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**CE IGCC Repowering Project
Preliminary Hazard Analysis**

**Topical Report
November 1, 1990 - May 31, 1993**

Lawrence J. Peletz

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**For
U.S. Department of Energy
Office of Fossil Energy
Morgantown Energy Technology Center
P.O. Box 880
Morgantown, West Virginia 26507-0880**

**By
Combustion Engineering, Inc.
1000 Prospect Hill Road
Windsor, Connecticut 06095**

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TOPICAL REPORT

PRELIMINARY HAZARD ANALYSIS

I SUMMARY

With sponsorship from the Department of Energy (DOE), and the state of Illinois, Combustion Engineering, Inc. is currently developing a design for a 60 Mw IGCC (Integrated Coal Gasification Combined Cycle) for City Water, Light & Power (CWL&P) in Springfield, Illinois. In addition to DOE and the state of Illinois, other contributors to the project are Combustion Engineering, Inc. and CWL&P. In order to address concerns for safety, Combustion Engineering organized a team of engineers to review the proposed operation of the IGCC unit and develop a preliminary hazard analysis (PHA).

A preliminary hazard analysis was conducted on the CE IGCC unit by representatives from ABB Lummus Crest Process Systems, Lummus Technical Division, Combustion Engineering, and Lummus Initial Operations. As a basis for the review, available technical data and documentation was used. Two areas of the unit were reviewed, the coal yard delivery system and the gasifier island. The coal yard consists of the coal delivery and handling systems, both of these systems are conventional. The gasifier island encompasses the coal pulverizer and feed system, gasifier and syngas cooler, char removal system, char recycle system, and high temperature sulfur removal system. With first of a kind equipment incorporated in the gasifier island, most of the concerns of potential hazards were centered here. At the time of the review, there were no process flow diagrams for the rest of the combined cycle. To prevent detaining the review of the gasifier island, the remaining areas were not reviewed at this time. However, the remaining areas will be reviewed before final unit design is completed. In reviewing the above mentioned systems, the PHA identified several hazards which will be the basis for a subsequent detailed Hazard and Operability (HAZOP) study which will be performed at a later stage of this project.

Results from the evaluation were documented by the team and then reviewed by engineers in the IGCC Product Development department. From the concerns of risks developed by the review team, rethinking of proposed operation and design of the plant during the preliminary design stages took place. (In doing so, cost and redesign time during final design phase will be reduced).

II INTRODUCTION

Combustion Engineering, Inc. (CE) received approval from the U. S. Department of Energy (DOE) to demonstrate an IGCC system based on CE's air-blown gasification technology. To operate at high efficiencies, new and innovative designs and equipment are required in the unit. To insure safe operation of the unit, a preliminary

hazard analysis (PHA) was conducted on the CE IGCC unit to identify potential hazards early in the conceptual design phase of the project.

The main purpose of a Preliminary Hazard Analysis is:

- To recognize and identify hazards early in the engineering design of a unit.
- To define the steps that should be taken to ensure the design produces a safe operating unit.

By incorporating a PHA review of a unit design, time and cost for redesign at a later date can be saved. A PHA review is a precursor to a more indepth review incorporated in a HAZOP or FEMA (Federal Emergency Management Agency) review.

Objectives of a PHA are:

- Estimation and identification of the magnitude of potential hazards to be addressed before final design.
- Develop recommendations and criteria for engineers to follow in future designs.
- Identify hazards related properties
- Determine if derived risks can be addressed with current knowledge and experience.

In order to perform a PHA study, the following steps are followed:

a. Obtain required data

The PHA is generally done during conceptual or the early development phase of a unit design. At this time, information pertaining to safety issues is usually not well developed. Support on gasifier information is required from in-house engineering and vendors supplying auxiliary equipment. Process flow diagrams are needed as a minimum to help the review team visualize the components in the unit's systems.

b. Conduct PHA study

To start the study, identification of hazards, potential initiating events, and other events associated with creating an accident are established. Areas that are included in a list of potential hazards are:

- Raw materials, intermediate and final products, and any reactants;
- Plant equipment with a history of being hazardous;
- Safety-related interfaces between equipment and materials;
- Operating, testing, maintenance, and emergency procedures;

- Environmental factors affecting plant operation;
- Facility support.

c. PHA team task

With the identification of the hazards, the PHA team should:

- Identify hazards causes.
- Determine consequences from the causes.
- Assign hazard categories to rate the severity of the hazard.
- Develop guidelines and criteria for engineering the unit. Criteria to consider may include: process alternatives, minimum storage of waste on site, warning systems to alert personnel, safe procedures for operation, training programs, and process alternatives to reduce hazardous waste.

d. PHA results

The final step for the PHA team is to generate a record of the findings.

The PHA was performed by representatives from ABB Lummus Crest Process Systems, Lummus Technical Division, Combustion Engineering, and Initial Operations ABB Lummus Crest.

In reviewing the unit, unfamiliarity with the gasification process has caused the review committee to show more concern for areas of the gasifier than with the conventional systems areas. This is to be expected since the gasifier is in the developmental stage and there are still unknowns in its operation. However, the gasification system was found to be no more hazardous than conventional systems. In operating the Process Development Unit (PDU), Combustion Engineering found that more concern had to be given to the "proven" auxiliary system equipment than to the gasifier and its operation. With the use of pulverized coal, the preparation and feed systems still must be operated so as to prevent explosions due to enclosed dust laden areas and to ignition due to material hideout.

Operating procedures for the 60 MW unit at CWL&P require that the gasifier and flue gas system be purged with an inert gas whenever there is a startup, shutdown or interruption in operation. This is to insure the system is clear of combustible gases.

III BACKGROUND

The CE process at CWL&P will use an air-blown entrained flow, two stage, slagging bottom gasifier. Figure 1 shows a schematic of the gasifier concept and Figure 2 shows the main components of the gasifier island. Some of the coal and all of the unburned carbon and ash are fed to the combustor section while the remaining coal is fed to the reductor section of the gasifier.

The coal and char in the combustor mix with air and the fuel-rich mixture is burned, creating the high temperature necessary to gasify the remaining coal and to melt the mineral matter in the coal. The slag flows through a slag tap at the bottom of the combustor into a water-filled slag tank where it is quenched and transformed into an inert, vitreous, granular material. This slag is non leaching, making it easy to dispose of in an environmentally acceptable manner.

The hot gas leaving the combustor enters the second stage called the reductor. In the reductor, char gasification occurs along the length of the reductor zone until the temperature falls to a point where the gasification kinetics become too slow. Once the gas temperature reaches this level, essentially no further gasification takes place and the gases subsequently are cooled with convective surface to a temperature low enough to enter the cleanup system.

The char is carried out of the gasifier with the product gas stream. The char is collected and re-cycled back to the gasifier, where it is completely consumed. Thus, there is no net production of char, which results in negligible carbon loss.

The product gas then enters a desulfurization system where it is cleaned of any sulfur compounds present in the flue gas. The clean fuel gas is now available for use in the gas turbine combustor for a combined cycle application. Figure 3 shows the overall combined cycle system.

IV DISCUSSION - ACTION FROM PRELIMINARY HAZARD ANALYSIS

With the writing of the preliminary hazard analysis (PHA) report, some of the areas of concern in the unit have been modified and in other areas, measures have been taken to address the concerns. The following will explain how the concerns of the report are addressed.

The review committee has two major concerns and a number of potential hazards in other areas. The two major concerns are: use of a common vent stack and the common use of the coal preparation bagfilter to discharge the coal drying air and vent the coal lockhoppers. These concerns are addressed in the following manner.

- Common vent stack - A major concern of the review committee is that during startup and shutdown conditions there will be an excess of oxygen in the flare stack when light off takes place. This concern is from the startup procedure of firing natural gas to warm the unit and then changing over to coal. In doing so there is a time that the flare goes from oxygen rich to a non-oxygen atmosphere. By changing conditions, there is a possibility of error in starting the flare before it is purged of oxygen. To eliminate this problem, the committee suggested using two stacks, one for venting and the other for

flaring. By incorporating the two stacks in the system, the chance of igniting the flare pilots in an oxygen rich atmosphere is reduced. The vent will be used during the firing of natural gas. Once the gasifier is warmed and at pressure, the air will be backed down, coal fired, and valving changed from the vent to the flare. In changing to the flare, the flue gas will flow through the hot gas clean up system. This recommendation was taken and two stacks are included in the process for startup and shutdown.

- **Separate Bag Filter for Coal Receiving Bin** - The PHA report is concerned with the use of steam as the medium for transporting and pressurizing of the coal system. Using steam may create problems due to the moisture and the need to heat the coal to a high temperature. Venting of the pressurizing steam from the lockhoppers to the coal preparation bag filter could cause potential condensation problems. With concerns for the operation and safety of the system, the gas medium has been changed to nitrogen. In doing so, fear of moisture buildup and hot coal and startup gas causing explosions are eliminated. By using nitrogen, the system will be inerted and the amount of moisture in the gas stream reduced.

In the PHA , a work sheet for each system and subsystem potential hazard areas are called out. Each hazard is categorized using a rating system of I to IV: Category I, negligible, will not result in personnel injury or equipment damage. Category II, marginal, can be controlled without injury to personnel or major equipment damage. Category III, critical, will cause personnel injury or major equipment damage. Category IV, catastrophic, will cause death or severe injury to personnel or massive equipment damage. Below is a description of actions taken in the preliminary engineering design phase and plans for future actions to address the potential hazards categorized as III, critical and IV, catastrophic. Categories I and II are not addressed at this time because they will be considered in the normal design process.

As basic ground rules, all systems and subsystems are designed to adhere to the appropriate codes when applicable, designed to reduce potential hazards, and operated using safe operating procedures. In cases where there are no applicable codes to use, codes applying to situations that are similar have been modified using "best engineering judgement".

Following are the actions taken to address the findings of the hazardous review committee for categories III and IV for the various systems and subsystems.

SYSTEM: COAL DELIVERY AND HANDLING

SUBSYSTEMS: RECEIVING PIT DUST COLLECTION
RECLAIM PIT DUST COLLECTION
LAKESIDE II TRIPPER AND DUST COLLECTOR

Internal Fire - To reduce the potential of internal fires caused by spontaneous ignition of the coal dust (which would cause equipment damage) in the receiving and reclaim pit dust collection systems, the equipment and controls are designed and selected following the NFPA codes. (NFPA 120)

SYSTEM: COAL MILLING

SUBSYSTEM: COAL PULVERIZER

Contained Explosion - To prevent the possibility of mill explosions, the following precautions are taken in the design of the pulverizer and system. Operating and control procedures are used that adhere to NFPA code 85F, Pulverized Fuel Systems. To prevent increased hideout and spillage in the mill, the discharge temperature of the coal and drying/transport gas is at a temperature that is above the dew point temperature during all operating modes. If an explosion does occur, provisions are designed into the system to either contain or relieve in a safe manner.

Tube Rupture in No. 1 & 2 Mill Heaters - The system to preheat the air to the coal pulverizer has been changed from the design reviewed. Instead of using steam and condensate heaters to heat the air, a duct burner will be used. This eliminates the concerns of tube rupture in the heaters. Use of the duct burner adds a margin of safety by using a flue gas as the transport and drying gas for the coal. The duct burner and controls are designed and operated per NFPA requirements.

SYSTEM: PULVERIZED COAL HEATING

SUBSYSTEM: CYCLONE/BAGHOUSE/CONVEYOR

Contained Explosion - With the mixture of hot air and coal there is a concern of explosions. To protect personnel, the components are designed and operated per NFPA 85F. By designing to NFPA 85F, the components are required to contain a pressure increase to 50 psig or relieve the pressure in a safe manner. The system has been changed to use flue gas as a heating and drying medium and nitrogen as the transport and pressurizing gas. Changing to nitrogen eliminates the need to heat the coal above the temperature required to dry it. Therefore, the potential of explosions due to heating of the coal particles with hot gas has been eliminated.

SUBSYSTEM: PULVERIZED COAL HEATER

Erosion - The original concern of erosion in the coal heater was with particulate scrubbing of the tubes. In changing the transport and pressurizing gas medium from steam to nitrogen, the need to heat the coal above the steam transport temperature is not required. This eliminates the need for a coal heater.

SYSTEM: PULVERIZED COAL LOCKHOPPERS

SUBSYSTEM: COAL LOCKHOPPERS, RECEIVING, FEED BINS AND LINES

Erosion - Particulate scrubbing in the lockhoppers and bins is also a concern with the review committee. This is reduced by designing the lockhoppers and bins for a mass flow condition. In doing this, the scrubbing of the particles along the bin walls and hoppers is very slow. Also, the material will be in a constant state of fluidization which will minimize scrubbing of the walls. The hopper walls will be lined with material that will reduce the friction to promote mass flow.

To reduce the erosion in the feed lines, the velocities are maintained low and the elbows are wear protected.

SYSTEM: PULVERIZED COAL

SUBSYSTEM: 2 TPD KINETIC EXTRUDER (FUTURE)

The kinetic extruder has been removed from the project. Therefore, there is no need for it to be covered in the PHA at this time.

SYSTEM: GASIFIER

Contained Explosion - The review committee has a concern that there is a potential for an explosion due to lighting off with a gaseous mixture in the gasifier. To prevent gasifier explosions during lighting off, NFPA code 85B and 85E will be modified and used to purge the unit after trips, startup, and shutdowns. In addition, CE will use its Gasifier Supervisory Safety System (GSSS) control system to manage the burners during various operating modes and a Distributed Control System (DCS) to provide for analog loop functions and to provide the operator interface.

Toxic Exposure - To reduce the chance of injury to personnel due to exposure to toxic gases, H₂S monitors will be installed in the appropriate areas. In addition, personnel training on proper sampling technique and protective wear will be provided.

Corrosion - Having a gas with H₂S in it causes concern for corrosion of the associated piping and ductwork. To reduce the rate of corrosion, CE's metallurgical laboratory will evaluate materials for their resistance to H₂S and make recommendations for materials and/or coatings required to prevent material corrosion. As mentioned above, monitors will be installed to detect and alarm if toxic gaseous are present in the gasifier work areas.

Fire - With the generation of a flammable gas that has a corrosive characteristic, there is the possibility of gas leakage. To protect against fires due to gas leakage, personnel will be trained to provide proper maintenance to the gasifier and associated equipment. For protection if a fire does occur, a fire protection system will be

installed throughout the unit.

Tube Rupture - As with the gas ductwork, there are concerns that the potential for waterwall tube corrosion may exist or there may be leakage from poor workmanship. To address this concern, the waterwall tubes will be designed, fabricated, and installed to ASME code requirements. Material for the tubes will be selected by CE's metallurgist to withstand anticipated corrosion and erosion. Design of the unit will also take into account gas velocities and constituents and their effects on the waterwall tubes.

SYSTEM: GASIFIER SLAG REMOVAL

Corrosion - Concern for the leakage of the product gas to the outer pressure vessel has promoted concern for the integrity of the material to maintain operating conditions. The seal between the inner waterwall and the outer seal of the gasifier is designed to rupture if the pressure differential across the waterwall is greater than a set value. By rupturing, the pressure differential is not exceeded and no mechanical damage occurs. The space between the outer shell and inner waterwall is filled with high pressure steam to prevent the entrance of product gas. The steam maintains a constant temperature differential across the outer shell as well as preventing the product gas from contacting it causing material corrosion.

SYSTEM: CHAR REMOVAL

Erosion/Corrosion - As with the coal system, there is concern that particulate scrubbing against the bins and piping will cause erosion. Char removal equipment and piping will be designed to minimize erosion by limiting material velocities. CE's metallurgist will recommend the proper materials or coatings to provide protection against corrosion in the equipment. In addition, a thickness allowance will be added to the wall thickness.

Toxic exposure - Protection against toxic exposure will be the same as for the gasifier area.

SYSTEM: CHAR LOCKHOPPERS

SUBSYSTEM: CHAR FEED SYSTEM

Erosion/Corrosion - Concerns of erosion are the same as in the char removal system. Precautions and design philosophy is the same as for the char removal system.

Toxic exposure - The same as for the char removal system.

SYSTEM: HIGH TEMPERATURE SULFUR REMOVAL SYSTEM

Toxic exposure - In cleaning the product gas in the hot gas clean up system, a number of toxic gases are generated as well as the potential release of catalyst fines. To reduce the potential hazards to personnel, the hot gas clean-up system will have gas monitors to detect any discharge of toxic gas. Venting of all gas streams will be done in a manner that is environmentally safe. Personnel will be trained in proper operation, maintenance, and emergency procedures for safe operation of the system. Sorbent material from the regenerator will be disposed of by transporting back to the supplier for reprocessing.

Erosion - By passing the product gas through a bed of solids, fines will become entrained in the gas. If not removed, they can cause damage to the gas turbine. To minimize the possibility of gas turbine damage, both the hot gas clean-up and turbine are being provided by the same supplier. Therefore, the supplier should provide proper clean-up of the gas stream from the clean-up system to meet the needs of the gas turbine.

Corrosion - As with earlier systems there is the concern of corrosion due to the H_2S in the gas. The vendor of the system is using a test facility to decide the proper materials for use in components of the system. Monitors will be installed to detect any leakage of hazardous gas to the environment.

Tube rupture in steam generator - Concerns for the material and workmanship of the high pressure steam parts are similar to those in the gasifier. Selection of materials for use in the steam generator will be selected by CE's metallurgist for the conditions in the system. ASME codes for non-fired pressure vessels will be used in selecting proper mechanical strengths.

V CONCLUSION

After the review team identified areas of concern with the gasifier, CE's engineering department modified and addressed the identified areas. Since this was done early in the plant design, costs are reduced because later redesign is minimized. In addition, the reviewed hazard concerns showed that there were no highlighted areas which could not be addressed.

Figure 2. Gasifier Island

Figure 3. CE IGCC Flow Diagram

Area Covered In
Hazard Analysis

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