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JET FUEL THERMAL STABILITY & ACTIVE METALS

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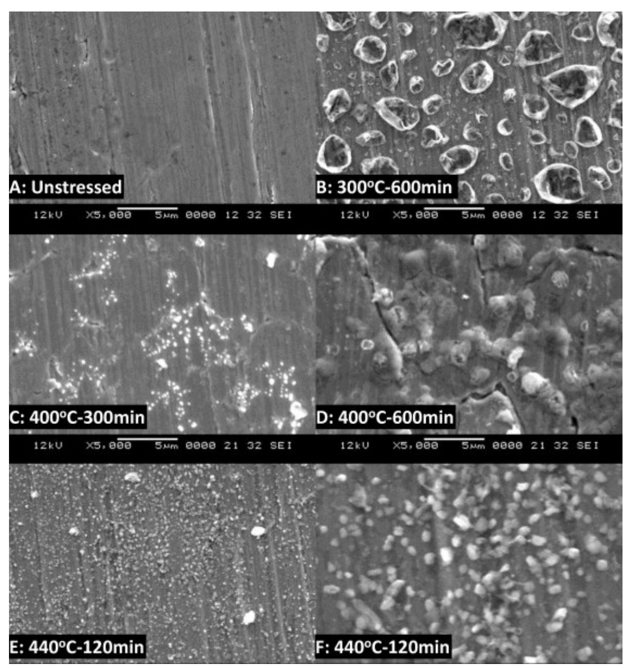
Background

Jet fuel is used as the primary heat sink in all modern aircraft. As jet fuel is subjected to high heat loads, it undergoes thermal stress and will degrade. This degradation will lead to the formation of solid deposits in the aircraft fuel system and specifically in fuel nozzles. Thermally generated deposits are detrimental to efficient operation of aircraft engines and rapid accumulation of solid deposits on various components of the fuel system, including valves, flow tubes, and nozzles could cause a catastrophic failure of the aircraft engine due to distorted fuel spray patterns . The most common places for jet fuel composition to change causing this thermal instability is during the manufacturing process and contamination during transport from the refinery to the end of the transport line which is the nozzle fueling the aircraft.

Jet fuel pipelines and bulk storage tanks require special operating and maintenance considerations to prevent contamination. These fuels are subject to stringent quality requirements necessitating special equipment and engineering. Along the distribution chain, from the refinery to the airport, jet fuels are stored in bulk oil storage terminals and transported via pipelines, marine vessels and road tankers. Once at the airport or refueling site these strict rules should not be disregarded and an organization must follow the same strict requirements to be ensured that the fuel quality has not deteriorated to unacceptable levels along the distribution chain to the aircraft.

Dedicated carbon steel pipes are used to transport jet fuels to airports. In addition to their external coating and cathodic protection systems, the fuel pipelines have an internal coating applied to mitigate corrosion and fuel contamination. Cadmium, copper, galvanized steel, zinc or other active metals and their alloys which are effective catalysts for oxidation reactions have an impact on the fuel's thermal stability and therefore should not be used in storage, handling and distribution systems for jet fuel.



Hydrocarbon Deposit Formations

Thermal stability of jet fuel and engines

Most advanced aircraft use fuel as the primary heat sink for both airframe and oil cooling. As a direct consequence of this function the bulk fuel temperature is increased. Jet fuel temperature is also increased as the fuel is exposed to hot engine components just prior to combustion, these hot components include the fuel nozzle support assemblies and the fuel nozzles. Jet fuel, when it is subjected to thermal stress, will undergo degradation either primarily by autoxidation if the fuel temperature is below 300°C, or by pyrolytic degradation, if the fuel temperature exceeds 400°C. This fuel degradation will form solid deposits that may develop as either filterable insolubles or as solid varnish-like deposits on fuel system surfaces. These insoluble compounds will be carried through the fuel system to collect in fuel filters and may agglomerate to form solid deposits. The varnish-like materials will form on fuel wetted hot metal surfaces, such as heat exchangers or in fuel nozzle orifices. The deposition, also known as surface fouling, reduces heat exchanger efficiency and may cause altered fuel spray patterns from fuel nozzles. This can lead to combustor buckling and over temperature in the first stage turbine blades due to poor combustor pattern factor.

Research by engine manufacturers into thermal stability has led to standard engine component design constraints such as limiting the bulk fuel temperature at the airframe / engine interface to between 80-120°C and limiting the bulk fuel temperature at the inlet to the fuel nozzles to 163°C, and the maximum wetted wall temperature in the fuel nozzles to 205°C. These limitations are set to ensure minimal fuel thermal degradation and thus minimal deposit formation in the fuel system and system components. These arbitrary limits, however, do not take into consideration the intrinsic variations in the thermal stability of current jet fuels.

Fuel chemical composition plays a significant role in the deposit-forming tendencies of aviation fuel, thus the refinery finishing process that the jet fuel is manufactured by has a significant influence on the thermal stability of the fuel. The main fuel finishing processes used by refineries are hydrotreating, MEROX and caustic washing. Some refiners may elect to simply 'straight run' their jet fuel if they believe it to be of sufficient quality to meet all specification requirements. The differing fuel finishing processes give differing fuel chemistries over which any fuel additive must operate effectively. Each batch of aviation fuel has a unique composition, thus the chemical reactions contributing to the deposit formation and degradation of one fuel will be different from those of all other fuels. Minor fuel constituents containing heteroatoms such as sulphur, nitrogen and metals have been identified as major contributors to deposit formation.

Fuel handling design

Safety engineering should be at the top of any operators mind when developing fuel handling equipment.

Main Concerns:

A. Prevent Contamination from: Water, Microbial organisms, Particulate, hydrocarbon oxidation.
B. Shut-off valves should be installed to prevent large or uncontrollable spills.
C. Filtration at all points prior to coming out of the nozzle into the aircraft.
D. Restricting flow to control static electricity, 1.5 m/s to 4 m/s max.

It is generally true that the "advanced" fuels are less subject to deterioration in normal storage than are the "improved" fuels. However, this situation may be influenced by the greater precautions taken in handling the advanced fuels. Fuel contamination is minimized by rigorous precautions, and the storage and handling systems may be designed to exclude materials known to have adverse effects on fuel stability.

High-quality hydrocarbon fuels for aerospace applications are often affected adversely by deterioration during normal storage and transfer. Such deterioration most frequently shows up as a drop in thermal stability. A great deal of work has been done on this problem, and various measures have been developed for preventing or correcting the deterioration. These measures include the use of special refining techniques, the use of additives, proper selection of storage system and storage conditions, and reclamation of degraded fuels by adsorptive treatment.

A crucial parameter of maintaining jet fuel quality is the design of the fueling system. The system must be arranged to minimize the potential for fuel contamination. Current practice is to internally line or coat all system piping, storage tanks and major equipment. The exception to this is welded pipe joints and smaller pipe fittings, which are left uncoated. High solids epoxy paint, suitable for hydrocarbon immersion service, is the coating of choice. Its slicker surface minimizes corrosion and sediment buildup on the vast majority of fuel exposed surfaces. The use of copper, brass, cadmium or zinc (galvanizing) in fuel-exposed equipment and piping is undesirable, because these metals can affect the thermal properties of the fuel or damage engine parts.

The main reason for jet fuel failing (JFTOT) Jet Fuel Thermal Oxidation Test at a refinery is metal contamination (i.e., the soluble metals Fe, Pb, Zn, Cd, etc.) that can catalyze gum formation at elevated temperatures producing a stain during the JFTOT. In real world applications, this would equate to possible blockage of fuel lines in jet engines. A remedy is to introduce metal deactivators which are designed to chelate or neutralize the presence of any soluble metals. Once the fuel had been neutralized, the fuel will pass the JFTOT.

The use of any unapproved Jet Fuel / Kerosene based fuel equipment is not recommended and operators shall ensure that all contamination is reduced to the max possible levels to have the cleanest fuel possible in the aircraft to prevent additional wear and tear on engines and to prevent accidents.

References

-ASTM D1655-12
-NFPA 407

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Rules, regulations & reference material

1. **ASTM-D1655-12: Standard Specification for Aviation Turbine Fuels**
2. **NFPA 407: Standard for Aircraft Fuel Servicing**
3. **FAA Part 139.321: Handling and Storing of Hazardous Substances and materials.**
4. **ExonMobile Aviation World Jet Fuel Specifications**
5. **Jet Fuel Pipelines and Storage Require Special Operation, Maintenance Considerations.**
6. **Gas Turbine Tutorial– Effects on Degradation and Life.**
7. **Jet Fuel Quality: Flying Clean and Dry**
8. **Solid Deposits Produced By The Thermal Stressing of Jet Fuel**
9. **Surface Effects of Copper on Deposit Formation From Jet Fuel**
10. **Gammon Tech "Tricks of the Trade" Article**