

## Production of hydrogen by catalytic steam reforming of “trap grease”

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At present, hydrogen is produced commercially mostly from fossil fuels such as natural gas, naphtha, and coal. However, the full environmental benefits of hydrogen-based energy systems can only be achieved when hydrogen is produced from renewable resources. We believe that in the future biomass can become an important sustainable source of hydrogen. Because of the chemical composition (6-6.5% hydrogen, 42-48% carbon), lignocellulosic biomass can only yield relatively low amounts of hydrogen - 12-14% based on the dry feedstock weight. Therefore, in order to compete with fossil fuels, the strategy for producing hydrogen from biomass must include co-products of higher value. Over the last several years we have been developing an integrated process [1-3], in which biomass is partly used to produce valuable materials (such as fibers) or chemicals (such as phenolics) while the residual fractions are utilized for generation of hydrogen.

Biomass-derived vegetable oils have a better potential for producing hydrogen than lignocellulosic materials because of their high carbon and low oxygen content, but their high costs make the process economics not favorable. However, we identified a waste stream, “trap grease”, that looks very promising for the production of hydrogen. “Trap grease” is a widely available low-cost waste material recovered from restaurants, food processing plants, and water treatment facilities. The estimated amount of 13 lbs/person/year of “trap grease”<sup>4</sup> is a potential source of 1 billion pounds (0.5 Mt/year) of hydrogen. The objective of this work was to evaluate the feasibility of producing hydrogen from “trap grease” by catalytic steam reforming.

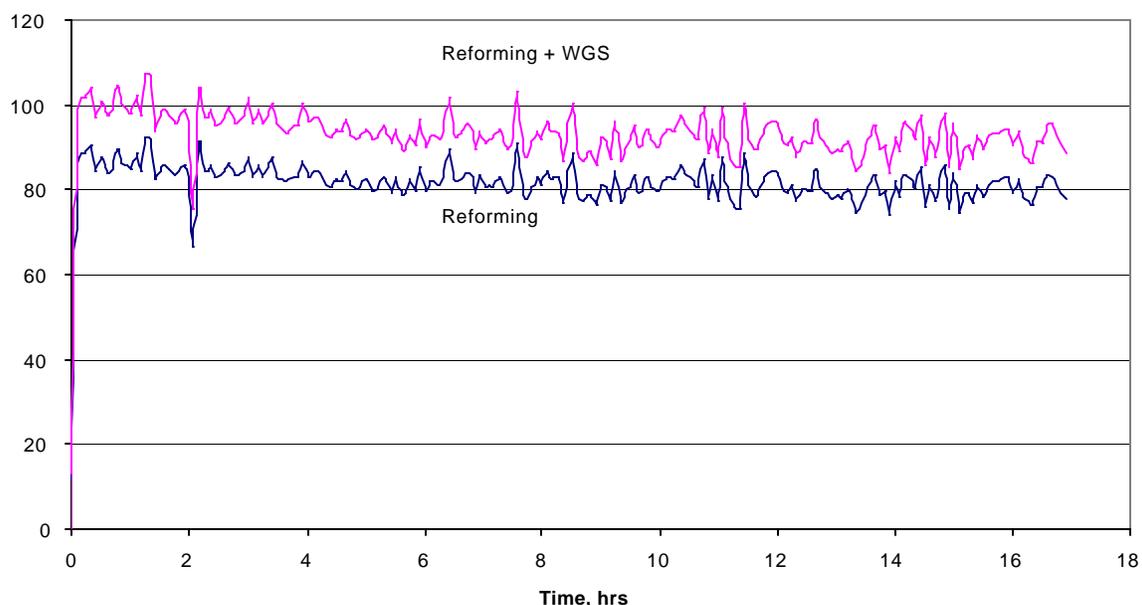
### Experimental Procedures and Results

Samples of trap grease were obtained from Pacific Bio-diesel, a company collaborating with the DOE Bio-diesel Program. The raw trap grease was filtered (at Pacific Bio-diesel) to remove solid impurities. The grease was a dark colored liquid of very high viscosity at room temperature. However, at 45°C its viscosity decreased to app. 80 cP, which made it easy to pump. The grease mainly comprised fatty acids and their mono-, di-, and triglycerides. The overall elemental analysis of the grease showed 75.5% carbon, 11.8% hydrogen, and 12.7% oxygen corresponding to the formula of  $C_{18}H_{33.8}O_{2.27}$ .

The steam reforming experiments were carried out using a bench-scale fluidized bed reactor system described previously<sup>3</sup>. The reactor contained 280g of commercial nickel-based catalyst (C11-NK) developed by United Catalysts for reforming moderately heavy petroleum fractions. The catalyst, ground to a particle size of 300-500 $\mu$ , was fluidized using superheated steam, which was also a reactant in the reforming process. “Trap grease” was preheated to 60°C and fed to the reactor using a diaphragm pump. An injection nozzle was used to spray liquid into the catalyst bed. The product collection line included a cyclone, a hot-gas filter, two heat exchangers that condensed excess steam and a condensate vessel. The outlet gas flow rate was measured by a mass flow meter and by a dry test meter. The concentrations of CO<sub>2</sub>, CO, and CH<sub>4</sub> in the reforming gas were monitored by an infra-red analyzer (NDIR Model 300) and hydrogen was observed via a thermal conductivity monitor (TCM4). In addition, the gas was analyzed every 5 minutes by an on-line MTI gas chromatograph, which provided concentrations of hydrogen, carbon monoxide, carbon dioxide, methane, ethylene, and nitrogen. The temperatures in the system as well as the flows were recorded and controlled by an OPTO data acquisition and control system. “Trap grease” reforming was carried out at 850°C with a methane-equivalent gas space velocity ( $G_{Cl} VHSV$ ) of 950 h<sup>-1</sup> and a molar steam to carbon ratio of 5. The experiments proceeded very smoothly and the concentrations of the major gas products were constant during the run time of 17 hours. The concentrations of minor products, methane and ethylene, increased during the first ten hours of the

experiment, which could be due to a decreasing catalyst activity. However, they leveled off in the second half of the test.

The hydrogen yield that was initially 31.1 g per 100 g of trap grease decreased to 28.7 g after 17 hours of operation. This corresponds respectively to 88% and 81% of the amount that could be produced if total organic carbon were converted to CO<sub>2</sub> (Figure 1). These yields could be about 10% higher if the reforming were followed by water-gas shift to convert CO to CO<sub>2</sub> (upper curve).



**Figure 1.** Hydrogen yield obtained from reforming of “trap grease”

The above results indicate that “trap” grease can be a convenient feedstock for producing hydrogen. It is available at a price of 2-4 ¢/lb. Since over 30 kg of hydrogen can be obtained from 100 kg of “trap grease”, the feedstock costs contributes only 1-2 \$/GJ to the total cost of hydrogen. With current market prices for hydrogen in the 6-9 \$/GJ range, “trap grease” offers an opportunity for further development. The technology needs to be further studied to determine the catalyst time on stream and the efficiency of regeneration. Also effects of possible contaminants, especially inorganics, should be thoroughly investigated.

### References

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