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THE MILITARY DEMAND FOR OIL — JET FUEL

SPECIAL SURVEY ON ROTTERDAM

UK North Sea tax concessions

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NOTES OF THE MONTH

Strategic significance of jet fuel – Part I

by Tom Cutler

Dating back to Whittle's successful experiment in April 1937, this year marks the 50th anniversary of jet fuel. In strategic terms, jet fuel has risen to prominence as the petroleum product that the military uses most. The announcement last year that all NATO countries will switch from the JP-4 naphtha blend to the kerosene-based JP-8 grade for land-based military aircraft in Europe, and the even more far-reaching proposal to phase out gasoline and diesel and use JP-8 instead for all of NATO's ground vehicles in Europe as well, will have important consequences for American and European refiners.

Mr Tom Cutler, of the US Department of Energy, is currently chairman of NATO's Petroleum Planning Committee. The views expressed in this article do not represent the official positions or policies of the US Department of Energy, the US Government, or the North Atlantic Treaty Organisation (NATO). The second part of this article, dealing in more detail with NATO's jet fuel conversion plans, will be published in the next issue of *Petroleum Economist*.

A PARADOXICAL feature of the jet fuel market is that although military aircraft comprise only a small fraction of peacetime demand, estimated to be less than 10%, military consumers around the world on average require jet fuel in one form or another for over two-thirds of their petroleum needs. Having surpassed sales of aviation gasoline in the mid-1960s, jet fuel today constitutes virtually 99% of aviation's aggregate demand for petroleum. At the same time, however, jet fuel accounts for less than 5% of total world oil consumption, with its share of regional markets ranging from a low of about 2% in Europe and certain Third World areas to a high of around 7% in North America. Throughout these regions the demand for jet fuel is essentially segregated into separate sub-markets for military and civilian aircraft.

Civilian aircraft, both commercial and private, purchase fuel at public airports normally serviced by major oil companies. The majors account for about three-fourths of total jet fuel sales, in part because they can afford the substantial capital investments necessary for storage and distribution facilities. Despite jet fuel's small share of overall oil demand, it is a market worth protecting from intruding smaller independents and traders since it offers considerable profit potential. In practice, however, airlines wield considerable market influence themselves as major purchasers of jet fuel and are able to negotiate substantial price discounts in their supply contracts as compared with smaller buyers.

Security of supply invariably matters more than price to the military sector, particularly in wartime. Its aircraft tend to obtain supplies at restricted military bases or atop aircraft carriers at sea (or even refuel in mid-air) to which civil aircraft do not fly. In some countries, jet fuel distribution networks serving military bases are operated independently from civilian pipeline systems; separate facilities are also the norm even when airfields are shared by civil and military aviation. This is partly due to the military's unique need for specialty fuels whose technical specifications often do not correspond to conventional standards.

Special mission military aircraft customarily fly faster and higher than their civilian counterparts and operate under more extreme conditions which can necessitate fuels derived from unusually complex or intensive refining processes. But the greater availability of commercial-type jet fuels has motivated some military authorities to consider modifying their fuel specifications to conform with civilian standards or to adjust their technical requirements when experiencing shortages so as to make access to the larger commercial supply base a technically feasible alternative. This approach to military oil supply planning is exemplified by NATO's announcement in May 1986 that its land-based aircraft in Europe will phase out their use of JP-4 (designated F-40 by NATO), the world's most widely-used militarily-unique jet fuel, and convert entirely to JP-8 (NATO grade F-34) which is essentially the same as the commercial Jet-A1 fuel (plus icing inhibitors, static dissipators, and anti-corrosion additives).

Although NATO's decision was initially motivated by safety concerns regarding the extremely volatile JP-4 as well as advantages of greater interoperability, and entailed nearly a decade of debate, adopting the more stable, commercially-oriented JP-8 grade will enhance short-term supply in times of war. NATO's conversion plan will also simplify the mammoth logistical task of moving the many different petroleum products that the military consumes.

Having agreed upon JP-8 as the standard jet fuel for its military aircraft in Europe, the NATO member countries are currently considering an even more ambitious proposal to become a "one-fuel" military force. Under this proposal, NATO would adopt JP-8 as the primary fuel used by its ground forces as well, thereby eliminating the need for gasoline and diesel fuel. NATO would thus reap enormous operational savings through simplified logistics and storage, and to the extent that military oil demands become overwhelmingly concentrated upon JP-8/Jet A1, conversion to a single-fuel force will tend to blur the distinctions between military and civilian jet fuels in NATO Europe. The US Army in Europe is already proceeding to implement this changeover for itself (and, in fact, US air and land forces are currently considering substituting JP-8 for JP-4 and ground fuels for all their overseas operations in order to achieve a worldwide single fuel capability). Given the expanded role of jet fuel should it become a standard ground fuel, NATO's conversion decisions and plans would dramatically elevate its strategic significance in Western Europe far beyond its customary usage solely for aviation purposes.

Origins of jet fuel

The jet fuel story is a classic case of military imperatives fostering technological advancements. Prior to the jet fuel era, the most essential petroleum fuel for the military was gasoline. This was the only fuel used by military flyers in World War I and predominated throughout the inter-war period despite Germany's development of diesel-powered aircraft. The turning point in the age of gasoline coincided

SUMMARY OF SUPERPOWER MILITARY JET FUELS

The abundance of different jet fuels developed by the USA and the USSR for a variety of military purposes, as listed below, is by no means representative of the diversity of fuels utilised by other armed forces, largely because the Soviets and Americans use a greater number of technically complex, limited purpose fuels. This trend toward fuels with specifications tailored solely to satisfy the requirements of specifically designated, high-performance aircraft is typified by the fact that several fuels listed below, such as US grades JP-7 and JP-TS, are of a composition unique to the superpowers. Due to the global orientation of their strategic doctrine and the potentially enormous quantities of fuel necessary for the effective extension of force far beyond their territorial boundaries, both superpowers have specified wide-cut grades for their inventory of jet fuels to maximise supply availability during periods of peak requirements. In fact, the Soviets have issued specifications for several types of wide-cut fuels as a precautionary measure and, due to substantial variations in the properties of their domestic crudes, especially sulphur content, they have taken the unusual step of establishing specifications adapted to the characteristics of crude streams indigenous to their different regions. However, due to the nation's frigid climate, Soviet jet fuels as a group are characterised by a uniform freeze-point of −60C, lower than Western standards, and the routine use of anti-icing additives. In anticipation of future shortages, both the US and USSR have also been developing synthetic jet fuels, but the occasion of their use will not result in additional fuel types since their properties are expected to conform to those of current fuels.

UNITED STATES

Type	Description
JP-1	Introduced in April 1944 as the first US jet fuel, the now obsolete JP-1 specification called for a narrow kerosene cut with a 300F to 500F boiling range. Due to this restrictive specification and the war-time demands for other fuels, its maximum production of 60 000 gallons per day was not sufficient to meet military requirements. By the end of 1944 the US began to consider wider-cut fuels of greater volatility and adequate availability.
JP-2	Introduced in 1945 as a wide-cut alternative to JP-1 to increase supply availability, JP-2 was used only as an experimental fuel and is now obsolete. Despite the production advantages due to its inclusion of gasoline components, its production was limited by viscosity restrictions. It was also plagued by hazardous levels of vapourization rates and cold start problems.
JP-3	Adopted in 1947, wide-cut JP-3 was produced by blending gasoline with kerosene. Its 45% yield from typical American crudes alleviated concerns over availability. However, excessive fuel losses were experienced at high altitudes due to its vapour pressure. Although its producibility was adequate from a national security standpoint, it was used only experimentally for the purposes of prototype development.
JP-4	JP-4 was introduced in 1951 as a lower vapour pressure version of JP-3. It is a wide-cut mixture of heavy naphtha and kerosene whose flash-point of −20F renders it explosively flammable at ambient temperatures. Minor revisions to the original specification were made in 1953 and 1955. It is also referred to as Jet-B in civilian nomenclature or as NATO grade F-40.
JP-5	A kerosene fuel of low volatility with a high flash-point (140F), JP-5 was introduced in 1952 and designated for use by carrier-based naval aircraft because a less hazardous fuel than JP-4 was needed for onboard storage and handling. Used also for presidential aircraft and in the Arctic, its narrow boiling range restricts its producibility to a fraction of JP-4 availabilities, thereby precluding refiners from producing enough for it to be adopted as the uniform fuel for all military aircraft. (NATO grade F-44)
JP-6	Obsolete, experimental kerosene fuel of high thermal stability.
JP-7	Kerosene type fuel of low volatility with exceptional properties of thermal stability for use by the SR-71 "Blackbird" high-performance reconnaissance aircraft.
JP-8	Virtually identical to commercial grade Jet A1, JP-8's flash-point of 105F was one of the reasons why the US in 1968 selected it to replace JP-4. One disadvantage of JP-8 is its freeze-point of −58F (compared to −72F for JP-4) which also renders it unacceptable for drones. (NATO grade F-34)
JP-9	A high density fuel produced from a blend of synthesised chemicals for use as a starter slug for air-launched cruise missiles and ramjets.
JP-10	A high-density hydrocarbon fuel composed of chemical blends for use by ramjets and as the main fuel for air-launched cruise missiles.
JP-TS (thermally stable)	A blend of highly refined kerosene of high thermal stability designated for use by the U-2 reconnaissance aircraft.

with the invention of the jet engine. Although it was some time before the jet earned its place as an aviation propulsion system, its acceptance spelled the demise of piston-engine propeller planes and paralleled the gradual ascendancy of kerosene-based aviation fuels.

The British engineer Frank Whittle is generally regarded as the pioneer in the field of jet aviation and is credited with first conceiving the use of gas turbines to propel aircraft in 1929. Although the theoretical premises of the gas turbine engine—precursor to the modern day jet—had been previously proposed and patented in the US and France, it was Whittle who recognised its potential for propelling planes faster and higher. Jet engines of that genre operated at an efficiency rate of no more than 60% of a comparable piston engine, but weighed only a quarter of the latter. This made it ideally suited for supplying thrust for airplanes whose weight/power ratio is a critical determinant of maximum speed. Designed to compress incoming air through a series of fans and then a combustion chamber into which fuel is sprayed and ignited, the turbine engine produced power continously by expanding and expelling the hot gases through a second series of turbine blades.

Whittle obtained a patent for his turbo-jet engine in 1932 but there was little interest in his work by engine manufacturers or the British Air Ministry because the heat thus generated could not be withstood by the metals then available. In 1936, while he was assigned to the Air Ministry, Whittle was able to persuade a group of investment bankers to finance the establishment of Power Jets Ltd and he was put on special detail to work on the project—with the stipulation, ignored by him, that he would devote no more than six hours per week on it. Whittle's first laboratory experiments used diesel oil and then gas oil but in 1937 he switched to simple illuminating kerosene due to vapourization and fuel injection problems with the other fuels.

On 12 April 1937 Whittle achieved the first successful test run of a turbo-jet engine designed for aviation, but it took almost a year—to March 1938—before the Air Ministry offered him a development contract. From that point on all of his work was conducted under the aegis of the Official Secrets

SOVIET UNION

Type	Description
T-1	A straight-run, kerosene-type fuel whose specifications issued in 1948 stipulated a maximum sulphur content of 0.1% on the expectation that it would be processed primarily from Baku crudes known for their low sulphur content. Also characterised by a relatively high minimum specific gravity and a relatively wide boiling range in order to enhance its supply availability.
TS-1	Interchangeable with T-1, this is a straight-run kerosene blend whose specifications allow a higher sulphur content (0.25%) because it was initially refined from high sulphur crudes of the Ural-Volga region (and subsequently from low-sulphur Siberian crude streams). Boiling ranges were set in order to maximise output but this fuel possesses limited qualities of thermal stability.
T-2	A high volatility, wide-cut grade that can be distilled from high sulphur crudes. Introduced in 1957 to augment production during periods of heavy jet fuel use.
T-3	Used in reconditioned gas turbine engines primarily in East Germany. No specs ever publicly released.
T-4	First introduced in 1957 as an interim fuel, has high sulphur content and wide distillation range, suggesting that it is processed by cracking and not straight distillation. Poor thermal stability; becomes gummy over long storage periods. Use is intended for large volume production in case of emergency.
T-5	An advanced hydrocarbon fuel for ramjets. Specifications issued in 1959 specifying high minimum specific gravity, high allowable viscosity, and high boiling range. It has poor thermal stability.
T-6	Hydrogenated fuel introduced in 1966 for supersonic applications, specifically in excess of Mach 4. Sometimes blended with T-5, it is a high density fuel with a high flash-point.
T-7	Second grade of hydrotreated fuel which was introduced in 1966 for Mach I-plus use for commercial jets (TS-1g designation) but undoubtedly a military fuel. Processed from low sulphur crudes, it is a thermally stable, kerosene type fuel.
T-8	Introduced in 1968 for Tu-144 SST with good thermal stability and low vapourization properties to meet IATA requirements. Also used by supersonic military aircraft.
RT	Introduced in the early 1970s for subsonic aircraft as a wide-cut, general service fuel with lubricity additives. Could potentially be used in emergencies when increased jet fuel production is desired as its thermal stability properties are similar to T-7.

NOTE: **The Peoples Republic of China** has established its own set of fuel specifications after having initially been reliant upon the Soviets during the 1950s for crude oil supplies, fuel specification guidelines, advanced processing techniques as well as technologies crucial to manufacturing military aircraft. There are four grades of Chinese jet fuels differentiated from each other by their distillation ranges which, in turn, depend upon the crudes and refining process used to produce them. Although China intends for its fuels to meet IATA standards for commercial aviation, little is publicly known about them: (1) RP-1 is a medium-cut fuel with a 28C flash-point and −60C freeze-point, (2) RP-2 is a medium-cut fuel with a 28C flash-point and −50C freeze-point, (3) RP-3 is a narrow-cut fuel with a 38C flash-point and −50C freeze-point, and (4) RP-4 is a volatile wide-cut fuel comparable to JP-4 with a −40C freeze-point. Because its jet fuels do not require many sophisticated additives, it has been China's policy to import additives as necessary rather than produce its own.

Act and in 1939 the Ministry was funding the project in its entirety in order to move from bench testing to a flyable prototype. In Germany, meanwhile, a young engineer named Hans von Ohain had also been working on jet engines with financial support and encouragement from the Heinkel firm. Ohain used gaseous hydrogen instead of liquid petroleum fuel during his early experiments of 1936–37 to demonstrate the validity of the jet propulsion concept, but later switched to gasoline for prototypes designed for the Luftwaffe. On 27 August 1939, just five days before Germany's invasion of Poland, Luftwaffe Flugkapitan Erich Warsitz flew the first turbo-jet aircraft, a Heinkel He 178 powered by a HeS-3b engine designed by Ohain.

This momentous accomplishment proved that jet propelled flight was possible. But the He-178 was beset by aerodynamic problems and the practicality of the turbo-jet was still controversial among Germany's leading aviation engineers due to its slow acceleration, tendency to flame out at altitude, and high fuel consumption. The situation was further complicated by the fact that Ernst Heinkel was not popular at the Luftministerium and later that year it bypassed him and approached the Junkers Aircraft Company instead to continue the government-sponsored effort. There, Anselm Franz embarked upon a radically new design for jet engines that resulted in the Jumo 004 which burned diesel fuel. Flight testing of the first jet fighter commenced on 2 April 1941 with the Heinkel He 280 V-1. It was superseded by the Messerschmitt Me 262A-2a Sturmvogel ("Stormbird") whose missions over France in July 1944 distinguished it as the first jet fighter ever to fly in combat.

Meanwhile, in England, breakthroughs had been slow in coming in mastering the mysteries of reliable continuous combustion until technicians from Shell's Fulham laboratory became involved. Their collaboration helped resolve the problems plaguing Whittle's engine and by January 1940 senior Air Ministry officials reported enthusiastically that the prospect of jet-powered military aircraft was a "potential war winner". Production planning began for a twin-engined jet fighter, premised on the expectation that its high speed and manoeuvrability would be able to counter the high altitude bombers Germany was expected to employ in its bid to invade Britain. At this point the British opted to rely upon a jet fuel composed essentially of kerosene as opposed to high octane aviation gasoline. From a technical point of view gasoline had always been regarded as a satisfactory fuel for jet engines, but the British were strongly influenced by the need to conserve scarce supplies of gasoline. Moreover, the flight envelope of the jet was expected to exceed that of piston engine aircraft and to require qualities for which gasoline was seen to be inadequate. Thus kerosene was selected.

This article will be concluded in our next issue.

(Continued from page 160)

document puts Standard's present net debt at $3.2bn and its total value at $8.4bn, assuming $15 per barrel oil (Brent price). On a $20/b basis it would be worth $13.2bn. Currently BP reckons $18/b to be the appropriate planning assumption, suggesting a value for Standard of $11.3bn. Standard itself provided details of its own five-year development plan, prepared in October 1986 on the assumption of $15/b oil. This foresees cash generation of around $2.5-2.6bn annually, and liquid resources rising from $1.55bn in 1987 to $3.044bn in 1991. It noted that the company would generate excess cash totalling $2.2bn over the five-year period while retiring debt of $1.4bn.

On the borrowing position, it may be noted that BP — acting through Morgan Guaranty Trust of New York — has had no difficulty in lining up a $5bn credit facility of four years' duration; and in December 1986 Standard itself reached agreements with 45 banks on committed borrowing facilities for $2bn. BP expects to repay loans employed in the take-over from the joint cash flow of the combined companies, but without specifying how long this might take. It has no current intention of selling Standard Oil assets not already earmarked for divestiture, but it will consider the feasibility of selling limited partnerships in a portion of Standard's Alaskan interests — Prudhoe Bay and/or TAPS.

Full consolidation of the group's US interests would be the logical outcome of a process which began with the 1969 agreement with what was then Standard Oil (Ohio). Basically, this provided for a transfer to Standard by BP of its Prudhoe Bay acreage, partial interests in other Alaskan leases, and its East Coast downstream assets recently acquired from Arco. In return, BP took a 25% shareholding in Standard (effective 1st January 1970) that was geared to rise to about 54% when output passed 600 000 b/d, which occurred in 1978 a year after Prudhoe Bay startup. (Its stake subsequently went over 55% when it refrained from tendering shares in response to a buy-back offer by Standard). The advantages of the agreement to both sides were considerable. BP was relieved of the development costs at Prudhoe Bay and indirectly became part-owner of Standard's considerable downstream assets in Ohio, Indiana and West Virginia which provided the marketing outlets for the ensuing production. Standard was transformed from a crude-deficient refiner/marketer into an integrated concern with a profitable surplus of crude which rapidly boosted its revenues during the late 1970s, as the rate of return soared from 3.6% in 1976 to 24.3% in 1980. Unfortunately, the company chose to use most of its rising cash flows from crude, which had boosted cash reserves to $3.8bn by end-1980, for investment in new projects rather than higher dividends to shareholders — including BP — who received well below the industry average from 1978 onwards. The reinvestment policy, formulated in 1980, featured diversification into coal, metals mining and industrial products, the high spot being the $1.77bn acquisition in June 1981 of Kennecott Corporation, a major producer of copper and other minerals. That was abruptly followed by a sharp fall in the price of copper, and Standard's metals mining operations showed losses in every year from 1981 to 1985; results in the industrial products sector were also poor, though less dramatically so.

There were problems, too, in upstream oil activities, where the exploration programme consistently disappointed by falling short of reserve-replacement targets. In only one year (1984) between 1978 and 1985 was more added to the company's proved liquid reserves than it used up in production. This unhappy situation reached its nadir near the end of 1983 with the costly failure of the Mukluk drilling operation in the Beaufort Sea. More recently, upstream results have been under pressure from the downward trend in crude oil prices and related write-downs of assets. After soaring as high as $24 per barrel by 1981, the wellhead price of Alaskan crude slid to $17 by 1985. Last year Standard's average sales price for crude oil and natural gas liquids was below $14 against over $26 in 1985, and contract prices received for its Alaskan oil were down to $13 on the Gulf Coast and $12 on the West Coast. Thus, almost the only bright feature in recent years has been downstream, where the acquisition of former Gulf Oil assets from Chevron in 1985 conveniently extended Standard's theatre of operations into the south-east.

As the majority shareholder, BP had become increasingly unhappy with Standard's performance and the limited control it was able to exercise. This finally surfaced in the management shake-up of April 1986 already referred to, when a BP managing director took over as Standard's chairman. Not until March this year, however, was the present take-over offer formulated as the final solution of a recurring problem. The formal announcement followed on the 1st April, and the offer (approved by BP shareholders on the 22nd) remained open until the 28th. On the 6th the company said that it would not raise its $70 per share bid, and rejected as unrealistic the valuation of $85 per share which had been made by Standard's financial adviser, First Boston Corporation. But it subsequently improved the terms (to the equivalent of $73.50 per share) to meet objections by Standard's independent directors. —*D.O.C.*