CONF-940812--19

7873

READINESS THROUGH RESEARCH

DEVELOPMENT OF THE IGT RENUGAS® PROCESS

by

Francis S. Lau
Ronald H. Carty

Paper to Be Presented at the

29th INTERSOCIETY ENERGY CONVERSION ENGINEERING CONFERENCE

Monterey, California
August 7-12, 1994

INSTITUTE OF GAS TECHNOLOGY

3424 South State Street Chicago, Illinois 60616

IGT

DISCLAIMER

DEVELOPMENT OF THE IGT RENUGAS® PROCESS

Francis S. Lau (312) 949-3692
Ronald H. Carty(312) 949-3751
Institute of Gas Technology
3424 S. State Street
Chicago, IL 60616

ABSTRACT

The RENUGAS® process was specifically developed for pressurized fluidized bed gasification of biomass to produce either an industrial fuel gas or a chemical synthesis gas depending on air- or oxygen-blown operation. The RENUGAS® gasifier is a single stage fluidized bed reactor with a deep bed of inert solids that provide stable fluidization behavior and needed heat capacity for efficient transfer of energy released by the combustion to the endothermic devolatilization and gasification reactions. The use of a deep single-stage bed of inert solids yields high carbon conversion and low oils and tars production.

The 11 metric ton per day RENUGAS® process development unit (PDU) built at IGT under a USDOE program, has been tested under various operating conditions with a variety of feedstocks from RdF to woody and herbaceous biomass. Currently, the PDU is being used to test hot gas cleanup for power turbines in support of the Hawaii demonstration gasifier.

Biomass conversions of over 95% were achieved for most biomass tested. The successful demonstration of the PDU tests resulted in RENUGAS® being selected for further scaleup to a 91 metric ton per day demonstration gasifier being constructed in Hawaii by the Pacific International Center for High Technology Research (PICHTR); a research program being conducted by Westinghouse Electric to validate a hot gas cleanup system for operation of the RENUGAS® gasifier with a gas turbine; and the feasibility study of a 70-80 Megawatt combined cycle power plant using an air blown RENUGAS® gasifier with alfalfa stems as the feedstock.

In this paper, the IGT RENUGAS® process is described and its status in three current programs is discussed.

IGT RENUGAS® PROCESS

Research leading to the RENUGAS® process began at IGT in 1977 with in-house research funds to develop a thermochemical gasification process specifically for biomass feedstocks. The properties of biomass feedstocks were recognized to be unique from those of coal, hence a process scheme different from that of coal gasifiers was tailored for biomass. Complete gasification with high carbon conversion was an important goal of the process concept. Typical biomass pyrolysis or charcoal production systems were not adequate for or directed toward gas production.

The initial research at IGT focused on determining the gasification rate-controlling process steps and investigating specific properties of biomass feedstocks and biomass char characteristics. A process for pressurized fluidized bed gasification was conceptualized and patented.

USDOE support of the RENUGAS® process development from 1981 through 1987 progressed from lab-scale to bench-scale and cold-flow fluidization testing of the critical process steps . This information was applied to the design of an adiabatic PDU able to gasify 11 metric tons per day at pressures up to 3.4 MPa. The PDU capacity was chosen to be between one-tenth and one-twentieth of the capacity of the expected commercial gasifiers. This is a reasonable scaleup factor for the highly reactive biomass feedstocks.

The PDU was operated over a period of two years during which 23 biomass gasification tests were conducted feeding over 80 metric tons of biomass and logging 220 hours of steady-state operation. The first series of tests were of short steady-state duration intended to investigate the effects of process parameters for process optimization. Parameters that were studied were gasification temperature, pressure, feed moisture, feedstock type, steam input, inert fluidized bed media, and fluidized bed height and superficial gas velocity. Longer term gasification tests were conducted at optimum conditions at the end of the DOE program, concluding with a successful 3-day steady-state gasification test that confirmed the results of the initial tests. Biomass conversion of 96% was achieved during the 3-day test.

From 1988 to the present, various specific feedstock gasification tests have been conducted for industrial sponsors and for DOE for a demonstration biomass gasifier plant. The biomass feedstocks that have been gasified include maple wood chips, whole-tree-chips from two U.S. regions, California highway clippings, refuse-derived-fuel, bark and paper mill sludge, and bagasse from Hawaii.

A simplified RENUGAS® process flow diagram is shown in Figure 1. Biomass is fed to a single, fluidized bed gasifier vessel that operates at pressure. Inert solids in the vessel form the stable fluidized bed into which the biomass is fed near the bottom. All of the biomass ash is carried overhead with the product gases. Mixing in the fluidized bed of the high heat capacity inert solids with the biomass char distributes the heat energy released from the combustion to the endothermic gasification reactions. By using the inert fluidized bed media, the low bulk density biomass char is retained longer in the gasifier and reduced in size thus exposing more char reaction surface area which contributes to higher carbon conversion. Thus single-screened biomass feedstocks can be fed to the fluidized bed gasifier.

The RENUGAS® process offers different gas product options by simple changes in gasifier operating conditions. The options depend mainly on the pressure selected for gasification and whether air or oxygen is used as the oxidant. If the gasifier is operated under air-blown conditions, then a low calorific gas is produced which can be used as an industrial fuel gas or, if generated at higher pressures, can be used for combined cycle power generation. When the gasifier is operated under oxygen-blown conditions, it produces a medium calorific gas, or synthesis gas, which after upgrading, could be suitable for production of methanol or other chemicals.

Pressurized operation makes the fluidization gas bubbles smaller which minimizes slugging behavior. Thus fluidization and mixing are smoother at high pressure than at near-atmospheric pressures. The pressurized product gases from the gasifier advantageously overcome pressure drops through piping, filters, and possible catalytic beds and thus improves process efficiency for both synthesis gas applications, and combined cycle power generation. The addition of steam to the RENUGAS® gasifier accomplishes greater char conversion by the steam-char reaction, lowers oils and tar production, and moderates the temperature in the region about the oxidant gas distributor.

RENUGAS® PDU GASIFICATION TEST INFORMATION

The initial RENUGAS® PDU parametric tests were conducted over a range of 754 - 982°C, from 0.6 to 2.14 MPa, and feed rates up to 467 kg/h. The steam input ranged from 0 to 1.2 kg/kg biomass and the feed moisture ranged from 5 to 27 wt%. Table 1 presents the input PDU test conditions and the output information for wood chip gasification tests exploring steam-oxygen-blown and air-blown operation. For process design considerations, the differences are apparent between oxygen- and air-blown conditions in terms of the gas composition, heating value, and the reported cold gas thermal efficiency which shows the thermal penalty of superheating nitrogen.

The gasification temperature is the single, most important operating parameter. It affects the composition, yield, and heating value of the product gas as is shown in Figures 2 and 3 for a typical woody biomass species. The biomass carbon that is converted to gases and condensible species and the oxidant demand also increase with the gasification temperature. For most biomass species tested in the single-stage RENUGAS® PDU, 95% carbon conversion was achieved with temperatures in the range of 815 to 899°C. The range of information provided by the PDU is needed for setting basic process conditions for specific biomass species.

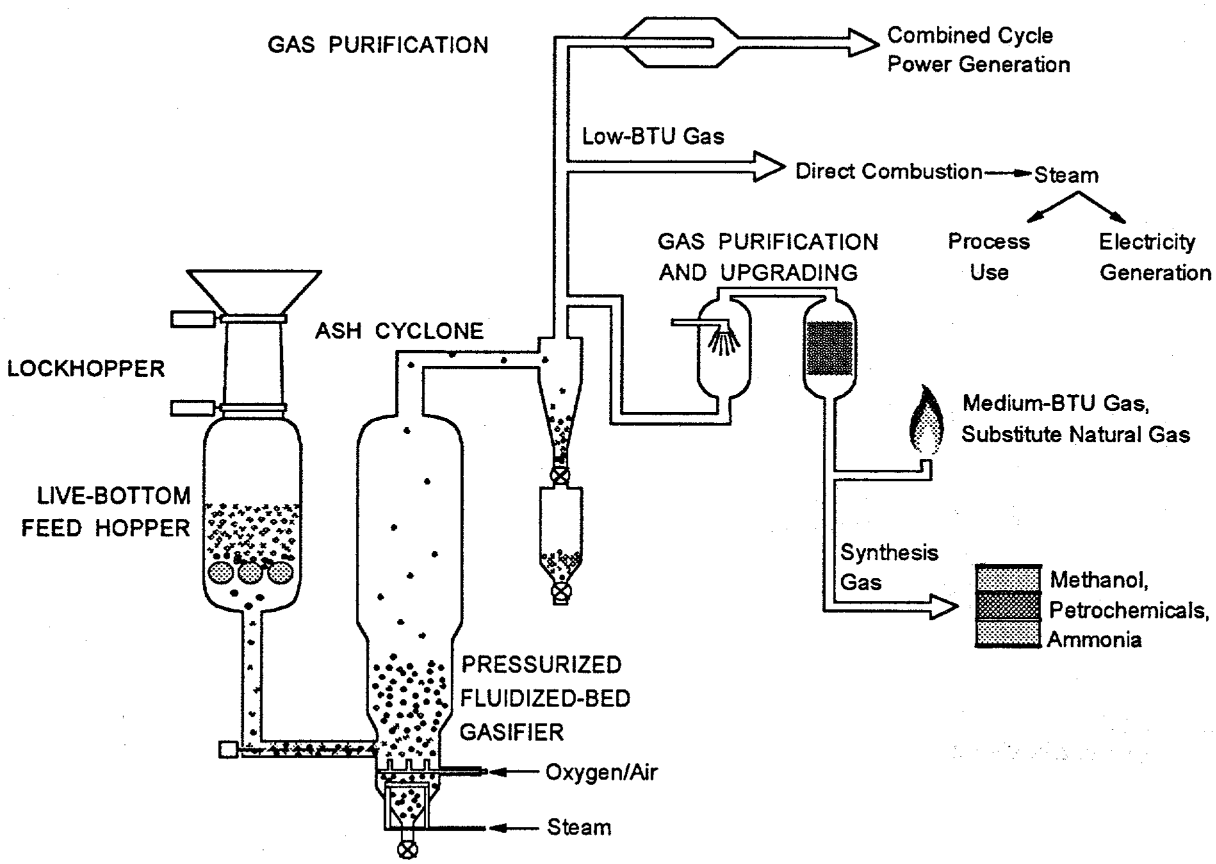

Figure 1. SCHEMATIC OF RENUGAS® PROCESS

Table 1. TYPICAL GASIFICATION CHARACTERISTICS OF WHOLE-TREE-CHIP FEEDSTOCK

	Oxygen-Blown Test T12-3A	Air-Blown Test GT-15
Pressure, bar	21.9	22.1
Temperature, °C	911	827
Feed Rate, kg/h	321	305.5
Moisture, wt%	9.14	14.5
Steam, kg/kg feed (wet)	0.69	0.41
Oxygen, kg/kg feed (wet)	0.26	0.25
Nitrogen, kg/kg feed (wet)	-	0.87
Product Gas Flow Rate, Nm^3/h	736	757
Product Gas Composition, vol%		
H_2	14.81	8.84
CO	8.43	7.49
CO_2	20.34	13.61
CH_4	8.87	5.11
C_2H_4	0.00	0.20
C_2H_6	0.02	0.27
C_3H_8	0.00	0.00
C_6H_6	0.48	0.49
N_2	0.00	28.24
H_2O	47.05	30.03
Total	100.00	100.00
Heating Value MJ/Nm^3 (dry)	13.78	5.79
Gas Yield, Nm^3/kg feed (wet)	1.61	2.03
Cold Gas Thermal Efficiency, %	80.7	73.0
Superficial Gas Velocity, m/s	0.60	0.58

CURRENT STATUS OF THE RENUGAS® TECHNOLOGY

Currently, IGT is participating in three development programs that are advancing the RENUGAS® biomass gasification technology through the demonstration and commercialization stages. These programs are:

- design and testing of a 90 metric ton per day demonstration gasifier being constructed in Hawaii by the Pacific International Center for High Technology Research (PICHTR)
- a research program being conducted by Westinghouse Electric to validate a hot gas cleanup system for operation of the RENUGAS® gasifier with a gas turbine
- the feasibility study of a 70-80 Megawatt combined cycle power plant using an air blown RENUGAS® gasifier with alfalfa stems as the feedstock by Northern States Power Company

The first two of these are closely linked and are designed to demonstrate the RENUGAS® technology for power generation. The aim of the third project is to lead to the first commercial installation of a combined cycle power generation facility based on this technology.

Hawaiian Demonstration Unit

Bagasse feeding and gasification tests were conducted by IGT in the RENUGAS® PDU in support of the program to build a 90 metric ton per day demonstration gasification plant in Hawaii by The Pacific International Center for High Technology Research Inc. (PICHTR). Other members of the team to build and operate the bagasse demonstration gasifier are The Hawaiian Natural Energy Institute, Parsons Honolulu, and The Hawaiian Commercial and Sugar Co. IGT is providing design and operational information and support to the program.

All of the major components of the demonstration facility have been purchased and are on site ready for assembly. These include the gasifier shell, the bagasse feeder, and the dryer. Site preparation is complete and the steel superstructure construction has begun. It is planned for the construction of the demonstration facility to be completed in the Summer of 1994 with shakedown to be completed and testing to begin in the Fall of 1994.

The facility, jointly funded by the USDOE, State of Hawaii - Department of Business, Economic Development and Tourism (SOH-DBEDT), and Industrial Partners, will be the center piece for DOE biomass to energy programs. In addition to demonstration of electrical energy production from the product gas, applications to methanol production, fuel cells and other bioproducts will be demonstrated.

Hot Gas Cleanup Program

In support of the U.S. Department of Energy's Biomass Power Program, a Westinghouse Electric led team consisting of the Institute of Gas Technology, Gilbert/Commonwealth, and the Pacific International Center for High Technology Research is conducting a 30 month research and development program. The program will provide validation of hot gas cleanup technology with a pressurized fluidized bed, air-blown, biomass gasifier for operation of a gas turbine. The PDU has been modified to incorporate the hot-gas cleanup vessel including ash lockhoppers. The approach being taken is to first evaluate the options available for HGCU systems and select the most appropriate system for the application. The filter system chosen will be operated at temperatures in the 760°-816°C range.

It has also been determined that a tar cracking reactor will be necessary for HGCU filter element protection. The HGCU filter system and tar cracker will first be operated at the IGT RENUGAS® PDU. A series of three, 72 hour, steady state tests will be conducted to evaluate performance of the HGCU system. The feedstock for these tests will be bagasse. Data from these tests will be used to determine alterations to hardware configurations, changes to the test plans, and design specifications for the scaled-up HGCU to be installed at the Hawaiian demonstration plant.

Once this series of short duration tests are completed the HGCU system and tar cracker will be dismantled and moved to the Hawaiian demonstration plant. There, PICHTR will install the equipment in a slipstream on the 91 metric ton per day demonstration plant. A long duration test of 500 hours will then be conducted to demonstrate the durability of the HGCU system as well as investigate transient operating conditions.

The modifications to the PDU including the addition of a tar cracker unit, gas and particulate sampling ports, and the HGCU designed and constructed by Westinghouse Electric have been installed and shakedown of the system is currently underway. The tar cracker will be tested prior to installation of the candle filters in the HGCU and its efficiency and operational parameters will be determined. Initial testing of the HGCU will begin in July of 1994.

Feasibility Analysis of a 70-80 Megawatt Combined Cycle Power Generation Facility

Northern States Power Company (NSP), Minnesota's largest electric utility, is leading a team that includes IGT, Tampella Power Corporation, Westinghouse Electric, and the University of Minnesota in conducting a cooperative cost-shared study to determine the feasibility of establishing a biomass fueled electric power generation system at NSP's existing coal-fired power plant in Granite Falls, Minnesota. The system will consist of a 70-80 Megawatt combined cycle power plant using an air blown RENUGAS® gasifier with alfalfa stems as the feedstock. Westinghouse Electric will supply the hot gas cleanup system, combustion turbine, and second stage steam power generator to complete the combined cycle system. The feasibility analysis is scheduled for completion in the Fall of 1994.

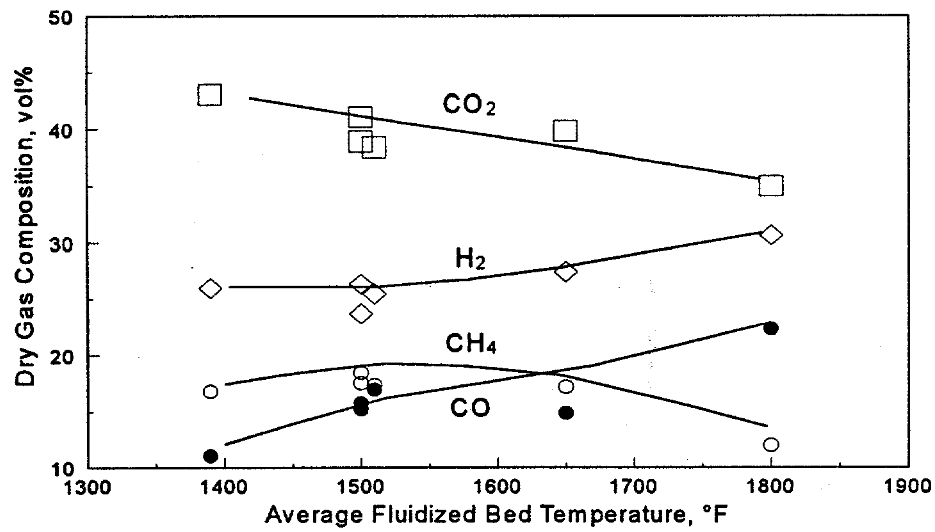

Figure 2. GAS COMPOSITION VERSUS TEMPERATURE (Maple Feed, Gasification Tests GT-1 Through GT-8)

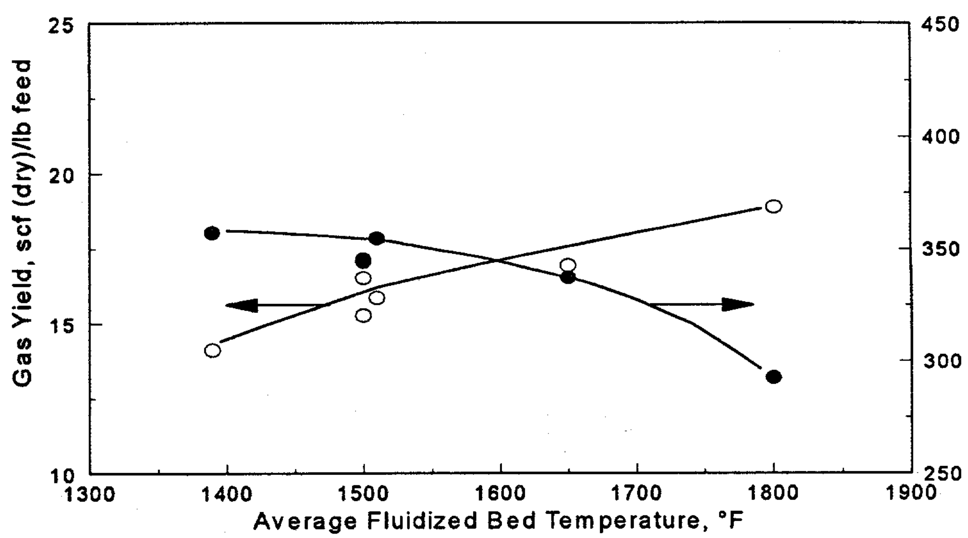

Figure 3. GAS YIELD AND HEATING VALUE VERSUS TEMPERATURE (Maple Feed, Gasification Tests GT-1 through GT-8)