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Availability and Cost Estimate of a High Naphthene, Modified Aviation Turbine Fuel

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AVAILABILITY AND COST ESTIMATE OF A HIGH NAPHTHENE, MODIFIED AVIATION TURBINE FUEL

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SUMMARY

Information from an Air Force study was used to determine the potential availability and cost of a modified conventional fuel with a high naphthene content which could have a thermal stability near that of JP-7 for high-speed civil transports. Results showed sufficient capacity for a fuel made of a blend of 50 percent naphthenic straight run kerosene and 50 percent hydrocracked product, assuming a near-term requirement of 210 000 BBL per day. Fuel cost could be as low as 62.5 to 64.5 cents per gallon, assuming $20 per barrel for crude.

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INTRODUCTION

The increasing interest in high-speed civil transports (HSCT) requires information on the availability and cost of fuels that are more thermally stable than Jet-A. A modified conventional fuel with a high naphthene content could have a thermal stability near that of JP-7 is one fuel that could be considered a candidate. The work reported herein is a preliminary estimate of the availability and cost estimate for producing such a commercial modified conventional fuel for HSCT. The primary source of information used in performing the analysis is from an Air Force study on the availability of high density jet fuels (ref. 1).

FUEL AVAILABILITY

In order to determine the potential availability of a thermally stable modified conventional fuel for HSCT, JP-7 requirements were selected as a starting point. These chemical and physical requirements and test methods are identified in MIL-T-38219B (USAF), and are summarized in table I. In production, however, the end point is usually limited to 500 °F to meet freezing point and hydrogen content requirements. Table II shows a typical set of measured JP-7 properties, which were obtained from reference 2.

It is estimated that in the near-term, the quantity of the modified conventional fuel required will be about that of current JP-4, which is about 210 000 barrels per day. Since the aircraft requiring this fuel will enter the market gradually, it will take a number of years to reach the estimated near-term requirements. To determine if refineries have the needed capacity for fuel production requirements, information from reference 1 was used.

In order to meet the thermal stability required of the fuel, streams high in naphthene content were considered. According to reference 1, the available near-term capacity for naphthenic straight run kerosene and hydrocracker kerosene is 253 200 BBL per day. These two streams could be used for the production of the modified conventional fuel. The kerosene streams in the model used in reference 1 are for a temperature range of 400 to 550 °F, which is the kerosene temperature range used by Bonner and Moore (ref. 3). To meet all JP-7 requirements, the end point of the kerosene streams should be reduced to 500 °F (table II). An estimate obtained by a computer program to determine a D86 boiling curve for the 400 to 550 °F boiling range product shows approximately 200 000 BBL per day of the kerosene streams should be available for the modified conventional fuel with a 500 °F end point. This is 10 000 BBL per day less than JP-4 requirements. This projection might be slightly optimistic; however, the available hydrocracker shutdown capacity of 43 800 BBL per day should be sufficient to make up any shortfall (ref. 1).

The projected availability of this modified conventional fuel is based on the assumption that refiners will have segregated naphthenic streams for fuel blending. Such segregation is practical only where there is a real demand. Presently this segregation takes place in PADD 3, where lube oil is processed, and in PADD 5, where crudes are highly naphthenic. Hence, as a first approximation it appears that there is more than sufficient capacity to produce 210 000 BBL per day of the desired fuel. Additional capacity could be available if requirements could be relaxed.

FUEL COST

All the information for estimating the fuel cost is in reference 1. The company where this work was done, Bonner and Moore Associates, Inc., is a well known and respected consultant to the oil industry. The information in reference 1 was therefore considered reliable and was used in estimating the fuel cost for this report. The fuel cost is based on blendstock replacement, which has averaged 1.052 times crude cost. Since the modified fuel will require segregated storage and loading system, it was estimated that capital recovery and related costs were $0.27 per barrel. The near-term fuel product of 210 000 BBL per day will be achieved gradually. Fuel production much less than this amount could increase the capital recovery and related costs. To show the effects of scaling, scaling factors of 0.7 and 0.8 was used for producing less than 200 000 BBL per day of the desired fuel.

From the streams available for blending, it appears that about 50 percent of the fuel will require hydrodearomatization. Capital recovery and hydrogen supply are the main cost in hydrodearomatization. Hydrogen consumption should be around 3000 standard cubic feed (SCF) per barrel. With hydrogen at a cost of $1 per 1000 SCF and capital cost of $6 per barrel of capacity, cost of hydrodearomatization per barrel of fuel product is $4.50 (50 percent of streams hydrotreated). These cost estimates are for the production level of the full near-term fuel requirements of 210 000 BBL per day. If it is assumed that the effect of scaling will occur below 200 000 BBL per day, production costs would increase for fuel requirements below this level. Based on this assumption, fuel cost estimates at 20, 25, and 100 percent of the near-term fuel requirements are shown in table III for scaling factors of 0.7 and 0.8.

This scaling effect would depend on the refinery and on the refinery product slate; hence, it may or may not occur. If all streams used in this fuel required hydrotreating to meet thermal stability requirements, the cost would increase to 59.6 cents per gallon for $15 per barrel crude and 72.2 cents per gallon for $20 per barrel crude. At $20 per barrel, the maximum cost would be 86.6 cents per gallon at the 10 percent level with all streams hydrotreated.

In addition to the above refining cost, additive costs and special storage tank preparation cost must be added. According to refinery sources, the cost should be only 1 to 3 cents per gallon. The special storage tank preparation is simply painting with epoxy paint. Transportation costs should be minimal if multiproduct pipelines can be used.

DISCUSSION

The fuel availability analysis shows that there is sufficient capacity to provide a modified conventional fuel with higher thermal stability at a production rate of 210 000 BBL per day. With the available hydrocracker shutdown capacity of 43 800 BBL per day, excess capacity is available.

According to refinery sources, the cost of recent production of Jet A was 54.5 to 56 cents per gallon with crude prices at $20 per barrel. The cost of the new fuel would be 62.5 to 64.5 cents per gallon (61.5 cents for the refined product plus 1 to 3 cents for additives), assuming multipurpose pipelines can be used for transportation. This is about a 15 percent increase in cost.

According to a producer of JP-7, it is being sold at more than $1.09 per gallon with crude at $20 per BBL. This excludes the cost of transportation. The cost of producing JP-7 is high because severe hydrotreating of the entire product is required to achieve a hydrogen content of 14.4 percent. Also JP-7 is not produced continuously. Production at one JP-7 supplier is only once every several weeks to refill the two dedicated storage tanks. Part of the high cost of JP-7 is the effect of scaling, which can be seen in table III. If all of the new fuel would require significant hydrotreating instead of just 50 percent of the blend, the fuel product cost could increase to 72.2 cents per gallon at the 100 percent level and 86.6 cents per gallon at the 10 percent level, assuming $20 per BBL of crude.

CONCLUDING REMARKS

From the preliminary analysis used in this report, there is adequate refinery capacity to provide 210 000 BBL per day of modified conventional fuel high in naphthene content for a high-speed transport in the near-term. The analysis shows that about 50 percent of the fuel blend would be a hydrocracked product with the other 50 percent a naphthenic straight run kerosene. The cost of producing such a blend was found to be 61.5 cents per gallon with another 1 to 3 cents for additives and epoxy painted fuel tanks, assuming crude at $20 per BBL.

The results obtained seem reasonable, but should only serve as preliminary estimates. Fuel property requirements and refinery analysis based on the fuel requirements are needed for a more exact prediction of fuel availability, quality, and cost. The results also assume that in the future there is not much change in product demand or refinery slate.

REFERENCES

1. Frederick, F.P.: High Density Jet Fuel Availability Study: Phase I - Refining Industry Survey. AFWAL-TR-86-2083, Jan. 30, 1987.

2. Sefer, N.R.; Erwin, J.; and Russell, J.A.: Synthetic Fuel Center Construction and Alternative Test Fuels Production. DOE/CS/50070-1, Sept. 1985.

3. Dickson, J.C.; Frederick, F.P.; and Sipowicz, W.W.: Impact of Alcohol Fuels on the U.S. Refining Industry - Vol. 2. DOE/CS/50007-1, Aug. 1983.

TABLE I. - CHEMICAL AND PHYSICAL REQUIREMENTS AND TEST METHODS

[Summary of Mil-T-38219B (USAF).]

Requirements	Values	Test method, ASTM standards
Aromatics, vol %, maximum	5	D1319
Mercaptan sulfur, wt %, maximum	0.001	D3227
Sulfur, total wt %, maximum	0.1	D1266 or D3220
Distillation, °C (°F)		D86
Initial boiling point, minimum temperature	182 (360)	
10 percent recovered, minimum temperature	196 (385)	
20 percent recovered, minimum temperature	206 (403)	
50 percent recovered, maximum temperature	Report	
90 percent recovered, maximum temperature	260 (500)	
End point, maximum temperature	288 (550)	
Residue, vol %, maximum	1.5	
Distillation loss, vol %, maximum	1.5	
Flash point, minimum, °C (°F)	60 (140)	D93
Density, kg/m^3, minimum (°API, maximum) at 15 °C	779 (50)	D1298
Density, kg/m^3, maximum (°API, minimum) at 15 °C	806 (44)	D1298
Vapor pressure, kPa (psi) at 149 °C, maximum	20.7 (3.0)	
Vapor pressure, kPa (psi) at 260 °C, maximum	331 (48.0)	
Freezing point, °C (°F), maximum	-43.3 (-46)	D2386
Viscosity, at -20 °C, centistokes, maximum	8.0	D445
Heating value, net heat of combustion MJ/kg (Btu/lb), minimum	43.5 (18 700)	D2382, D3338
Hydrogen content, mass percent, minimum	14.4	D3343, D3701
Copper strip corrosion, 100 °C (212 °F), maximum	1b	D130
Thermal stability		
JFTOT, change in pressure drop in 5 hr, mm Hg, maximum	25.0	
JFTOT, delta TDR spun, maximum	12	
Existent gum, mg/100 ml, maximum	5.0	D381
Particulate matter (total solids)		D2276
FOB origin deliveries, mg/l maximum	0.3	
FOB destination deliveries, mg/l maximum	0.5	

TABLE II. - MEASURED JP-7 PROPERTIES[a]

Property	Method	Base fuel
Description	D = ASTM	JP-7
Identification number	----------------	FL-0233-T
Cetane number	D613	57.2±1
Surface tension, dynes/cm	Ring	26.1
Density:		
Sp Gr at 60 °F	D1298	0.7954
°API		46.4
Distillation,	D86	°C °F
IBP		198 388
5 vol %		206 402
10		207 404
20		208 406
30		209 408
40		210 410
50		211 412
60		213 416
70		216 420
80		220 428
90		228 442
95		237 458
FBP		259 498
Viscosity, cSt at 40 °C	D445	1.57
Heat of combustion	D240	
Gross, MJ/KG		46.934
Btu/lb		20 178
Net, MJ/KG		43.815
Btu/lb		18 837
Flash point, °C (°F)	D93	69 (157)
Cloud point, °C (°F)	D2500	-43 (-45)
Elemental analysis,		
M percent	Micro-combustion	
Carbon		85.66±0.09
Hydrogen		14.70±0.01
Sulfur	XRF	<0.01
H/C atom ratio	----------------	2.04
Hydrocarbon type, vol %	D1319	
Saturates		96.9
Olefins		1.0
Aromatics		2.0

[a]Ref. 2.

TABLE III. - FUEL COST BREAKDOWN

[Scaling factor = 0.7.]

	Percent required					
	10		25		100[a]	
	Crude cost $ per BBL					
	15	20	15	20	15	20
Fuel cost per BBL	15.78	21.04	15.78	21.04	15.78	21.04
Hydrodearomatization, per BBL	7.40	7.40	5.98	5.98	4.50	4.50
Storage facilities, cost per BBL	0.54	0.54	0.41	0.41	0.27	0.27
Fuel cost $ per BBL	23.72	28.98	22.17	27.43	20.55	25.81
Fuel cost ¢ per gallon	56.5	69.0	52.8	65.3	48.9	61.5

[a]100 percent is 210 000 BBL per day.

[Scaling factor = 0.8.]

	Percent required					
	10		25		100[a]	
	Crude cost $ per BBL					
	15	20	15	20	15	20
Fuel cost per BBL	15.78	21.04	15.78	21.04	15.78	21.04
Hydrodearomatization, per BBL	6.21	6.21	5.42	5.42	4.50	4.50
Storage facilities, cost per BBL	0.43	0.43	0.36	0.36	0.27	0.27
Fuel cost $ per BBL	22.42	27.68	21.56	26.82	20.55	25.81
Fuel cost ¢ per gallon	53.4	65.9	51.3	63.9	48.9	61.5

[a]100 percent is 210 000 BBL per day.

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