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U.S. Department of Energy
Pittsburgh Energy Technology Center

Refining and End Use Study of Coal Liquids

Contract No. DE-AC22-93PC91029

Quarterly Report
October - December 1995

MASTER

Section 1

Introduction and Summary

This report is Bechtel's ninth quarterly technical progress report and covers the period of September 25, 1995 through December 31, 1995.

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 fourth quarter of 1995 were in the areas of:

- IL catalytic cracking - Microactivity tests were conducted on various wax blends
- IL wax hydrocracking - A pilot plant run was conducted on a wax/petroleum blend
- DL2 characterization and fractionation

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

2.1 DL2 Distillation

The preparation of feedstock samples by distillation fulfills two goals: 1) it provides an assay of stream yields for the PIMS linear programming model, and 2) it provides samples for characterization in the lab and pilot plant. In the same way that the first coal liquid feed was fractionated into boiling range cuts, the POC-2 product, termed DL2 in the End Use Study, was distilled into four materials. The DL2 cuts required to produce these materials are as follows:

- Cut 1 divides the light naphtha from the medium naphtha
- Cut 2 divides the naphtha from the distillate
- Cut 3 divides the light distillate from the heavy distillate + bottoms.

Figure 2-1 displays the boiling point distribution for DL2 and the boiling curves for the four individual streams; light naphtha, medium naphtha, light distillate, and heavy distillate. Figure 2-2 compares the proportions of the cuts for DL1 and DL2, showing relatively greater light naphtha and heavy distillate in DL2. The significance of these relative abundances must be interpreted with consideration of the properties of the various fractions as presented and discussed in Section 2-2.

The cuts were achieved by a combination of continuous and batch distillation. Cut 2 was performed first producing an overhead of the two naphthas via atmospheric distillation in a 15 theoretical plate, 4" diameter continuous distillation pilot plant shown in Figure 2-3. The use of this equipment was kindly permitted by the US Army TARDEC Fuels and Lubricants Research Facility. Next Cut 3 was performed under vacuum in the same equipment. The sequence of work for both Cuts 2 and 3 is recorded in Table 2-1.

2.1.1 Cut 2 distillation

The Cut 2 atmospheric distillation of DL2 was unremarkable in itself. Table 2-1, however, recounts the gradual fouling of the preheater and eventual failure of the reboiler electrical heaters. Both of these problems were brought on by a previous distillation, which had left a coating of insoluble coke on the equipment. Before Cut 2 was made, vigorous washing flushed out all of the removable material, but did little to displace the deposited coke that eventually shut off flow in the preheater.

The distillation was interrupted while a comprehensive refurbishment of the distillation pilot plant corrected the operational problems arising from the internal deposits. It is not believed that the properties of the DL2 feed contributed significantly to the deposits. Briefly, the retrofit consisted of the following:

- 4" column and reboiler - The packing and internals were replaced, the vessels and feed points were cleaned, and the gaskets were renewed.

- Feed system - A new preheater with a lower watt density and a pulsation dampener were installed. The electrical problems of the feed flowmeter were fixed.

- Overhead system - The circuit was cleaned, an in-line sample cylinder was added, and level indication was added to the overhead tank. This permitted computer monitoring of the overhead flow, thus adding a check to the measured flows in the feed and bottoms lines.

- Bottoms system - The bottoms line was cleaned, the size of the heat exchangers was increased, the bottoms level indicator was cleaned and a nitrogen purge was added, and the bottoms flowmeter was repaired.

- Vacuum system - The glass vacuum traps were replaced with large capacity stainless steel vessels. A mechanical chiller was connected to the new product chiller in the overhead line.

The DL2 atmospheric distillation was completed after a successful break-in run to eliminate leaks and operability problems

2.1.2 Cut 3 distillation

The vacuum distillation of Cut 3 was more complicated than Cut 2 and several attempts were made before a successful separation was achieved. The pressure drop of the new packing was higher than the drop calculated from the product literature, resulting in operability problems. These were resolved by installing a fresh charge of the original packing type, a structured packing of rolled wire mesh. The subsequent distillation was difficult to manage with suggestions of water (bumping) or an unusual component (possible foaming) being present.

Obvious checks including water draws of the feed storage vessel and laboratory distillations of the suspect feed were not definitive, but at least did not confirm either possibility. The new charge of packing may have contributed to the difficulty by being harder to "wet" or providing a path for channeling in the stack of material. Eventually a combination of feed flowrate, operating pressure, and reflux rate was found, which permitted completion of Cut 3.

2.1.3 Cut 1 distillation

The separation of the naphthas was accomplished by batch distillation to accelerate progress while the above work proceeded. Accordingly 443 gallons of the mixed naphthas were sent to Pittsburgh Applied Research Center (PARC) for distillation in their 500-gallon stripper still. Figure 2-4 shows that in addition to performing Cut 1, PARC was asked to remove the 350°F+

portion. This material (approximately 3 vol%) will be added back into the light distillate produced in Cut 3.

The Cut 1 cutpoint was difficult to achieve in this equipment and required further work in a Fractioneer™ still. As a result of the handling involved, numerous small fractions resulted. To obtain property data, a lab characterization was conducted on a retained sample distilled to substantially the same plan followed at PARC. Those results and the analyses for the other fractions are presented in the next section.

2.2 CHARACTERIZATION OF DL2 FRACTIONS

Samples of each of the four fractions of DL2 were submitted to the laboratory for testing according to the same suite of tests that was applied to DL1 fractions. The results of the testing are presented in Table 2-2. For convenience of comparison, the analytical results for DL1 fractions are given in Table 2-3. The effect of the in-line hydrotreater in the POC-2 production run is pervasive throughout the properties as may be seen in the comparisons offered below. Harder to discern is the effect of the coal type of origin between the eastern bituminous (POC-1 feed) and the western subbituminous (POC-2 feed). The structure of the subbituminous coal would, however, indicate that it may play a role in the higher concentrations of cycloparaffins in the POC-2 liquid.

In Figures 2-5 through 2-9, the key properties of the DL1 and DL2 fractions are compared. Figure 2-5 shows the specific gravities of the fractions of DL1 and DL2. Except for the light naphtha, the DL2 fractions are less dense. Corresponding fractions are lower in density than typical matched petroleum materials, but are acceptable for all fuel uses. In Figure 2-6, a similar low trend for DL2 is seen for sulfur. Hydrotreating of the naphthas would still be necessary due to the low heteroatom content required of reformer feeds. The low levels are required to protect the reformer catalyst. The values of nitrogen are very low and acceptable for most uses and widely superior to petroleum. The abundance of hydrogen resulted in the lower DL2 aromatic contents shown in Figure 2-7. As shown in Figure 2-8, all DL2 fractions except for the medium naphtha have a higher cycloparaffin content.

As shown in Table 2-2, both the cetane number and the octane number are low. Except for blending low concentrations of coal liquid distillate into diesel (stability permitting), further processing is required for adequate ignition quality. Ring opening would be required to boost the cetane number, and reforming, with appropriate pretreatment, is needed for octane number improvement.

Another strong consideration for transportation fuel use would be the emissions potential of a component. One indication of emissions potential is the polynuclear aromatic hydrocarbon (PAH) concentration. Figure 2-9 shows the PAH content for DL2 is significantly lower than for

DL1. Although the PAH concentration of interest is the exhaust concentration, which arises during the combustion and exhaust system processes, the prevalence of PAH in diesel fuel is linked with higher particulate emissions.

Considered overall, both coal liquids are generally similar to petroleum in their hydrocarbon type compositions as indicated by ASTM D 1319, Fluorescent Indicator Analysis. The cycloparaffin contents are higher than the corresponding petroleum fractions, but high cycloparaffins are preferable to aromatics because they result in higher smoke point and cetane values. Heteroatom concentrations are low for DL2 resulting from the intense hydrogenation. DL2 will be an acceptable fuel component source and may lend beneficial properties for lowered emissions.

SwRI Activities

Table 2-1. DL2 Distillations Summary

Bk/Pg	Date	Actions/Descriptions
8/2	6 March 95	Dist 63: Separate 1400 gal DL2 (FL-2364) 32 V% Ohd (naphthas)
		Resembles Dist 54 (DL1) set feed 6.3 gph at startup
	7 March 95	Interrupt startup to clean out preheater - plugging
8/10	8 March 95	Start saving product
	9 March 95	Reboiler fuse blew twice - forced to go off spec a while
	10 March 95	Shutdown for weekend
8/18	14 March 95	Restart unit on Dist 63
8/24	20 March 95	Reboiler blowing fuses - shutdown to repair elect connectors
8/27		Saving product again
8/29	21 March 95	QC test showed high end point on ohd, went off spec to correct
		Fuses blowing and preheater plugged - shut down/regroup
8/40	24 Mar 95	Rigorous refit of fractionator: new product cooler, new preheater, revamp
9/3	13 June 95	reboiler, redid vac traps, upgraded flow meas., new packing, ohd sx tube
9/4	13 June 95	Restart Dist 63
		Feed flow variations affecting % ohd
9/20	19 June 95	Saving product
	21 June 95	Shutdown - Dist 63 complete
9/26	11 July 95	Dist 64: Separate LD1 from HD1+AT1
		FL-2531 feed Objective: 44% ohd 500 F TBP cut point
		Problems with reboiler level control
		Flooding both reboiler and column
9/36	13 July 95	Shut down

SwRI Activities

9/37	14 July 95	Cleaned pressure relief valves on feed and btms pumps
9/39	18 July 95	Restart Dist 64
		Temps very unstable - liquid surges in column?
	20 July 95	Shut down
9/47	24 July 95	Restart Dist 64
		Increased Pressure to 200 torr
	26 July 95	Installed Nitrogen bleed on Ohd accumulator
		Shut down
	27 July	Pack column with fresh structured packing (York Twist/Glitsch Goodloe)
9/58	3 Aug 95	Dist 65: resume Dist 64 objective with new packing
	4 Aug 95	Shut down - out of week
	7 Aug 95	Restarted - pressure 200 torr
		Reboiler bumping - disrupting operation
	11 Aug 95	Shut down
9/79	14 Aug 95	restart
10/7	17 Aug 95	Added DB100 antifoam to one drum of feed
10/9	18 Aug 95	Still "surging" - Shut down
10/10	23 Aug 95	Rinse Silicone feed from still
10/11	23 Aug 95	Dist 66: 1-drum experiment - remove H_2O & lights at atmos pressure
		High N_2 flow trying to strip H_2O
10/13	24 Aug 95	Shut down

SwRI Activities

10/14		Start dist 67: feed was bottoms from Dist 66
		Vac dist to take 5 to 15% ohd
10/17	25 Aug 95	Shut down - made ~64 gal btms
10/17	28 Aug 95	Dist 68: Try for cut - remainder of LD1 from HD1
		Use btms from Dist 67 for feed
		looking for 500 deg TBP ~27 % ohd
10/21		09:15 saving product
10/23		Finish Dist 68
10/25	30 Aug 95	Start dist 69: fresh feed, vac operation, target ~42% for 500 F cut pt
10/46	7 Sep 95	Saving product, feed ~5.3 gph
	7 Sep 95	Liquid went off spec
10/49	8 Sep 95	Found N2 rotometer broken
10/50	8 Sep 95	Saving product again with feed 3.6gph
10/51	8 Sep 95	Shut down for weekend
	11 Sep 95	Restart Dist 69
10/61	13 Sep 95	Saving product with feed rate ~6gph
10/79	18 Sep 95	End of neat feed, start silicone feed
10/82	19 Sep 95	Saving product
10/83	20 Sep 95	End of Dist 69

Table 2-2. Analysis of DL2 Distillation Fractions

Description	Whole Liquid	Lt. Naphtha	Med.Naphtha	Lt.Distillate	Hvy.Distillate
ID. No.	FL-2364	LN1	MN1	LD1	FL-2539
Volume %.	100	7.5	24.2	24.4	44.0
Density, API	33.9	60.6	49.7	32.3	23.3
Sp Gr	0.8553	0.7366	0.7808	0.8638	0.9139
Sulfur, ICP, PPM	10.0	37.4	53.0	13.1	20.9
Viscosity, D 445 cSt @ 40 C	1.76		<1.00	1.69	5.76
RON, D 2699		low	<59.6		
MON, D 2700		low	<58.2		
Cetane No. D 613				32.0	37.9
Cetane I. D 4737				27.8	34.2
Pour., F, D 97	-23.8	<-85	<-85	<-85	-7.6
Smoke, mm, D 1322	13.6			14.5	10.0
Aniline, F, D 611	107.9	107.2	108.6	104.5	121.6
Total N, D 4629	42ppm	<1ppm	<1ppm	50ppm	43ppm
Basic N, UOP313	45ppm	<1ppm	<1ppm	54ppm	47ppm
HC Type, D 1319,					
Paraffins, V%	79.4	97.2	91.9	74.3	59.7
Olefins, V%	0.8	0.9	0.8	1.7	3.5
Aromatics V%	19.8	1.9	7.3	24.0	36.8
HC Type, D 2424, V%/M%					
Paraffins	12.5/10.7	26.6/22.9	11.6/10.7	10.9/9.3	14.8/11.6
Cycloparaffins	67.8/63.9	70.6/64.6	79.1/77.5	71.2/66.5	57.0/52.3
Alkyl Benzenes	5.6/6.4	2.8/12.5	9.3/11.8	17.4/23.5	20.7/25.9
PAH	1.9/2.7	0/0	0/0	0.5/0.8	7.6/10.2

SwRI Activities

Benzene V%	0.07	1.10	0.14		
Distillation, F, D 86					
IBP	176	133.0	203.0	372.0	512.5
5 V%	217	152.0	220.5	390.5	525.0
10	248	155.0	224.5	393.0	530.0
20	300	160.0	231.5	398.0	537.0
30	357	164.0	240.0	404.5	544.0
40	411	167.5	248.5	410.0	551.5
50	461	170.0	258.5	417.0	560.0
60	500	174.0	270.5	426.5	571.0
70	535	177.0	283.0	436.5	584.0
80	571	182.0	296.5	449.5	601.5
90	613	188.0	310.0	466.0	626.5
95	647	194.0	319.5	481.0	648.5
EP	665	205.0	332.0	516.0	661.5

SwRI Activities

Figure 2-3 Continuous Distillation Pilot Plant

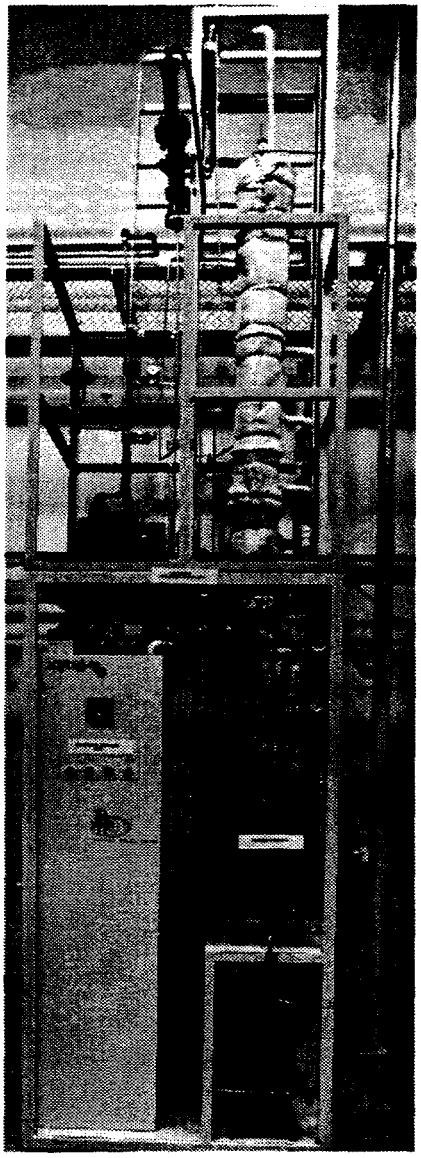


Table 2-3. Analysis of DL1 Fractions

Test Description	Method	Whole Liquid	Lt. Naphtha		Med. Naphtha		Hvy. Naphtha	Lt. Distillate			Residual	
PIMS Desig.		DL1	LN1c		MN1c		Swing	LD1c		HD1c	AT1c	HD1+ AT1
Origin		POC-1	Lab	Prod'n	Lab	Prod'n	Lab	Lab	Prod'n	Lab	Lab	Prod'n
ID. No., FL-		2236	2290	2386	2291	2385	2292	2293	2371	2994	2295	2372
Vacuum Dist.	D 1160	18333mL (Lab start)	1441mL		4382mL		22mL	4400mL		4163mL	1747 (bal-ance)	
Production	Plant			67 gal		309 gal			358 gal			514 gal
Density Grams/mL@15 C	D 1298	0.8623	0.7352	0.7210	0.7995	0.7937	0.8650	0.8968	0.8757	0.9195	0.9384	0.9189
Sp Gr @60/60		0.8628	0.7354	0.7212	0.7999	0.7941	0.8654	0.8973	0.8762	0.9200	0.9390	0.9194
API @60 F		32.5	60.9	64.7	45.4	46.7	32.0	26.2	30.0	22.3	19.2	22.4

Table 2-3 (continued) - Analysis of DL1 Fractions

Test Description	Method	Whole Liquid	Lt. Naphtha		Med. Naphtha		Hvy. Naphtha	Lt. Distillate			Residual	
PIMS Desig.		DL1	LN1c		MN1c		Swing	LD1c		HD1c	AT1c	HD1+ AT1
Origin		POC-1	Lab	Prod'n	Lab	Prod'n	Lab	Lab	Prod'n	Lab	Lab	Prod'n
Distillation F/ C	D 86 or D 1160											
IBP		141/60.6	128/53	109/43	220/104	214/101	376/191	398/203	385/196	559/293	467/242	522/272
5 V%		194/90	154/68	125/52	240/116	232/111	386/197	461/238	401/205	567/297	651/344	534/279
10		223/106	161/73	136/58	251/122	238/114	388/198	473/245	406/208	568/298	651/344	541/283
20		282/139	167/75	143/62	264/129	246/119	390/199	476/247	410/210	569/298	653/345	547/286
30		348/176	172/78	149/65	274/134	254/123	392/200	479/248	412/212	571/300	654/346	554/290
40		410/210	176/80	154/68	283/139	262/128	394/201	482/250	420/216	573/301	654/346	560/293
50		462/239	179/82	157/69	296/147	272/133	396/202	485/252	422/217	575/302	657/347	569/298
60		502/261	183/83	161/72	308/153	284/140	399/204	489/254	437/225	579/304	660/349	576/302
70		534/279	187/86	164/73	320/160	291/144	402.206	494/257	445/229	583/306	665/352	592/311
80		566/297	191/88	168/76	334/168	310/154	406/208	501/261	454/234	587/308	671/355	606/319
90		603/317	197/92	171/77	349/176	324/162	412/211	510/266	466/241	593/312	682/361	633/334
95		631/333	204/96	175/79	362/183	334/168	417/214	516/269	476/247	599/315	695/368	654/346
EP		661/349	237/113	182/83	388/198	354/179	434/223	522/272	489/254	606/319	707/375	670/354

Table 2-3 (continued) - Analysis of DL1 Fractions

Test Description	Method	Whole Liquid	Lt. Naphtha		Med. Naphtha		Hvy. Naphtha	Lt. Distillate			Residual	
PIMS Desig.		DL1	LN1c		MN1c		Swing	LD1c		HD1c	AT1c	HD1+ AT1
Origin		POC-1	Lab	Prod'n	Lab	Prod'n	Lab	Lab	Prod'n	Lab	Lab	Prod'n
Sulfur, Mass %	D 2622	490ppm	530	150	350	690	220	250	230	210	670	300
Viscosity, cs 40 C	D 445	1.78cst	0.56cst	-	0.82cst	0.79	1.40cst	2.60cst	1.71	6.00cst	17.24cst	5.90
HC type w/Sep'n	D 1319 mod											
Paraffins, V%		66.3%	92.9%	92.9	82.6%	83.0	61.4	51.8	36.7	46.3	35.4	52.2
Olefins, V%		1.0%	3.8%	4.4	4.2%	4.5	1.5	1.6	4.6	2.4	0	2.6
Aromatics V%		32.7%	3.3%	2.7	13.2%	12.5	37.1	46.6	58.7	51.3	64.6	45.2
HC Type, M%	D 2425											
Paraffins		13.0	25.2	30.1	6.1	7.5	9.0	12.4	8.5	16.0	19.6	9.4
Cycloparaffins		56.5	72.8	68.9	83.3	79.1	64.0	49.7	53.6	40.7	20.8	34.3
Alkyl Benzenes		7.8	1.9	1.0	9.4	12.1	11.6	8.2	11.6	6.3	6.4	11.4
PAH		30.5	2.0	0.0	10.6	09.2	27.0	37.9	2.8	43.3	58.8	16.2
Benzene V%	D 4815	0.12	1.48	0.0	0.06	2.14	0	0	0.05*	0*	0*	0.05*

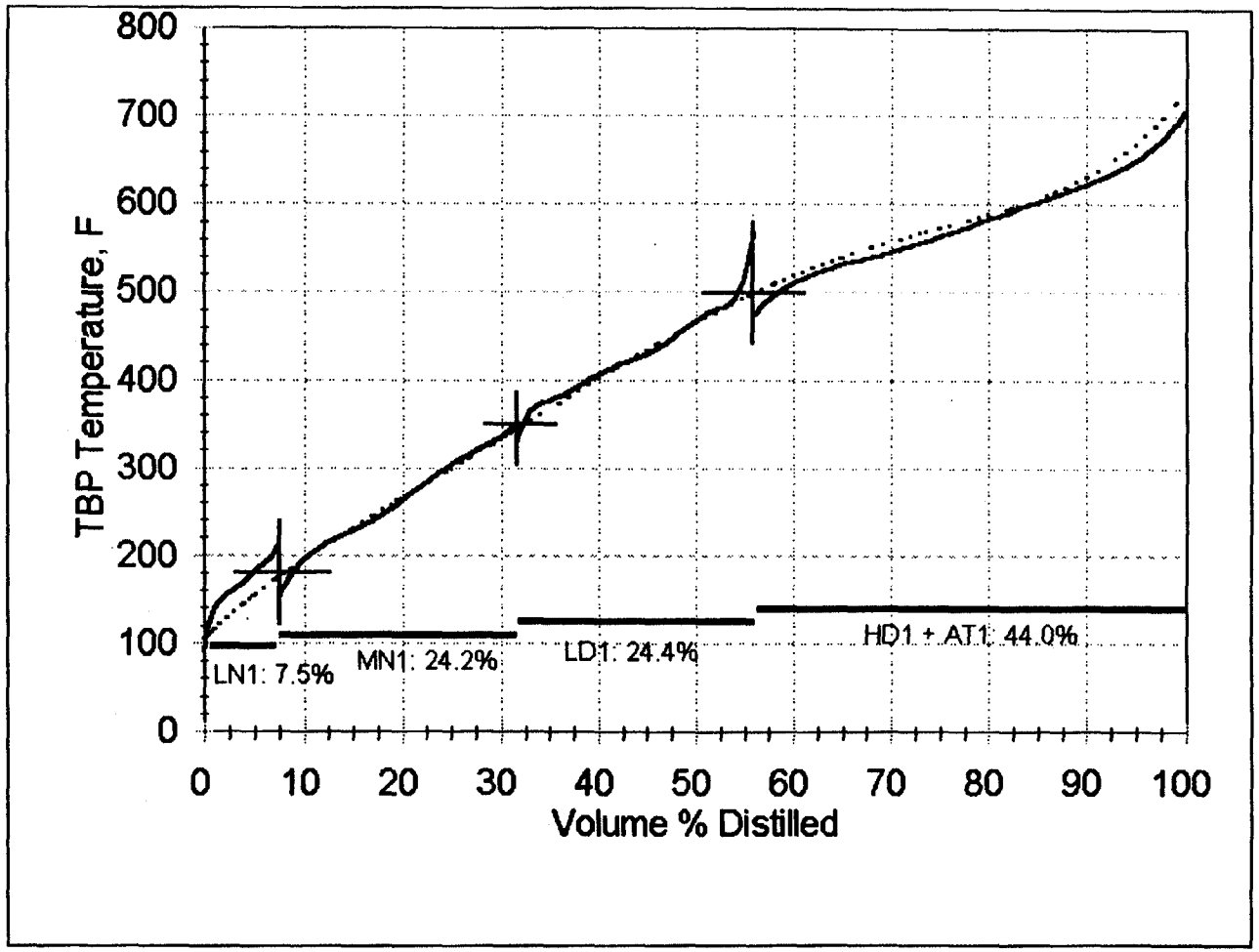
Table 2-3 (continued) - Analysis of DL1 Fractions

Test Description	Method	Whole Liquid	Lt. Naphtha		Med. Naphtha		Hvy. Naphtha	Lt. Distillate			Residual	
PIMS Desig.		DL1	LN1c		MN1c		Swing	LD1c		HD1c	AT1c	HD1+ AT1
Origin		POC-1	Lab	Prod'n	Lab	Prod'n	Lab	Lab	Prod'n	Lab	Lab	Prod'n
RON	D 2699	-	73.7	78.0	54.6	81.0	66.2	-	-	-	-	-
MON	D 2700	-	68.0	61.6	63.1	78.0	74.6	-	-	-	-	-
Cetane Index	D 4737	-	-	-	-	-	21.5	27.9	-	34.7	-	34.0
Pour Point F/ C	D 97	-	-	-	-	-	>-60/-51	>-60/-51	-	-15/-26	32/0	-
Smoke Point, mm	D1322	-	-	-	-	-	12.2mm	8.5mm	-	7.3mm	<1.5mm	-
Aniline Point F/ C	D 611	-	-	-	-	-	81.1/27.3	85.3/29.6		103/39.5	Too Dark To Test	-
Total Nitrogen ppm	D 4629	529	-	47	-	209	618	661	605	491	824	590
BasicNitrogen ppm	UOP313	-	-	-	-	-	660	610	-	390	470	-

- = not measured * = best estimate(high boiling sample)

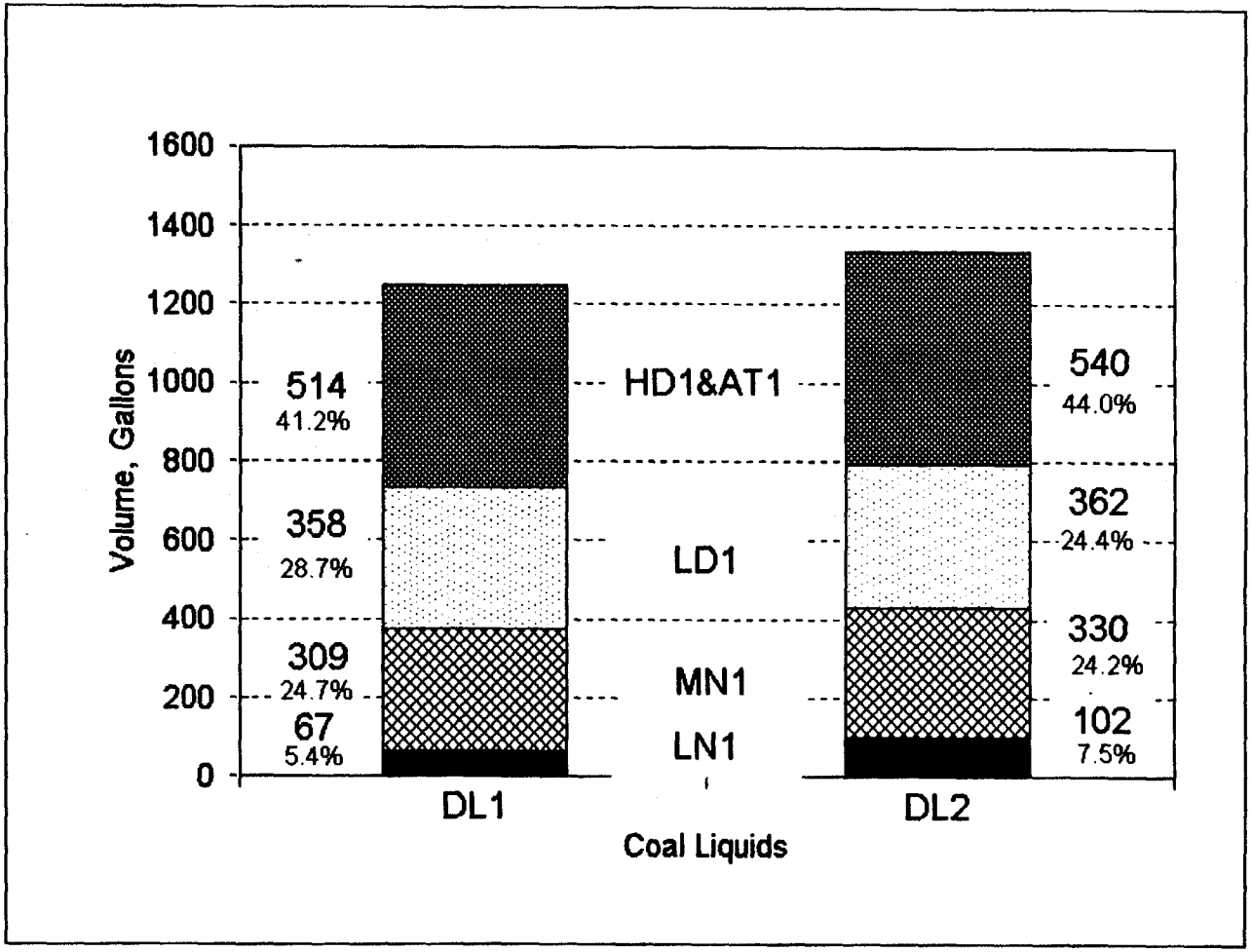
SwRI Activities

Figure 2-1 DL2 Distillation



SwRI Activities

Figure 2-2 Comparison of DL1/DL2 Fractions



SwRI Activities

Figure 2-4 Distillation of DL2 Naphtha

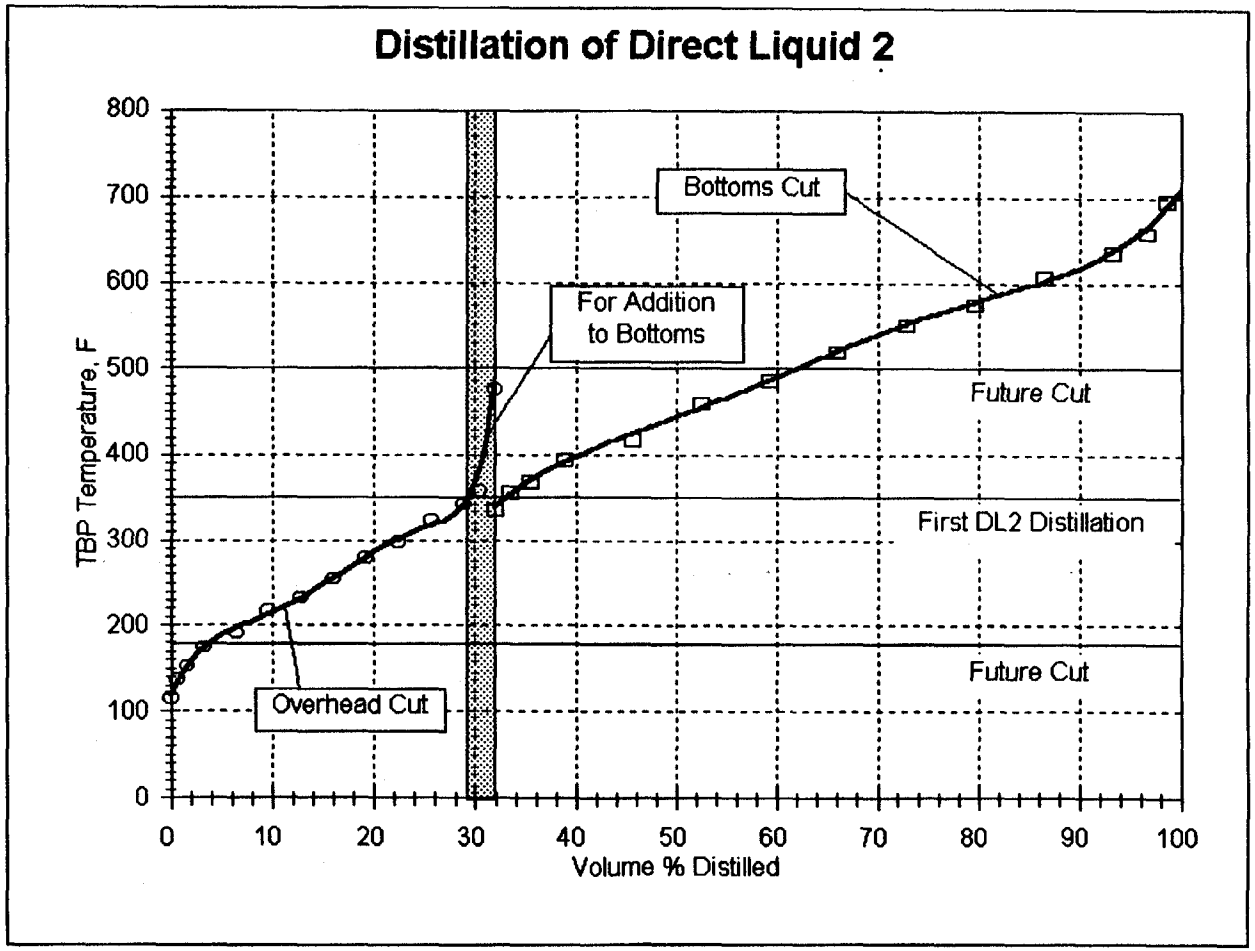


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Figure 2-5 Comparison of Specific Gravities DL1/DL2

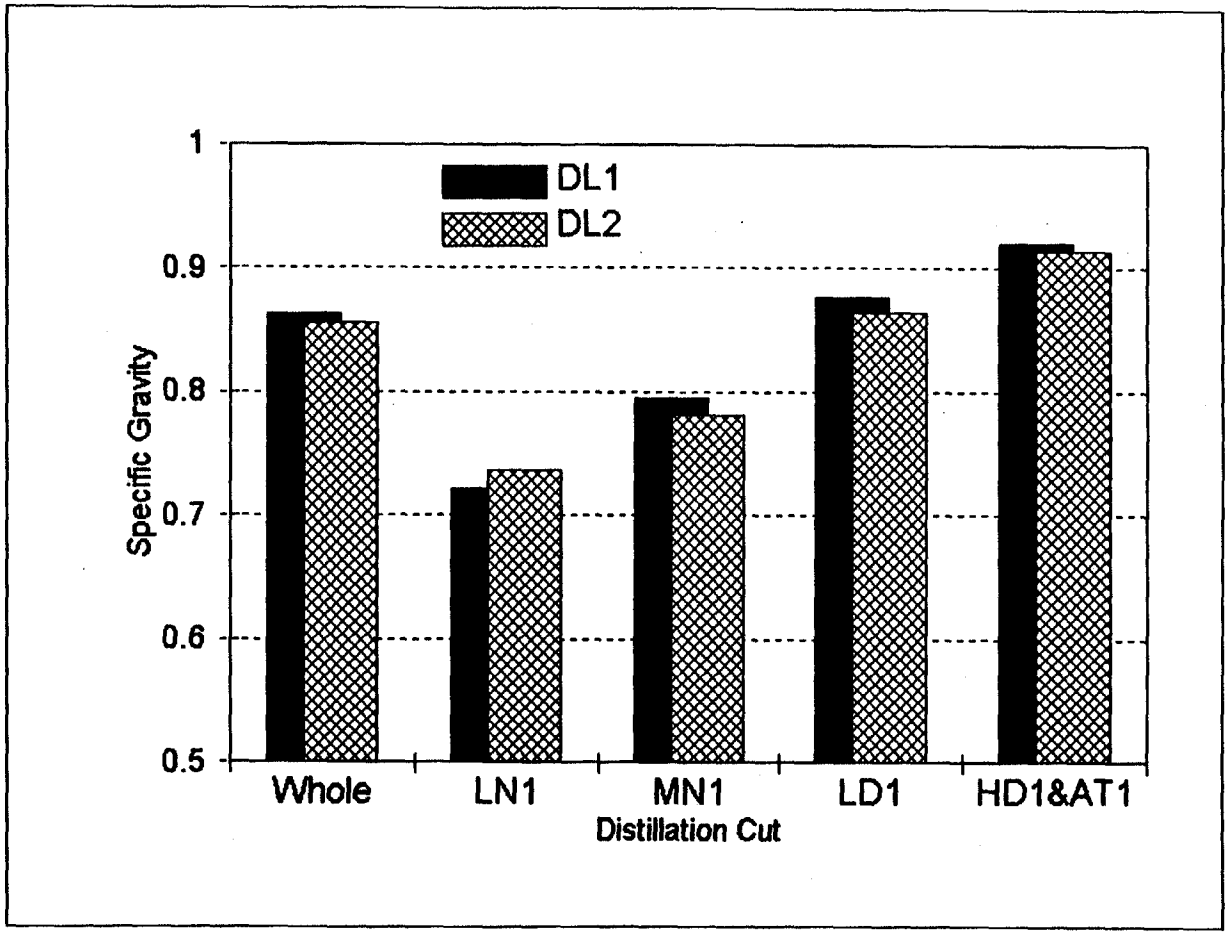

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Figure 2-6 Comparison of Sulfur Contents DL1/DL2

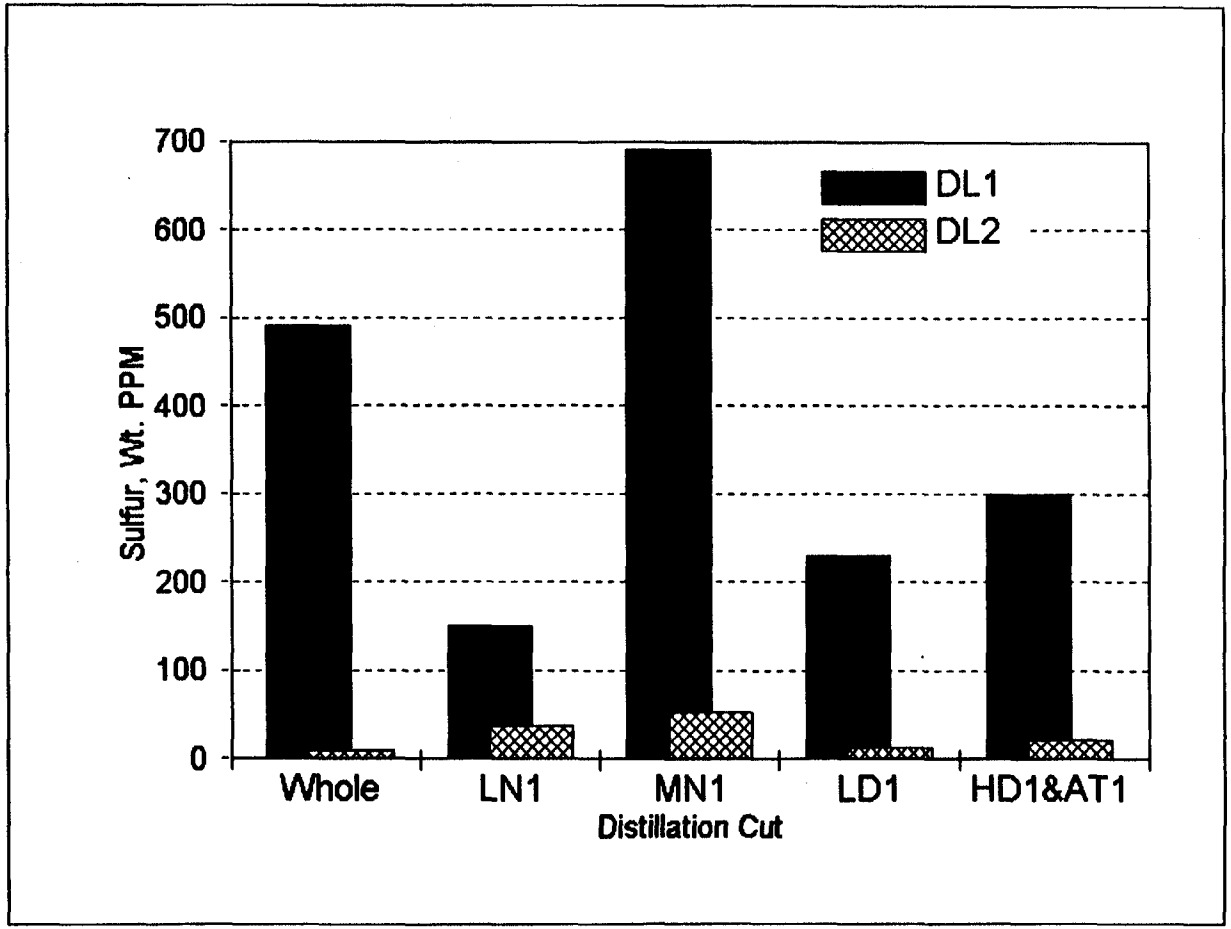

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Figure 2-7 Comparison of Aromatic Contents DL1/DL2

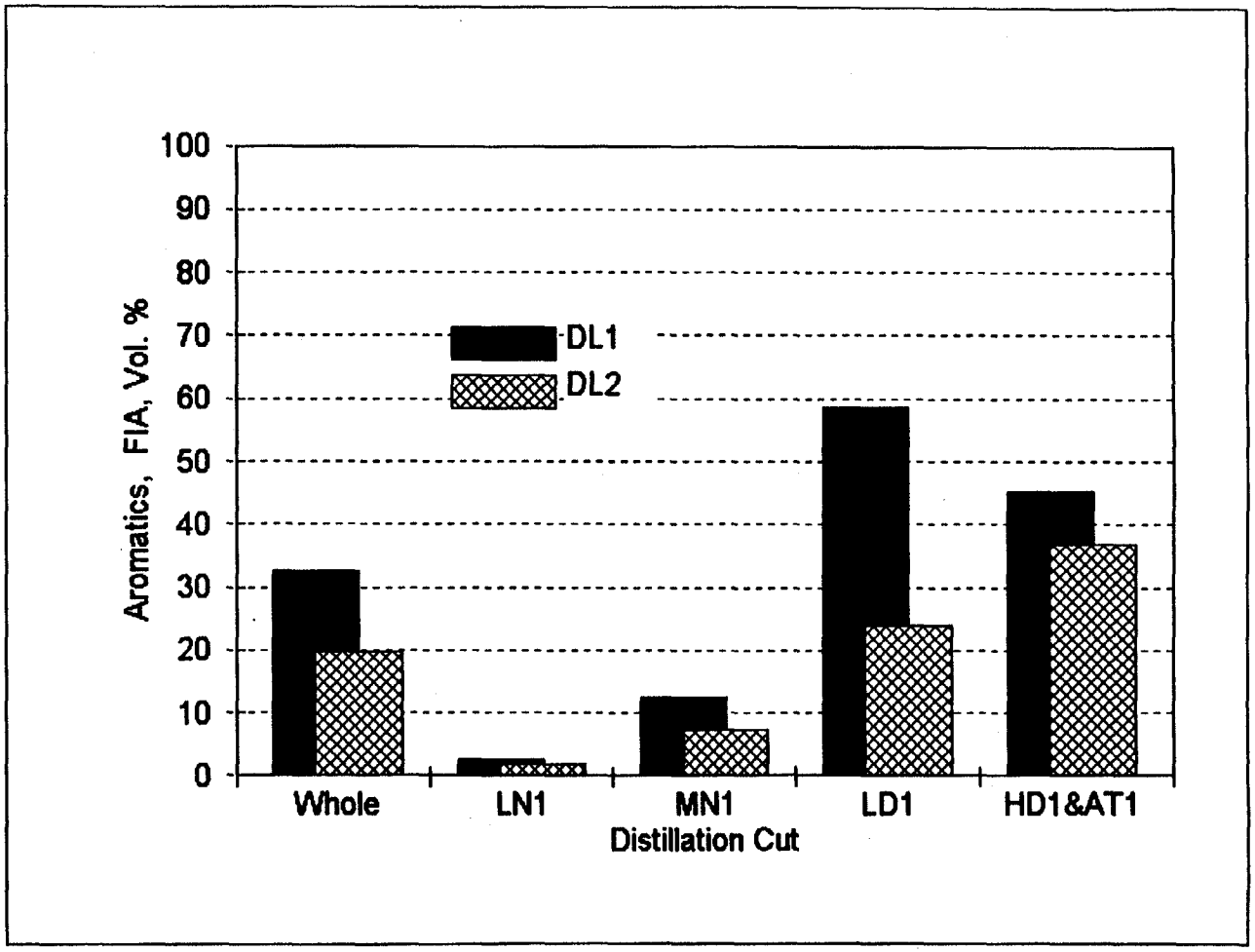

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Figure 2-8 Comparison of Cycloparaffin Concentrations DL1/DL2

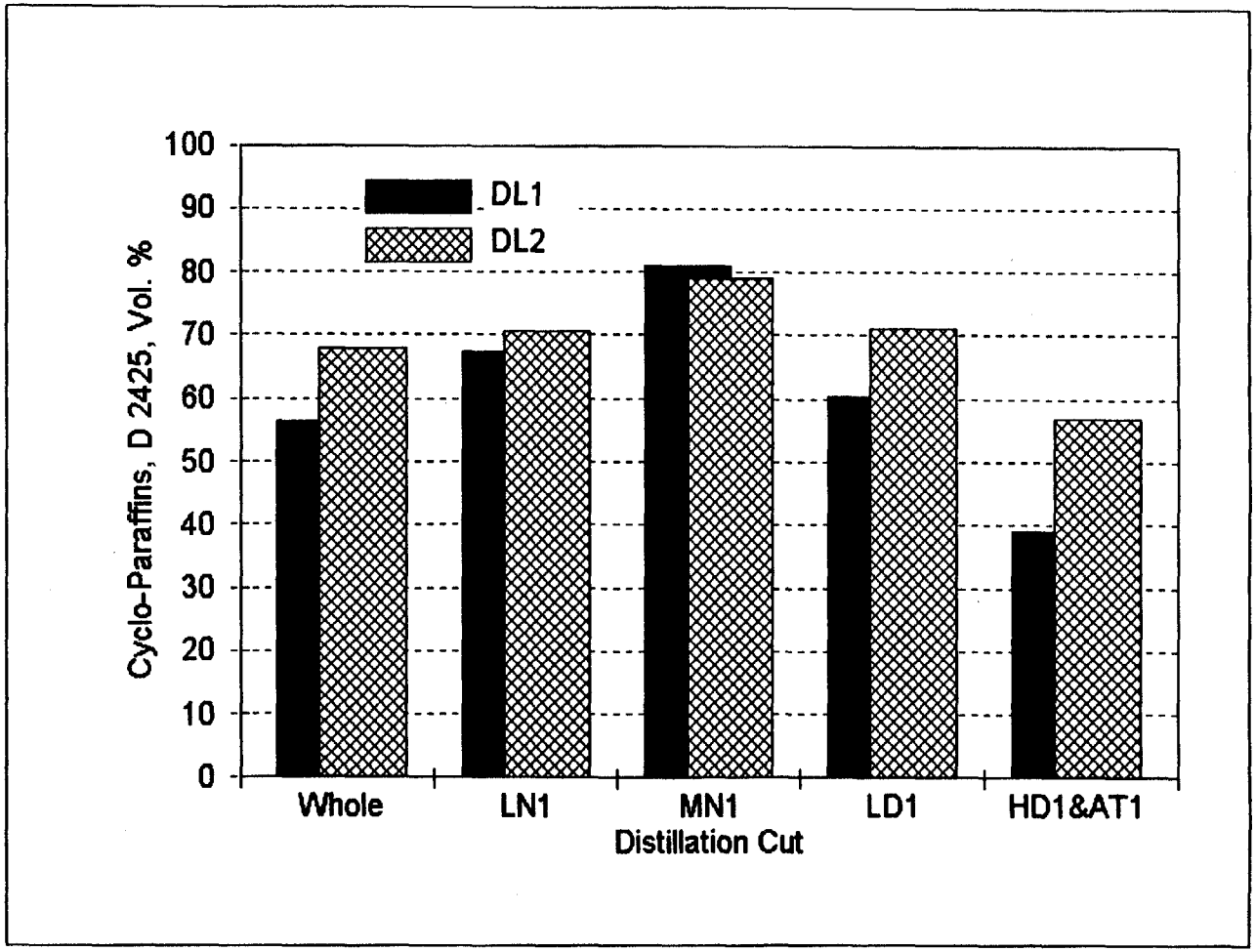

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Figure 2-9 Comparison of PAH Levels DL1/DL2