

AEROSPACE INFORMATION REPORT

AIR6443™

REV. A

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Superseding AIR6443

Impact of Copper Contamination on the Thermal Stability of Jet Fuels

RATIONALE

Copper contamination in jet fuels, more prevalent in naval applications, has a significant impact on the thermo-oxidative stability of jet fuels. Fuel oxidation and formation of carbonaceous deposits can negatively impact fuel system component, and fuel system, performance. This AIR discusses the sources and composition of copper contamination in jet fuels and the effect of copper contamination on the mechanism(s) of fuel oxidation. It summarizes the principal methods for measurement of copper contamination in jet fuels and discusses methods for removal of copper contamination from jet fuels.

AIR6443 contained: (1) formatting errors in several of the chemical equations, (2) Section 2 (References) that did not conform to the SAE style, (3) several incorrect references in 2.5, (4) missing information in Figure 2, and (5) a few typos. Revision A corrects these errors. In addition: (1) discussion about JFTOT has been moved from 4.1.1 to 4.1.2 since 4.1.1 is focused on the fuel thermo-oxidation mechanism, (2) the discussion in 4.2 on copper strip corrosion per ASTM D130 has been deleted since it does not relate to the scope of the document, (3) Section 5 has been revised to be more consistent with the reference (Colbert and Nowak, 2003), (4) 7.2.1 (Ion Exchange Resins) has been revised, including the removal of several references, since some of the content was considered not to be relevant to the scope of this document, (5) ASTM D7566 has been added to the list of references, and (6) there are editorial changes for clarity and to conform to the SAE guidelines for standards.

1. SCOPE

This SAE Aerospace Information Report (AIR) discusses the sources of copper in aviation jet fuels, the impact of copper on thermal stability of jet fuels and the resultant impact on aircraft turbine engine performance, and potential methods for measurement of copper contamination and reduction of the catalytic activity of copper contamination in jet fuels. This document is an information report and does not provide recommendations or stipulate limits for copper concentrations in jet fuels.

1.1 Purpose

While copper alloy containment vessels and plumbing are the exception in shore-based jet fuel storage and transport, they can be found in naval applications where copper alloys, such as admiralty brass, are used; attributes such as corrosion resistance and inability to cause sparks are among the reasons for their use. Dissolved copper in jet fuels is known to stimulate the thermo-oxidative degradation of the hydrocarbon species in jet fuels. Thus, the removal of copper from jet fuel is critical to maintaining fuel properties and fuel system performance in turbine engines. The purpose of this document is to summarize available information on copper contamination in jet fuels, the impact of copper on jet fuel thermal stability, methods for measurement of copper in jet fuels, and potential methods for reduction of the catalytic activity of copper contamination in jet fuels. The information in this AIR is not intended as a specification for copper concentration in jet fuels or recommendation/acknowledgement for the use of copper in aircraft/engine fuel systems.

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2. REFERENCES

2.1 Applicable Documents

The following publications form a part of this document to the extent specified herein. The latest issue of SAE publications shall apply. The applicable issue of other publications shall be the issue in effect on the date of the purchase order. In the event of conflict between the text of this document and references cited herein, the text of this document takes precedence. Nothing in this document, however, supersedes applicable laws and regulations unless a specific exemption has been obtained.

2.1.1 ASTM Publications

Available from ASTM International, 100 Barr Harbor Drive, P.O. Box C700, West Conshohocken, PA 19428-2959, Tel: 610-832-9585, www.astm.org.

ASTM D3241 Standard Test Method for Thermal Oxidation Stability of Aviation Turbine Fuels

ASTM D6732 Standard Test Method for Determination of Copper in Jet Fuels by Graphite Furnace Atomic Absorption Spectrometry

ASTM D7111 Standard Test Method for Determination of Trace Elements in Middle Distillate Fuels by Inductively Coupled Plasma Atomic Emission Spectrometry (ICP-AES)

2.1.2 CRC Publications

Available from Coordinating Research Council, 5755 North Point Parkway, Suite 265, Alpharetta, GA 30022, Tel: 678-795-0506, <https://crcao.org/>.

CRC Report No. 663 Handbook of Aviation Fuel Properties

2.1.3 Other Publications

Colbert, J. and Nowack, C. (2003, September 14-19). *The impact of copper-contaminated JP-5 on thermal management systems of advanced aircraft* [Conference paper]. 8th International Conference on Stability and Handling of Liquid Fuels, Steamboat Springs, Colorado, USA.

David, P., Goddard, A., Taylor, S.E., and Woodward, A.J. (1997, October 12-17). *Copper contamination of jet fuel from ships' heating coils* [Conference paper]. 6th International Conference on Stability and Handling of Liquid Fuels, Vancouver, British Columbia, Canada.

Dortwegt, R. and Maughan, E.V. (2001). *The chemistry of copper in water and related studies planned at the advanced photon source*. Proceedings of the 2001 Particle Accelerator Conference, IEEE.

Ford, J.C., Bradley, R.P., and Angello, L.C. (1973). *JP-4 thermal stability survey* (Report No. AFAPL-TR-23-27). United States Air Force Aero Propulsion Laboratory.

Liang, W. and Whangbo, M.-H. (1993). Conductivity anisotropy and structural phase transition in Covellite CuS. *Solid State Communications*, 85(5), 405-408. [https://doi.org/10.1016/0038-1098\(93\)90689-K](https://doi.org/10.1016/0038-1098(93)90689-K).

Lu, Q., Wei, J-F., Collins, G.E., Morris, R.E., Serino, P.M., and Guo, Y. (2003). Rapid determination of dissolved copper in jet fuels using bathocuproine. *Energy & Fuels*, 17(3), 699-704. <https://doi.org/10.1021/ef0202642>.

Morris, R. (2015). *The impact of dissolved copper on jet fuel*. Chemical Sensing and Fuel Technology Section, Code 6181, Naval Research Laboratory, Washington, DC.

Morris, R. and Turner, N. (1990). Influences exerted by metal deactivator on the thermal stability of aviation fuel in the presence of copper. *Fuel Science and Technology International*, 8(4), 327-350.
<https://doi.org/10.1080/08843759008915929>.

Moses, C. and Kamin, R. (2003, September 14-19). *Effect of copper contamination on the fouling rates of aircraft fuel nozzles* [Conference paper]. 8th International Conference on Stability and Handling of Liquid Fuels, Steamboat Springs, Colorado, USA.

Puranik, D.B., Guo, Y., Singh, A., Morris, R.E., Huang, A., Salvucci, L., Kamin, R., David, V., and Chang, E.L. (1998). Copper removal from fuel by solid-supported polyamine chelating agents. *Energy & Fuels*, 12(4), 792-797.

Rawson, P. and Stansfield, C-A. (2009). *Field method for detection of metal deactivator additive in jet fuel* (Report No. DSTO-TR-2302). Air Vehicles Division, Defence Science and Technology Organisation: Commonwealth of Australia.

Shertzer, R. (1973). *Investigation of the reduction of thermal stability of fuel by copper contamination on aircraft carriers* (Report No. NAPT-PE-14). Naval Air Propulsion Test Center.

West, Z. (2011). *Studies of jet fuel autoxidation chemistry: catalytic hydroperoxide decomposition & high heat flux effects* [Doctoral dissertation, University of Dayton].

2.2 Related Publications

The following publications are provided for information purposes only and are not a required part of this SAE Technical Report.

2.2.1 SAE Publications

Available from SAE International, 400 Commonwealth Drive, Warrendale, PA 15096-0001, Tel: 877-606-7323 (inside USA and Canada) or +1 724-776-4970 (outside USA), www.sae.org.

AIR4023 Aircraft Turbine Fuel Contamination History and Endurance Test Requirements

AIR7484 Guidance on the Impact of Fuel Properties on Fuel System Design and Operation

2.2.2 ASTM Publications

Available from ASTM International, 100 Barr Harbor Drive, P.O. Box C700, West Conshohocken, PA 19428-2959, Tel: 610-832-9585, www.astm.org

ASTM D1655 Standard Specification for Aviation Turbine Fuels

ASTM D7566 Standard Specification for Aviation Turbine Fuel Containing Synthesized Hydrocarbons

2.2.3 CRC Publications

Available from Coordinating Research Council, 5755 North Point Parkway, Suite 265, Alpharetta, GA 30022, Tel: 678-795-0506, <https://crcao.org/>.

CRC Aviation Handbook: Fuels and Fuel Systems (1967)

2.2.4 U.S. Government Publications

Copies of these documents are available online at <https://quicksearch.dla.mil>.

MIL-DTL-5624 Turbine Fuel, Aviation, Grades JP-4 and JP-5

MIL-DTL-83133 Turbine Fuels, Aviation, Kerosene Types, NATO F-34 (JP-8), NATO F-35, and JP-8 + 100

2.2.5 Other Publications

Cabbiness, D.K. and Margerum, D.W. (1969). Macrocyclic effect on the stability of copper(II) tetramine complexes. *Journal of the American Chemical Society*, 91(23), 6540-6541.

Hazlett, R. (1991). *Thermal oxidation stability of aviation turbine fuels*. ASTM International.

3. COPPER IN JET FUELS

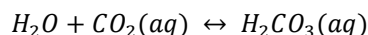
3.1 Sources of Copper in Jet Fuels

Jet fuel, in its refined state, is free of copper. Copper is introduced in to jet fuel through jet fuel storage, transport, and handling, mostly where copper alloys, such as admiralty brass, are used in oceanic applications with copper alloy containment vessels and plumbing. This copper is known to become entrained in the jet fuel in various forms (particulate and dissolved species) and stimulate thermo-oxidative degradation of the hydrocarbons in jet fuels. Specific sources of copper from copper-bearing alloys include (refer to Morris, 2015; Moses and Kamin, 2003):

- a. Copper-nickel alloy piping
- b. Copper alloys, such as brass, that could be present in fuel system components such as valves, fittings, and bearings
- c. Ship heating coils during sea transportation (refer to David et al., 1997)
- d. Navy shipboard fuel handling systems (80/20 Cu/Ni admiralty metal)
- e. Leaded bronze bearings in fuel systems

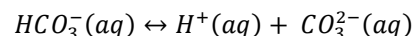
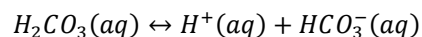
Copper leaches out of fuel handling systems that contain copper alloys such as brass. Free and dissolved water in jet fuel promotes extraction of copper from the fuel handling system and introduction into the fuel by potentially increasing fuel acidity. The water contaminant contains both dissolved oxygen and carbon dioxide from prior air exposure; this causes the formation of oxides at the metal surface. If undisturbed, this oxide layer is stable and will act to passivate the copper, preventing further corrosion. However, over time, dissolved carbon dioxide in the water will form carbonic acid (H_2CO_3).

Formation of carbonic acid from water and dissolved carbon dioxide:



When the acidic proton disassociates from carbonic acid, it will react with the oxygen, removing the protective oxide layer from the copper on the metal surface.

Carbonic acid loses up to two protons through acid equilibria:



After this occurs, the surface layer of copper is left in a +2 ionic form and will easily dissolve. This results in the metal surface being left unprotected, allowing the process to repeat (refer to Dortwegt and Maughan, 2001).

3.2 Copper Concentration in Jet Fuels

The U.S. Air Force and the U.S. Navy have evaluated typical copper levels in JP-4 and JP-5 fuels. Copper concentrations of 17 ppb or less, on the average, have been reported by the Aero Propulsion Laboratory for JP-5 (refer to Ford et al., 1973; Morris, 2015). Significantly higher concentrations of copper, 40 to 1300 ppb - average of 250 ppb, have been reported in Naval shipboard surveys (refer to Moses and Kamin, 2003; Ford et al., 1973; Morris, 2015).