Aviation Fuel Conductivity: To be or not to be?

Dr. Cyrus P. Henry Jr.

In recent years, the UK Aviation Fuel Committee (AFC) has discussed the need for a mandatory conductivity requirement for aviation fuel, specifically Jet A-1 fuel, as prescribed in "Defence Standard 91-91, Turbine Fuel, Aviation Kerosene Type, Jet A-1". The question arose because ASTM allows, but does not require, that aviation fuels meeting the ASTM D1655 "Specification for Aviation Turbine Fuels" have a conductivity of 50pS/m or more at aircraft fueling.

As a result, the Energy Institute (EI) sponsored an effort to investigate the differences between fuel use and handling in the U.S. compared to international fueling systems. The goals of the study are to:

1) Investigate the soundness of the science behind the aviation conductivity requirement, and

2) Recommend further studies needed to help the AFC better understand the risks associated with handling low-conductivity fuels.

BACKGROUND

Fuels with low conductivity, especially those in the <1 to 3 pS/m range,[1] retain an electrostatic charge generated during fuel transfer. An electrostatic potential can build up on the surface of the fuel, which can lead to a spark discharge with enough energy to ignite a flammable air/vapor or air/mist mixture.

Static Dissipator Additives (also known as Antistatic Additives or Conductivity Improver Additives) have been developed to efficiently improve the conductivity of fuels. The additives, when properly applied, reduce charge accumulation in a vessel being filled and have been very successful in minimizing the risk of electrostatic ignition.

HISTORY OF ADDITIVE USE IN GROUND FUELS

In the 1960s, Shell introduced the ASA-3 additive for use in ground and aviation fuels. Its use in ground fuels was stimulated by multiple instances of fires that occurred during the loading of tank trucks with low-conductivity diesel or home heating oil, usually following a prior delivery of a gasoline cargo,[2] commonly referred to as "switch loading".

Static Dissipator Additives have long been required in Canadian middle distillate fuels. In the late 1960s, one refinery suffered a series of four accidents leading to three deaths, spurring the requirement, first as an industry agreement, and subsequently by a specification requirement.[3]

In the 1970s, other additives were developed for use in ground fuels. DuPont Petroleum Fuel Additives developed Stadis® 450 in 1974, which was subsequently accepted for use in aviation fuels in 1983. In the early 1990s, production of ASA-3 was discontinued due to concerns about its chromium content.

In Europe and the U.S., there were surges in the number of electrostatic incidents during the conversions to low-sulfur and ultra-low sulfur diesel fuels.[4,5] The increased propensity of fires appeared to be directly linked to reduced fuel conductivity.

Surveys of early production samples of No.2 ultra-low sulfur diesel fuel frequently exhibited conductivities of <1 pS/m., not seen with low-sulfur diesel fuel.[6] Walmsley[7] estimated a 30-fold increase in electrostatic ignition risk with ultra-low sulfur diesel fuels.

European experience and the U.S. conversion to ultra-low sulfur diesel resulted in an industry Safe Handling Requirement that was added to the ASTM D975 Specification for Diesel Fuel Oils. This Safe Handling Requirement stated a minimum conductivity of 25 pS/m at time, and temperature of fuel handling and use.[8] Areas of Europe and elsewhere use Static Dissipator Additives in ground fuels by agreement among suppliers, but it is not part of EN590, the European diesel fuel specification.

ADDITIVE USE IN AVIATION FUELS

The United States Air Force, after extensive evaluation, adopted the use of Static Dissipator Additives in the early 1980's, primarily to

resolve recurring fires during fueling of A-10 aircraft. A-10 aircraft fuel tanks were filled with reticulated plastic foam, which primarily functioned as a flame barrier. However, the foam media had the detrimental impact of highly charging the fuel.

Another factor in the adoption of Static Dissipator Additives in aviation turbine fuels was the global use of wide cut fuels, also known as Jet B. Jet B, and its military counterparts, had a much greater flammability envelope than kerosene fuels over the range of aircraft fueling conditions.

During the period from 1953 to 1971 there were 35 aviation accidents attributed to static ignition; all but three involved wide cut jet fuel or aviation gasoline.[9] The first exception was a 1966 low order explosion that occurred in a Britannia aircraft being fueled with kerosene-type fuel. The cause of the ignition was attributed to misting or foaming, but further details were not available. Two low-order explosions occurred in May and December of 1970, while fueling Boeing 727s with Jet A at the Minneapolis-St. Paul airport.

Two key findings quickly emerged: [9]

- The paper separator elements installed in the filter-coalescer vessels immediately upstream of the aircraft being fueled were particularly high charging.
- The inlet nozzle in the Boeing 727 No.2 tank had been replaced, which caused fuel to spray above the liquid level, promoting fuel misting.

The paper separator elements, generally identified as "Type 10 elements", were extensively tested in laboratory and field scenarios, and were uniquely high charging under a number of conditions.

The paper separator elements were replaced by Teflon® coated screen separators that demonstrated a low electrostatic charging tendency.[9] The Boeing 727 fuel inlet was relocated to remain under the liquid level during fueling. Thus, it was possible to decisively react by reducing both the probability of electrostatic discharge, and the likelihood of a flammable environment.

In support of these actions, extensive testing was carried out by the CRC. Several CRC reports were issued with findings and conclusions.

Synopsis of the findings:

- Among 230 commercial jet fuels tested in airport filtration equipment, only one appeared to exhibit the criteria for a high charging fuel.
- The conductivity of 410 samples of Jet A and Jet A-1, and JP-4 and JP-5 ranged from 0.09 to 40.5 pS/m, with 80% below 10 pS/m and 30% below 1 pS/m.
- Charging tendency of 230 fuels evaluated with "Type 10 elements" separator paper using the Mini Static Test ranged from 34 to 5940 µC/m.[3]

General conclusions:

- Fuel charging by coalescers was deemed less significant than that from separators because of the relaxation volume of the filter vessel.
- Overall, there was no correlation between conductivity and charging tendency of a fuel.[10]

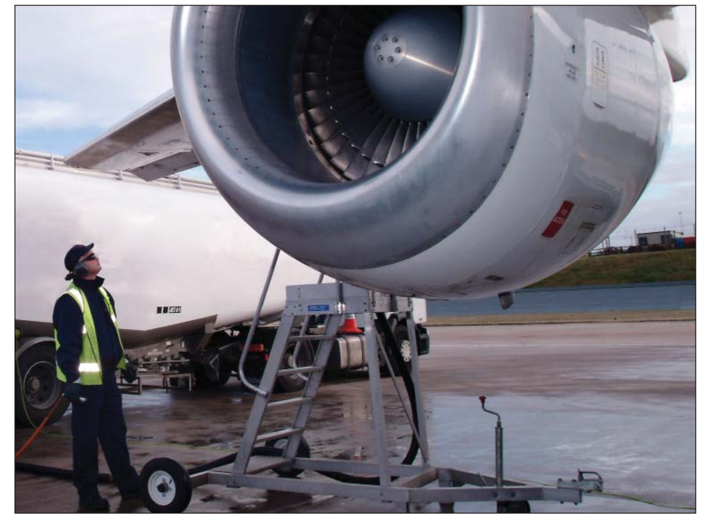
Massive efforts were undertaken to resolve and understand the Minneapolis-St. Paul incidents. The conclusion was that hardware changes were deemed sufficient and no action was taken to mandate use of Static Dissipator Additives.

THE KEY QUESTION TO CONSIDER

Do we need a mandatory conductivity requirement in Def Stan 91-91 or in ASTM D1655 for aviation fuels? Several factors should be considered when evaluating this question.

If the U.S.'s historical non-requirement of conductivity is to be utilized in making a decision globally, differences in field conditions between the U.S and the rest of the world must be clearly understood.

Potential changes in fuels and fuel handling and use practices within the industry should be investigated.



For Example:

Climatic Conditions - Fuel conductivity and the presence of a combustible environment is directly impacted by climate conditions. A worldwide study is needed to determine the temperature of aviation fuels in tanks being filled, fuels being loaded, and local ambient temperatures in locations with seasonably high temperatures relative to flash points. Local ambient temperature records are needed to estimate extremes outside the study periods.

Fueling Frequency - The presence of a flammable environment is enhanced by the increase in temperature of the respective fluid. Typically, aircraft are refueled with an ambient temperature fuel on top of the cold fuel remaining in the wing tank from the previous flight. Data is needed on variations to this common approach, specifically refueling after sitting on the tarmac for extended periods of time waiting for takeoff, or while standing idle, etc.

Fueling Rates - A fluid's charging rate can be enhanced by increased flow of the fluid through a conduit. U.S. and international aircraft fueling rates appear to be steadily edging upward. More information is needed to determine the actual difference, and impact on fuel charging. The relevance to past U.S. handling and use history should be investigated.

Flammable Environment - A comprehensive review of the frequency of flammable ullage during aircraft fueling is needed. Aircraft manufacturers should be surveyed to verify the extent of misting at current flow rates, and their estimates on frequency of flammability.

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Flash Point - The lower the flash point of a fuel, the higher the probability of an electrostatic discharge incident (EDI). The flash points of fuels available in the U.S. are generally higher than their global counterparts. The variance is due to the difference in precision between the fuel flash point referee test method for ASTM and Def Stan, and the fungibility considerations in the U.S. fuel distribution system. Both of these constraints give rise to directional increases in actual flash points of U.S. jet fuels. The impact of this bias, and the impact of EDI risk may require a more thorough investigation.

Fuel Types - Fuel composition has an impact on the flammability as well as the conductivity and charging tendency of the fuel. Wide cut fuels are unlikely to be broadly available in the future, however TS-1 fuel with a minimum 28°C flash point is in use in Eastern Europe (and may be in flights returning to rest of the world). Ultra-low sulfur jet fuel with very low conductivity and unknown charging propensity is on the horizon. The possible impacts of fuel composition on EDI risk for both the U.S. and the rest of the world needs further investigation.

Water-Absorbing Monitors - These have become the final line of defense to prevent water and dirt entering the aircraft fuel system. The monitors are generally located in-line between the filter separator vessel and the aircraft; fuel exits monitor cartridges only a few seconds upstream of aircraft entry. The CRC suggested in a 1994 report that any further reduction in relaxation downstream of monitors should be carefully evaluated for electrostatic safety.[11] While monitors are nominally low-charging, experience with charring of improperly grounded monitors by electrostatic discharges suggests substantial electrostatic charge can be generated in the fuel. Serious consideration should be given to changes in fuel conductivity for facilities that currently utilize monitors.

CONCLUSIONS

The U.S. fuel system is continually evolving. The risks associated with electrostatic ignition in the U.S. will likely evolve as well. Reliance on past experience may pose an unaccounted-for risk, especially where fuel composition along with field use and handling conditions are in flux.

There is still work to be done to fully understand the parameters impacting the risks associated with non-conductive aviation fuels.

The AFC task force should complete the required work before any changes are made to either the ASTM or Def Stan requirements pertaining to the aviation fuel conductivity requirement.

Dr. Cyrus P. Henry Jr. holds a Ph.D. in Organic Chemistry from the University of Wisconsin. He has worked in Petroleum Technology for over forty-three years mainly in the employ of DuPont Petroleum Fuel Additives, and later Octel America, Inc. Working with petroleum products and additives since 1970, Dr. Henry has focused on additives for middle distillate and aviation turbine fuels and is the inventor of Stadis® 450 and Stadis® 425. Dr. Henry has participated in electrostatic research relevant to fuels and hydrocarbons since 1973, including applicable activities in ASTM and the Aviation Fuel and Coordinating Research Council and is a co-author of various ASTM Test Methods and CRC publications involving electrostatic hazards, and fuel conductivity and stability properties. He has served as an officer of Subcommittee J on Aviation Fuels for over 30 years, is a past Vice-Chairman of Committee D-2 on Petroleum Products and Lubricants, and is a past member of the ASTM Board of Directors. Dr. Henry has authored numerous papers and presentations on aviation and middle distillate fuel additives, stability and conductivity testing, and fuel specifications. He has served on the IASH steering committee and was a participant in the CRC Aviation Fuel committee, the International Air Transport Aviation Turbine Fuel Working Group, the Canadian General Standards Board, and is a past Chairman of the International Civil Jet Fuel Specification Liaison Group.

Please address any comments or questions about *Aviation Fuel Conductivity:* To Be or Not To Be to Jack Burgazli at the following email address.
Jack.Burgazli@innospecinc.com

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