AVIATION FUELS OUTLOOK

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Passenger and cargo air traffic are expected to grow substantially in the next two decades. Even with an emphasis on fuel efficiency, the domestic demand for jet fuel is projected to increase from the current 5.2% of total refinery product output to as much as 10% of the total 1995 output. Options for satisfying this demand (Fig. 1) are being evaluated in current Boeing studies.

Approximately 15% of the U.S. refineries market commercial jet fuel (Jet A). In the long term, the product slate at these refineries is optimized for maximum profit. This typically means that there must be an available market for the entire line of products with emphasis on quality products such as jet fuel and gasoline. The market for each major product also must be reasonably secure. Refiners have indicated that a desirable market range for jet fuel is 15 to 25% of a refinery's product slate. Currently delivered Jet A has an average freezing point of -45° C and a 54° C flash point. These properties result in a typical refinery Jet A yield within the desirable market range as shown in Fig. 2. Refiners can maintain or even increase their Jet A market share by delivering Jet A with properties closer to the -40° C freezing point and 37.8° C flash point specification limits. Relaxing the freezing point and/or flash point requirements would result in a higher potential Jet A yield, as shown in Figs. 3 and 4. However, it is unlikely that the marketed yield would increase significantly; certainly not to the refinery jet fuel fraction yield required to satisfy Jet A requirements projected for 1995.

In some cases, the quantity of marketable jet fuel is limited by Jet A specification requirements, such as the 3% naphthalene maximum associated with smoke point. However, in most cases Jet A specification requirements do not restrict the quantity of jet fuel marketed by a refinery as indicated by the inspection data summary shown in Fig. 5. This situation is expected to exist for at least the balance of this century as shown for the selected property projections given in Figs. 6 and 7.

A promising direction towards increasing the jet fuel supply is to attract more refiners to the jet fuel market. There are many refiners currently not marketing jet fuel who have sufficient jet fuel potential to warrant the added distribution and quality control costs. Figures 8 and 9 show the jet fuel production capability of a major independent East Coast refinery currently not marketing Jet A. A yield of Jet A specification fuel of up to 20% is possible from this refinery. Fuel properties such as aromatic content, specific gravity, heat of combustion and smoke point fall within the existing specification limits for Jet A. Attracting new refiners to the jet fuel market will depend on economic incentives, ability to transport fuel, and projected market stability.

Synthetic fuels from shale or coal are the long term option for increasing the jet fuel supply. Oil shale and coal are the only two energy sources with large enough reserves to contribute to the nation's transportation energy need. There is a wide variety of options available for incorporating coal and oil shale into the energy supply system. Several of these, shown in Fig. 10, offer promise and were evaluated as a source for Jet A.

Many coal gasification processes have a liquid by-product that can be upgraded to a synthetic crude. This by-product liquid accounts for less than 10% of the plant product fuel output. The output of Jet A after refining would be less than 30% of this by-product liquid. Therefore, it is doubtful that by-product liquids from coal gasification processes can be significant sources of jet fuel.

Synthetic crudes from shale or coal liquid processes can be refined into finished products in a new refinery designed for the synthetic, or mixed with petroleum based crudes and refined in an existing refinery. The existing refinery may require some modification depending on the quantity of syncrude added to the feedstock and product mix requirements. Liquid products also can be obtained from coal by producing a synthesis gas and catalytically reforming the gas into a wide variety of finished products.

The syncrude from coal and shale and the finished product from coal processes allow a product slate that can be adjusted to product demand. The cost in both capital and energy increases with the severity of the processing required to satisfy a fixed product slate. It is possible to dedicate a synthetic fuel facility to the production of jet fuel with yields as high as 80% commercial plus military. However, it is not clear that the added expense could be justified by a commercial user or would be cost competitive in the long term.

Synthetic crudes from oil shale and coal can be processed to satisfy the Jet A specification as shown in Fig. 11. The desirability to produce jet fuel of a particular quality must be evaluated in terms of cost and energy efficiency of the total system including the aircraft.

The principal problem with oil from shale is its high nitrogen content. Fuels with a high nitrogen content tend to be unstable. Nitrogen also causes problems in refineries and it is expected that refinery requirements will dictate a nitrogen reduction that will be acceptable for aircraft.

Coal liquids from direct hydrogenation processes have a high aromatics, hence low hydrogen content. High aromatics cause increased combustor liner temperatures and a reduction in fuel energy. The acceptance of highly aromatic fuels in an aircraft would reduce fuel processing requirements and cost. However, aircraft fuel quantity requirements and maintenance would increase. Energy losses associated with the aircraft and ground system would be particularly severe if high aromatics were associated with high fuel freezing point. The energy saving from reduced fuel processing must be balanced against added airplane, refinery, storage and distribution system energy requirements as indicated in Fig. 12. The fuel produced using coal synthesis processes can satisfy Jet A requirements with little cost or energy loss penalty.

In the near term, the most likely commercial utilization of synthetic crudes will be as an additive to petroleum based crude feedstocks. This will allow an evolutionary development of shale and coal resources without requiring major modifications to the existing fuel refining and supply system.

A 20% shale syncrude mixed with crude oils and used as feedstock in refineries with access to the shale areas can easily handle syncrude quantities expected from production over the next two decades. The introduction of this syncrude into a Midwest refinery currently marketing jet fuel could cause a small drop in Jet A yield, as shown in Fig. 13. The nitrogen content of the jet fuel would be abnormally high and, if fuel thermal stability requirements could not be satisfied, the nitrogen might have to be removed. All other fuel properties could satisfy Jet A requirements.

Commercialization of coal liquid processes that produce a syncrude, such as donor solvent, is not expected until the late 1980's. Therefore, 10% coal liquids mixed with petroleum based crudes can account for coal syncrude production well into the next century. The introduction of this syncrude into a Gulf Coast refinery currently marketing jet fuel could cause a small drop in Jet A yield, as shown in Fig. 14. All other fuel properties could satisfy Jet A requirements.

In summary, Boeing studies to date have indicated that the most effective means to satisfy an increasing demand for jet fuel are: (1) Attract more refiners to the jet fuel market; (2) Encourage development of processes to convert oil shale and coal to transporation fuels. Furthermore, changing the Jet A specification would not significantly alter jet fuel availability.

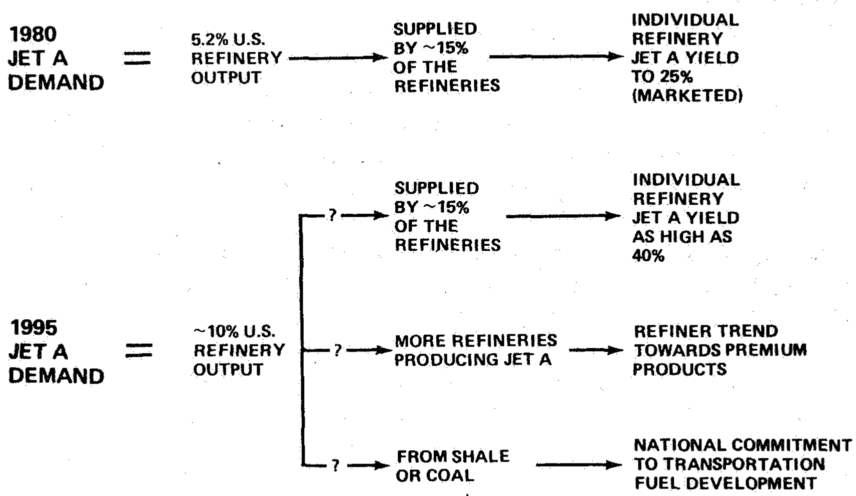


Figure 1. Jet A Supply Options

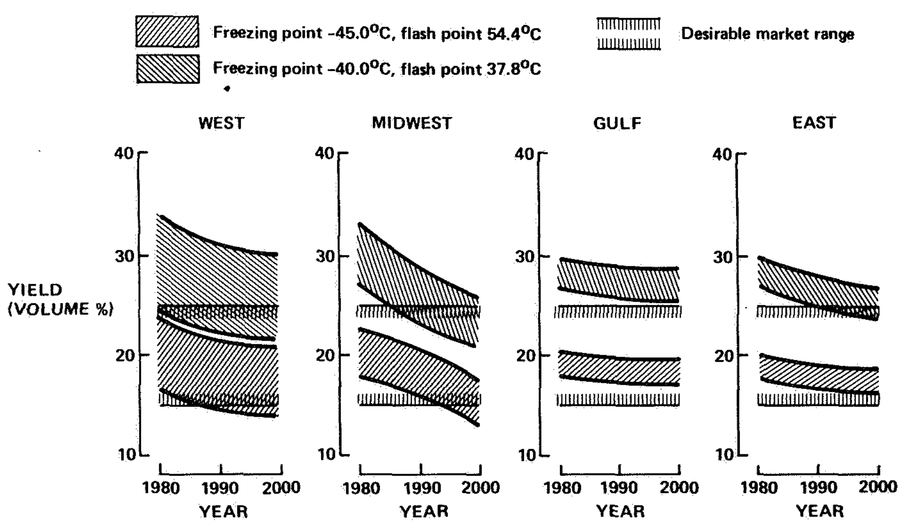


Figure 2. Refinery Jet Fuel Fraction—Yield

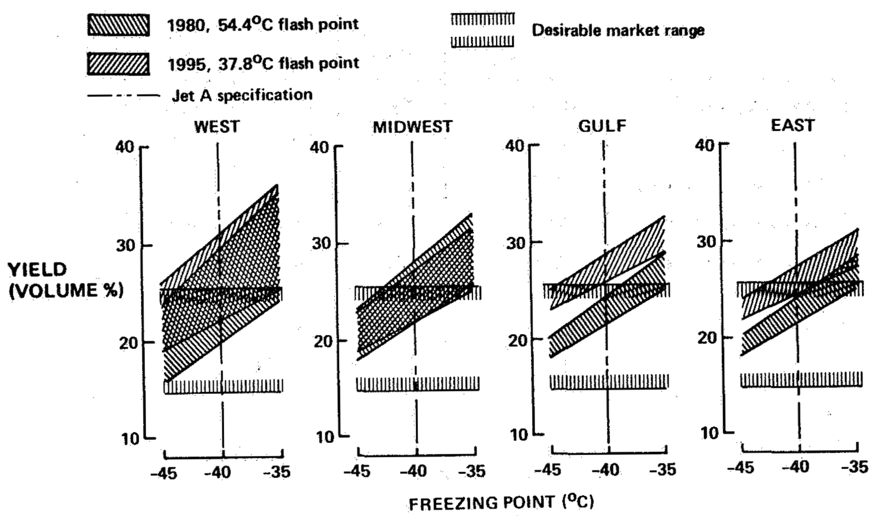


Figure 3. Jet Fuel Processing—Freezing Point Sensitivity

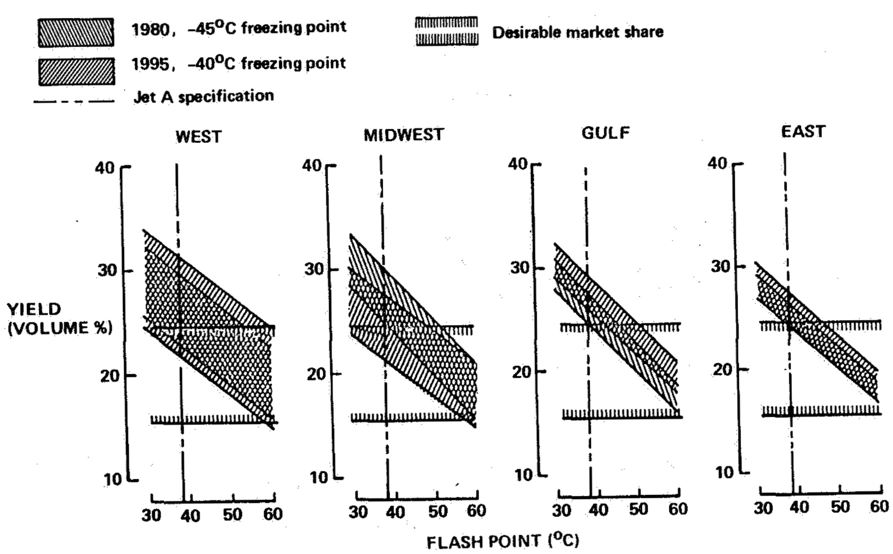


Figure 4. Jet Fuel Processing—Flash Point Sensitivity

	Jet A spec	Mean	Max	Min	At spec limit*
Freezing point (°C)	-40.0	-45.0	-40.0	-64.0	2
Flash point (°C)	37.8	54.4	64.4	37.8	1
Aromatics (volume %)	20/25	17.4	23.5	11.0	0
Smoke point (mm)**	20/18	22.7	28.0	18.7	1
Heat of combustion (MJ/kg)	42.8	43.2	44.0	43.0	0
Specific gravity	0.775/0.840	0.811	0.833	0.794	0
Sulfur	0.3	0.053	0.130	0.002	0

*Out of 60 samples

**Napthalenes < 3 volume %

Figure 5. Jet A Inspection Data Limits—1978

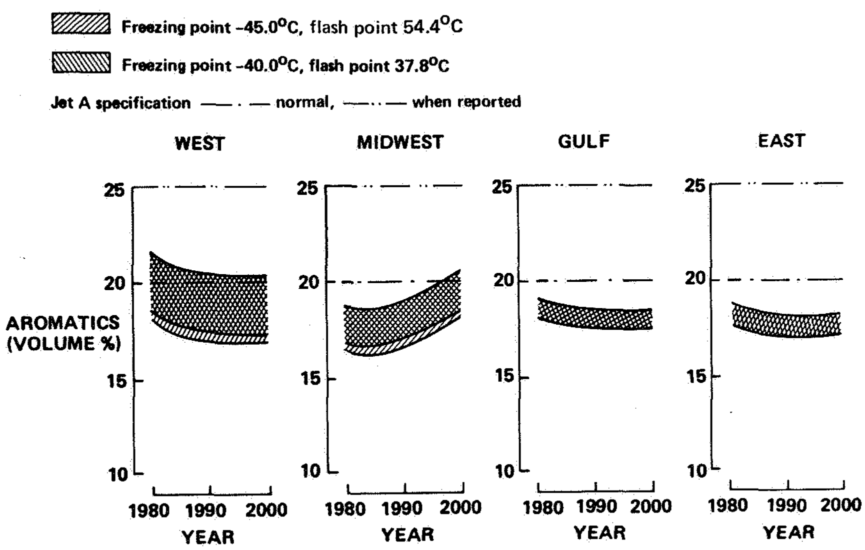


Figure 6. Refinery Jet Fuel Fraction—Aromatics

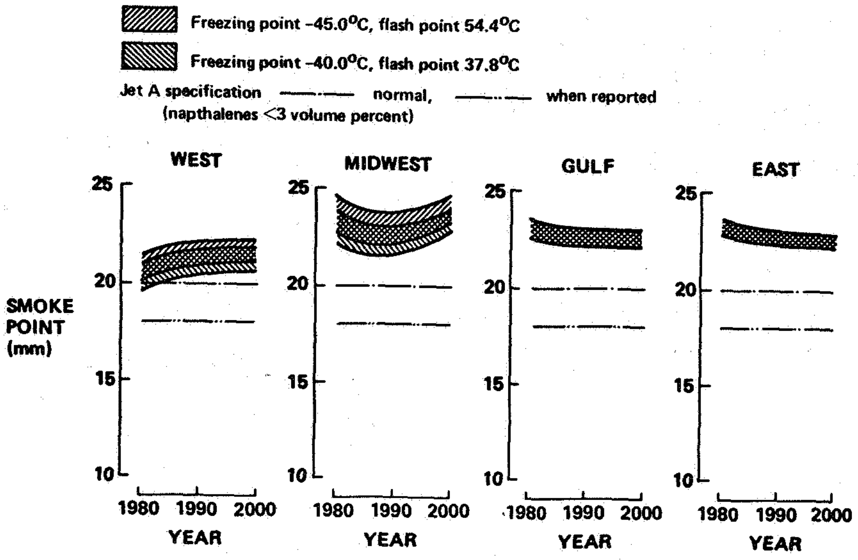


Figure 7. Refinery Jet Fuel Fraction—Smoke Point

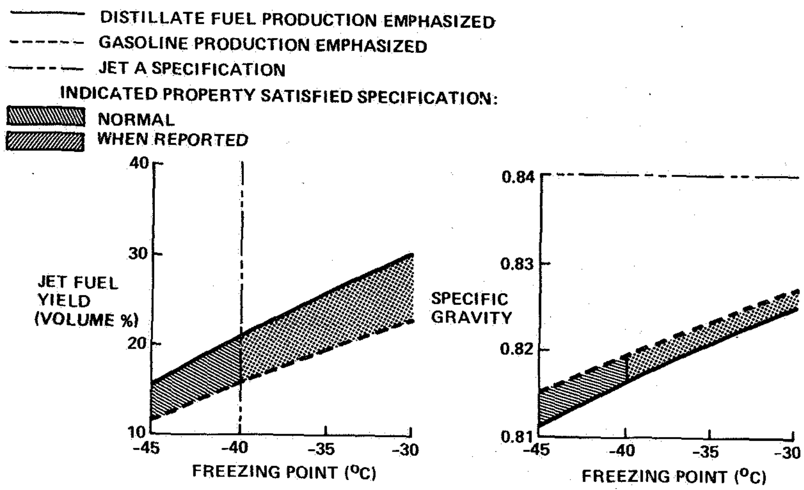


Figure 8. Jet Fuel Processing—Independent Refinery

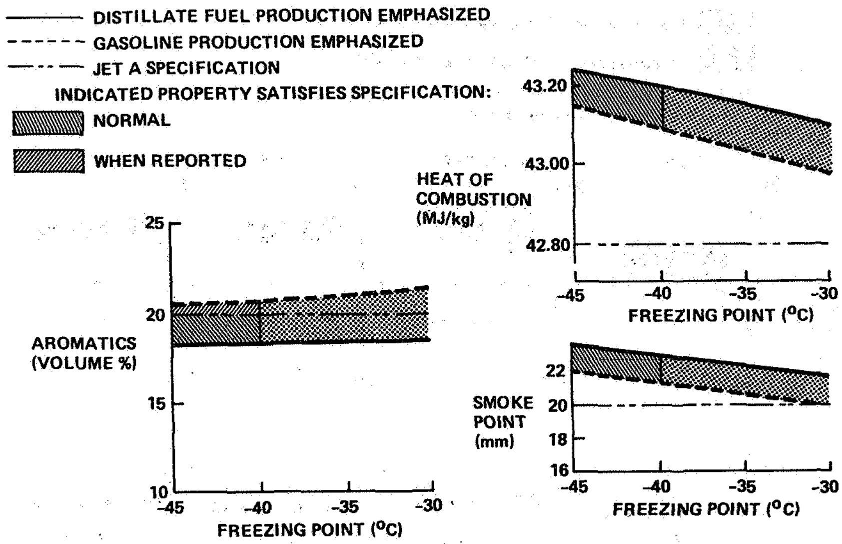


Figure 9. Jet Fuel Characteristics—Independent Refinery

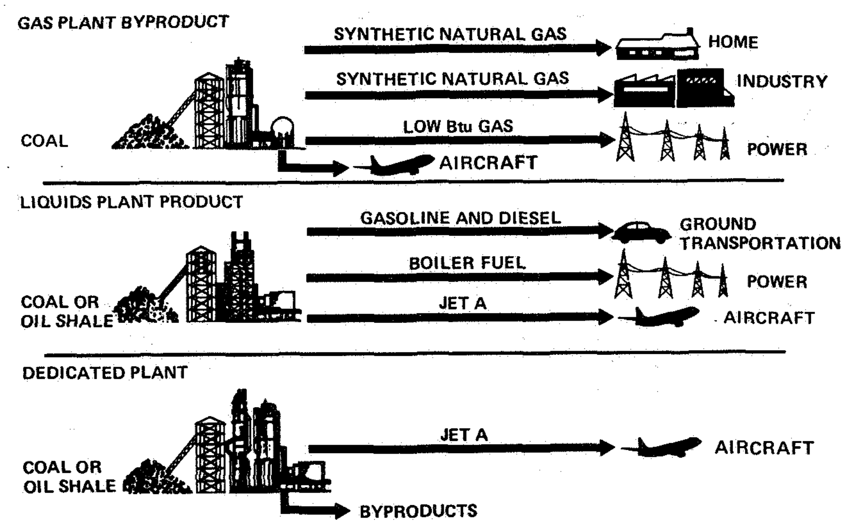
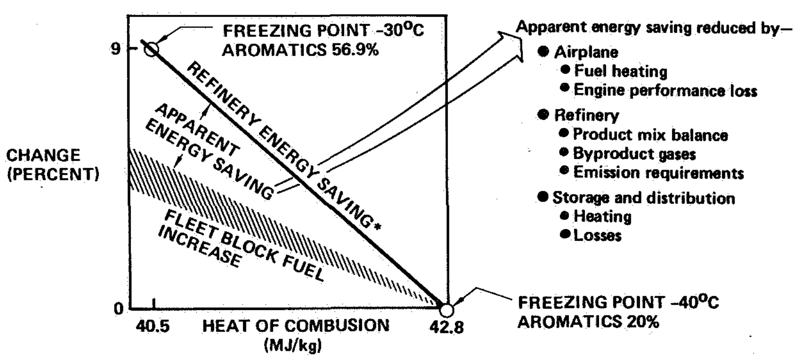


Figure 10. Synthetic Jet Fuel Production Options

Properties	Jet A selected specifications	Jet/coal hydrotreated	Jet/shale hydrotreated
Gravity (deg API at 16°C)	37 to 51	39	41
Freezing point (°C)	-40 maximum	-40	-40
Net heating value (MJ/kg)	42.8 minimum	43.0	43.0
Aromatics (volume %) If supplier notifies user	20 maximum 25 maximum	10.7	13.3
Smoke point (mm) If supplier notifies user	20 minimum 18 minimum	18	21
Flash point (°C)	37.8 minimum	41.1	40.6
Nitrogen (ppm)	–	33	205

Figure 11. Synthetic Jet Fuel Properties



*100% coal liquids; refinery hydrogen from coal

Figure 12. Refinery and Airplane Energy Sensitivity

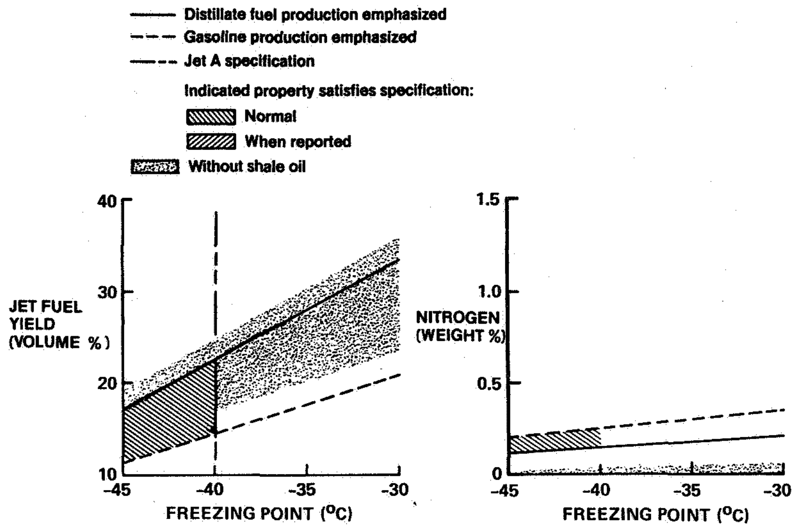


Figure 13. 20% Paraho Shale Oil Processing

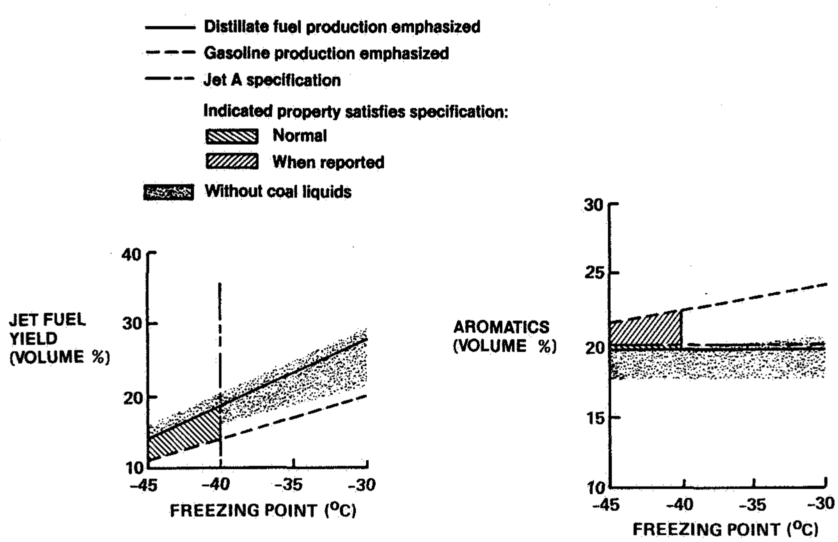


Figure 14. 10% Coal Liquids Processing