Environmental Assessment of Coal Gasification: IERL-RTP

by

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March 1978

1.0 INTRODUCTION

The United States Environmental Protection Agency has initiated a comprehensive program to evaluate the environmental impacts of processes capable of producing synthetic fuels from coal. This program is being directed by the Fuel Process Branch of the Energy Assessment and Control Division (EACD) of the Industrial Environmental Research Laboratory at Research Triangle Park, North Carolina (IERL-RTP). Technologies being assessed include low/medium-Btu gasification, high-Btu gasification and liquefaction. The purpose of this document is to summarize the current status and results of the low/medium-Btu and high-Btu gasification segments of the program.

1.1 BACKGROUND

The United States has been fortunate in the past to possess large reserves of the three major fossil-fuel energy sources: natural gas, petroleum and coal. However, in recent years the nation's energy picture has changed drastically due to increased fuels consumption leading to increasingly severe shortages of domestic oil and natural gas and very rapid escalations in the prices of imported oil and gas. Because of these circumstances, there has been growing interest by government and industry in the technologies used to produce "clean burning" gaseous and liquid fuels from coal. The EPA's Synthetic Fuels Program is aimed at ensuring that this country's synthetic fuel industry will be developed in an environmentally acceptable fashion.

1.2 PROGRAM OBJECTIVES AND APPROACH

The primary objectives of IERL-RTP's Synthetic Fuels Program are:

- To define the environmental effects of synthetic fuel technologies with respect to their multimedia discharge streams and to assess their health and ecological effects,
- To define control technology needs for an environmentally sound synthetic fuel industry.

In order to achieve these program objectives, an assessment approach has been adopted which involves work in the following six major areas:

- Current Process Technology Background
- Environmental Data Acquisition
- Environmental Objectives Development
- Current Environmental Background
- Control Technology Assessment
- Environmental Alternatives Analysis.

The interrelationships between these areas are shown in Figure 1. Some of the information will be obtained from other EPA laboratories and other researchers especially in health and ecological effects. The following paragraphs briefly summarize the scope of the six areas.

Work in the Current Process Technology Background area involves two major activities: conducting an information survey of literature and industry sources; and performing an engineering analysis of the available data. This analysis seeks to identify 1) which aspects of the technology are most important and need further study, and 2) what information is missing or incomplete.

The purpose of the Environmental Data Acquisition is to fill the data gaps identified by the engineering analysis effort. This information may be obtained from testing at commercial or pilot plant facilities or by conducting laboratory experiments. These data acquisition activities may also be used to verify data reported by industry or in the literature.

After a technology's emission sources (i.e., its potential problem areas) have been identified, the next step in an environmental assessment program is determining which sources need to be controlled and to what levels. To answer these questions, environmental goals must be developed. These goals comprise the results of the Environmental Objectives Development and may be based on:

- best control technology
- existing standards
- estimated permissible concentrations
- natural background pollutant levels
- preventing significant deterioration
- minimum acute toxicity.

Background data required in the development of environmental goals include existing standards and ambient pollutant levels. Obtaining this information is the purpose of the Current Environmental Background task.

These first four areas should define a technology's pollutant emission sources which may require control and control goals for those sources. Work in Control Technology Assessment involves identifying applicable control techniques and assessing such factors as their control effectiveness, costs and energy requirements. If control techniques are not available, control technology development will precede the assessment activities.

Determining the best control option(s) for emission sources and the best set(s) of control options for a given plant is the aim of the Environmental Alternatives Analysis task. This will be accomplished by use of Source Analysis Models, which compare the emissions from a plant employing a set of control options to the environmental goals.

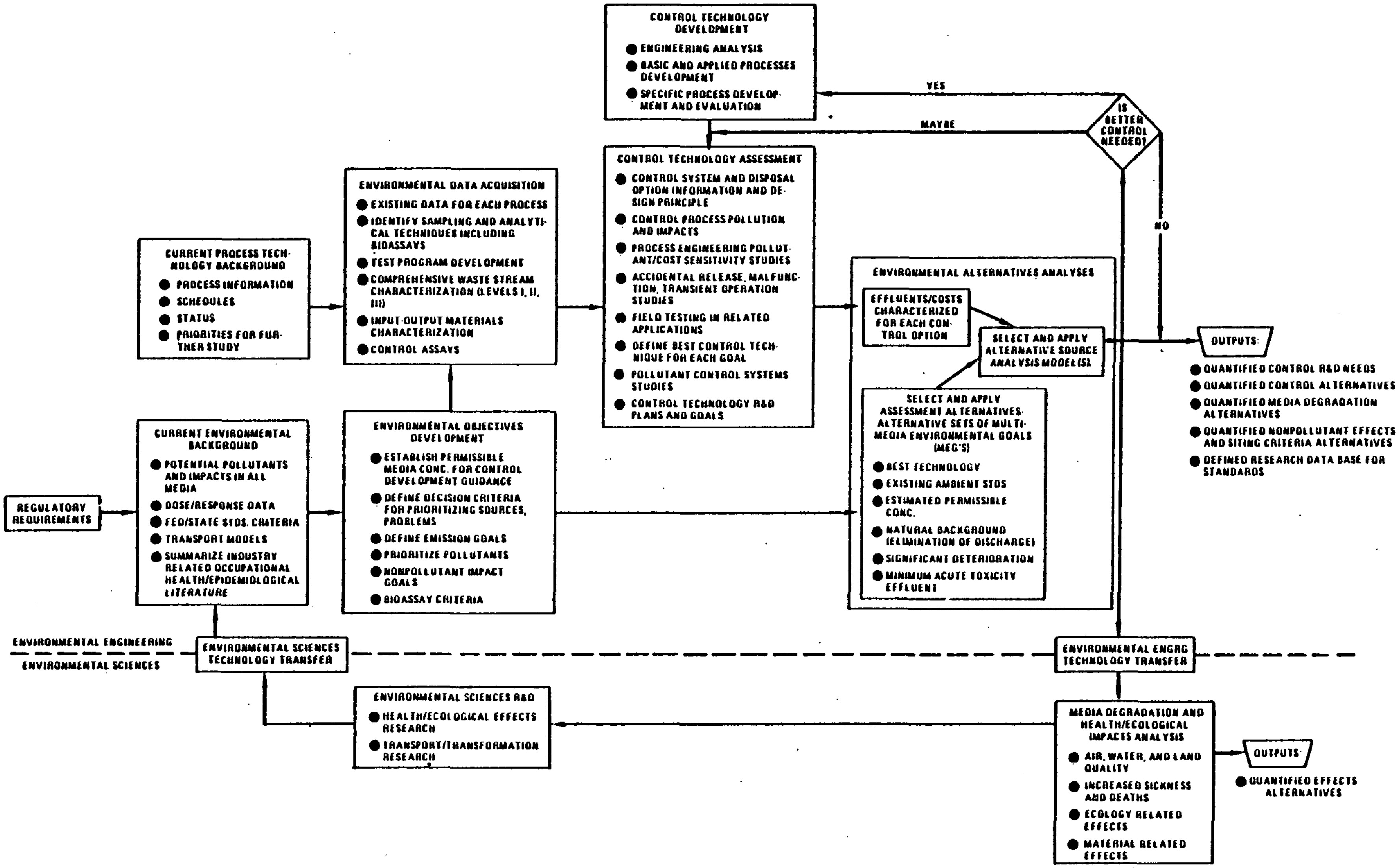

Figure 1

Environmental Assessment/Control Technology Development Diagram

Consideration must be given to the relative degree of hazard of the various pollutants and to cost vs. benefit of controlling the pollutants.

The results of the Synthetic Fuels Program will be communicated in a series of information transfer documents and used as IERL-RTP input to standards setting and regulatory functions. In order to accomplish the goals of the program, contracts have been signed to perform work in the six areas. Radian Corporation is EPA's prime contractor for the low/medium-Btu gasification program, while TRW, Inc. is the prime contractor for the high-Btu gasification program. Table 1 lists the contractors that are doing work in one or more of the six areas for the Synthetic Fuels Program.

The sections which follow discuss the coal gasification related activities of the contractors in the environmental assessment areas. Sections 2.0 and 3.0 address the process technology background and data acquisition activities. Since the majority of work to date in the assessment program has been on these tasks, they have received major emphasis in this document. Activities in the tasks which develop environmental goals are discussed in Sections 4.0 and 5.0, while activities in the tasks dealing with the assessment and analysis of control techniques are discussed in Sections 6.0 and 7.0.

2.0 CURRENT PROCESS TECHNOLOGY BACKGROUND

The current process technology background task is aimed at gathering and assessing the most current information available for the processes under consideration. The activities undertaken in developing the current process technology background include:

- Technology characterization
- Selection of processes having a high potential for near-term commercialization
- Determination of waste streams
- Identification of control equipment requirements for characterizing waste streams.

The results to date of these activities are discussed below. Progress for low/medium-Btu gasification (Radian Corporation) in this task area is further along than for high-Btu gasification (TRW, Inc.) because of the earlier start date for the low/medium-Btu project.

2.1 TECHNOLOGY CHARACTERIZATION

All gasification processes involve partial oxidation of coal. Where the system is "air blown," gas with a low heating value of approximately 5.6×10^6 J/Nm^3 (150 Btu/scf) is produced. "Oxygen blown" systems produce gas with a medium heating value of about 13.1×10^6 J/Nm^3 (350 Btu/scf). Medium-Btu gas can be further up-graded to high-Btu gas (approximate heating value of 35.5 J/Nm^3 or 950 Btu/scf) by catalytically converting the CO and H_2 contained in the gas into CH_4.

Table 1. EPA'S SYNTHETIC FUELS ASSESSMENT PROGRAM ELEMENTS - PROJECT TITLES, CONTRACTORS, AND EPA PROJECT OFFICERS

Project Title	Contractor	EPA Project Officer
Environmental Assessment of Low/Medium-Btu Gasification (March 1976-March 1979)	Radian Corporation 8500 Shoal Creek Blvd. Austin, Texas 78758 (512) 454-4797 (E.C. Cavanaugh/G.C. Page)	William J. Rhodes IERL-RTP (919) 541-2851
Environmental Assessment of High-Btu Gasification (April 1977-April 1980)	TRW, Inc. 1 Space Park Redondo Beach, CA 90278 (213) 536-1116 (Chuck Murray)	William J. Rhodes IERL-TRP (919) 541-2851
Environmental Assessment of Coal Liquefaction (August 1976-August 1979)	Hittman Associates 9190 Red Branch Road Columbia, MD 21043 (301) 730-7800 (Dwight Emerson)	William J. Rhodes IERL-RTP (919) 541-2851
Control Technology for Products/By-Products (Sept. 1976-Sept. 1979)	Catalytic, Inc. 1500 Market Street Center Square West Philadelphia, PA 19102 (215) 864-8104 (A.B. Cherry)	Chester A. Vogel IERL-RTP (919) 541-2134
Control Technology for Converter Output (January 1977-January 1980)	Hydrocarbon Research, Inc. P.O. Box 2391 334 Madison Avenue Morristown, NJ 07960 (201) 540-0180 (Harold Stotler)	Chester A. Vogel IERL-RTP (919) 541-2134
Waste Stream Disposal and Utilization (April 1977-April 1980)	Pullman-Kellogg Research & Development Center 16200 Park Row Industrial Park Terrace Houston, Texas 77054 (713) 493-0291 (Louis Bostwick)	Chester A. Vogel IERL-RTP (919) 541-2134

Table 1. EPA'S SYNTHETIC FUELS ASSESSMENT PROGRAM ELEMENTS - PROJECT TITLES, CONTRACTS, AND EPA PROJECT OFFICERS

Continued

Project Title	Contractor	EPA Project Officer
General Support (April 1976-December 1977)	Cameron Engineers, Inc. 1315 South Clarkson Street Denver, CO 80210 (303) 777-2525 (Ted Borer)	L. David Tamny IERL-RTP (919) 541-2709
Acid Gas Cleaning Bench Scale Unit (October 1976-September 1981) (Grant)	North Carolina State Univ. Dept. of Chemical Engineering Raleigh, NC 27607 (919) 737-2324 (Dr. James Ferrell)	Thomas W. Petrie IERL-RTP (919) 541-2708
Water Treating Bench Scale Unit (November 1976-October 1981) (Grant)	Univ. of North Carolina Dept. of Environmental Sciences & Engineering School of Public Health Chapel Hill, NC 27514 (919) 966-1052 (Dr. Philip Singer)	Thomas W. Petrie IERL-RTP (919) 541-2708
Pollutant Identification From a Bench Scale Unit (November 1976-October 1981) (Grant)	Research Triangle Institute P.O. Box 12194 Research Triangle Park, North Carolina 27709 (919) 341-5836) (Dr. Forest Mixon)	Thomas W. Petrie IERL-RTP (919) 541-2708

2.1.1 Low/Medium-Btu Gasification Technology

The production of low/medium-Btu gas involves three basic operations: coal pretreatment, coal gasification, and gas purification. The specific processes used to satisfy the requirements of each of these operations will be determined mainly by 1) the properties of the coal feedstock, 2) the type of gasifier that is employed, and 3) the economic factors associated with each site-specific application. A number of processes and their interrelationships are depicted in Figure 2.

2.1.2 High-Btu Gasification Technology

High-Btu gasification involves the same basic operations that are used in the production of medium-Btu gas plus additional processes to produce a product gas having a high heating value. The additional processes are shift conversion (to adjust the H_2:CO ratio to 3:1) and methanation (to convert CO and H_2 to CH_4). Quenching for tar and oil removal and stringent acid gas removal are required in high-Btu gasification systems to meet product specifications and protect the methanation catalyst from being poisoned.

2.2 PROCESS ASSESSMENT

An important aspect of the current process technology background effort is the identification of processes which have a high potential for commercialization. Criteria for selecting these processes include:

- Development status
- Process cost and energy efficiency
- Applicability
- Probability of successful development and application
- Environmental impact.

The following sections discuss the status, cost, applicability and environmental impact of gasification technology.

2.2.1 Development Status

The production of low- and medium-Btu gas from coal has been practiced both in the United States and overseas for many years. At one time there were about 11,000 coal gasifiers in use in the U.S. As the availability of natural gas increased, the number of operating gasification systems declined significantly. There are only a few coal gasifiers now operating in the United States on a commercial basis. However, in general the development status of low/medium-Btu gasification can be regarded as commercial.

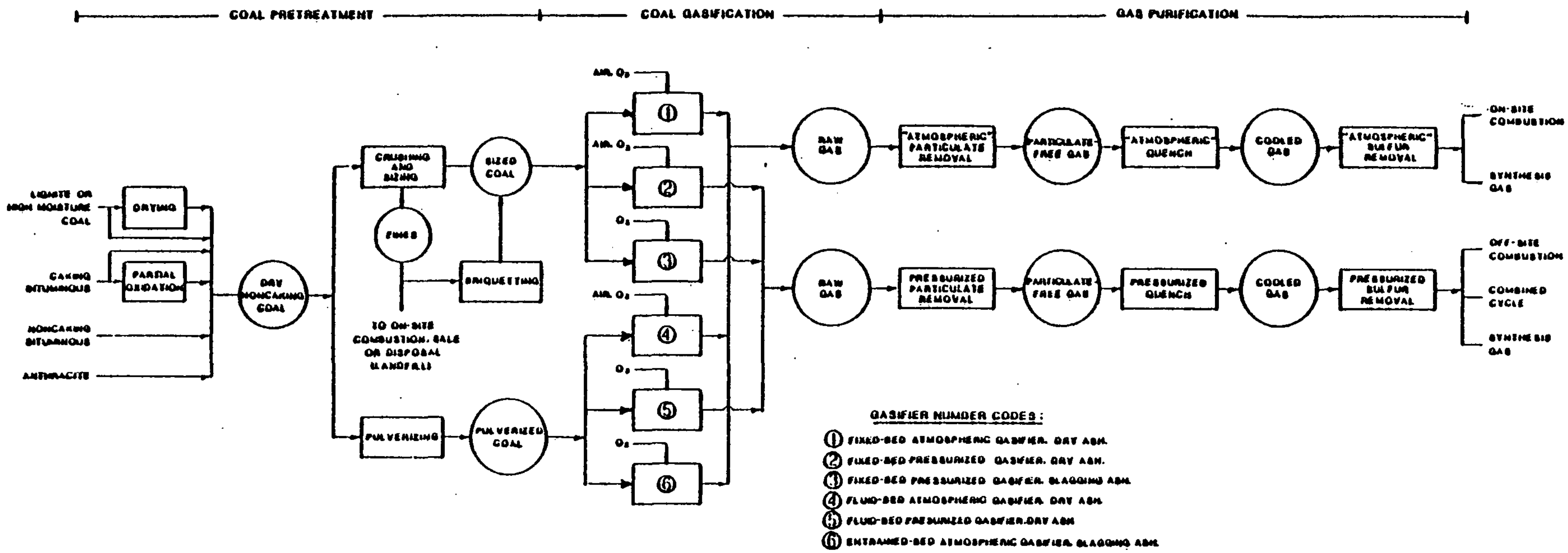

Figure 2

Low/Medium-BTU Coal Gasification Processes

Economic reasons generally favor operation of high-Btu gasification systems at high pressures. Of the commercially available processes, only the Lurgi process operates at high pressure. Development work is underway on several new high pressure processes which show promise for having process, economic, and environmental advantages over the Lurgi process.

Status of Coal Pretreatment Processes

The coal pretreatment processes which may be required in a gasification plant (either low-, medium-, or high-Btu) include crushing and grinding, sizing, partial oxidation, pulverization, drying, and/or briquetting. The specific processes used will be determined by the properties of the coal feedstock and the type of gasifier employed. These processes, with the exception of partial oxidation, have been used for years in the gasification, coal-fired electric utility and charcoal industries. However, much work (e.g., the Synthane Process) has been done to develop a reliable partial oxidation process for reducing the caking tendencies of certain types of coal. Therefore, the development status of all coal pretreatment processes is regarded as commercially available.

Status of Gasification Processes

Approximately 70 different gasification processes can be identified which either have been used commercially in the past or are currently under development. Twenty-five of the most prominent of these gasification processes are shown in Table 2.

Eight of the gasifiers listed in this table are being used to satisfy some commercial demand for low/medium-Btu gas. These are:

- Chapman (Wilputte)
- Foster Wheeler/Stoic
- Koppers-Totzek
- Lurgi
- Wellman-Galusha
- Wellman Incandescent
- Winkler
- Woodall-Duckham/Gas Integrale.

A number of the other gasifiers listed in Table 2 appear to have significant commercialization potential. For example, a commercial-scale Riley-Morgan system has been operated as a development/test unit.

Radian Corporation has compiled a list of 14 gasifiers which appear to be the most promising candidates for satisfying near-term commercial needs for low/medium-Btu gas. This list is shown in Table 3. The considerations which led to Radian's selection of this group are described in their report Environmental Assessment Data Base for Low/Medium-Btu Gasification Technology (EPA-600/7-77-125a and b), issued in November 1977.

Table 2. STATUS OF U.S. AND FOREIGN LOW- AND MEDIUM-BTU GASIFICATION SYSTEMS

Gasifier	Licensor/Developer	Number of Gasifiers Currently Operating (No. of Gasifiers Built)				Scale
		Low-Btu Gas	Medium-Btu Gas	Synthesis Gas	Location	
Lurgi	Lurgi Mineralöltechnik GmbH	5	(39)	(22)	Foreign	Commercial
Wellman-Galusha	McDowell Wellman Engineering Co.	8 (150)	-	-	US/Foreign	Commercial
Woodall-Duckham/ Gas Integrale	Woodall-Dickham (USA) Ltd.	(72)**	-	(8)**	Foreign	Commercial
Koppers-Totzek	Koppers Company, Inc.	-	-	(39)**	Foreign	Commercial
Winkler	Davy Powergas	-	(23)**	6(14)	Foreign	Commercial
Chapman (Wilputte)	Wilputte Corp.	2 (12)	-	-	US	Commercial
Riley Morgan	Riley Stoker Corp.	1	-	-	US	Commercial
Wellman Incandescent	Applied Technology Corp.	(2*)**	-	-	US/Foreign	Commercial/ Demonstration
BGC/Lurgi Slagging	British Gas Corp. and Lurgi Mineraloltechnik GmbH	-	1	-	Foreign	Demonstration
Bi-Gas	Bituminous Coal Research, Inc.		1		US	Demonstration
Foster Wheeler/Stoic	Foster Wheeler/Stoic Corp.	1*(2)**	-	-	US	Demonstration
Pressurized Wellman-Galusha (MERC)	DOE	1*	-	-	US	Demonstration
GFERC Slagging	DOE	-	1*	-	US	Demonstration
Texaco	Texaco Development Corp.	-	-	1*	US	Demonstration
BCR Low-Btu	Bituminous Coal Research, Inc.	1*	-	-	US	Demonstration
Combustion Engineering	Combustion Engineering Corp.	1*	-	-	US	Demonstration

Table 2. STATUS OF U.S. AND FOREIGN LOW- AND MEDIUM-BTU GASIFICATION SYSTEMS

Continued

		Number of Gasifiers Currently Operating (No. of Gasifiers Built)				
Gasifier	Licensor/Developer	Low-Btu Gas	Medium-Btu Gas	Synthesis Gas	Location	Scale
Hygas	Institute of Gas Technology	–	1	–	US	Demonstration (High-Btu)
Synthane	DOE	–	1	–	US	Demonstration (High-Btu)
CO_2	DOE	–	1	–	US	Demonstration (High-Btu)
Foster Wheeler	Foster Wheeler Energy Corp.	1	–	–	US	Pilot
Babcock & Wilcox	The Babcock & Wilcox Co.	1	–	–	US	Pilot
U-Gas	Institute of Gas Technology Phillips Petroleum Corp.	1	–	–	US	Pilot 400 lb/hr (181 kg/hr)coal
Westinghouse	Westinghouse Electric Corp.	1	–	–	US	Pilot
Coalex	Inex Resources, Inc.	1 (1*)	–	–	US	Pilot
COGAS	COGAS Development Co.	–	1	–	US	Demonstration (High-Btu)

* Under construction.
Demonstration scale indicates 2000 to 10,000 lb/hr. (907 to 4536 kg/hr) coal feed.
Pilot scale indicates 400 to 1500 lb/hr (181 to 680 kg/hr) coal feed.

** *Undetermined number overseas currently in operation.*

Table 3. PROMISING LOW/MEDIUM-BTU GASIFICATION SYSTEMS

First Group[1]	Second Group[2]	Third Group[3]
Wellman-Galusha	Chapman (Wilputte)	Pressurized Wellman-Galusha (MERC)
Lurgi	Riley Morgan	
Woodall Duckham/ Gas Integrale		
Koppers-Totzek		BGC/Lurgi Slagging Gasifier
Winkler		Texaco
Wellman Incandescent		Bi-Gas
Foster Wheeler/Stoic		Coalex

1 Commercially available; significant number of units currently operating in the U.S. or in foreign countries.

2 Commercially demonstrated in limited applications.

3 Commercial or demonstration-scale units operating or being constructed; technology is promising and should be monitored.

In their environmental assessment of high-Btu gasification technology, TRW, Inc. has selected nine high pressure gasification systems for detailed analysis. These processses are:

- Hygas
- Bi-Gas
- COGAS
- Hydrane
- Synthane
- Texaco
- CO_2 Acceptor
- Self-aggomerating ash
- Lurgi.

These processes are in various stages of incomplete development. The exception is the Lurgi process which has been used commercially in foreign countries to supply medium-Btu gas for a variety of industrial users. With the addition of shift conversion and methanation, the Lurgi medium-Btu process is considered a proven high-Btu gasification process.

Status of Gas Purification Processes

The purpose of the gas purification operation is to remove undesirable constituents from the product gas. Purification may include:

- particulate removal
- gas quenching and cooling
- acid gas removal.

The intended end-use of the product gas determines which of these purification steps to use. For example, for on-site combustion of low-Btu gas produced from a low sulfur coal, only particulate removal may be required. For the production of high-Btu gas, all three purification steps are required.

Removal of particulates from gasifier product gas is generally accomplished through the use of dry collectors such as cyclones or electrostatic precipitators and/or the use of water or oil scrubbers. These processes are normally employed when tars and oils as well as other impurities such as ammonia must be removed from the product gas. The use of water or oil scrubbers will also cool the product gas. Other candidate cooling processes include waste heat boilers and air or water cooled heat exchangers.

Acid gas removal processes remove compounds such as H_2S, COS, CS_2, mercaptans, HCN and CO_2 from the product gas. In theory, either high (>420°K or 300°F) or low temperature acid gas removal processes can be used. High temperature processes utilize iron oxide, dolomites, molten metals, etc. as sorbents. They should yield higher efficiencies, but are only in the development stage. Thus, most existing and proposed gasification plants use low temperature processes.

A variety of low temperature acid gas removal processes are commercially available. Most were developed for use in the natural gas, refinery and chemical process industries. There do not appear to be any insurmountable problems associated with their use in coal gasification plants. Radian has identified 14 acid gas removal processes as the most likely candidates for near-term commercial use in coal gasification systems:

- Physical Solvent Processes
  - Rectisol
  - Estasolvan
  - Selexol
  - Fluor Solvent
  - Purisol
- Chemical Solvent Processes
  - MEA
  - DIPA
  - MDEA
  - DGA
  - DEA
  - Benfield
- Combination Chemical/Physical Solvent Processes
  - Amisol
  - Sulfinol
- Direct Conversion Process
  - Stretford

2.2.2 Cost and Applicability

The potential uses for coal gasification technology are to produce:

- High-Btu or substitute natural gas
- Low or medium-Btu combustion fuel
- Low or medium-Btu synthesis or reducing gas.

The economics and applicability of gasification technology for some of these uses are uncertain at this time. An assessment of current technology provides insight to this uncertainty.

Substitute Natural Gas - In view of the decreasing availability of natural gas, one option for coal utilization is in the production of substitute natural gas (SNG). Several consortiums of natural gas suppliers and distributors are considering constructing large scale substitute natural gas plants using available technology. Actual construction activities, however, are slow in getting underway.

The major impediments to the construction of these plants involve cost. First, investments which would seriously tax the financial resources of the consortium members are required in most cases. For example, a 7 million m^3 (250 million scf) per day plant would require a capital investment on the order of $1.3-1.5 billion. Second, SNG costs are predicted to be on the order of $4-5 per thousand cubic feet (28 cubic meters) as compared to current intrastate prices of about $2 per thousand cubic feet (28 cubic meters) for new natural gas. These higher product costs, combined with uncertainties in future natural gas price regulations, have made financial institutions wary of lending the large sums of money required to build substitute natural gas plants. Moreover, the actual plant and SNG vs. natural gas costs are still controversial.

Given these cost impediments, there appear to be some realistic concerns about the applicability of current coal gasification technology to the production of SNG. Nonetheless, an analysis of the advantages and disadvantages of SNG production seems to indicate that there is a place for coal gasification in the supply of gas for residential heating (water, space heating, cooking). A recent American Gas Association study (Ref. 1) concludes that SNG may have both energy efficiency and cost advantages over electrification (the most viable alternative).

Although this conclusion was reached by an industry group with strong interests in promoting SNG production, it is certainly not totally unrealistic. For example, using conventional technologies in the residential end-use sector, the AGA data indicates the use of SNG has an overall energy efficiency of 36% and costs the consumer about $7 per useful million Btu (1.055 billion joules). The AGA data for coal electrification with advanced technology (heat pumps) indicates overall energy efficiencies ranging from 35 to 53% and costs ranging from $7 to $10.5 per useful million Btu (1.055 billion joules) depending on location within the U.S. Thus, depending on location, 1) electrification appears to be slightly favored based on energy usage, but 2) SNG is generally cheaper than electrification. Considering that electric heat pumps are more expensive and more failure-prone than gas furnaces, the balance may shift to SNG production as opposed to electrification for residential use.

Combustion Fuel - A second use for coal gasification is in the production of combustion fuel, either in large scale facilities for use by the electric utility industry or in small facilities for industrial applications. The cost and applicability of low/medium-Btu gasification for the production of electrical generation fuel must be compared with the most viable alternative. Direct combustion of coal and the use of flue gas desulfurization (FGD) appears to be the most viable alternative. A coal fired power plant using FGD will produce electricity with a busbar cost of about 3.5-4.0 cents per kW-hr. A power plant using gasified coal will produce electricity costing about 5.0 to 5.5 cents per kW-hr. Thus, it appears that, for large scale electrical generation facilities where FGD is practical, direct combustion of coal with FGD has economic advantages over combustion of gasified coal.

A more likely possibility for the future production of electricity is gasification coupled with a combined cycle generating system. In such systems, gas from coal is produced at a high pressure, combusted and expanded through a gas turbine. The turbine exhaust is then utilized in a conventional steam boiler. The economics of combined cycle operation may be better than conventional direct combustion because higher efficiencies (46% as compared to 38% for conventional systems) can be obtained. However, at this time the high temperature gas turbines needed to achieve these high efficiency levels are not commercially available.

It now appears that there is significant potential for the use of coal gasification to produce industrial fuel. There are many industries which require a gaseous fuel. These industries have low priority for receiving natural gas and thus will be increasingly sensitive to natural gas curtailments. Consequently, they will be increasingly amenable to the use of coal gasification.

The cost of supplying low/medium-Btu fuel gas to this class of users will be highly dependent on site specific factors such as coal cost, coal availability and gas purity requirements. However, in applications where the gasifier output stream can be utilized without expensive gas clean-up, costs of $2 to $3 per million Btu (1.055 billion joules) are anticipated. Gas clean-up (acid gas removal) would boost this cost by about $1 per million Btu. Although this cost is high compared to current natural gas prices, there may be overriding factors to consider. For example, the higher cost of gas from coal gasification may be recouped by not having plant capacity idle during natural gas curtailments.

Synthesis or Reducing Gas - The production of synthesis or reducing gas is a third option for utilizing coal via coal gasification. Synthesis gas finds use in the production of ammonia, methanol, aldehydes, and oxo-alcohols. Hydrogen-rich reducing gases are widely used in hydrodesulfurization and hydrocracking processes in the refining industry. Other applications for reducing gases include various processes in the metals industry and in the regeneration sections of some flue gas desulfurization processes.

While several coal-based ammonia plants are currently operating overseas, there does not appear to be significant interest in coal gasification to produce synthesis or reducing gas in the U.S. This is due principally to the fact that synthesis and reducing gases are currently derived from natural gas or liquid fuel feedstocks which are much cheaper than gas produced from coal. However, this situation may change in the future as alternative gaseous and liquid feedstocks become more scarce.

2.2.3 Environmental Impact of Coal Gasification

The multimedia emissions from coal gasification operations range from conventional pollution problems such as coal dust emissions to such ill-defined problems as fugitive emissions. As part of Radian's engineering analysis of low/medium-Btu gasification technology, a list of environmental assessment data requirements was compiled. These are summarized in Table 4. The following paragraphs briefly discuss some of the more significant problems which are highlighted in the table.

Problems with emissions from coal preparation processes generally seem solvable with available technology. Wastes from coal storage, handling, size reduction, and classification processes also can be managed using available techniques for controlling coal dust emissions, disposing of mineral wastes, and handling runoff waters from storage piles. However, opportunities for the development of less costly or, in some cases, more efficient controls clearly exist.

Air emissions occur from coal dryers, briquetting and partial oxidation processes. Control of them may be difficult because volatile hydrocarbons can be liberated as coal is heated. The exact character of these materials has not been determined as far as their potential health and ecological effects are concerned. Hence, the limit to which they must be controlled and the adequacy of available control technology have not been determined.

The coal gasification operation appears to be the most serious source of potential gasification system pollution problems. For all systems, the feeding of coal and the withdrawal of ash provide opportunities for the escape of coal or ash dust and hydrocarbons. Since they are products of the thermal processing of coal, they must be considered to be potentially toxic. These problems are similar for all gasifiers even though emissions from some types of equipment may consist largely of coal or ash dust. Also, it is certain that gasifiers and associated equipment will be sources of fugitive leaks from valves, flanges, and fittings. This leakage, unless controlled to adequate levels, can be hazardous.

The gas purification processes also appear to present difficult control problems. The gas cooling steps will produce water contaminated with suspended and dissolved organics and inorganics, many of which will be toxic. The ability of conventional wastewater treatment processes (e.g., API separators, sour water strippers, and biological oxidation) to effectively treat this waste stream has not been demonstrated.

Except for the Stretford process, all of the acid gas removal processes previously identified will produce a H_2S-rich vent stream which needs to be controlled. In most cases this stream will be sent to a sulfur recovery process (Claus or Stretford). The tail gases from these sulfur recovery processes may require further treatment, depending upon the tail gas composition. Other waste streams from these acid gas and sulfur recovery processes will include liquid blowdown streams and sulfur. The sulfur can normally be sold as a by-product. However, the blowdown streams will contain reactant degradation products and may contain dissolved organics including phenols and dissolved inorganics such as HCN and H_2S. Effective control/disposal techniques for the blowdown streams have not been demonstrated.

Table 4. DISCHARGES FROM LOW- AND MEDIUM-BTU GASIFICATION SYSTEMS

Operation Discharge stream source	Discharge streams	Description	Remarks
Coal Pretreatment			
Storage, handling and crushing/sizing	Dust emissions	The air emission from coal storage piles, crushing/sizing and handling will consist primarily of coal dust. The amount of these emissions will vary from site to site depending on wind velocities and coal size.	Asphalt and various polymers have been used to control dust emissions from coal storage piles. Water sprays and enclosed equipment have been used to control coal handling emissions. Enclosures and hoods have been used for coal crushing/sizing.
	Water runoff	The amount of data on dissolved and suspended organics and inorganics in runoff water produced for coal storage piles and dust control or supression processes are minimal.	Proper runoff water management techniques have been developed. More data on the characteristics of this waste water need to be obtained to determine the need for treating this effluent.
	Solid wastes from crushing and sizing	This stream consists of rock and mineral matter rejected from crushing and sizing coal. There is little data concerning the trace components in this stream and the potential of these components to contaminate surface and groundwaters is not known.	This waste has been disposed of in landfills. Leaching data need to be obtained to evaluate the potential environmental impacts associated with this solid waste.
Coal drying, partial oxidation and briquetting	Vent gases	These emissions will contain coal dust and combustion gases along with a variety of organic compounds liberated as a result of coal devolatization reactions. There are currently little data on the characteristics of these organic species.	The organic compounds need to be characterized to determine whether this discharge stream needs to be controlled. Afterburners in addition to particulate collection devices may be required.
Coal Gasification			
Coal feeding device	Vent gases	There are currently no data on the characteristics of these gases. These vent gases may contain hazardous species found in the raw product gas exiting the gasifier.	Vent gases from coal feeders can represent a significant environmental and health problem. Control of these emissions is required; however, the characteristics of these gases need to be determined to implement an adequate control method.

Table 4. DISCHARGES FROM LOW- AND MEDIUM-BTU GASIFICATION SYSTEMS

Continued

Operation Discharge stream source	Discharge streams	Description	Remarks
Ash removal device	Vent gases	There are currently no data on the characteristics of this discharge stream. This stream may contain hazardous species found in the raw product gas and may require control.	Many sources of contaminated water may be used for ash quenching. Therefore, volatile organics and inorganics may be released in these vent gases. Characterization of emissions is needed to define control technology elements.
	Spent ash quench water	There are limited data on the discharge stream. This stream will contain dissolved and suspended organics and inorganics and will require control.	Characterization of this waste stream is required to define control technology requirements. Further treatment of this stream is essential.
	Ash or slag	There are limited data on the characteristics of the ash and slag especially concerning the amount of unreacted coal, trace elements and total organics.	Leaching tests need to be done on this solid waste to determine whether further treatment is necessary before ultimate disposal. The organic content of the liquor used to quench the ash may affect the final disposal of the ash.
Coal gasifier	Start-up vent stream	There are currently no data on the composition of start-up vent stream. Depending on the coal feedstock, there may be tar and oil aerosols, sulfur species, cyanides, etc. in this stream; therefore, control of pollutants generated during start-up is required.	This stream can be controlled using a flare to burn the combustible constituents. The amount of heavy tars and coal particulates in this stream will affect the performance of the flare. Problems with tars and coal particles can be minimized by using charcoal or coke as the start-up fuel.
	Fugitive emissions	There are no data available on these emissions. They can be expected to contain hazardous species that are in the raw product gas such as hydrogen cyanide.	These emissions will determine the extent of workers' exposure to hazardous species and define the need for continuous area monitoring of toxic compounds and personnel protection equipment.

Table 4. DISCHARGES FROM LOW- AND MEDIUM-BTU GASIFICATION SYSTEMS

Continued

Operation Discharge stream source	Discharge streams	Description	Remarks
Gas Purification			
Particulate removal	Collected particulate matter	There are little data on the characteristics of this solid waste stream. This stream will contain unreacted carbon, sulfur species, organics, and trace elements.	Characterization of this stream is needed to determine whether it can be used as a by-product or whether further treatment is necessary before disposal. Current data indicate that there is a significant amount of unreacted carbon in this stream and it may be used as a combustion fuel.
Gas quenching and cooling	Spent quench liquor	There are little data on the composition of this stream; however, current data indicate that there are significant quantities of suspended and dissolved organics (primarily phenols) and inorganics present in this stream.	Characterization of this stream will determine the type of water pollution control techniques required to treat the spent quench liquor. These control techniques will vary depending upon the quantity and composition of this effluent stream.
Acid gas removal	Tail gases	There are little data on the composition of these tail gases. These gases will contain sulfur species and hydrocarbons.	These gases are the primary feedstock to the sulfur recovery and control processes. Trace constituents such as hydrocarbons, trace elements, and cyanides will affect the performance of these sulfur recovery processes.
	Spent sorbents and reactants	No data have been reported on these streams. These streams will contain hazardous species such as cyanides, heavy metals, and organics and will require further treatment before disposal.	Characterization of this stream is required if it is to be treated using on-site pollution control devices.

Compared to any low/medium-Btu plant's processes, shift conversion and methanation are additional processes found in a high-Btu plant. They have negligible impact on the environmental problems of a gasification facility. A high-Btu coal gasification facility should have environmental problems similar to those of a low/medium-Btu facility which uses gas cooling and acid gas removal processes. However, some differences should be expected due to different pressures, temperatures, and other system factors.

3.0 ENVIRONMENTAL DATA ACQUISITION

Environmental assessment data acquisition activities are directed at acquiring information to fill data gaps such as those identified in the current process technology background task. They also may verify data reported in the literature or by industry. The results of the data acquisition task, in combination with other available data, will help to identify environmental problems, suggest potential controls for those problems and project the effectiveness of those controls.

A three phased or three level approach to conducting environmental assessment testing has been developed. Level 1 is a comprehensive screening step that provides semi-quantitative data (accurate within a factor of $\pm$ 2 or 3) on all influent and effluent streams. Level 2 testing is intended to provide a more detailed analysis of the environmental problems identified in the Level 1 tests. The third level of testing involves continuous monitoring of selected priority pollutants identified in Level 1 or 2 tests.

At this time, the program for environmental data acquisition has involved site-specific field testing, pollutant identification, and assay technique development.

3.1 LOW/MEDIUM-BTU GASIFICATION

Radian has tested or arranged for environmental tests to be conducted at four low/medium-Btu gasification facilities: a) Holston Army Ammunition Plant, Kingsport, Tennessee; b) Kosovo Kombinat, Pristina, Yugoslavia; c) Glen-Gery Brick Company, York, Pennsylvania; and d) University of Minnesota, Duluth, Minnesota. During visits to these and several other potential environmental testing sites, Radian obtained grab samples of selected liquid and solid waste streams. IERL-RTP Level 1 analytical procedures plus some additional analyses were run on these samples. The results of this analytical work have been summarized in a report published in December 1977 and entitled Analyses of Grab Samples from Fixed-Bed Coal Gasification Processes, (EPA-600/7-77-141).

Testing of the Holston plant was completed in September 1977. This facility has been in operation over 30 years using Chapman (Wilputte) gasifiers to convert bituminous coal into low-Btu gas for use as a combustion fuel for industrial furnaces. The objectives of the Holston test program were:

1) To evaluate Level 1 sampling and analytical procedures for their applicability to emission streams from low-Btu gasification processes.

2) To identify the origin and fate of potentially hazardous components in a specific goal gasification plant.

3) To obtain control technology data relating to:

- Emissions from coal feed systems

- The effectiveness of a hot cyclone as a particulate removal device.

The results of this test program are being evaluated. A complete report on the test results should be available in the Spring of 1978.

An environmental test plan for the Kosovo plant has been developed jointly by the Rudarski Institute (Belgrade, Yugoslavia), EPA, and Radian as part of a cooperative environmental research program. The Kosovo complex has been in operation since 1971, using Lurgi gasifiers to convert lignite from adjacent mines to fuel gas and fertilizer plant feedstocks. The test plan was completed in September 1977; sampling and analytical activities at the Kosovo facility started in November 1977. Radian is also providing on-site technical assistance during the tests.

Preliminary test plans have also been developed for the Glen-Gery (Wellman-Galusha gasifier) and University of Minnesota (Foster Wheeler/Stoic gasifier) sites. Testing at Glen-Gery is planned for early 1978 and at the University of Minnesota for late 1978. Both of these test programs will be conducted in cooperation with DOE's Gasifiers in Industry program.

3.2 HIGH-BTU GASIFICATION

TRW, Inc., in planning its high-Btu gasification environmental assessment program, has placed strong emphasis on environmental sampling and analysis at selected sites. A list of domestic and foreign installations suitable for testing has been prepared. Candidate facilities are being contacted to determine the best possibilities for field testing. The lack of time since TRW began work on this program has prevented further progress in data acquisition.

3.3 ENVIRONMENTAL ASSESSMENT TEST PROGRAM GUIDELINES

Radian Corporation is preparing a report which provides guidelines for the development of environmental test programs. Major emphasis is placed on the strategy involved in the selection of sample points and specific sampling and analytical techniques. This material is being incorporated into a comprehensive document, Guidelines for Preparing Environmental Test Plans for Coal Gasification Facilities, which will be available in early 1978.

3.4 GENERAL INVESTIGATIONS

In addition to Radian's and TRW's work in the areas of low/medium- and high-Btu gasification the EPA also has programs underway to assess on a more general basis the environmental effects of converting coal into synthetic fuels. Highlights from two of these programs follow.

As noted in Table 1, Research Triangle Institute (RTI) has initiated a program to characterize the pollutants contained in the product gas output stream from a laboratory gasifier. The RTI program will consist of three phases: screening studies, parametric control evaluations, and reaction kinetics research. The screening studies will consider, qualitatively, the variety of chemical compounds produced during gasification reactions. RTI estimates that up to 300 different compounds may be screened in the course of these tests. In the parametric studies, the impact of reactor operation upon product gas pollutant levels will be examined. Parameters to be considered include coal type, grind size, pretreatment method, bed depth, temperature, pressure, steam flow rate, residence time and the presence of catalysts and additives. Other variables such as bed type (fixed, entrained, fluidized) and reactor type (batch, semi-batch, plug flow, mixed flow) will also be considered. The reaction kinetics phase of the research program will be planned in the coming year.

As part of the effort mentioned in Table 1, Catalytic, Inc. is working on a Control Assay Development (CAD) program for coal conversion processes. The objective of the CAD program is to develop and perform quick screening treatments for streams suspected of containing pollutants requiring control. Analyses will be made before and after treatment to evaluate the effectiveness of the pollutant control method. This program is expected to shorten the period of time between problem identification (e.g., through Level 1 testing) and final recommendations for control technology application.

4.0 CURRENT ENVIRONMENTAL BACKGROUND

Work in this area is designed to identify and summarize current regulations applicable to coal gasification processes and to obtain data on the ambient levels of pollutants expected to be emitted from coal gasification facilities. Most of the programs mentioned in Table 1 began by establishing the current background relevant to their area.

For example, Pullman-Kellogg has nearly completed the task of gathering federal, state, regional and international environmental standards. The compositions of effluents expected from processes using current or developing control technologies will be checked against these environmental standards.

In another example, researchers at the University of North Carolina at Chapel Hill collected data on the composition of wastewater from coal conversion processes. They organized the data according to major classes of compounds and specified a synthetic wastewater composition for ongoing work on biological treatment of coal conversion wastewater.

For a third example, Research Triangle Institute has produced, in addition to work on pollutant identification from a bench scale gasifier, a draft document entitled, Summary of Key Federal Regulations and Criteria for Multimedia Environmental Control. It is designed to be a guide for more detailed analyses of current regulations needed in the assessment activities they and others are undertaking.

5.0 ENVIRONMENTAL OBJECTIVES DEVELOPMENT

In order to determine if an emission source requires control, environmental goals must be identified. This is the purpose of environmental objectives development. Environmental goals can be based on several criteria including existing standards, best control technology, and minimum acute toxicity levels. Goals can also be based on emission levels or ambient levels.

At this time, the major effort in this area is being performed by Research Triangle Institute. RTI has developed Multimedia Environmental Goals (MEG's) for several hundred pollutants. These identify many of the pollutants of which investigators need to be aware. They also define the concentration levels at which these pollutants might be of concern or to which they can be controlled.

Two major phases of work have been pursued in the development of MEG's. First, ambient pollution levels have been related to corresponding concentrations in humans, animals, and plants. These concentrations have been related to toxic or other detrimental effects within the organism. Second, substances have been characterized by their chemical, physical, and other behavioral properties to provide a data base that can be used by environmental assessment contractors.

RTI has published a two-volume document, Multimedia Environmental Goals for Environmental Assessment, (EPA-600/7-77-136a and 136b). The document explains the formats and nomenclatures used in the MEG charts and presents MEG charts for some 200 pollutants. Future plans include the development of MEG charts for over 400 additional compounds.

6.0 CONTROL TECHNOLOGY ASSESSMENT

Pullman-Kellogg is working to develop control technology for waste utilization and disposal. An early step taken in this program was to define potential environmental problems associated with fuel conversion processes. Information on the composition and quantity of typical discharge streams from coal conversion processes was gathered through literature searches and contacts with process operators. Most of this information was primarily concerned with process operations and included very little effluent stream data. Pullman-Kellogg will continue to monitor the literature and identify where field data are most needed to fill information gaps.

HRI has prioritized a selected group of 16 acid gas removal processes to arrive at appropriate choices for the following typical end-uses: a) high pressure (1000 psig) (6895kPa) gasification for the manufacture of SNG, b) intermediate pressure (400 psig) (2758kPa) gasification for the manufacture of turbine fuel, c) low pressure gasification for the manufacture of low pressure fuel gas, and d) low pressure gasification and compression for the manufacture of synthesis gas. An overview of control technology for industrial gasifiers is also being prepared by HRI. This overview will cover several important areas including coal gasification technology, gas cleanup systems, and comparisons of conventional industrial gas cleanup processes to modern technologies.

In addition to doing general overviews of control technology requirements that are being developed in the programs listed in Table 1, Cameron Engineers is compiling a Multimedia Environmental Control Engineering Handbook (MECEH). This document will include a detailed description of environmental control technologies that appear to be applicable to coal conversion processes. This document will include information on commercially available pollution control equipment. The objectives of the handbook are to: a) categorize all commercially available control technologies into a systematic format, which can be easily accessed; b) provide technical data for each process, including process descriptions, ranges of application, efficiencies, and capital and operating costs; and c) provide a list of those who supply the specific equipment and/or license the technology.

Cameron has also edited and prepared individual sections of a first generation standards of practice manual (SPM) for the Lurgi process. This SPM is titled Evaluation of Background Data Relating to New Source Performance Standards for Lurgi Gasification, (EPA-600/7-77-057). The report, which was issued in June 1977, is the result of a task group effort which reviewed state-of-the-art emission controls for first generation coal gasification plants. The objective of this effort was to provide a compilation of technical background information for use in supporting reasonable levels for New Source Performance Standards for coal gasification plants. Organizations involved in this effort included Cameron Engineers, Inc., Catalytic, Inc., Hittman Associates, and Radian Corporation.

7.0 ENVIRONMENTAL ALTERNATIVES ANALYSIS

Environmental alternatives analysis is aimed at providing a methodology for identifying the best control options for an emission source and the best set of control options for a given plant. Considerations in this analysis will include cost and the relative degree of hazard for the various pollutants. It is too early for much work in this area because programs in the other areas are not sufficiently advanced. Aerotherm is developing a Source Analysis Model (SAM) that can be used to relate the degree of hazard associated with a given emission from a stream or plant to some defined environmental goals. (This methodology is being developed outside of the Synthetic Fuels Program but is one of the methodologies that will be used.) The report, SAM/IA: A Rapid Screening Method for Environmental Assessment of Fossil Energy Process Effluents, February 1978 (EPA-600/7-78-015) is available and is one of the models under development.

REFERENCES

Ref. 1 American Gas Association, A Comparison of Coal Use for Gasification Versus Electrification. Arlington, Va., 26 April 1977.