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INTEGRATED SOLAR RECEIVER/ BIOMASS GASIFIER RESEARCH

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NOTICE

INTEGRATED SOLAR RECEIVER/BIOMASS GASIFIER RESEARCH AT SERI

by

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BACKGROUND

Because of declining domestic production of fossil fuels, increasing attention is being given to the production of fuels and chemicals from renewable resources such as biomass. Biomass can be pyrolyzed using heat from a concentrating solar collector to produce unsaturated hydrocarbons (olefins), which can be particularly valuable as feedstocks in the chemical industry and as precursors to gasoline in the fuels industry. Use of solar thermal energy to drive the pyrolysis increases the yield of olefins because it eliminates the need to use some of the biomass feedstock as a fuel for the process. The rate of pyrolysis greatly affects the product distribution. The relatively slow pyrolysis of biomass in a fixed bed reactor produces mainly carbon monoxide and hydrogen. In contrast, the characteristic high temperature and low residence time of fluidized or entrained bed reactors induce fast pyrolysis of the biomass, producing significant quantities of olefins.

Processes for producing liquid fuels from olefin-rich pyrolysis gases obtained from fast pyrolysis of biomass are being developed by J. Kuester at Arizona State University (Kuester 1979) and J. Diebold (Diebold and Smith 1979) at the Naval Weapons Center, China Lake, Calif. These processes are illustrated in Fig. 1. In the Diebold process the biomass, carried by steam, is blown through an entrained bed gasifier. The olefins are then separated from the rest of the reaction products and polymerized thermally to gasoline; the other gases are used as fuel for the process. The Kuester process uses a fluidized bed gasifier and a catalytic Fischer-Tropsch reactor which converts the olefins, hydrogen, and carbon monoxide into n-propanol and paraffinic hydrocarbons. The advantages over the Diebold process are shorter residence time and elimination of the gas separation requirement. One disadvantage is the low octane rating of the fuel.

As part of the solar thermal program at the Solar Energy Research Institute (SERI), an entrained bed reactor/receiver for fast pyrolysis of biomass is being developed for use with either the Diebold or Kuester process.

LABORATORY RESEARCH

Before an integrated pyrolysis reactor/receiver can be designed and operated properly, many questions must be answered concerning the mass, momentum, and energy transport processes occurring within the reactor. In particular, the effects of the following variables on olefin yields need to be determined:

- type of biomass feedstock,
- reactor wall temperature,
- reactor length,

- residence time,
- carrier gas temperature,
- carrier gas to biomass flow rate ratio,
- convective heat transfer rate, and
- biomass particle size.

The effects of these variables are being investigated in the High Temperature Applications Laboratory at SERI using the apparatus shown in Fig. 2. A twin-screw feeder meters the finely divided biomass into a superheated-steam carrier stream which transports the biomass through an electrically heated tubular reactor. After leaving the reactor, the flow is quenched in a venturi scrubber. The liquids and char flow into a holding tank, and the gases flow through an orifice meter before being flared off. An air-driven ejector at the end of the system provides suction on the system and premixes the gases with air before the flare.

The reactor consists of five flanged stainless steel tube sections 30 cm long with a 12-mm inside diameter. Sections can be added or removed to vary reactor length. A resistance wire heater, controlled by a variable transformer, is wound about each reactor section. Wall thermocouples and thermocouple probes are located at 15-cm intervals along the reactor length. The variable transformers can be adjusted to simulate constant wall temperature or constant heat flux along the reactor. Gas sampling ports are located at 15-cm intervals.

A gas-fueled, 2-hp boiler provides steam for the system at a maximum outlet pressure of 0.7 MPa (100 psig). The saturated steam is superheated in a gas-fired kiln and flows through a sonic orifice in a housing below the screw-feeder outlet.

Temperatures, pressures, flow rates, and reactor power levels are monitored and stored by a data logger. Gas samples are collected in evacuated cylinders and analyzed with a Hewlett-Packard Model 5840 gas chromatograph.

The planned operating ranges of system variables are:

Biomass feed rate: 0.5 to 1.0 kg/h
Reactor length: 30 to 150 cm
Reactor wall temperature: 500°C to 1000°C
Residence time: 15 to 150 ms
Steam temperature: 500°C to 1000°C
Steam/biomass ratio: 0.5 to 2.0
Biomass particle size: 50 to 500 μm.

REACTOR ANALYSIS

To promote understanding of the significance of reactor parameters, a one-dimensional model of a biomass pyrolysis reactor was developed. The model employs the global kinetics expression for gasification rate of cellulosic feedstock developed by Antal (1979). The endothermic heat of reaction, average wall heat transfer coefficient, wall temperature, and mass flow rates of steam and biomass are parameters in the model.

Figure 3 is a plot of the extent of the reaction versus distance along the reactor calculated by the computer model using parameters representative of the laboratory reactor.

To help clarify the interaction between heat transfer and reaction rate, the input variables of the computer model were manipulated until the outlet temperature and extent of reaction matched the experimental values. Since Antal's measurements were made at much lower heating rates than those used in our laboratory experiment, it was necessary to increase the pre-exponential factor in his kinetic expression by an order of magnitude.

Tempered by data obtained from the laboratory experiments, the model will be useful in establishing design values and operating variables for the pyrolysis reactor/receiver.

BIOMASS RECEIVER

A sketch of the first biomass pyrolysis receiver to be fabricated at SERI is shown in Fig. 4. This design is based on the copper receiver currently under development at SERI (Bohn and Bessler 1979). Two coils are embedded within the copper: one for steam generation and the other for pyrolysis. The copper mass stores heat, thus dampening transient insolation variations, and also serves as an excellent heat transfer medium. The maximum operating temperature of 950° C is limited by the melting temperature of copper.

The biomass receiver has been designed for testing at SERI on a paraboloidal solar concentrator, 6 m in diameter. Although this receiver design may not be optimum, it will permit early integration of the pyrolysis system hardware with the solar concentrator.

Due to the complexity of the pyrolysis system and the requirement for solids transport, the pyrolysis reactor/receiver may be more easily integrated into a central receiver system than a distributed receiver system. Therefore, after the SERI tests, the biomass receiver should be scaled up and tested at one of the central receiver test facilities.

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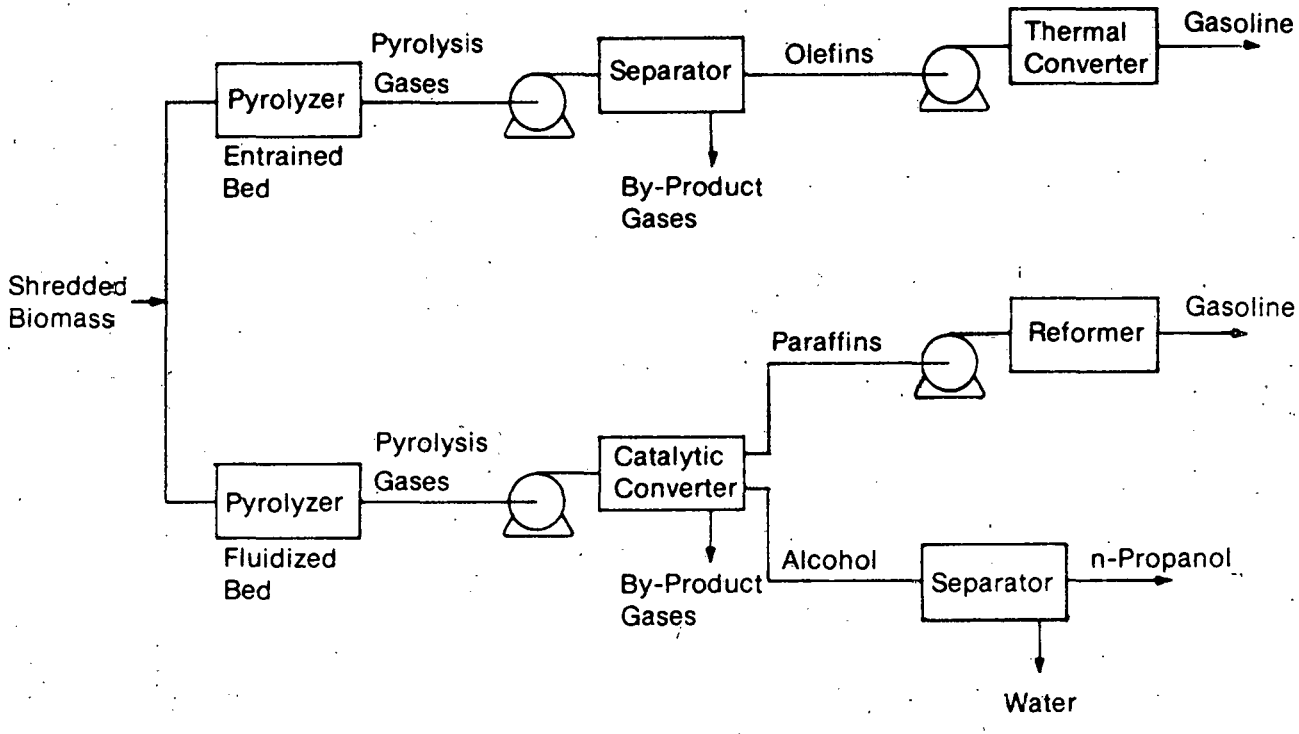

Figure 1. Processes for Producing Liquid Fuels from Biomass

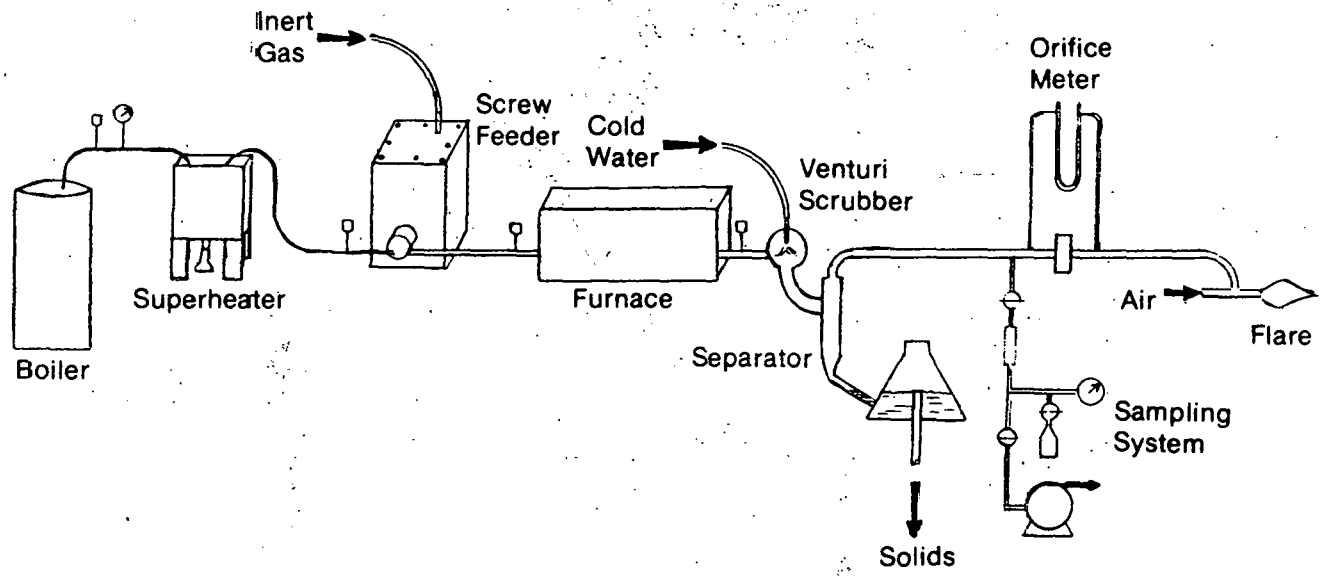

Figure 2. Laboratory Apparatus for Biomass Pyrolysis

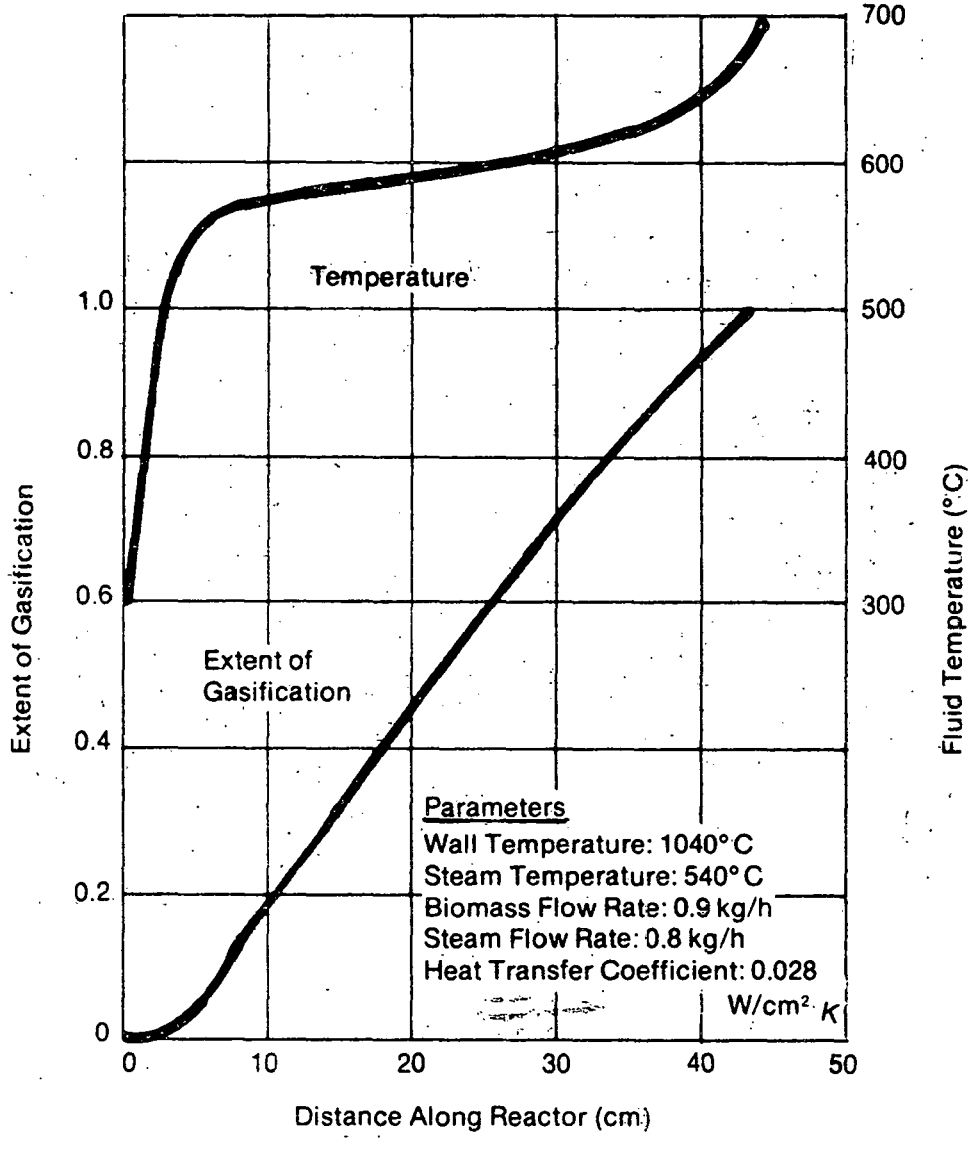

Figure 3. Theoretical Profiles of Temperature and Extent of Gasification

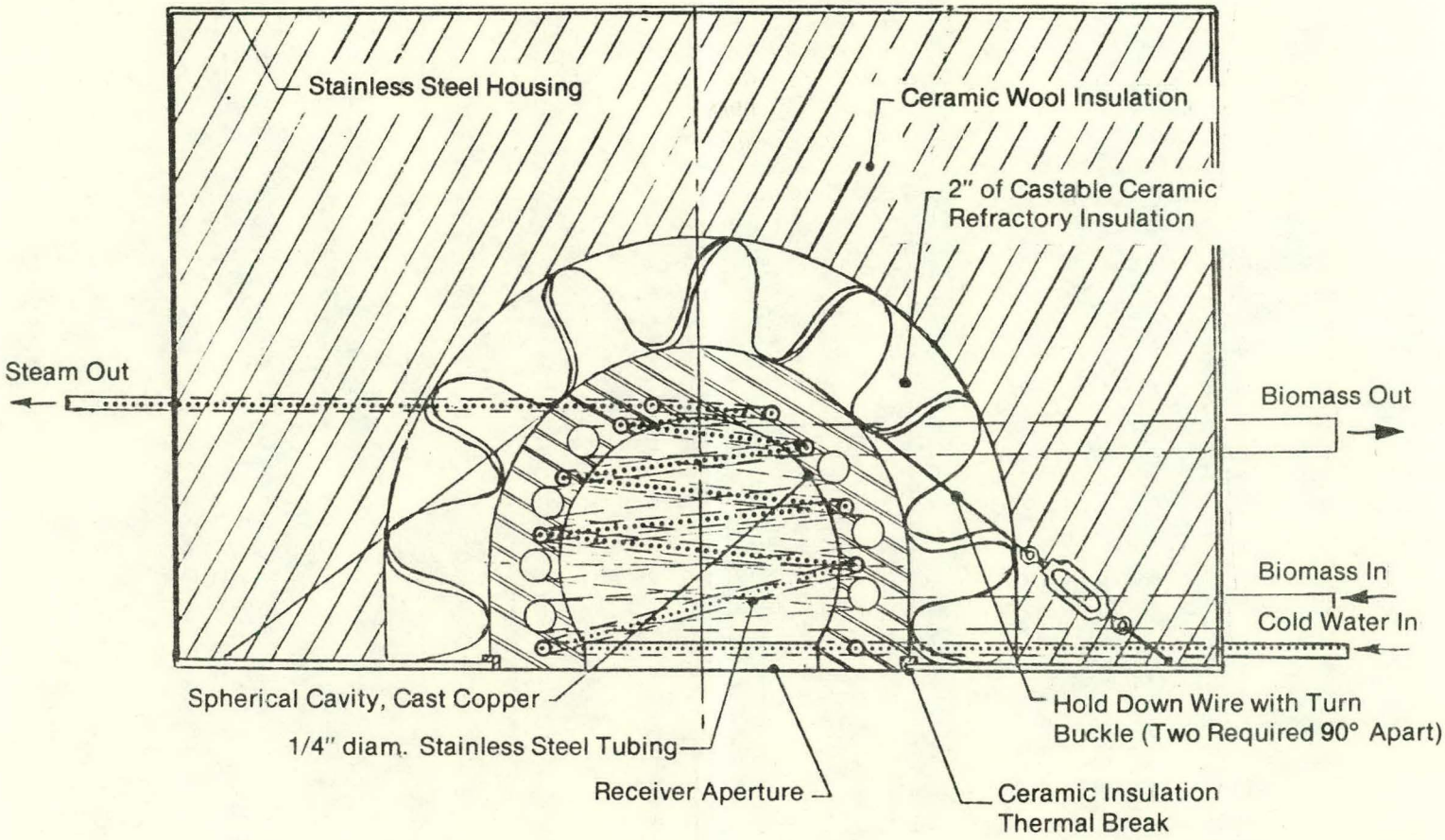

Figure 4. Solar Thermal Receiver for Pyrolysis of Biomass

*GPO: 1980--677-175/99