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USE OF REFINERY COMPUTER MODEL TO PREDICT JET FUEL PRODUCTION

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SUMMARY

This report is a parametric study of several factors that affect yields and properties of broad-specification jet fuel. The Refinery Simulation Model, developed under contract by Gordian Associates, Inc. and modified at NASA LeRC is used to make the calculations. This computer program can simulate different types of refineries and emphasizes jet fuel production.

Two refinery configurations are used, each one processing a different crude mix. Results obtained from the Refinery Simulation Model are used to correlate jet fuel yield as a function of final boiling point, hydrogen content and freezing point. A set of calculations was performed specifying only boiling range for jet fuel (maximum yield blends). Yield of jet fuel increases linearly with increasing final boiling point (at a fixed initial boiling point). For the second set of calculations a minimum hydrogen content for jet fuel was also specified. In this case yield increases with final boiling point only to some extent. If the specified hydrogen content is greater than the hydrogen content of the maximum yield blend on a certain boiling range, yield decreases with increasing final boiling point (and a fixed initial boiling point). A third set of calculations was performed by specifying both boiling range and a maximum freezing point for jet fuel. The results (yield as a function of final boiling point) obtained in this set of calculations were similar to the results obtained by specifying boiling range and minimum hydrogen content. If the specified freezing point is smaller than the freezing point of the maximum yield blend on a certain boiling range, yield decreases with increasing final boiling point (and a fixed initial boiling point). These trends are similar for both refineries.

Refinery performances are also compared in terms of energy consumption.

INTRODUCTION

Current specification jet fuel is produced from mid-distillate pertroleum fractions by distillation and mild hydrogenation. Recent price increases and shortages of petroleum crudes have brought into consideration possible future changes to increase jet fuel production by (ref. 1):

(1) Conversion of high-boiling-point petroleum fractions to jet fuel boiling range by cracking and hydroprocessing

(2) Use of nonpetroleum sources such as shale oil, coal liquids and tar sands as refinery feedstocks

(3) Relaxation of fuel specifications

Implementation of the first two alternatives will require high energy and hydrogen consumption and will result in higher operating costs in the refinery (ref. 2). Relaxing jet fuel specifications will make it easier for refineries to supply fuel but performance of combustor and fuel system will be affected. The optimum fuel production process will have to take into account the three alternatives (ref. 3).

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Key specifications to be broadened in future jet fuels include boiling range and aromatics content. Boiling range is the most important property in determining yield of fuel from crude oil. It is also used to maintain a minimum flash point, related to initial boiling point, and a maximum freezing point, related to final boiling point. It is generally agreed that hydrogen content is a better measure of combustion properties than the currently specified aromatics content (refs. 3 and 4). Aromatics content is related to hydrogen although the relationship is very approximate. Raising the maximum aromatics content specification will make it possible to produce jet fuel from low grade petroleum-derived process streams and nonpetroleum crudes. Relaxing these specifications will mean higher fuel yields, but also, higher freezing points and poorer combustion characteristics.

This report is a parametric study of several factors that affect jet fuel yield. The Refinery Simulation Model, developed under contract by Gordian Associates, Inc. and modified at NASA LeRC was used to make the calculations. This computer program can simulate different types of refineries. It can handle the processing of petroleum, shale oil and coal derived crudes. It calculates material and energy balances, costs, profit-ability; and the production of jet fuel of specified boiling range and hydrogen content, and other refinery products.

The purpose of this report is to show the use of the Refinery Simulation Model to predict jet fuel yields as influenced by broadening boiling range, hydrogen content and freezing point specifications. Two existing refinery configurations are used, each one processing a different crude mix. One of these refineries is supplied with a light crude petroleum blend with a relatively high fraction in the jet fuel boiling range. Jet fuel production in this refinery is further increased by molecular conversion in cracking units. This combination of crude and refinery represents a maximum in jet fuel yields for this study. The other refinery is supplied with a heavier crude blend that has a lower fraction in the jet fuel boiling range. This refinery does not have the capability of including cracked streams in jet fuel production. The operation of this refinery represents a minimum in jet fuel yields for this study. To run the parametric calculations, a fixed initial boiling point of 177° C is used. Final boiling point of jet fuel is varied from 274° to 343° C. Results are presented in terms of jet fuel yield as a function of final boiling point, hydrogen content and freezing point. Values of other jet fuel properties (smoke point, sulfur content, aromatics content, etc.) are also reported. An estimate of the energy efficiency of the two refineries is shown.

GENERAL DESCRIPTION OF COMPUTER PROGRAM

The Refinery Simulation Model (ref. 5) is a Fortran computer program that can simulate different types of refineries. (See fig. 1 for refinery flowchart.) Processing units included in the model are:

1. Atmospheric distillation
2. Vacuum distillation
3. Fluid catalytic cracking
4. Thermal cracking
5. Mid-distillate desulfurizer
6. Kerosene hydrotreater
7. Fluid coker
8. Visbreaker
9. Mid-distillate hydrocracker
10. Gas oil hydrocracker
11. Catalytic reforming
12. Alkylation
13. Polymerization
14. Butane isomerization
15. Hydrogen production

The user sets the refinery configuration by specifying the sizes of process units. The feed to atmospheric distillation can be any petroleum, shale or coal derived crude. Presently, there are 21 petroleum, 3 shale oil, 1 coal crude assays stored in a crude assay subroutine. For crudes not stored in this subroutine, the assays can be input by the user.

The program calculates overall and unit material and energy balances. The material balances include stream flowrate, density and composition (sulfur, nitrogen and hydrogen wt %). The energy balances include steam, fuel, power and hydrogen consumption.

Refinery products reported by the program are mid-distillate, residual, jet fuel and gasoline. For jet fuel, the user specifies boiling range and hydrogen content. Flowrates and key properties are reported for these fuel blends. Octane numbers are reported for gasoline and viscosity, density, sulfur, nitrogen and hydrogen content are reported for mid-distillate and residual fuels. For jet fuel the following properties are reported: sulfur, nitrogen, hydrogen and PNA (paraffins, naphthenes and aromatics) contents, along with freezing point, smoke point and heat of combustion. (Paraffins include branch and straight-chain saturated hydrocarbons; naphtenes include cyclic saturated hydrocarbons.)

For a detailed description of the computer program, see reference 5.

For this study the computer program was modified to allow the user to specify initial boiling point of jet fuel. Originally the jet fuel blend was made of kerosene streams and had a fixed initial boiling point of 205° C. The modification was done by blending naptha (boiling range 120°-205° C) in the jet fuel pool and adding the necessary naptha properties to the crude assays.

ANALYSIS

Two refinery configurations are established, each one processing a different crude mix. Refinery configuration data for both refineries were obtained from reference 6. In each case, the refinery configuration is kept constant for the entire running sequence.

Refinery A is an existing East Coast refinery. In this study, it processes a 50/50 mix of Murban and Louisiana Delta Crudes. Murban is a light paraffinic crude from the Middle East. Table 1 shows crude assay data used by the computer program. Properties are given for the whole crude and six partial boiling range fractions representing cuts from the atmospheric and vacuum distillation units. Properties that are not required for some of the cuts are not shown. Louisiana Delta is a light naphthenic crude. Table 2 shows crude assay data for Louisiana Delta Crude. The resultant crude mix is light (34.4° API), paraffinic (42% paraffins for the kerosene fraction) and low in sulfur and nitrogen (0.5% S and 0.1% N). Unit sizes are specified in barrels per day (BPD) except for the hydrogen plant which is specified in millions of standard cubic meters per day (MMSCMD). Refinery A has the following configuration:

Atmospheric Distillation	150 000 BPD
Vacuum Distillation	90 700 BPD
Fluid Coker	44 000 BPD
Fluid Catalytic Cracker	62 000 BPD
Gas Oil Hydrocracker	20 000 BPD
Kerosene Hydrotreater	10 000 BPD
Catalytic Reformer	42 000 BPD
Distillate Desulfurizer	10 000 BPD
Alkylation	8 000 BPD
Hydrogen Plant	2 MMSCMD

Figure 2 shows a simplified refinery flowchart that includes only units and streams involved in jet fuel production. This refinery has gas oil hydrocracking and catalytic cracking which convert a significant portion of gas oil (boiling point over 566° C) to jet fuel boiling range, and mid-distillate desulfurizer to upgrade the cracked streams. (The computer program yields a complete slate of refinery products, but in figure 2 only units and streams associated with jet fuel are shown.) The operation of this refinery represents the maximum in jet fuel yields for this study.

Final boiling point for jet fuel produced in Refinery A is varied from 247° to 343° C (525° to 650° F). The average of these two values is slightly below the 300° C (572° F) maximum end point current specification for Jet A. Specified hydrogen content is varied from 13.75 to 14.5 weight percent. The initial boiling point is kept at 177° C (350° F).

Refinery B is on existing West Coast refinery. In this study, it processes a 50/50 mix of Alaska North Slope and Wilmington crudes. Alaska North Slope is a heavy crude with high aromatics content. Table 3 shows the crude assay data for the Alaska North Slope Crude. Wilmington is a heavy naphthenic crude. Table 4 shows the crude assay data for Wilmington Crude. The resultant crude mix is heavy (24.2° API), naphthenic (52% naphthenes for the kerosene fraction), and high in sulfur and nitrogen (1.23% S and 0.44% N). The refinery has the following configuration:

Atmospheric Distillation	100 000 BPD
Vaccum Distillation	54 000 BPD
Fluid Coker	24 600 BPD
Fluid Catalytic Cracker	46 000 BPD
Catalytic Reformer	24 000 BPD
Gas Oil Desulfurizer	23 000 BPD
Kerosene Hydrotreater	46 000 BPD
Alkylation	11 500 BPD
Hydrogen Plant	2.9 MMSCMD

Figure 3 shows the simplified refinery flowchart for jet fuel production in Refinery B. This refinery has fluid catalytic cracking but does not have any units to upgrade the cracked streams. Processing a low quality crude mix and not having gas oil hydrocracking, the operation of this refinery represent the minimum in jet fuel yields for this study.

The specifications for jet fuel produced in Refinery B are the same as Refinery A except that hydrogen content is varied from 13.25 to 13.5 weight percent.

RESULTS AND DISCUSSION

Three sets of parametric calculations were performed using the refinery configurations and crude mixes described in the Analysis section. In the first set of calculations production of jet fuel was calculated for a series of cases by specifying only boiling range for jet fuel. A fixed initial boiling point of 177° C was used and final boiling point was varied from 274° to 343° C. This production represents the maximum yield of jet fuel for each boiling range and they do not necessarily meet current Jet A specifications. Table 5 shows selected values of current Jet A specifications (ref. 7). For the second set of calculations a minimum hydrogen content was specified over the same variations in boiling range. Similar calculations were performed by specifying a maximum freezing point.

MAXIMUM JET FUEL YIELD AND PROPERTIES

The properties of maximum yield jet fuel produced in both refineries are shown in table 6. These blends include all refinery product streams (straight run and hydroprocessed kerosene and straight-run naphta) within the specified boiling range. Compositional properties and densities of individual streams were calculated from crude assay data and process unit data in the computer program. Compositional properties are blended by weight and densities are blended by volume. Densities are reported in °API and converted using the standard relationship. $°API = 141.5/\rho - 135.5$ where ρ is density in kg/l. Heat of combustion is calculated as a function of density, boiling range and sulfur content (ref. 8) and blended by weight. Freezing point is calculated as a function of density and boiling range using Nelson correlation (ref. 9), and it is blended by the method of Reid and Allen (ref. 10). Smoke point is the standard lamp measurement of ASTM D-1322 (ref. 7). Where experimental data is lacking, smoke point is calculated as a function of density and boiling range (ref. 11), and it is blended by reciprocal volume.

For jet fuel produced in Refinery A, the API gravity varies from 45.4° to 37.9° which is within the limits of current Jet A specification of 51° max., 37° min. API. Jet fuels produced in Refinery B with an end point higher than 316° C (600° F) do not meet current Jet A specifications on gravity. All jet fuels in both refineries meet the 0.3 weight percent maximum sulfur content except the fuels produced in Refinery B with end points over 324° C (615° F). Heat of combustion is constant for all fuels and meets the 42.6 kJ/g min. for Jet A. Only the jet fuels produced in Refinery A with an end point below 291° C (555° F) meet the 25 mm minimum smoke point specifications. The fuels produced in Refinery A, being lighter and having a higher hydrogen content, have a higher smoke point.

As expected, most jet fuel properties tend to go outside current specifications as the final boiling point increases. Obviously, broadening the distillation range to increase jet fuel yield will require some relaxation of current specifications. The computer program provides a quantitative prediction of these changes.

Figure 4 shows maximum yield of jet fuel as a function of final boiling point. This yield includes all refinery streams within the specified boiling range. Maximum yield increases linearly with final boiling point and a fixed initial boiling point. These two refineries represent extremes in terms of jet fuel production.

JET FUEL YIELD WITH SPECIFIED HYDROGEN CONTENT

Figure 5 shows hydrogen content of maximum jet fuel from table 6 as a function of final boiling point. Hydrogen content decreases linearly with increasing final boiling point. It is higher for Refinery A which starts with a better crude feed and has more extensive processing.

For the second set of calculations, several values of minimum hydrogen content were also specified. Results of these calculations are shown in figure 6 for Refinery A and in figure 7 for Refinery B. To make this blend the computer program arranges the streams within the specified boiling range in order of decreasing hydrogen content and blends them from top down to get a hydrogen content equal or greater than the specified one. If the hydrogen content of the maximum yield blend is smaller than the specified hydrogen content, low hydrogen content streams are eliminated to increase the blend hydrogen content. This causes the yield to decrease with increasing final boiling point. The intersection of this line (decreasing yield with increasing final boiling point) and the maximum yield line represents a final boiling point where the highest yield can be obtained for a certain hydrogen content specification.

JET FUEL YIELD WITH SPECIFIED FREEZING POINT

Freezing point as a function of final boiling point from table 6 is shown in figure 8. According to Nelson correlation (ref. 9), freezing point increases with increasing mid-boiling point and decreasing specific gravity. Freezing point is also affected by fuel composition. Straight chain or symmetrical hydrocarbons crystalize more readily so that paraffinic fuels usually have higher freezing points than naphthenic fuels. All jet fuels produced in Refinery A, being lighter and more paraffinic than those produced in Refinery B in similar boiling ranges, have higher freezing points. As final boiling point increases, compositional differences become less significant; at the highest final boiling point both values of freezing point are almost identical.

In the third set of calculations, both freezing point and boiling range of jet fuel were specified. Results of this calculation are shown in figure 9 for Refinery A and in figure 10 for Refinery B. These plots were obtained by plotting yield of jet fuel vs. freezing point at specified final boiling points and then obtaining lines of constant freezing point. To meet a certain freezing point specification, selective blending of streams should be done. If the product blend freezing point is higher than the specified one, high freezing point streams are eliminated to lower the blend freezing point. At this point yield starts to decrease with increasing final boiling point. The intersection of this line (decreasing yield with increasing final boiling point) and the maximum yield line represents a final boiling point where a maximum yield is obtained for a certain freezing point.

Yields of jet fuel obtained by specifying only boiling range are much higher than the average present yield of 6.5% (ref. 12). When constraints are placed on key properties like freezing point or hydrogen content, yields decrease significantly. Besides there are other uses for the mid-distillate portion of the crude barrel like heating oil and engine diesel.

REFINERY PERFORMANCE

Jet fuels produced in Refinery A have higher hydrogen content and better smoke point characteristics. On the other hand, jet fuels produced in Refinery B have lower freezing points. An optimization of both cases would be required to obtain a reasonable yield of jet fuel that meet all current specifications.

Table 7 shows an energy report for both refineries. Refinery A, having more extensive processing, has a slightly higher fuel consumption and a much higher hydrogen consumption. The computer program also calculates economic parameters like cost, investment and profitability. A detailed economic analysis cannot be made because the computer program does not optimize economic operation.

DISCUSSION

The results presented in this report should be interpreted considering the assumptions involved in formulating the computer program. The crude assay data shown in tables 1 to 4 was compiled by Gordian Associates from authoritative petroleum industry sources. This crude assay data represents average properties. Also some of the properties like smoke point, heat of combustion and freezing point were estimated. Correlations for heat of combustion and smoke point are accurate and consistent with other commonly used correlations (ref. 12). There are no accurate correlations for calculating freezing points of individual streams and blends. The correlations used in this computer program are very approximate, but they are the best available. Processing unit data was also obtained from industry sources and is based on refinery or pilot plant experience. However, the relative trends in yields and properties presented in this report can be regarded as accurate.

CONCLUDING REMARKS

The purpose of this report is to show a correlation of jet fuel yield as a function of final boiling point, hydrogen content and freezing point using results obtained from the Refinery Simulation Model. This computer program predicts refinery performance and fuel properties in given refinery configurations, each one processing a different crude mix. The refinery configurations and crudes are chosen to represent extreme situations in fuel production.

Results indicate that increasing final boiling point (with a fixed initial boiling point) increases yield and decreases hydrogen content of jet fuel. Specifying a minimum hydrogen content in addition to boiling range changes the relationship between yield and final boiling point. After the specified hydrogen content is higher than the hydrogen content of the maximum yield blend on a certain boiling range, yield decreases with increasing final boiling point.

Increasing final boiling point also increases freezing point of jet fuel. If a maximum freezing point is specified in addition to boiling range, yield increases with increasing final boiling point only to some extent. After the specified freezing point is smaller than the freezing point of the maximum yield blend on a certain boiling range, yield decreases with increasing final boiling point (which is similar to the results obtained by specifying a minimum hydrogen content). Increasing final boiling point also makes other jet fuel properties (gravity, smoke point, sulfur content, etc.) go outside current specifications. This interdependency will make it necessary to relax some specifications to increase yield for future jet fuels.

Comparison of refinery performance are made in terms of product yields and properties and energy consumption. The first refinery has gas oil hydrocracking and processes a lighter, more paraffinic crude. This refinery produces higher yields of jet fuel with higher hydrogen contents and better smoke point characteristics. It also has higher energy and hydrogen consumption. The second refinery processes a heavier crude and does not have a means of converting high boiling point fractions to jet fuel boiling range. However, jet fuels produced in this refinery have lower freezing points. An optimization between both cases and combinations of specifications is required to obtain reasonable yields of jet fuel with controlled relaxation of current specifications.

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TABLE 1. - PROPERTIES OF MURBAN CRUDE OIL

Cut	Property										
	Yield (Vol. fraction)	°API	S, Wt %	N, Wt %	H, Wt %	PNA, Vol. %	Freeze point		Smoke point, mm	Heat of combustion	
							°C	°F		kJ/g	Btu/lb
Light straight run (IBP-120° C)	0.175	80.9	0.02	0.0	15.8						
Heavy naphtha (120°-205° C)	0.211	58.2	0.06	0.0	15.4	P-69.7 N-18.6 A-14.2	-51	-60			
Light kerosene (205°-274° C)	0.165	43.9	0.46	0.025	14.1	P-49.7 N-30.4 A-19.9	-23	-10	25.7	43.2	18 600
Heavy kerosene (274°-343° C)	0.143	34.9	0.75	0.109	12.9	P-49.7 N-30.4 A-19.9	-21	-5	14.7	42.7	18 380
Vacuum gas oil (343°-566° C)	0.147	27.6	1.58	2.40	12.5						
Vacuum bottoms (566° C +)	0.151	18.3	1.85	4.15	11.9						
Whole crude		40.5	0.71	0.1	13.5					43.0	18 510

TABLE 2. - PROPERTIES OF LOUISIANA DELTA CRUDE OIL

Cut	Property										
	Yield (Vol. fraction)	°API	S, Wt %	N, Wt %	H, Wt %	PNA, Vol. %	Freeze point		Smoke point, mm	Heat of combustion	
							°C	°F		kJ/g	Btu/lb
Light straight run (IBP-120° C)	0.073	68.0	0.01	0.0005	15.0						
Heavy naphtha (120°-205° C)	0.129	48.2	0.03	0.001	13.8	P-38.2 N-50.0 A-11.8	-64	-84			
Light kerosene (205°-274° C)	0.150	38.3	0.11	0.003	13.2	P-34.4 N-52.7 A-12.9	-46	-50	20.0	42.5	18 290
Heavy kerosene (274°-343° C)	0.175	31.9	0.12	0.011	12.7	P-34.4 N-52.7 A-12.9	-17	2	18.0	42.4	18 230
Vacuum gas oil (343°-566° C)	0.360	22.2	0.40	0.118	12.0						
Vacuum bottoms (566° C +)	0.103	9.6	0.90	0.731	11.6						
Whole crude		30.6	0.3	0.12	12.8					42.9	18 460

TABLE 3. - PROPERTIES OF ALASKA-NORTH SLOPE CRUDE

Cut	Property										
	Yield (Vol. fraction)	°API	S, Wt %	N, Wt %	H, Wt %	PNA, Vol. %	Freeze point		Smoke point, mm	Heat of combustion	
							°C	°F		kJ/g	Btu/lb
Light straight run (IBP-120° C)	0.074	60.0	0.00	0.0005	14.5						
Heavy naphtha (120°-205° C)	0.120	47.6	0.05	0.001	13.8	P-38.0 N-38.0 A-24.0	-66	-86			
Light kerosene (205°-274° C)	0.110	36.0	0.23	0.009	13.0	P-38.0 N-38.0 A-24.0	-41	-42	17.0	42.8	18 400
Heavy kerosene (274°-343° C)	0.130	31.1	0.60	0.028	12.7	P-38.0 N-38.0 A-24.0	-9	15	15.0	42.4	18 520
Vacuum gas oil (343°-566° C)	0.370	21.5	1.15	0.219	11.9						
Whole crude		26.8	1.04	0.23	12.3					41.7	17 940

TABLE 4. - PROPERTIES OF WILMINGTON CRUDE

Cut	Property									
	Yield (Vol. fraction)	°API	S, Wt %	N, Wt %	H, Wt %	PNA, Vol. %	Freeze point		Smoke point, mm	Heat of combustion	
							°C	°F		kJ/g	Btu/lb
Light straight run (IBP-120° C)	0.070	70.3	0.05	0.0005	15.1						
Heavy naphtha (120°-205° C)	0.100	51.4	0.10	0.001	14.3	P-25 N-67 A-8	-76	-104			
Light kerosene (205°-274° C)	0.120	38.0	0.50	0.023	12.8	P-25.0 N-67.0 A-8.0	-40	-40	18.0	42.9	18 460
Heavy kerosene (274°-343° C)	0.120	22.0	1.05	0.085	11.7	P-25.0 N-67.0 A-8.0	-18	0	16.0	42.7	18 380
Vacuum gas oil (343°-566° C)	0.226	17.4	1.50	1.015	11.3						
Vacuum bottoms (566° C +)	0.344	7.1	3.40	1.185	9.8						
Whole crude		21.7	1.43	0.65	11.5					41.5	17 860

TABLE 5. - SELECTED VALUES OF CURRENT

JET A SPECIFICATIONS

Aromatics	20 vol. %, max.
Sulfur	0.3 wt %, max.
Final boiling point	300° C (572° F) max.
Specific gravity (60° F)	0.7753 min. (51° API max.) 0.8398 max. (37° API min.)
Freezing point	-40°, max.
Heat of combustion	42.6 kJ/g, min.
Smoke point	25 mm, min.

TABLE 6. - PROPERTIES OF MAXIMUM JET FUEL PRODUCED

Final boiling point, °C (°F)	API gravity	Hydrogen, Wt %	Nitrogen, Wt %	Sulfur, Wt %	Freezing point, °C (°F)	H_c, kJ/g	Smoke point, mm
Refinery A							
274 (525)	45.4	14.07	0.0065	0.12	-35.6 (-32)	43.4	25.9
282 (540)	44.5	13.99	.0086	.13	-34.0 (-29.2)	43.4	25.3
291 (555)	43.5	13.91	.0108	.14	-32.4 (-26.4)	43.4	24.8
299 (570)	42.5	13.83	.0130	.15	-30.9 (-23.6)	43.3	24.4
307 (585)	41.6	13.75	.0154	.16	-29.4 (-20.4)	43.3	24.1
316 (600)	40.7	13.67	.0177	.16	-27.9 (-18.2)	43.2	23.8
324 (615)	39.7	13.58	.0202	.17	-26.4 (-15.5)	↓	23.6
332 (630)	38.8	13.50	.0226	.18	-24.9 (-12.8)	↓	23.4
343 (650)	37.9	13.42	.0251	.19	-23.4 (-10.1)	↓	23.3
Refinery B							
274 (525)	40.7	13.40	0.0015	0.05	-44.2 (-47.6)	43.2	21.9
282 (540)	40.3	13.35	.0032	.08	-43.5 (-46.2)	43.2	21.2
291 (555)	39.7	13.30	.0055	.12	-42.1 (-43.7)	43.1	20.6
299 (570)	39.1	13.23	.0081	.16	-40.0 (-40.0)	43.1	20.2
307 (585)	38.3	13.17	.0111	.20	-37.4 (-35.3)	43.1	19.8
316 (600)	37.4	13.10	.0144	.25	-34.4 (-29.9)	43.0	19.4
324 (615)	36.4	13.03	.0179	.29	-31.1 (-24.1)	43.0	19.1
332 (630)	35.6	12.96	.0215	.34	-27.7 (-17.8)	43.0	18.9
343 (650)	34.3	12.86	.0226	.4	-22.9 (-9.2)	42.9	18.6

TABLE 7. - ENERGY REPORT

Energy consumption (% of refinery input)	Refinery A	Refinery B
Steam	0.79	0.78
Fuel	6.92	6.44
Power	0.25	0.25
Hydrogen	1.11	0.45
Overall energy efficiency	91.03	92.08

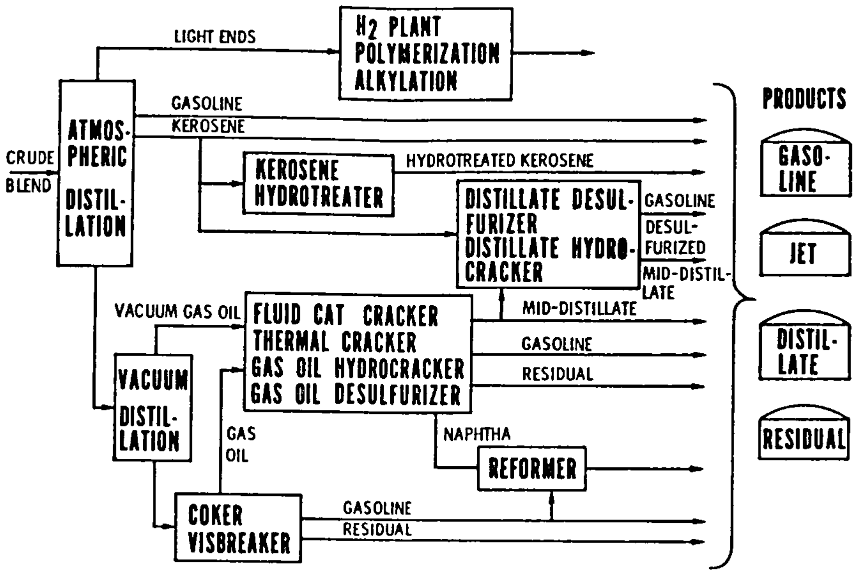

Figure 1 - Simplified refinery flowchart

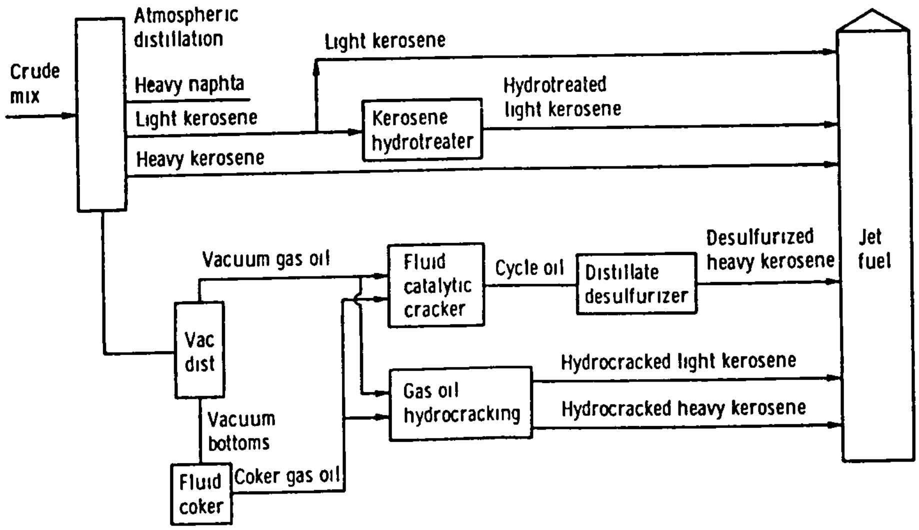

Figure 2. - Simplified refinery flow chart for jet fuel production in Refinery A

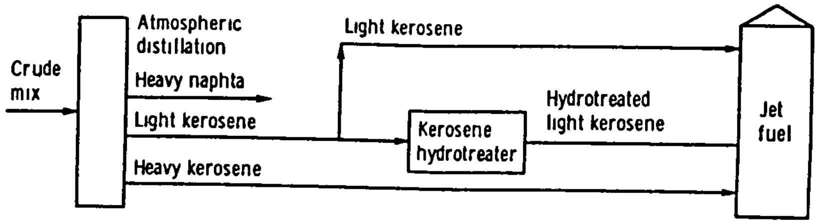

Figure 3 - Simplified refinery flow chart for jet fuel production in Refinery B

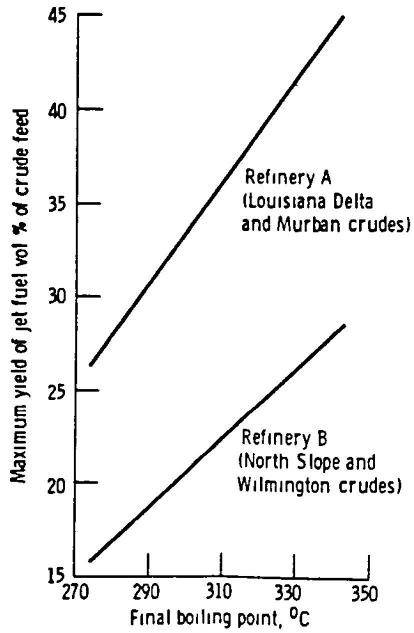

Figure 4 - Maximum yield of jet fuel as a function of final boiling point.

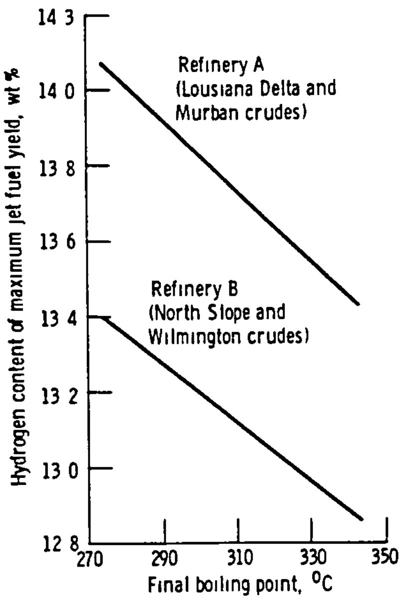

Figure 5 - Hydrogen content of jet fuel as a function of final boiling point

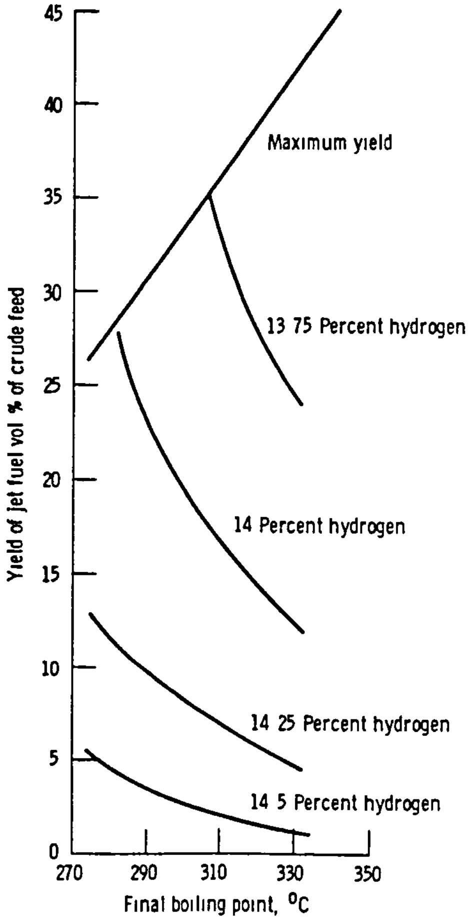

Figure 6 - Yield of jet fuel as a function of specified hydrogen content and final boiling point for Refinery A

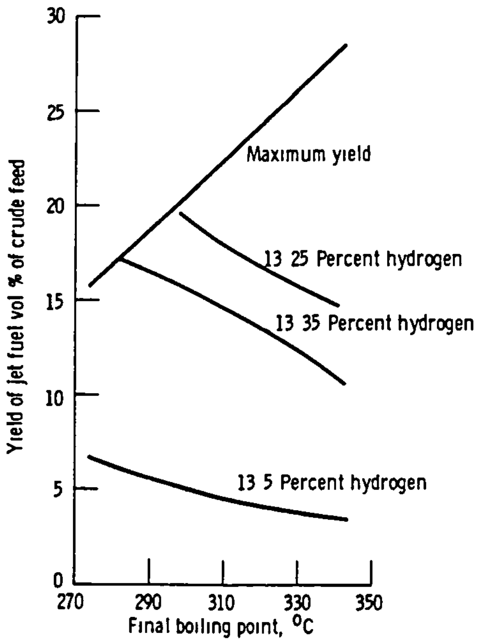

Figure 7 - Yield of jet fuel as a function of specified hydrogen content and final boiling point for Refinery B

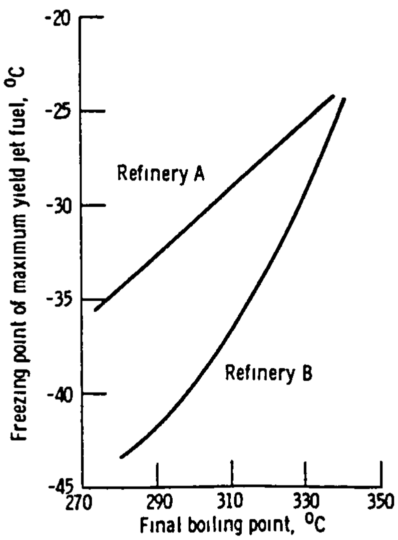

Figure 8 - Freezing point as a function of final boiling point for maximum yield jet fuel

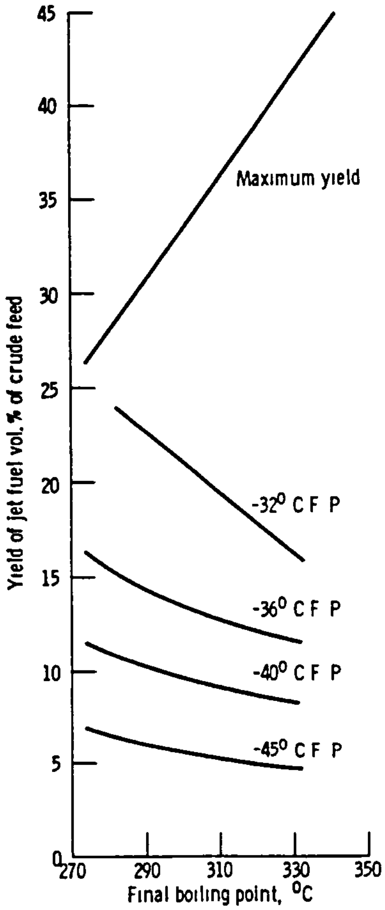

Figure 9 - Yield of jet fuel as a function of freezing point and final boiling point for Refinery A

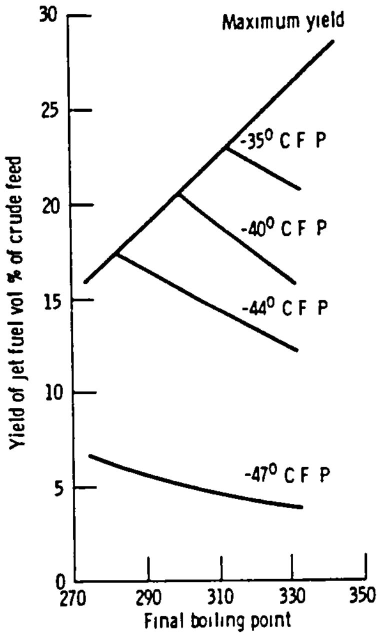

Figure 10 - Yield of jet fuel as a function of freezing point and final boiling point for Refinery B

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16 Abstract

This report is a parametric study of several factors (crudes, refinery operation and specifications) that affect yields and properties of broad specification jet fuel. The Refinery Simulation Model, developed under contract by Gordian Associates, Inc. and modified at NASA LeRC was used to make the calculations. This computer program can simulate different types of refineries. Results obtained from the program are used to correlate yield as a function of final boiling point, hydrogen content and freezing point for jet fuels produced in two refinery configurations, each one processing a different crude mix. Refinery performances are also compared in terms of energy consumption.

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