## Session II: ENVIRONMENTAL ASSESSMENT

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Chairman

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# LOW-BTU GASIFICATION-ENVIRONMENTAL ASSESSMENT

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*Abstract*

*Radian Corporation is under a 3-year contract to EPA's Industrial Environmental Research Laboratory at Research Triangle Park, North Carolina, to perform a comprehensive environmental assessment of low-Btu gasification and its utilization. The period of this contract is March 1976 through March 1979. In this paper, the scope and current status of Radian's effort on this program as well as a general summary of the results achieved to date are presented.*

*Basically, Radian's technical activities have fallen into three general task areas: environmental assessment, data acquisition and program support. To date, the bulk of the program effort has been expended in compiling and assessing current data on low-Btu gasification process technology and its related environmental impacts. As part of this effort, a data base containing over 10,000 articles and contact reports has been compiled and assessed.*

*Concurrently, a significant effort has been directed toward making arrangements for conducting environmental tests at operating gasification plants both in this country and abroad. The candidate commercial test sites being considerd in this country are all equipped with fixed-bed, air-blown, atmospheric pressure gasifiers. Efforts to expand the range of gasifiers and coal types tested have led to a consideration of ERDA-sponsored as well as overseas facilities as candidate test sites. While final arrangements for site testing activities are not yet complete, future program effort is expected to be concentrated in the area of acquiring and analyzing environmental test data.*

## INTRODUCTION

This paper is based upon information compiled in an ongoing EPA program whose objective is a comprehensive environmental assessment of low/medium-Btu gasification and utilization technology. This three-year assessment program was initiated in March 1976. Radian's program efforts are therefore about half complete at this point.

One of the first questions that one faces when dealing with a very broad subject area such as environmental assessment is: "What is an environmental assessment?" Since this subject is covered in detail by Bob Hangebrauck in another paper, I will not dwell on this issue. However, I would like to reiterate some of the key elements of EPA's overall approach to environmental assessment since this will provide some very important background information on Radian's program efforts.

## ENVIRONMENTAL ASSESSMENT PROGRAM GUIDELINES

Basically, EPA's overall environmental assessment program objectives, as defined by Hangebrauck[1] are:

1. to determine the multimedia environmental loadings and costs associated with the application of alternative control methods to potential low/medium-Btu coal gasification plant emission sources; and
2. to compare the magnitudes of those projected loadings with appropriate target values established through surveys of existing regulations, estimates of multimedia environmental goals or the results of bioassay screening tests.

Ultimately, this effort should result in a specification of:

1. potential emission sources of environmental concern in a coal gasification facility;
2. the effectiveness and cost of controlling those emissions to varying levels through the application of candidate control methods; and
3. areas in which existing controls appear to be inadequate for purposes of controlling hazardous pollutant emissions to acceptable levels.

Development needs identified as a result of this effort will be expressed such that control

technology development priorities are clearly indicated.

The specific tasks which have been defined by the EPA as being necessary to complete an environmental assessment are the following:

1. Current Process Technology Background;
2. Environmental Data Acquisition;
3. Current Environmental Background;
4. Environmental Objectives Development;
5. Control Technology Assessment; and
6. Environmental Alternatives Analysis.

The general types of activities which will take place in each of these task areas are fairly obvious from the task titles. For a more detailed description of these tasks, the reader should refer to the previously referenced Hangebrauck document[1].

Radian's program activities to date have been concentrated in the first two of the six task areas listed above. Our first iteration at assessing the current status of and significant trends in low/medium-Btu gasification and utilization technology was marked by the release of a draft document by Cavanaugh, et al., June 1977[2]. Significant effort has also been devoted toward making arrangements for conducting environmental tests at pilot and commercial scale gasifiers located both in this country and abroad. At the present time, one major testing campaign has been completed at an existing commercial U.S. site and several other tests are planned.

Because the bulk of our program progress has been made on the Current Process Technology Background and the Environmental Data Acquisition tasks, this paper will concentrate on the results of our efforts in these two task areas. While our work in the other task areas has started, to date these efforts have mainly taken the form of working in conjunction with the EPA and other prime contractors to establish methodologies and examples of useful outputs from these tasks.

More specifically, this paper will concentrate on the following aspects of Radian's environmental assessment program. First, the environmental data base which we have accumulated to date on low/medium-Btu gasification technology will be summarized. As part of this discussion, the resources used to compile this data base, the environmental problem areas identified and the driving forces which appear to be controlling the commercialization of the technology will be described. This discussion will naturally lead to a discussion of the guidelines we have used in formulating priorities for our environmental data acquisition program. Finally, I will describe the test site opportunities we have identified and our overall strategy and timetable for conducting meaningful environmental tests.

## CURRENT PROCESS TECHNOLOGY BACKGROUND

The approach which we have taken in trying to gain an insight into the current status of low/medium-Btu gasification technology has involved an aggressive campaign to procure available information from two major sources:

1. the open literature; and
2. contacts with experts.

Obtaining information from the first of these two resource areas involved an extensive literature survey utilizing both computer-aided and manual search techniques. Abstracts of publications relating to all aspects of this program were systematically screened, catalogued and cross-referenced using keywords established by project personnel. To facilitate this effort, a special project library was set up to support the activities of the technical members of the project team. To date, a gasification process environmental data base containing over 10,000 articles, news releases and contact reports has been systematically compiled as a result of this effort. The approach used in setting up this information handling system is documented in an interim project technical report.[3]

Although the open literature has provided a considerable amount of useful information on this program, efforts to establish a dialogue with persons who have active interests in gasification technology application and development have been far more fruitful in helping our project team to develop a meaningful perspective of current trends. This effort has also helped considerably in the area of iden-

tifying candidate sites for environmental testing. This aspect of the project will be summarized in a later section of this paper.

*Modular Approach*

One of the major problems which was faced on this program was related to the question of how you represent a very complex technology composed of a large number of candidate processes which can be arranged in many different ways. In its most simplified form, low/medium-Btu gasification technology can be represented by the following block diagram


but, this approach does not provide a very meaningful mechanism for organizing and interpreting process and control technology information. One approach to this problem of analyzing a complex technology which has proven itself to be useful in several previous EPA programs is a modular or unit operations approach.

With this approach, a complex technology or industry is broken down into its generic unit operations, each of which is characterized as having specific input and output streams. On this basis, the production of low/medium-Btu gas can be assumed to require the process operations shown in Figure 1.

Each of these unit operations can in turn be represented by a series of optional process modules as shown in Figures 2, 3 and 4.

Now, while a technology can be represented in a general sense by block diagrams such as those shown in Figures 1-4, site-specific environmental determinations must be based upon an analysis of a specific coal feed which is converted into a product which is consumed by a specific end user. For this reason, it is important to consider the potential end uses of low/medium-Btu gas as well as the specific processes which appear to be best suited to producing the required product gas.

*Significant End Use Options for Low/Medium-Btu Gas*

Potential end uses for low/medium-Btu gas which apear to be commercially significant at present are:

1. as a fuel for direct firing of process heaters requiring a clean fuel gas. This is a very likely near-term application for the technology;
2. as a fuel for process heaters and steam boilers which cannot economically be converted to direct coal-fired units. This option is most attractive in a situation where a gasification system can be used to supply large number of remote users;
3. as a gas turbine fuel, including use in combined cycle units. One potentially attractive approach here is the use of a gasifier and storage system to supply fuel for a utility peaking turbine; and
4. as a synthesis or reducing gas. This end use option would not be competitive with liquid fuel reforming in most applications.

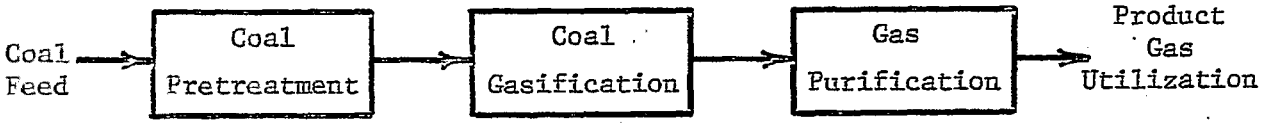


**Figure 1. Coal gasification process unit operations.**

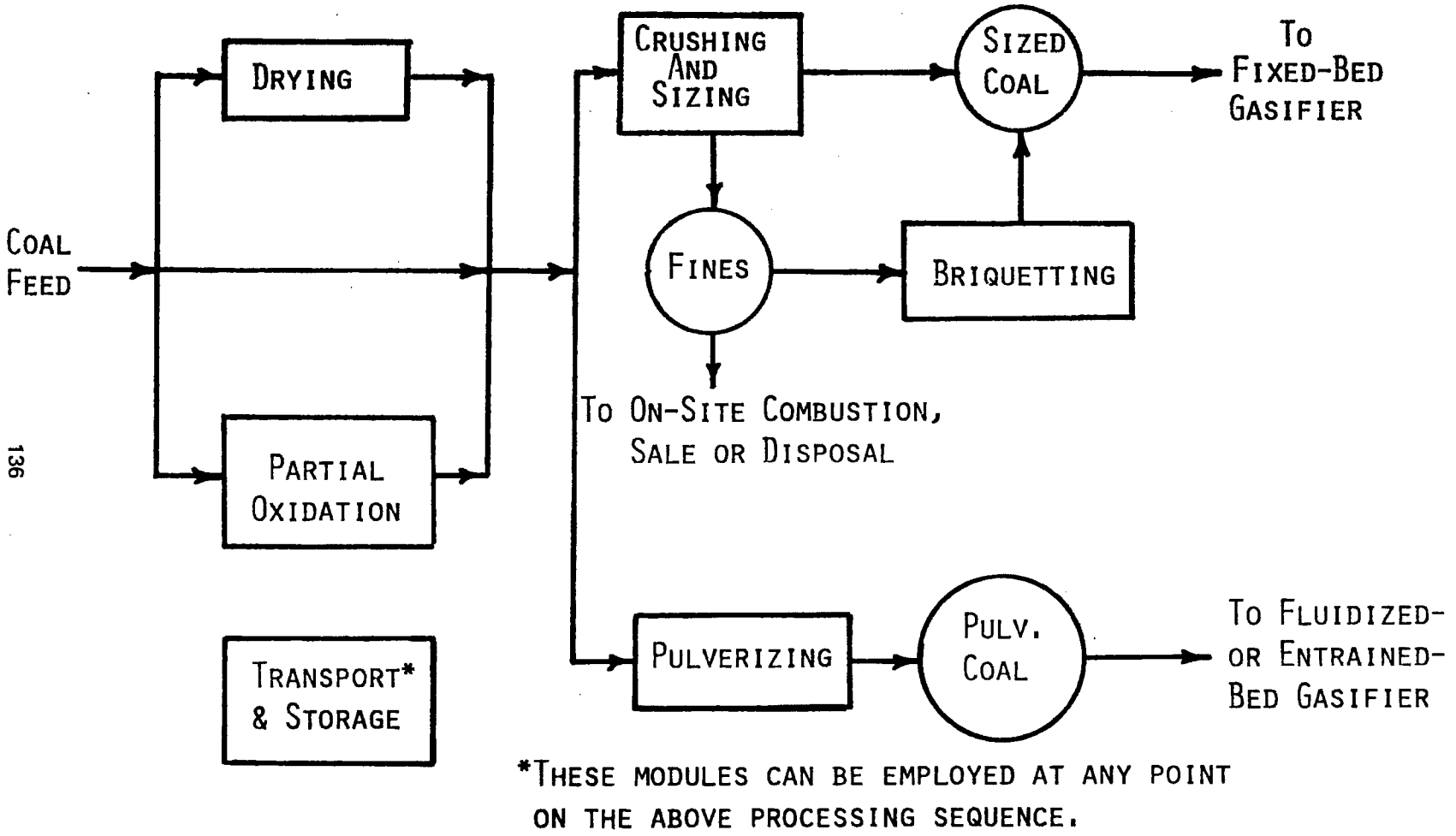


**Figure 2. Process modules—coal pretreatment operation.**

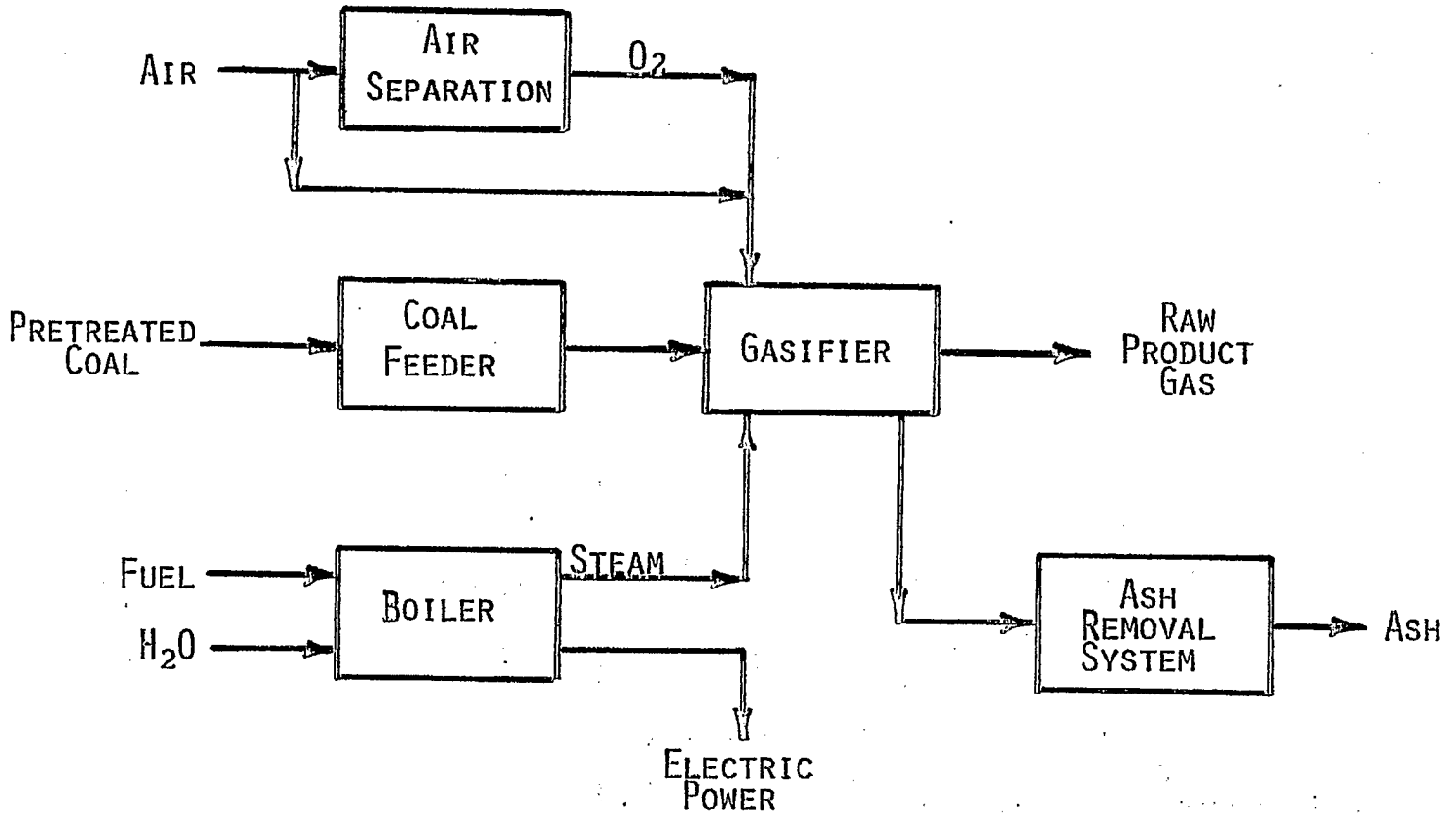


**Figure 3. Process modules—coal gasification operation.**

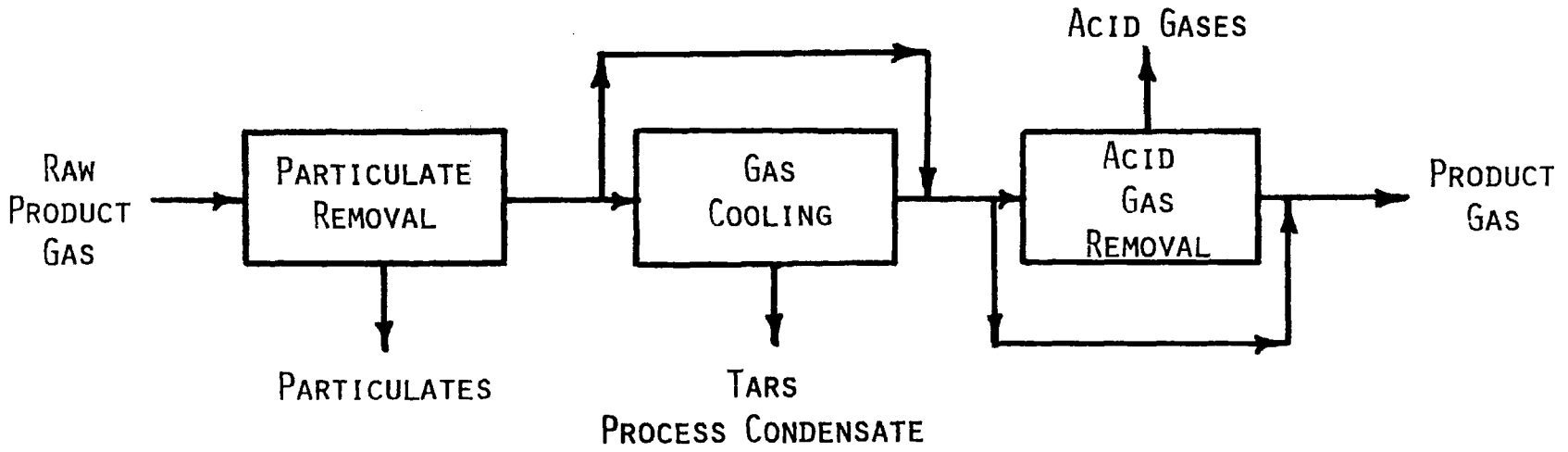


**Figure 4. Process modules—gas purification operation.**

All of these end uses for clean gaseous fuels have traditionally been satisfied by natural gas consumption. As this country's natural gas supplies diminish, however, many industrial users of natural gas are finding that low/medium-Btu gas is becoming an increasingly attractive alternative to the complete replacement of existing gas-fired facilities.

*Significant Processing Options*

The gasification processes that appear to be best suited to satisfying near-term needs for low/medium-Btu gas are listed in Table 1. While this is by no means a complete list of available processes, it does include most of the systems for which there appears to be considerable commercial or governmental agency support.

As shown in Table 2, these promising gasification systems fall into six different groups when classified on the basis of their significant design features. This classification scheme is also significant from an environmental standpoint because the product, by-product and emission streams associated with these various gasifiers will vary considerably as functions of the process design features listed.

For example, relative to high temperature, entrained-bed systems, fixed-bed systems will tend to produce a product gas that contains significantly greater quantities of coal devolatilization products. This will create more of a tar/oil fraction handling and disposal problem. Relative to dry ash systems, slagging systems will produce a fused ash material

**TABLE 1**

**PROMISING LOW/MEDIUM-BTU GASIFICATION SYSTEMS**

| Commercial Widespread Use | Commercial Limited Use | Developmental |
|---|---|---|
| Koppers-Totzek | Chapman (Wilputte) | Bi-Gas |
| Lurgi | Riley Morgan | BGC Slagging Lurgi |
| Wellman-Galusha | | Foster Wheeler/ Stoic |
| Winkler | | GFERC Slagging |
| Woodall-Duckham/ Gas Integrale | | MERC Pressurized Wellman-Galusha |
| | | Texaco |

**TABLE 2**

**PROMISING LOW/MEDIUM-BTU GASIFICATION SYSTEMS**

| Classification By Gasifier Type | | | |
|---|---|---|---|
| Fixed Bed | Dry Ash | Atmospheric | Chapman (Wilputte) |
| | | | Foster Wheeler/Stoic |
| | | | Riley Morgan |
| | | | Wellman-Galusha |
| | | | Woodall Duckham/GI |
| | | Pressurized | Lurgi |
| | | | MERC |
| | Slagging | Pressurized | BGC Lurgi |
| | | | GFERC |
| Entrained Bed | Slagging | Atmospheric | Koppers-Totzek |
| | | Pressurized | Bi-Gas |
| | | | Texaco |
| Fluid Bed | Dry Ash | Atmospheric | Winkler |

which should exhibit significantly different leaching characteristics.

The requirements of the coal pretreatment module are generally dictated by the properties of the feed coal and the feed specifications of the gasifier used. Gas purification process requirements are determined by the specifications of the intended end use process. Again, these process constraints are environmentally significant. Potential emissions of volatile organics from coal drying and partial oxidation processes appear to be a troublesome problem. By the same token, gas cooling and low temperature acid gas removal processes generate a tar/oil stream and a process condensate which are difficult to dispose of in an environmentally sound manner. Applications which can utilize hot, raw gasifier product gas directly can avoid this troublesome problem, a consideration which explains one of the main driving forces behind efforts to develop high temperature acid gas removal processes.

A factor which is not addressed in this paper, but one which must be kept in mind, is that process economics will ultimately dictate the choice of a coal feedstock, process configuration and process operating conditions for a given application. This choice must take into account the environmental tradeoffs and control technology requirements associated with various process options, but, in the final analysis, process and control technology options will both be selected on an economic basis.

*Environmental Problem Areas*

In addition to providing a more detailed breakdown of the modules required to satisfy the requirements of the three major process operations, Figures 2, 3, and 4 also provide a useful starting point for the identification of potential gasification plant environmental problem areas. In the coal pretreatment operation, there are three major classes of emission problems:

1. coal dust emissions from all coal handling and storage operations;
2. volatile component emissions from all modules that involve the thermal treatment of coal (drying, partial oxidation and possibly briquetting and storage); and
3. water runoff from coal storage areas or from the use of water sprays for dust suppression.

Qualitatively, the coal dust emitted from coal handling operations would be similar to the coal feed material, but good techniques for calculating dust emission rates as functions of coal properties and the characteristics of the process hardware are not available. Some data on coal devolatilization products have been reported, but much of this information is of limited use to this program. The leaching characteristics of a variety of specific coal types are probably better defined than some of these other problem areas, but additional work on specific coals which appear to be reasonable candidates for gasification process feed materials is needed.

In the coal gasification operation the major sources of environmental emissions are:

1. gasifier start-up vent;
2. leaks and other fugitive emissions of raw product gas, e.g., through the coal feeding device;
3. ash handling procedures which can generate ash dust; and
4. leached ash components (associated with rainfall or ash sluice water) which are a problem in wet ash handling systems.

The gasifier start-up vent stream would normally be flared. One question related to this operation for which no data exist is, "Are hazardous raw gas components adequately controlled using this approach?" This question of hazardous component behavior in combustion processes is a much broader issue, however. The fate of both tar and low/medium-Btu gas components in combustion processes warrants considerable further study since this issue impacts:

1. the emissions of hazardous components from many candidate product/by-product utilization processes; and
2. the adequacy of incineration or flaring as a control technique for hazardous hydrocarbon vapors.

In the gas purification operation, the major sources of emission streams are:

1. particulate removal processes which remove tar aerosols and coal fines from the hot raw product gas;

2. quenching operations which usually produce condensed organic (tar/oil) and aqueous (process condensate) materials. Disposal or treatment of these materials is a very troublesome problem because of the wide range of pollutants they contain;
3. acid gases removed from the product gas; and
4. fugitive emissions from handling all of these materials.

As a general statement, it can be said that a significant amount of data are available on environmental problems associated with coal gasifier operations. These data are inadequate for purposes of making comprehensive environmental and control technology assessments, however. Of particular importance to this program are data which

- provide more detailed characterizations of the types of emissions streams just discussed,
- specify levels of hazardous components present in those streams as functions of key process variables, and
- predict the fates of those components in utilization and/or treatment processes.

It is these objectives which are now guiding our current efforts to expand our environmental data base through meaningful test programs at operating gasification sites.

## ENVIRONMENTAL DATA ACQUISTION

In this section, the concerns which are guiding Radian's overall data acquisition effort are described. Our current approach to conducting environmental tests at a specific site is summarized in a paper by Bombaugh[4], so this issue will not be addressed here.

Sites which were considered to be potential candidates for environmental testing include:

- domestic facilities
  - operating commercial-scale units
  - developmental/demonstration units
- foreign facilities
  - a wide range of commercial-scale test opportunities is represented by this group.

Commercial scale gasifiers which are presently operating in this country are shown in Table 3. Of this group, only the Holston gasifier has been tested to date. Environmental testing of a Wellman-Galusha gasifier at Glen-Gery's York, Pennsylvania plant is planned for early 1978 in conjunction with ERDA's industrial gasifier test program. No firm plans exist for conducting tests at the other two sites listed, although extensive discussions of test possibilities have been held with the two groups involved.

Several limitations in the test possibilities afforded by these commercial gasifiers are obvious from the data presented in Table 3. All of these sites use fixed-bed, air-blown gasifiers. The only particulate removal technique utilized is a hot cyclone. Only one site has gas quenching and tar/condensate handling facilities. Only one gasifier uses a variety of coal types.

Because of these limitations in commercial sector test opportunities, consideration of alternate domestic sites for environmental testing is justified. Some of the possibilities here are

- EPA-sponsored test units at Research Triangle Institute and North Carolina State University which will study gasification process pollutant generation and control technology effectiveness,
- ERDA-sponsored development units at MERC and GFERC,
- ERDA-funded gasifiers which will be installed at a variety of domestic sites, and
- privately-funded development units.

The EPA-sponsored test units are not yet operational. Discussions have been held with MERC and GFERC representatives concerning possibilities for cooperative EPA/ERDA test programs, but no specific agreements have been reached. The first ERDA-sponsored industrial gasifier to be started up will be Glen-Gery's York, Pennsylvania unit. The next gasifier is not scheduled for startup until at least the third quarter of 1978. Discussions with a large number of private sponsors of gasification-related R&D programs have been held, but, to date, no promising test opportunities in that area have been identified.

Because of this further limitation in the

TABLE 3

CANDIDATE DOMESTIC TEST SITES-OPERATING COMMERCIAL GASIFIERS (ALL LOW-BTU)

| Site | Gasifier and Coal Type | Cleanup | Utilization |
|---|---|---|---|
| Holston Army Ammunition Plant Holston, TN. | Chapman Bituminous | Hot Cyclone Water Quench Two Stages of Water Scrubbing | Low-Btu Gas-Burned in Process Furnace Tar-Burned in Boiler |
| Glen-Gery Brick Co. 4 Sites in Eastern PA. | Wellman-Galusha Anthracite | Hot Cyclone | Gas Burned in Brick Kiln |
| National Lime Carey, Ohio | Wellman-Galusha Bituminous | Hot Cyclone | Gas Burned in a Lime Kiln |
| Riley Stoker Demonstration Unit Worcester, MA. | Riley-Morgan Variable | Hot Cyclone | Gas Flared |

availability of viable developmental sites in this country, a number of commercial sites in foreign countries have been considered as candidates for environmental testing. Process and emission data will be obtained from a medium-Btu gasification facility located in Kosovo, Yugoslavia starting in the fall of this year. Details of this program are described in a paper by Mitrovic[5]. The possibility of conducting environmental tests in Europe and Africa is being jointly pursued by Radian and TRW, but, to date, no firm developments in this area can be reported.

## SUMMARY AND CONCLUSIONS

The conclusions which can be drawn from the results of Radian's program efforts to date fall into three general areas:

- Current Technology Status
- Need for Environmental Data Acquisition
- Test Opportunities

On the subject of the current status of low/medium-Btu gasification, there is very clearly a significant interest in the near-term application of this technology in the United States. The most promising potential market appears to be associated with supplying the gaseous fuel needs of existing industrial processes which can no longer depend upon traditional sources of natural gas. Use of low/medium-Btu gas as a gas turbine fuel or as a synthesis/reducing gas may be feasible in some applications, but widespread usage of gasification technology to satisfy these demands is not anticipated to be significant in the near term.

Radian's survey of available data on the environmental aspects of low/medium-Btu gasification processes has shown that existing data are not sufficient to support the level of analysis required to produce the desired end products of this assessment program. Major deficiencies are found in the areas of characterizing the emissions of minor and trace contaminants from gasification processes (particularly trace organics). There is also a general lack of information on fugitive emissions and minor process vent streams.

Available U.S. test sites will provide opportunities for gathering useful environmental data

on fixed-bed, atmospheric pressure systems using anthracite and bituminous coal feedstocks. Efforts to expand the range of gasifiers and coal types available for testing has led us to push for involvement in both ERDA-sponsored and overseas test programs. Radian participation in these programs will be a key element in the development of an ability to predict the impact of coal feedstock and process variable changes upon control technology needs.

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