AN OVERVIEW OF COAL GASIFICATION ENVIRONMENTAL CONTROL TECHNOLOGIES

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ABSTRACT

This paper outlines some of the history, conversion process principles, products, waste streams and byproducts of the coal gasification concept. The environmental concerns briefly discussed are: regulatory issues, gaseous/particulate emissions, solid waste and liquid waste control, as well as biological effects. Specific processes are not covered; but generic aspects of effects and controls assessment include characteristics of waste streams, evaluation of control, unknowns/uncertainties, controls development, and various research and development needs. These topics provide the background for describing pilot testing concepts for predicting operating conditions, chemical characterization/biological effects of operation, performance of controls and byproduct utilization.

INTRODUCTION

Gas manufactured from coal (Reference 1) was first produced in the late 18th century by heating coal in the absence of air. To supply the necessary heat, additional coal was burned outside of the vessel. Combustion gases were segregated from the air-deficient interior gas. By 1812, the first coal-gas company was chartered in London to distribute a product used for lighting. Four years later, the first U.S. company was chartered in Baltimore.

Initially, gas with a heating value ranging from 475 to 560 Btu per cubic foot (depending on the type of coal and process conditions) was produced by destructive distillation of coal. Coke ovens, which manufacture coke mainly for steel industry use, produce an off-gas similar in composition. This coke-oven gas, where available, often supplemented the supply of coal gas made from plants involving the destructive distillation of coal. Unfortunately, about 70 percent of the feed coal remains as a solid residue in these processes, and disposal of the residue was a problem except in the coking-type operation where coke was the primary product. The solution to the disposal problem for the carbon-rich residue lead a step beyond distillation to gasification of the residue.

Coal gasification (depending on the process) may be preceded by distillation in the same vessel, but such gasification involves the subsequent reaction of the solid with air or oxygen and steam. The distillation step gases which are first released have a high Btu content because methane and higher

hydrocarbons contained in the coal are among the first components to emerge as the coal decomposes. However, the gasification step makes a gas with a much lower heating value because the gas produced is essentially a mixture of carbon monoxide, carbon dioxide, and hydrogen.

The gasification of coal follows two basic paths, using either air- or oxygen-supported combustion to supply required heat. This heat-producing step is necessary to maintain endothermic gasification reactions. Gasification with air produces a clean gas of low (100-250 Btu/ft³) heating value due to a significant concentration of nitrogen introduced in the air supply. To make a low inert content gas suitable for synthesis, it is necessary to gasify with oxygen. This second route produces clean gas of either medium (250-550 Btu/ft³) or high (950-1000 Btu/ft³) heating value. The latter case (for high Btu/gas) requires additional process steps to reach the higher heat content and, as such, is not pertinent to the basic objective of this overview which is limited to the study of industrial fuel.

Industrial gaseous fuels can generally be classified as low or medium Btu fuels that are burned in equipment designed to exhaust the products of combustion through a chimney directly to the atmosphere. On the other hand, pipeline- or "towns"-gas quite often discharges the products of combustion directly into a closed environment (such as a house or factory) and, therefore it must have tight restrictions placed upon it. One such restriction sets a maximum for the sulfur level.

The discussion in this paper will be limited primarily to the production of medium Btu industrial coal gas. Figure 1 is a generalized basic block-form flow diagram of the typical coal gasification system for such gas production. The major process components are: the gasifier unit, acid gas removal process equipment, sulfur recovery unit, and tail gas cleanup process section.

The gasification process produces both desirable and undesirable products, such as: CO, H₂, CH₄, C₂H₄, CO₂, N₂, Ar, H₂S, COS, CS₂, RSH, SO₂, NH₃, HCN, NO_x, O₂, H₂O, formates, and phenols; as well as numerous solid, liquid, and particulate products. The environmental control problem becomes one of separation, disposal, and/or control for product enhancement (also a performance function), and possible waste product (or byproduct) utilization.

Figure 1. General Flow Diagram of a Coal Gasification Plant

The Resource Conservation and Recovery Act of 1976 mandates the consideration of the conservation and recovery of byproduct streams when applying waste management practices to industrial facilities. However, such objectives have to be met in a manner that also helps preserve and enhance the quality of air, water, and land resources.

The main byproduct streams, coarse and fine slag, from coal gasification plants can be assessed for technical feasibility, marketing potential, and from an environmental impact standpoint.

For most byproduct uses, some typical potential environmental impacts which could be considered are: (1) heavy metal toxicity concerns of byproduct leachate in ground or surface water; (2) radiological concerns due to the concentration of some naturally occurring components in certain byproducts; and (3) the potential for water quality degradation from concentrations of nontoxic dissolved solids (such as metal sulfates and chlorides).

The following potential uses may be viable for research and development:

1. Highway construction
2. Cement manufacturing
3. Mineral wool manufacturing
4. Mineral recovery (including sulfur)

ENVIRONMENTAL CONCERNS

Regulatory Issues

As of 1980, no Federal regulations have been promulgated specifically for coal gasification technology. However, existing regulations may be extended to cover portions of the plant operations (i.e., coal preparation, onsite steam generation, storage of hydrocarbon products, etc.) The gasification plant will have to comply with the Clean Air Act (CAA), Clean Water Act (CWA), Toxic Substances Control Act (TSCA), Resource Conservation and Recovery Act (RCRA), Safe Drinking Water Act (SDWA), and possibly other Federally initiated acts and directives (i.e., Executive Orders).

Regulatory alternatives are addressed on a media specific basis in EPA's draft, Pollution Control Guidance Document (PCGD), for coal gasification and indirect liquefaction. Appropriate recommendations in the PCGD should be thoroughly reviewed and considered in coal gasification project planning.

Emerging technologies such as coal gasification pose unique problems from a regulatory standpoint. These new technologies are not completely covered by any of the existing Federal rules and regulations. Although some of the waste streams are identified and covered under existing regula-

tions or extensions thereof, unidentified streams will have to fall into an evolving regulatory framework of guidelines and standards.

Establishing regulatory authority involves confronting various problems. One problem in the coal gasification process is that the waste streams are most often unique to the unit processes or combinations of processes in a plant. Hence, the regulatory strategies are generally being structured to address combinations of processes and not to discriminate against individual process technologies.

EPA's PCGD, now in preparation, addresses the regulatory alternatives on a media-specific basis. It discusses cross-media trade-off in a qualitative aspect and various streams that need to be addressed, on both a control and regulatory specific basis, within each media.

The available data base for coal gasification has many limitations. Judgment made for characterizing limitations of waste streams and concerning control process capabilities are based on considerable extensions of experience gained and data gathered from related industries.

The regulatory approach is expected to first address these uncertain areas or their limitations and then to be modified as the new data base is obtained from new generation plants.

Gaseous Emissions

The raw gas from a gasifier is generally composed of CO and H₂ with several other potential pollutants present in relatively small quantities. If CO and H₂ were emitted, they would be considered waste products or pollutants. In most instances, however, CO and H₂ will be recycled to the main gas stream to avoid loss of heating value.

This overview concerns itself with the fate of other components and control technologies for reducing the concentrations of these components to acceptable levels in the main and waste gas streams. Some of those compounds will be removed in the cooler/washer and, if not stripped from the water, will be further processed in the wastewater treatment. Most of the potential pollutants remaining in the main gas stream are acidic gases and are removed with H₂S in the acid gas removal system. After sulfur removal, the waste gas may be combusted in an incinerator or auxiliary boiler where it can be controlled with conventional cleanup equipment (in as much as it will be similar in composition to those species normally found in pulverized coal-fired combustion flue gas). Other waste gas streams which could include any potential pollutants also may be combusted and treated as above.

Since pollutant concentrations in several of the waste gas streams may be extremely low and considered nonhazardous, these waste streams may not need any controls. Only a complete characterization of the gas streams to determine the fate of all of the components permits a determination of those streams that absolutely need controls and those which can be vented to the atmosphere.

Should an accident occur, a release of part of the main gas stream may result. Identification of the components of all of the gas streams is also needed so that safety procedures and health precautions can be made in preparation for such an event.

Particulate Emissions

Particulate control is essential to ensure safe and economical functioning of the gasification process as well as for protection of the environment. Many plant components, including some of the particulate control devices, may be considered novel or emerging technologies. Much of the coal gasification literature reveals that only limited characterization of gasification process stream particulates has been accomplished.

Some of the particulate control steps required for process operations are the sole steps before atmospheric emission. In addition, the tolerance of compressor and acid-gas removal systems for particulates has not yet been thoroughly documented. Consequently, definition of process particulate control requirements, assessment of control technologies, and characterization of atmospheric emissions are not easily determined.

The principal particulate emissions sources from a coal gasification plant appear to be:

1. Coal transport and preparation facilities.
2. Vents and flares, especially during startup, process transients, and shutdown.
3. Tail gas.
4. Auxiliary boilers and combustors (if coal fired).

Solid and Liquid Emissions

Due to concentrated efforts in the industry for obtaining data on process performance, the information relating to the qualitative and quantitative characteristics of the waste is meager. Available control technologies have been evaluated to determine capabilities to meet anticipated regulations, but control and disposal methods for effluent materials have not yet been commercially demonstrated.

All these considerations have created a need to identify the nature and characteristics of liquid and solid wastes from coal gasification technologies. This identification can lead toward development of methods for achieving minimum pollutant discharge.

Most existing literature indicates that the liquid waste streams will likely contain a wide variety of the components found in the product gas as well as sulfur and nitrogen compounds, particulates, phenols, tar and oil (depending on the gasifier configuration), and soluble salts (as high as 3,000 ppm). Full scale operation of coal gasification plants will produce large quantities of ash and slag. These streams will contain water leachates, organic/inorganic compounds, and trace elements.

Biological Environmental Effects

Conclusions on the potential toxicity of gasification waste streams have been derived from extrapolated small-scale facility and related industry data. This data provides a preliminary indication that concentrations of trace elements, cyanides, carbon monoxide, carbonyl sulfide, hydrogen sulfide, phenols and ammonia, and fine particulates present in various waste streams will be of concern.

Four major study goals should be achievable through toxicity sampling and analysis. These are: (1) characterization of the chemical, physical, and biological properties of the process streams; (2) predictions of environmental effects; (3) probabilities of environmental release; and (4) requirements of control levels.

Effects and Control Assessment

The purpose of environment control and assessment is to provide a systematic basis for selecting and/or developing environmental controls for commercial-scale gasification plants. The studies must include an assessment of the controllability and potential environmental effects of coal gasification plant waste streams. From this data base (formulated from available information), recommendations can be generated. These recommendations fall into one of the following three categories:

- A. Control Technology Recommendations--If the emissions data base is determined to be sufficiently similar to that of a projected gasification facility; appropriate control technologies can be recommended for use.
- B. Control Technology and Confirmatory Research Recommendations--In some cases, a reliable data base may be gathered for a gasification facility, but the transferability or scale-up of the data is questionable. For these cases, research is required to confirm the composition of the process stream and the adequacy of the selected environmental control.
- C. Research and Development--Comprehensive sampling programs at appropriate test facilities may be required to establish an adequate data base for waste streams with insufficient available data. Once this data is established, a plan for selection and/or development of appropriate controls can be formulated.

The control and effects assessment studies should include the following aspects peculiar to coal gasification control technology:

- o Particulate emission control
- o Solid waste disposal
- o Gaseous emission control
- o Liquid emission control
- o Byproduct utilization (fly ash, bottom ash, slag, sludge, etc.)

Investigations within each of the first four areas should include waste stream identification

and characterization, capabilities of best available technology (BAT) controls, and areas requiring continued research.

To summarize, the control and effects assessment must draw on current literature to develop waste stream characterizations. Current, proposed, and anticipated regulations and EPA's Multimedia Environment of Goals (MEG's) can then be used to develop a waste stream prioritization. Assessments of controllability and environmental effects then lead to recommendations of appropriate control technologies and research.

Control and R/D Needs

For gaseous emission cleanup, several components are used in the typical coal conversion plant. These are: acid gas removal, a sulfur recovery unit (Claus unit), and a (Claus) tail gas cleanup process. From these processes most undesirable components are greatly reduced and the elemental sulfur is recovered. It may be possible to meet regulations (depending on the operations) without a Claus tail gas cleanup system. In this case the gas is sent to the auxiliary boiler, which produces steam for the conversion process; and the returned gas is converted to SO₂ which is removed by the boiler flue gas desulfurizer unit (FGD).

Figure 2 details a number of air pollution controls for coal gasification process waste streams.

Unknowns and uncertainties in the use of new and modified controls will require some confirmatory and developmental research.

Depending on the process particulate control, methods can be called upon to handle high ash loadings in the raw gas product. Following the gasifier, a spray tower quenches the gas. A cyclone separator may precede the quench. After quenching, cyclones and waste heat recovery (if used), a final gas cleanup before desulfurization is effected in a venturi scrubber or other type of impingement or orifice scrubber.

Other particulate control is accomplished in the coal preparation and transport by means of scrubbers.

Aerosols of the type associated with FGD may be present in the tail gas from the gasification plant. In this case, a venturi scrubber or wet electrostatic precipitator may be employed to control mist from the tail gas and gas removal steps described above.

Additional stack-gas particulate assessment and control studies will be needed because of significant variability in conventional power plant data and specie types/quantities. The specie characteristics are highly dependent on plant design, coal properties, and pollution control equipment.

Some of the major items which will influence final control device design and selection are:

Figure 2. Air Pollution Control Layout (Reference 3)

1. Component equipment sensitivity to particulates.
2. Particulate control device performance.
3. Characterization of specific emissions.
4. Adequate high-temperature, high-pressure particulate sampling techniques (needed data for most gasifier designs).

For wastewater discharge, the major treating modules would:

- o Remove suspended solids from emulsified oils.
- o Remove dissolved salts and inorganic volatile contaminants.
- o Use an ultimate disposal process to facilitate final disposition of any wastewaters that cannot be economically upgraded.

Oil and suspended solids separation methods include: gravity separation, filtration, flocculation-flotation, and ultrafiltration.

Dissolved organics are removed by extraction, adsorption, biological treatment, cooling tower oxidation (stripping), and reverse osmosis.

Dissolved inorganics are removed by such methods as: stripping, evaporative brine concentrations, ion exchange, membrane desalination, and neutralization.

The ultimate disposal module usually involves holding ponds or evaporation ponds which may be very expensive in terms of land costs and whenever used in areas with slow evaporation rates (less than 20 inch/year)--such as much of the eastern U.S.

Solid waste disposal poses a significant problem in coal gasification. The forms of waste are usually:

- o Ash/slag
- o Coal residue
- o Biological oxidation sludge
- o Spent catalysts and filter media
- o Coal fines
- o Sulfur

Coal fines and sulfur may be useful as byproducts. The others may or may not require treatment before disposal but most often involve considerable landfill allocations.

The various methods of treatment/disposal/utilization will be under study as plants are planned and designed.

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