PROGRESS REPORT (May, 1977)

Report No. C00-2982-15

Project: Conversion of Cellulosic and Waste Polymer Material to Gasoline
Contract No. EY-76-S-02-2982. *000

Principal Investigator: James L. Kuester

Other Personnel: M. Wallington, D. Lu, E. Sabin, R. Gough, M. Durkin

The project is now at the half way point in the contract. This progress report will review the activities of the first year and project activities for the second year. A preliminary material and energy balance summary is also included.

Present Status

The project objectives remain to produce various grades of liquid fuels from cellulosic and waste polymer material. Three reaction systems are involved: (1) pyrolysis, (2) Fischer-Tropsch, and (3) reformer. At the start of the contract period, an initial configuration for these systems was essentially complete. The major immediate goals were to establish operational reliability, select appropriate catalysts and commence operating variable studies to establish optimum operating conditions (maximize liquid fuel capacity subject to product quality constraints). To date, the following has been accomplished.

Fischer Tropsch Reactor - A catalyst (non commercial) has been developed that will produce a projected yield of about 80 gallons of liquid fuel per ton of dry solid organic feed. This exceeds the original project expectations. This yield has been obtained using a simulated pyrolysis gas (mixed gases from cylinders). The organic liquid from this reactor is paraffinic in nature and thus a candidate for a diesel or jet fuel.

MASTER

DISTRIBUTION OF THIS DOCUMENT IS UNLIMITED

REA

DISCLAIMER

This report was prepared as an account of work sponsored by an agency of the United States Government. Neither the United States Government nor any agency Thereof, nor any of their employees, makes any warranty, express or implied, or assumes any legal liability or responsibility for the accuracy, completeness, or usefulness of any information, apparatus, product, or process disclosed, or represents that its use would not infringe privately owned rights. Reference herein to any specific commercial product, process, or service by trade name, trademark, manufacturer, or otherwise does not necessarily constitute or imply its endorsement, recommendation, or favoring by the United States Government or any agency thereof. The views and opinions of authors expressed herein do not necessarily state or reflect those of the United States Government or any agency thereof.

DISCLAIMER

Portions of this document may be illegible in electronic image products. Images are produced from the best available original document.

A water phase is also produced containing a significant amount of normal propanol. A catalyst activity decline with time has been observed. The Fischer-Tropsch reactor (fluidized bed) is operationally reliable.

Reformer - A commercial catalyst has been obtained that will convert the paraffinic organic phase from the Fischer-Tropsch reactor into a high octane internal combustion engine type fuel. The reactor is operated as a fixed bed. No major problems have been encountered.

Pyrolysis - Considerable attention has been placed on the pyrolysis system. The basic scheme of a dual fluidized bed reactor-combustor is still used. The fluidized reactor has the virtues of rapid heat transfer (promotes ethylene formation) while the dual concept precludes contaminating the pyrolysis gas with combustion products. The problems with this system have been primarily concerned with solids feeding, hot solids (sand) transfer, temperature control and removal of tars from the overhead system.

The original screw feeders (side inlet) were replaced by pressurized top mounted hoppers with addition tubes extending into the reactor and combustor beds. This scheme is a major improvement. The reliability of the hot solids transfer loops is primarily dependent on maintaining differential pressure control between the two vessels. This has been achieved via a differential pressure control system and two flow controllers on the feed gas streams. Temperature control has been a major problem. Efforts to achieve sufficient combustor bed temperatures via gas burning below the distributor plate were unsuccessful due to temperature limitations on commercial alloys (2100°F). Coal feeding (or recycle char in a commercial unit) works but contributes to tar formation in the overhead system.

The tar formation problem (both from cellulose and coal) "appears" to be the last major hurdle in achieving an operationally reliable system. The strategy to date has been to keep the lines hot until a cold trap cartridge filter was reached where the tars were condensed and removed via the disposable cartridge. This was not a totally reliable scheme in that some tar material manages to get thru the filters and into the recycle compressor. Also there is the possibility of fires inside the cartridge filters if a sufficient amount of oxygen is present. In an effort to eliminate the tar problem, one of the cyclone separators has been converted to a water scrubber. Tests are underway.

All analytical data obtained on pyrolysis gas samples to date have revealed the presence of significant amounts of the desired constituents: hydrogen, carbon monoxide and ethylene. The stream appears relatively clean with other components being primarily methane, carbon dioxide, ethane, nitrogen and water.

Other - A sizable effort has been directed at developing analytical procedures (primarily gas chromatography) and developing preliminary economic projections for this project. Both efforts are formalized in reports and are available on request.

Future Plans

The major activities planned for the second year of the contract are as follows:

(1) resolve the current activity decline problem in the Fischer-Tropsch reactor. The present thrust is to analyze for the cause and then correct via operating procedure modification or regeneration.

(2) remedy the tar formation problem in the pyrolysis system. The current approach is via a wet scrubber.

(3) test the pyrolysis system to produce an appropriate gas for feeding the Fischer-Tropsch reactor.

(4) run the Fischer-Tropsch reactor on real pyrolysis gas.

(5) complete economic study and final report.

APPENDIX

Preliminary Material and Energy Balance

Stream:	A	B	C	D	E	F	G	H	I
Enthalpy (Btu/hr):	(-4449)	(56.5)	(-865)	(-28,981)	(-2843)	(-2427)	(-858)	(-1569)	(0)
Component Flow Rates (lb/hr)									
cellulose	1.78								
H ₂ O			0.124			0.192		0.192	
C ₅ -C ₇			0.0733						
H ₂				0.187	0.0183				
CH ₄				1.56	0.153				
C ₂ H ₆				0.171	0.0168				
C ₂ H ₄				3.36	0.330				
C ₃ H ₈ , C ₃ H ₆				0.576	0.0565				
C ₄				0.0623	0.00611				
CO				2.86	0.281				
CO ₂				6.04	0.592				
Straight chained paraffins						0.301	0.301		
Branched paraffins						0.122	0.122		
Aromatics									
Cycloparaffins									
Low mol wt. gases & alcohols						0.0215	0.0215		
EtOH						0.00124		0.00124	
iPrOH						0.000827		0.000827	
nPrOH						0.0339		0.0339	
iBuOH + BuOH						0.000368		0.000368	
unidentified						0.000987		0.000987	
ash + char		0.125							
O ₂									
N ₂									
SO ₂									
Cl ₂									
Total	1.78	0.125	0.198	14.8	1.45	0.674	0.444	0.230	

Stream:	J	K	L	M	N	O	P	Q
Enthalpy (Btu/hr):	(-913)	(0)	(0)	(-25,944)	(-1921)	(-7436)	(-7436)	(-31,824)
Component Flow Rates (lb/hr)								
cellulose								
H ₂ O				0.124		0.0156	0.0156	
C ₅ -C ₇				0.0733				
H ₂				0.205				0.205
CH ₄				1.71	0.129			1.709
C ₂ H ₆				0.188	0.195			0.188
C ₂ H ₄				3.69				3.69
C ₃ H ₈ , C ₃ H ₆				0.632				0.632
C ₄				0.0684				0.0684
CO				3.15	0.153	0.0571	0.0571	3.15
CO ₂				6.63	0.303	0.0898	0.0898	6.63
Straight chained paraffins	0.205							
Branched paraffins	0.102							
Aromatics	0.124							
Cycloparaffins	0.0133							
Low mol wt. gases & alcohols								
EtOH								
iPrOH								
nPrOH								
iBuOH + BuOH								
unidentified								
ash + char		0.0672					0.0672	
O ₂			3.65			3.54	3.54	
H ₂			12.0			12.0	12.0	
SO ₂						0.000994	0.000994	
Cl ₂						0.000621	0.000621	
Total	0.444	0.0672	15.7	16.5	0.779	15.7	15.8	16.3

MATERIAL AND ENERGY BALANCE SUMMARY

Material Balance:

Streams In (lbs/hr)

A	1.78
L	15.65
Total	<u>17.43</u>

Streams Out (lbs/hr)

C	0.198
H	0.230
I	0
J	0.444
K	0.067
N	0.779
O	15.711
Total	<u>17.43</u>

Energy Balance:

Streams In (Btu/hr)

A	-4449
L	0
compressor	2806
reformer heater	114
Total	<u>-1529</u>

Streams Out (Btu/hr)

C	- 865
H	-1569
I	0
J	- 913
K	0
N	-1921
O	-7436
receiving tank heat loss	2806
trap #1	6795
Fischer Tropsch Cooler	198
trap #2	1307
trap #3	169
Total	<u>-1529</u>

Thermal Efficiency:

$$\begin{aligned}\text{Heating value of cellulose} &= 7560 \frac{\text{Btu}}{\text{lb}} \times 1.78 \frac{\text{lb}}{\text{hr}} \\ &= 13,423 \frac{\text{Btu}}{\text{hr}}\end{aligned}$$

$$\begin{aligned}\text{Heating value of gasoline} &= 19,540 \frac{\text{Btu}}{\text{lb}} \times 0.444 \frac{\text{lb}}{\text{hr}} \\ &= 8676 \frac{\text{Btu}}{\text{hr}}\end{aligned}$$

$$\text{Compressor power requirements} = 2806 \frac{\text{Btu}}{\text{hr}}$$

$$\text{Reformer heater requirements} = 114 \frac{\text{Btu}}{\text{hr}}$$

$$\text{Thermal efficiency} = \frac{8676}{13,423 + 2806 + 114} = \underline{53\%}$$

Gasoline Yield:

$$\begin{aligned}\text{Yield} &= \frac{0.444 \text{ lbs gasoline}}{\text{hr}} \left| \frac{\text{gal}}{6.26 \text{ lbs gasoline}} \right| \frac{\text{hr}}{1.78 \text{ lbs cellulose}} \left| \frac{2000 \text{ lbs}}{\text{ton}} \right| \\ &= 80 \text{ gals gasoline/ton cellulose}\end{aligned}$$