

## **Panel Discussion: The Impact of U. S. Environmental Regulations on Jet Aircraft Engines**

---

The third major transportation fuel after gasoline and diesel fuel is jet fuel. A panel representing manufacturers and users of aircraft gas turbine engines and their fuels was requested to consider the significance of fuel quality on jet engine performance. T. F. Lyon of General Electric, R. P. Lohmann of Pratt & Whitney Aircraft (United Technologies), B. F. Rayner of Rolls Royce and S. E. Casper of United Airlines examined quality aspects related to engine emissions, durability, operability and certification. While none of the Clean Air Act changes, mandated or implied, affect jet fuels directly, there is concern about possible secondary effects as the result of refinery changes made to manufacture reformulated gasoline and low sulfur diesel fuel.

Current Federal Aviation Administration regulations for aircraft engines (Federal Air Regulation, Part 34) limit unburned hydrocarbons and smoke during operations below 910 m (3000 feet). The International Civil Aviation Organization (a United Nations unit) additionally controls carbon monoxide and nitrogen oxides. Fuel properties affecting carbon monoxide and unburned hydrocarbons at ground idle (the engine condition which produces these products) are viscosity, density and surface tension. Nitrogen oxides emissions are directly related to engine power levels and are produced at take-off, climb and cruise conditions. Fuel hydrogen content or a correlating parameter such as smoke point tends to be the most important fuel property affecting these emissions because decreasing hydrogen content increases the adiabatic flame temperature in the combustor. Hydrogen content or smoke point is also the most important parameter for the control of smoke (carbon particles) because fuels with lower hydrogen content or smoke points tend to produce more smoke. Carbon particles formed during combustion can also cause turbine erosion if not burned completely within the combustor.

The durability of fuel system components is related to fuel composition. Elastomers appear sensitive to the aromatic types and level in the fuel. High fuel pump wear is related to the absence of polar components in the fuel. Combustor liner life is controlled by flame radiation, with aromatics radiating more energy than the more saturated hydrocarbons. However, the major concern is over fuel thermal instability which promotes deposition of insoluble materials in high temperature portions of the engine fuel system. When these deposits occur in fuel nozzles and distort spray patterns, non-uniform temperature patterns ("hot streaks") can develop in the combustors and severely damage turbines.

Engines must be designed to operate over extreme conditions which include a temperature range of -54 to +50°C and the introduction of solid particles and water. Other variables critical to engine design include

heat transfer, combustion and pump cavitation. Fuel system design is also controlled by the fuel specifications which invariably represent the product most suitable and available at the time the specification is written. Even so, it is possible to experience unacceptable operation on specification fuels. One cited example involved a narrow-cut JP-4 which evaporated in the engine fuel manifold and thus caused combustion problems in a system designed for conventional JP-4. However, a chromatographic analysis of the fuel revealed components with higher vapor pressures than predicted by tests or correlations. A more subtle but more prevalent challenge to the designer are long term fuel changes requiring specification modifications but with very little or only limited operating experience on such fuels.

The airline community, which depends on jet fuel as its life blood, must comply with all aspects of Federal Air Regulations. Airlines do not have the authority to arbitrarily deviate from aircraft certification requirements by relaxing fuel quality standards or to commit to alternative fuel specifications without engine and/or airframe manufacturers' consent and approval. Airlines have not yet been informed by fuel suppliers or engine builders how the Clean Air Act changes will affect jet fuel quality. Airlines are conscious that compositional changes in jet fuel may be forced by reformulated gasoline and low sulfur diesel fuel. They are also aware that new engines are stressing certain fuel characteristics such as thermal stability and any compositional changes should not lead to the deterioration of critical properties such as thermal stability. Whatever the future compliance requirements are, the airlines have to be prepared to accept and respond to new operating conditions but at the same time remain responsive to the travelling public by ensuring a dependable flow of quality fuel. It is hoped that any future changes imposed on the airlines will have a minimum economic impact on operations and will have a reasonable transition period for compliance. The airlines do expect petroleum refiners to coordinate any proposed jet fuel specification changes with ASTM, the engine manufacturers and the airlines.

The ensuing discussion revealed disappointment that no answers were forthcoming on the future quality of jet fuel, particularly in view of the long lead time required for specification changes. In reply it was pointed out that the API presentation had shown that heavy naphtha excluded from jet fuel would need a home in jet fuel. It was also indicated that the decline in hydrogen availability suggests that more chemical treating for mercaptan removal will take place. Experimental results have shown chemically treated fuels to have lower thermal stability than hydrogen treated fuels. In turn, this raises concern over thermal stability at the point of aircraft loading because presently the test is only performed during product certification at the refinery and subsequent degradation, if any, is not detected. Overall, it appears that current specifications will require constant monitoring to assure their adequacy, particularly when reformulated gasoline and low sulfur diesel fuel go into production.

Concern was also expressed over the environmental effects of the High Speed Commercial Transport currently under a NASA research program. Here the critical atmospheric components are nitrogen oxides which can

damage the protective ozone layer in the atmosphere. Extensive atmospheric modelling studies are being conducted and targets for engine exhaust components are still tentative. It is too early in the program to define any ASTM role.