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Maintenance and Operation of the U.S. DOE Alternative Fuel Center

Final Subcontract Report
5 August 1994 – 4 August 1995

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April 1996

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Executive Summary

Program Title: Maintenance and Operation of the U.S. DOE Alternative Fuel Center

Sponsor: National Renewable Energy Laboratory

Contract Number: XS-2-12130-1

Project Number: 01-5151

Inclusive Dates: August 5, 1994 - August 4, 1995

Technical Objectives

The work in the Alternative Fuel Center(AFC) was divided into five tasks to fulfill its role in the mission of Alternative Fuels Utilization Program (AFUP) of increasing the data for alternative fuels and for improving vehicle emissions through better fuels and combustion systems. The tasks were:

Task 1: Facility maintenance for the Alternative Fuel Center of the Office of Energy Efficiency and Renewable Energy at Southwest Research Institute

Task 2: Facility upgrade: control system and hydrogen recycle flowmeter (completed in year 2)

Task 3: Other government research

Task 4: Industry research (on a noninterference basis)

Task 5: Safety and health compliance

Approach

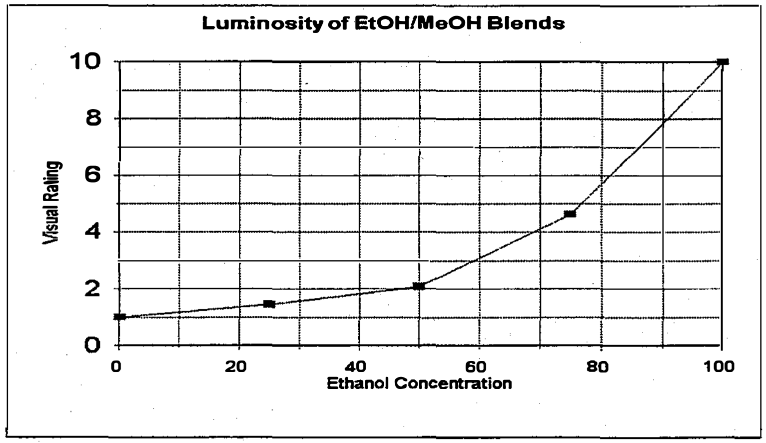
As in years one and two of the operating contract, the duties for maintenance and coordination of the AFC hydrogenation pilot plant were arranged to respond first to AFUP work arising in the course of the year, as in the case of the luminosity study (below), and to respond as fully as possible (on a noninterference basis) to the needs of industry in the areas of alternative fuels production, analysis, and utilization. The means for making known the capability and availability of the AFC equipment and functions was by discussions at meetings, tours, and distributed publications.

Accomplishments

The maintenance of the pilot plant and fuel samples of the AFC was kept up throughout the year, while participating in several outside projects. Equipment wear and tear generated in the course of those outside projects was repaired and parts purchased through each participating project, saving AFC project funds for more long-term enhancement of capabilities.

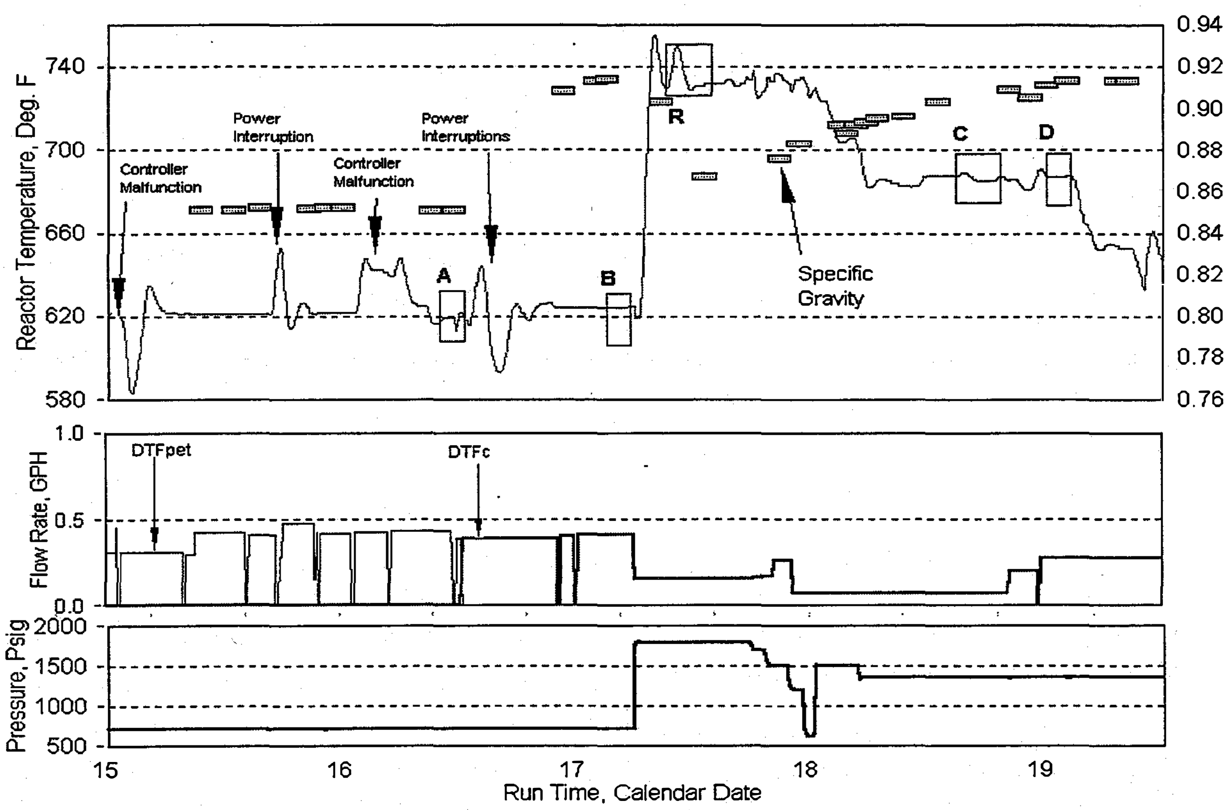
An AFUP investigation this year included experiments of flame luminosity for mixtures of ethanol and methanol. Both neat alcohols and three intermediate blends were burned in controlled tests to rate flame brightness. Methanol was assigned a brightness rating of 1 and ethanol was assigned 10. The ethanol dominates the flame luminosity as shown in the figure below.

An initiative was the addition of a new, approximately 1.6 liter, small reactor in parallel with the existing reactor train. The smaller volume permits quicker changes in operating condition, thus being conducive to scoping studies in preparation for work in the larger reactors or for calculations of process parameters. The small reactor flowrates were too low for the existing stripper/still, so the stripper preheater was modified to serve double duty as a small stripper for the new reactor, as well as, its usual preheating for the main stripper/still.



Another augmentation of capabilities was the addition of flow meters to increase the resolution of overall and elemental mass balances. Three flowmeters were installed to collect data to use with gas analyses in the calculation of hydrogen solubility loses and calculation of heteroatom balances. This upgrade of the mass balances used the full capabilities of the new operating software in the hydrogenation pilot plant.

The data collections were also used to create operating timelines of process variables through the course of processing runs. These plots give an overview of the entire run and can be combined with product measurements to chart product quality. The plot below is a timeline from a recent run.



Contents

List of Figures

Page

List of Tables

Page

Introduction

The Alternative Fuel Center (AFC) was established by the U.S. Department of Energy (DOE) as part of the Alternative Fuels Utilization Program (AFUP) to provide drum quantities of finished transportation fuels from a variety of sources. Since 1978, the AFUP of the Office of Energy Efficiency and Renewable Energy has investigated the possibilities and limitations of expanded scope of fuel alternatives and replacement means for transportation fuels from alternative sources to complement conventional petroleum fuels. The main function was to provide test fuels in 5- to 500-gallon quantities for research projects on the utilization of alternative fuels.

DOE funded the design, construction, and installation of a hydrogenation pilot plant capable of performing a range of hydrotreating, reforming, and hydrocracking operations. Southwest Research Institute (SwRI) provided the building, utilities, and laboratory and safety systems needed for the pilot plant. Later, the U.S. Navy provided a pilot-scale continuous distillation unit, and SwRI provided batch distillation equipment, which are conveniently housed in the same building as the hydrotreater pilot plant, but are not formally part of the Alternative Fuel Center (AFC). A plan view drawing of the AFC is shown in Figure 1.

The AFUP is part of the Alternative Fuels Utilization Program, which includes research, development, and demonstration of alternative fuel vehicle (AFV) technologies and is managed at the National Renewable Energy Laboratory (NREL) in Golden, Colorado.[1] The AFC work reported here contributes to the two primary objectives of the AFUP: (1) data for alterative-fuel-capable vehicles to enhance our energy security and (2) data for controlling emissions for improved air quality. At present the synergy with the objectives of outside projects going on in the AFC is the principal category of operation.

As pointed out in the NREL report, having the capability to use and rely on domestic fuel resources benefits the balance-of-trade deficit and strengthens the national economy. In addition, the United States national security interests outside the United States are reduced. Research and development of alternative fuel utilization technology increased competition to transportation fuel markets and advanced technologies for conventional transportation fuels, as well as alternative fuels themselves. The availability of alternative fuels sets a theoretical ceiling on conventional transportation fuel prices. By strengthening our alternative fuel utilization capability, the United States strategic and economic strengths increase.

Alternative fuels have improved the environment. Organic emissions from most alternative fuels have lower reactivity in the atmosphere compared to emissions from conventional transportation fuels. Results include less low-altitude ozone being formed, which results in cleaner air. There are also benefits for some alternative fuels which produce less emissions of nitrogen oxides, that can also contribute to urban ozone formation. Particulate emissions are generally lower for alternative fuel vehicles.

The goal of AFUP research and development at NREL is to develop light-duty and heavy-duty vehicle and fuel utilization technologies that will be commercially superior to technologies that rely on conventional, petroleum-derived transportation fuels. The reference for development is a point in the future when new

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[1] Alternative Fuels Utilization Program 1995 Annual Report, NREL Report No. MP-425-8301, Prepared by National Renewable Energy Laboratory, Golden, Co.

technology will be developed and become commercial. This assumes that commercial technology being used today will advance, so AFUP objectives must meet or exceed the anticipated improvements. Utilization technology includes 1) methods for enhancing fuel formulation, 2) fuel storage and handling, 3) engine and vehicle performance, and 4) emissions profiles. AFUP does not address directly resource availability, resource recovery, resource processing, or resource economics, but it assumes that resources are available. Nevertheless, utilization technology must consider every avenue to conserve primary resources as a means of achieving program goals and improving commercial competitiveness. Energy efficiency (i.e., fuel economy) is therefore of prime importance for all alternative fuel options. Alternative fuels investigated in the AFUP include methanol, ethanol, natural gas, liquefied petroleum gas (LPG), hydrogen, fuel ethers, and other renewable fuels that may be derived from biomass. Reformulated gasoline and modern diesel fuel are also included in the program as baselines against which alternative fuel performance may be compared.

The NREL AFUP works, under the direction of DOE, with industry, other government agencies, universities, and coalitions to coordinate and improve the research program. Multiplication of results often occurs from programs in which AFUP resources are combined with resources of collaborating organizations to work on common objectives. Data from the Alternative Motor Fuels Act (AMFA) and the Energy Policy Act of 1992 (EPACT) programs are stored in the DOE Alternative Fuels Data Center housed at NREL. The AFC is available to participate in all of these efforts.

This report covers the third year of the current contract. AFC objectives were accomplished under the following five tasks:

Task 1: Facility maintenance

Task 2: Facility upgrade

Task 3: Other government research

Task 4: Industry research

Task 5: Safety and health compliance.

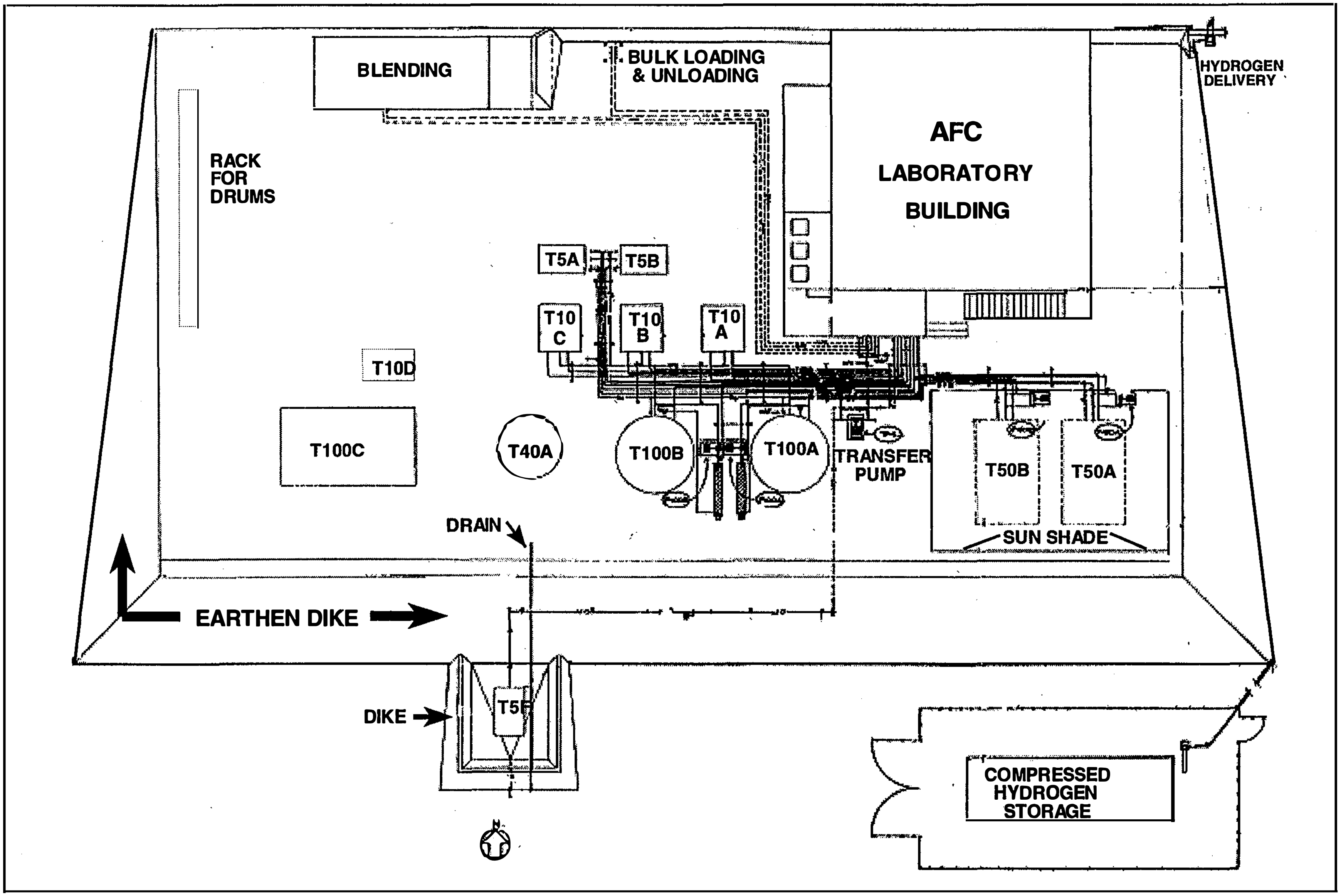


Figure 1. Plan View of AFC.

The greatest amount of work this year was for other government projects, although there was some commercial work. The main projects are discussed in the section for Tasks 3 and 4. Equipment upgrades included a new, small reactor and several flow meters. The small reactor permits rapid changes among operating conditions and requires less feed liquid for scoping studies and trial runs. The resulting array of accessible conditions is presented in Table 1.

The additional flowmeters allow more detailed and more accurate mass balances to be made around and within the hydrogenation unit. With the new data and appropriate gas analyses, heteroatom balances can be calculated and hydrogen loses can be measured. These topics are discussed in more detail under Task 2.

Each of the five tasks are discussed in the following sections. A table summarizing the monthly progress reports is provided in Exhibit 1.

Table 1. Extremes in Available Process Conditions

<table>
<tr><th colspan="4">Parameter</th><th>Device</th><th>Units</th><th>Max</th><th>Min</th><th>Sensor</th></tr>
<tr><td colspan="4">Multizone Temperature</td><td>FRN101
FRN201</td><td>°F</td><td>~950</td><td>280</td><td>TE107-111
TE207-211</td></tr>
<tr><td colspan="4" rowspan="3">Liquid Flow</td><td>P51A</td><td rowspan="2">GPH</td><td>3.0</td><td>0.1</td><td>WT51A</td></tr>
<tr><td>P51B</td><td>1.6</td><td>0.1</td><td>WT51B</td></tr>
<tr><td>Total</td><td>BblPH</td><td>0.109</td><td>0.0024</td><td>Calculation</td></tr>
<tr><td rowspan="4">Vessel Gal</td><td>Vessel</td><td>Empty</td><td>Packed</td><td rowspan="4">LHSV</td><td rowspan="4">Hr^{-1}</td><td rowspan="2">2.9</td><td rowspan="2">0.06</td><td rowspan="4">Calculation</td></tr>
<tr><td>G+R</td><td>2.15</td><td>1.56</td></tr>
<tr><td>R</td><td>1.16</td><td>1.05</td><td>4.4</td><td>0.09</td></tr>
<tr><td>Small</td><td>0.507</td><td>0.38</td><td>23</td><td>0.5</td></tr>
<tr><td colspan="4">Pressure</td><td>PCV121</td><td>PSIG</td><td>2500</td><td>400*</td><td>PT101</td></tr>
<tr><td colspan="4" rowspan="2">Hydrogen Flow</td><td>C11</td><td rowspan="2">SCFH</td><td>75</td><td>0</td><td>FT21A</td></tr>
<tr><td>C121</td><td>250</td><td>25</td><td>FT21B</td></tr>
<tr><td colspan="4">Contacting Rate</td><td>-</td><td>SCFB</td><td>>5000</td><td>230</td><td>Calculation</td></tr>
<tr><td colspan="9">* Lower pressures for reforming are arranged by special adjustments</td></tr>
</table>

Task 1: Facility Maintenance

The AFC comprises of samples, structures, equipment, and the storage infrastructure on a specially diked work area spread over about an acre at SwRI. Descriptions of the facilities are in Exhibit 2 at the end of this report.

Modifications to the hydrotreater pilot plant have increased its utility and made it more versatile. The changes, made in response to the needs of non-AFUP projects, provide benefits for all subsequent work, including AFUP processing:

- An additional, small reactor and heat exchanger to streamline trial runs, or 'scoping studies', for limited quantities of feed stocks or unusual processing conditions
- A modification in the distillation section to make sampling faster and more representative when operating the small reactor
- The installation of gas meters to provide greater accuracy and detail for the mass balances.

Additional Reactor

Sections of the updated flow diagram, Figure 2 , highlighted with hash marks, denote the recent modifications and new equipment. These changes were made with flexibility in mind to preserve all original functions, while providing for new purposes.

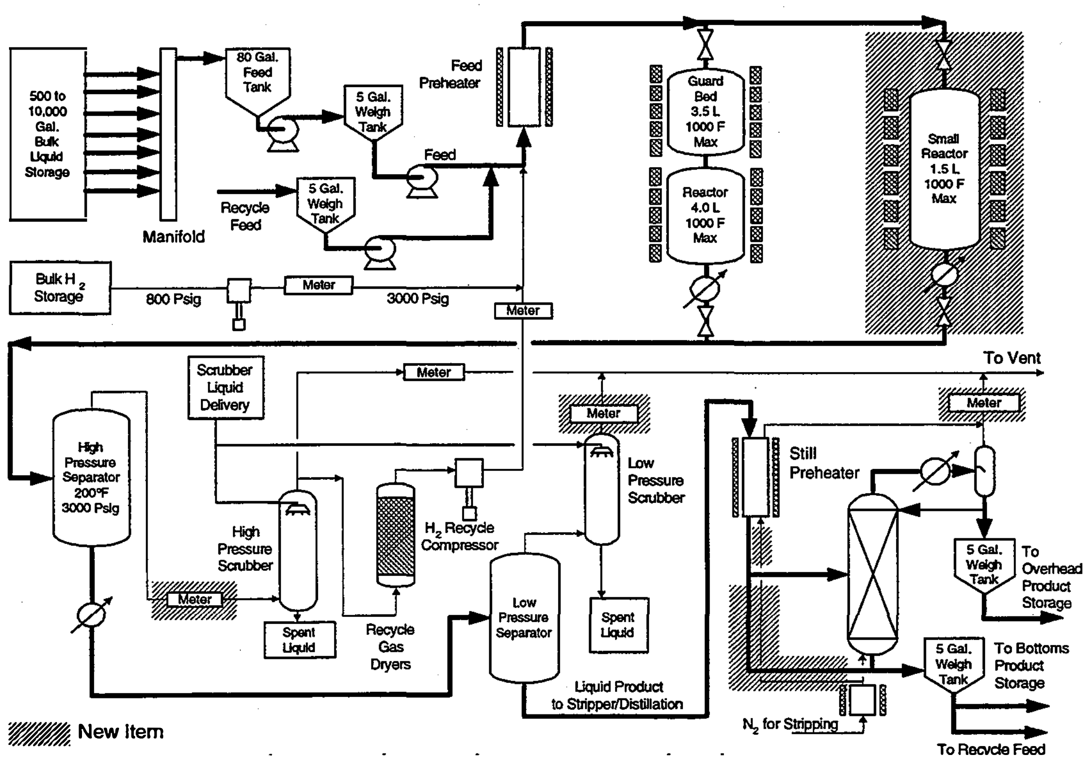


Figure 2. Modifications to AFC hydrogenation pilot plant

The new reactor was small-sized relative to both the distillation column capacity, and the product cooler. The two inch I.D. distillation column, holding a large volume compared to about 0.25 gallons per hour rate typically used with the small reactor, caused a long delay between the reactor exit and the sample port. Since some back-mixing naturally occurs in the column, obtaining a representative, steady-state sample often required several additional hours after completing a change of reactor parameters. The delay caused the use of excessive experiment time, while operators waited for the changes in product quality to go through stripping for sour gas removal and arrive at the sample port. Sampling ahead of the column, and removing the sour gases by caustic washing, proved unsatisfactory, because, in the presence of air, some reversal of the de-sulfurizing reactions occurred. Avoiding the problem with complete nitrogen blanketing during the whole procedure was cumbersome.

The new reactor, 81 inches long by 1.503 inches internal diameter, contains 0.622 gallons (2.36 liters) total volume. The upper section, 17 inches, packed with inert, tabular alumina provides internal heating, and three inches at the bottom provides catalyst support and initial product cooling, leaving 61 inches for active catalyst. The catalyst volume, 0.423 gallons (1.60 liters), allows production of small samples made the same way larger samples can be made, with both large and small reactors using reactor geometries resembling those used commercially. As shown in the loading diagram, Figure 3, the bed currently contains a 50 volume percent mixture of active catalyst and tabular alumina, so the active volume is 0.21 gallons (0.80 liters). In addition to conserving feed stocks in conventional operation, the small reactor facilitates exploration of unusually high space velocities, up to 12 liquid hourly space velocity (LHSV) with the current catalyst packing and feed pump.

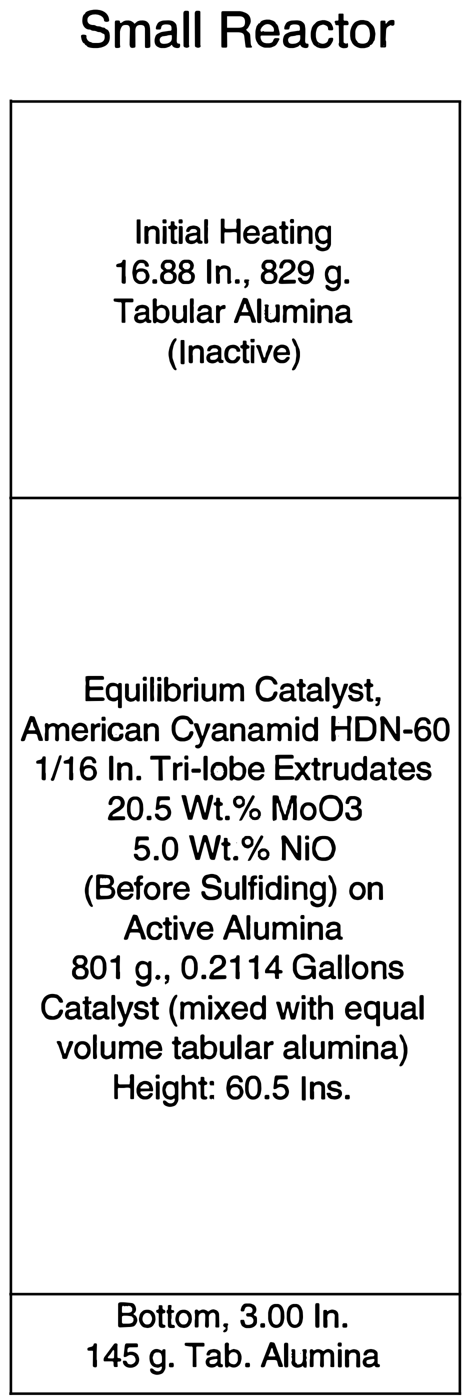


Figure 3. Catalyst loading

Small Stripper

Changes made in the distillation section solved the problem, providing the versatility to accommodate both large and small flow rates. The still pre-heater was modified to perform the additional function of stripper for low flow rates, and a by-pass was installed around the column to the sampling port and the bottoms product tank. Coke had built up in the old one-half inch pre-heater tube, and it was replaced with a new three-quarter inch tube filled with Poropak ® poured column packing to provide the surface area needed for effective stripping of the sour gases. Even with the packing in place, the larger diameter readily accommodates the flow rates used with the large reactor and the distillation column, and the packing gives better heat transfer. For the small reactor, a nitrogen line with a 'J-tube' to keep a liquid level in the bottom of the column in the stripper mode, routes stripping gas back through the pre-heater rather than forward to the product weigh tank. The column pre-heater now functions well as a pre-heater, but making minor changes in the flow paths convert it for use as a small-flow stripper.

A new product cooler was purchased for use only with the small reactor. It was a Parker-Hannifin counter-flow heat exchanger, coiled to form a helix, with the product flowing through an inner, stainless-steel tube, and cooling water flowing in the annular space between the inner tube and an outer, copper tube. Installation beneath the small reactor, and its configuration, facilitates draining of the heat exchanger and reactor.

Mass Balance

Mass balances give useful information to operators and engineers both during hydrotreater operation, and for post-run analyses. When the hydrotreater was initially constructed, the gas metering and analysis system accounted for the major gas flows, and the other flows were small enough to be lumped into other streams for most work. The major gas flows included the feed hydrogen, the recycle gas after scrubbing and drying, and the portion of gas from the high-pressure scrubber that went to the vent. In addition, stripping gas and vent gas were each monitored for the column, so hydrocarbon light ends losses could be estimated from the difference in the two flow rates.

The original system did not account for the gas volumes absorbed during scrubbing and drying. The absorbed volumes intentionally included the sour gases, hydrogen sulfide and ammonia, but this prevented obtaining sulfur and nitrogen balances. A new flow meter now provides the additional information required. The orifice-plate meter measures the total flow out of the high-pressure separator, which should equal the recycle plus high-pressure vent gas flows, plus the scrubbing and drying losses. With a gas analysis at this point, the mass balance calculations can account for the sulfur and nitrogen gases, and provide the corresponding elemental balances. The sampling point hardware was already in place.

The other two new meters provide increased accuracy to the overall balance. The new meter on the low-pressure vent gas accounts for that relatively small quantity, and the new meter on the still vent replaces an older instrument which had worn out and become inoperable.

The on-line mass balance calculation requires access to previously recorded data. Xytel Corp. updated our data retrieval program to include several additional variables, allowing us to use the new flow-meters in the customary way for the on-line mass balance calculation. The new printout, Figure 4 , provides nitrogen and sulfur balances, as well as a separate accounting for the high- and low-pressure gas flows, instead of the combined 'HP/LP gas' previously reported.

The overall computer upgrade, put into place last year, now provides easier access to historical process data for analysis than did the old computer system. The new data format allows convenient importing into spreadsheets for post-run graphing, calculating related values, or statistical analyses. The data collection repeats at short intervals so the resulting record displays the processing history in detail. As an example, Figure 5 shows a processing time-line obtained during work on the *End Use Study described below.* The squares indicated by the block letters give the time intervals used for mass balance calculations (not shown), and the terms DTFpet and DTFc indicate different feed stocks. Note that the feed flow rate, based on feed-tank weight loss, occasionally indicated zero due to the temporary period of weight gain during tank refill.

The hydrotreater modifications provided major, new capabilities at modest cost. The Institute provided the new reactor and the associated furnace at no cost to the project. These two items had been purchased several years ago for about $20,000, intended for use on a project that never came about. The reactor had not been used previous to this installation. A simple changing of thermocouple connections allows using the large reactor temperature controller for the small reactor, so a new controller was not required. The product cooler ($1200) and the new meters ($ 2300) were purchased with project funds designated for parts, and the project also funded the program modification giving increased access to the historical data base ($500). Modifications to the distillation section required only inexpensive items which were mostly on-hand.

In summary, as a result of changes made this year, the following new capabilities have been added at minimal project cost:

- Scoping studies at low flow rates, typically 0.25 gallons per hour, using the same conditions, if desired, as available at the higher rates (up to about 4 gallons per hour)
- With preferred reactor geometry, maximum specific processing rate to 12 LHSV (up from 2.8), useful for reactions occurring faster than most conventional petroleum processing
- Provision for sulfur and nitrogen mass balances
- Improved accuracy of overall mass balances.

Maintenance and Custody

The continuing work of maintaining the hydrogenation pilot plant is carried out during all operations of the equipment - on AFC duties and outside work. A benefit of the outside work is the exercise it provides to the equipment an replacement of worn and outdated parts. Occasionally, upgrades are obtained in this manner. The environment of the equipment is maintained also as reflected on the monthly inspection log of Table 2. The detection equipment discrepancies noted there would not routinely be corrected with project funds, and recently a plan for reinstating these monitoring devices was worked out and funding identified.

The more notable repair actions on the hydrotreater equipment are listed in Table 3. Items marked with an asterisk were funded on outside work as were replacements of small items and replaceables (gaskets, rupture disks, fuses, etc).

In August, 1995, an inventory of AFC test fuels and components in storage was performed. AFC project materials (with brief descriptions) are listed in Table 4,, including those AFC materials used in earlier AFC operating contracts.

RUN NO: 52-5

MASS BALANCE: REPORT FOR: Mo. 1 Day 25 Year 95 Time 8:30
Starting at the above time and continuing 1380 MINS

FEED/DESC. FL-2385, DL1, MNIC

	VOL(*)	GAS MW	LIQ SG	WT(Lbs)	WT(%)	VOL(%)
FEEDS						
LIQUID HC	43.574	n/a	0.7840	284.500	100.00	100.00
FEED H2	1263.600	2.016	n/a	6.713	2.36	n/a
TOTAL FEED	43.574	n/a	0.7840	291.213	102.36	100.00
PRODUCTS						
HP/LP GAS	486.300	2.016	n/a	2.584	0.91	n/a
FRACT GAS	0.000	2.016	n/a	0.000	0.00	n/a
RECYCLE GAS	3450.400	2.016	n/a	18.332	6.44	n/a
OHD LIQUID	2.129	n/a	0.7500	13.300	4.67	4.89
BTMS LIQUID	40.385	n/a	0.7790	262.000	92.09	92.68
RECYCLE LIQUID	0.000	n/a	0.7790	0.000	0.00	0.00
TOTAL PRODUCTS	42.515	n/a	n/a	277.884	97.67	97.57
GAIN/LOSS	-1.059	n/a	n/a	-13.330	-4.69	-2.43

HYDROGEN BALANCE	GAS VOL (SCF)	MOL % H2	H2 VOL (SCF)	CONTACT (SCF/BBL)
HYDROGEN FEED	1263.600	99.90	1262.336	1216.74
HP/LP GAS OUT	486.300	99.90	485.814	n/a
FRACT GAS OUT	33.200	99.90	0.000	n/a
H2 RECYCLE	3450.400	99.90	3446.949	3322.45
GROSS H2 COMSUMED	n/a	n/a	776.523	748.48

* Gas volumes in SCF, liquid volumes in gallons.

GAS BALANCE	FEED (SCF)	PROD (SCF)	GAIN (SCF)	PROD/FEED (%)
	1263.60	519.50	-744.10	41.11 %

OPERATING CONDITIONS SUMMARY:

AVERAGE REACTOR TEMPERATURES (DEG F)			
GUARD BED		731.1	degF
REACTOR		713.3	degF
TOTAL (Disregard if G. B. was bypassed)		719.3	F
AVERAGE REACTOR PRESSURE		1592	psig
REACTOR UTILIZATION:			
CATALYST LOADING:	WEIGHT	13.151	Lbs
	VOLUME	1.557	Gals
FEED RATE:	WEIGHT	12.370	LB/H
	VOLUME	1.895	G/HR
WEIGHT HOURLY SPACE VELOCITY (WHSV)		0.941	WHSV
LIQUID HOURLY SPACE VELOCITY (LHSV)		1.217	LHSV
STRIPPING N2 RATE TO DISTILLATION COLUMN		5.500	SCFH

NOTE: This report was printed at 12:23:16 on 01-27-95.

Figure 4. Updated mass balance printout

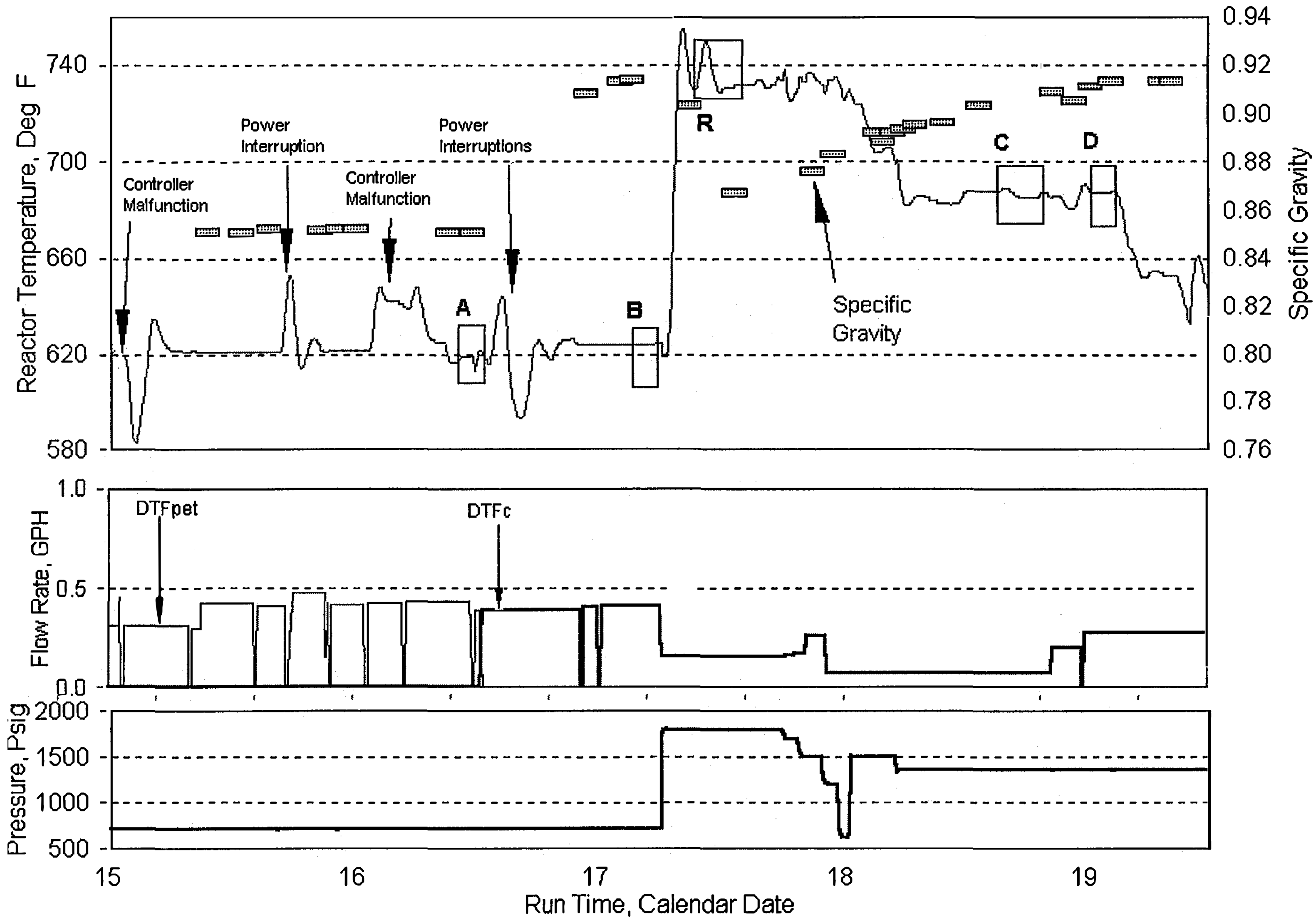


Figure 5. Timeline from pilot plant processing

Table 2. Summary of AFC Monthly Log

Function	Aug 94	Sep 94	Oct 94	Nov 94	Dec 94	Jan 95	Feb 95	Mar 95	Apr 95	May 95	Jun 95	July 95	Aug 95
Fire & Smoke Detectors	1	1	1	1	1	1	1	1	1	1	1	1	1
Gas Alarms	234	234	234	234	234	234	234	234	234	234	234	234	234
Air Filters	X	x	x	x	x	x	x	x	x	x	x	x	x
Air & Water Systems	X	x	x	x	x	x	x	x	x	x	x	x	x
Emergency Lights	X	x	x	x	x	x	x	x	x	x	x	x	x
Lower Revetment	X	x	x	x	x	x	x	x	x	x	x	x	x
Hydrogen Trailer	X	x	x	x	x	x	x	x	x	x	x	x	x
Oil Traps	X	x	x	x	x	x	x	x	x	x	x	x	x
Upper Revetment	X	x	x	x	x	x	x	x	x	x	x	x	x
Tank Inspections	X	x	x	x	x	x	x	x	x	x	x	x	x

#1 Mainbay smoke detector not working
#2 Combustible gas detector failed
#3 H2S detector failed
#4 Hydrogen sensor
x checked and or verified

Table 3. Hydrotreater Maintenance

Item	Date	Description	Cost
1	Aug 94	Repacked HV430	50 *
2	Aug 94	Rebuilt preheater 401	100 *
3	Oct 94	Replaced PT81	250 *
4	Oct 94	Rebuilt PCV121	100 *
5	Nov 94	Replaced LT91B	1029 *
6	Nov 94	Replaced 3 TC's in Rx	200 *
7	Nov 94	Replaced Brain Board	213 *
8	Apr 95	Rebuilt feed pumps P51A,P51B	1100
9	Aug 95	Install new flow meters FT82, FT91, FT401	2287

Table 4. AFC Fuels and Fuel Components in Storage

SwRI ID No.	Product Type	No. of 55 Gal. Drums	Description
FL-1309	Middle Distillate	1	High nitrogen shale oil hydrotreated in Run 10
FL-1330	Oil	1	Paraho shale oil blend
FL-1393	Naphtha	1	Wilsonville coal liquid hydrotreated in Run 12
FL-1418	Naphtha	1	Wilsonville coal liquid hydrotreated in Run 13
FL-1440	Oil, DF range	5	Coker gas oil from Texaco
FL-1442	Oil, DF range	0.5	Low sulfur, light coker gas oil htd in Run 14
FL-1443	Oil, DF range	1	Low arom, light coker gas oil htd in Run 14
FL-1538	Oil, DF range	1	Light cycle oil
FL-1615	Oil, DF range	1	Low sulfur, light cycle oil, hydrotreated
FL-1627	Diesel fuel	13	Straight run, petroleum derived
FL-1840	Diesel fuel	1	Fischer-Tropsch Diesel
FL-1873	Diesel fuel	1	Low aromatics, htd, straight run diesel
FL-1932	Oil	23	Paraho shale oil
FL-2028	Naphtha	2	FCC product, hydrotreated in Run 26
FL-2032	FCC naphtha	6	FCC product
FL-2062	Naphtha	2	FCC product, hydrotreated in Run 30
FL-2065	Oil	1	Coal liquid, direct liquefaction, paraffinic
FL-2066	Solvent	1	Blend, paraffinic solvent and methanol

Notes: DF = diesel fuel, 350°-650°F
FCC = fluid catalytic cracking
Oil = full boiling range material

Flame Luminosity of Ethanol/Methanol Mixtures

The objective of this work was an examination of the variation of flame luminosity at several ethanol concentrations in mixtures of methanol and ethanol. The experiments were done previously and reported this period. Solutions were prepared, combusted, and rated as described below. All work was carried out in a fume hood with the exhaust fan turned off.

Three stock solutions were made at 25 Vol%, 50 Vol%, and 75 Vol% ethanol in methanol. 5mL of each solution and both neat alcohols were individually pipetted into clean petri dishes for combustion. For photometer-rated experiments, one dish was set 50cm from the optometer, which was 75° above the table top with the petri dish at the apex of the angle. For visually-rated experiments, a row of five dishes was placed in the center of the fume hood 5-6 cm apart.

Visually-rated experiments were done by assigning a rating of one unit of brightness to the methanol flame, when viewed in the fume hood with the other flames. These ratings were made in a darkened room. The ethanol flame was assigned a rating of 10 brightness units. The ratings were assigned from a photographic record after all experiments were complete.

The Visual Ratings can be shown as follows:

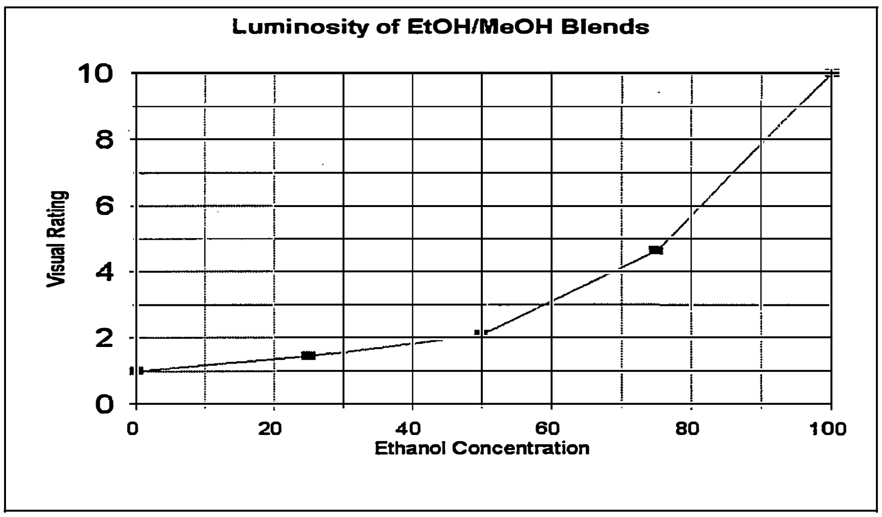


Figure 6. Flame Luminosity of ethanol/methanol mixtures

Similar trends were observed in photometer-rated experiments

Summary - The ethanol dominates the flame luminosity because it contains a carbon-carbon bond, which leads to soot formation in the plasma of the flame. In methanol, there is no carbon-carbon bond, so its flame is free of soot particles, which glow in the heat of the flame, producing black body radiation of many frequencies in the visible range.

Task 2: Facility Upgrade

Work on this task is complete, but the following summary is presented as an overview of the recently installed control system and operator interface.

In October, 1993, acquisition of the control system upgrades for the hydrogenation pilot plant began. The hydrogenation pilot plant was constructed 13 years ago by Xytel. Because the computer and control hardware and software had become obsolete with the manufacturers, the pilot plant was experiencing more frequent and serious service interruptions that arose from the control system. Xytel was selected to perform a facility upgrade of the control system because of its experience with several proprietary items on the pilot plant.

The computer upgrade for the pilot plant included the computer/interface hardware, FIX software, and computer system documentation. The control system software that was installed is based on FIX DMACS™ (Version 3.02) software package from Intellution, Inc. The function of the program is System Control and Data Acquisition (SCADA).

The engineering portion of the package contains the following features: it is a menu-driven system and control strategy configuration with on-line help, it has a real-time display builder with mouse support, the program allows set up of password protection, operator entry limits, display linkages, tag groups, and key macros, and set up of historical trending of process variables, and formatting of run-time reports, etc.

In January 1994, the hydrogenation pilot plant control system upgrade was installed on site. Xytel provided a turnkey operation for configuring the system based upon the previous pilot plant system functions. The control system database was created based on the process I/O and control strategies used by Xytel on the many Distributed Manufacturing and Control Software (DMACS) systems they have made. Standard displays were created for the use of the operator to monitor and control the process. Xytel used the C-Data Base Access package to write a custom background program to interface with the weight scales in the system.

Tasks 3 and 4: Other Government and Industry Research

The goals of the AFC are to develop higher quality fuels and improve the ability to utilize alternative fuel sources. These goals are advanced through the support of other government and industrial projects that use the AFC. The processing runs for other government programs and industry is shown below in Table 5. In addition to the new alternative fuels knowledge produced over the last 2 years by the AFC project, use of the AFC by other government agencies and industries for outside projects has contributed to better fuels and alternative fuel sources. Further, a regular schedule of pilot plant utilization helps to keep the equipment in good working order. The repair parts purchased on these projects help pay for routine maintenance.

Table 5. Summary of AFC Processing Runs

Run #	Start	Feed ID	Feedstock Description	Sponsor	Product 1	Product 2
DIST 55	7/18/94	FL-2336	Diesel Component	Oil Company	FL-2353 OH	FL-2354 BT
DIST 56	7/20/94	FL-2181	DF2	"	FL-2357 OH	FL-2358 BT
DIST 58	8/1/94	FL-2084	Diesel Component	"	FL-2369 OH	FL-2370 BT
DIST 59	8/17/94	FL-2366		"	FL-2378 OH	FL-2383 OH
HYDRO 48	11/7/94	AL-20573-F	CAT1H	US Navy	Trial run	
HYDRO 49	11/14/94	FL-2372,2338	DL1 COAL LIQ, DFT Pet	EndUse Study	Trial run	
HYDRO 50	11/29/94	FL-2372		"		
HYDRO 51	12/7/94	FL-2385,2310	MN1c coal liq, NTF pet	"	Trial run	
HYDRO 52	01/18/95	FL-2385	DL1 CUT #3	"	FL-2473	
HYDRO 53	02/24/95	FL-2385,2310	DL1 COAL DERIVED	"		
HYDRO 54	03/15/95	FL-2371	OVHD FROM DIST 57	"		
SULFIDING	11/07/95	H2 Only	CATALYST REGEN	Operations		

The following paragraphs summarize the major government and industry research projects performed this year outside of the AFUP work.

Refining and End-Use Study of Coal Liquids

The role of coal-derived liquids for domestic transportation fuels is being studied in the DOE program *Refining and End Use Study of Coal Liquids* at Southwest Research Institute. Both direct- and indirect-liquefaction products are in the project. This is one of the three key programs of the DOE Office of Fossil Energy, which also include pilot plant production of "direct" coal liquids by HRI,Inc. in New Jersey and "indirect" liquids by Air Products in La Porte, Texas.

Quantities of gasoline, diesel, and jet fuel will be made for engine tests of performance and emissions from each of three to eight coal liquid feedstocks. The sequence of data gathering, study, sample production and testing is shown in Figure 6. The first three feedstocks include two coal liquids made by direct liquefaction in which the coal is dissolved in solvent and processed to convert and isolate the components most like petroleum. The third feedstock is from indirect liquefaction where coal is gasified with limited oxygen and the vapors are reacted in Fischer-Tropsch catalyst to form mostly paraffins much as in Germany in the 1940s.

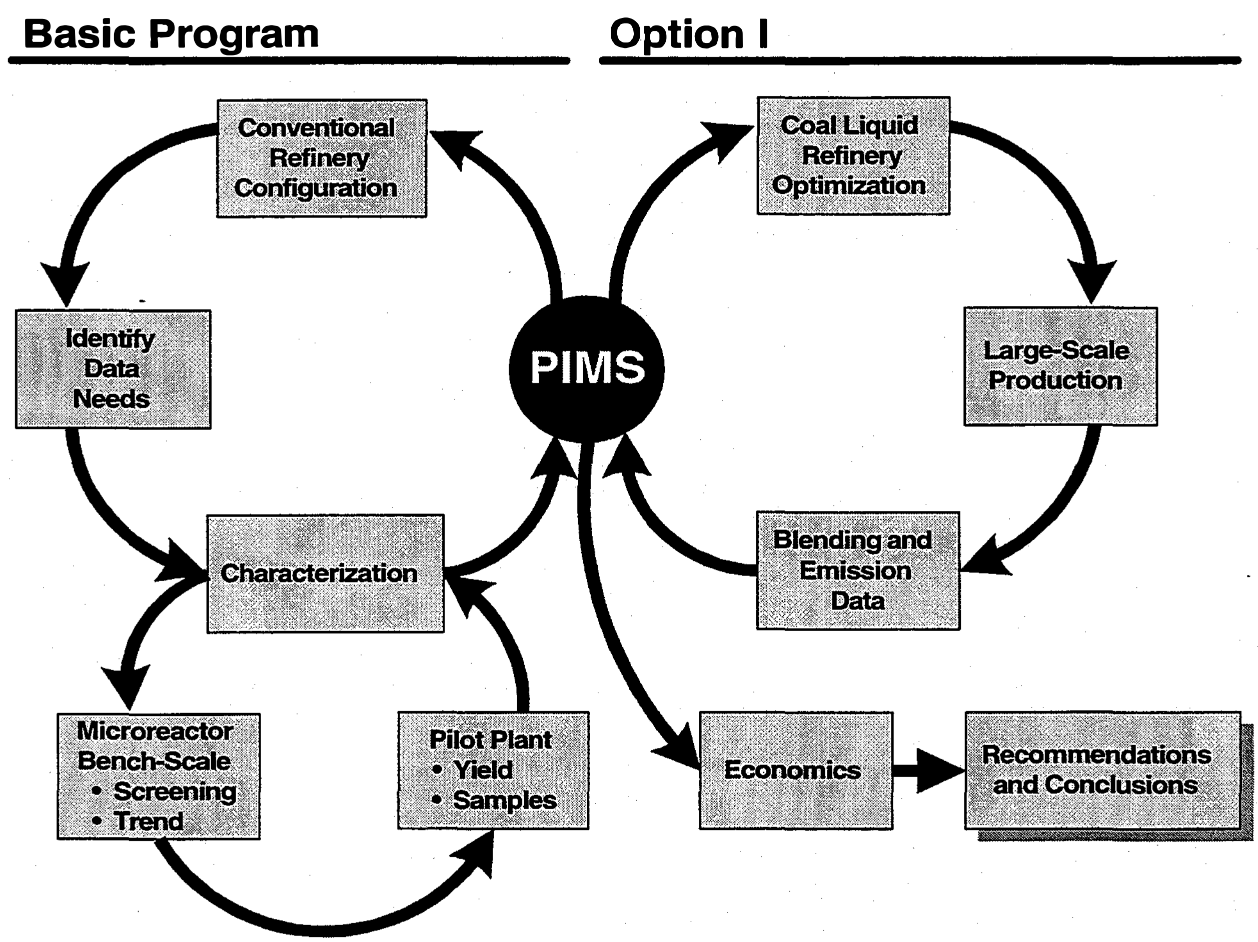


Figure 7. Organization of *End Use Study* work

It is widely believed that there will never be another US refinery built from scratch, a so-called grassroots facility, much less a dedicated refinery for coal fuel. Therefore, integrating coal liquids into the existing refining system becomes the approach. Questions about what percentage of coal liquid to add and where in the refining process to add it must be answered. The work in the project is outlined on the accompanying drawing, showing the refinery modeling program PIMS at the center.

This program by Bechtel Corporation, the prime contractor, uses linear programming to apportion the many streams of feedstock among the individual processing plants in a refinery that perform the upgrading operations on petroleum. The basic program will first identify an appropriate refinery layout to achieve the needed conversions of coal/petroleum feedstocks to finished fuels. For instance, coal liquids lack the sulfur levels typical of petroleum, requiring less severe treatment to limit sulfur, while direct liquids are high in aromatics that must be directed to the most beneficial place for them in the product slate. A different refinery layout will be chosen for direct and indirect liquids.

Existing data describing petroleum refining operations are inadequate to yield good predictions about refinery performance on the coal liquids, so laboratory tests and pilot plant studies will be made to acquire data for PIMS to come up with recipes for a full slate of refined products. These recipes will be used in Option 1 to produce quantities of test fuels for testing.

The test matrix will include the usual list of ASTM tests for specification fuels, but will aim at advanced property limits extrapolated to the 2001-2015 time frame. All fuels will then receive single cylinder testing in a variable compression ratio engine (VCR) with limited tests of exhaust emissions at steady-state operating conditions. Selected fuels will go on for modified FIP evaluation in appropriate multicylinder, transient tests.

The future of coal liquids for transportation fuels depends on meeting the ever more restrictive requirements for exhaust emissions such as will be tested in the program, and no fuel source will be adopted without favorable economics. The costs and value of the coal liquids to refining will be investigated as part of the final PIMS model. The specialized composition of indirect coal liquids, being almost entirely paraffins, may hold special promise for diesel fuel quality in the future.

The purpose of this program is twofold: a) to develop fuels that will meet gasoline and diesel fuel specifications for the future in the year 2015 and beyond, and b) to determine how the United States can use its large reserves of coal for transportation fuels. Quantities of gasoline, diesel, and jet fuel will be made for engine tests of performance and emissions from each of three to eight coal liquid feedstocks. The first three feedstocks include two coal liquids made by direct liquefaction in which the coal is dissolved in solvent and processed to convert and isolate the components most like petroleum. The third feedstock is from indirect liquefaction, in which coal is gasified and limited oxygen and the vapors are reacted in Fischer-Tropsch catalyst to form mostly paraffins much as that done in Germany in the 1940s. Because of the prevailing and foreseen limitations on refinery construction and operations, the approach becomes on of integrating coal liquids into the existing refining system. The refinery modeling program PIMS is used to outline the integration process, which may help determine where and in what percentages the coal liquid should be added to the process. Linear programming will be used to apportion the many streams of feedstock among the individual processing plants in the refinery that perform the upgrading operations on petroleum. The costs and value of the coal liquids to refining will be investigated as part of the final PIMS model.

Effect of Refining Severity on the lubricity of NATO F-76 Fuel

At present, more severely refined fuels are being produced with decreased sulfur and aromatic components in order to reduce vehicle exhaust emissions. Both military and commercial fuel specifications have been revised. The U.S. Environmental Protection Agency (EPA) specified a maximum sulfur content of 0.05 wt% for diesel fuel, effective 01 October 1993. The California Air Resources Board (CARB) mandated a more stringent requirement of 10 vol% aromatics, also effective 01 October 1993. In Europe, sulfur content is limited to 0.3 wt% maximum and is expected to fall to 0.05 wt% by 1996. Severe equipment wear has already been reported through use of very low sulfur fuel in Sweden.

The more severe refining processes required to remove sulfur may result in the production of fuels devoid of the reactive components necessary for effective lubrication. A previous U.S. Army-sponsored study showed a strong correlation between decreasing sulfur and aromatic content and wear for randomly selected fuels from around the world.[2] Similarly, increased wear may occur in

[2] Lacey, P.I. "Wear Mechanism Evaluation and Measurement in Fuel-Lubricated Components," BFLRF Report No. 286 (AD A284870), Available from Defense Technical Information Center, Alexandria, Va., September 1994.

the fuel systems of both ground and marine vehicles that operate with these fuels. Lubricity[3] additives exist; however, due to variation in additive quality or concentration, no specification for minimum acceptable protection is available.

The primary objective of the Navy project is to define the effects of increasingly severe hydrotreatment (i.e., the refining process used to reduce sulfur and aromatic content) on the lubricity and expected wear resistance of F-76 NATO diesel fuels. A correlation between lubricity and sulfur/aromatic content should result. A secondary objective is to define the effects of humidity, deionized water, salt water contamination, aging, and red dye on lubricity. Following is a description of the test program designed to meet these objectives.

The aim of the study is to use these wear mechanism-specific tests to define the effects of decreasing sulfur and aromatic content on F-76 diesel fuel lubricity. Because the concentrations of sulfur and aromatics are closely related to refining severity, a number of refinery sources will be used in an attempt to broadly define the critical level of refining severity past which fuel system-related wear may be an issue. General properties of these test fuels are given in Table 6. In addition, the correlation between refining severity and lubricity will be examined: Does fuel lubricity decrease linearly with increasing refining severity, or does wear rate increase disproportionately at a critical sulfur/aromatic level? A table summarizing the expected work sequence is provided in Appendix A. The first three tasks have been completed. The remaining tasks are being delayed pending completion of the present test plan and will require approximately 12 months to complete.

Successful completion of this project will allow the U.S. Navy to make informed decisions relating to the effects of reformulated low-sulfur, low-aromatic diesel fuels on the likely durability of fuel handling and injection equipment. Additionally, it may be possible to predict wear resistance indirectly from readily measured chemical or physical properties.

[3] In the Navy study, the term "lubricity" is used according to the broad definition provided by Appeldoorn and Dukek (SAE Paper No. 600712, Society of Automotive Engineers, Warrendale, PA, 1966.): "If two liquids have the same viscosity, and one gives lower friction, wear, or scuffing, then it is said to have better lubricity."

TABLE 6. Fuel Samples in Navy Lubricity Study

Refinery	Total Barrels	Sulfur, wt%			Cetane No	90% Point, °C	End Point, °C	Flash Point °C	Viscosity cSt @ 40°C	Density,kg/L @ 15.6°C
Method		Min	Max	Avg	ASTM D 976	ASTM D 86	ASTM D 86	ASTM D 93	ASTM D 445	ASTM D 1296
Coastal Refining & Marketing	4,342,073	0.39	0.76	0.56	48.7	330.6	359.2	78.0	3.27	0.8527
ARCO, Blaine Refinery	552,684	0.53	0.61	0.58	46.4	338.8	356.7	88.3	4.26	0.8704
Oil Refiners Ltd. Haifa, Israel	1,730,104	0.60	0.99	0.89	51.2	333.8	366.1	81.8	3.53	0.8465
CEPSA, Gibraltar Refinery , Spain	475,086	0.73	1.00	0.82	52.7	343.4	371.6	66.8	3.04	0.8416
ESSO Fawley Refinery, UK	170,674	--	--	0.15	47.0	342.0	369.0	85.0	3.77	0.8659
Gold Line Refinery Lake Charles, LA	1,178,216	0.02	0.12	0.05	54.4	323.0	347.0	71.5	3.55	0.8388

Visitors and Tours

The DOE AFC received many visitors during the year. Numerous quick stops are not recorded, but Table 7 lists several of the year's notable tours. The exposure to visitors is beneficial for the work of the Center by making known its capabilities and mission. Table 7 does not include the project visits by NREL staff or by the sponsors of the many nearby projects who may stop when they are visiting their work. The international visitors are particularly noteworthy, particularly in the cases where the guest had requested to visit the AFC from having heard about it before their visit.

Table 7. Tours and Visits to DOE Alternative Fuel Center

Date	Identity	Number	Interest
29JUL94	Shell	1	Technician Duties
15AUG94	Antek Instruments	1	Online Sulfur Analysis
2NOV94	Shell Malaysia	2	Distillation
14NOV94	End Use Study Participants	8	Project Work in AFC
6MAR95	Yukong (Korea)	2	Pilot Plant Operation
20APR95	Chevron	1	Fixed-Bed Processing
21APR95	Petronas Research (Malaysia)	1	Fuel Properties
25APR95	Graduate Student	1	Tour
11MAY95	Intevep (Brazil)	1	Heat Transfer

Task 5: Health and Safety Compliance

Health and safety aspects of all AFC maintenance and operations were closely monitored over the past year. No formal noncompliance issues with any local, state, or federal entities resulting from this work occurred over the contract year. Normal `wear and tear' of the building monitoring systems have resulted in malfunctioning sensors, as noted in Table 2. A plan for reinstating these functions is in progress.

Conclusions

- The AFC equipment was maintained in ready-to-operate working order in the reporting period.

- The AFC test fuel sample inventory has been maintained in good order this year.

- Flame luminosity of ethanol/methanol mixtures is dominated by the ethanol concentration in all concentration ranges.

- Outside processing interests have shifted from the rush of efforts fro environmental regulation compliance more toward refinery process improvement and new processes.

- Capabilities to serve AFUP was augmented through outside work and the installation of new sensors and mass balance capabilities, including:

  - Sulfur and nitrogen mass balances

  - Improved accuracy of overall mass balances.

- Installation of a new, small (~1 liter) reactor, providing enhanced functions, among which are:

  - Scoping studies at low flow rates, typically 0.25 gallons per hour, using the same conditions, if desired, as available at the higher rates (up to about 4 gallons per hour)

  - With preferred reactor geometry, maximum specific processing rate to 12 LHSV (up from 2.8), useful for reactions occurring faster than most conventional petroleum processing

- Beyond the specific alternative fuels data produced this year by the AFC project, the continued interest in the AFC by other government agencies and industries for participation in their research, is a further product of the AFUP. In promoting its own program, the AFUP is furthering knowledge of and preparedness for alternative transportation fuels by aligning with the research of other organizations pursuing parallel missions.

Exhibit 1. Index of Monthly Progress Reports

XS-2-12130-1 Summary of Monthly Progress Reports (01-5151) Year 3

Topics	25	26	27	28	29	30	31	32	33	34	35	36
Maintenance	●				●	●			●	●	●	●
Outside Processing	●	●	●	F4	●	●	●	●	●	●		
Modification	●						F1					
Small Reactor		●	●	F1				F1				
Luminosity Study		●			F1							
Mass Balance			●						F1		●	
Visitor and Tours			●		●		●	●				
Travel/Contacts						●						

● Topic covered
F Figure (number)

XS-2-12130-1 Summary of Monthly Progress Reports (01-5151) Year 2

Topics	13	14	15	16	17	18	19	20	21	22	23	24
Sample Inventory	●								T2			
Maintenance		●	●	●	●	●			●	●		
Travel/Contacts				●								
Outside Processing	●		●			●	●	●	●	●	●	●
Low Reactivity/ Emissions Gasoline	●											
Visitor and Tours								●	●		●	●
Control Upgrade		●	●	●	●	F1-5	●		●			
Ethanol RVP				●	●							
Small Reactor						●						
Schedule									T1	T		

● Topic covered
T Table (number)
F Figure (number)

XS-2-12130-1 Summary of Monthly Progress Reports (01-5151) Year 1

Topics	1	2	3	4	5	6	7	8	9	10	11	12
Sample Inventory										●T	●T	
Maintenance Log	●		●					●	●	●	●	●
Equipment Custody					●							
Hydrotreat Cracked Gasoline		●	●	●								
Travel/Contacts					●							
Outside Processing				●	●		●	●	●	T	●	●
Hydrogen Trailer & Pilot Plant Components			●	●		●	●			●	●	●
Low Reactivity/ Emissions Gasoline	●	●	●	●	●							
Visitor and Tours									●	●	●	●
Environmental Safety	●	●	●	●	●	●	●	●	●	●	●	●
Control Upgrade	●		●	●	●	●	●	●	●	●	●	●

Note: Reference Month 1 = August 1993

● Topic covered
T Table (number)
F Figure (number)

Exhibit 2. Annual Government Property Inventory

Refer to: 03-5151

GOVERNMENT PROPERTY INVENTORY & CERTIFICATION

NREL Subcontract No: XS-2-12120-1 Subcontractor: Southwest Research Institute

DOE Tag No.	Item Description or Nomenclature	Mfgr. Name Model No. & Serial No.	Acquisition/ Fabrication Cost	Acquisition Reference Number	Location	Disposition Status	Condition Code
DOE01272	Fuel Storage Facility		192,338.00	Mod. 1	SwRI Division 03		5
DEN301270	Computer	Apple IIE	2,856.00	Mod. 1	SwRI Division 03		5
NAS301147	Tank Aboveground		3,735.00	Mod. 1	SwRI Division 03		5
NAS301148	Tank Aboveground		3,735.00	Mod. 1	SwRI Division 03		5
NAS301149	Tank Aboveground		2,680.00	Mod. 1	SwRI Division 03		5
NAS301150	Tank Aboveground		2,680.00	Mod. 1	SwRI Division 03		5
NAS301151	Tank Aboveground		1,285.00	Mod. 1	SwRI Division 03		5
NAS301152	Tank Aboveground		1,285.00	Mod. 1	SwRI Division 03		5
NAS301153	Tank Aboveground		1,285.00	Mod. 1	SwRI Division 03		5
DEN301271 A & B	Hydrotreater System		427,869.00	Mod. 1	SwRI Division 03		5
MM01427	Air Ambient Vaporizer	Ceyaire	1,455.00	Mod. 1	SwRI Division 03		5
MM01428	Cexhectric 6kw Gas Heater		1,942.00	Mod. 1	SwRI Division 03		5
MM01425	3,000 Gallon Cryogenic Tank		19,500.00	Mod. 1	SwRI Division 03		5
MM01426	Cryogenic Pump Unit		17,880.00	Mod. 1	SwRI Division 03		5
MM01423	Seamless Pressure Vessel (Surge Tank)		3,500.00	Mod. 1	SwRI Division 03		5
MM01424	Dual Channel Gas Detection System		1,912.00	Mod. 1	SwRI Division 03		5
MM01422	Laminar Flow Element		1,340.00	Mod. 1	SwRI Division 03		5

I, an authorized representative of the subcontractor, hereby certify that the above information is complete and accurate.

Don Sylvester (signature) 28 Sep 95

(Signature) (Date)

Don Sylvester Property Administrator

(P inted Name) (Title)

Refer to: 03-5151

GOVERNMENT PROPERTY INVENTORY & CERTIFICATION

NREL Subcontract No: XS-2-12120-1   Subcontractor: Southwest Research Institute

DOE Tag No.	Item Description or Nomenclature	Mfgr. Name Model No. & Serial No.	Acquisition/ Fabrication Cost	Acquisition Reference Number	Location	Disposition Status	Condition Code
N/A	Valve, Excess Flowcheck		125.00	Mod. 1	SwRI Division 03		5
N/A	Gas Detector		193.00	Mod. 1	SwRI Division 03		5
N/A	Hard Disk Drive	Vulcan	499.00	Mod. 1	SwRI Division 03		5
N/A	Charge Amplifier	504E	685.00	Mod. 1	SwRI Division 03		5
N/A	2 Each Pressure Transducer	12AP300CVK	1,600.00	Mod. 1	SwRI Division 03		5
N/A	Power Supply 4 Amp		217.00	Mod. 1	SwRI Division 03		5
N/A	Pump MB41		208.00	Mod. 1	SwRI Division 03		5
N/A	Heat Exchanger BCF		479.00	Mod. 1	SwRI Division 03		5
N/A	Data General 4222 Digital Interface		400.00	Mod. 1	SwRI Division 03		5
N/A	Pressure Regulator	H2H50	115.00	Mod. 1	SwRI Division 03		5
N/A	Circulation Heat	CCH-21005	313.00	Mod. 1	SwRI Division 03		5
N/A	Rotameter	110-24	842.00	Mod. 1	SwRI Division 03		5
N/A	Timing Light Transducer	7080-012	180.00	Mod. 1	SwRI Division 03		5
N/A	Doric Controller	DC-7025-L	395.00	Mod. 1	SwRI Division 03		5
N/A	Injector Pump		450.00	Mod. 1	SwRI Division 03		5
N/A	Storage Cabinet	Grainger 3W043	161.00	Mod. 1	SwRI Division 03		5
N/A	Filing Cabinet	14121CL-DS	53.00	Mod. 1	SwRI Division 03		5

I, an authorized representative of the subcontractor, hereby certify that the above information is complete and accurate.

Don Sylvester (signature)   28 Sep 95
(Signature)   (Date)

Don Sylvester   Property Administrator
(Printed Name)   (Title)

Refer to: 03-5151

GOVERNMENT PROPERTY INVENTORY & CERTIFICATION

NREL Subcontract No: XS-2-12120-1 Subcontractor: Southwest Research Institute

DOE Tag No.	Item Description or Nomenclature	Mfgr. Name Model No. & Serial No.	Acquisition/ Fabrication Cost	Acquisition Reference Number	Location	Disposition Status	Condition Code
N/A	Blower w/Motor		320.00	Mod. 1	SwRI Division 03		5
N/A	Pressure Regulating Valve		400.00	Mod. 1	SwRI Division 03		5

I, an authorized representative of the subcontractor, hereby certify that the above information is complete and accurate.

Don Sylvester (signature) — 28 Sep 95

(Signature) (Date)

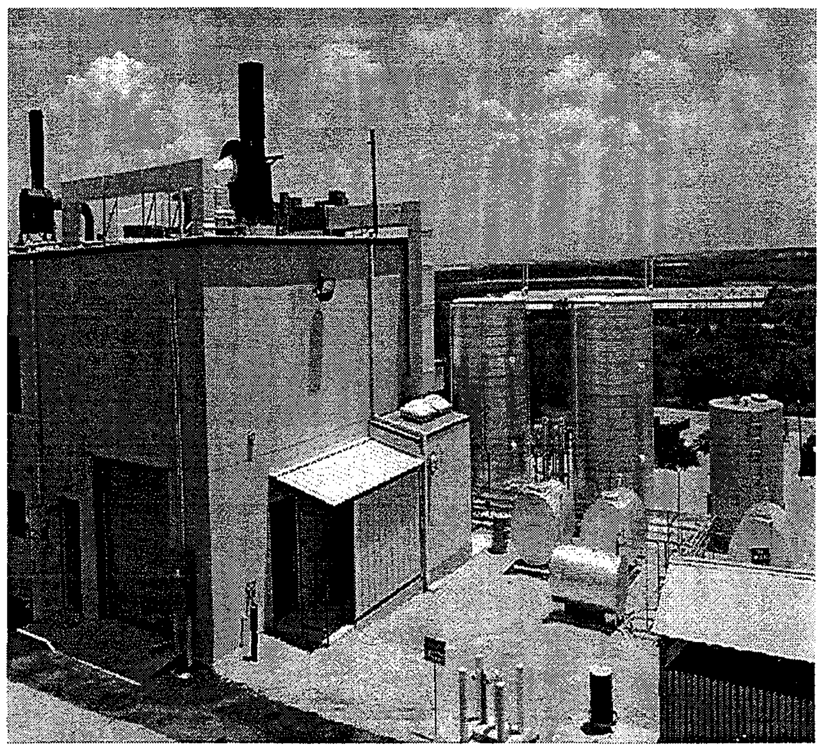
Don Sylvester — Property Administrator

Printed Name) Title)

Exhibit 3. Description of Facilities

FACILITIES DESCRIPTION
US DOE ALTERNATIVE FUEL CENTER
AT SOUTHWEST RESEARCH INSTITUTE

The Synthetic Fuel Center (SFC) was established by the Department of Energy (DOE) as part of the Alternative Fuels Utilization Program (AFUP) to provide drum quantities of finished transportation fuels from a variety of sources. Since 1978 the AFUP of the Office of Energy Efficiency and Renewable Energy has investigated the possibilities and limitations of expanded scope and replacement means for transportation fuels from alternative sources to complement conventional petroleum fuels. The main function was to provide test fuels in 5- to 500-gallon quantities for research projects on the utilization of alternative fuels.



US DOE ALTERNATIVE FUEL CENTER

DOE funded the design, construction, and installation of a hydrogenation pilot plant capable of performing a range of hydrotreating, reforming, and hydrocracking operations. SwRI provided the building, utilities, and laboratory and safety systems needed for the pilot plant. Later, the U.S. Navy provided a pilot-scale continuous distillation unit, and SwRI provided batch distillation equipment, which are conveniently housed in the same building as the hydrotreater pilot plant, but are not formally part of the AFC

The AFC is comprised of samples, structures, equipment, and storage infrastructure on a specially diked work area spread over about an acre at Southwest Research Institute. Descriptions of the facilities are provided in the following sections.

HYDROGENATION UNIT CAPABILITIES

The pilot unit was designed with flexibility to handle a range of hydrogenation operations. Nominal feed rate is 1.0 to 2.2 gal/hr. The reactor section operates at pressures to 3000 psig and temperatures to 1000°F. Hydrogen circulation capacity of 250 scf per hour is equivalent to about 4.800 scf per barrel at maximum feed rate. Appropriate operating conditions and catalyst types can be selected for the following product objectives at various levels of severity:

SEVERITY	PRODUCT OBJECTIVE
Low	Hydrotreat to reduce sulfur and nitrogen content of reformer feed or distillate fuel.
Moderate	Hydrotreat to prepare feedstocks for hydrocracking or to increase hydrogen content of fuel.
Intermediate	Hydrogenate aromatics to produce low-emission diesel fuel.
High	Hydrocrack light cycle oil to make high energy density jet fuel.
High	Catalytic reforming of low octane naphtha.

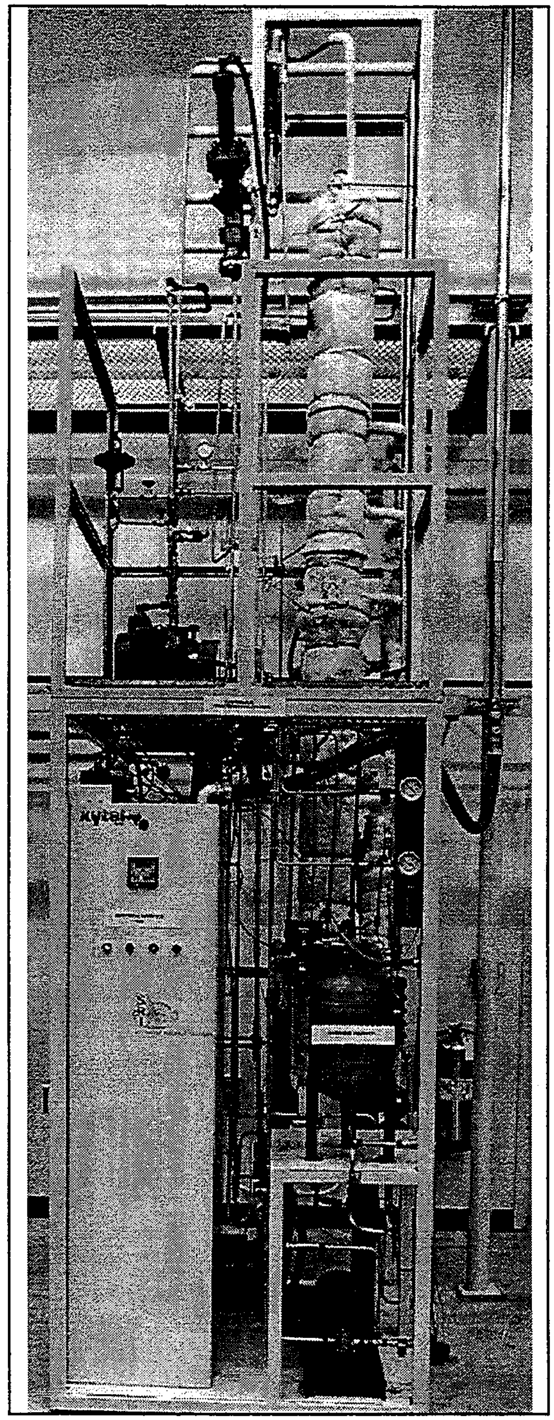
The attached process schematic of the unit shows feed joined by hydrogen through a preheater to two fixed-bed reactors in series. Reactor effluent is cooled and liquid product is recovered in two stages of separation. Recycle hydrogen and vent gases are scrubbed to remove contaminants. The liquid product goes to a distillation column, which is used as a stripper to remove H_2S or adjust the flash point. Alternatively, the distillation column can take a light product overhead at atmospheric pressure or under vacuum. The column bottoms may be collected as product or recycled to the reactor section. The recycle pump can also be used to increase total feed rate to 3.5 gal/hr

Continuous Fractionation Unit

A pilot scale Continuous Distillation Apparatus is available for research projects with 1- to 5-day run times. The distillation equipment was funded by the U.S. Navy Air Propulsion Center in cooperation with the U.S. Army Belvoir Research and Development & Experimental Center. The facility is housed in the Synthetic Fuel Center on the grounds at SwRI and includes all tankage lines, pumps, heat exchangers, and automatic controls for independent operation. The column has the capacity to fractionate approximately 120 gal/day of distillable feed, producing overhead products in the range of 10% to 90% of the feed, with the remainder as bottoms product. The column is also equipped for vacuum distillation. Column specifications are:

Column Type: Continuous flow/full packing
Pressure Range: 0.2 - 14.7 psi
Temp. Range: 150° to 600°F (900°F equiv. vacuum)
Feed Rate: Nominally 5 gal/hr
Overhead Product: 10% to 90% of feed
Reflux Ratio: Variable (0 - 5:1)
Theoretical Plates: 10-40 (depending on operating conditions, packing)

The distillation system is designed for unattended fractionation of feedstocks over the range of operating conditions listed above. Process control and data acquisition is through a dedicated microcomputer system linked directly to the process. A sophisticated safety system is part of the operating program and contains dissimilar alarm logic to provide, on one level, troubleshooting actions, and on a higher level, controlled system shutdown. Feed enters the column via a preheater through any of five ports. Light product is condensed overhead and directed back to the column as reflux or to the overhead product receiver. Bottoms product is drawn from the reboiler at the bottom of the column as the level in the reboiler rises.


Continuous Fractionation Pilot Plant.

TEST FUEL CUSTODY AND STORAGE

Control and preservation of the test fuels produced and acquired for the AFUP is a prime concern. Avariety of large and small storage options were incorporated in the AFC. These storage methods are designed for efficiency in providing physical security for samples being retained including protection from loss, water, heat, oxidation, and contamination.

For large samples, a suite of tanks is available. These vessels are interconnected *via* a pipeway providing filling, draining, vapor return, inerting, temperature sensing, and level measurement. The tanks include:

- 2 Insulated Tanks, 10 000 gallon

- 2 Covered Tanks, 5 000 gallon
- 3 Tanks, 1000 gallon
- 4 Tanks, 500 gallon

Additionally there are small mobile tanks for transport and blending, which may be held on weighing scales. With stationary and mobile transfer pumps, a variety of on site blending and handling duties may be performed, including

- Precision Blending
- Sample Transfer
- Filtration
- Clay Treating
- Water Separation

Drum storage in a large, outdoor storage area is available. The location is diked for spill protection and organized by a locator grid for sapmle placement. Limited, refrigerated indoor storage is also available. Small samples are retained in ventillated, indoor storage.

All stored materials are recorded in a sample tracking system to maintain custody. Origin and volumes are kept along with information about MSDS and use in local research. Together with comprehensive laboratory facilities, any storage and analysis requirement can be met.

REPORT DOCUMENTATION PAGE

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13. ABSTRACT *(Maximum 200 words)* The Alternative Fuel Center (AFC) was established by the U.S. Department of Energy (DOE) as part of the Alternative Fuel Utilization Program (AFUP). The AFC is designed to provide drum quantities of finished transportation fuels from a variety of sources. DOE funded the design, construction, and installation of a hydrogenation pilot plant capable of performing a range of hydrotreating, reforming, and hydrocracking operations. Southwest Research Institute provided the building, utilities, and laboratory and safety systems needed for the pilot plant. The AFC work reported here contributes to the two primary objectives of the AFUP: data for alternative-fuel-capable vehicles to enhance our energy security, and data for controlling emissions for improved air quality.

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