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AN ASSESSMENT OF THE TECHNICAL AND ECONOMIC
FEASIBILITY OF CONVERTING WOOD RESIDUES TO LIQUID
AND GASEOUS FUEL PRODUCTS USING STATE-OF-THE-ART
AND ADVANCED COAL CONVERSION TECHNOLOGY

by

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Introduction

Gorham International Inc. has completed approximately fifty percent of its contract program designed to determine the feasibility of retrofitting coal gasifiers for use with wood residues. The program thrust is to determine which state-of-the-art and advanced coal gasification technologies are technically and economically suitable for wood residue gasification. Production of low Btu, medium Btu and synthesis gases will be included in the assessment. Potential design, operational and construction modifications are being systematically identified.

The program efforts completed to date include: (1) critical review of U.S. and foreign patents and published literature related to gasification of carbonaceous materials, (2) on-site interviews with over 30 gasifier developers, users and manufacturers, (3) telephone interviews with over 75 firms active in coal and biomass gasification technology development and commercial operations, (4) identification of the primary advantages and disadvantages relative to utilization of wood feedstocks in fixed bed, fluidized bed, entrained flow and molten bath coal gasifiers.

The project components currently being carried for which results are not yet available include (1) development of preliminary capital and operating costs for fixed bed, entrained flow and fluidized bed gasification systems based on coal feedstock, (2) determination of desired wood feedstock requirements for alternative coal gasification systems, (3) estimation of the economic impacts of retrofitting coal gasifiers with wood feedstocks, (4) preliminary identification of the barriers to implementation of wood gasification, (5) estimation of the rate of gasification for selected coal gasification technologies utilizing wood residues as feedstock.

This report will discuss the general approach for the coal gasification technology screening relative to the potential of specific gasification systems to utilize wood feedstocks. Also discussed is a general description of the gasification technology performance evaluation which will be carried out on those gasification technologies determined to possess potential technical feasibility to operate with wood feedstocks.

When this performance evaluation is completed, the results will be used in concert with the output of the above mentioned technology screening and technology application matching to select specific coal gasification technologies for more detailed technical and economic evaluation. The general application matching approach is discussed briefly in this report in the section, "Primary Coal Gasification Technology Applications."

The last report section presents the preliminary discussion of the parameters critical to the development of wood gasification as an alternative energy source. This discussion is the result of initial efforts designed to develop implementation plans, to identify implementation barriers and to develop alternative implementation strategies.

Project activities for the remainder of this contract program will focus on (1) the development of quantitative documentation to determine the wood retrofit potential of specific coal gasification technologies judged to have maximum conversion possibilities and (2) the development of a real world oriented implementation plan to enable a rational progression from the current coal gasification technology status to commercialization of such technologies retrofitted to utilize wood feedstocks.

Wood Retrofit Feasibility Assessment

The major project efforts to date have focused on data gathering and analysis to make a preliminary wood retrofit feasibility assessment prior to initiation of more detailed technical and economic evaluations.

Based on an evaluation of selected technical parameters, manufacturer/developer interest, prior experience with wood and the availability of equipment for wood feedstock trials, an initial assessment of overall wood retrofit feasibility has been made for the following coal gasification systems:

Dry Ash Entrained Flow Gasifiers

Koppers-Totzek

Ruhrgas Vortex

Slagging Entrained Flow Gasifiers

Babcock & Wilcox Gasifier

Foster Wheeler

BI-GAS

Combustion Engineering

Texaco Coal Gasification Process

Bell Aerospace High Mass Flux

Shell-Koppers

Fluidized Bed Gasifiers

Winkler

COGAS

HYGAS

Synthane

HRI Fast Fluid Bed

CO₂ Acceptor

Battelle Agglomerating Burner Process

Westinghouse

Exxon

U-Gas®

BCR Tri-Gas

Fixed Bed Gasifiers

Lurgi, Dry Ash

Slagging Lurgi

Woodall Duckham/Gas Integrale

Riley-Morgan

IFE Two-Stage

Wellman-Galusha

Wilputte

GEGAS

DOE-MERC Stirred Bed Gasifier

Molten Bath Gasifiers

Kellogg Molten Salt

Rockwell International - Molten Salt

Saarberg/Otto

A narrative discussion of each system's wood retrofit potential and a comparative analysis of systems is being prepared for distribution to individual gasification systems manufacturers/developers prior to discussions designed to finalize the overall wood retrofit potential ratings. The results of each technology assessment will be included in the final contract report.

Gasification Technology Performance Evaluation

Based on the previously reported practical analyses those gasification technologies judged to have the best retrofit potential for wood feedstocks will be evaluated for operational performance.

Gasification technology selection for this analysis will be based primarily on (1) manufacturer/developer interest in operation with wood fuel, (2) apparent retrofit difficulty and associated costs, (3) fuel form and size characteristics, (4) scale of operation, and (5) heating value of product gas. The performance of selected gasifiers will then be compared using simple stoichiometric and equilibrium calculations that have been found suitable for coal gasification (Barnhart et al, 1979). These analyses methods will consider the effects of wood moisture and reactivity, gasifier type (fixed, fluidized and entrained beds) and carbon efficiency. Predicted parameters such as (1) throughput, (2) product heating value, (3) cold gas efficiency and (4) hot gas efficiency should provide a suitable basis for comparing the potential of those gasification technologies most adaptable to utilization of wood feedstocks. The cold gas efficiency is a reflection of the chemical enthalpy of the product gas; while the hot gas efficiency considers both the chemical and sensible enthalpy of the product gas. The predicted throughputs and heating values will enable identification of industrial process applications amenable to utilization of specific retrofitted coal gasification technologies. The cold and hot gas efficiencies will identify those gasification systems most suitable for production of medium and low Btu gases, respectively.

The proposed calculations will proceed in the following manner:

- (1) Determination of the oxidizer/fuel ratio corresponding to the maximum theoretical cold gas efficiency

- (2) Determination of the maximum throughput for a given carbon efficiency
- (3) Determination of the gasifier temperature via an energy balance
- (4) Determination of the product mole fractions by assuming water gas equilibrium at the calculated gasifier temperature
- (5) Determination of the product gas heating value
- (6) Determination of the cold and hot gas efficiencies

In these calculations, the effect of moisture content and the possibility of operation without steam addition (particularly for low Btu gas) will be considered. Also, to facilitate comparisons with prior analyses of biomass and solid waste gasification systems using wood feedstocks, the raw wood feedstock will be a fifty percent moisture "standard wood" as defined by SRI International (Kohn, et al, 1979).

Upon completion of the above analysis, a preliminary implementation program and schedule will be developed for each gasification technology determined to have significant potential for retrofit with wood. The implementation plan will cover necessary technological and nontechnological efforts required for the selected systems to progress from their current state-of-the-art to commercialization using wood as a feedstock. In addition to the standard technical parameters related to actual system operation, a preliminary assessment of financial risk, political, institutional, regulatory, organizational and governmental requirements and potential barriers will be carried out for specific gasification systems. The ultimate result of the above discussed evaluation procedure will be a projected implementation plan and program schedule for the coal gasification technologies with the best retrofit potential with wood feedstocks.

Primary Coal Gasification Technology Applications

Coal gasification technologies have been developed and designed for primary usage in specific applications. Thus, the process applications considered in the original system development have influenced the resultant mode of operation. The four basic operational modes generally considered are:

1. Atmospheric Air Blown
2. Pressurized Air Blown
3. Atmospheric Oxygen Blown
4. Pressurized Oxygen Blown

Nominally, product gas from air blown systems are classified as low-Btu while oxygen blown systems are labeled medium Btu. Based on the published and stated design objectives and applications data, the following is a summary of primary applications for the more prominent coal gasification technologies. The primary design applications represent usage with little or no modification.

<u>Gasifier Type and Developer/Marketer</u>	<u>Status</u>	<u>Primary Design Application(s)</u>
<u>Fixed Bed</u>		
Lurgi - Dry Ash	C	Synthesis Gas (Chemicals & SNG) Combined Cycle Power Generation
Lurgi - Slagging	P.P.	Synthesis Gas (Chemicals & SNG) Large Scale Fuel Gas
GEGAS/General Electric	P.P.	Combined Cycle Power Generation

<u>Gasifier Type and Developer/Marketer</u>	<u>Status</u>	<u>Primary Design Application(s)</u>
<u>Fixed Bed Continued</u>		
Riley Morgan/Riley Stoker	C.	Small Scale Fuel Gas
IFE/Swindell Dresser	C.	Small Scale Fuel Gas
Wellman Galusha/ McDowell-Wellman	C.	Small Scale Fuel Gas
Wilputte	C.	Small Scale Fuel Gas
IGI/Babcock Contractors	C.	Small Scale Fuel Gas
MERC Stirred Bed/DOE	P.P.	Small Scale Fuel Gas
<u>Fluidized Bed</u>		
Union Carbide/Battelle	PDU	Synthesis Gas - Chemicals
Westinghouse	PDU	Combined Cycle Power Generation
Exxon	P.P.	Synthesis Gas
Hydrocarbon Research	P.P.	Small Scale Fuel Gas
Winkler/Davy Powergas	C.	Combined Cycle Power Generation
HYGAS/IGT	P.P.	Synthesis Gas - Sng

<u>Gasifier Type and Developer/Marketer</u>	<u>Status</u>	<u>Primary Design Application(s)</u>
<u>Fluidized Bed Continued</u>		
U-Gas/IGT	P.P.	Combined Cycle Power Generation
BCR-Low Btu	PDU	Combined Cycle Power Generation
CO ₂ Acceptor/Conco	P.P.	Synthesis Gas - SNG
CoGAS/Cogas Development Company	P.P.	Synthesis Gas - SNG
Synthane/PERC	PDU	Synthesis Gas - SNG
<u>Entrained Flow</u>		
Flash Hydropyrolysis/ Rockwell International	L.S.	High Btu gas
BI-GAS/Bituminous Coal Research	P.P.	Synthesis Gas - SNG
Combustion Engineering	P.P.	Large Scale Fuel Gas
Ruhrgas Vortex	C.	Low Btu Fuel Gas
Foster Wheeler	P.P.	Combined Cycle Power Generation
Koppers-Totzek	C.	Synthesis Gas - Chemicals

<u>Gasifier Type and Developer/Marketer</u>	<u>Status</u>	<u>Primary Design Application(s)</u>
<u>Entrained Flow Continued</u>		
Texaco	P.P.	Synthesis Gas - Chemicals
Bell Aerospace Textron	P.P.	Low Btu Gas
Babcock & Wilcox	S.C.	Synthesis Gas - Chemicals

While many of the above gasification technologies have been proposed for uses other than the primary design objectives, the above indicated initial design applications are factors which must be considered when making a final selection of coal gasification technologies for potential use with wood gasification. Thus, the anticipated and target end uses for wood gasification systems should be selected and marketed with the appropriate coal gasification systems' primary design applications to maximize the potential for retrofit success.

Implementation Criteria

Prior to commercialization, retrofitted coal gasification technologies will face several hurdles and potential barriers to implementation. Thus, this contract includes an analysis of potential implementation barriers, formulation of strategies to overcome these barriers and ultimate development of a systematic plan of commercialization which will address key barriers and result in a time and cost effective commercialization route.

Many of the variables which must be reviewed and addressed prior to commercialization of retrofitted coal gasifiers are similar to those for standard coal or biomass gasification. Thus, the approach to development of this implementation plan will include a critique of both coal and biomass gasification programs and attempt to select complementary strategy development utilizing the optimum mix of current and proposed approaches for both coal and biomass.

At this point, only preliminary efforts have been conducted in the implementation planning area with concentrated efforts scheduled upon selection of coal gasification systems and of primary end use technology applications.

The principal items of concern relative to implementation barriers can be grouped into four broad categories as follows:

1. Technical Risk
2. Economics
3. Institutional
4. Environmental

1. Technical Risk: The technical risk associated with all alternative energy sources is a significant barrier to implementation and is a major factor in the increasing dependence on foreign

energy supplies. However, wood retrofitted coal gasification technologies may be able to capitalize on conventional coal gasification progress and overcome this factor more rapidly than biomass systems developed from ground zero. One factor favoring wood retrofitted coal gasifiers is the use of a generally favorable feedstock in systems already proven on a more difficult feedstock. While we do not envision retrofitted systems becoming commercial prior to the original coal units, they could be commercialized in a parallel program provided proper development and implementation programs are formulated and instituted in a timely manner.

In addition to the technical risks associated with gas production, synthetic gas utilization represents considerable uncertainty and concern to potential gas users.

Thus, specific technological programs to demonstrate the routine 1 day term operability of alternative energy production systems of all types are essential to overcome technical risk barriers.

2. Economics: As with any new technology, economic feasibility is an essential element prior to capital fund commitments. Currently, the major deterrent to implementation of alternative energy sources are production of required energy at a competitive price. While the desire for energy independence and long term cost projections can be used to illustrate the desirability of a "construct now" philosophy, the current higher cost per unit of energy makes it difficult, if not impossible, to obtain industrial commitments of required capital funds.

Based on the uncertainty of future energy pricing and the unstable national energy policy, solid economic projections are difficult to make. However, programs designed to define and eliminate technical risk can aid in development of comparative economics by providing more solid design/operational data and by enabling complete project design based on hard data.

3. Institutional: The institutional factors relative to the integration of new energy production sources into the conventional energy picture represent a complex picture. While some traditional sales have started to bend slightly, the rigid, bureaucratic regulatory agencies and utility companies move very slowly and are careful to protect their operational domains. Relationships between buyers and sellers coupled with regulatory controls are an area of much study and proposed new relationships which will play a major role in the speed of new energy source commercialization over technical and economic barriers to be overcome. Thus, preliminary attention and preplanning are essential if these factors are not to cause inordinate delays once energy suppliers/users are satisfied that technical and economic feasibility has been established.

4. Environmental: Any process oriented industry is faced with environmental concerns and energy production via any means is no exception. While technical and economic concerns are caused by regional environmental controls, these must be considered as a part of the overall development and implementation process to avoid surprises at the commercialization stage. The primary impact of environmental requirements will be the increased cost of installing and operating facilities required to meet standards. Probably the most difficult environmental related problem to deal with is the public involvement in site selection and approval. Again, this is now a way of life and proper preparation and education programs are essential to cope with the public concern.

While the above brief discussions only present the gross problems and not solutions, they highlight the major classes of barriers which will be addressed in development of the implementation plan and strategy for wood retrofitted coal gasification technologies during the latter phase of this contract program.

Summary and Fourth Quarter Plans

The overall project schedule was adjusted during the third quarter resulting in rescheduling of all final individual gasification system evaluations and analyses into the fourth quarter. The major efforts planned for the fourth quarter are as follows:

1. Selection of coal gasification systems with greatest potential for retrofit with wood feedstocks.
2. Gasification system performance evaluation (operational evaluation based on preliminary kinetic assessment).
3. Techno-economic analyses of selected gasification systems based on results of item 2 and selected technology applications.
4. Development of basic wood retrofitted coal gasification technology implementation plan.
5. Identification of barriers to implementation and development of strategies to overcome identified barriers.

A revised project completion schedule is being prepared and will be included in the April monthly report.