SYNFUELS IMPACT: THE FEDERAL VIEWPOINT

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FORCES AT WORK AFFECTING LIQUID SYNFUELS DEVELOPMENT

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Ladies and Gentlemen, I am especially pleased to be here with you in the Southwest Texas area where some of my earliest engineering experience was with Humble Oil Co. My wife and I have fond recollections of those times and it's good to be back in San Antonio. For those of you who have not previously been here I can assure you that, given half a chance, the people of this area will show you magnificent hospitality traditional of the Southwest.

The remarks that I will make are somewhat out of phase in the program due to the rescheduling that has been necessary. My remarks were intended as mood music, so to speak--to acquaint you with the general background of forces at work--to give my viewpoint on the atmosphere in which fuel/engine technology development must now proceed. With that note of mild regret that my comments may be somewhat misplaced, let me then proceed to discuss with you some facets of the atmosphere in which the federal program re fuel/engine technology is proceeding. I would title these remarks something like, "Comments on forces at work establishing the atmosphere within which the federal synfuels engine/ fuel technology program develops."

First of all, let me set the bounds of my discussion. My remarks will refer only to transportation energy use because we're talking about liquid fuels and that's the primary energy fuel for the transportation sector. No other single consuming sector approaches the auto as a dominant factor in fuel requirements. Roughly speaking, transportation accounts for about one-half of our energy needs and, of that, the auto requires about one-half. Requirements for the air sector warrant special mention. A few years ago there was discussion about broadening the volatility limits of turbine fuels. I haven't heard much of that lately, but let me suggest that with the recent commitment to new generation of turbine aircraft, it is most unlikely that we will see significant change in turbine fuels. This follows, considering the complexity of aircraft systems and the sensitivity of those systems (including supply and distribution systems) to fuel characteristics. Thus it appears to this individual that it is most unlikely that we will within the near future see any change in the fuel acceptable to the air transportation industry.

There was reference this morning to the time frame within which technology changes. As that comment was made, it occurred to me that we all too frequently discount or fail to recognize the long time-constant in technology developments. For example, I, who first started riding DC3's, am prone to think of the jet aircraft as a relative newcomer on the scene. But in last week's paper there was prominent coverage of the fact that the first of the 707's had its twentieth birthday in commercial service last week. In like fashion the new generation of aircraft and their support systems, representing enormous capital investments, will be around for a long, long time. And we will not see precipitous change to the character of fuels that go into those systems.

Projections as currently used by the Department of Transportation show that passenger vehicle fuel demand trends downward with the implementation of mandatory auto fuel economy standards and levels off by about 1990. However, light-duty vehicle truck demand is expected to increase with that increase roughly offsetting the decrease in passenger vehicle demand. Thus, for the foreseeable future we are looking at vehicle demand of a hundred billion gallons a year. This then is the liquid fuel demand to be addressed in the development of a synfuels supply strategy for liquid fuels for transportation. Here I pose a question that I view as being very important in our technical approach toward fuel supply. Will there be an evolutionary trend in engine development, or will change be revolutionary? Depending upon the group with which I discuss the question, the viewpoint varies widely. This group probably would say, "Yes, it's going to be an evolutionary trend--there will not be a revolutionary new system." But there are numbers of people within the federal establishment who speak of expectations for revolutionary new systems to enable realization of 100 mpg fuel economy. Serious, well-intentioned high level management people have asked me in the very near past, "Dick, why don't you design a completely new engine at Bartlesville; after all," so my prompter said, "You have a staff of 30 or 40 experts there." But that isn't to be, and the changes in vehicle systems will be evolutionary.

Through the mid-1985's the reciprocating engine will continue in external form essentially as we've known it for many years. But, there will be very important changes. Except as precluded by the 3-way catalyst, systems will be characterized by lean combustion, and all systems will incorporate more-closely controlled air-fuel ratio, F/A mixing, mixture distribution, and by more sophisticated overall control upon the system. To me this equates, not to a relaxation of fuel requirements, but, if anything, to a tightening of the fuel requirements for cleanliness, detergency, and overall consistency in fuel quality.

While the familiar "old" engines will remain with us, there will be emphasis upon the diesel and upon turbocharging. The diesel has promise, very large promise, but there are real questions that need to be answered as quickly as they can be answered responsibly before the fuels and engine industries commit to this technology. We of the technical fraternity need to use our good offices, whatever they may be, to bring EPA and other government agencies together working with industry to answer questions and come up with solid guidelines for justifiable performance requirements toward which industry can target its developments. I say to my friends in DOE that for the short term probably the most serious question and one of the heaviest responsibilities facing DOE in the area of fuels concerns the government posture toward the diesel auto. Whether or not the diesel is going to be on the scene in great number can have a very significant impact upon the form of synthetic fuels development. This applies to strategy and technologies for 100% synthetic fuels but applies equally in implications for development of those supplementary fuels that must necessarily bridge the time and supply gap between conventional and non-petroleum fuels. If the diesel can have such large impact we should ask the question, "Is this force a real one or is it just a passing fancy?" And, in answer, there is little question but that there is real advantage in the diesel. First, it has a built-in advantage in the sense that, vis-a-vis gasoline, there is more energy packed in a gallon of diesel fuel; its mile-per-gallon economy should be better by that amount. In addition, the diesel has much better light-load fuel economy. That fact can be quite significant in choosing the diesel for use where its characteristics can be used to best advantage--for example, light delivery service. In brief, the move toward more diesel autos is a very important force at work--and there are impressive figures behind promotion of the diesel. Within government circles there is widespread use of a projection that shows savings of about 3 billion barrels of crude oil by 2000 if the diesel replaces 75% of gasoline-fueled auto production by 1990. This savings is roughly the equivalent of the North Slope of Alaska reserve. Whether you or I agree or do not agree, the prominent use of such numbers amounts to a large driving force toward increased diesel use.

There is another interpretation that can be put upon the diesel "savings." With the implementation of mandatory fuel economy standards, actual barrels of crude may not be saved, but what may be done is to restore transportation function that otherwise might become unavailable in choice of autos. Either way one looks at it, there is validity in saying that there is significant gain in going to a degree of dieselization in the passenger vehicle fleet. But whatever the merit of diesel versus gasoline, if we are to recognize prominent forces at work to influence engine/fuel technology, we must recognize the diesel trend. After all, saving a North Slope oil field is pretty strong medicine in the halls of Congress.

I would comment briefly concerning the stratified-charge engine because this engine shows promise for development as an engine relatively free of either octane or cetane requirement. Successful development of such a technology would have enormously favorable impact because, in general, the least expenditure of energy in refining is possible with production of a wide-boiling-range fuel which is neither gasoline nor diesel fuel. Unfortunately, while versions of the stratified-charge engine work magnificently under some conditions, it does require exquisite balance between many dynamic elements in the fuel injection/ignition/combustion sequence. Because it does have this element of complexity, successful development is far from assured and I would therefore suggest that we not anchor our fuels development philosophy to this technology. But neither is it to be ignored, and we should continue to look for solutions to the problems that are inherent in this engine.

Looking at engines past 1985, what do we see? Without doubt, the conventional reciprocating internal combustion engine will still be with us--with the changes that I've earlier indicated. Beyond that, there are those who hold hope for the Stirling and gas turbine engines as continuous combustion systems for vehicular use. Why are these engines promoted so agressively in some circles? The reason is that, as continuous combustion systems they have a non-discriminatory appetite for fuels. However, over-promotion of the broad-digestability characteristic of the continuous combustion systems leads to a misconception that these systems can burn corn shucks, cottonseed hulls, and liquid fuels of any kind so long as the mechanical system will tolerate the fuel and blow it into the engine. Nothing could be further from the truth for in some respects, the gas turbine can be a very delicate eater--so to speak. The systems that handle the fuel for these engines must be finely tuned and adjusted for whatever particular fuel is used. For this reason--and for other good reasons--it is highly unlikely that there will be development of an engine with true multifuel capability, i.e., the capability to use any of a variety of fuels without system readjustment. We should not, therefore, base a synthetic fuels development strategy on assumption of a system that will accept any fuel that may or could be developed--and in my view it is technically unsound to promote either the gas turbine or the Stirling because of that perceived virtue. In brief, it looks very doubtful that either the Stirling or gas turbine will be moved off top-dead-center in its development for the transportation industry except for some possible applications of the gas turbine in the 400 to 500 horsepower range.

Let's now look briefly at the real-world situation with regards to fuel economy standards. Higher miles per gallon is the name of the game being played with federal regulatory programs, but that isn't necessarily what we're after. What we're after is higher miles per barrel of crude. The crude oils that typically are entering U.S. refineries differ significantly. Some, via simple distillation, yield a large fraction of the barrel as gasoline, others very little gasoline but a larger yield of middle distillate--or residual--and so forth. But if crudes differ, so do the mixes of petroleum products around the world. In the U.S. we consume in the product mix about 50% gasoline, roughly 25% middle distillates, with the rest being fuel oil. In the U.K. it's about a third of each; while in Japan the product mix is about 20% gasoline, 20% distillates, and the rest resid. This, it might be said, is proof positive that one can produce any mix from a barrel of crude--and, to a degree, that is true. For example, simple distillation plus some reforming of the naphtha may produce the desired mix of gasoline, distillates, and fuel oil. If somewhat more distillate is needed, this can be obtained by additional processing of the heavy fuel oil fractions. But the adjustment can be carried only so far until the production of additional distillate--or diesel--becomes very expensive. About three years ago the Department of Transportation sponsored a study of fuel and transportation systems expected within the 1980's-and-later time frame. This study brought high visibility to the fuel economy advantage of the diesel and within some quarters there was highly vocal advocacy for almost total dieselization of light-duty passenger vehicles. Because it was thought that there might be problems in supplying the amount of diesel fuel that would be required, DOE retained Bonner and Moore Consultants to conduct a study of the refining industry to provide insight into problems that might be encountered in producing more diesel fuel.

The gist of the Bonner and Moore study is that with increased diesel production in the aggregate of the transportation fuels product mix, energy requirement for refining first decreases, but then increases sharply as diesel demand increases beyond about 50% of the light-duty vehicle demand. However, if a third fuel--a broad-boiling-range material--also is produced the overall refinery energy requirement can be reduced well below the requirement calculated for any case wherein only diesel and gasoline are used for passenger vehicles. In short, Bonner and Moore projected that with a 10/70/20 gasoline/ distillate/ broadcut split in the LDT fuel demand mix, the refinery energy requirement would be about 5% of refinery input instead of about 8½% in the case of a historical gasoline/diesel mix. It also can be noted that the 3½% delta is referred to total refinery feed--thus 3½% of total refinery throughput is saved by shifting about 1/3 of passenger car fuel from gasoline to diesel and broadcut fuel. The leverage is indeed impressive.

The conclusion with respect to parallel development of engine/fuel technologies appears to be obvious; to the extent possible the engine should allow broad latitude in fuel formulation; that probably equates to the engine's requiring little in the way of either cetane or octane quality. In mating the fuel and engine the key word is "adaptability." It is not necessary that the engine use anything available, changing on a day-to-day basis; instead the system should be adaptable to a variety of fuels. Whether or not--and in what degree-we can realize this adaptability is yet to be seen. The jury isn't in on that at all, but it is clear that broad latitude in fuels design is highly desirable in synfuels development.

The final point that I would make in these remarks is that engine and fuels developments should be moved forward simultaneously in an iterative process of moving minimally processed fuels toward somewhat higher quality, while fuels-sensitive engines are moved toward progressively greater insensitivity. Herein may lie a major weakness in the federal program; one program manager addresses fuels, another addresses a transportation engine, while yet another concerns himself with industrial engines. Each is addressed as if it were totally separate technologically from the others. Nothing could be more disastrous in efficient design and execution of effort toward best mutual accommodation of fuels and engines in the transition from all-petroleum to a mix of petroleum and non-petroleum fuels. With your help, we in the governmental effort can contribute toward well coordinated, efficiently interactive research and development on engine/fuels technologies for the years ahead; this we must do.

IMPACT OF SYNFUELS ON CIVIL AVIATION

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IMPACT OF SYNFUELS ON CIVIL AVIATION

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San Antonio, Texas - October 11, 1978

Projected Aviation Fuel Demand

All transportation modes account for about 54% of total U.S. petroleum consumption. Automobiles use about 30%, buses and trucks about 13%, and civil aviation about 4%. Air carriers account for about 92% of the civil aviation petroleum usage while general aviation accounts for about 8%.(1)

Estimates of total jet fuel and aviation gasoline consumed in the U.S. in 1976 by domestic and international civil aviation and projected demand in 1988 are presented in Table 1.(2,3) Military aircraft fuel consumption and demand are included in these estimates.(4)

TABLE 1

U.S. Jet Fuel and Aviation Gasoline Consumption and Forecast
(In Millions of Gallons)

	1976		1988	
	Jet Fuel	Avgas	Jet Fuel	Avgas
General Aviation	495	432	1,369	764
Air Carrier (Domestic)	7,822	20	11,940	4
International (U.S. and Foreign Airlines)	1,619	—	2,900	—
Total Civil	9,936	452	16,209	768
Military Aircraft	4,515	300	5,961	200
Total Civil & Military	14,451	752	22,170	968

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In 1976, civil aviation accounted for over 9.9 billion gallons of jet fuel and military aircraft accounted for 4.5 billion gallons, a total of about 14.5 billion gallons. A total demand of about 22.2 billion gallons is projected for 1988; 16.2 billion gallons for civil aviation and 6.0 billion gallons for military aviation. The fuel consumption of civil aviation in 1976 was about double that in 1966. By the year 2000, fuel requirements for civil aviation are expected to again double.[1]

Jet fuel conservation efforts are underway which include options that are directly within the purview of the FAA, such as in operation of the Nation's airport and airway system, and options that are within the purview of the airlines and airframe and engine manufacturers. If all proposed options are implemented, it is estimated that up to 28.0 billion gallons of jet fuel could be saved between 1978 and 1988 and that 5.0 billion gallons less fuel would be required in 1988.[1]

Short Term Considerations for Increasing Jet Fuel Supply

Civil turbine-powered aircraft use a low-volatility kerosene base jet fuel (kerojet) having a minimum ASTM specification flash point of 100° F. (38° C.). The current market for kerojet is 86% air carrier, 7% military, 5% general aviation, and 2% other. The military kerojet demand, previously limited to Navy carrier-based aircraft, will expand now that the Air Force has switched from naphtha-base jet fuel to kerojet in its European operations and may do so domestically in 1979. If the Air Force does convert, it could bring about a need for 20% more kerojet beginning late next year.[5] In order to assure an adequate kerojet supply for both civil and military aircraft in the U.S., it was indicated at a recent ASTM Symposium on the Reduction of Jet Fuel Flash Point that it may be necessary within the next 3-5 years to consider the use of kerojet with reduced flash points from 80-100° F. (27-38° C.). ASTM is planning to request the Coordinating Research Council (CRC) to better define the fire safety of reduced flash point kerojet fuels since relatively little quantitative information is available on the fire safety of such fuels. If it is shown that there is no significant difference in the relative safety between reduced flash point and current flash point kerojet fuels, it is anticipated that ASTM will propose to reduce the minimum specification flash point. It is noted that Canadian National Standard CAN2-3.23-77 was issued in March 1977 for a kerojet fuel having a reduced flash point of 92° F. (33° C.).

Synthetic Fuel Considerations

The NASA, ERDA, Department of Defense, and Industry are evaluating a range of jet fuels refined from crude oils derived from shale oil and coal. These studies have indicated that shale oil is the most viable alternate fuel source and that coal is a technically feasible but more costly long range source. However, if these fuels were to meet current specifications, major boiling range conversion and aromatics hydrogenation would be required which would increase costs and energy consumption in the refining process.

The current fuel specifications include limits on the boiling range and aromatics content. The initial boiling point determines the flash point while the final boiling point determines the freeze point. The aromatics content determines smoke formation, compatibility with elastomeric materials, and affects engine combustion temperatures and durability. It has been estimated that decreasing the intial boiling point could increase kerojet production by 10% for every 5° F. (3° C.) reduction in flash point. As mentioned earlier, it is planned to study the effect of reduced flash point on inflight and post-crash fire safety. It should also be noted that reducing the flash point would tend to reduce the potential benefits of anti-misting fuel additives which are being evaluated for improving post-crash fire safety. Raising the final boiling point could increase kerojet production by 5-10% for every 5° F. (3° C) reduction in freeze point. The 20% limit on aromatics content is not seen to be a limiting factor on kerojet production from petroleum crude oils.(6)

The degree to which the petroleum derived fuel specification can be broadened for future aircraft will play an important role in consideration of synthetic fuels. As a result of a workshop held in June 1977, at the NASA Lewis Research Center, Cleveland, Ohio, a broad-specification referee fuel was recommended for use in R&D programs involving new combustion systems, engines, and aircraft and for testing in existing aircraft. Such a fuel will enable information to be obtained on the problems that could result from the use of synthetic fuels that could be efficiently produced and the design trade-offs required to resolve the problems. This referee fuel specification maintains a minimum flash point of 100° F. (38° C.) and raises the freeze point to -20° F. (-29° C.). It increases the maximum aromatics content limit to 35% which should be adequate to cover the expected aromatics increases from synthetic fuels derived from shale oil. A lower hydrogen content mean value of 12.8% was chosen to correspond to the 35% aromatics limit.(7)

It is anticipated that use of the synthetic fuels will result in engine combustor problems because of increased flame radiation, reduced ignition and altitude relight capability, and higher levels of carbon monoxide, hydrocarbons, oxides of nitrogen, and smoke emissions. Revised emission standards will probably be needed to accomodate synfuels. Synfuels will also tend to increase the problem of deposits related to fuel thermal stability. Aircraft fuel system problems may be expected with respect to water solubility characteristics and pumpability of high-freeze point synfuels. It is hoped that sufficient quantities of the broad-specification referee fuel can be produced to assist in testing new engines and aircraft which might be introduced into service in the 1990's. In addition to engines and aircraft specifically designed to use synfuels, the retrofitting of current-model aircraft in 1990 to use synfuels must also be considered.

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U.S. JET FUEL AND AVIATION GASOLINE CONSUMPTION AND FORECAST

(IN MILLIONS OF GALLONS)

	1976		1988	
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TOTAL CIVIL AND MILITARY	14,451	752	22,170	968

RECOMMENDED BROAD-SPECIFICATION REFEREE FUEL

* MAINTAINS CURRENT MINIMUM FLASH POINT OF 100° F
* RAISES FREEZE POINT TO -20° F
* INCREASE MAXIMUM AROMATICS TO 35%

KEROJET SPECIFICATIONS

* INITIAL BOILING POINT (IBP) DETERMINES FLASH POINT (CURRENT MINIMUM 100° F)

  -- DECREASING IBP COULD INCREASE KEROJET PRODUCTION BY 10% FOR EVERY 5° F REDUCTION IN FLASH POINT

* FINAL BOILING POINT (FBP) DETERMINES FREEZE POINT (JET A, -40° F; JET A-1, -58° F; JET B, -72° F)

  -- RAISING FBP COULD INCREASE KEROJET PRODUCTION BY 5-10% FOR EVERY 5° F REDUCTION IN FREEZE POINT

* AROMATICS (CURRENT MAXIMUM 20%)

  -- NOT A LIMITING FACTOR ON KEROJET PRODUCTION