1. Introduction

Morgantown Energy Technology Center (METC) is planning to expand its in-house coal gasification R&D capabilities by installing a research facility that can address a number of concepts including entrained, fluid bed, and catalytic gasification and flash pyrolysis. This Advanced Gasification Concepts (AGC) facility is, in addition, intended to have sufficient flexibility to allow its use beyond the stated objectives that formed the basis for its design. The design, as it currently stands, includes piping and instrumentation diagrams, vessel drawings and specifications, instrumentation lists and specifications, and equipment layout and isometric drawings. Before the design is finalized, a critique is needed to ensure that the intended flexibility and objectives can be met.

This Technical Review of the Entrained Design Report was prepared by Monsanto Research Corp. (MRC) to satisfy the requirements of the U. S. Department of Energy Field Task Proposal/Agreement bearing Contractor Number P79-8-249. The overall objective was to provide Morgantown Energy Technology Center (METC) with a critique of the design report entitled "Engineering and Specification for Entrained Coal Gasification Bench-Scale Pilot Plant," dated August 1979, prepared by Science Applications, Inc. (SAI).

The design approach was evaluated to determine whether the present design will meet the research objectives, including the need for flexibility.

Heat and material balances, critical velocity requirements, vessel arrangements, potential operational problems, and instrumentation were reviewed.

The mechanical design review included a critique of the drawings and specifications, adherence to standards and codes, materials of construction, vessels, piping, valves, heaters, and fittings. In addition, utilities requirements, heat transfer and particulate removal calculations, and pumping and heat exchanger requirements were checked.

An evaluation of the equipment cost includes a critique of the reliability of the equipment cost breakdown, the areas of cost uncertainty, and the areas for potential cost savings.

A safety analysis is provided that identifies highly probable and highly serious potential safety hazards and includes appropriate recommendations.

2. Summary of conclusions and recommendations

This section is a concise comprehensive summary of the significant conclusions and recommendations pertaining to the functional capabilities, cost, and safety of the system. It does not include the suggestions regarding minor clarifications. Additional discussions regarding the conclusions and recommendations are presented in the subsequent sections of the report.

2.1. Several statements in the report require updating and clarification before the associated items are procured. Overall project accuracy should be defined. The criteria should be revised to reflect the actual flow rates for both the gas and coal streams and the actual vessel sizes based on the final reactor volume. Comments in the critique are based on a 3 in. i.d. x 4 ft long reactor, rather than the designs in the SAI report.

2.1.1. The coal feed storage and the char pot volumes should be increased.

2.1.2. The range of the coal feeder should be increased to 1.8 to 24 lb/hr.

2.1.3. The gas flow rates should be increased to the levels shown on the revised Table 3.2. in Section 3 of this report.

2.2. Because of expected high temperatures, further investigation into the use of Dowtherm G or a change in the process to lower the temperature at the char cooler inlet is recommended.

2.3. It was concluded that the proposed rotary star feeder, coupled with modifications based on METC's experience is the best approach.

2.4. The specific design for the heater/reactor has been in a state of development during the time this review was made. A recent design has a larger reactor section (3 in. i.d. and 4 ft long) than the designs described in the report. Design improvements have minimized or eliminated many of the concerns regarding the reactor designs in the report. A review will be made of a different reactor whose size is 3 in. i.d. x 30 in. long.

2.5. The heat transfer calculations in SAI's report for the gas heater are numerically incorrect. The proposed heater design can provide sufficient heat transfer area if higher temperatures can be used, but concern exists regarding the temperature limitations of the silicone carbide. It is recommended that the heater be designed with multiple heating zones, that consideration be given to additional preheater capacity, and that the heat transfer calculations be again reviewed when the heater design is more firm and the maximum gas flow rates have been firmly established. Verbal discussions with SAI indicate that their representative concurs with the above conclusions and recommendations: SAI recommends use of silicone carbide in the 3000°F to 3100°F range.

2.6. The flexibility of the instrumentation for this project could be increased by the use of dual thermocouples to eliminate unnecessary loss of data and the use of data loggers to provide programmable capability.

2.7. The hole configuration for entry of the gas into the reactor and the subsequent mixing of the gas and coal should be dealt with experimentally as suggested in the SAI report.

2.8. The product condenser, H-501, will be marginal at best and should be increased in size since the increased cost would be minimal.

2.9. Since quality control is not mentioned in the documentation provided, it is recommended that consideration be given to the implementation of appropriate quality control measures.

2.10. The liquid cooling system cannot be checked until the heater/reactor is designed. It is not expensive to add extra capacity for future flexibility and it is recommended that this be done.

2.11. The cost estimate should be redone since it was primarily based on both a high and a low pressure system.

2.11.1. Items not on the flow sheet should be deleted from the estimate; for example, dual system components, reverse osmosis system, and N_2 and CO_2 compressors.

2.11.2. Most of the material costs assigned to individual items seemed reasonable.

2.11.3. The estimated cost of the engineering seems low considering the significant amount of effort needed to complete the project.

2.11.4. The allowance for contingency is low for this early in the life of the project.

2.11.5. An escalation factor should have been added to allow for the rise in costs due to inflation.

2.12. The safety requirements of the system and facility and their relationships are not clearly defined in the report. It is recommended that the planned SAR be completed. The following safety recommendations are made:

2.12.1. Use only blow-out walls rather than blow-out walls and a blow-out roof because of the problems associated with snow and ice loading on the roof and the problems of containment of the blow-out portion of the roof.

2.12.2. Use flashback arrestors in pipelines carrying flammable gases and provide pressure sensing and venting devices at all points where pressures may be isolated.

2.12.3. Revise the action and alarm levels for toxic and flammable gases to better ensure personnel safety.

2.12.4. Provide a two-speed ventilation system for the cell. The high speed ventilation should prevent build-up of toxic or flammable gases, and the low speed should maximize the sensitivity of gas detection monitors.

2.12.5. Consider "Human Factors" in the design of the information/alarm systems to ensure proper reaction from operators to system deviations.

2.12.6. Provide fire protection, preferably Halon, for the electronic equipment.

2.12.7. Provide emergency power to all systems necessary to monitor and shut down the process including such things as the air supply to air-operated valves.

2.12.8. Investigate the possible use of the Fenwall explosion suppression system inside the cell area.

3. General review of design report

Section 3 includes general discussions of topics applicable to most of SAI's design report, but not specifically applicable to any single page or few pages of the design report. It complements the discussions in Section 4, which address topics page by page.

3.1. Valving

Temperature, pressure, and flow conditions are specified for each valve, but no manufacturer is listed. Valve specifications need to match conditions at the point of use, and when material lists are generated, these conditions should be verified.

It is important that relief valves be properly sized for flow and that the valve materials are compatible with the gas compositions. It would also be desirable to have a remote indication to show activation for each relief valve.

3.2. Piping Interface

In general, the interfacings do not appear to be a problem. Note, however, that as the final design is generated for the heater/reactor interfacing to the star feeder, gas preheater, steam injector, and char pot will all be important to consider in relation to the temperature gradients at these points.

In general, the vessels appear to have oversized inlet/outlet connections. For example, vessel V-505 calls for a 1-in. Grayloc fitting when 1/2 in. Grayloc could be used for the process connections. Even 1/2 in. Graylocs would require downsizing to fit 1/2 in. tubing.

3.3. Process Flow Limits

Changes in reactor volume have a major impact on the gas and coal flow rates through the system. Several of the test cases were reviewed in an attempt to find the flow limits. These calculations were restricted per METC to a pressure range of 200 to 600 psig and a gas residence time of from 5 to 10 sec for the 3-in. i.d. x 4 ft long reactor size. Table 3-1 in this report lists these limiting tests. The final reactor size should be determined to accurately set these flow requirements.

3.4. Dowtherm System

The recommended temperature use range for Dowtherm G is listed as up to 650°F. The system as designed should not exceed 650°F bulk temperature but film temperatures between 700 - 800°F at the char cooler should be expected. The maximum recommended film temperature is 725°F.

An article in Chemical Engineering, May 28, 1973, p. 91, states that by "exceeding the maximum recommended fluid temperature by 50°F, a 10% sample loss (attributable to venting of volatile products and carbon deposition) has been shown to result from 2 to 4 weeks of continuous operation."

Further investigation into Dowtherm G and other heat transfer media should be done or the process should be changed to reduce the temperature in the char cooler.

Table 3-1 - PROCESS FLOW LIMITS FOR 3-in. i.d. x 4 ft REACTOR

Test Number	Temp. (°F)	Pressure (psig)	Residence Time (sec)	Flow (SCF/lb coal)	Flow (SCFH Specific Gas)	Limit Comment
II A_{1-3} [a]	2800	600	6	65	128	Max. CO Flow
II D_{1-3}	2800	500	5	85	145	Max. CO_2 Flow
III B_{1-3}	2200	600	5	100/50	1180	Max. N_2 Flow
III C_{1-3}	2200	600	5	100/50	1180	Max. H_2 Flow
III D_{1-3}	2200	600	5	100/50	1180	Max. H_2O Flow
					(lb coal/hr)	
II D_{3-1} [b]	3000	200	10	86	1.8	Min. Coal Flow (Total 158 SCFH)
III B_{3-1} [b]	2800	200	5	100	3.4	Low Coal Flow (Total 335 SCFH)
III B_{1-3}	2200	600	5	50	24	Max. Coal Flow

[a] Indices - Relate to SAI Table 6.1 and the order in which the temperature and pressures are listed - i.e. II A_{1-3} - first temperature and third pressure in table.

[b] This pressure minimum is different from those listed on page 35 of SAI report.

If it is decided to retain the Dowtherm G system, METC should take advantage of the free analysis service for Dowtherm media from Dow Chemical and periodically (six months to a year) submit a sample.

3.5. Quality Control

Quality control is not mentioned in any of the documentation provided. The system involves unique designs, hazardous materials, and considerable complexity. As the end result must be meaningful experimental data, it is recommended that consideration be given to the implementation of appropriate quality control measures that meet the intent of a formal program such as DOE AL Appendix 08XA.

3.6. Solids Monitoring

No provision for monitoring solids flow in the system during an experimental run was included in the final report. A further review should be made of this area and consideration given to possible alternatives for verifying solids flow.