U.S. Department of Energy
Pittsburgh Energy Technology Center

Refining and End Use Study of Coal Liquids

Contract No. DE-AC22-93PC91029

Quarterly Report
January - March 1996

Section 1

Introduction and Summary

This report is Bechtel's tenth quarterly technical progress report and covers the period of January 1, 1996 through March 24, 1996.

1.1 Introduction

Bechtel, with Southwest Research Institute, Amoco Oil R&D, and the M.W. Kellogg Co. as subcontractors, initiated a study on November 1, 1993, for the U.S. Department of Energy's (DOE's) Pittsburgh Energy Technology Center (PETC) to determine the most cost effective and suitable combination of existing petroleum refinery processes needed to make specification transportation fuels or blending stocks, from direct and indirect coal liquefaction product liquids. This 47-month study, with an approved budget of $4.4 million dollars, is being performed under DOE Contract Number DE-AC22-93PC91029.

A key objective is to determine the most desirable ways of integrating coal liquefaction liquids into existing petroleum refineries to produce transportation fuels meeting current and future, e.g. year 2000, Clean Air Act Amendment (CAAA) standards. An integral part of the above objectives is to test the fuels or blends produced and compare them with established ASTM fuels. The comparison will include engine tests to ascertain compliance of the fuels produced with CAAA and other applicable fuel quality and performance standards.

The final part of the project includes a detailed economic evaluation of the cost of processing the coal liquids to their optimum products. The cost analyses is for the incremental processing cost; in other words, the feed is priced at zero dollars. The study reflects costs for operations using state of the art refinery technology; no capital costs for building new refineries is considered. Some modifications to the existing refinery may be required. Economy of scale dictates the minimum amount of feedstock that should be processed.

To enhance management of the study, the work has been divided into two parts, the Basic Program and Option 1.

The objectives of the Basic Program are to:

- Characterize the coal liquids
- Develop an optimized refinery configuration for processing indirect and direct coal liquids
- Develop a LP refinery model with the Process Industry Modeling System (PIMS) software.

The work has been divided into six tasks.

Task 1 - Development of a detailed project management plan for the Basic Program
Task 2 - Characterization of four coal liquid feeds supplied by DOE
Task 3 - Optimization of refinery processing configurations by linear programming

Task 4 - Pilot plant analysis of critical refinery process units to determine yield, product quality and cost assumptions. Petroleum cuts, neat coal liquids, and coal liquids/petroleum blends will be processed through the following process units: reforming, naphtha and distillate hydrotreating, catalytic cracking and hydrocracking.
Task 5 - Development of the project management plan for Option 1
Task 6 - Project management of the Basic Program and Option 1

The objectives of Option 1 are to:

- Confirm the validity of the optimization work of the Basic Program
- Produce large quantities of liquid transportation fuel blending stocks
- Conduct engine emission tests
- Determine the value and the processing costs of the coal liquids

This will be done by processing the coal liquids as determined by the optimization work, blending and characterizing the product liquids, and running engine emission tests of the blends. Option 1 has been divided into three tasks.

Task 1 - Based on the pilot plant and linear programming optimization work of the Basic Program, production runs of pilot plants (hydrotreating, reforming, catalytic cracking, and hydrocracking) will be conducted to produce sufficient quantities for blending and engine testing.
Task 2 - The pilot plant products will be blended, characterized, and engine tested
Task 3 - An economic analysis will be conducted to determine the costs of processing the coal liquids through the existing refinery

Table 1-1 shows which organization has the primary responsibility for each task.

1.2 Summary

The major efforts conducted during the first quarter of 1996 were in the areas of:

- DL2 light distillate hydrotreating
- DL2 heavy distillate catalytic cracking

Section 1

Introduction and Summary

Table 1-1 Project Task Primary Responsibility Chart

Task	Description	Bechtel	SwRI	Amoco	Kellogg
1	Project Management Plan (PMP) development	x			
2	Feed characterization		x		
3	Linear programming	x			
4	Pilot plant analysis -				
	Cat cracking of DL liquids				x
	Cat cracking of indirect wax			x	
	Hydrocracking of wax			x	
	Fractionation, reforming, hydrotreating, etc.		x		
5	Option 1 PMP development	x			
6	Project management	x			
Option 1 - Task 1	Pilot plant production -				
	Cat cracking of DL liquids and wax				x
	All other production work		x		
Option 1 - Task 2	Fuel blending, characterizing, engine testing		x		
Option 1 - Task 3	Economic analysis	x			

x = key participant

Section 2

SwRI Activities

2.0 DL2 Light Distillate Hydrogenation Experiments

The objectives of these experiments were to hydrotreat DL2 light distillate and to obtain process data at various operating conditions. The data from this work will be used in the PIMS linear programming refinery model being developed by Bechtel.

The feedstocks for the experimental points in the run are as follows:

- DL2 light distillate cut, FL-2541 (350 to 500°F TBP).
- Petroleum kerosene hydrotreater feed, FL-2342.
- A blend of 33.3 vol% coal liquid FL-2541 and 66.7 vol% petroleum liquid FL-2342.
- For comparison, a few points were obtained with the DL1 light distillate, FL-2371. The run will not involve any DL1/petroleum blends.

2.1 Planned Test Conditions for DL2 Light Distillate Hydrotreating, Run 55

The results of previous hydrotreater runs were reviewed to define the test conditions necessary for the DL2 light distillate hydrotreating tests. The conditions of the DL1 heavy distillate run (No. 49) were too severe to observe a variation in sulfur removal. More than 90% sulfur was removed at all of the process conditions. The range of conditions were adequate to see a variation in nitrogen removal between 40% and 100%. The DL1 naphtha run (No. 51) results showed the opposite trends for heteroatoms. Sulfur removal varied from 74% to 91%, while virtually all of the nitrogen was removed at each of the conditions.

In considering significantly lower severity processing than in past experiments in this project, it is useful to review the equipment capabilities. Table 2-1 gives the practical extremes for flowrate, temperature, and pressure for the pilot plant.

The least severe condition available from the hydrotreating pilot plant seemed well below the threshold for minimal change to the feed stock. It is also less severe than conditions used in the in-line hydrotreater used during the production of the POC-2 product. Since previous runs showed the most severe conditions exceeded the requirements for processing DL1, and DL2 would seem to require even less severity than DL1, the intent for the DL2 processing is to set the hydrotreating severity from minimal effects on feed properties to sufficient severity to meet the product specifications. In addition, the test conditions should include typical refinery operating conditions which will be used in the LP model. Typical refinery conditions, however, may not coincide with any particular point of the experimental matrix, but are closest to points F-R-S or K-M defined below.

The lowest severity condition should make a minimal change in the most restrictive property. Jet A is a likely finished product, but grade 1D diesel fuel is also possible. Table 2-2 lists a few

properties likely to be restrictive for either product, and the corresponding value for the neat DL2 light distillate stock.

Hydrotreating at high severity should provide a product meeting the aromatics and specific gravity limits. However, it was a concern that even at low aromatics levels (e.g. below 8%), neither the smoke point nor the cetane number specifications could be met. Should that result occur, it would still provide valuable information for the project. Therefore, the criteria for the highest severity point in the matrix was to reach either the smoke point, or cetane number specification, or, in lieu of those, reaching an aromatics concentration of less than 8%.

In addition to the properties listed in Table 2-2, it is frequently useful to have data on sulfur reduction, although the feed contains only 11 ppmw. Sulfur may be a sensitive indicator of minimal severity hydrotreating to decide if process conditions needed for the hydrogenation of the corresponding petroleum light distillate will accomplish desulfurization for the DL2 light distillate. Smoke point and cetane number analyses were chosen to review processing success; specific gravity and aromatics were measured on all samples, and low severity samples were analyzed for sulfur concentration. The experimental points are shown in Figure 2-1 as a wire-frame diagram in P-T-SV space.

The experimental matrix was modified from the normal rectangular array used in past work. The analyses of Yui and Sanford[1] indicate that aromatics hydrogenation is a reversible reaction, and that thermodynamic equilibrium limits conversion at high temperatures and low pressures. The DL2 light distillate contains an unusually high concentration of naphthenes (66%) which favors the reverse (dehydrogenation) reaction. If the reaction reverses, naphthenes would yield aromatics, and typically some coke on the catalyst. The product could be less likely to meet specifications than the feed. Since the conditions most likely to cause the reverse reaction occur at high temperature and low hydrogen partial pressure, the low-pressure face of the experimental space for varying temperature and LHSV was reduced in range from the 520-680°F used in common practice to only 520-650°F. The corresponding high-pressure face was thought to be adequate, and was left as in previous experiments.

The planned matrix of test conditions is shown in Table 2-3.

2.2 Experimental Results

The experimental sessions occurred before and after Christmas, 1995. The progress of the runs is depicted in Figures 2-2, 2-3, and 2-4. The first two plots represent the conditions during the first processing session, while Figure 2-4 shows the second session.

The process conditions from the operating log are reported in Table 2-4. For LP modeling purposes, petroleum data was required at point A. After obtaining point A, the feed was changed

1. S.M. Yui and E.C. Sanford (Syncrude Canada), "Kinetics of Aromatics Hydrogenation And Prediction of Cetane Number of Synthetic Distillates", Proceedings API Refining Department, May 1985.

to the DL2 liquid, and point B was obtained at the same conditions as A. Points N, T, M, and the other points were from the matrix as shown.

After point B, the highest severity condition was determined. Because of the naphthenes, achieving severity by increasing pressure was more effective than by increasing temperature. Once points B and C were established, the remaining points were obtained without variation, and were done in alphabetical order.

Recorded in the Table 2-4 are feedstock identity, feed flow rate, system pressure, makeup hydrogen flow rate, and average reactor temperature for each point on the experimental matrix. The analyses of the liquid samples obtained at each point are presented in Table 2-5. The principal measurements were density, hydrogen content, sulfur concentration, nitrogen concentration, and smoke point. The results for heteroatom removal are discussed in the next section.

2.3 Discussion of Results

Sulfur Removal

At the completion of Run 55, all samples were analyzed for sulfur and nitrogen. All the sulfur results were less than 2 ppmw and near the analytical detection limit. Since the sulfur concentration in the feedstock was only 13 ppmw, the removal was essentially complete.

Nitrogen Removal

The DL2 feed contained 64 ppmw nitrogen, and the product nitrogen concentrations varied from 61 to less than 2 ppmw over the range of process severities. The nitrogen variation in the experiments can be examined graphically for each face of the three dimensional experimental space. Figures 2-5 through 2-10 show the nitrogen contents as curves of constant concentration versus severity. It should be noted that the small wiggles in the contour lines are not specific depictions of the data; that is, they are artifacts of the plotting software, which arise when it is used with a data set of limited size.

The variation in nitrogen concentrations over the 500 psig face, is shown in Figure 2-5. The results indicate that nitrogen removal is strongly dependent on both LHSV and temperature. The upper right region of the plot corresponds to higher processing severity than the lower left region. The closer contour spacing in the upper right portion of the diagram means that the dependence is stronger there. That is, a given change in either temperature or LHSV provides more change in nitrogen concentration in the high-severity region than in the low-severity region.

Figure 2-6 shows the corresponding results at 2000 psig. At the higher pressure, the dependence of nitrogen removal on temperature is less pronounced. In addition, the dependence on severity is only slightly stronger in the high-severity region of the plot, (i.e. in the upper right) than in the lower severity region.

Figures 2-7 and 2-8 show the nitrogen concentration dependence on pressure and temperature at low and high space velocities, respectively. At 1.0 Hr^{-1} LHSV, the pressure dependence is small; most of the change in nitrogen removal results from temperature change. In contrast, Figure 2-8 shows a fairly linear dependence on both parameters at 4.0 Hr^{-1} LHSV over the experimental range.

Figures 2-9 and 2-10 show the low and high temperature faces of the experimental space. The results show marked LHSV dependence in each temperature range, but only a slight pressure dependence. Over the whole range of experiments, the generally weak pressure dependence was untypical of an analogous petroleum stock and unexpected from experience with DL2.

The petroleum-coal liquid blend was not completely denitrogenated at the high-severity corner of the 500 psig face (500 psig, 650 °F, and 1 Hr^{-1} LHSV) as was the coal liquid. The blend started with nitrogen concentration at 25 ppmw, and was reduced to 10 ppmw at the same corner. It was further reduced to 3 ppmw when the pressure was increased to 2000 psig. Compared to most commercial hydrotreating, these are low concentrations.

The concentrations of both sulfur and nitrogen in the pilot plant streams were so small, they frequently did not show up in the gas analyses made during the experiments. As a result, the elemental balances with respect to the gas samples were not meaningful. The overall mass balances have been calculated for both the coal liquid and blend experiments. The complete table is too extensive to include in its entirety here, but Table 2-6 summarizing the main results, is presented. The average deviation from closure was about 6 wt.%.

Aromatics Reduction

For use in jet fuel and diesel fuel, the aromatics should be lower than the 24.0 vol% of the light distillate feedstock. The limit for jet fuel use of 22.0 vol% maximum was readily achieved in the matrix of process conditions. The aromatic contents shown in Table 2-5 show a decrease of 0 - 3 vol% or more. (The value of 7 vol% for point C should be checked more carefully.) Other properties for jet fuel use may be obtained by blending. For example, the density of the light distillate products is high, probably from cycloparaffins. The smoke point is improved slightly over the feed and would meet the specification at point C.

This range of aromatics reductions also is reasonable for using the hydrotreated light distillate as a diesel blend stock. Although there is no national aromatics specification at this time, one could be imposed nationally as was done in California.

Cetane Number Control

The change in the cetane number due to hydrotreating was determined by calculating the cetane index of the feed and hydrotreated products. The cetane index of the neat light distillate is 27.6, while the cetane number is 32. The improvement in cetane index across the experimental matrix, 0 - 2.4, (as indicated by the average of cetane indices by ASTM D 976 and D 4737) was not

enough to meet the cetane number specification minimum of 40 for D1 grade. It should be noted, however, that the difference between the cetane index and the cetane number values seen in the feed material also should be true for the hydrotreated products as well. Therefore, the cetane numbers of the hydrotreating products should be 4 to 5 points higher than the cetane index values shown in Table 2-5. In summary, the products should be acceptable diesel blending components, particularly considering the low heteroatom content.

2.4 Summary

The difficulty observed in the results for partially altering the very low heteroatom contents of the DL2 light distillate and the subsequent difficulty of measuring the low sulfur and nitrogen concentrations thus produced are both indications of the effectiveness of the POC-2 production procedure. The desireable properties of the neat DL2 light distillate are presumably the result of the in-line hydrotreater and/or the switch to western coal. These results show the suitability of the DL2 light distillate for refining with petroleum into specification transportation fuels.

SwRI Activities

Table 2-1. Extremes in available processing conditions

Parameter				Units	Maximum	Minimum
Temperature				F	~950	280
Liquid Flow				Pump 1, gph	3.0	0.1
				Pump 2, gph	1.6	0.1
				Total, bbl/H	0.109	0.0024
Vessel volumes, gallons	Vessel**	Empty	Packed			
	G & R	2.15	1.56	Hr^{-1}	2.9	0.06
	R	1.16	1.05		4.4	0.09
	S	0.507	0.38		7.9	0.26
Pressure				psig	2500	400*
Hydrogen Flow				Makeup, scfh	75	0
				Recycle, scfh	250	25
Contacting Rate				SCFB	>5000	230
* Lower pressures for reforming are arranged by special adjustments ** G - guard bed, R - main reactor, S - small reactor						

Table 2-2. Properties restricting use of untreated light distillate

Type	Description	ASTM Test No.	Property Limit	Neat DL2 Lt. Distillate
Jet A	Aromatics Volume %, Max	D 1319	22	24.0
Jet A	Specific Gravity, Range	D 1298/D 4052	0.775 to 0.840	0.8638
Jet A	Smoke Point, mm, Min*	D 1322	25*	14.5
Diesel 1D	Cetane Number, Min	D 613	40	32
* The minimum value may be 19, if the naphthalenes (D 1840) meet a 3 volume % limit.				

Table 2-3. Planned test sequence for DL2 light distillate hydrotreating

Item	Operation	Feed	LHSV	Pres., psi	Temp.°F
A	Start-up, initial data	KTFpet	1.0	500	650
B	Test Reverse Reaction	LD1c, DL2	1.0	500	650
C	Coal Liquid Process Data	LD1c, DL2	1.0	2000	680
D	Coal Liquid Process Data	LD1c, DL2	1.0	2000	520
E	Coal Liquid Process Data	LD1c, DL2	1.0	500	520
F	Coal Liquid Process Data	LD1c, DL2	4.0	500	520
G	Coal Liquid Process Data	LD1c, DL2	4.0	2000	520
H	Coal Liquid Process Data	LD1c, DL2	2.5	2000	600
I	Coal Liquid Process Data	LD1c, DL2	2.5	1250	593
J	Coal Liquid Process Data	LD1c, DL2	2.5	500	585
K	Coal Liquid Process Data	LD1c, DL2	4.0	500	650
L	Coal Liquid Process Data	LD1c, DL2	4.0	2000	680
M	Blend Process Data	LD1c, DL2/ KTFpet	4.0	500	650
N	Blend Process Data	LD1c, DL2/ KTFpet	1.0	500	650
O	Blend Process Data	LD1c, DL2/ KTFpet	1.0	2000	680
P	Coal Liquid Process Data	LD1c, DL1	1.0	2000	680
Q	Coal Liquid Process Data	LD1c, DL1	2.5	1250	593
R	Coal Liquid Process Data	LD1c, DL1	4.0	500	520
S	Coal Liquid Process Data	LD1c, DL1	4.0	500	520
T	Petroleum Process Data	KTFpet	4.0	500	520
U	Petroleum Process Data	KTFpet	1.0	500	650
V	Exptl Sample for FCC	DL2,HD1	1.0	2000	680
W	Petroleum Process Data	KTFpet	1.0	500	650

Table 2-4. Actual DL2 light distillate test conditions

Item	Feed		GPH*	Psig	Make-up H_2, SCFH	Temp.°F
*	FL-2342	KTFpet	~1.0	500	24.2	650
A	FL-2342	KTFpet	0.22	500	6.0	649
B	FL-2541	LD1c	0.23	499	6.0	641
C	FL-2541	LD1c	0.22	2000	6.0	679
D	FL-2541	LD1c	0.17	1995	6.0	520
E	FL-2541	LD1c	0.22	500	6.0	521
F	FL-2541	LD1c	0.84	500	24.2	521
G	FL-2541	LD1c	0.84	2004	24.2	519
H	FL-2541	LD1c	0.50	2005	15.1	598
I	FL-2541	LD1c	0.52	1250	15.1	590
J	FL-2541	LD1c	0.54	501	15.1	580
K	FL-2541	LD1c	0.85	500	24.2	644
L	FL-2541	LD1c	0.84	2000	24.2	681
M	Blend	LD1c+ KTFpet	0.83	499	24.2	649
N	Blend	LD1c+ KTFpet	0.21	490	6.0	650
O	Blend	LD1c+ KTFpet	0.21	1992	6.0	676
P	FL-2371	DL1,KTFc	0.20	2000	6.0	678
Q	FL-2371	DL1,KTFc	0.53	1250	14.0	592
R	FL-2371	DL1,KTFc	0.85	500	24.1	520
S	FL-2371	DL1,KTFc	0.21	500	6.0	680
T	FL-2342	KTFpet	0.83	500	24.5	520
U	FL-2342	KTFpet	0.21	500	6.0	650
V	FL-2539	DL2,HD1	0.24	2000	5.9	680
W	FL-2342	KTFpet	0.24	502	6.0	636
* Catalyst volume = 0.21 gal						

Table 2-5. Feed and product properties - light distillate hydrotreating

SAMPLE No.	Log Bk/Pg	Temp F Rx Avg	Feed Rates	Pressure Psig	Density SpGr	H_2 M% NMR	Sulfur PPM	Nitrogen PPM	Equivalent Arom vol%	Cet. Index D976/D4737	Smoke Pt mm
A-16	33-14	649	0.220	499	0.8042	14.08	0.95	1.3	17.0	46.1/47.6	22.0
B-26	33-19	641	0.220	490	0.8612	12.94		1.4	23.8	28.2/28.6	14.4
C-35	33-24	679	0.220	2000	0.8495	13.63	0.5	1.8	7.0	31.8/32.3	23.7
D-46	33-30	520	0.170	1996	0.8593	13.06		36.6	21.0	28.8/29.2	15.2
E-54	33-34	522	0.220	501	0.8621	12.85	<0.1	46.3	23.6	28.0/28.3	14.9
F-65	33-38	521	0.830	499	0.8635	12.90	1.44	61.4	24.1	27.6/27.9	15.0
G-72	33-43	520	0.830	2004	0.8632	12.61	0.67	56.1	23.6	27.6/28.0	15.2
H-80	33-45	599	0.500	2005	0.8616	12.70		34.7	21.8	28.1/28.5	15.2
I-90	33-47	591	0.523	1249	0.8626	12.62	<0.1	42.1	23.2	27.8/28.2	16.1
J-96	33-50	579	0.535	498	0.8634	12.62	<0.1	46.1	24.1	27.6/28.0	15.7
K-105	33-53	642	0.847	499	0.8639	12.57	<0.1	41.2	23.2	27.4/27.8	15.1
L-112	33-56	679	0.847	2000	0.8607	13.01		26.4	21.0	28.4/28.8	15.4
M-120	33-59	649	0.825	499	0.8271	13.65	0.94	10.2	21.6	38.6/39.7	16.3
N-130	33-65	650	0.217	499	0.8268	13.75	<0.1	3.7	21.5	38.2/39.5	16.3
O-138	33-70	671	0.214	2005	0.8165	14.21	0.29	<1	6.0	41.5/42.9	22.1
P-165	34-11	678	0.204	2000	0.8613	15.52		1.1	34.2	29.2/29.4	15.0
Q-173	34-17	592	0.529	1248	0.8740	12.19		344	58.0	25.6/25.7	11.3
R-188	34-29	520	0.850	500	0.8753	12.36		629	59.1	25.3/25.3	11.1
S-155	34-4	680	0.214	500	0.8672	12.27		29.4	58.7	27.5/27.6	11.2

Table 2-5. (cont'd) Feed and product properties - light distillate hydrotreating

SAMPLE No.	Log Bk/Pg	Temp F Rx Avg	Feed Rates	Pressure Psig	Density SpGr	H_2 M% NMR	Sulfur PPM	Nitrogen PPM	Equivalent Arom vol%	Cet. Index D976/D4737	Smoke Pt mm
T-195	34-32	520	0.835	499	0.8092	12.82		20.2	20.5	44.0/45.5	21.3
U-205	34-39	650	0.206	500	0.8068	13.96		1.1	18.5	45.0/46.5	24.2
V-177	34-18	680	0.240	1999	0.8993	12.55		20	20.7	38.2/39.1	13.2
W-147	33-80	636	0.240	502	0.8989	13.96		1.1	18.6	43.8/45.3	23.3
FL-2342	33-2	-	-	-	0.8101	13.74	1490	5	20.5	43.6/45.1	22.3
FL-2541	33-15	-	-	-	0.8639	12.79	11	66	24.0	27.4/27.8	14.5
Blend	33-56	-	-	-	0.8218	13.45	997	24	21.7	40.0/41.2	16.6
Fl-2371	33-65	-	-	-	0.8762	12.18	230	605	58.7	25.0/25.1	10.9
Fl-2539	-	-	-	-	0.9139	12.27	21	43	36.8	34.9/34.6	12.5

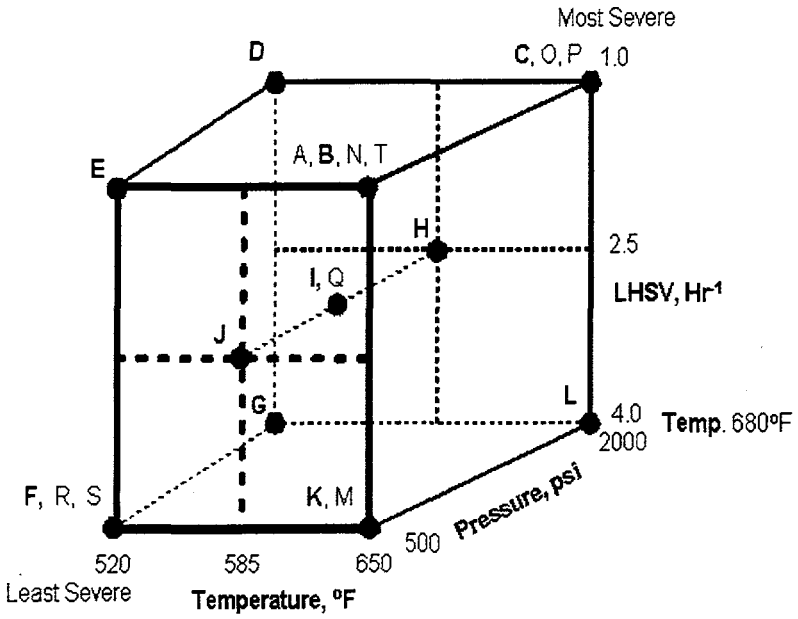
SwRI Activities

Table 2-6. Summary of mass balances for hydrotreating experiments with DL2 light distillate

Run No./ Feed	Liq Feed Sp. Gr.	React. Temp F	React. psig	LHSV	Gas Feed SCF/Bbl	Recycle SCF/Bbl	Cons. SCF/Bbl	Liq Feed Lbs	Tot. Feed Wt%	Btm Liq Sp. Gr.	Btm Liq Lbs	Btm Liq Gal	Total Product Lbs	Total Product Gal	Gain Wt%
55A/pet	0.8101	649	500	1.04	1219	2290	581	6.01	102.3	0.8042	5.69	0.849	6.20	0.918	2.1
55B/coal	0.8634	641	500	1.08	1284	1806	650	6.31	102.4	0.8612	6.51	0.909	6.88	0.922	6.6
55C/coal	0.8634	678	2000	0.79	1504	2362	958	2.85	102.8	0.8495	2.73	0.386	2.85	0.394	-3.0
55D/coal	0.8634	520	1999	0.80	1488	2485	769	3.79	102.8	0.8593	4.14	0.579	4.39	0.587	12.9
55E/coal	0.8634	521	497	1.07	1113	1827	478	5.66	102.1	0.8621	5.92	0.824	6.31	0.839	9.2
55F/coal	0.8634	521	500	3.97	1483	2414	629	14.62	102.3	0.8635	15.41	2.145	15.69	2.151	5.0
55G/coal	0.8634	519	2000	3.67	1328	2587	753	24.55	102.5	0.8632	25.21	3.513	25.64	3.518	1.9
55H/coal	0.8634	597	2001	2.35	1272	2553	969	14.85	102.4	0.8616	15.53	2.168	15.77	2.177	3.8
55I/coal	0.8634	590	1250	2.41	1235	2498	980	19.88	102.3	0.8626	20.86	2.908	21.13	2.924	3.9
55J/coal	0.8634	580	500	2.51	1206	2410	658	20.33	102.3	0.8634	21.56	3.003	22.12	3.107	6.0
55K/coal	0.8634	642	520	4.02	1179	2403	641	23.81	102.2	0.8639	24.89	3.465	25.32	3.485	4.1
55L/coal	0.8634	678	2000	3.72	1346	2584	771	32.45	102.5	0.8607	33.40	4.667	34.12	4.679	2.6
55M/blend	0.8280	649	500	3.94	1044	2098	629	35.01	102.3	0.8272	37.79	5.489	38.91	5.545	8.7
55N/blend	0.8280	650	500	1.20	1005	1994	383	6.82	101.9	0.8268	6.10	0.894	6.75	0.940	-3.6
55O/blend	0.8280	672	1944	1.04	1154	5816	849	3.00	102.1	0.8165	2.60	0.382	2.63	0.382	-14.7

SwRI Activities

Figure 2-1 Test matrix for DL2 light distillate hydrotreating



DL2:	B Thru L use LD1c A, S, and T use LD1pet M, N, and O use LD1b
DL1:	P, Q, and R use LD1c

Figure 2-2 Timeline for DL2 light distillate hydrotreating, beginning of Run 55

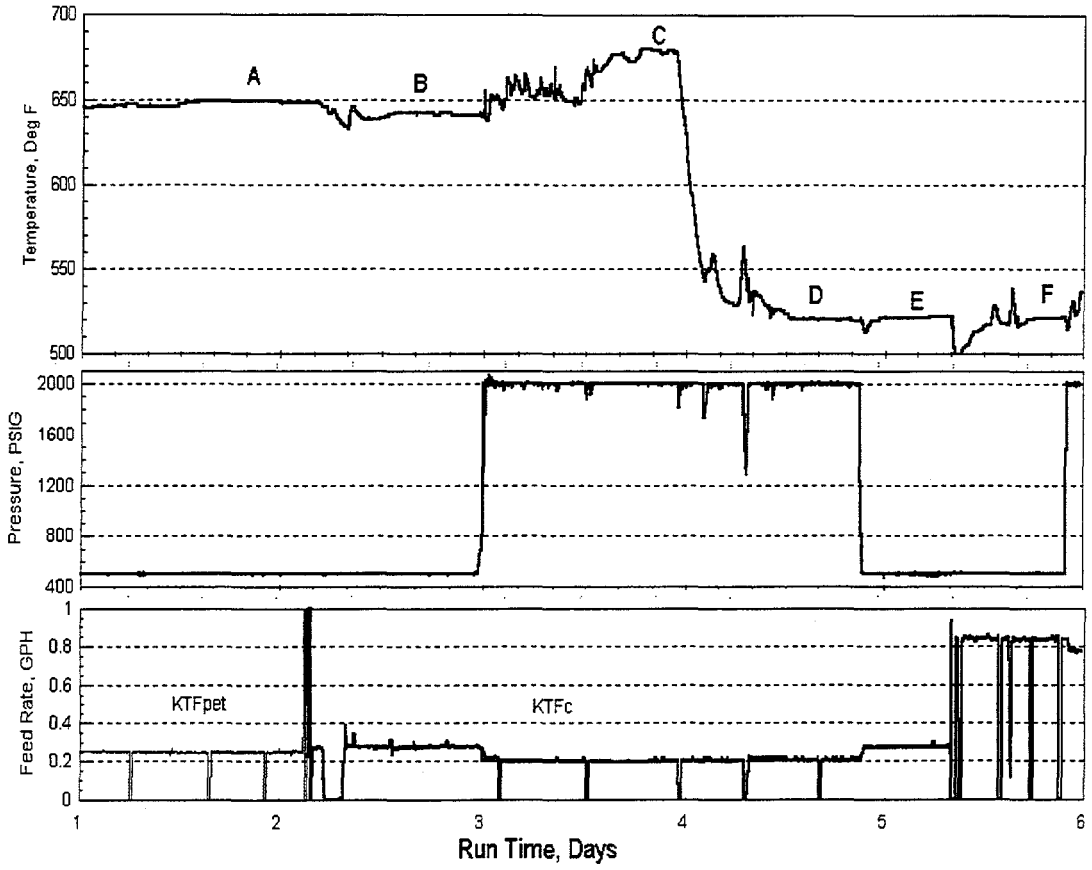


Figure 2-3 Timeline for DL2 light distillate hydrotreating, end of first session of Run 55

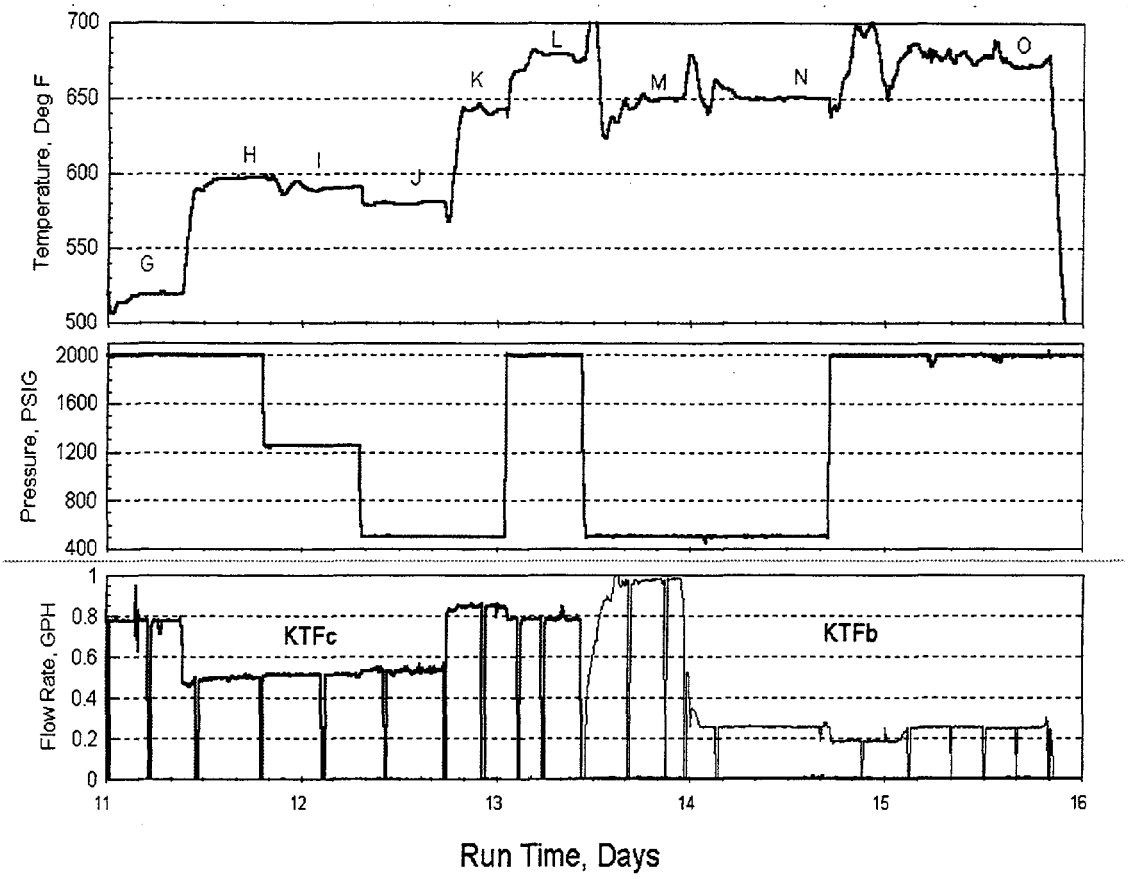


Figure 2-4 Timeline for DL2 light distillate hydrotreating, end of Run 55

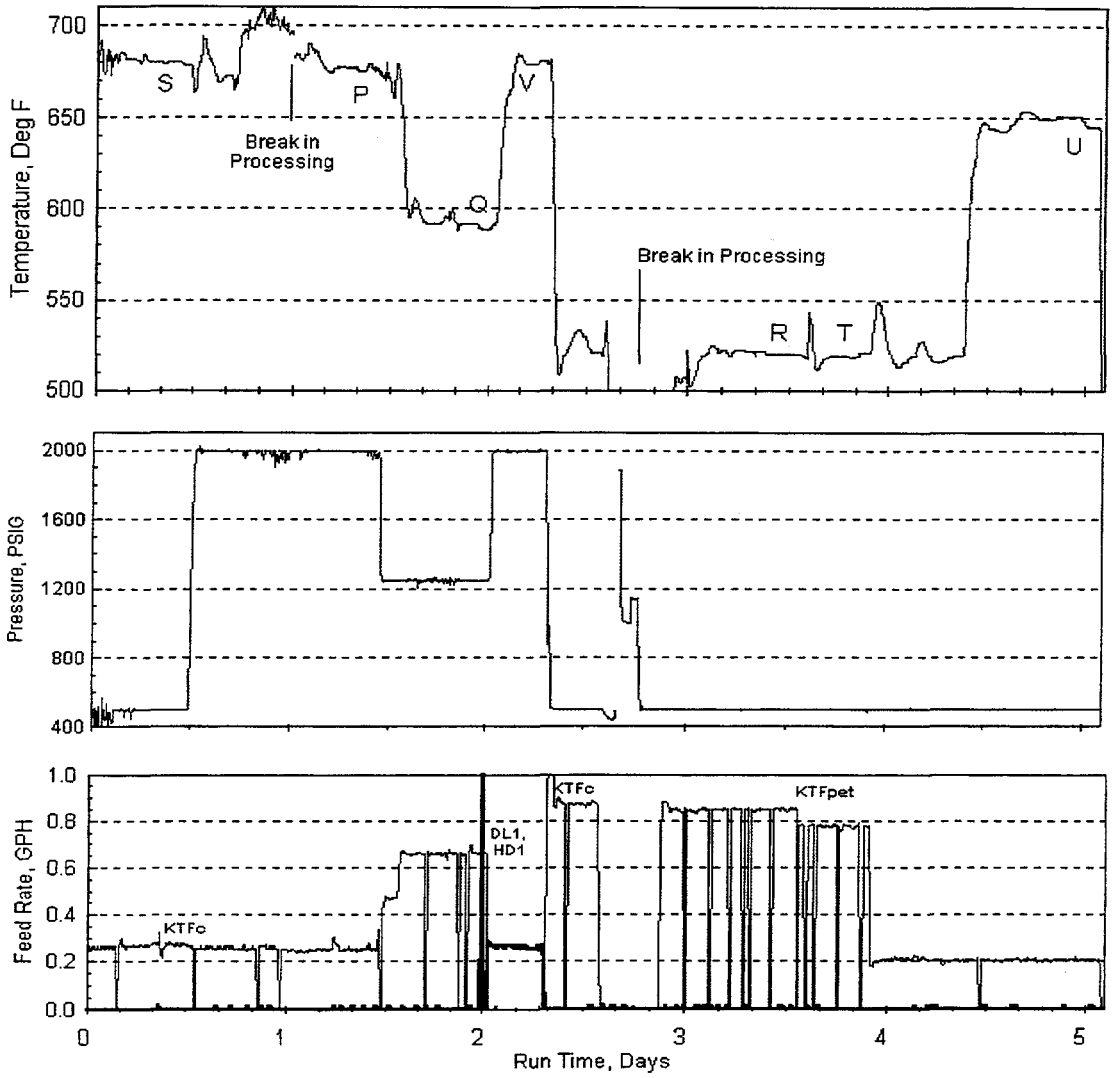


Figure 2-5 Contours of nitrogen concentration, ppmw - temperature vs. LHSV at 500 psig

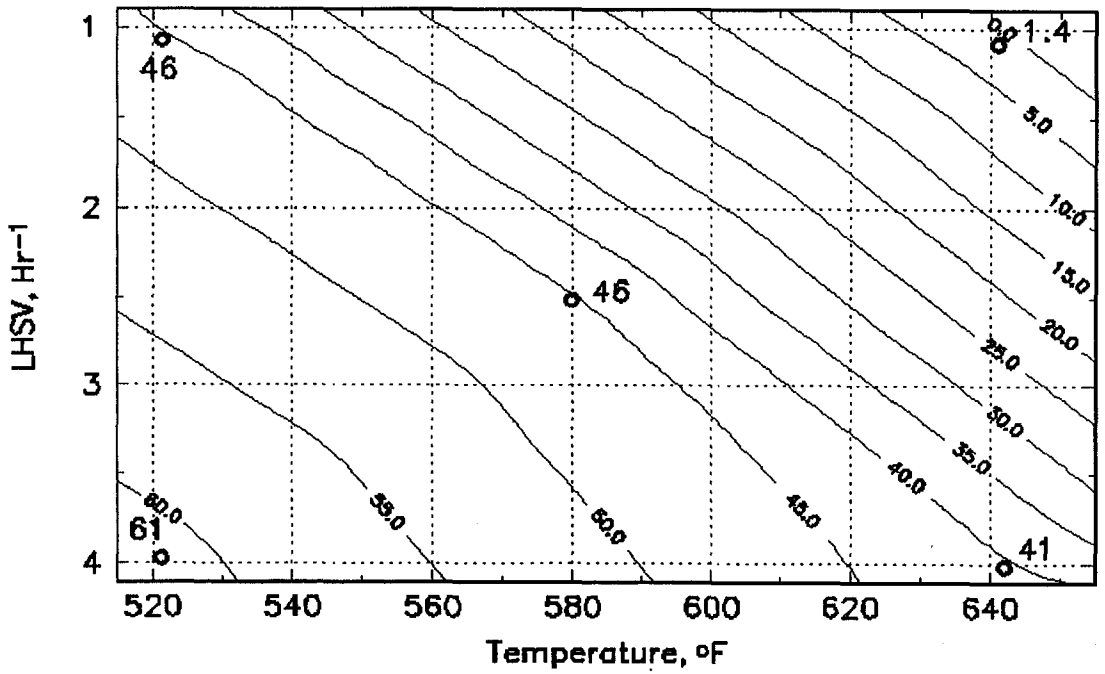


Figure 2-6 Contours of nitrogen concentration, ppmw - temperature vs. LHSV at 2000 psig

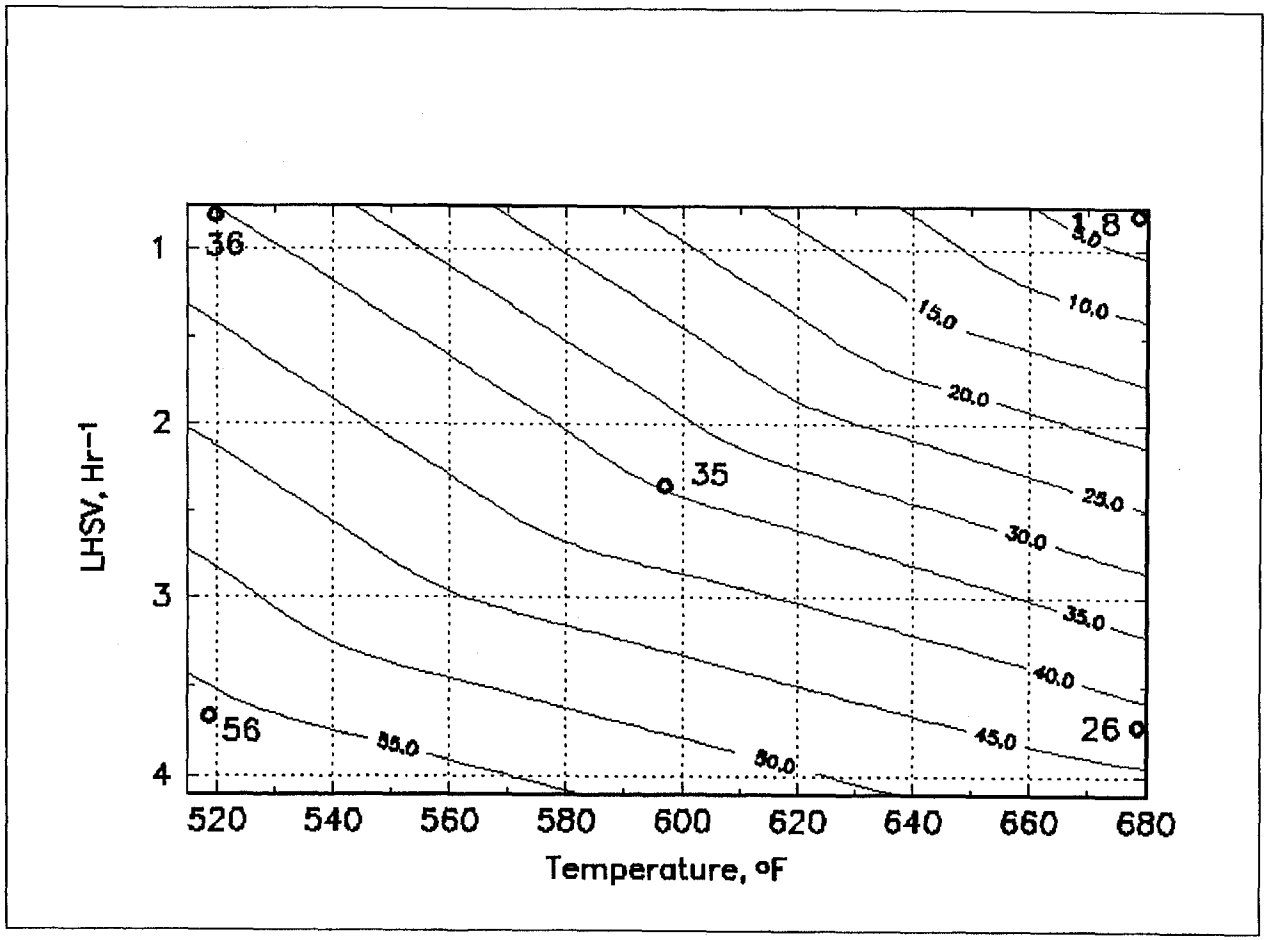


Figure 2-7 Contours of nitrogen concentration, ppmw - temperature vs. pressure at 1.0 hr^{-1} LHSV

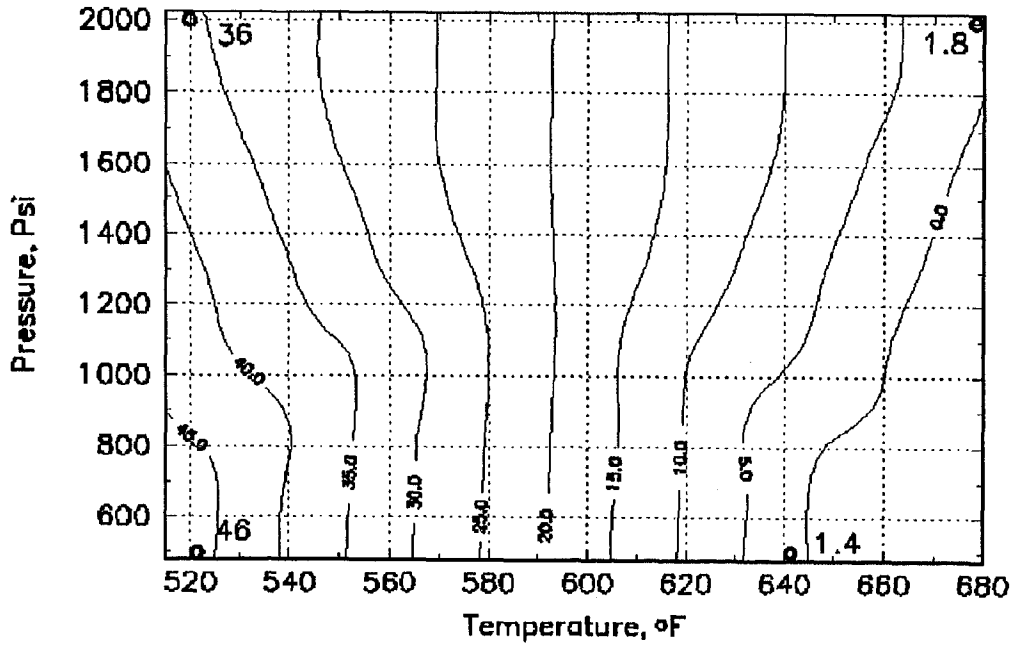


Figure 2-8 Contours of nitrogen concentration, ppmw - temperature vs. pressure at 4.0 hr^{-1} LHSV

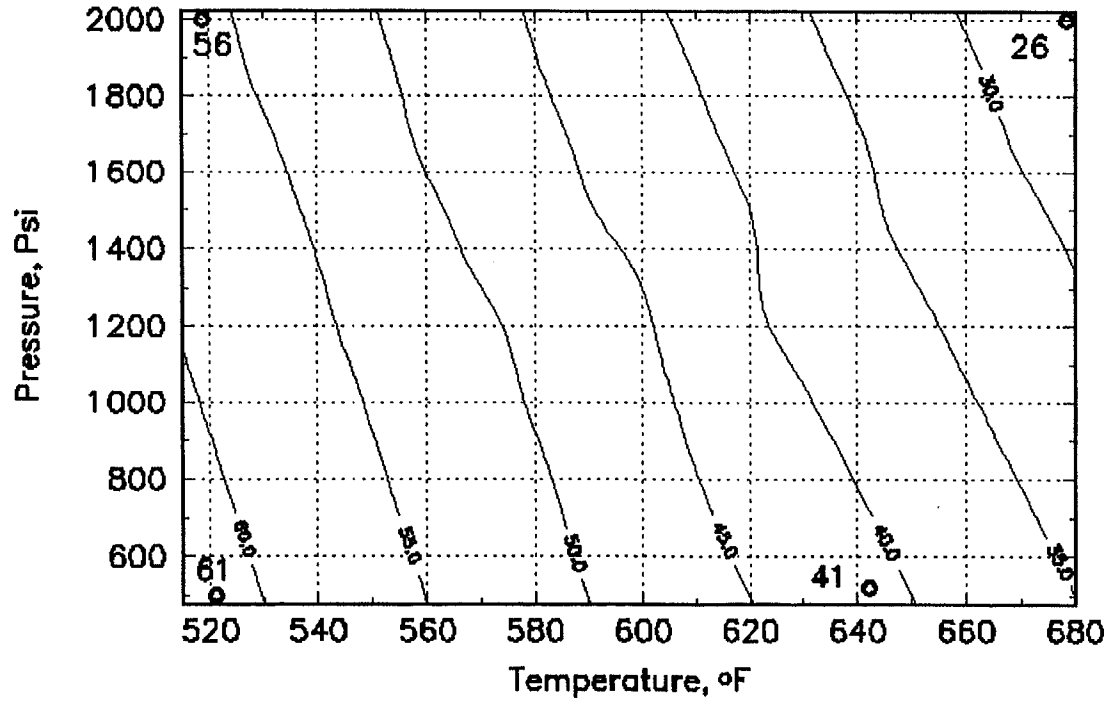


Figure 2-9 Contours of nitrogen concentration, ppmw - pressure vs. LHSV at 520°F

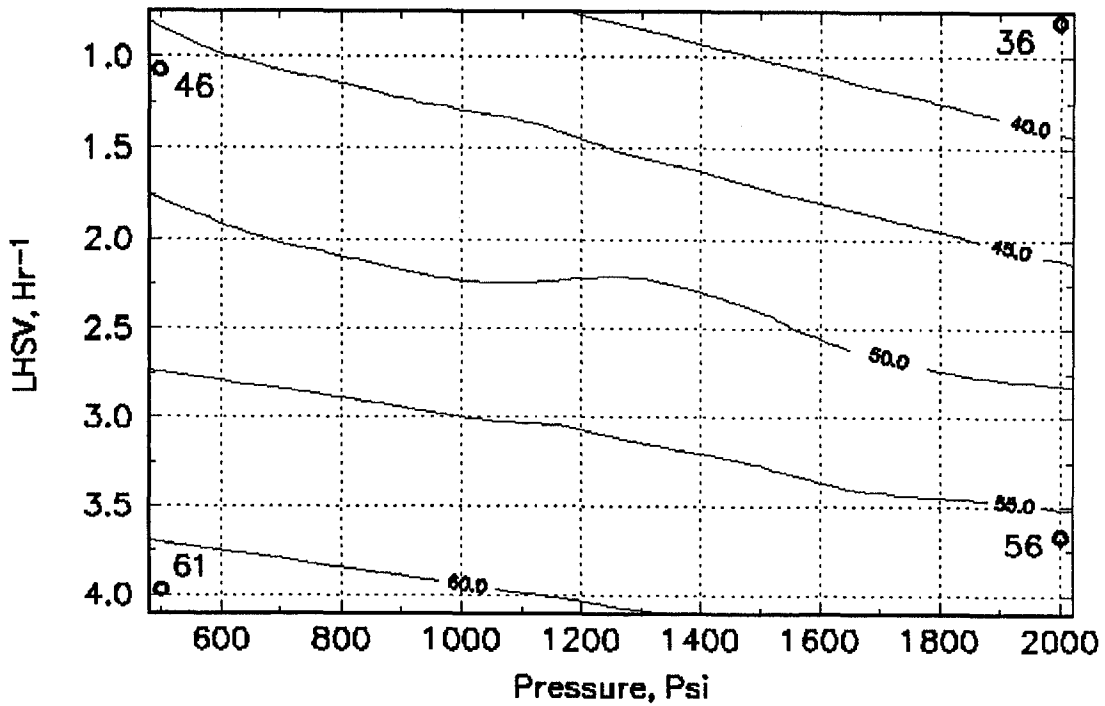


Figure 2-10 Contours of nitrogen concentration, ppmw - pressure vs. LHSV at 650-680°F