DESIGN OF A WOOD WASTE-TO-OIL PILOT PLANT

Elsio Del Bel, Sam Friedman, Paul M. Yavorsky
and Henry H. Ginsberg

Pittsburgh Energy Research Center, U.S. Department of the Interior
Bureau of Mines, 4800 Forbes Avenue, Pittsburgh, Pa. 15213

The Pittsburgh Energy Research Center of the U.S. Bureau of Mines has, for a number of years, been involved in programs for the conversion of coal to fuel oil. One such process, based on the findings of Fischer & Schrader [1] that low-rank coals could be hydrogenated with carbon monoxide and steam, is currently being developed. An interesting and significant offshoot of this work was the observation that lignin, cellulosic materials, and plastics could be converted to oil by the same chemical processing. Thus, the potential exists for the disposal of vast amounts of environmental pollutants and the creation of a replenishable energy source. Estimates indicate that the equivalent of one billion tons of dry, mineral matter-free organic waste will be generated in the U.S. in 1974. The energy value of this waste is 12-16 x 10^{15} Btu or approximately 17 pct of the total estimated 1974 energy consumption in the country. Basically the waste-to-oil process involves the reaction of carbon monoxide and steam with organic waste material in the presence of sodium carbonate catalyst at temperatures of 250°-400° C and 2,000-4,000 psig pressure. The technical feasibility of the process was demonstrated in batch autoclave and bench-scale continuous process unit runs[2,3]; the results and observations from this work was the basis for the design of a pilot plant for converting 1-3 tons per day of wood chips to oil. This pilot unit is currently being constructed on the site of the Bureau of Mines Metallurgical Station at Albany, Oregon. An overall process-flow diagram is presented in Figure 1.

Wood Chips Drying and Grinding

The wood chips (1/4" x 2" x 2" maximum size) will be withdrawn from the storage bin by the table feeder and fed into a rotary dryer where the moisture content will be reduced from 45 to 4 wt pct. The dry chips will be pulverized to -50 mesh in a hammermill and then conveyed pneumatically in an inert gas stream to the wood flour surge bin.

Feed Systems

The area of principal difficulty encountered in the operation of the bench-scale continuous units was the feeding of the wood oil slurry into the reactor. This problem is caused by the fibrous nature of the cellulosic waste material and its low-bulk density. Accordingly, three separate feed systems were designed into the wood-to-oil pilot plant; namely,

1. Wood-oil slurry feed
2. Pretreated wood-oil slurry feed
3. Solids feed

In the wood-oil slurry feed system, the pulverized wood will be continuously mixed with some of the product oil to form a slurry containing 30 wt pct solids. This slurry, which is extremely stiff, will be injected into the reactor feed lines by a high-pressure plunger pump with special check valves to minimize fouling.

The pretreated wood-oil slurry system is very similar to the wood-oil slurry feed technique with the exception that the raw wood chips will first undergo a partial carbonization to increase their bulk density. Hopefully, slurries of greater than 30 wt pct concentration of wood can be prepared through this technique. The pretreatment will involve heating the raw wood chips with some additional water to 500° F in a closed vessel. A pressure of approximately 700 psig will be developed from the steam. After process conditions have been maintained for a fixed time period, the pretreater and its contents will be cooled to 150° F by means of an external pump loop and an air cooled heat exchanger. The pretreated wood will then be separated from the water by vacuum filtration, dried, pulverized to -50 mesh, mixed with recycle oil, and fed to the reactor as described previously.

Direct solids feeding of wood flour will be accomplished by a lock-hopper system. This method of operation permits the greatest throughput per reactor volume but is quite complex and difficult to operate. Basically the feed system consists of two pressure-balanced lock hoppers which will be used alternately. The process gas, carbon monoxide, must be used to pressurize the feed system because of partial pressure considerations; i.e., the partial pressure of the carbon monoxide in the reactor would be reduced considerably if inert gas were used to pressurize the lock hoppers. Metering of the solids will be effected by a rotary feeder installed on the exit side of each lock hopper. During operations, a lock hopper at atmospheric pressure will be filled with -50 mesh wood flour from the storage bin. The unit will then be pressurized to operating pressure and the solids fed to reactor via the rotary feeder. When a lock hopper is empty, the pressure in the vessel is reduced to atmospheric by first venting to a carbon monoxide surge tank and finally to a flare stack. The surge tank, which is not shown in figure 1, is used to capture most of the carbon monoxide from the lock hopper for re-compression and reuse in the next cycle. In this feed system, recycle oil will be pumped separately into the reactor so that the desired ratio of wood-to-oil can be maintained.

Catalysts and Process Gas

Sodium carbonate solution will be prepared and pumped continously into the reactor by means of a high-pressure plunger pump.

Carbon monoxide process gas will be taken from 35,000 scf tube trailers and compressed to operating pressure in a non-lubricated, non-contaminating diaphragm-type compressor. The compressed process gas will be preheated in a gas-gas interchanger and sparged into the reactor. Later, synthesis gases of various H_2:CO molar ratios will be used as the process gas.

Reaction and Subsequent Processing

The reaction will take place continuously at temperatures in the range of 250°-400° C and pressures of 1,500 to 4,000 psig. The liquid flow from the reactor will be cooled to 200° C in an air-cooled bottoms cooler and pressure reduction will be effected by a pressure reducing valve operating on a reactor liquid level controller. As the pressure is reduced, some liquid will flash and the remaining will be collected in a bottoms tank and then pumped to a centrifuge where oil and water are separated. The oil will then be filtered to remove any solids and transferred to a hold tank. Residual gases from the flash tank will be measured, analyzed continuously for carbon monoxide, carbon dioxide, and hydrogen and flared in the flare stack.

The reactor off-gases will be cooled in a gas-gas interchanger and then undergo a pressure reduction by means of a reducing valve operating on a pressure controller. The gas will then be cooled to 80° C in an off-gas cooler, measured, analyzed continuously for carbon monoxide, carbon dioxide, and hydrogen, and finally flared.

The plant has the capability of producing 3 barrels of oil per day from wood waste. The product oil will be collected in an oil hold tank and then transferred to 55-gallon drums. Routine product oil analysis will include water and solids content, benzene solubles and insolubles, asphaltenes, viscosity, and heating value. Present plans call for the processing of other organic waste products upon completion of the wood-to-oil program.

Literature Cited

1. Fischer, F. and H. Schrader. Brennstoff-Chem. 2 257 (1921).

2. Appell, H. R., Y. C. Fu, Sam Friedman, P. M. Yavorsky, and Irving Wender. U.S. Bureau of Mines R.I. 7560, Converting Organic Wastes to Oil.

3. Friedman, S., Henry H. Ginsberg, Irving Wender, and Paul M. Yavorsky. Continuous Processing of Urban Refuse to Oil using Carbon Monoxide. The 3rd Mineral Waste Utilization Symposium. IIT Research Institute, Chicago, Illinois, March 14-16, 1972.

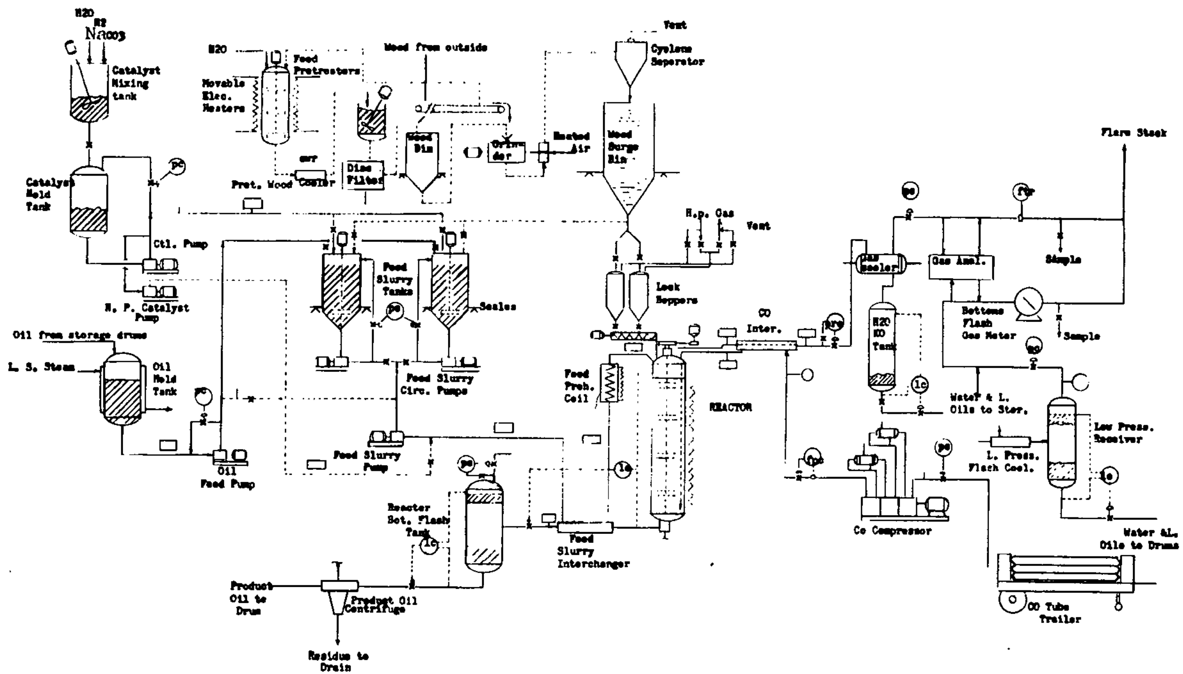

Figure 1 – Schematic flow diagram wood waste-to-oil pilot plant