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ENVIRONMENTAL AND HEALTH STUDY OF A LOW-BTU GASIFIER*

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DISCLAIMER

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ABSTRACT

An environmental and health, monitoring and testing plan is now being implemented at the low-Btu gasifier located on the campus of the University of Minnesota-Duluth. This is one of several project plans under consideration by the Department of Energy in conjunction with the Gasifier in Industry demonstration program.

Numerous staff of the Oak Ridge National Laboratory and Department of Energy participated in the development and review of the monitoring and testing plan which includes on-line studies, in-plant studies, and local area studies to be integrated through multidisciplinary assessments. A description is provided of the process and facilities, of the rationale for the environmental and health plan, and of the principal program components including process measurements and controls, occupational exposures and effects, environmental fate and effects, and assessments.

INTRODUCTION

The Gasifier in Industry Program of the Department of Energy (DOE) is part of a broader activity to develop and improve technologies for converting coal to synthetic gas and liquid fuels.[1] Specifically, this program involves demonstrating the integration of existing low-Btu gasification

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technology in various operational environments. State-of-art technology is to be applied in six selected projects, one of which is the gasifier located on the campus of the University of Minnesota-Duluth (UMD).

Information to be gathered during the demonstration period will consider questions of environmental acceptability as well as those related to technical and economic uncertainties. The Oak Ridge National Laboratory (ORNL) was requested by the DOE to develop for their consideration a comprehensive, environmental and health plan for study of the UMD Gasifier.[2] Following is a description of the monitoring and testing activities involved in developing the environmental and health data base.

Characteristics of Program Plan

A number of environmental and health concerns in coal gasification were identified previously by DOE, and listed in an Environmental Development Plan.[3] The issues and information requirements to satisfy these concerns for coal gasification were subsequently enhanced by staff of the Assistant Secretary for Environment, DOE; and it was the latter determination of environmental and health tasks that were used as guides in plan development for UMD.

Design of the program plan for UMD is based upon several premises: (1) the study period will be limited to three years; (2) state-of-the-art capabilities in monitoring and testing will be applied wherever practicable; (3) the first-year program will emphasize scoping and screening activities to delineate the requirements for more detailed investigations; and (4) program activities will be conducted without interruption of normal plant operation. Although every effort will be made to utilize methods and instruments already available, some development in monitoring and testing protocols may be required to address unexpected problems. Screening activities during the first year will be followed by detailed investigation of the major concerns and important constitutents, and by initiating monitoring and testing efforts into potential problem areas identified in the screening studies.

Four general areas of study are emphasized in the study plan; on-line studies, in-plant studies, local area studies, and multidisciplinary assessments that encompass the entire effort. On-line studies, or process characterization, provides guidance for sample testing and information for control technology evaluation; in-plant studies provides information for occupational health controls and for correlations of potential to actual personnel exposures; local area studies identify pollutant fate and potential effects and provide confirmation of projections based upon effluent monitoring; and local impact assessments are concerned with the potential impacts on health and environment, and with the adequacy of environmental and engineering controls.

PROCESS MEASUREMENTS AND CONTROLS

An existing oil-fired heating plant at UMD has been converted to burn low-Btu gas produced by coal gasification.[4] Tar by-products from the gasifier will be collected, and these will be used for peak heating requirements in an existing oil-fired boiler. The major components of the heating plant are illustrated in Figure 1, and include a coal handling section, the gasifier, environmental control devices, and the boiler-steam-off gas section.

A Wyoming bituminous coal from the Elkol Mine, containing 6.6% ash and 0.5% sulphur, will be the initial feed stock. Coal will be received at the Duluth docks as 90% 1-1/4 x 3/8 in., then screened and trucked to the heating plant. Several other lignite and bituminous coals have been proposed for testing.

After tramp iron removal and another screening for fines removal, coal will be dropped through purged lock hoppers into the gasifier. The gasifier is a Foster-Wheeler, Stoic two-stage design. Gas and tars are produced as the coal falls through the 250-1100°F devolatilization zone and are removed from the top of the gasifier. Combustion and gasification of the devolatilized coal in a 1100-1800°F zone, fed by air and steam, produce bottom gas. Ash is removed beneath the gasifier from a water-filled pan, which serves to quench the hot ash and seal against operating pressure (less than 30 in. H_2O).

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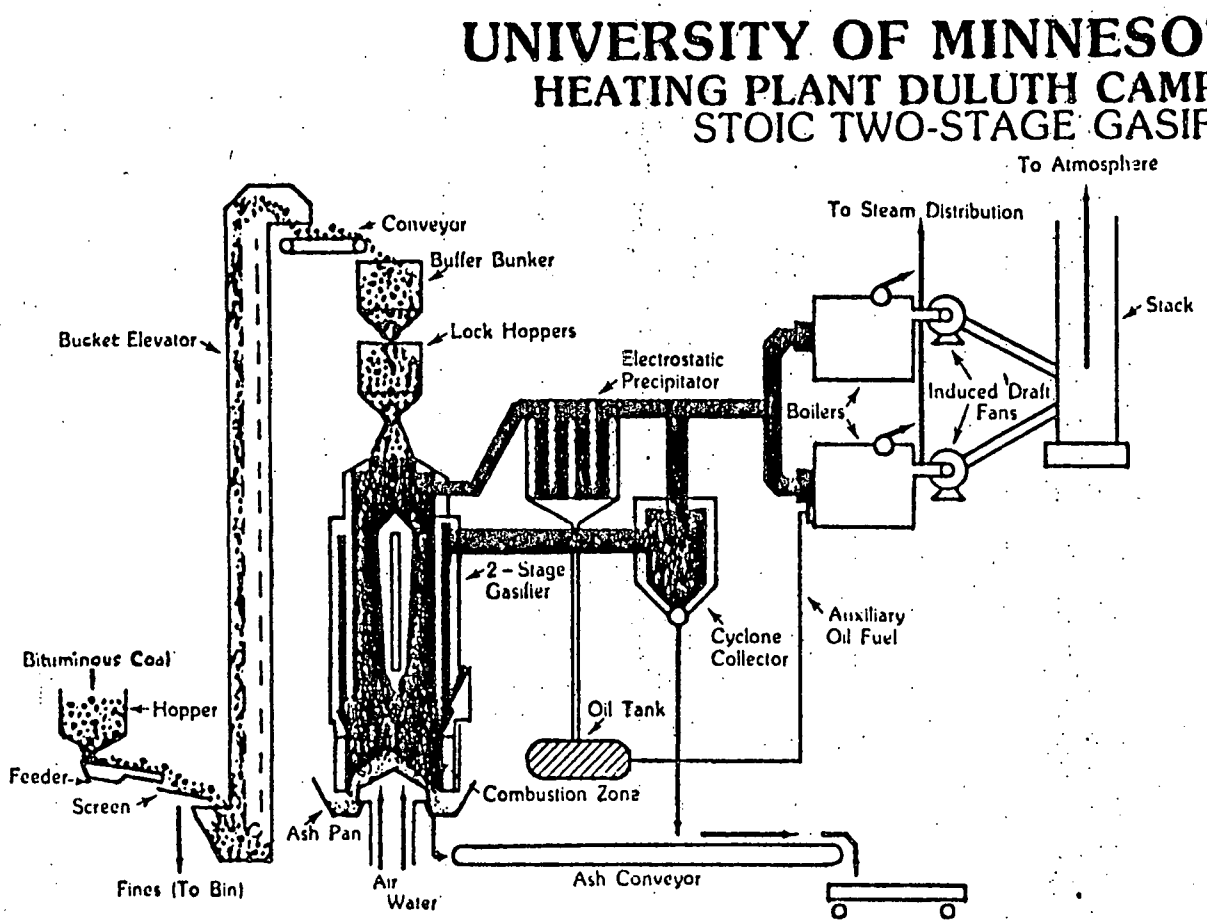

Fig. 1. Schematic diagram of University of Minnesota-Duluth heating plant.

Top and bottom gases must be cleaned of tars and particulates before combination into boiler feed. Since bottom gas at 1100°F is primarily laden with particulates, a hot cyclone removes the dust for storage or disposal. In contrast, top gas (250°F) will contain tars and some particulates. These will be removed in a hot electrostatic precipitator and stored in heated underground tanks for use as boiler feed during the winter months.

Two modified 25,000 lb/hr steam boilers will burn low-Btu gas. Tars collected from the underflow of the electrostatic precipitator will either be burned directly in an existing 50,000 lb/hr Combustion Engineering boiler. Gas-fired boiler flue gases vent to the main heating plant stack, while tar-fired boiler flue gases vent to a stub stack. Figure 2 shows the recently completed addition of the gasifier to the heating plant, on which shake-down tests began October 24, 1978.

Process Sampling And Characterization

Numerous sampling points have been designated to achieve the requirements of process measurements, and these are identified in the flow schematic of the heating plant (Figure 3). The details of process sampling and analyses are described in the project plan. In general, process sampling strategy provides for characterization of materials introduced into the process, and of intermediate or final product, recycle or waste streams.

The sampling schedule, analytical procedures, and the constitutents or parameters to be measured were chosen to allow early measurement of traditionally monitored or suspected materials, and to maximize the likely detection of unexpected and hazardous constituents. Results must be adequate to document process conditions, to evaluate the efficiency of environmental control technology, to identify limitations in sample size or analytical methodologies, to identify possible biological hazards in potential fugitive emissions, and to prioritize materials for subsequent bioassay.

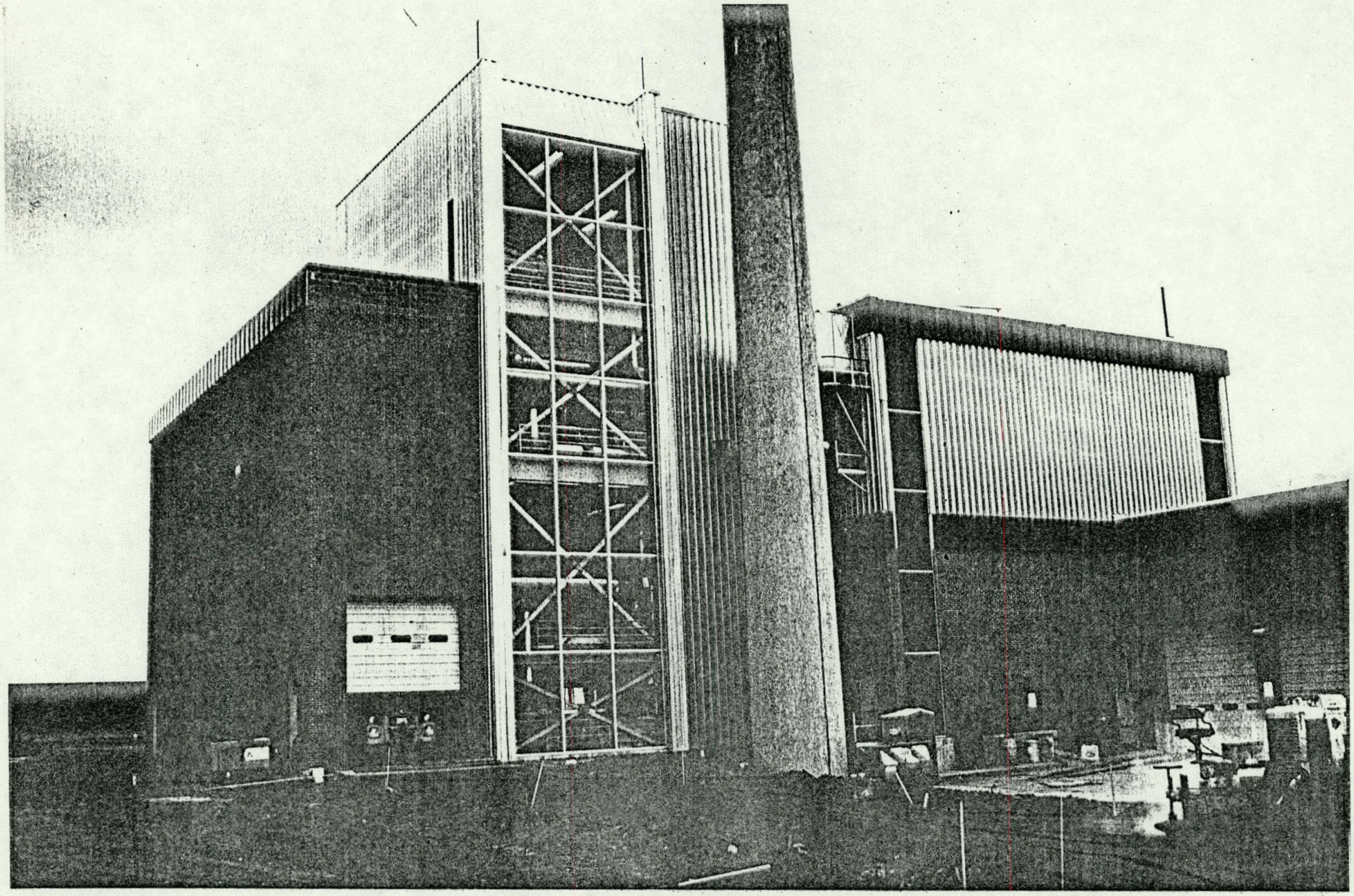

Fig. 2. University of Minnesota-Duluth Heating Plant and Coal Gasifier.

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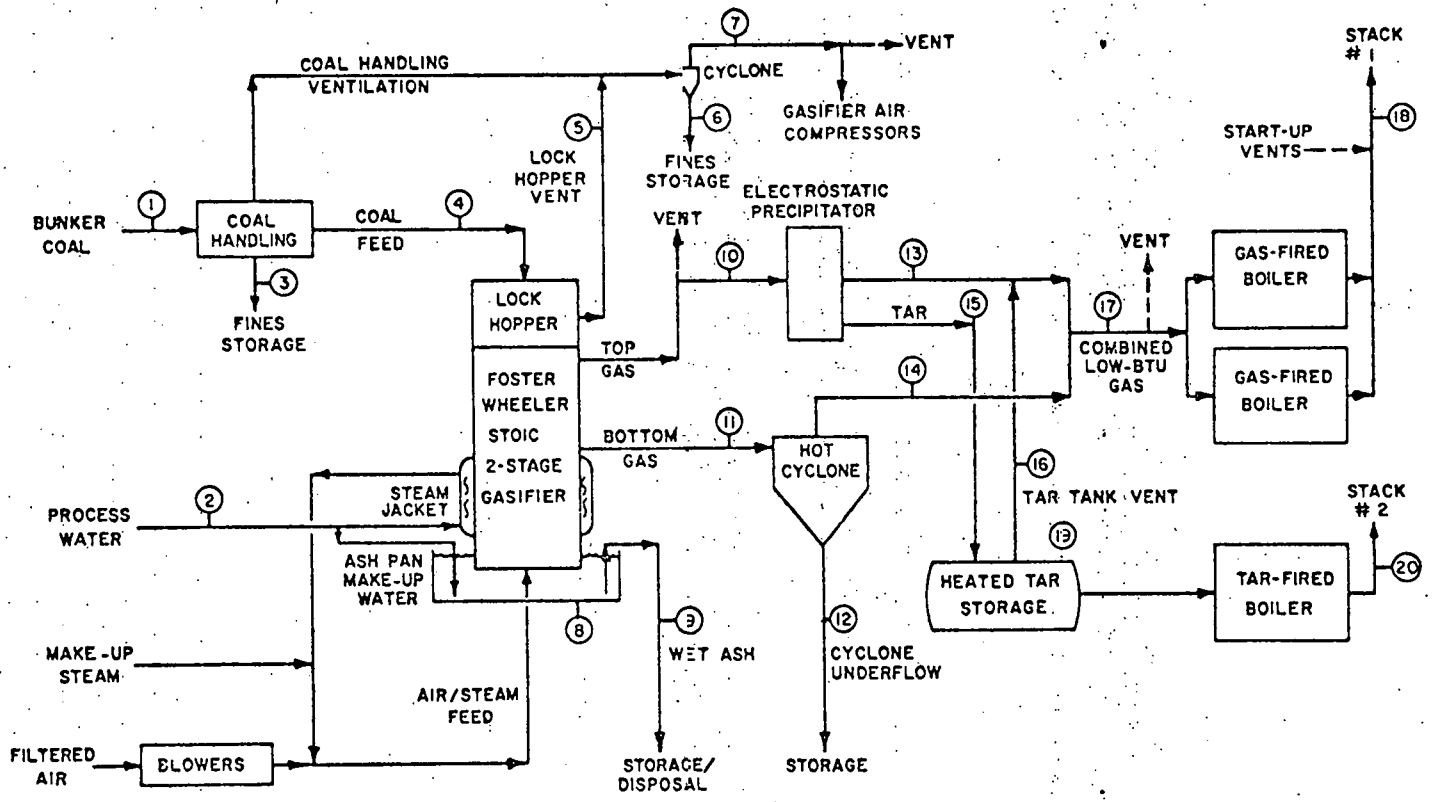

Fig. 3. Flow Schematic and Sampling Points for University of Minnesota-Duluth Heating Plant.

On-line instrumentation required for process sampling and monitoring is summarized in Table 1. Gas chromatographs will monitor the primary gases (N_2, CO, CO_2, H_2), water vapor, and sulfur compounds (H_2S, COS, CS_2) at the electrostatic precipitator, cyclone, and stack effluents. SO_x and NO_x will be monitored initially in the main stack effluent. Grab samples and samples classified by use of four special sampling trains will also be used in process and effluent characterization. Table 2 includes a general description and the intended application of each sampling train. Twenty-three chemical and physical tests will be used initially in characterizing some 400 process samples collected the first year.

OCCUPATIONAL EXPOSURE AND EFFECTS

Potential exposure of man in the working environment includes consideration of plant area controls and effects on man if exposures occur. Monitoring and testing activities thus involve the requirements of worker protection and the potential effects of exposure to primary effluents and fugitive emissions.

Plant Area Sampling and Characterization

The primary objective of an industrial hygiene program is to recognize, evaluate, and control exposures which may have the capability of producing overt health effects. An industrial hygiene and medical surveillance program has been established in cooperation with the University. The University has prime responsibility for protecting the health of their employees, and we have participated to complement the University requirements and to provide information for occupational health control assessments.

Two types of monitoring for potential exposures is provided. Area monitoring for CO, PAH, NH_3, NO_x, fugitive emissions, heat, noise, and various chemical stresses, provides an indication of possible exposures, and will be accomplished by various instruments providing real-time monitoring. A partial listing of area monitors and their function is provided in Table 3. Personnel monitoring defines the actual exposures. A variety of standard industrial hygiene techniques employing filter cassettes and gas badges will be used to define the time-weighted exposures to gaseous and particulate contaminants.

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Table 1. On-line instrumentation for continuous process monitoring

Instrument	Monitored streams	Analysis
Gas chromatograph	13, 17	N_2, CO, CO_2, C_1, C_2, C_3
	18, 20	N_2, O_2, CO_2
Gas chromatograph	13, 17	H_2O, H_2
	18, 20	H_2O
Gas chromatograph	13, 17	H_2S, COS, CS_2, methyl mercaptan, ethyl mercaptan, thiopene
	18, 20	SO_2
Continuous monitor	18	SO_x
Continuous monitor	18	NO_x

Table 2. Sampling trains for UMD gasifier

Gas sampling train	In-stack particle sampler	Heated isokinetic probe[a]	Heated 3-cyclone series[a,b]	Knock-out drum, electrostatic precipitator[a]	Heated filter[a]	Gas cooler/ condenser	XAD-2 organic sorbent	Ice-cooled impingers: Reagent solutions	Ice-cooled impingers: Empty	Ice-cooled impingers: Drierite	Vacuum pump and dry test meter	Purpose
1		X		X	X	X			X	X	X	Measurement of tar loading.
2	X	X			X				X	X	X	Measurement of particulate loading and sizes.
3		X		X	X	X	X	X		X	X	Assessment of tar loading; collection of samples for organic, aqueous, and trace element analyses.
4		X	X		X	X	X	X		X	X	Assessment of particulate loading and size; collection of samples for organic, aqueous, and trace element analysis.

[a] Heated to 300°F to prevent water condensation.

[b] Alternative staged particle separators could be used.

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Table 3. Area monitors

Control pollutant	Type of instrument and capability
CO	Multipoint, continuously operating sensor station for CO analysis with visual and audio alarm
NH_3, NO_x, SO_2, C_6H_6, C_6H_5OH, naphthalene and its derivatives	Second derivative, UV absorption spectrometer with multipass gas cell for real-time monitoring of selected effluents
Respirable aerosol and dust particles (coal dust, tarry fumes and ash particles)	Piezobalance, portable monitor for measuring respirable aerosols with mass concentrations readout each minute; analyses for particulate polycyclic aromatic hydrocarbons (as benzene solubles) to determine integrated exposures will be conducted as part of the conventional industrial hygiene program; attempts will then be made to correlate the mass concentration and benzene soluble fraction for specific locations in the gasifier plant. If such correlations are found to exist then one would have indirect, but near real-time method for measuring benzene solubles

Medical surveillance is necessary to ensure full protection of all personnel involved in operation and maintenance of the gasifier. Information recorded by such surveillance will be correlated with results of personnel monitoring and become a part of the assessment activity. The University provides for complete physical examinations, with special attention given to skin abnormalities and sputum cytology tests for employees at the gasifier.

Occupational Toxicology

The principal focus of occupational toxicology is the testing of primary effluents and fugitive emissions for potential effects on man. Information will be developed in response to questions of (a) relative toxicity of by-products and effluents, (b) toxicity variation with process conditions, and (c) toxicity potential of fugitive emissions.

A two-level bioassay program is designed to test the effluents and potential fugitive emissions. Level one, or cellular bioassays, will be used to ascertain how the relative toxicity of effluents, by-products, and fractions thereof vary with process changes, to screen for further testing, and to correlate with whole animal, somatic effects. Tests in this category make use of a variety of biological systems including bacteria, yeast, and mammalian cells to investigate mutagenic effects. These shorter-term tests will provide guidance and be complemented by longer-term validating assays using drosophila, cultured mammalian cells, and whole animal (mouse) systems. Not all tests will be run on all samples collected at a given point, but priorities will be established based upon the biological activity detected in the screening assays.

Level two, or mammalian somatic toxicity tests, compliment the mutagenic and cytotoxic testing. These assays involve use of whole animals to characterize the acute, subacute, and chronic toxicity of products and effluents. Only selected samples will be used initially in the more expensive toxicity tests, with selection based on the probability of direct or indirect human exposure and on current information of potential emissions. Additions to the toxicity testing program are likely as the information base on biological activity develops.

ENVIRONMENTAL FATE AND EFFECTS

Environmental area monitoring includes the collection and analyses of samples, operation of continuous monitors, and application of appropriate ecological toxicity tests. Information derived from these activities is used to characterize and quantify air, water, and solid effluents which may impact the immediate environs of the plant.

Design of the monitoring program considers the ambient environmental conditions and the expected operating characteristics of the gasifier. The following information guided the development of the monitoring program: (a) the Duluth-Superior urban area is industrialized, and operation of the heating plant is not expected to modify the ambient air to a discernable level; (b) water use at the gasifier is expected to be primarily consumptive and not result in any liquid effluents, and (c) the principle solid waste is ash from the gasifier.

Two instrumented monitoring stations will monitor primarily criteria air pollutants (CO, NO_x, hydrocarbons, SO_2, oxidants, and particulates) with periodic sampling for total organics and organic speciation. The monitoring scheme and sampling frequency are listed in Table 4. If stack monitors indicate sufficient efflux of noncriteria pollutants (e.g., COS, NH_3, HCN) then additional measures will be adopted to monitor for these pollutants.

Water quality measurements will be limited to samples taken from wells in a sanitary land fill used for ash disposal. In the event of unusual plant operating conditions, liquid effluents and surface streams will be monitored. Gasifier ash will be leached, to investigate this important environmental parameter, and the water samples and leachates will be analyzed for a variety of organic and inorganic constituents. Screening activities will be used, as appropriate, to test the toxicity, transport, degradation, and bioaccumulation characteristics of either whole effluent streams, selected chemical fractions, or specific model compounds.

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Table 4. On-line environmental monitoring

Analyses	Instrumentation	Sampling frequency
Gases:		
CO	Infra-red spectrometer	Continuous
NO_x	Chemiluminescence detector	Continuous
Hydrocarbons	Gas chromatograph	Continuous
SO_2	Flame photometric detection	Continuous
Oxidants	Chemiluminescence detector	Continuous
Particulates:		
Total particulates[a]	High volume sampler	24-hr sampling, collection weekly

[a]Gravimetric analyses carried out by sampling personnel.

ASSESSMENTS

Site specific assessments will be used to ensure a maximum integration and utilization of information developed by the program elements of sample collection, analytical characterization, biological and environmental testing, and occupational control and medical surveillance.

Analyses of potential impacts includes consideration of:

a. Human health related assessments -- including the industrial worker and the general public;
b. Ecological related assessments -- both terrestrial and aquatic systems in the site area; and
c. Operational assessments -- involving (1) environmental control equipment, its efficiency and reliability, and (2) occupational health control, and the engineering systems used to reduce fugitive emissions.

Information developed in these assessments will be combined with that from studies of several other low-Btu gasifiers, and will be used to investigate the potential impacts of anticipated industry growth.

Sample and Data Management

Successful execution of this program requires that a large number of samples be characterized by many investigators; and that the data and information developed be of high quality and readily accessible in assessment activities. Several thousand samples subjected to numerous analyses and tests, and the on-line monitoring equipment output must be handled the first year. Both sample and data management are required.

Initially, all samples other than those characterized on site will enter a Sample Management Center at ORNL. Samples will be treated as required, forwarded to project leaders responsible for various discipline oriented tasks, and distributed to individual investigators. The Center will serve as the interface between the UMD sampling staff, the discipline task groups, and the Data Management Center.

The Data Management Center will provide a computerized data management system for storage and retrieval of data and information, and will include: (a) structure for data base development; (b) procedures to ensure proper identification and recording of data; (c) network to provide user access to the files; and (d) data analyses routines.

CONCLUDING REMARKS

Design of the monitoring and testing program for UMD involves all of the uncertainties in the characteristics of a gasifier only recently operational, and consequently in the nature of the process streams, byproducts, and effluent streams. Parameters and tests were chosen with emphasis on screening methodologies as opposed to only selected constituents. Program changes can be expected after the first full year of study, with emphasis on investigation of the more significant components.

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