1. INTRODUCTION

1.1 Background

Along with improved control of air and water pollution, the country is faced with urgent needs for energy sources. To improve the energy situation, intensive efforts are under way to upgrade coal, the most plentiful domestic fuel, to liquid, gaseous and solid fuels which give less pollution. Other processes are intended to convert liquid fuels to gas. A few of the coal gasification processes are already commercially proven , and several others are being developed in large pilot plants. These programs are extensive and will cost millions of dollars, but this is warranted by the projected high cost for commercial conversion plants and the wide application expected in order to meet national needs.

Coal conversion is faced with potential environmental problems peculiar to the conversion process as well as problems that are common to coal-burning electric utility power plants. It is thus important to examine the alternative conversion processes from the standpoint of pollution and thermal efficiencies and these can then be compared with direct coal utilization when applicable.

This type of examination is needed well before plans are initiated for commercial applications. Similar industries, such as the petroleum industry, have gradually grown over a number of years. Much knowledge has been gained concerning stream compositions in the plant, control technology and other operating parameters. This is not true of coal conversion plants. The country is faced with the possibility of having a new industry suddenly emerge on a vast scale with very little background and knowledge of potential environmental hazards. At a time when the country is faced with an energy gap it is also faced with large environmental problems. If recognition of and action taken on the latter is not done early in the area of coal conversion, then the filling of the energy gap may have to be delayed considerably to avoid worsening of the environmental situation.

Coal is a dirty material and the potential exists in coal gasification and liquefaction for far more environmental problems than have even been conceived in coal combustion. Coal combustion is a drastic operation that contains within itself a great amount of pollution control: potential organic pollutants are converted essentially one hundred percent to carbon dioxide and water; many inorganic materials are converted to innocuous oxides. In fact, incineration is an often used technique of destroying unwanted materials. Even so, coal combustion leads to environmental problems that have not been completely solved despite many years of experience. Problems connected with sulfur, nitrogen oxides and trace element emissions are examples of these.

Coal conversion by liquefaction or gasification is much more condusive to environmental contamination. The conditions for coal conversion are far milder than for its combustion; instead of destroying potential pollutants, they are actually formed. Massive streams of dirty water, many hydrocarbon streams, numerous gaseous vents and huge quantities of solids offer the potential for almost every conceivable method of environmental pollution.

Unfortunately, there is little operating experience on which to draw that will predict where and in what form undesirable chemicals will appear. In conceptual designs, the main process streams can be reasonably identified and quantified, but as secondary and tertiary streams are added to the design, the composition of the streams becomes less and less obvious. The picture has been so cloudy that it was not known where knowledge was lacking. With massive funding of coal conversion technology a great need is present to develop adequate pollution controls before many large plants are built. Otherwise, large amounts of funds will have to be spent in retrofitting such plants to add on pollution control equipment, and the time delays could be very large before such plants could operate in a manner that is safe for the environment. To clarify the environmental picture and to furnish a base for additional or new pollution control technology development, the Environmental Protection Agency contracted for the present study to be made by Exxon (formerly Esso) Research and Engineering Company under Contract No. EPA-68-02-0629.

Much of the work under this contract has been reported in individual final task reports and no attempt is made to include all the information in the final report. References to individual task final reports are given in appropriate places. This final report rather addresses itself to summarizing and generalizing the work that has been performed.

1.2 Literature Survey

1.2.1 Trace Elements in Fossil Fuels

An extensive and in-depth literature survey was made to compile available information concerning trace element concentrations in coal, crude oil and shale oil for U.S. fossil fuels. The results of this survey, the interpretation and critique of the information, and information gaps have been reported in a final task report (1) and at an EPA symposium (2).

1.2.2 Coal and Crude Oil Conversion/Treatment Processes

A large quantity of literature information was collected on the various techniques for treating and converting coal and crude oils. Included were physical cleaning techniques, coal gasification processes, coal liquefaction processes, petroleum gasification processes, and a number of miscellaneous conversion and treating processes. The last category included various petroleum refinery processes and sulfur removal processes. Information obtained indicated the need for more extensive work to fill the gaps in the environmental aspects of the processes. This literature information was used extensively in later parts of the program.

1.3 Discussion With Process Developers

A number of visits were made to the developers of various processes for coal conversion. During these visits, unpublished, non-confidential information was obtained relating to possible polluting streams and techniques that might be used to clean the streams. An attempt was made to obtain as much information as possible to use in preliminary environmental plant designs. The visits to and discussions with the developers were very helpful in these studies. The following is a list of developers visited:

U.S. Bureau of Mines
Applied Technology Corporation
Institute of Gas Technology
Koppers Company, Inc.
Consolidation Coal Company, Inc.
Stearns-Roger Inc.
FMC Corporation
Pittsburg and Midway Coal Mining Company
Hydrocarbon Research, Inc.

1.4 Trips to Commercial Plants

A number of commercial plants in the U.S., Europe and South Africa were visited in the course of this contract. A significant amount of non-confidential information relating to pollutants, pollution control and energy efficiency was obtained. This information was useful in confirming the design parameters used for the developing processes, since in many cases the design bases for the latter processes were sketchy. The following is a list of companies whose plants were visited:

Consumers Power Company
Westfield Development Centre of the Scottish Gas Board
Azot Sanayii
South African Coal, Oil and Gas Corporation, Ltd.

1.5 Preliminary Process Designs

Information collected during discussions with developers and commercial plant vendors and operators, together with information from the literature were used to prepare preliminary designs of coal conversion plants. These designs were prepared to pin-point the areas where concern for pollution control should be focused and to obtain overall thermal efficiencies for the processes. For some processes, we used rather detailed engineering designs prepared by others; for other processes, screening type designs, with little optimization, were prepared using the little information that was available. The basis and information sources for each study were defined as much as possible. Plant location, which can have a major effect on air and water conditions, pollution controls required and product disposition, was not specified. Since the basis for each process was different regarding such items as coal feed, product slate, etc., great caution should be taken in making comparisons between the various processes. The process reports are listed in References 3-10 and 41-44.

Where possible, an attempt was made to obtain consistency in the various process designs but this was frequently impossible due to fundamental differences in the processes themselves. For example, feed coals were different and products were frequently different. In almost all cases, consistency was sacrificed to meet the desires of the developers pertaining to specific coals, products, methods of pollutant removal, etc. or to conform, as far as possible, to other designs prepared for governmental agencies or developers. In no case was technical accuracy knowingly sacrificed to conform to anyone's desires or other designs. In all cases, engineering alternatives were suggested. Environmental technology needs were highlighted in each case.

The various plants were made self-sufficient in that utilities were included in the designs. Costs or economics were not included and areas such as coal mining and general offsites as well as small utility consumers such as instruments, lights, etc., were excluded.

An example of the items considered in these studies is indicated by the table of contents from a typical process final report shown in Figure 1.

1.6 Analytical Test Plan

It became obvious early in this work that sufficient information was not available to accurately predict all possible pollutants in the processes and to determine the fate of these pollutants (including trace elements of interest). Consequently, an Analtyical Test Plan was prepared that could be used to determine the course of the pollutants through the various units of coal gasification and liquefaction processes. A "typical" flow plan was shown for gasification and liquefaction. Streams to be sampled were specified for these plants, and analyses to be performed were indicated. Methods of sampling, sample storage and methods of analysis for each material were specified. Ranges of expected pollutant concentrations were specified where possible. Actual examples of analyses of important streams were given, when available. Existing local and Federal regulations and proposed regulations were outlined for each pollutant. The Analytical Test Plan should serve as a guide and model for analysis of pollutant containing streams in any coal conversion plant.

1.7 Transient Pollutants

An attempt was made to point out sources and types of transient pollutants, i.e., pollutants resulting from start-ups, shut-downs, upsets, maintenance, etc. The material in this section has not appeared in previous reports. It was prepared by C. E. Jahnig and E. M. Magee.

Figure 1

Typical Table of Contents from a Process Report

(From Ref. 4)

Figure 1 (Continued)

Typical Table of Contents from a Process Report

(From Ref. 4)