommendations for any hazard categorized as 'Catastrophic' (I) whose likelihood is not 'Remote', any hazard categorized as 'Critical' (II) whose likelihood is 'probable' or 'frequent', and any hazard categorized

TABLE III

1000 LB/DAY PDU PRESSURE VESSEL DATA

<u>Vessel</u>	<u>Year Built</u>	<u>Material</u>	<u>Certified?</u>	<u>Working Pressure</u>	<u>Modifications</u>
Reactors (3)	1977	316 SS	Yes	4500 psi @ 850°F	Yes - not documented
Primary Separator F-2	1976	316 SS	Yes	5250 psi @ 750°F	None known
Light Oil Sepa- rator F-3	1976	316 SS	Yes	5500 psi @ 650°F	None known
Gas Scrubber L-1	1977	316 SS	Yes	4500 psi @ 150°F	None known
Gas Scrubber L-2	1977	316 SS	Yes	4500 psi @ 150°F	None known
Stripper C-1	Unknown	316 SS	Unknown	25 psi @ 300°F	None known
Stripper C-2	Unknown	316 SS	Unknown	25 psi @ 300°F	None known

TABLE III-1

LIKELIHOOD RANKINGS AND HAZARD CATEGORIES*

Likelihood Rankings

Frequent	-	Likely to occur often
Probable	-	Likely to occur occasionally
May Occur	-	Unlikely, but may occur at some time
Remote	-	Unlikely to occur at any time

Hazard Categories

I - Catastrophic:	Death or permanent total disability; or loss of large, expensive operation or building or off-site structure.
II - Critical:	Permanent partial disability; or loss of major equipment item, some damage to adjacent units, or loss of entire small operation.
III - Marginal:	Temporary disability; or moderate damage to major equipment, but repairable.
IV - Negligible:	First aid case or no injury; or minor damage to major equipment, or loss of minor equipment, or no damage.

*Based on Reference (2).

as 'Marginal; (III) whose likelihood is 'frequent'. No hazards meeting these requirements were identified, primarily because the consequences to personnel are controlled and limited by location of the high pressure-high temperature equipment within the hot cell.

Recommendations were developed for all hazards identified as Catastrophic - Remote, or Critical - May Occur. The scenarios and recommendations for these hazards are discussed below. Hazards are referenced by the entry number with which they appear in the hazards analysis fact sheets (Table III-3 at the end of this section).

a. Rupture of Hydrogen Compressor

Hazard Category - I

Likelihood Ranking - Remote

Both the make-up and recycle hydrogen compressors are located outside the hot cell. Rupture of the compressor is categorized as a Category I hazard based on the potential consequences to personnel, if present, from either missile fragments or ensuing fire/explosion. The likelihood ranking is based on generic failure data for compressors. It is recommended that a compressor preventive maintenance and inspection program be instituted (if not now in place) to assure compressors are properly maintained and that premature failures do not occur.

b. Vessel Rupture Due to Overpressure

Hazard Category - II

Likelihood Ranking - May Occur

This scenario applies to the following vessels: make-up and recycle accumulators, reactors, heavy oil separator, light oil separator, amine absorber, and kerosene absorber (Hazards 19, 24, 27a, 29a, 32a, 35, and 39, respectively).

Overpressurization may be initiated by a plug in the system or failure of the backpressure control system or closure of anyone of a number of manual valves. The slurry feed system is provided with a pressure switch to shutdown the feed pumps when system pressure reaches 4000 psi, and a relief valve to put the pumps on recycle at 5000 psi. However, the make-up hydrogen compressor does not have a high pressure switch and the relief valve does not operate until 7500 psig. If the relief valve fails, higher pressure may be realized. The following recommendations are made to reduce the likelihood from 'May Occur' to 'Remote'.

- (1) Provide pressure switch set at 4500 psig on make-up hydrogen line to shut down compressor.
- (2) Reset compressor relief valve to 5000 psig.
- (3) Provide high pressure switches for system pressure transducers (PT 3 through PT 8) set at 4500 psig to shutdown feed pump and compressor (redundancies to feed pump and compressor switches).

The recycle compressor is provided with a pressure control system modulating a valve in the recycle line around the compressor. However, the pressure transducer is located downstream of a valve on the discharge line. If this valve is closed or becomes plugged, the pressure control system is inoperative. The pressure transducer should be located before the first valve on the discharge of the compressor. This will reduce likelihood of overpressurization from 'May Occur' to 'Remote'.

The amine and kerosene strippers are provided with off-gas vents to the flare system. However, the vent capacity may not be sufficient in the event of system failure (full flow of vapor from light oil separator directed through stripper). There is insufficient design detail provided to determine the credibility of overpressurizing the strippers. The strippers should be provided with relief valves with separate lines to the flare system if present vent line capacity is inadequate. This will assure a 'Remote' likelihood.

c. Fire/Explosion in Hot Cell Due to H₂ Leak

Hazard Category - II

Likelihood Ranking - May Occur

Hydrogen leaks may occur at the preheaters, reactors, separators, absorbers, accumulators or interconnecting piping. The system is pressure tested prior to commencing each run to ensure there are no leaks at the outset. General dilution ventilation and a hydrogen monitor are provided in the hot cell. However the geometry and confinement aspects of the electrical heaters associated with the preheater, reactors, and separators are probably such (insufficient detail provided to fully assess) that dilution or detection of leaking hydrogen cannot be presumed. Therefore, likelihood has been judged to be 'May occur'.

d. Vessel Rupture Due to Metallurgical Change

Hazard Category - II

Likelihood Ranking - May Occur

This hazard was discussed under 'General Process Concerns - Metallurgical Considerations'. It particularly applies to vessels where

operating temperatures are the highest or gases may be most concentrated (reactor, heavy oil separator, absorbers, and amine stripper; Hazards 27c, 29d, 35c, 37c, and 39c, respectively). A program of vessel inspection and monitoring is recommended to detect progressive or incipient metal damage. This will aid in reducing likelihood of an incident to 'Remote'.

e. Rupture of Steam Jacket Due to Overpressurization

Hazard Category - II

Likelihood Ranking - May Occur

Several tanks are provided with steam jackets (recycle oil tank, slurry mix tank, slurry feed tank, heavy oil receivers; Hazards 4, 8, 13, 46, respectively). Steam pressure is reduced from the main header pressure of 130 psig to supply these jackets. In the event of pressure regulator failure, the jackets may be overpressurized and rupture. A hazard category of II has been assigned on the basis of potential for burning personnel, if present. Steam jackets should be provided with relief valves set to operate below the rated jacket pressure. This would reduce likelihood from 'May Occur' to 'Remote'.

f. Rupture of Reactor Due to High Temperature
(loss of Strength) (Hazard 27b)

Hazard Category - II

Likelihood Ranking - May Occur

The reactors are provided with several zones each of electrical heaters. Temperature is normally controlled via a thermocouple - controller - SCR - heater loop. A single failure in the control loop could result in excessive heat input and high reactor temperature. A likelihood ranking of 'May Occur' is assigned based on a single failure scenario. It is recommended that an independent high-temperature cutoff safety system, similar to that provided on the preheater, be provided for the reactors. This would reduce likelihood to 'Remote'.

g. Failure of Reactor (Hazard 27d)

Hazard Category - II

Likelihood Ranking - May Occur

Random failure of a pressure vessel is always a possibility. The likelihood of failure of vessels meeting the ASME code can be considered 'Remote' based on the generic failure rate of such vessels. The reactors were originally constructed and certified to the ASME Code. However, indications are that modifications involving cutting and welding were subsequently

made to the reactors. These modifications and subsequent inspections, if any, are not documented. Therefore, a likelihood ranking of 'May Occur' has been assigned to reactor failure. Documented reinspection would provide assurance that the likelihood of failure is, in fact, remote.

h. Fire/Explosion in Vacuum Still (Hazard 70b)

Hazard Category - II

Likelihood Ranking - May Occur

The vacuum still normally operates at 10-15 mm Hg and 250°-300°C. The precise autoignition temperature of the heavy oil is not known, but there are organic materials whose ignition temperatures are below the 300°C operating temperature. Therefore it must be presumed that ignition may result if air contacts the hot material in the still. Failure of the vacuum pump could lead to backflow of air through the flare system to equalize pressure in the still, thus resulting in ignition. It is therefore recommended a nitrogen source be interlocked with the vacuum pump to 'flood' the still with nitrogen in the event of vacuum pump failure. This would reduce incident likelihood to 'Remote'.

i. Fire/Explosion in Light Oil Receiver (D-14) (Hazard 64)

Light oil receiver D-14 is the only system tank or receiver for which the Process Flow Diagram does not indicate a nitrogen purge. Provision of a nitrogen purge on this receiver as well will assure a 'Remote' likelihood of an incident.

3. Index of Identified Hazards

A number of other hazards, in addition to those discussed in Paragraph 2, were identified. These hazards were either judged to be less likely to occur or less severe in consequences. All identified hazards were documented by subsystem and given a sequential number for reference. An index of identified hazards by subsystem is given in Table III-2. The hazards are documented on hazards analysis fact sheets in Table III-3.

TABLE III-2
INDEX OF IDENTIFIED PROCESS HAZARDS

<u>Subsystem</u>	<u>Hazard Numbers</u>	<u>Page No.</u>
Slurry Feed	1-15	III-12
Make-up Hydrogen	16-20	III-16
Recycle Hydrogen	21-24	III-18
Reaction	25-28	III-19
Separation	29-34	III-22
Amine Absorption	35-38	III-26
Kerosene Absorption	39-42	III-29
Centrifugation	43-51	III-32
Light Oil	52-54	III-36
Vacuum Distillation	55-71	III-37

TABLE III-3. PROCESS HAZARDS ANALYSIS

SYSTEM: 1000 lb/day PDU

SUBSYSTEM: Slurry Feed

EQUIPMENT: Recycle Oil Tank D-1

HAZARD IDENTIFICATION		CONSEQUENCES		EXISTING CONTROL MEASURES	COMMENTS AND RECOMMENDATIONS
DESCRIPTION	LIKELIHOOD RANKING	DESCRIPTION	HAZ. CAT.		
1. Overpressurization of tank.	Remote	Damage to tank. Release of hot recycle oil.	III	Relief valve set at 10 psig. Hydrostatic test at 8 psig.	Install check valve in inert line. Monitor weigh scale during operation.
2. Overfill tank.	May Occur	Contamination of inert gas system with hot recycle oil or oil flow thru relief valve to flare.	III		
3. Ignition of vapors in tank head space.	Remote	Fire or explosion in tank, with possible rupture of tank, release of oil and ensuing external fire. Personnel injured, if present.	II	Tank is normally inerted. Maximum steam temperature is below flash point of recycle oil (assumed equivalent to SRC II). No other normal ignition sources.	Details of steam jacket piping not included. Jacket should have relief valve if one is not included.
4. Overpressurization of steam jacket.	May Occur	Rupture of jacket. Personnel injured or burned, if present.	II	Pressure reduced in two stages 130 → 40 → 5 psig.	

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TABLE III-3 (CONT'D.)

SYSTEM: 1000 lb/day PDU

SUBSYSTEM: Slurry Feed

EQUIPMENT: Slurry Prep Tank D-2

HAZARD IDENTIFICATION		CONSEQUENCES		EXISTING CONTROL MEASURES	COMMENTS AND RECOMMENDATIONS
DESCRIPTION	LIKELIHOOD RANKING	DESCRIPTION	HAZ. CAT.		
5. Overpressurization of tank.	Remote	Damage to tank. Release of hot slurry.	III	Relief valve set at 12 psig. Hydrostatic test at 8 psig.	Install check valve in inert line for back-up. Details of jacket piping not included. Jacket should have relief valve if one not now provided.
6. Overfill tank.	Remote	Contamination of inert system with oil or slurry, or oil flow thru coal port or relief line.	III	D-2 has larger capacity than D-1. D-2 normally empty before oil is charged from D-1.	
7. Ignition of vapors or coal dust in tank head space.	Remote	Fire or explosion in tank. Possible rupture with release of material and ensuing fire. Personnel in- jured, if present.	II	Tank is normally inert before coal is added. Maximum steam temperature is below flash point of vehicle oil. No normal ignition sources.	
8. Overpressurize steam jacket.	May Occur	Rupture of jacket. Injury or burns to personnel, if present.	II	Steam pressure reduced in two stages 130 → 40 → 5 psig.	
9. Recirculation pump J-1 deadheaded.	May Occur	Damage to pump internals, or drive motor.	III	Pump relief valve set at 150 psig.	

III-13

TABLE III-3 (CONT'D.)

SYSTEM: 1000 lb/day PDU

SUBSYSTEM: Slurry Feed

EQUIPMENT: Slurry Feed Tank D-3

HAZARD IDENTIFICATION		CONSEQUENCES		EXISTING CONTROL MEASURES	COMMENTS AND RECOMMENDATIONS
DESCRIPTION	LIKELIHOOD RANKING	DESCRIPTION	HAZ. CAT.		
10. Overpressurization of tank.	Remote	Damage to tank. Release of hot slurry.	III	Relief valve set at 12 psig. Hydrostatic test at 8 psig.	Install check valve on inert line. Operators should assure there is sufficient available volume in D-3 before transferring contents of D-2.
11. Overfill tank.	May Occur	Contamination of inert system with slurry.	III		
12. Ignition of vapors in tank head space.	Remote	Fire or explosion in tank with possible rupture and release of material with ensuing fire. Personnel injured, is present.	II	Tank is normally inerted. Maximum steam temperature is below flash point of vehicle oil. No ignition sources normally present.	Details of jacket piping not included. Jacket should have pressure relief, if not now provided.
13. Overpressurized Steam Jacket	May Occur	Rupture of jacket. Injury or burns to personnel, if present.	II	Steam pressure reduced in two stages 130 → 40 → 5 psig.	
14. Recirculation pump J-2 deadheaded.	May Occur	Damage to pump intervals or drive motor.	III	Relief valve set at 150 psig.	

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TABLE III-3 (CONT'D.)

SYSTEM: 1000 lb/day PDU SUBSYSTEM: Slurry Feed EQUIPMENT: Slurry Feed Pump J-3

HAZARD IDENTIFICATION		CONSEQUENCES		EXISTING CONTROL MEASURES	COMMENTS AND RECOMMENDATIONS
DESCRIPTION	LIKELIHOOD RANKING	DESCRIPTION	HAZ. CAT.		
15. Overpressurization of discharge line or downstream piping or equipment.	Remote	Rupture of downstream piping or vessel. Release of flammable liquid and gas with likely ensuing fire.	II	Pressure switch cut-off at 4000 psig. Relief valves (recycle line) set at 5000 psig.	

TABLE III-3 (CONT'D.)

SYSTEM: 1000 lb/day PDU		SUBSYSTEM: Make-up Hydrogen		EQUIPMENT: Compressor and Associated Piping	
HAZARD IDENTIFICATION		CONSEQUENCES		EXISTING CONTROL MEASURES	COMMENTS AND RECOMMENDATIONS
DESCRIPTION	LIKELIHOOD RANKING	DESCRIPTION	HAZ. CAT.		
16. Overpressurization of discharge side of compressor.	May Occur	Rupture or damage to downstream equipment or piping. Release of hydrogen with possible ensuing fire or explosion. Personnel injured, if rupture occurs outside hot cell and personnel are present.	II	Compressor relief valve set at 7500 psig.	Present relief valve setting of 7500 psig is above downstream component pressure ratings at operating temperature. It is recommended a pressure switch cutoff set at ~4000 psig be installed on the hydrogen line, similar to the slurry feed line, and relief valve be re-set to 5000 psig.
17. Fire/explosion in compressor room due to hydrogen leak.	Remote	Equipment damage. Serious injury to personnel, if present.	II	Hydrogen monitors located at each compressor and alarmed at 25% lcl.	
18. Compressor rupture.	Remote	Fire/explosion and shrapnel hazard to adjacent units or personnel.	I		Preventive maintenance.

TABLE III-3 (CONT'D.)

SYSTEM: 1000 lb/day PDU

SUBSYSTEM: Make-up Hydrogen

EQUIPMENT: Accumulator F-1

HAZARD IDENTIFICATION		CONSEQUENCES		EXISTING CONTROL MEASURES	COMMENTS AND RECOMMENDATIONS
DESCRIPTION	LIKELIHOOD RANKING	DESCRIPTION	HAZ. CAT.		
19. Rupture of accumulator.		Fire/explosion and fragment damage in hot cell. Loss of run.		Accumulator located inside hot cell. Personnel are isolated from the hazard.	
a) Overpressurized	May Occur		II		Recommendation for Hazard 16.
b) Premature failure.	Remote		II		Periodic inspection and testing.
c) Failure due to hydrogen embrittlement	Remote		II		300 series SS immune to H ₂ damage at low temperatures.
20. Fire/explosion due to hydrogen leak.	Remote	Damage to equipment in hot cell. Loss of run.	II	System pressure tested before run commences. Hot cell provided with general dilution ventilation. Hydrogen monitor/ alarm installed in hot cell.	

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TABLE III-3 (CONT'D.)

SYSTEM: 1000 lb/day PDU

SUBSYSTEM: Recycle Hydrogen

Compressor, Accumulator, and Ancillaries
EQUIPMENT:

HAZARD IDENTIFICATION		CONSEQUENCES		EXISTING CONTROL MEASURES	COMMENTS AND RECOMMENDATIONS
DESCRIPTION	LIKELIHOOD RANKING	DESCRIPTION	HAZ. CAT.		
21. Overpressurization of system.	May Occur	Rupture or damage to downstream equipment or piping. Release of hydrogen with possible ensuing fire or explosion.	II	Discharge pressure controlled by PCV on compressor recycle line. Relief valve on compressor set at 5000 psig.	V-41 is located between compressor and PT-10. If V-41 is closed or becomes plugged, system can overpressurize. Recommend PT-10 be located before V-41.
22. Fire/explosion due to hydrogen leak.	Remote	Equipment damage, serious injury to personnel, if present.	II	System pressure tested before run commences. Hydrogen monitor located over compressor.	
23. Compressor rupture.	Remote	Fire/explosion and shrapnel hazard to adjacent units and personnel, if present.	I		Preventive maintenance.
24. Accumulator rupture.		Fire/explosion and fragment damage in hot cell.		Accumulator is located within hot cell. Personnel are isolated.	
a) Overpressurized	May Occur		II		See recommendations for Hazard 21.
b) Premature failure	Remote		II		Periodic testing and inspection.
c) Hydrogen embrittlement	Remote		II		300 Series SS immune to H ₂ damage at low temperatures.

TABLE III-3 (CONT'D.)

SYSTEM: 1000 lb/day PDU

SUBSYSTEM: Reaction

EQUIPMENT: Preheater

HAZARD IDENTIFICATION		CONSEQUENCES		EXISTING CONTROL MEASURES	COMMENTS AND RECOMMENDATIONS
DESCRIPTION	LIKELIHOOD RANKING	DESCRIPTION	HAZ. CAT.		
25. Excessively high process stream temperature.	Remote	Failure of piping or downstream vessels due to exceeding pressure rating at upset temperature. Equipment in hot cell - operators isolated from hazard.	II	Preheater is on closed loop temperature control. Independent thermocouple and cutoff set $\sim 20^{\circ}\text{C}$ above control set point. Several thermocouples located throughout preheater which may indicate out-of-limit condition in the event of temperature control or safety cutoff failure. Two separate temperature recorders.	
26. Fire/explosion due to hydrogen leak.	May Occur	Loss of preheater. Ensuing fire.	II	System is pressure tested before starting run.	Dilution or detection of leaking H_2 cannot be presumed due to 'confinement' aspects of preheater geometry and insulation. Likely ignition source is contact of H_2 with energized preheater element.

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TABLE III-3 (CONT'D.)

SYSTEM: 1000 lb/day PDU		SUBSYSTEM: Reaction		EQUIPMENT: Reactors	
HAZARD IDENTIFICATION		CONSEQUENCES		EXISTING CONTROL MEASURES	COMMENTS AND RECOMMENDATIONS
DESCRIPTION	LIKELIHOOD RANKING	DESCRIPTION	HAZ. CAT.		
27. Rupture of reactor.					
a) Failure due to over-pressurization.	May Occur	Rupture of reactor. Release of hydrogen and slurry with vaporization of vehicle solvent and ensuing fire or explosion.	II	Reactor is located in hot cell. Personnel isolated from hazard.	Pressure transducers are for indicating and recording function only. Slurry feed pump should shutdown at system pressure of 4000 psig and relief should operate at 5000 psig on slurry feed pump and recycle compressor. However, make-up compressor does not relieve until 7500 psig. It is recommended that slurry feed pump, make-up compressor, and recycle compressor be interlocked to system pressure transducers with set point of 4500 psig max. This would reduce likelihood to 'remote.'
b) Failure at operating pressure due to loss of material properties at excessively high temperature.	May Occur	Rupture of reactor. Release of hydrogen and slurry with vaporization of vehicle solvent and ensuing fire or explosion.		Reactor heaters on closed loop control.	It is recommended a high temperature cutoff using components independent of the control loop be provided, similar to the system for the preheater. This would reduce likelihood to 'remote.'

TABLE III-3 (CONT'D.)

SYSTEM: 1000 lb/day PDU		SUBSYSTEM: Reaction		EQUIPMENT: Reactors	
HAZARD IDENTIFICATION		CONSEQUENCES		EXISTING CONTROL MEASURES	COMMENTS AND RECOMMENDATIONS
DESCRIPTION	LIKELIHOOD RANKING	DESCRIPTION	HAZ. CAT.		
27. Rupture of reactor. (continued)					
c) Failure due to loss of material properties from H_2 embrittlement, H_2S , or other metallurgical change.	May Occur				The 300 Series SS are resistant to attack by gases such as H_2 , H_2S , CO, CH_4 , H_2O at the maximum normal process temperature (450°C). However, stress corrosion effects, and possible synergistic effects of constituent gases are not well understood. Therefore, close monitoring of vessel condition is advisable.
d) Failure at normal operating conditions-	May Occur			System is pressure tested prior to starting run.	Vessels were certified at time of purchase. The history of use and modifications is not well documented. Periodic inspection, testing and vessel history log system is recommended.
28. Fire/explosion due to leak of hydrogen.	May Occur	Damage to equipment located in hot cell.	II	Reactors located in hot cell. Consequences to equipment only. System is pressure tested before starting run.	Hot cell is provided with general dilution ventilation and H_2 monitor/alarm. Assessment of likelihood of a hydrogen leak being diluted below l.e.l. or being detected before ignition is difficult due to lack of documentation detail on reactor heaters and insulation design. It must be presumed ignition of a leak is likely therefore.

TABLE III-3 (CONT'D.)

SYSTEM: 1000 lb/day PDU

SUBSYSTEM: Separation

EQUIPMENT: Primary Separator F-2

HAZARD IDENTIFICATION		CONSEQUENCES		EXISTING CONTROL MEASURES	COMMENTS AND RECOMMENDATIONS
DESCRIPTION	LIKELIHOOD RANKING	DESCRIPTION	HAZ. CAT.		
29. Rupture of separator.		Release of hydrogen, flashing of vehicle solvent, with ensuing fire or explosion.	II	Separator located in hot cell.	Rated for 5250 psig at 750°F. See recommendations for system pressure cutoffs. (Hazards 16, 27a)
a) Overpressurization.	May Occur				
b) Loss of material properties - high temperature due to failure of E-1 coolers system.	Remote				Complete failure of coolers would result in ~450°C temperature at separator. Based on 5250 psig @ 750°F rating and relative allowable stress of SA182F316 and SA193B16 at 850°F versus 750°F, the separator should withstand >4000 psig at 850°F.
c) Loss of material properties - high temperature due to failure of separator temperature control heaters.	Remote			Heaters are on manually set powerstat control and are sized for maintenance of temperature rather than high heat duty. Potential for increasing system temperature is thus limited to 35-80°C.	

TABLE III-3 (CONT'D.)

SYSTEM: 1000 lb/day PDU

SUBSYSTEM: Separation

EQUIPMENT: Primary Separator F-2

HAZARD IDENTIFICATION		CONSEQUENCES		EXISTING CONTROL MEASURES	COMMENTS AND RECOMMENDATIONS
DESCRIPTION	LIKELIHOOD RANKING	DESCRIPTION	HAZ. CAT.		
29. Rupture of separator. (continued)					
d) Loss of material properties - metallurgical change due to H_2 embrittlement, H_2S , or other factors.	May	Release of hydrogen, flashing of vehicle solvent, with ensuing fire or explosion.			The 300 Series SS are resistant to attack by gases such as H_2 , H_2S , CO, CH_4 , H_2O at the maximum normal process temperature ($450^\circ C$). However, stress corrosion effects, and possible synergistic effects of constituent gases are not well understood. Therefore, close monitoring of vessel condition is advisable.
e) Random failure.	Remote	Release of hydrogen, flashing of vehicle solvent, with ensuing fire or explosion.		Vessel was certified at time of purchase. No known modifications.	
30. Fire/explosion due to hydrogen leak.	May Occur	Damage to equipment located in hot cell.	II	Separator located in hot cell. System pressure tested before starting run.	See comments under Hazard 28.
31. Overfill separator due to letdown valving failure.	May Occur	Carryover of heavy oil thru 'vapor' line to I.O separator.	III	Letdown valves on timing cycle designed to maintain low separator level. Level indication system on separator.	Monitor operation of valves and level indicator during operation.

TABLE III-3 (CONT'D.)

SYSTEM: 1000 lb/day PDU SUBSYSTEM: Separation EQUIPMENT: Light Oil Separator F-3

HAZARD IDENTIFICATION		CONSEQUENCES		EXISTING CONTROL MEASURES	COMMENTS AND RECOMMENDATIONS
DESCRIPTION	LIKELIHOOD RANKING	DESCRIPTION	HAZ. CAT.		
32. Rupture of separator.		Release of hydrogen with ensuing fire or explosion.	II	Separator located in hot cell.	Rated @ 5500psig @ 650°F. See recommendations for system pressure cutoffs (Hazards 16, 27a).
a) Overpressurization	May Occur.				
b) Loss of material properties - high temperature due to failure of upstream cooling systems.	Remote				Complete failure of coolers would result in ~450°C temperature. Rating of separator is sufficient to withstand 4000 psig at 850°F based on relative allowable metal stresses.
c) Loss of material properties - high temperature due to failure of separator heaters.	Remote			Separator normally operated at ambient temperature and thus heaters not expected to be in service.	
d) Loss of material properties - metallurgical change.	Remote				The 300 Series SS are resistant to attack by gases such as H ₂ , H ₂ S, CO, CH ₄ , H ₂ O at the maximum normal process temperature (450°C). However, stress corrosion effects, and possible synergistic effects of constituent gases are not well understood. Therefore, close monitoring of vessel condition is advisable.
e) Random failure.	Remote			Vessel certified at time of purchase. No known modifications.	

TABLE III-3 (CONT'D.)

SYSTEM: 1000 lb/day PDU

SUBSYSTEM: Separation

EQUIPMENT: Light Oil Separator F-3

HAZARD IDENTIFICATION		CONSEQUENCES		EXISTING CONTROL MEASURES	COMMENTS AND RECOMMENDATIONS
DESCRIPTION	LIKELIHOOD RANKING	DESCRIPTION	HAZ. CAT.		
33. Fire/explosion due to hydrogen leak.	May Occur	Damage to equipment located in hot cell.	II	Separator located in hot cell. System pressure tested before starting run.	See comments under Hazard 28.
34. Overfill separator due to letdown valving failure.	Remote	Carryover of light oil to recycle purification system.	III	Letdown valves on timing cycle designed to maintain low separator level. Level indication system on separator.	Monitor operation of valves and level indicator during operation.

TABLE III-3 (CONT'D.)

SYSTEM: 1000 lb/day PDU		SUBSYSTEM: Amine Absorption		EQUIPMENT: Amine Absorber L-1	
HAZARD IDENTIFICATION		CONSEQUENCES		EXISTING CONTROL MEASURES	COMMENTS AND RECOMMENDATIONS
DESCRIPTION	LIKELIHOOD RANKING	DESCRIPTION	HAZ. CAT.		
35. Rupture of absorber		Loss of absorber. Release of H_2 , H_2S , CH_4 , with ensuing fire or explosion likely.	II	Absorber located in hot cell.	See comments and recommendations for system pressure cutoffs (Hazards 16, 27a). The 300 Series SS are resistant to attack by gases such as H_2 , H_2S , CO , CH_4 , H_2O at the maximum normal process temperature ($450^\circ C$). However, stress corrosion effects, and possible synergistic effects of constituent gases are not well understood. Therefore, close monitoring of vessel condition is advisable.
a) Overpressurization	May Occur				
b) Loss of material properties - upstream temperature upset.	Remote			Normal operating temperature is near ambient. Materials of construction display little reduction in allowable stress up to $800^\circ F$. There are numerous thermocouple readouts which should warn of a high system temperature in the separation system or downstream thereof.	
c) Loss of material properties - metallurgical change.	May Occur				
d) Random failure	Remote			Vessel was certified at time of purchase. No known modifications.	
36. Fire/explosion due to hydrogen leak.	Remote	Damage to absorber and adjacent units in hot cell.	II	Hot cell provided with general dilution ventilation and H_2 monitor.	

TABLE III-3 (CONT'D.)

SYSTEM: 1000 lb/day PDU

SUBSYSTEM: Amine Absorption

EQUIPMENT: Stripper C-1 and Tank D-4

HAZARD IDENTIFICATION		CONSEQUENCES		EXISTING CONTROL MEASURES	COMMENTS AND RECOMMENDATIONS
DESCRIPTION	LIKELIHOOD RANKING	DESCRIPTION	HAZ. CAT.		
36. Rupture of stripper or tank.		Fragments, release of H ₂ S bearing off-gas with possible fire or personnel exposure.	II		Rated 25 psig @ 300°F. Stripper is 316 SS. Tank is 304 SS.
a) Overpressurization	May Occur			Vent line to flare provides relief, but insufficient design detail to determine if adequately sized to handle load if LIC-3 fails wide open.	Provide pressure relief valves to protect vessels if present vent undersized for abnormal load.
b) Loss of material properties - high temperature upset.	Remote			Normal operation at 120°F or less. Maximum steam temperature in stripper pre-heater is <300°F rated temperature of stripper. Stream cooled between stripper and tank.	
c) Loss of material properties - metallurgical change.	May Occur				The 300 Series SS are resistant to attack by gases such as H ₂ , H ₂ S, CO, CH ₄ , H ₂ O at the maximum normal process temperature (450°C). However, stress corrosion effects, and possible synergistic effects of constituent gases are not well understood. Therefore, close monitoring of vessel condition is advisable.
d) Random failure.	Remote				

TABLE III-3 (CONT'D.)

SYSTEM: 1000 lb/day PDU

SUBSYSTEM: Amine Absorption

EQUIPMENT: Amine Pump J-5

HAZARD IDENTIFICATION		CONSEQUENCES		EXISTING CONTROL MEASURES	COMMENTS AND RECOMMENDATIONS
DESCRIPTION	LIKELIHOOD RANKING	DESCRIPTION	HAZ. CAT.		
38. Overpressurize discharge.	Remote	Damage to amine pump.	III	Relief valve set at 5000 psi.	

TABLE III-3 (CONT'D.)

SYSTEM: 1000 lb/day PDU

SUBSYSTEM: Kerosene Absorption

EQUIPMENT: Absorber L-2

HAZARD IDENTIFICATION		CONSEQUENCES		EXISTING CONTROL MEASURES	COMMENTS AND RECOMMENDATIONS
DESCRIPTION	LIKELIHOOD RANKING	DESCRIPTION	HAZ. CAT.		
39. Rupture of absorber.		Loss of absorber. Release of H_2 , CH_4 , other light hydrocarbons with ensuing fire or explosion likely.	II	Absorber located in hot cell.	316 SS construction.
a) Overpressurization	May Occur				See comments and recommendations for system pressure cutoffs (Hazards 16, 27a).
b) Loss of material properties due to upstream temperature upset.	Remote			Normal operating temperature is near ambient. Materials of construction display little reduction in allowable stress up to 800 F. There are numerous thermocouple readouts which should warn of a high system temperature in the separation system or downstream thereof.	
c) Loss of material properties due to metallurgical change.	May Occur				The 300 Series SS are resistant to attack by gases such as H_2 , H_2S , CO, CH_4 , H_2O at the maximum normal process temperature (450°C). However, stress corrosion effects, and possible synergistic effects of constituent gases are not well understood. Therefore, close monitoring of vessel condition is advisable.
d) Random failure.	Remote			Vessel was certified at time of purchase. No known modifications.	
40. Fire/explosion due to hydrogen leak.	Remote		II	General dilution ventilation and H_2 monitor.	

TABLE III-3 (CONT'D.)

SYSTEM: 1000 lb/day PDU

SUBSYSTEM: Kerosene Absorption

EQUIPMENT: Scrubber C-2 and Tank D-5

HAZARD IDENTIFICATION		CONSEQUENCES		EXISTING CONTROL MEASURES	COMMENTS AND RECOMMENDATIONS
DESCRIPTION	LIKELIHOOD RANKING	DESCRIPTION	HAZ. CAT.		
41. Rupture of scrubber or kerosene tank.		Fragments. Release of kerosene and flammable off-gas with possible ensuing fire.	II		
a) Overpressurization.	May Occur			Vent line to flare provides relief, but insufficient design detail to determine if adequately sized to handle load in LIC-4 fails wide open.	Provide pressure relief valves to protect vessels if present vent lines are undersized.
b) Loss of material properties - high temperature upset.	Remote			Normal operation at 120°F or less. Maximum steam temperature in scrubber preheater (E-7) is <300°F rated temperature of scrubber. Cooler located between scrubber and kerosene tank.	
c) Loss of material properties due to metallurgical change.	Remote				The 300 Series SS are resistant to attack by gases such as H ₂ , H ₂ S, CO, CH ₄ , H ₂ O at the maximum normal process temperature (450°C). However, stress corrosion effects, and possible synergistic effects of constituent gases are not well understood. Therefore, close monitoring of vessel condition is advisable.
d) Random failure	Remote				Likelihood based on generic failure rate for vessels.

TABLE III-3 (CONT'D.)

SYSTEM: 1000 lb/day PDU		SUBSYSTEM: Kerosene Absorption		EQUIPMENT: Kerosene Pump J-6	
HAZARD IDENTIFICATION		CONSEQUENCES		EXISTING CONTROL MEASURES	COMMENTS AND RECOMMENDATIONS
DESCRIPTION	LIKELIHOOD RANKING	DESCRIPTION	HAZ. CAT.		
42. Overpressurize discharge	Remote	Damge to kerosene pump. Possible release of kerosene.	III	Relief valve set at 5000 psig.	

TABLE III-3 (CONT'D.)

SYSTEM: 1000 lb/day PDU

SUBSYSTEM: Centrifugation

EQUIPMENT: Heavy Oil Receivers, D-9 A&B

HAZARD IDENTIFICATION		CONSEQUENCES		EXISTING CONTROL MEASURES	COMMENTS AND RECOMMENDATIONS
DESCRIPTION	LIKELIHOOD RANKING	DESCRIPTION	HAZ. CAT.		
43. Overpressurization of tank.	Remote	Damage to tank. Release of heavy oil.	III	Tanks normally vented to flare system. Pressure relief valves set at 10 psig. Tank tested at 8 psig.	
44. Overfill tank.	Remote		III	Capacity of receiver(s) is much greater than the primary separator feeding it (them). Inventory in tank monitored by weigh scales.	
45. Ignition of vapors in head space.	Remote	Fire or explosion in tank. Rupture of tank with release of heavy oil and ensuing external fire.	II	Continuous purge of N ₂ through head space. No normal ignition sources in tank. Temperature is below expected flash point of heavy oil, but flammable vapors present due to flashing associated with pressure let-down.	Inert gas flow must be greater than pump rate of transfer pump J-8 to avoid possible backflow problems in flare line.
46. Overpressurization of steam jacket.	May Occur	Rupture of jacket. Release of live steam.	II	Pressure reduced in two stages: 130 → 40 → 5 psi.	Details of steam jacket piping not included. Jacket should have relief valve if one not now provided.

TABLE III-3 (CONT'D.)

SYSTEM: 1000 lb/day PDU

SUBSYSTEM: Centrifugation

EQUIPMENT: Heavy Oil Pump J-8

HAZARD IDENTIFICATION		CONSEQUENCES		EXISTING CONTROL MEASURES	COMMENTS AND RECOMMENDATIONS
DESCRIPTION	LIKELIHOOD RANKING	DESCRIPTION	HAZ. CAT.		
47. Pump deadheaded.	May Occur	Damage to pump or drive motor.	III		

TABLE III-3 (CONT'D.)

SYSTEM: 1000 lb/day PDU SUBSYSTEM: Centrifugation EQUIPMENT: Centrifuge Oil Tank D-10 & Pump J-9

HAZARD IDENTIFICATION		CONSEQUENCES		EXISTING CONTROL MEASURES	COMMENTS AND RECOMMENDATIONS
DESCRIPTION	LIKELIHOOD RANKING	DESCRIPTION	HAZ. CAT.		
48. Overpressure or overfill tank.	May Occur	Damage to tank. Release of heavy oil.	III	Operating temperatures are below flash point of heavy oil. No credible ignition sources.	Operators should monitor addition of oil to ensure tank is not overfilled.
49. Ignition of vapors in tank head space.	Remote	Internal fire or explosion with possible tank rupture and ensuing external fire.	II		
50. Centrifuge circulation pump deadheaded.	May Occur	Damage to pump or drive motor.	III		

TABLE III-3 (CONT'D.)

SYSTEM: 1000 lb/day PDU SUBSYSTEM: Centrifugation EQUIPMENT: Centrifuge

HAZARD IDENTIFICATION		CONSEQUENCES		EXISTING CONTROL MEASURES	COMMENTS AND RECOMMENDATIONS
DESCRIPTION	LIKELIHOOD RANKING	DESCRIPTION	HAZ. CAT.		
51. Mechanical damage to centrifuge due to excessive vibration, mechanical interference.	May Occur	Damage to centrifuge requiring replacement.	III		Preventive maintenance and checking dynamic balance will minimize likelihood.

TABLE III-3 (CONT'D.)

SYSTEM: 1000 lb/day PDU

SUBSYSTEM: Light Oil

EQUIPMENT: Light Oil Receivers D-7 A&B

HAZARD IDENTIFICATION		CONSEQUENCES		EXISTING CONTROL MEASURES	COMMENTS AND RECOMMENDATIONS
DESCRIPTION	LIKELIHOOD RANKING	DESCRIPTION	HAZ. CAT.		
52. Overpressurization of tank.	Remote	Damage to tank. Release of light oil.	III	Tanks are normally vented to flare system. Pressure relief valves set at 10 psig.	Inert gas flow must be greater than maximum takeoff rate from receivers to avoid possible backflow problems in flare line.
53. Overfill tank.	Remote		III	Capacity of receiver(s) is much greater than the light oil separator feeding it (them). Inventory in tank indicated by weigh scales.	
54. Ignition of vapors in tank head space.	Remote	Fire or explosion in tank with possible rupture, release of light oil and ensuing external fire.	II	Continuous purge of N ₂ through head space. No normal ignition sources in tank. Temperature is below expected flashpoint of contents.	

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TABLE III-3 (CONT'D.)

SYSTEM: 1000 lb/day PDU

SUBSYSTEM: Vacuum Distillation

EQUIPMENT: Flash Still F-4

HAZARD IDENTIFICATION		CONSEQUENCES		EXISTING CONTROL MEASURES	COMMENTS AND RECOMMENDATIONS
DESCRIPTION	LIKELIHOOD RANKING	DESCRIPTION	HAZ. CAT.		
55. Overpressurization of still.	Remote	Damage to still. Possible rupture and release of heavy oil with ensuing fire.	II	Relief valve set at 100 psig. Still normally relieved thru line to flare system.	
56. Overfill still.	May Occur	Not significant.	IV	Overflow line to heavy oil receiver D-13.	
57. Ignition of vapors in still head space.	Remote	Internal fire or explosion with possible rupture of still, release of contents and ensuing external fire.	II	No identified ignition sources. Vapors above upper flammable limit.	

TABLE III-3 (CONT'D)

SYSTEM: 1000 lb/day PDU

SUBSYSTEM: Vacuum Distillation

EQUIPMENT: Heavy Oil Receiver D-13 & Pump J-10

HAZARD IDENTIFICATION		CONSEQUENCES		EXISTING CONTROL MEASURES	COMMENTS AND RECOMMENDATIONS
DESCRIPTION	LIKELIHOOD RANKING	DESCRIPTION	HAZ. CAT.		
58. Overpressurization of tank.	Remote	Damage to tank. Release of heavy oil with possible ensuing fire.	III	Receiver vented to flare system	Nitrogen addition rate must be sufficient to avoid possible flare line backflow problems associated with high tank take-off rate.
59. Overfill receiver.	Remote	Contamination of vapor lines with liquid.	III	Tank inventory indicated by weigh scales. Heavy oil normally being pumped out of tank to heavy oil feed tank D-15.	
60. Ignition of vapors in head space.	Remote	Internal fire or explosion with possible tank rupture leading to release of material and ensuing external fire.	II	Tank normally inerted. No identified internal ignition sources.	
61. Heavy oil pump J-10 deadheaded.	Remote	Damage to pump or drive motor.	III	Relief valve set at 100 psig.	

TABLE III-3 (CONT'D.)

SYSTEM: 1000 lb/day PDU SUBSYSTEM: Vacuum Distillation EQUIPMENT: Light Oil Receiver D-14 & Pump J-12

HAZARD IDENTIFICATION		CONSEQUENCES		EXISTING CONTROL MEASURES	COMMENTS AND RECOMMENDATIONS
DESCRIPTION	LIKELIHOOD RANKING	DESCRIPTION	HAZ. CAT.		
62. Overpressurization of tank.	Remote	Damage to tank. Release of light oil with possible ensuing fire.	III	Receiver vented to flare system	Provide receiver with N ₂ purge similar to all other receivers.
63. Overfill tank.	Remote	Contamination of vapor lines with light oil.	III	Tank inventory indicated by weigh scales. Light oil normally being discharged from tank.	
64. Ignition of vapors in head space.	May Occur	Fire or explosion with possible rupture, release of material and ensuing external fire.	II	No normal ignition sources.	
65. Light oil pump J-12 dead headed.	Remote	Damage to pump or drive motor.	III	Relief valve set at 100 psig.	

TABLE III-3 (CONT'D.)

SYSTEM: 1000 lb/day PDU SUBSYSTEM: Vacuum Distillation EQUIPMENT: Heavy Oil Feed Tank D-15 & Pump J-13

HAZARD IDENTIFICATION		CONSEQUENCES		EXISTING CONTROL MEASURES	COMMENTS AND RECOMMENDATIONS
DESCRIPTION	LIKELIHOOD RANKING	DESCRIPTION	HAZ. CAT.		
66. Overpressurization of tank.	Remote	Damage to tank. Release of heavy oil.	III	Tank vented to flare system.	N ₂ flow must be sufficient to prevent possible flare line backflow problems in the event of high take-off rate from tank.
67. Overfill tank.	Remote	Contamination of vapor lines with heavy oil.	III	Tank inventory indicated by weigh scales.	
68. Ignition of vapors in head space.	Remote	Fire or explosion with possible tank rupture, release of material and ensuing external fire.	II	Tank inerted with N ₂ . No normal ignition sources.	
69. Metering pump J-13 dead headed.	Remote	Damage to pump or drive motor.	III	Relief valve set at 100 psig.	

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TABLE III-3 (CONT'D.)

SYSTEM: 1000 lb/day PDU

SUBSYSTEM: Vacuum Distillation

EQUIPMENT: Vacuum Still & Ancillaries

14-III

HAZARD IDENTIFICATION		CONSEQUENCES		EXISTING CONTROL MEASURES	COMMENTS AND RECOMMENDATIONS
DESCRIPTION	LIKELIHOOD RANKING	DESCRIPTION	HAZ. CAT.		
70. Air flow into vacuum distillation system					
a) Leak into system under vacuum.	Probable	Possible formation of flammable mixtures if leak is severe enough.	III	System designed to minimize leakage. Severe leaks should be indicated by inability to maintain vacuum level.	Severity of incident in the event of ignition is limited by the absolute pressure of the mixture.
b) Failure of vacuum pump.	May Occur	Inflow through leak sites and backflow through vacuum line to equalize pressure in still. Formation of flammable mixture in still. Ignition of contents if operating temperature exceeds heavy oil ignition temperature.	II		
71. High reboiler temperature.	May Occur	Vaporization of higher boiling constituents than normally desired. Possible decomposition reactions.	III	Reboiler temperature normally controlled.	

C. WORKPLACE HEALTH ANALYSIS

The Workplace Health Analysis is a constituent analysis of an overall safety analysis which considers potential hazards to employee health as a result of working in the operation under design conditions. Included is an identification of potential health hazard materials present in the operation, and an evaluation of the potential for operator exposure to these materials.

Materials in use or which are produced in the 1000 lb/day PDU are listed in Table III-4. As can be seen from the table, potential health hazards relate to inhalation of irritant or toxic materials, or contact with recognized or suspected carcinogenic liquids. Potential for occupational exposure will be minimized by operator care in executing manual operations in the process and use of proper protective equipment.

Potential exposure scenarios are discussed in the following paragraphs and are documented on fact sheets in Table III-5. No workplace monitoring data was included in the information package for the system. Therefore, the extent to which potential exposure hazards actually exist is difficult to assess. A monitoring program should be conducted to establish baseline concentrations of airborne contaminants at the locations and operations identified.

1. Addition of Coal to Slurry Preparation Tank

Pulverized coal arrives at the unit in 55-gallon drum quantities. It is screened by hand into 5-gallon cans. It is then scooped by hand and added to the slurry preparation tank thru a five-inch port. The coal particle size is nominally 100% thru 80-mesh, 80% thru 200-mesh. It is likely that localized coal dust clouds will be formed in these manual operations and that unprotected personnel would be exposed via inhalation of the dust. Therefore, particulate filter respirators should be required unless it can be otherwise established that an inhalation hazard does not exist.

The nitrogen purge to the tank is normally shut-off during coal addition to reduce the outflow of vapors thru the open port. Exposure to vapors is therefore less likely than exposure to the coal dust. Vapor concentrations should be determined by monitoring to confirm absence of a hazard.

2. Fill Kerosene and Flush Oil Tanks

Contact with kerosene due to spilling or splashing may occur when filling these tanks. Face shield and skin protection should be worn to avoid contact.

TABLE III-4

POTENTIAL HEALTH HAZARD MATERIALS

<u>Material</u>	<u>Health Hazard</u>
Diethanolamine	Liquid may cause severe eye damage Excessive exposure may cause injury to liver and kidney
Kerosene	Recognized carcinogen
Pulverized Coal	Silicosis
Coal-Derived Liquids	Suspected carcinogens
Off-Gases	Irritant or toxic S,N, or O compounds

3. Drain Catch-Pots

The unit contains a number of knock-out, blowdown, or catch-pots which are drained from time-to-time during the course of a run. The potential for contact with hot coal-derived liquids, or inhalation of flashing vapors exists in this operation, especially if the pot is at elevated pressure, the drain valve is opened rapidly or the operator is not particularly careful. Procedures and operator training should stress importance of being extremely careful in conducting this operation. Face and skin protection should be worn as a minimum to avoid contact.

4. Sampling of Process Streams

Samples are taken of the various process streams at specified time intervals. The specific methods and procedures used for drawing samples were not documented in the technical information package. In general, hazards associated with sampling are similar to those in draining the catch-pots. Standard safe procedures should be developed and followed, and protective equipment should be required as necessary to safeguard operators from exposure.

5. Clean Centrifuge Bowl

Operation of the heavy oil centrifuges requires that the sludge be scraped and removed manually. This manual operation represents one of the most credible potential exposure hazards of all those identified, due to the process conditions, nature of the materials, and nature of the manual operation. Local exhaust ventilation in the form of 'elephant snouts' is provided at the centrifuge platform and the cleaning work table. The effectiveness of this ventilation in controlling airborne contaminants is uncertain since no monitoring data was included in the technical data package. Monitoring data should be obtained and evaluated to determine if existing exhaust ventilation is sufficient. Avoidance of skin contact will require the use of protective gloves as a minimum.

6. Exposure at Control Station

The control station is maintained at positive pressure relative to the operating bay and the compressor room. Therefore, presence of airborne contaminants is unlikely.

7. Clean-up

Clean-up procedures are not documented in detail. As a minimum, precautions to avoid contact with coal-derived liquids should be taken. Other precautions may be advisable as a function of solvent(s) used in clean-up procedures.

TABLE III-5. WORKPLACE HEALTH ANALYSIS

SYSTEM: 1000 lb/day PDU

SUBSYSTEM:

EQUIPMENT:

POTENTIAL HAZARD		CONSEQUENCES	EXISTING CONTROL MEASURES	COMMENTS AND RECOMMENDATIONS
EQUIPMENT ITEM OR PROCEDURAL STEP	RANKING			
1. Addition of coal to slurry preparation tank.				
a) Inhalation of pulverized coal dust.	Probable	Potential long term health hazard due to silica content.	Purge flow is shut off to reduce velocity currents.	Coal should be handled and added to slurry prep tank in a manner which minimizes formation of dust cloud and operator exposure. Respiratory protection should be required unless it can be established by monitoring that an exposure hazard does not exist.
b) Inhalation of coal-derived liquid vapors.	May Occur	Exposure to possible toxic or irritant vapors.	Purge flow is shut off to reduce outflow of vapors from tank port.	Determine airborne concentrations by monitoring to establish whether a potential exposure hazard exists.
2. Charge kerosene and flush oil tanks.				
a) Contact with kerosene or inhalation of vapors.	May Occur	Contact dermatitis possible. Moderate toxicity by inhalation. Potential long term carcinogenic hazard.		Use only with adequate ventilation. Wear skin and eye/face protection.
3. Drain catch-pots				
a) Inhalation of toxic or irritant vapors.	May Occur	Upper respiratory tract irritation. Possible headache, nausea, or limited narcosis or asphyxiant effects.		Extent of potential hazard should be determined by monitoring and protective equipment provided as indicated.
b) Contact with coal-derived liquids.	May Occur	Eye or skin irritation. Possible thermal burns if liquid is hot.		Check pressure for possible splash or flashing hazards. Drain carefully and slowly. Wear eye, face, and skin protection.

TABLE III-5 (CONT'D.)

SYSTEM: 1000 lb/day PDU

SUBSYSTEM:

EQUIPMENT:

POTENTIAL HAZARD		CONSEQUENCES	EXISTING CONTROL MEASURES	COMMENTS AND RECOMMENDATIONS
EQUIPMENT ITEM OR PROCEDURAL STEP	RANKING			
4. Sampling for process streams.				
a) Exposure to toxic or irritant vapors/gases.	May Occur	Upper respiratory tract irritation. Possible headache, nausea, or limited narcosis or asphyxiant effects.		Extent of potential hazard should be determined by monitoring and protective equipment provided as indicated.
b) Contact with coal-derived liquids.	May Occur	Eye or skin irritation. Possible thermal burns if liquid is hot.		Check pressure for possible splash or flashing hazards. Drain carefully and slowly. Wear eye, face, and skin protection.
5. Clean centrifuge bowl.				
a) Exposure to toxic or irritant vapors/gases.	May Occur	Upper respiratory tract irritation. Possible headache, nausea, or limited narcosis or asphyxiant effects.	Local exhaust ventilation is provided.	Adequacy of exhaust ventilation should be confirmed. Exhaust should be upgraded or protective equipment provided if an exposure hazard exists.
b) Contact with centrifuge residue (coal-derived materials).	May Occur	Contact dermatitis. Cutaneous absorption with long term possible health effects.		Wear protective equipment to avoid contact.
6. Exposure to toxic or irritant material while monitoring process.	Unlikely	Eye, skin, or respiratory tract irritation. Possible headache, nausea, or other toxic exposure symptoms.	System checked for leaks prior to operation. Control hallway is kept at positive pressure relative to operating bays.	
7. Clean-up.	May Occur	Contact with coal-derived liquids and solvents possible. Possible solvent inhalation hazard.	Procedures not specified in enough detail to ascertain.	Protective equipment to avoid contact with coal-derived liquids, and solvents. Ventilation or respiratory protection may be indicated depending on solvents used.

D. WORKPLACE SAFETY ANALYSIS

The Workplace Safety Analysis is a constituent analysis of the overall safety analysis which addresses potential occupational injury hazards of the Operation under normal operational conditions.

Identified potential occupational injury hazards for the 1000 lb/day PDU relate to manual operations, rotating equipment, and electrical equipment. Identified hazards are documented in Table III-6 and discussed in the paragraphs which follow.

1. Addition of Coal to Slurry Preparation Tank

The use of a ladder or platform is needed to add the coal to the tank port. Only approved ladders or platforms should be used. Care should be taken to avoid slipping or falling from the ladder or platform.

2. Rotating Equipment

Rotating equipment includes compressors, pumps, agitators, and centrifuges. Equipment should be audited to determine adequacy of existing guards. Periodic inspections should be made to assure guards are in place.

3. Centrifuge Cleaning

The centrifuge bowl is removed manually for cleaning. Care must be taken to minimize possibility of dropping the bowl. Operators should be protected against foot injury by safety-toe shoes.

4. Electrical Hazards

Electrical equipment in the 1000 lb/day PDU includes motor drives and associated wiring for such items as compressors and pumps, electrical heaters with associated power wiring, and control and instrument wiring. Motors generally meet Class I, Group D designations. Operators and maintenance personnel should be cognizant of the hazards associated with the types of equipment installed and should take proper precautions when maintenance, repair, or disassembly/assembly of equipment is required.

TABLE III-6. WORKPLACE SAFETY ANALYSIS

SYSTEM: 1000 lb/day PDU

SUBSYSTEM:

EQUIPMENT:

PAGE 1 OF 1

POTENTIAL HAZARD		CONSEQUENCES	EXISTING CONTROL MEASURES	COMMENTS AND RECOMMENDATIONS
EQUIPMENT ITEM OR PROCEDURAL STEP	RANKING			
1. Add coal to slurry preparation tank. a) Potential for fall or slip.	May Occur	Fall from ladder or platform resulting in injury to operator.		Use only approved step ladder or work platform.
2. Compressors, pumps, agitators, centrifuges. a) Potential for unguarded rotating equipment.	May Occur	Operator injury if unguarded rotating element is contacted.	Equipment guarded by enclosure or location.	Audit equipment for guards and inspect periodically to assure guards are in place.
3. Centrifuge Cleaning. a) Drop centrifuge bowl.	May Occur	Injury to operator if dropped on unprotected foot.		Require safety-toe shoes. Take precautions to minimize "slipperiness" of bowl before carrying by hand.
4. Electrical Equipment a) Potential for electric shock.	Unlikely	Electrical burns, serious injury, or possibly death.		Disconnect and lockout equipment before conducting maintenance, repair, or disassembly/assembly. Do not use water or other conductive extinguishing agents to fight fire involving energized electrical equipment.

E. ENVIRONMENTAL ANALYSIS

The Environmental Analysis is a constituent analysis of an overall Safety Analysis which addresses the emissions, effluents, and wastes associated with an Operation under normal operational conditions.

The flow rates and quantities of materials in the 1000 lb/day PDU are on a relatively small scale and therefore represent a limited environmental concern. Vapor and gaseous emissions are burned in a flare. Liquid waste materials are drummed and shipped to landfill. Incineration of waste materials in an approved permitted facility offers an alternate disposal method which would result in a lower long term environmental impact and therefore should be explored.

Approximately 60 lb/day of gases and vapors will be discharged to the flare when the unit is operating at design rate. Emission of resultant combustion products (largely H_2O and CO_2) is not of any appreciable concern.

Total generation of liquid/semi-liquid waste is on the order of one 55-gallon drum per 24 hour operating day. Currently this material is disposed of in landfill. The inherent difficulties in assuring long term storage conditions and security of landfills leads one to the conclusion that incineration of waste would offer an overall lower environmental risk than landfill. Very small quantities (as determined by material balance) of liquid may find their way to the building drain via traps, knock-out pots, catch-pots, etc. Quantities involved do not represent an appreciable environmental concern.

TABLE III-7. ENVIRONMENTAL ANALYSIS

SYSTEM: 1000 lb/day PDU

SUBSYSTEM:

EQUIPMENT:

PAGE 1 OF 1

MATERIAL RELEASE IDENTIFICATION CONSTITUENTS	TYPE OF RELEASE	QUANTITY	EXISTING CONTROL MEASURES	COMMENTS AND RECOMMENDATIONS
1. Off-Gases	Emission flared. Combustion products to atmosphere.	~60 lb/day		
2. Heavy Oil Bottoms Higher boiling coal derived liquids/sludge.	Material is disposed of as follows: drummed in DOT approved containers and shipped to landfill.	~180 lb/day		Explore alternative of incineration in an approved permitted facility.
3. Light Oil from Separator Condensed water and light coal-derived hydrocarbons.	Material is disposed of as follows: drummed in DOT approved containers and shipped to landfill.	~45 lb/day		Explore alternative of incineration in an approved permitted facility.
4. Light Oil from Vacuum Still Light coal-derived hydrocarbons.	Material is disposed of as follows: drummed in DOT approved containers and shipped to landfill.	~35 lb/day		Explore alternative of incineration in an approved permitted facility.
5. Catch-Pot Condensibles	Bled to building drain.	~10 lb/day		

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REFERENCES

1. DOE Order 5481.1, "Safety Analysis and Review System for DOE Operations, "U.S. Department of Energy, March 20, 1979.
2. "Management Implementation Plan for a Safety Analysis and Review System," Report No. A08639-520-03-009, Hercules Aerospace Division, Hercules Incorporated, Allegany Ballistics Laboratory, April 1981.

APPENDIX A
SYSTEM DOCUMENTATION

1. Engineering Drawings

- a) 1000 lb/day Disposable Catalyst Liquefaction PDU, 2-13-81, JAM
- b) Instrumentation - 1/2 TPD Liquefaction, 3-17-80, JAM

2. Equipment and Procedures Data (mostly handwritten)

- a) Liquefaction of Coal with Disposable Catalysts, 1/2 TPD PDU (2 page process description)
- b) 1000 lb/day PDU Start-up Procedure (4 pages)
- c) Start-up of Recycle Gas Absorber (3 pages)
- d) Procedures for Unplanned Power Outages, 1-31-80 (1 page)
- e) Vessels (6 pages, dimensional & construction details)
- f) Feed Pumps & Compressors (2 pages)
- g) Thermocouples in 1/2 TPD PDU (6 pages)
- h) 1/2 TPD Disposable Catalyst Unit Powerstats, 3-24-80 (1 page)
- i) Instrumentation (3 pages)
- j) Disposable Catalyst Unit, Valve Locations & Descriptions (9 pages)

3. Miscellaneous Data

- a) Memo dated 2-19-81: Pressure vessel certifications, operating crew data, and rules governing personnel in high bay
- b) Data Request - 1000 lb/day PDU: answers to specific questions in letter to Mr. Cimino dated April 30, 1981
- c) 1000 lb/day Liquefaction with Stills, 1-21-81 (overall material balance)
- d) Summary of Programmed Operating Conditions
1/2 TPD Disposable Catalyst PDU (typical operating conditions, runs DCD-12 thru DCD-16)
- e) Specs for Tests DCD-13B and DCD-14 in 1/2 TPD Disposable Catalyst PDU
- f) Start-up Procedure, 1000 lb/day PDU, Test #DCD-14
- g) Procedure for Changeover from Run DCD-13B to DCD-14
- h) Procedure for Changing Run Conditions DCD-14 to DCD-15
- i) DCD-12 Data Recording
- j) Copies of Blank Data Sheets. (9 pages)

APPENDIX B

ANALYSIS METHODOLOGY

This appendix documents the general methodologies used to conduct the Safety Analysis. Discussion is presented for the four analysis components. process hazards, safety concerns, health concerns, and environmental concerns.

A. Process Hazards Analysis

The process hazards analysis was conducted in a four-step approach: (1) Hazards Identification, (2) Likelihood Ranking, (3) Consequence Assessment, and (4) Design and Operating Criteria recommendations.

1. Hazards Identification

Hazards identification begins with system familiarization by the analyst to develop an intimate understanding of the process, of how it is intended to function, and of the important process variables. System familiarization consists of a review of process documentation, an on-site visit, and discussions with operations, engineering, and management personnel.

Potential hazards are identified by a systematic analysis of the system documentation; e.g., process flow diagrams, equipment drawings and data, material and energy balances, and operating procedures. Several techniques are used in the systematic analysis. The basic technique is usually identification by inspection, which is supplemented by the additional techniques of FMEA and logic modeling. This approach is preferred to rigid adherence to any single methodology. A straight FMEA is undesirable for the following reasons. First, each individual component may have numerous modes of failure, only several of which may represent potential hazards. Potential hazards are likely to get 'lost' or 'buried' among the many other line items in a FMEA. Second, the FMEA considers hazards arising from single failures only. Third, the logic of a FMEA is inductive rather than deductive. It thus becomes divergent rather than convergent in terms of thought processes and analysis 'bookkeeping'. A FMEA is useful for identifying hazards arising from single component failures, or for establishing cause and effect relationships in an equipment item, but is not preferred as a sole method or means of documenting an analysis.

Identification by inspection is the primary technique used in the analysis. Potential hazards considered include fire/explosion, over-pressurization, vessel failure, or abnormal material release. Identified hazards are documented in tabular form on a 'fact sheet', the first column of which consists of a description of the identified potential hazard.

2. Likelihood Ranking

The identified potential hazard is assigned a likelihood ranking based on the analyst's evaluation of a number of factors. These factors may include, as appropriate to the individual hazard, such items as the following: potential stimulus in the process versus response of the process materials or equipment (e.g. resultant system pressure vs pressure rating of equipment, or energy of potential ignition source vs ignition energy of flammable material), number and types of components which must fail for the hazard to occur, existing safeguards, ignition sources, concentrations of process materials, severity of service, magnitude of design safety factor, and previous experience. Qualitative likelihood rankings are as follows:

<u>Ranking</u>	<u>Description</u>
Frequent	Likely to occur often
Probable	Likely to occur occasionally
May Occur	Unlikely, but may occur at some time
Remote	Unlikely to occur at any time

3. Consequence Assessment

The severity of the consequences of potential hazards are assessed, considering such factors as size and construction of equipment, quantity or flow rate of materials and their properties, location and layout of equipment, numbers and location(s) of personnel, and existing safeguards or mitigating factors. Consequences are described and hazard severity categories are assigned based on this assessment. Existing measures which control or mitigate the hazard are documented.

4. Design and Operating Criteria

Recommendations are provided for all identified incidents which violate specified risk criteria or recommendation guidelines. Recommendations are based on analyst knowledge of the causative factors, likelihood rankings, process potentials and material response data. Recommendations may also be provided to further reduce the likelihood or severity of hazards, even though they meet the established criteria or guidelines. Recommendations may take the form of equipment substitution, design changes, procedural changes, or other engineering or administrative controls.

B. Safety Hazards

Workplace safety hazards are identified by inspection of documentation and on-site review, and is usually based upon and builds upon information and knowledge generated during the process hazards analysis.

Specific attention is given to operator-equipment interaction, manual process operations, and potential equipment hazards. The workplace safety analysis is intended to focus on process related hazards and is not intended to be or represent a complete OSHA compliance inspection or audit.

An assessment of likelihood and severity is made. Existing safeguards and controls are documented. Recommended control measures and comments are provided.

C. Health Hazards

Workplace health hazards are identified by inspection of documentation and on-site review, and is usually based on information and knowledge developed in the course of the process hazards analysis. Potentially hazardous materials in use or likely to be generated in the process are identified and documented. Potential sources and modes of operator exposure are identified by inspection and an assessment of likelihood and consequences is made based on system design or procedure, quantity or rate of material, existing control methods, and monitoring data, if available. Recommendations for additional engineering controls, personal protective equipment, or monitoring are made based on the hazard evaluation. The workplace health hazards are not intended to be a full-fledged occupational health, hygiene and monitoring program; but is intended to identify areas where attention should be focused and where controls, monitoring or personal protective equipment may be indicated.

D. Environmental Hazards

Environmental hazards are identified by inspection of documentation and monitoring data, where available, and is usually based on information and knowledge developed in the course of the process hazards analysis. Releases of material from the process are identified and characterized. Existing control measures are evaluated and documented. Recommendations for additional control measures or monitoring are developed as deemed advisable. The Environmental Analysis is not intended to represent a complete Environmental Impact Statement, but is intended as a check on the basis of the EIS, where applicable and data exist, as an aid to identifying areas where attention and monitoring should be focused to correct problems or determine if violations exist, or to document that violations, in fact do not exist.

APPENDIX C

SAFETY ANALYSIS REQUIREMENT DETERMINATION

For illustrative purposes, the technical sections of the Safety Analysis Requirement Determination have been completed and are included in the following pages.

SAFETY ANALYSIS REQUIREMENT DETERMINATION

SUMMARY AND SIGNATURES

OPERATION: 1000 lb/day PDU

Sub-Operation (if any): _____

1. SAR not required (Check as applicable)

- ☐ Solely construction activity
- ☐ Nuclear safety of weapon designs
- ☐ Contract, PETC/DOE will not assume ES&H responsibility

If any checked, proceed to Step 6.

2. SAR may be Required (Check as applicable)

- ☐ Contract, PETC/DOE will assume ES&H responsibility
- ☒ In-House operation

3. Complete Sheet 2 and attach

- ☐ SA not required. Go to Step 6.
- ☒ SA is required. Go to Step 4.

4. Complete Sheet 3 and attach.

Level 1 SA required

5. Complete Sheet 4 and attach

Cost estimate \$ _____

- ☐ New operation (SAR must be complete before operation commences)
- ☐ Pre-existing facilities. Should SAR be completed before facility put to next use?
- ☐ YES ☐ NO

6. _____

Signature of preparer Title Date

7. ☐ Concur ☐ Do not concur

Signature of reviewer

Title

Date

Reasons and Comments:

SAFETY ANALYSIS REQUIREMENT DETERMINATION

HAZARDS GENERALLY ENCOUNTERED/ACCEPTED

OPERATION: 1000 lb/day PDU

Sub-Operation (if any) _____

1. Answer the following for the operation

YES NO

- Any operating temperatures above 120°F or below -20°F? ☒ YES ☐ NO
- Any operating pressures above 15 psig or below ambient? ☒ YES ☐ NO
- Any equipment rotating above 4000 rpm? ☐ YES ☒ NO
- Any materials with NFPA Health Hazard Rating of 2 or above? ☐ YES ☐ NO
- Any materials with NFPA Flammability Rating of 2 or above? ☒ YES ☐ NO
- Any materials with NFPA Reactivity Rating of 2 or above? ☐ YES ☒ NO
- Any tools and/or equipment not typically found in the home or office? ☒ YES ☐ NO
- Any sources of ionizing radiation other than instrumentation? ☐ YES ☒ NO
- Any other factor(s) which indicate(s) a SA is needed ☐ YES ☐ NO

☐ All of the above checked NO. SA is not required☒ Some of the above checked YES. Proceed to Step 2

2. Certain DOE operations may involve equipment and/or materials which result in an answer of YES in Step 1, but which represent only hazards of a type or magnitude which are routinely encountered and/or accepted by the public. Check as applicable:

- ☐ Motor vehicle operation, maintenance (types of vehicles used by the general public)
- ☐ Small quantities (≤ 5 gallons) of commercial fuels and lubricants used solely in operation of machinery and vehicles
- ☐ Kitchen and domestic appliances
- ☐ Office equipment
- ☐ Portable power tools
- ☐ Domestic water systems
- ☐ Machine shop equipment
- ☐ Domestic hot water systems
- ☐ Portable electric heaters
- ☐ Utility boilers which meet the following conditions:
Built, instrumented, inspected, and tested to ASME Code
Capacity: $\leq 250,000$ lb/hr at ≤ 250 psig

☐ Other - Identify: _____

3. Considering the exclusions of Step 2, are there any items in Step 1 which are still answered YES?

☒ YES SA is required☐ NO SA is not required

4. _____

Signature of preparer

Date

SAFETY ANALYSIS REQUIREMENT DETERMINATION

LEVEL OF ANALYSIS

OPERATION: 1000 lb/day PDU

Sub-Operation (if any) _____

1. Short description: <i>Continuous disposable catalyst coal liquefaction unit. High pressure-high temp equipment in hot cell. Documentation informal and general in nature.</i> ☐ State-of-the-Art ☒ Advanced Technology		
2. Type of operation ☐ Non-chemical ☐ Laboratory ☐ Bench-scale ☒ PDU ☐ Pilot plant ☐ Demonstration ☐ Commercial	3. Materials in use ☒ Explosive ☒ Flammable ☒ Toxic ☐ Corrosive ☒ Erosive ☐ None of the above	4. Personnel exposure ☒ Remote operation ☒ Occasionally exposed ☐ Frequently exposed ☐ Normally exposed <i>liquefaction process remote</i> <i>Occasional exposure to peripheral process areas</i>
5. Operating parameters: Other considerations: Thruput or batch size <u>45 lb/hr</u> Operating temperature range <u>460 °C</u> Operating pressure range <u>2000 psig</u>		
6. Considering the type of operation, process, materials, personnel and siting factors, assign a Level of SA based on consequences of potential incidents as follows: <div style="display: flex; justify-content: space-between; margin-top: 10px;"> <div>Non-chemical or laboratory unit:</div> <div>Level 1</div> </div> <div style="display: flex; justify-content: space-between; margin-top: 10px;"> <div>Bench-scale unit:</div> <div>Level 1 or 2 using criteria below</div> </div> <div style="display: flex; justify-content: space-between; margin-top: 10px;"> <div>Process development unit:</div> <div>Level 1, 2 or 3 using criteria below</div> </div> <div style="display: flex; justify-content: space-between; margin-top: 10px;"> <div>Pilot plant:</div> <div>Level 2 or 3 using criteria below</div> </div> <div style="display: flex; justify-content: space-between; margin-top: 10px;"> <div>Demonstration or Commercial Units:</div> <div>Level 3</div> </div>		
<div style="border: 1px solid black; display: inline-block; padding: 2px 5px; margin-bottom: 10px;">CRITERIA</div> <div style="margin-left: 20px;"> Level 3 - Potential for major off-site impacts Level 2 - Potential for permanent disability or death, or significant equipment/facility loss on-site Level 1 - Negligible potential for serious injury, and loss of equipment not a major concern </div>		
Based on the above, a Level 1 SA is assigned. (Highest level which applies)		
7. _____ <div style="display: flex; justify-content: space-between; margin-top: 10px;"> <div>Signature of preparer</div> <div>Date</div> </div>		

SAFETY ANALYSIS REQUIREMENT DETERMINATION

BUDGETARY COST ESTIMATE

OPERATION: 1000 lb/day PDU

Sub-Operation (if any) _____

1. Complete this Step for backfit operations only, otherwise go to Step 2.

A. Operating experience	B. Previous Analysis	C. Accident experience
Years _____	☐ None applicable	☐ No significant accident
Use _____	☐ Qualitative	☐ Disabling injury
_____	☐ Quantitative	☐ Facility damage
_____		☐ Fatality
- D. Considering the factors above, should the Safety Analysis be completed prior to the operation being put to next use? ☐ YES ☐ NO

2. The following Budgetary Cost Estimate Guidelines are based on a percentage of EITHER the construction cost of the operation OR the design engineering manpower cost. Use the upper end of the ranges for a complete Safety Analysis, the lower end of the ranges for a complete Process Hazards Analysis only. Better estimates can be made as SA experience is accumulated.

<u>SA Level</u>	<u>Percent of Construction Cost Basis</u>	<u>Percent of Design Engineering Basis</u>
1	0.1 - 0.3	2 - 4
2	1 - 2	5 - 10
3	2 - 4	5 - 10

For backfit operations consider the extent and applicability of existing analyses when determining budget allocation.

Level of SA (from Sheet 3): 1

Cost estimate _____ % of \$ _____ = \$ _____

Basis and reasoning:

3. _____
Signature of Preparer

Date

APPENDIX D

PRESCRIBED STANDARDS

DOE has adopted certain operational environment, safety, and health standards. These are classified as either prescribed standards or recommended standards. Prescribed standards define minimum requirements with which DOE and its contractors must comply, while recommended standards are those which shall be considered for guidance. Prescribed standards are presented for different classifications or types of hazards. Those, which in our judgment, are likely to be applicable to coal conversion processes, as opposed to other types of operations or facilities in general, are identified below. Specific standards which appear to be specifically or directly applicable are further identified by an asterisk (*).

EMERGENCY PREPAREDNESS

- (1) Executive Order 11490, Assigning Emergency Preparedness Functions to Federal Departments and Agencies, and Amendments
- (2) Emergency Planning, Preparedness and Response Program, Chapter 0601 and Appendix 0601.
- (3) Damage Assessment, Chapter 0621 and Appendix 0621.
- (4) Facilities General Design Criteria, Chapter 6301 and Appendix 6301.
- (5) Telecommunications, Chapter 0270 and Appendix 0270, Part VIII.
- (6) DOE Response to Accidents Involving Nuclear Weapons in the Custody of the DOD, Chapter 0527 and Appendix 0527.
- (7) Prevention of Accidental or Unauthorized Nuclear Detonations, Chapter 0460.
- (8) Immediate Evacuation Signal for Use in Industrial Installations Where Radiation Exposure May Occur, ANSI N 2.3-1967 (ANSI).

ENVIRONMENTAL PROTECTION

- *(1) Prevention, Control, and Abatement of Air and Water Pollution, Chapter 0510 (DOE IAD 0510-1), Implementing Executive Order 11752, Prevention, Control, and Abatement of Environmental Pollution at Federal Facilities, and the Following Standards, Regulations, and Guidelines Promulgated Pursuant to Federal Environmental Legislation:

APPENDIX D (CONT'D.)

ENVIRONMENTAL PROTECTION (CONT'D.)

(1) (a) Air

- 1 New Source Performance Standards (40 CFR 60)
- *2 National Hazardous Air Pollutant Standards (40 CFR 61).
- 3 Regulations Designating Air Quality Control Regions (40 CFR 81).

(b) Water

- *1 Discharge of Oil (40 CFR 110)
- *2 Oil Pollution Prevention (40 CFR 112)
- *3 National Oil and Hazardous Substances Contingency Plan (40 CFR 1510)
- *4 Water Quality Standards Approved by the Federal Government (40 CFR 120)
- *5 Thermal Discharges (40 CFR 122)
- *6 Policies and Procedures for the National Pollutant Discharge Elimination System (40 CFR 125)
- *7 Pretreatment Standards (40 CFR 128)
- 8 Secondary Treatment Information (40 CFR 133)
- 9 Transportation for Dumping, and Dumping of Material Into Ocean Waters (40 CFR 220-226)
- 10 Best Technology Available for the Design, Construction, and Capacity of Cooling Water Intake Structures for Minimizing Adverse Environmental Impact (40 CFR 401 and 40 CFR 402)

(c) Drinking Water

- 1 Interim Primary Drinking Water Regulations (40 CFR 141)
- 2 Interim Primary Drinking Water Regulations Implementation (40 CFR 142)

(d) Solid Waste

- *1 Thermal Processing of Solid Wastes and Land Disposal of Solid Wastes (40 CFR 240 and 241)
- *2 Solid Waste Storage and Collection (40 CFR 243)

(e) Radiation

- 1 Standards and Requirements for Radiation Protection, DOE 0524
- 2 Performance Testing and Procedural Specifications for Thermoluminescence Dosimetry (Environmental Applications) ANSI N 545-1975 (ANSI)

APPENDIX D (CONT'D.)

ENVIRONMENTAL PROTECTION (CONT'D.)

(1) (f) Pesticides

- 1 Environmental Safeguards on Activities for Animal Damage Control on Federal Lands (Executive Order 11643)
 - 2 Regulations for Enforcement of the Federal Insecticide, Fungicide, and Rodenticide Act (40 CFR 162)
 - 3 Regulations for the Acceptance of Certain Pesticides and Recommended Procedures for the Disposal and Storage of Pesticides and Pesticides Containers (40 CFR 165)
 - 4 Exemption of Federal and State Agencies for Use of Pesticides Under Emergency Conditions (40 CFR 166)
 - 5 Worker Protection Standards for Agricultural Pesticides (40 CFR 170)
 - 6 Certification of Pesticide Applicators (40 CFR 171)
- *(2) Intrastate or Interstate Regulations of Environmental Protection Authorities.
- *(3) Effluent and Environmental Monitoring and Reporting, Chapter 0513.
- (4) Standards and Requirements for Radiation Protection, Chapter 0524.

FIRE PROTECTION

- *(1) Industrial Fire Protection, Chapter 0552
- *(2) General Design Criteria, Chapter 6301
- *(3) National Fire Codes (NFPA)
- (4) Standard for Fire Protection of AEC Electronic Computer Data Processing Systems. WASH 1245-1 (Compliance With this Standard Satisfies the Requirements for NFPA-75.)
- *(5) Lists of Inspected Appliances, Equipment, and Materials (UL)
- *(6) Factory Mutual Approval Guide (FM)
- (7) TP20-11 General Fire Fighting Guidance for Nuclear Weapons

APPENDIX D (CONT'D.)

HEALTH PROTECTION

a. Radiation Protection

- (1) Standards and Requirements for Radiation Protection, Chapter 0524
- (2) Occupational Radiation Exposure Information, Chapter 0525
- (3) Performance Specifications for Direct Reading and Indirect Reading Pocket Dosimeters for X and Gamma Radiation, ANSI N13.5-1972 (ANSI)
- (4) Radiation Symbol, ANSI N2.1-1969 (ANSI)
- (5) Radiological Safety in the Design and Operation of Particle Accelerators, ANSI N43.1-1969 (ANSI)
- (6) Specification and Performance of Onsite Instrumentation for Continuously Monitoring Radioactivity in Effluents, ANSI N13.10-1974
- (7) Personnel Neutron Dosimeters (Neutron Energies Less than 20 MeV), ANSI N319-1976
- (8) Implant Plutonium Monitoring for Personnel Protection, ANSI N317-1977
- (9) "Standards for the Unrestricted Release of Radioactively Contaminated Equipment and Facilities," ANSI N328
- (10) "Inspection and Test Specifications for Direct and Indirect Reading Quartz Fiber Pocket Dosimeters," ANSI N322-1977.

b. Occupational Medicine

- *(1) Occupational Medical Program, Chapter 0528
- *(2) DOE Employee Occupational Health Services Program, DOE 4161.

c. Industrial Hygiene

- *(1) Current Threshold Limit Values (ACHIH)
- *(2) Practices for Respiratory Protection, ANSI Z88.2-1969 (ANSI)

d. Public Health and Sanitation

Food

- (1) "Food Service Sanitation Manual," USPHS Publication No. 934 (1962)
- (2) "The Vending of Food and Beverages," USPHS Publication No. 546 (1965)

APPENDIX D (CONT'D.)

HEALTH PROTECTION (CONT'D.)

d. Public Health and Sanitation (Cont'd.)

Water

- (1) National Primary Drinking Water Regulations, 49 CFR 141, USEPA (1975)
- (2) "Manual for Evaluating Public Drinking Water Supplies," USEPA Publication No. 1820 (1971)
- (3) "Manual of Individual Water Supply Systems, USEPA Publication No. 430 9/73-003 (1975)
- (4) "Quality Standards for Bottled Water," USEPA (1973) 21 CFR 11
- (5) "A Sanitary Standard for Manufactured Ice," USPHS 1183 (1964)
- (6) GSA Handbooks on Performance Standards for Cleaning Public Buildings (General Services Administration).

OCCUPATIONAL SAFETY

a. General Safety

- *(1) General Design Criteria, Chapter 6301
- (2) Forest Service Safety Standards (USDA)
- *(3) Boiler and Pressure Vessel Code; Sections I-XI (ASME)

b. Construction Safety

- (1) Construction Safety Program, Chapter 0505
- (2) Pipeline Safety Standards Title 49 CFR Part 192

c. Crane Safety

- *(1) ANSI Series B 30.2 Through B 30.9 (ANSI)
- *(2) Crane Manufacturers Association of America, Specification No. 70 (CMAA)

d. Drilling Safety

- (1) Petroleum Safety Orders, Administrative Code, Title 8, Chapter 4, Subchapter 14, State of California (Except the Requirements of Paragraph (b) Section 6640, of Article 41 of the 1959 Orders is Permanently Waived-API RP 98 Applies)
- (2) Applicable Division of Production Specifications and Recommended Practices on Oil Field Equipment (API)
- (3) Safe Practices in Drilling Operations, Third Edition, 1967 RP 2010 (API)

APPENDIX D (CONT'D.)

e. Electrical Safety

- *(1) National Electrical Code, NFPA 70 (ANSI-C1)
- *(2) National Electrical Safety Code (ANSI-C2)

f. Explosives Safety

- (1) Safety Manual, AMCR 385-100, U. S. Army Materiel Development and Readiness Command
- (2) DOD Ammunition and Explosives Safety Standards, DOD 4145.27M (DOD)
- (3) Blaster's Handbook (DuPont)

g. Firearm Safety

- (1) Physical Protection Handbook (GSA-)
- (2) Pistols and Revolvers, FM 23-35, 7-60 (AMC)
- (3) Safety With Firearms Handbook (NRA)
- (4) Firearms Handling Handbook (NRA)

h. Mine and Tunnel Safety

- (1) Federal Metal and Nonmetallic Mine Safety Act, Public Law 89-5771, Standards, 30 CFR 55, 56, 57
- (2) Tunnel Safety Orders, Administrative Code, Title 8, Chapter 4, Subchapter 20, State of California
- (3) Mine Safety Orders, Administrative Code, Title 8, Chapter 4, Subchapter 12, State of California

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